AN14782

Dual PAN on IW612

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Document information

Information	Content
Keywords	AN14782, OpenThread, ZigBee, dual PAN, Wi-Fi, multi-chip integration, wireless coexistence, IW612, K32W0x1
Abstract	This application note provides a comprehensive insight into the dual personal area network (dual PAN) feature on NXP IW612 with Wi-Fi coexistence configuration.

1 Introduction

This application note explores the dual PAN solution running on NXP IW612 hosted platforms. It is an extension to *NXP Dual PAN Feature and Performance Results* (document AN14476).

The NXP IW612 is a tri-radio single-chip solution that integrates support for 2.4/5 GHz dual-band 1 × 1 Wi-Fi 6, Bluetooth/Bluetooth Low Energy, and IEEE802.15.4 protocols. This device functions as a transceiver and connects to any host processor (MPU/MCU), enabling various hardware and software configurations.

The tri-radio capability of the IW612 makes it an ideal choice for Matter applications running over Wi-Fi and Thread. The IW612 operates as both a Matter controller and a Thread border router. This functionality enables complete Matter support for local and cloud-based control and monitoring of Internet of Things (IoT) products across major ecosystems. In addition to Thread, the 802.15.4 radio on the IW612 also supports ZigBee. This capability makes the device well suited for ZigBee bridges that connect ZigBee devices to cloud systems or IP-based networks such as Matter.

The IW612 integrates dedicated CPUs and memories for both the Wi-Fi and Bluetooth/802.15.4 subsystems, enabling real time, independent protocol processing. The IW612 connects to external host processors through interfaces such as SDIO 3.0 for Wi-Fi, Universal Asynchronous Receiver Transmitter (UART) for Bluetooth, and Serial Peripheral Interface (SPI) for 802.15.4.

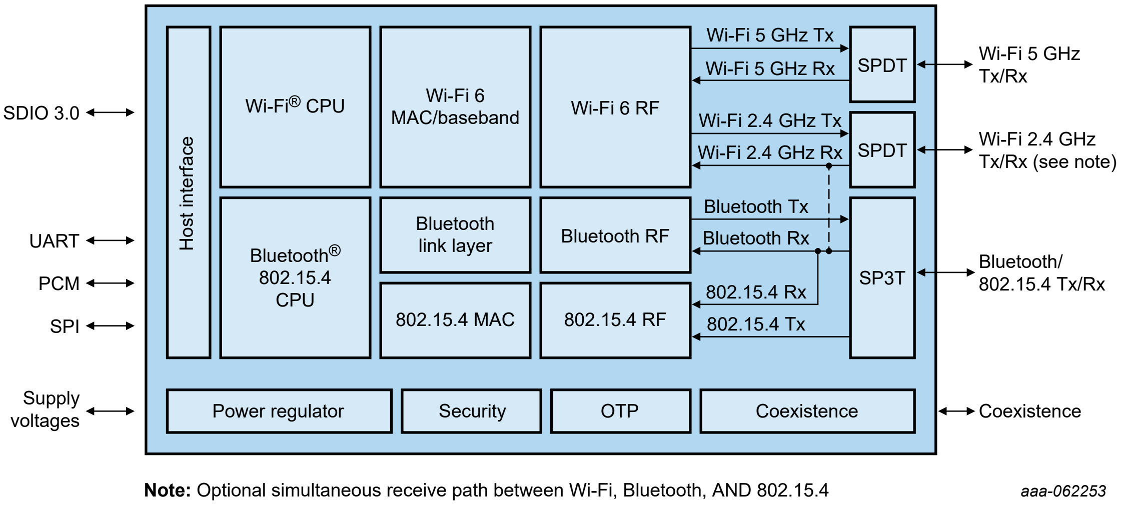

Figure 1. IW612 internal block diagram

The NXP IW612 is suitable for devices designed for smart entertainment, such as smart speakers, and for gateway, hub, or bridge solutions like Matter controllers and Thread border routers. It also supports smart home devices including security cameras, industrial systems such as building automation, and smart appliances like washers.

2 System overview

This section provide an overview of the dual PAN system based on NXP IW612 transceiver.

2.1 Hardware overview

This application note refers to wireless devices as transceivers from a hardware perspective. This document also applies particularly when the context implies that the transceiver is part of an integrated system and not the actual radio hardware—for example, the antenna. The IW612 transceiver contains three separate radios—for

Wi-Fi, Bluetooth, and IEEE802.15.4, which share common hardware components like radio front end and the antennas.

The IW612 transceiver supports several hardware configurations such as:

- ST-SA configuration, where all wireless protocol radios are multiplexed on the same antenna hardware operating on the IW612 transceiver.
- ST-DA configuration, where the Bluetooth, and 802.15.4 protocol radios use a separate antenna than the Wi-Fi 2.4 GHz and 5 GHz radio on the IW612 transceiver.
- DT-TA or simply DT configuration where, using the IW612 transceiver in a dual antenna configuration, the system runs Wi-Fi on the first IW612 antenna and IEEE 802.15.4 PAN (for the OpenThread stack) on the second IW612 antenna, with Bluetooth supported but not used in testing. Another IEEE 802.15.4 PAN (for the ZigBee stack) operates on a separate device, such as K32W0x1. This configuration tests the IW612 external coexistence interface for connecting to external radios. Both the IW612 transceiver and the external radio device connect to the host system through serial interfaces.

An overview of the three configurations can be seen in Figure 2.

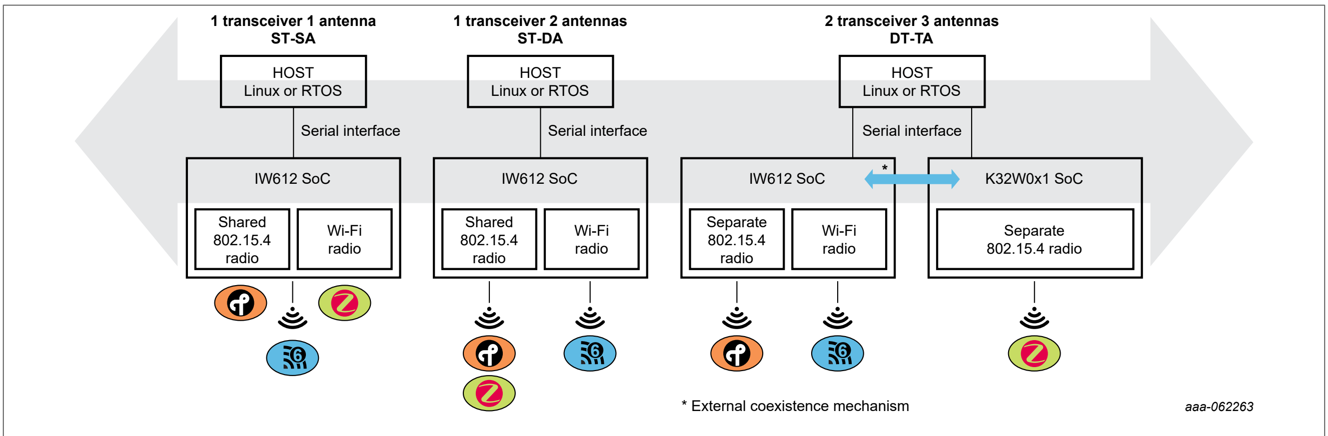

Figure 2. Overview of IW612 dual PAN radio configurations

The ST-SA Device under Test (DUT) configuration is based on the NXP FRDM-IMX93 board. This board is a low-cost, compact development platform featuring the i.MX 93 applications processor. The board includes an onboard IW612 module. It features an NXP tri-radio solution with Wi-Fi 6 + Bluetooth 5.4 + 802.15.4, making it ideal for developing modern industrial and IoT applications.

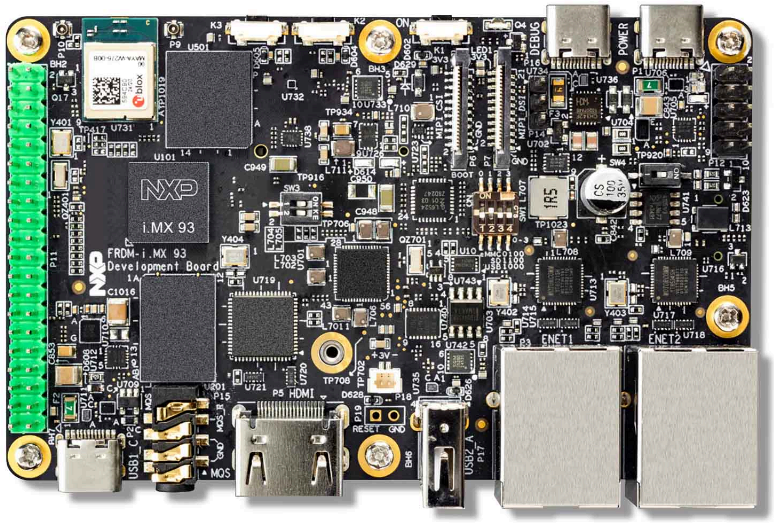

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Figure 3. FRDM i.MX 93 top view

The ST-DA DUT configuration uses a combination of the NXP i.MX 8M Mini EVK (8MMINILPD4-EVK) board and an NXP IW612 RD board. This setup provides all the necessary outputs to support both single and dual antenna configurations.

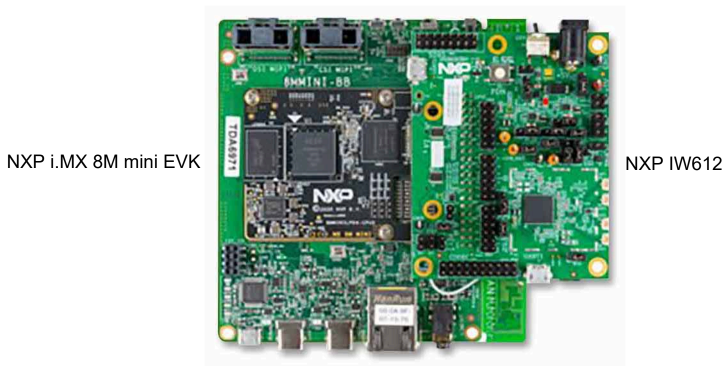

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Figure 4. Single transceiver dual antennas hosted MPU configuration

Figure 5 illustrates the dual transceiver, three-antenna DUT configuration. It includes a hosted MPU device, NXP i.MX 8M, connected to an IW612 transceiver for Wi-Fi and OpenThread through an SPI interface. A separate K32W0x1 device acts as a ZigBee transceiver and connects through an UART interface. The IW612 and K32W0x1 devices communicate using a WCI-2-based coexistence mechanism over UART.

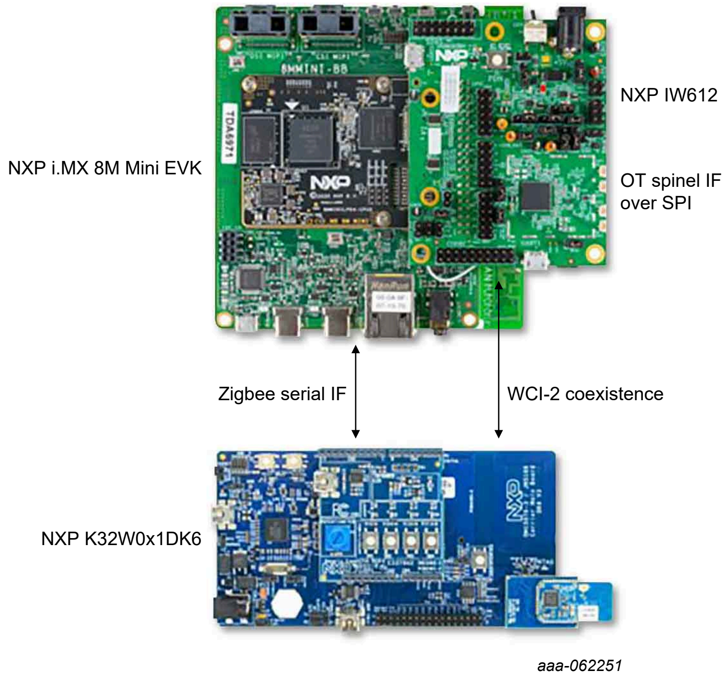


Figure 5. Dual transceiver triple antenna hosted MPU configuration

2.2 Software overview

The host MPUs in this setup run i.MX MPU Matter images based on Yocto recipes. The following details apply for the single transceiver DUT configuration using the IW612 transceiver (ST-SA/ST-DA).

From a software perspective, the available IEEE802.15.4 stack support on NXP IW612 includes OpenThread and ZBOSS stacks. A daemon application called zb_mux enables this dual-stack functionality. *Dual PAN Software User Manual for IW612* (document UM12265) provides details on how to get the dual PAN software and how to deploy it on the i.MX platform.

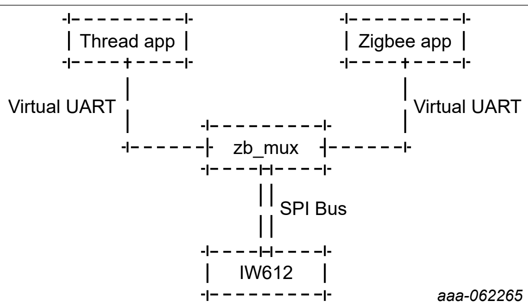


Figure 6. Thread and ZigBee applications running on zb_mux daemon

To start the dual PAN daemon, run the following command:

```
./imx-dualpan.sh --ch <channel> --zb <zb_app>--ot <ot_app> [--fw <IW612-
firmware>]
```

The running ZigBee application (zb_app) uses the simple gateway example (simple_gw), which runs the ZigBee ZBOSS stack configured as a ZigBee coordinator. The dotted line in Figure 7 illustrates the boundary of the ZigBee network. This dotted line emphasizes the central role of the application in forming the network and allowing devices to join.

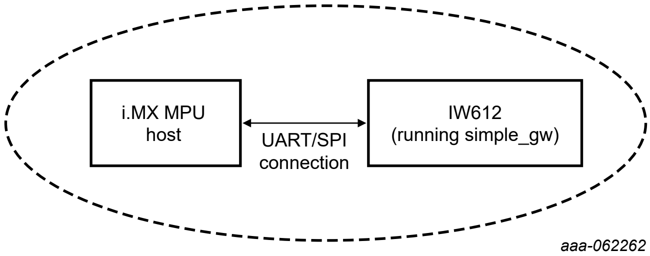


Figure 7. Simple_gw application

You can find the ZigBee software build and deployment details in *Zigbee Software User Manual for IW612* (document UM12029).

The running OpenThread application ot_app is the ot-daemon, enabling OpenThread as a service. The OT daemon uses UNIX sockets for input and output, allowing clients to connect and communicate using the OpenThread CLI protocol. The Radio Coprocessor (RCP) is used with the OT daemon.

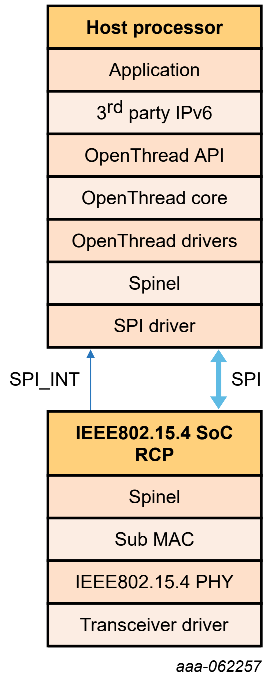


Figure 8. Ot-daemon application structure

You can find details on building and deploying the OpenThread software for the NXP i.MX MPUs with NXP IW612 transceiver in *OpenThread Software User Manual for IW612* (document UM11844).

The following details describe the dual transceiver DUT configuration, which includes both the IW612 and K32W0x1 transceivers (DT). The software running on the hosted processor consists of two components:

- OpenThread Border Router (OTBR) agent: Build from ot-br-posix. The OpenThread daemon uses the Spinel protocol to communicate through SPI with IW612. Refer to the meta-nxp-connectivity for the instructions on how to build and set up the OTBR for Yocto.
- ZigBee coordinator application: An NXP application controls the ZigBee stack. This application follows a Network Coprocessor (NCP) architecture, where the radio processor runs the ZigBee stack code, and the host manages part of the application layer logic. The Serialink protocol is used to send ZigBee commands between boards at a baud rate of 1 M. You can find instructions to build the application for the i.MX MPU platforms or for x86 Linux in the latest K32W0x1 or MCX W71 SDKs, specifically in the `README.md` file at `middleware\wireless\zigbee\examples\zigbee_coordinator\build_linux`.

You can build the application using the CMAKE system.

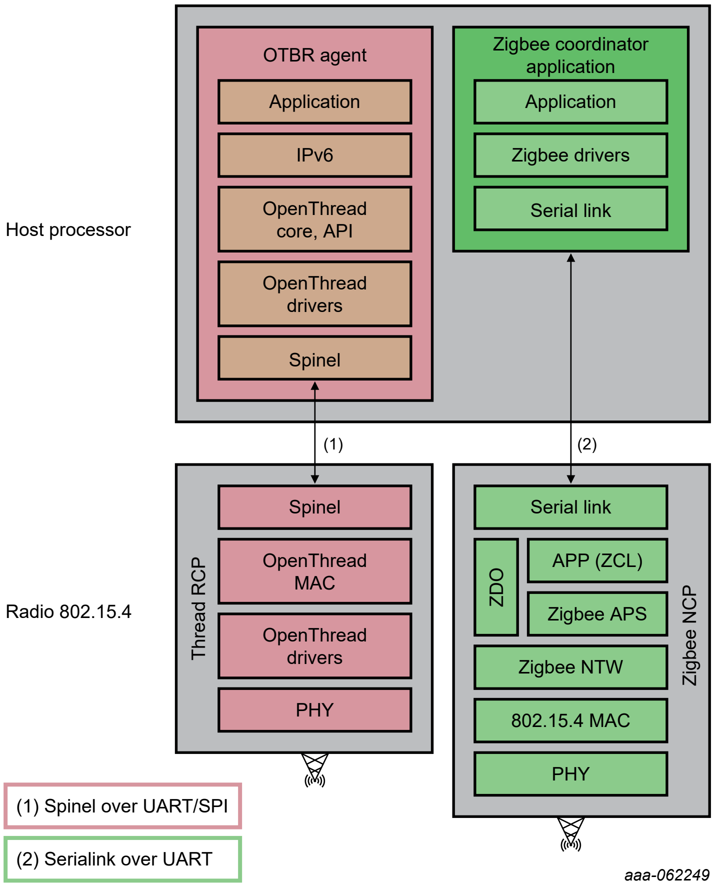


Figure 9. Dual radio DUT detailed software architecture details

3 Coexistence of wireless protocols

Coexistence mechanisms for internal and external radios ensure arbitration between the protocols when using overlapping radio bands.

The protocols that coexist in the 2.4 GHz ISM band include Bluetooth LE, IEEE 802.15.4–based protocols, such as Thread and ZigBee, and Wi-Fi (IEEE 802.11). These three protocols are used in IoT applications such as Matter.

- Bluetooth operates in the 2.4 GHz ISM band (2400 MHz-2483.5 MHz) band. It is based on the IEEE 802.15.1–Wireless Medium Access Control (MAC) and Physical (PHY) specifications for Wireless Personal Area Networks (WPANs).
- IEEE 802.15.4 defines 16 channels, ranging from channel 11, with a central frequency of 2405 MHz, and channel 26, with a central frequency of 2480 MHz. Each channel has a 2 MHz bandwidth and 5 MHz channel spacing.
- IEEE 802.11 defines 14 channels, but in contrast with IEEE 802.15.4, the channel usage depends on the regulatory domain. IEEE Std. 802.11b recommends using nonoverlapping channels 1, 6, and 11 for North America and channels 1, 7, and 13 for Europe. North America does not use channels 13 and 14.

IEEE 802.15.4 ensures reliable coexistence with other 2.4 GHz wireless technologies and provides mechanisms in Annexer E of the IEEE 802.15.4 specification to enhance coexistence.

The Figure 10 shows that for both North America and Europe, you can choose up to four 802.15.4 channels that do not overlap with the Wi-Fi channels.

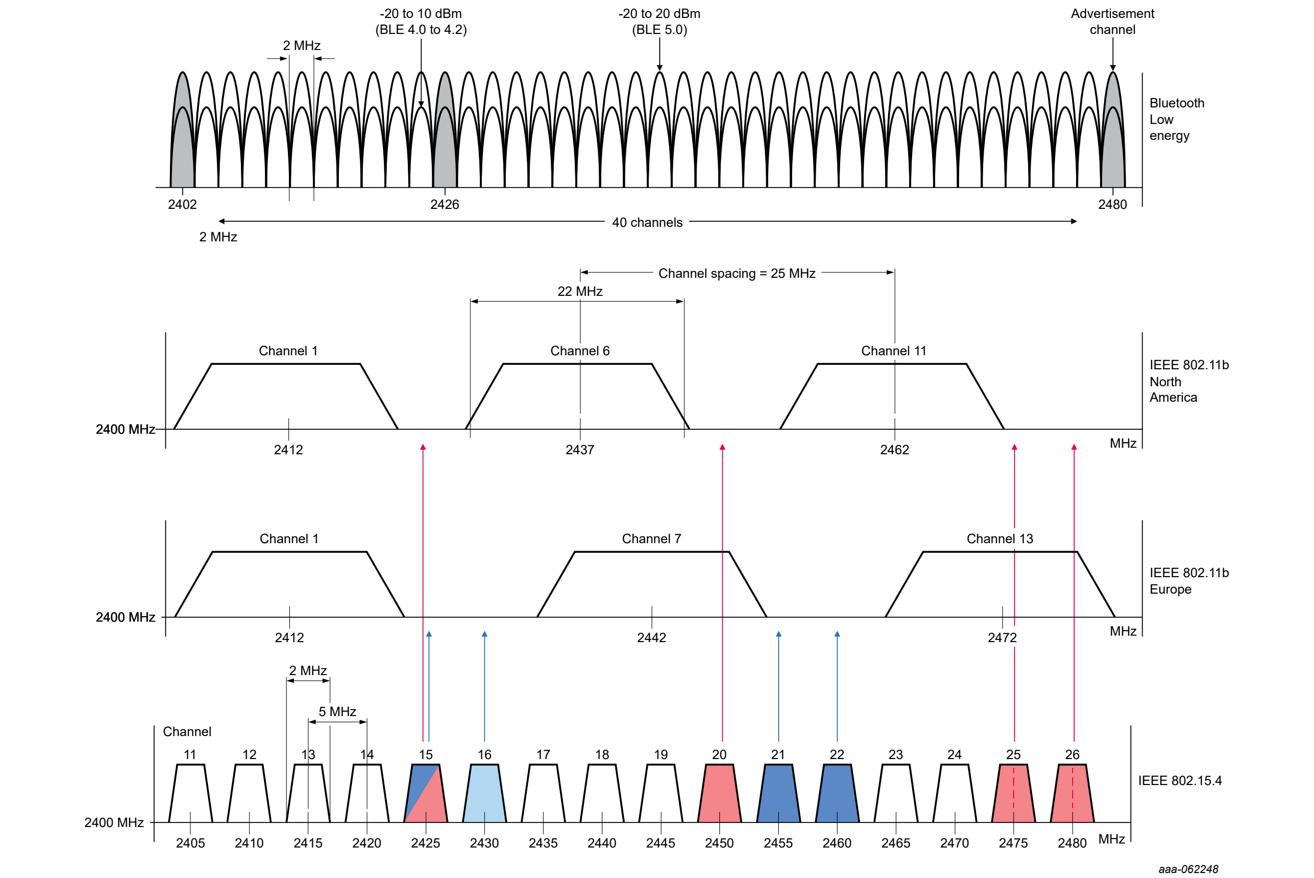


Figure 10. Bluetooth LE vs IEEE 802.15.4 channel vs. nonoverlapping IEEE 802.11b channels (US, Europe)

Note: *The 802.15.4 channels colored blue are recommended to use in Europe, while the ones in red in North America.*

Coexistence among wireless technologies depends on three main factors:

- Frequency
- Time
- Space

You can achieve coexistence by controlling at least one of these factors through:

- Frequency separation between the operating channels of the networks
- Low occupancy of the channel
- Setting sufficient distances between networks or nodes

In real-world deployment, interference always exists because none of these factors can be fully controlled. The objective is to achieve an acceptable performance level of services delivered across coexisting wireless technologies.

3.1 Coexistence in NXP IW612 wireless transceiver

The following are the two mechanisms offered by NXP to synchronize the overlapping band wireless protocols using real-time packet arbitration:

- Packet Traffic Arbitration (PTA): Hardware-accelerated mechanism
- UART and GPIO coexistence interface (UART + GPIO): Hardware-accelerated mechanism

Central hardware PTA support on IW612 includes an internal arbiter for managing coexistence among Bluetooth/802.15.4, Wi-Fi, and one external radio.

For coexistence with external radios using IW612, a custom UART and GPIO protocol support is available. This support is also available on the K32W0x1 chip, enabling flexible coexistence solutions. The UART messages are based on custom WCI-2 protocol.

The following outlines key aspects of the UART and GPIO protocol implementation between IW612 and K32W0x1:

- Wireless coexistence interface 2 protocol is a protocol defined in Bluetooth Core Spec – Vol. 7 Part C.
- The physical transport protocol used for custom WCI-2 is the UART.
- This setup forms the *external coexistence interface* between IW612 and K32W0x1. (See Figure 11)
- Separate GPIO lines are used to signal from IW612 to K32W0x1 for the permission to transmit or receive.

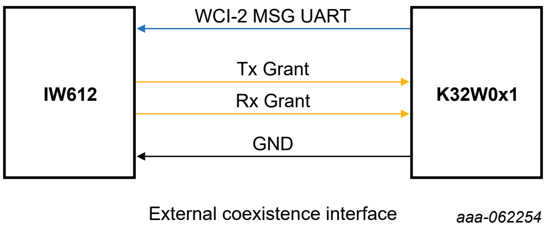


Figure 11. Wiring diagram for WCI-2 protocol between IW612 and K32W0x1

You can find more information regarding external coexistence interfaces on IW612 in *External Coexistence Interface for AW611, IW611, and IW612* (Document AN14410).

4 Test setup description

The Figure 12 shows an overview of the system used to test the NXP dual PAN solutions.

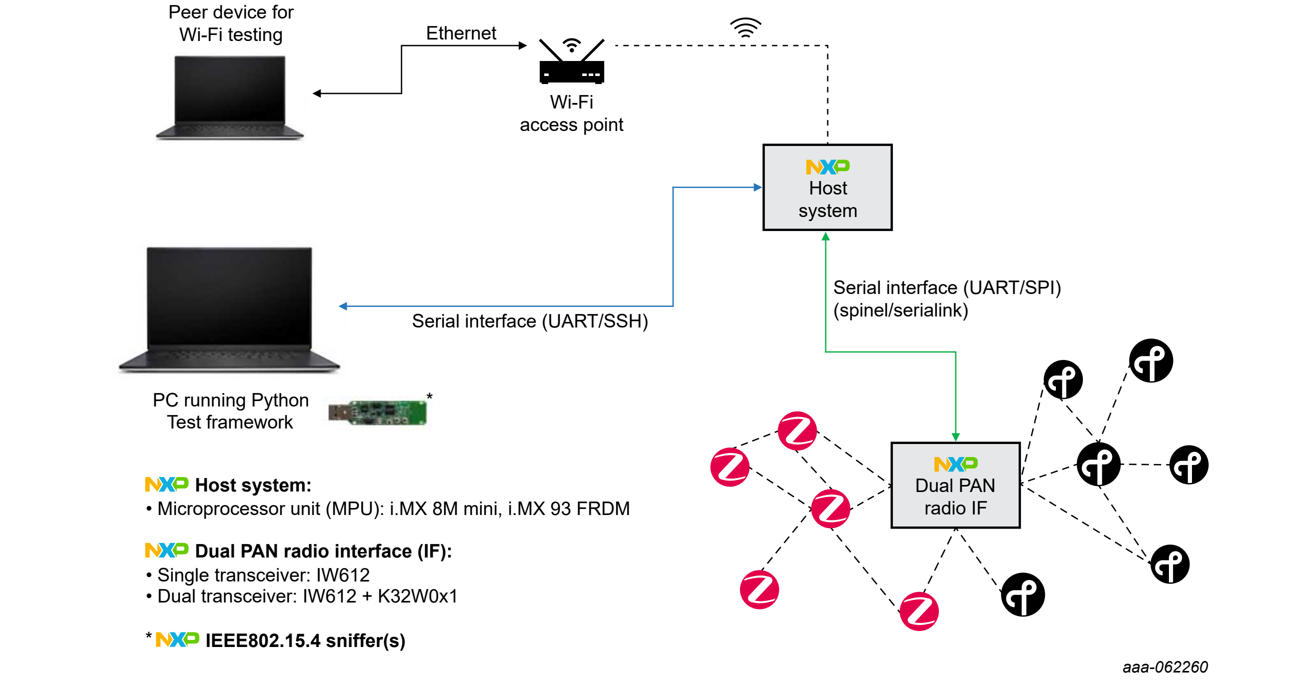


Figure 12. Overview of test setup

To demonstrate the functionality of dual PAN, the following hardware test setup is required:

- A PC runs the test framework developed in Python. It interacts with the OTBR agent to perform Thread operations and communicates with the ZigBee coordinator application to initiate ZigBee commands and procedures.
- NXP IEEE802.15.4 wireless sniffers for packet sniffing over Thread and ZigBee channels. These sniffers validate the communication and protocol behavior.
- Dual PAN device under test, which includes an NXP host processor and NXP narrowband radio (transceiver) SoCs.
- The peer device used for Wi-Fi testing. This device can be a PC, or another Ethernet-connected device that supports Internet Control Message Protocol (ICMP) and/or bandwidth throughput testing software such as iperf. The Ethernet connection was used to minimize Wi-Fi channel usage by the peer device.
- A Wi-Fi access point supports Wi-Fi testing.
- One or more ZigBee nodes: K32W0x1 and MCX W71.
- One or more Thread nodes: K32W0x1 and MCX W71.

Table 1. Hardware setup

Transceiver configuration	Device	MPU	
Single transceiver	Host	i.MX MPU (8M/93)	
	Radio	IW612 (Wi-Fi/Thread/ZigBee)	
Dual transceiver	Host	i.MX MPU (8M/93)	
	Radio	IW612 (Wi-Fi/Thread)	K32W0x1 (ZigBee)

The test setup condition for this document uses an open environment, typical for an office or home setting. It does not include shielding from other 2.4 GHz electromagnetic radiations, such as Bluetooth LE, Wi-Fi, or proprietary technologies.

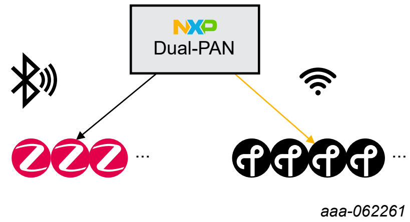


Figure 13. Open environment conditions

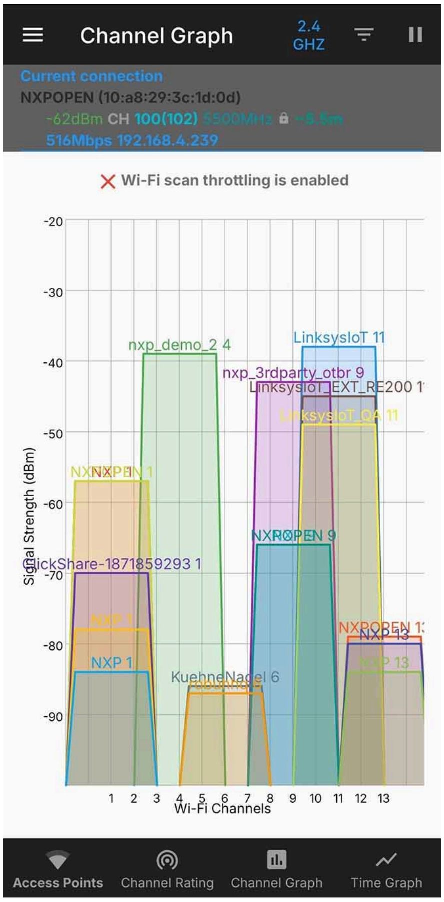
Based on Figure 10 showing the overlap of Wi-Fi and IEEE802.15.4 channels, the following channels are chosen:

- ZigBee: Channel 22
- Thread: Channels 18 and 22
- Wi-Fi 2.4 GHz: Channels 4 and 11
- Wi-Fi 5 GHz: Channel 36

Choose Wi-Fi 2.4 GHz channel 11 to overlap with IEEE802.15.4 channel 22 to exercise the coexistence mechanisms of IW612.

Due to the open nature of the environment, accurately quantifying the number of active Wi-Fi access points and Bluetooth LE devices is challenging. However, third-party tools that scan both Wi-Fi and Bluetooth LE traffic can provide an estimate.

For Wi-Fi, use the open source android app *WifiAnalyzer* to showcase the channel occupation on both 2.4 GHz and 5 GHz bands. The Service Set Identifier (SSID) for the Access Point (AP) in the 2.4 GHz band is nxp_demo_2, while in the 5 GHz band, it is nxp_demo.


Channel Graph
2.4 GHZ
Current connection
NXPOPEN (10:a8:29:3c:1d:0d)
-62dBm CH 100(102)
516Mbps 192.168.4.239
Wi-Fi scan throttling is enabled
Signal Strength (dBm)
-20
-30
-40
-50
-60
-70
-80
-90
nxp_demo_2 4
LinksysIoT 11
nxp_3rdparty_otbr 9
NXP 1
KuehneNagel 6
NXP 13
1 2 3 4 5 6 7 8 9 10 11 12 13
Wi-Fi Channels
Access Points
Channel Rating
Channel Graph
Time Graph

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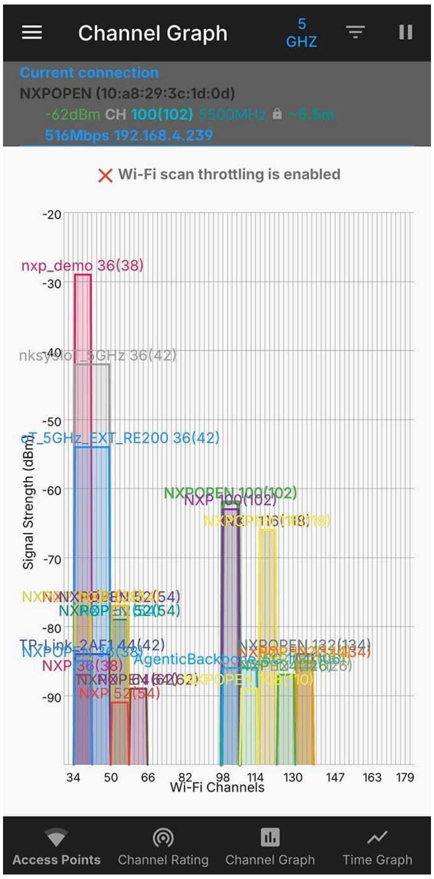

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Figure 14. 2.4 GHz and 5 GHz Wi-Fi channel scan on Android device

An Android phone running the nRF connect application captures a plot of Received Signal Strength Indicator (RSSI) values over time for nearby Bluetooth LE devices.

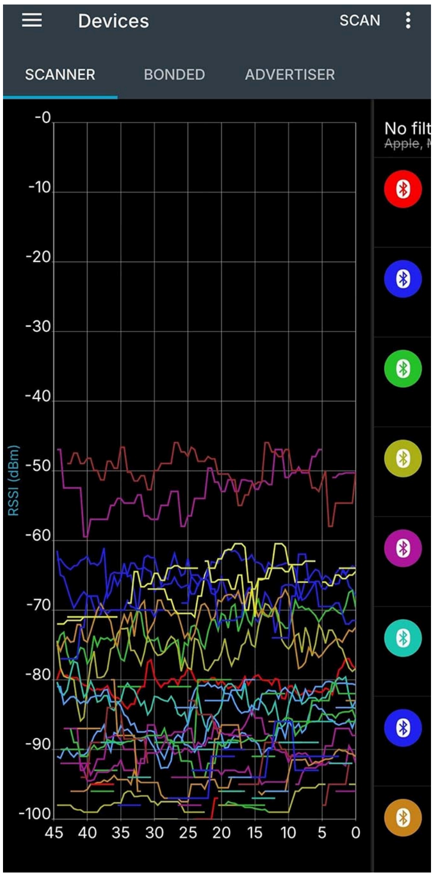

Figure 15. Bluetooth Low Energy RSSI scan on Android device

Dual antenna testing focuses on achieving antenna isolation, which depends on factors such as:

- Distance between antennas
- Antenna orientation
- PCB shielding, and so on

This application note achieves an antenna isolation value of 25 dB.

To set up antenna isolation, load the proper antenna calibration data. *Calibration Structure for AW611, IW611, and IW612* (document AN13983) provides the process to create the calibration data. Load the calibration by executing the commands in *Getting started with NXP-based Wireless modules on i.MX 8M Quad EVK Running Linux OS* (document UM11483). Based on the instructions for bringing up the OTBR, at step 12, load the Wi-Fi drivers and modify the `/lib/firmware/nxp/wifi_mod_para_iw612.conf` to point to the required calibration data.

The default content of the file is:

```
SDIW612 = {
cfg80211_wext=0xf
max_vir_bss=1
cal_data_cfg=none
ps_mode=1
auto_ds=1
host_mlme=1
fw_name=nxp/sduart_nw61x_v1.bin_symlink
```

```
}
```

The calibration data change requires modifying `cal_data_cfg=none` to the path of the calibration data. For example: `cal_data_cfg=/path/to/data/ WlanCalData_ext.conf`

5 Test details

This application note describes the test cases for dual PAN analysis. The main aspects relate to the number of devices, channel configuration (same channels for both PANs or different channels), and setup conditions. The NXP dual PAN DUT refers to both the single transceiver and the dual transceiver solutions. For the single transceiver and dual transceiver solutions, refer to the Section 2.1.

The target tests for validation include:

- Thread: Measure ping latency and ping success rate by configuring the payload and transmission interval.
- ZigBee: Measure cluster command success rate by configuring the payload and using a random interval. These commands are part of the ZigBee Test Profile 2 (TP2) testing framework, and ensure that the devices conform to the ZigBee protocol stack. TP2 commands test network layer behavior. The ZigBee TP2 framework doesn't allow payloads larger than 135 bytes.
- Wi-Fi: Measure packet latency and success rate by changing Wi-Fi frequency, channel, antenna setup, attenuation, and payload type. Start with 64-byte pings, and include other packet sizes in future tests.
- Iperf: Simulate scenarios closer to real-world applications, such as high-traffic devices like security cameras or Wi-Fi gateways.

The following tests generically apply the same principles to the other configurations of NXP devices.

Table 2 provides a comprehensive overview of a typical test setup for dual PAN minimal test.

Table 2. T0.1.1 dual PAN minimal test setup

Parameter	Description
Setup components	• 1 x Dual PAN DUT • 1 x OpenThread node • 1 x ZiBbee node • 1 x Wi-Fi AP • 1 x Device on Wi-Fi LAN
Details	This test measures the Key Performance Indicators (KPIs) of the Thread, ZigBee, and Wi-Fi networks in a minimal test setup with one OpenThread node and one ZigBee node. The DUT connects to a Wi-Fi AP on either 2.4 GHz or 5 GHz bands. The test uses ICMP protocol for Thread and Wi-Fi, and TP2 protocol for ZigBee. Configurations used: • ST-SA • ST-DA • DT-TA Test conditions: • IEEE 802.15.4 Channels: – Same for each PAN on ST-SA and ST-DA – Same or different for each PAN on DT-TA • Wi-Fi Channels: – Channel 36 for 5 GHz band for baseline – Same channel: Channel 22 for Thread and ZigBee – Different channels: Channel 22 for ZigBee, channel 18 for Thread • Setup Configuration: Open environment Steps: 1. Connect DUT to a Wi-Fi network. 2. Create a ZigBee network on a dual PAN node, with the device acting as ZigBee Coordinator. 3. Join one ZigBee node. 4. Create a Thread network on a dual PAN node, with the device acting as OpenThread leader. 5. Join one OpenThread node. 6. Collect IEEE 802.15.4 Thread and ZigBee KPIs by using different payloads and intervals. Collect IEEE 802.11 Wi-Fi KPIs with 64 B payload and 1 second interval. Number of commands for each protocol: 100
KPIs	• Thread: Ping latency (RTT), ping success rate by configuring payload size and transmission interval. • ZigBee: Cluster command success rate by configuring the transmission interval. • Wi-Fi: Ping latency (RTT), ping success rate
Results	Refer to the section, Section 6.1.

Table 3 provides a comprehensive overview of a typical test setup for dual PAN Wi-Fi bandwidth minimal test:

Table 3. T0.1.2 dual PAN Wi-Fi bandwidth minimal test setup

Parameters	Description
Setup components	• 1 x Dual PAN DUT • 1 x OpenThread node • 1 x ZigBee node • 1 x Wi-Fi AP • 1 x Device on Wi-Fi LAN
Details	This test measures the KPIs of the Wi-Fi network in a minimal test setup with one OpenThread node and one ZigBee node. The DUT connects to a Wi-Fi AP on either 2.4 GHz or 5 GHz bands. The test uses ICMP protocol for Thread and TP2 protocol for ZigBee. On the Wi-Fi side, the test uses iperf for User Datagram Protocol (UDP) and Transmission Control Protocol (TCP). Configurations used: • ST-SA • ST-DA • DT-TA Test conditions: • IEEE 802.15.4 Channels: – Same for each PAN on ST-SA and ST-DA – Same or different for each PAN on DT-TA • Wi-Fi Channels: – Channel 36 for 5 GHz band for baseline – Same channel: Channel 22 for Thread and ZigBee – Different channels: Channel 22 for ZigBee, channel 18 for Thread • Setup Configuration: Open environment Steps: 1. Connect DUT to a Wi-Fi network. 2. Create a ZigBee network on a dual PAN node, with the device acting as ZigBee Coordinator. 3. Join one ZigBee node. 4. Create a Thread network on a dual PAN node, with the device acting as OpenThread leader. 5. Join one OpenThread node. 6. Start ICMP traffic on OpenThread with a 128-Byte payload at a 1 second interval. Run TP2 traffic on ZigBee with 20 Bytes, 84 Bytes, and 135 Bytes at a 0.5/1 second interval. 7. Start iperf server on peer device over Wi-Fi LAN. 8. Start iperf client on DUT and connect to server on peer device: Iperf -c 192.168.x.x -t 300 (for UDP, add '-u'). 9. Collect IEEE 802.11 Wi-Fi KPI for bandwidth on TCP and UDP. Number of commands for each protocol: 100
KPIs	Wi-Fi bandwidth performance
Results	Refer to the section, Section 6.2.

Table 4 provides a comprehensive overview of a typical test setup for a dual PAN Wi-Fi fixed bandwidth minimal test:

Table 4. T0.1.3 dual PAN Wi-Fi fixed bandwidth minimal test setup

Parameter	Description
Setup components	• 1 x Dual PAN DUT • 1 x OpenThread node • 1 x ZigBee node • 1 x Wi-Fi AP • 1 x Device on Wi-Fi LAN
Details	This test measures the KPIs of the Thread and ZigBee networks in a minimal test setup with one Open Thread node and one ZigBee node. The DUT connects to a Wi-Fi AP on either 2.4 GHz or 5 GHz bands. The test uses ICMP for Thread and TP2 protocol for ZigBee. On the Wi-Fi side, the test uses iperf for UDP and TCP. Configurations used: • ST-SA • ST-DA • DT-TA Test conditions: • IEEE 802.15.4 Channels: – Same for each PAN on ST-SA and ST-DA – Same for each PAN on DT-TA • Wi-Fi Channels: – Channel 36 for 5 GHz band for baseline – Same channel: Channel 22 for Thread and ZigBee • Setup Configuration: Open environment Steps: 1. Connect DUT to a Wi-Fi network. 2. Create a ZigBee network on a dual PAN node, with the device acting as ZigBee Coordinator. 3. Join one ZigBee node. 4. Create a Thread network on a dual PAN node, with the device acting as OpenThread leader. 5. Join one OpenThread node. 6. Start ICMP traffic on OpenThread with a 128-Byte payload at a 1 second interval. Run TP2 traffic on ZigBee with 20 Bytes, 84 Bytes, and 135 Bytes at a 0.5/1 second interval. 7. Start iperf server on peer device over Wi-Fi LAN. 8. Start iperf client on DUT and connect to server on peer device: Iperf -c 192.168.x.x -b 25M -t 300 9. Collect IEEE 802.15.4 Thread and ZigBee KPIs. Number of commands for each protocol: 100
KPIs	• Thread Ping latency (RTT) and Ping success rate. • ZigBee: Cluster command success rate by configuring the transmission interval.
Results	Refer to the section, Section 6.3.

Table 5 provides a comprehensive overview of a typical test setup for a dual PAN Wi-Fi fixed bandwidth test.

Table 5. T0.2.1 dual PAN Wi-Fi fixed bandwidth test setup

Parameter	Description
Setup Components	• 1 x Dual PAN DUT • 5 x OpenThread node • 5 x ZigBee node • 1 x Wi-Fi AP • 1 x Device on Wi-Fi LAN
Details	This test measures the KPIs of the Thread and ZigBee networks in a typical test setup with five Open Thread node and five ZigBee node. The DUT connects to a Wi-Fi AP on either 2.4 GHz or 5 GHz bands. The test uses ICMP for Thread and TP2 protocol for ZigBee. On the Wi-Fi side, the test uses iperf for UDP and TCP. Configurations used: • ST-SA • ST-DA • DT-TA Test conditions: • IEEE 802.15.4 Channels: – Same for each PAN on ST-SA and ST-DA – Same for each PAN on DT-TA • Wi-Fi Channels: – Channel 36 for 5 GHz band for baseline – Same channel: Channel 22 for Thread and ZigBee • Setup Configuration: Open environment Steps: 1. Connect DUT to a Wi-Fi network. 2. Create a ZigBee network on a dual PAN node, with the device acting as ZigBee Coordinator. 3. Join the five ZigBee nodes. 4. Create a Thread network on a dual PAN node, with the device acting as OpenThread leader. 5. Join the five OpenThread nodes. 6. Start ICMP traffic on OpenThread with a 128-Byte payload at a 1 second interval. Run TP2 traffic on ZigBee with 20 Bytes, 84 Bytes, and 135 Bytes at a 0.5/1 second interval. 7. Start iperf server on peer device over Wi-Fi LAN. 8. Start iperf client on DUT and connect to server on peer device: iperf -c 192.168.x.x -b 25M -t 300 9. Collect IEEE 802.15.4 Thread and ZigBee KPIs. Number of commands for each protocol: 100
KPIs	• Thread Ping latency (RTT) and ping success rate. • ZigBee: Cluster command success rate by configuring the transmission interval.
Results	Refer to the section, Section 6.4.

6 Test results

This section presents the measured outcomes for each test case, based on the defined KPIs. The results also record performance metrics, such as latency, success rate, and throughput, and compares them against the expected benchmark.

6.1 T0.1.1 Dual PAN minimal test setup results

This section summarizes the performance measurements for Thread, ZigBee, and Wi-Fi in the minimal dual PAN configuration, based on the defined KPIs and conditions.

6.1.1 Single Transceiver Single Antenna (ST-SA)

The following results summarize the performance for the ST-SA configuration under the defined dual PAN minimal test setup.

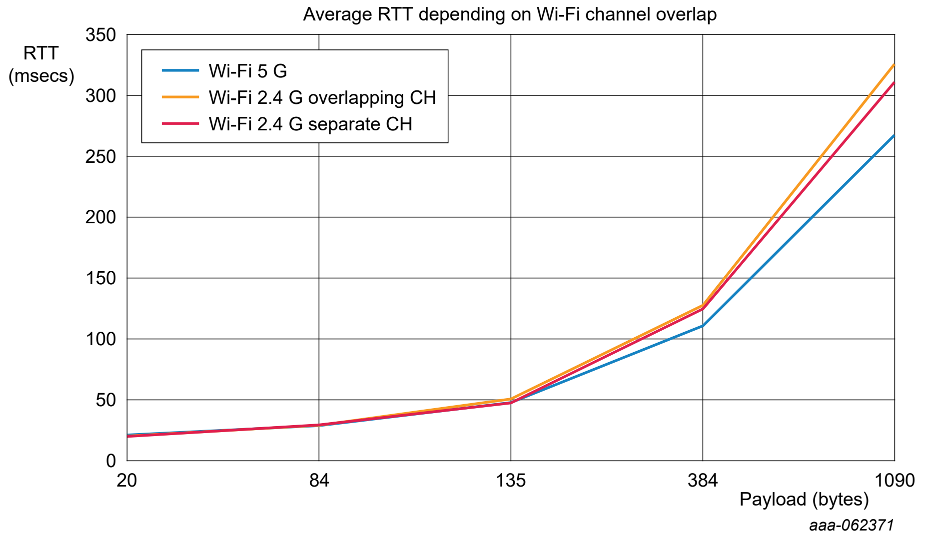

Figure 16. Average RTT on OpenThread depending on Wi-Fi channel overlap with 802.15.4 channel

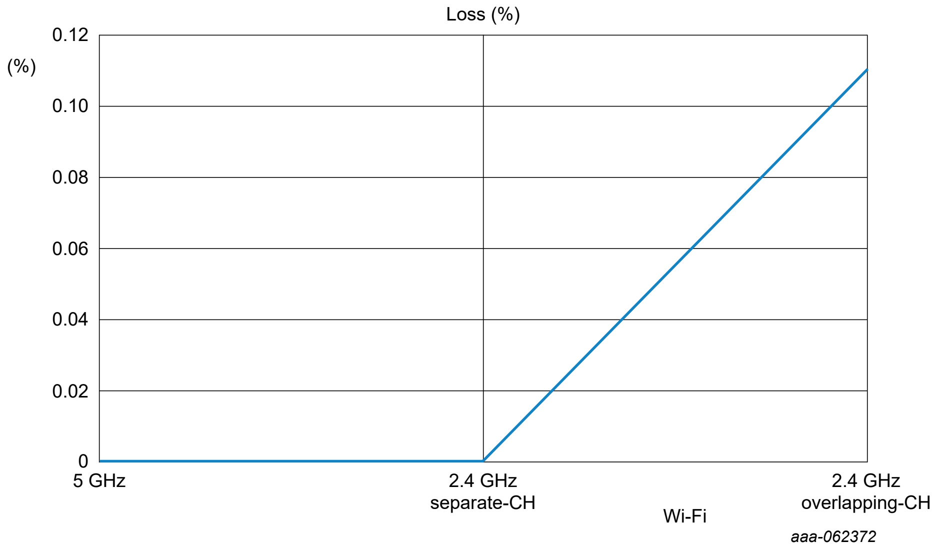

Figure 17. ST-SA packet loss on Wi-Fi depending on Wi-Fi channel overlap with 802.15.4 channel

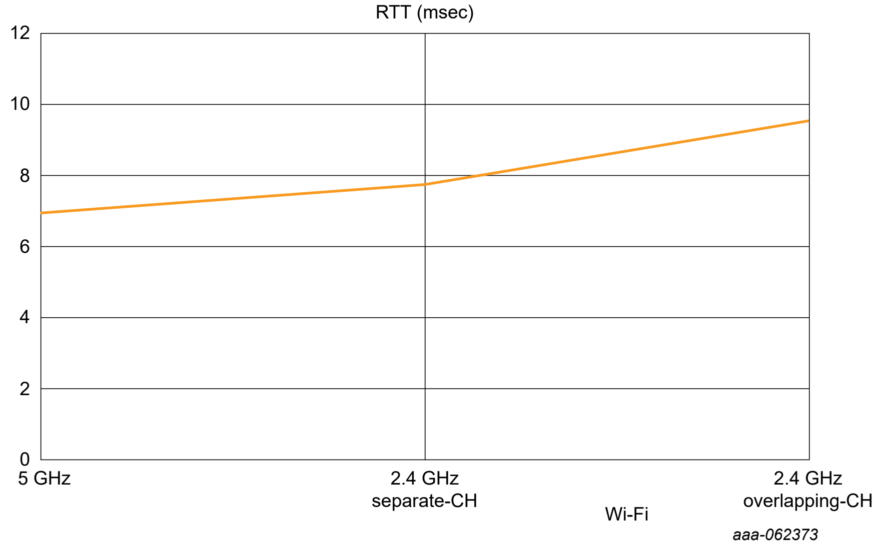

Figure 18. ST-SA RTT on Wi-Fi depending on Wi-Fi channel overlap with 802.15.4 channel

Table 6. ST-SA OpenThread and ZigBee KPIs results with Wi-Fi on 5 GHz channel

Operation	Interval (sec)	KPI function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	98
		RTT [msec]	21.34	29.28	47.6	110.66	267.346
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	98	100	100
		RTT [msec]	20.5	28.84	49.346	110.7	267.86
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	20.88	28.36	46.5	111.22	266.74
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msecs]	20.906	28.826	47.815	110.86	267.315

Table 7. ST-SA Wi-Fi KPIs for 5 GHz channel

Wifi_kpi	Percentage
ICMP Loss [%]	0.00 %
ICMP Success [%]	100.00 %
Wi-Fi RTT Average [msec]	6.945

Table 8. ST-SA OpenThread and ZigBee KPIs results with Wi-Fi on 2.4 GHz channel separated from 802.15.4 channel

Operation	Interval (sec)	KPI function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	99
		RTT [msec]	19.41	27.64	46.21	124.7	302.111
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	100	100	99
		RTT [msec]	19.37	30.43	48.87	126.79	294.663
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	100	99	99	99
		RTT [msec]	21.26	29.9	47.424	122.322	335.989
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msec]	20.013	29.323	47.501	124.604	310.921

Table 9. ST-SA Wi-Fi KPIs for 2.4 GHz channel separated from 802.15.4 channel

wifi_kpi	Percentage
ICMP Loss [%]	0.00 %
ICMP Success [%]	100.00 %
Wi-Fi RTT Average [msec]	7.747

Table 10. ST-SA OpenThread and ZigBee KPIs results with Wi-Fi on 2.4 GHz channel overlapping with 802.15.4 channel

Operation	Interval (sec)	KPI function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	99
		RTT [msec]	20.8	29.5	57.56	135.47	330.14
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	99	100	99
		RTT [msec]	19.83	28.12	46.686	120.79	320.2
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	99	100	99	99

Table 10. ST-SA OpenThread and ZigBee KPIs results with Wi-Fi on 2.4 GHz channel overlapping with 802.15.4 channel*...continued*

Operation	Interval (sec)	KPI function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
		RTT [msec]	19.5	29.252	47.83	126.373	326.781
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msec]	20.043	28.957	50.692	127.544	325.707

Table 11. ST-SA Wi-Fi KPIs for 2.4 GHz channel overlapping with 802.15.4 channel

wifi_kpi	Percentage
ICMP Loss [%]	0.04 %
ICMP Success [%]	99.96 %
Wi-Fi RTT Average [msec]	9.541

6.1.2 Single Transceiver Dual Antenna (ST-DA)

The following results summarize the performance for the ST-DA configuration under the defined dual PAN minimal test setup.

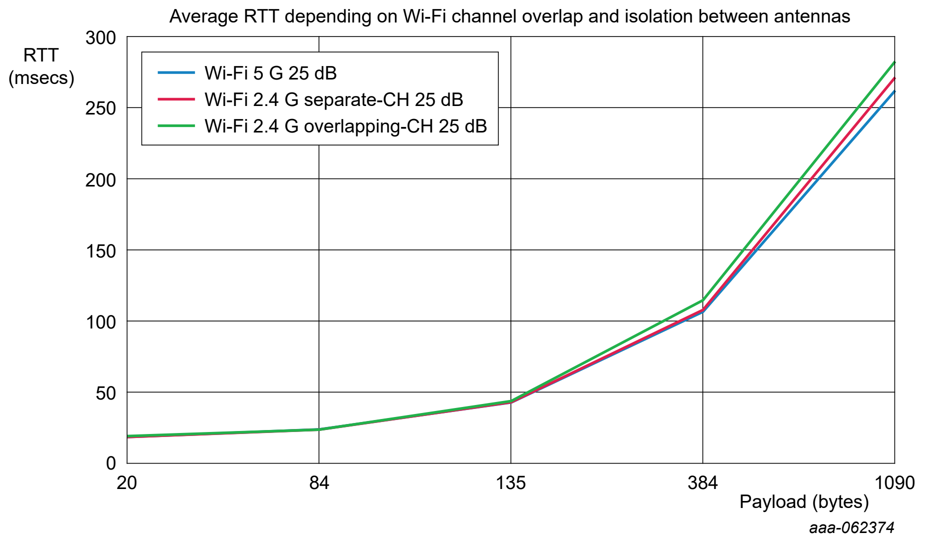

Figure 19. ST-DA Average RTT on OpenThread depending on Wi-Fi channel overlap with 802.15.4 channel and antenna isolation

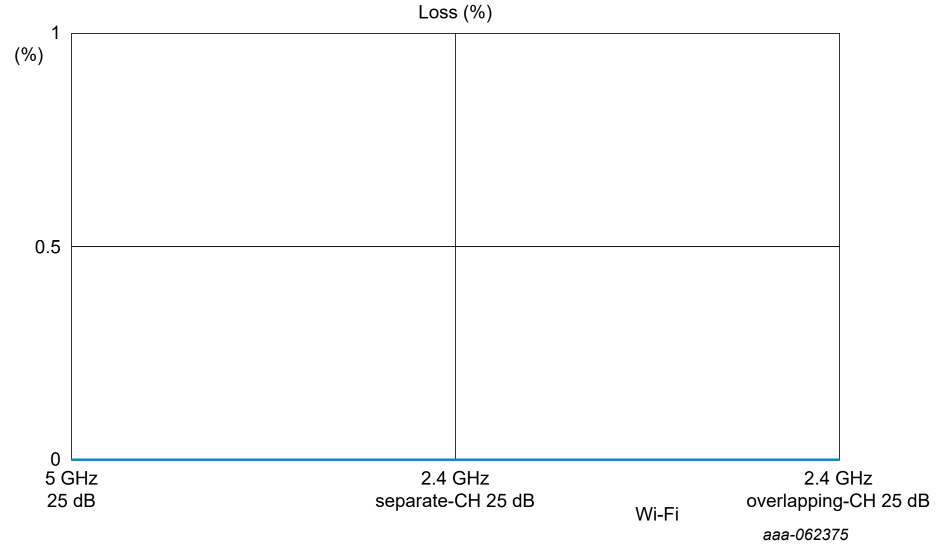

Figure 20. ST-DA packet loss on Wi-Fi depending on Wi-Fi channel overlap with 802.15.4 channel and antenna isolation

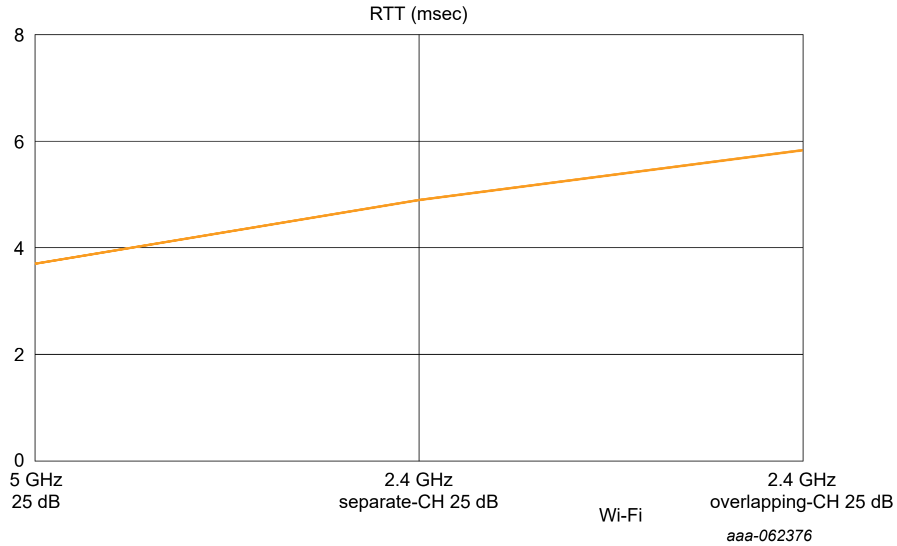

Figure 21. ST-DA RTT on Wi-Fi depending on Wi-Fi channel overlap with 802.15.4 channel and antenna isolation

Table 12. ST-DA OpenThread and ZigBee KPIs results with Wi-Fi on 5 GHz channel with 25 dB isolation

Operation	Interval (sec)	KPI function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	18.74	24.14	41.82	106.98	263.34
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	18.34	24.3	43.4	107.34	257.66

Table 12. ST-DA OpenThread and ZigBee KPIs results with Wi-Fi on 5 GHz channel with 25 dB isolation...*continued*

Operation	Interval (sec)	KPI function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	18.28	23.34	43.14	105.3	264.96
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msec]	18.453	23.926	42.786	106.54	261.986

Table 13. ST-DA Wi-Fi KPIs for 5 GHz channel with 25 dB isolation

wifi_kpi	Percentage
ICMP Loss [%]	0.00 %
ICMP Success [%]	100.00 %
Wi-Fi RTT Average [msec]	3.705

Table 14. ST-DA OpenThread and ZigBee KPIs results with Wi-Fi on 2.4 GHz channel with 25 dB isolation separated from 802.15.4 channel

Operation	Interval (sec)	KPI function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	18.42	23.1	42.74	106.36	270.288
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	100	99	100
		RTT [msec]	17.76	24.8	43.12	109.183	273
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	19.14	23.14	43.26	107.78	270.52
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msec]	18.44	23.68	43.04	107.774	271.269

Table 15. ST-DA Wi-Fi KPIs for Wi-Fi on 2.4 GHz channel with 25 dB isolation separated from 802.15.4 channel

wifi_kpi	Percentage
ICMP Loss [%]	0.00 %
ICMP Success [%]	100.00 %
Wi-Fi RTT Average [msec]	5.452

Table 16. ST-DA OpenThread and Zigbee KPIs results with Wi-Fi on 2.4 GHz channel with 25 dB isolation overlapping with 802.15.4 channel

Operation	Interval (sec)	KPI function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	19.14	23.82	44.44	114.88	276.78
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	19.4	23.8	43.48	114.32	284.92
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	18.74	23.48	43.24	114.46	285.68
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msec]	19.093	23.7	43.72	114.553	282.46

Table 17. ST-DA Wi-Fi KPIs for Wi-Fi on 2.4 GHz channel with 25 dB isolation overlapping with 802.15.4 channel

wifi_kpi	Percentage
ICMP Loss [%]	0.00 %
ICMP Success [%]	100.00 %
Wi-Fi RTT Average [msec]	5.831

6.1.3 Dual Transceiver Triple Antenna (DT-TA)

The following results summarize the performance for the DT-TA configuration under the defined dual PAN minimal test setup.

6.1.3.1 Same 802.15.4 PAN channels results

The following results present the performance of the DT-TA configuration with the same IEEE 802.15.4 PAN channels under the defined dual PAN minimal test setup.

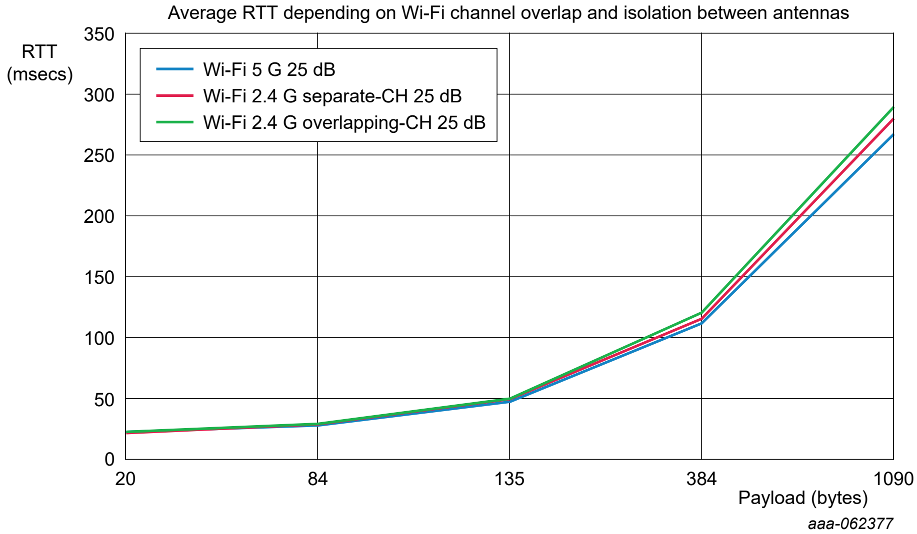

Figure 22. DT-TA Average RTT on OpenThread depending on Wi-Fi channel overlap with 802.15.4 channel and antenna isolation

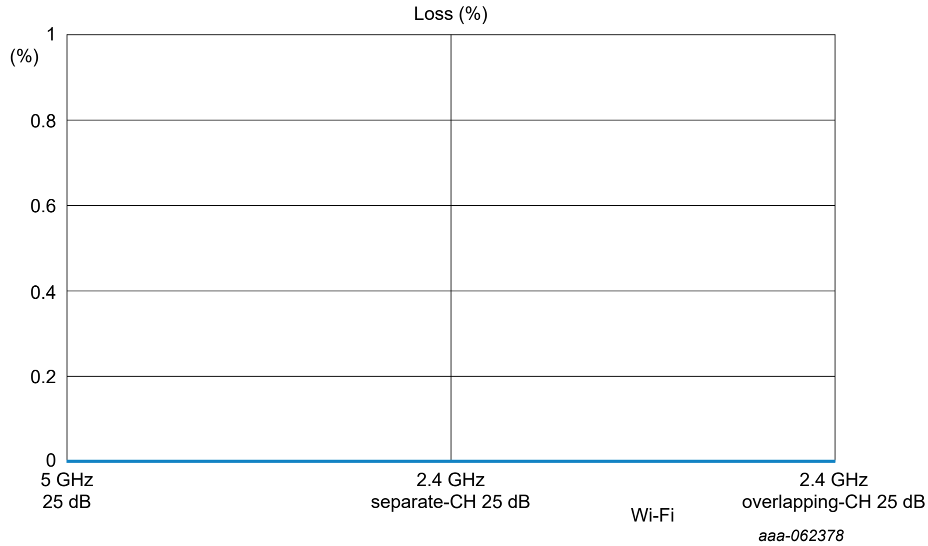

Figure 23. DT-TA Packet loss on Wi-Fi depending on Wi-Fi channel overlap with 802.15.4 channel and antenna isolation

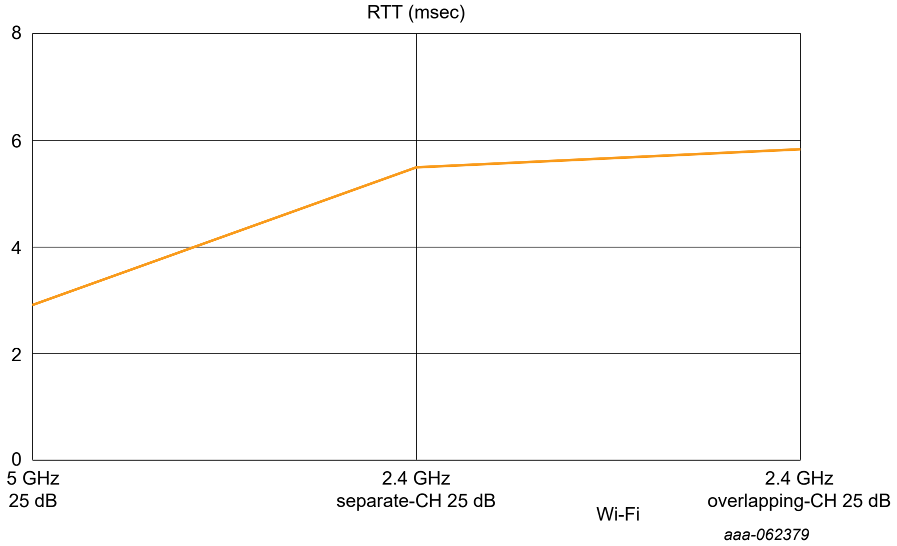

Figure 24. DT-TA RTT on Wi-Fi depending on Wi-Fi channel overlap with 802.15.4 channel and antenna isolation

Table 18. DT-TA OpenThread and ZigBee KPIs results with Wi-Fi on 5 GHz channel with 25 dB isolation

Operation	Interval (sec)	KPI function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	21.78	27.34	47.32	112.72	267.9
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	22.36	27.66	47.4	110.8	265.8
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	23	27.98	47.46	111.12	267.1
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msec]	22.38	27.66	47.393	111.546	26.933

Table 19. DT-TA Wi-Fi KPIs for 5 GHz channel with 25 dB isolation

wifi_kpi	Percentage
ICMP Loss [%]	0.00 %
ICMP Success [%]	100.00 %
Wi-Fi RTT Average [msec]	2.894

Table 20. DT-TA OpenThread and ZigBee KPIs results with Wi-Fi on 2.4 GHz channel with 25 dB isolation separated from 802.15.4 channel

Operation	Interval (sec)	KPI Function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	21.64	28.78	49.7	115.2	280.62
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	21.64	28.78	49.7	115.2	280.62
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	100	100	100	98
		RTT [msec]	21.68	28.58	48.82	115.8	278.244
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msec]	21.653	28.713	49.406	115.4	279.828

Table 21. DT-TA Wi-Fi KPIs for 2.4 GHz channel with 25 dB isolation separated from 802.15.4 channel

wifi_kpi	Percentage
ICMP Loss [%]	0.00 %
ICMP Success [%]	100.00 %
Wi-Fi RTT Average [msec]	5.471

Table 22. DT-TA OpenThread and ZigBee KPIs results with Wi-Fi on 2.4 GHz channel with 25 dB isolation overlapping with 802.15.4 channel

Operation	Interval (sec)	KPI function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	22.9	29.26	50.42	120.7	288.72
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	22.72	28.32	49.54	121.2	288.8
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	100	100	100	100

Table 22. DT-TA OpenThread and ZigBee KPIs results with Wi-Fi on 2.4 GHz channel with 25 dB isolation overlapping with 802.15.4 channel*...continued*

Operation	Interval (sec)	KPI function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
		RTT [msec]	22.14	29.6	48.98	118.96	290.2
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msec]	22.586	29.06	49.646	120.286	289.24

Table 23. DT-TA Wi-Fi KPIs for Wi-Fi on 2.4 GHz channel with 25 dB isolation overlapping with 802.15.4 channel

wifi_kpi	Percentage
ICMP Loss [%]	0.00 %
ICMP Success [%]	100.00 %
Wi-Fi RTT Average [msec]	5.804

6.1.3.2 Different 802.15.4 PAN channels results

The following results present the performance of the DT-TA configuration with different IEEE 802.15.4 PAN channels under the defined dual PAN minimal test setup.

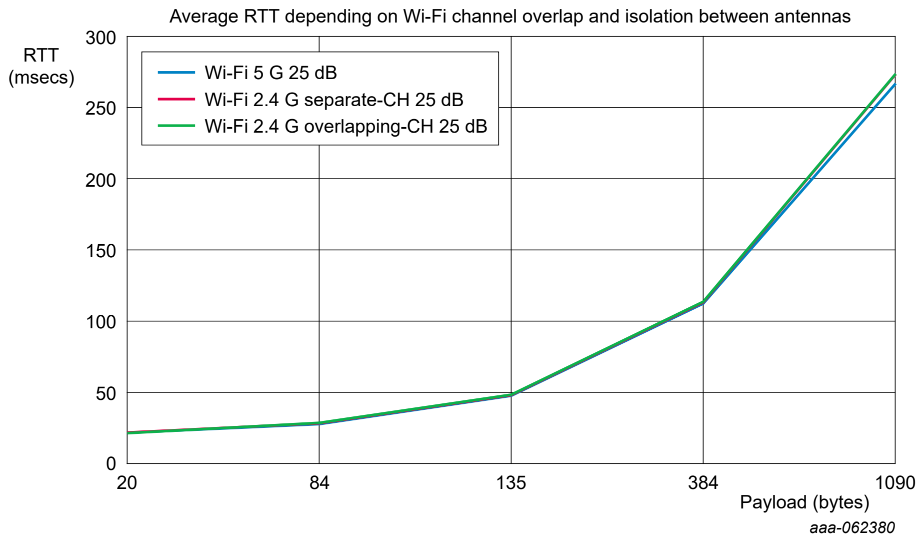

Figure 25. DT-TA Average RTT on OpenThread depending on Wi-Fi channel overlap with 802.15.4 channel and antenna isolation

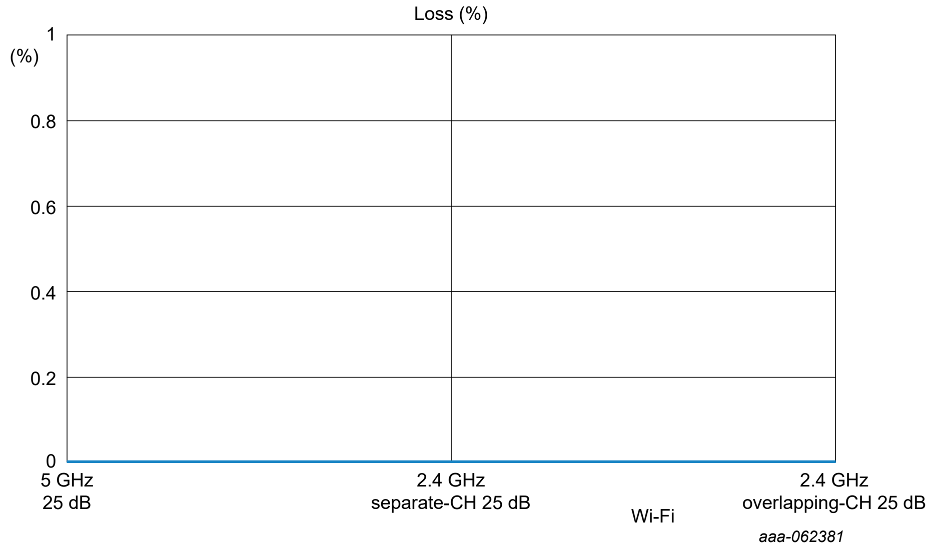

Figure 26. DT-TA Packet loss on Wi-Fi depending on Wi-Fi channel overlap with 802.15.4 channel and antenna isolation

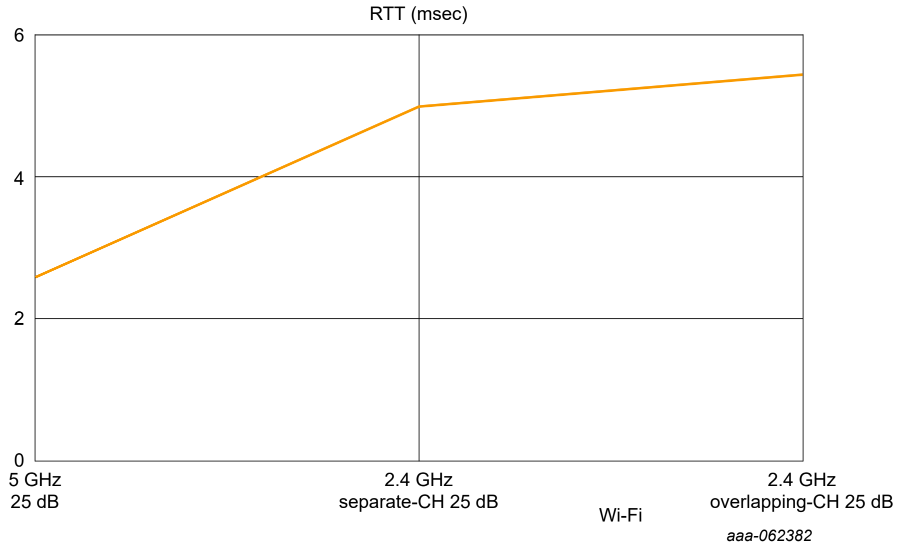

Figure 27. DT-TA RTT on Wi-Fi depending on Wi-Fi channel overlap with 802.15.4 channel and antenna isolation

Table 24. DT-TA OpenThread and Zigbee KPIs results with Wi-Fi on 5 GHz channel with 25 dB isolation

Operation	Interval (sec)	KPI Function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	21.8	27.8	47.22	113.2	269.18
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	21.26	27.36	47.84	113	266.92

Table 24. DT-TA OpenThread and Zigbee KPIs results with Wi-Fi on 5 GHz channel with 25 dB isolation*...continued*

Operation	Interval (sec)	KPI Function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	21.2	27.58	47.52	110.38	264.48
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msec]	21.42	27.58	47.526	112.193	266.86

Table 25. DT-TA Wi-Fi KPIs for 5 GHz channel with 25 dB isolation

wifi_kpi	Percentage
ICMP Loss [%]	0.00 %
ICMP Success [%]	100.00 %
Wi-Fi RTT Average [msec]	2.606

Table 26. DT-TA OpenThread and ZigBee KPIs results with Wi-Fi on 2.4 GHz channel with 25 dB isolation separated from 802.15.4 channel

Operation	Interval (sec)	KPI Function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	21.96	28.4	47.8	114.8	271.46
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	21.54	27.96	47.74	112.82	273.48
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	21.36	28.26	48.26	111.78	275.24
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msec]	21.62	28.206	47.933	113.133	273.393

Table 27. DT-TA Wi-Fi KPIs for 2.4 GHz channel with 25 dB isolation separated from 802.15.4 channel

wifi_kpi	Percentage
ICMP Loss [%]	0.00 %

Table 27. DT-TA Wi-Fi KPIs for 2.4 GHz channel with 25 dB isolation separated from 802.15.4 channel*...continued*

wifi_kpi	Percentage
ICMP Success [%]	100.00 %
Wi-Fi RTT Average [msec]	5.011

Table 28. DT-TA OpenThread and ZigBee KPIs results with Wi-Fi on 2.4 GHz channel with 25 dB isolation overlapping with 802.15.4 channel

Operation	Interval (sec)	KPI Function	Payload: 20 bytes	Payload: 84 bytes	Payload: 135 bytes	Payload: 384 bytes	Payload: 1090 bytes
ot_kpi	2	ICMP success rate [%]	100	100	100	100	98
		RTT [msec]	21.22	28.24	48.16	113.5	273.489
zb_kpi	2	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	1	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	20.96	28.72	48.6	113.4	274.26
zb_kpi	1	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	0.5	ICMP success rate [%]	100	100	100	100	100
		RTT [msec]	21.5	28.46	47.94	113.8	273.4
zb_kpi	0.5	TP2 success rate [%]	100	100	100	NA	NA
ot_kpi	NA	ot_rtt_mean [msec]	21.226	28.473	48.233	113.566	273.716

Table 29. DT-TA Wi-Fi KPIs for Wi-Fi on 2.4 GHz channel with 25 dB isolation overlapping with 802.15.4 channel

wifi_kpi	Percentage
ICMP Loss [%]	0.00 %
ICMP Success [%]	100.00 %
Wi-Fi RTT Average [msec]	5.447

6.1.4 Test conclusions

The following graphs present the mean RTT results for OpenThread and Wi-Fi.

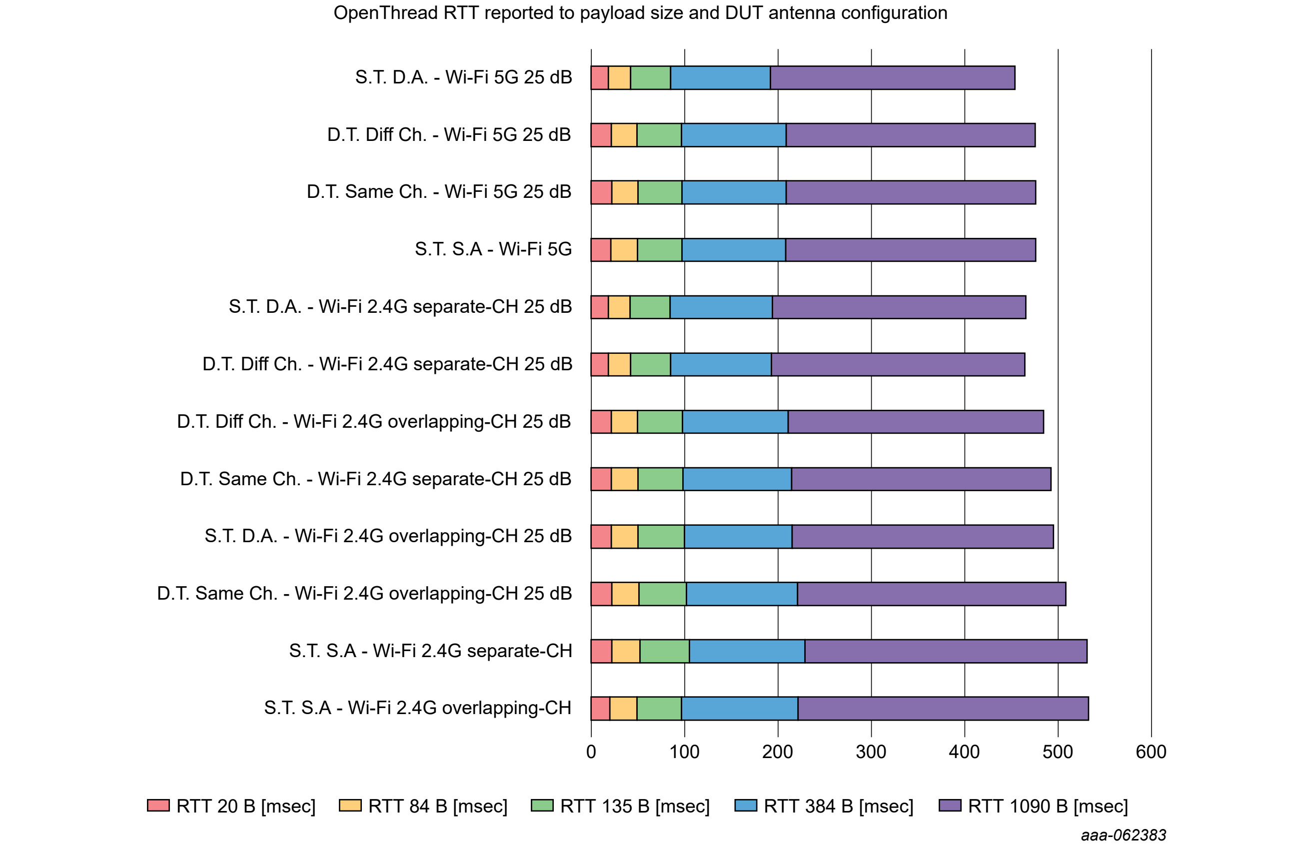

Figure 28. OpenThread RTT reported to payload size and antenna configuration

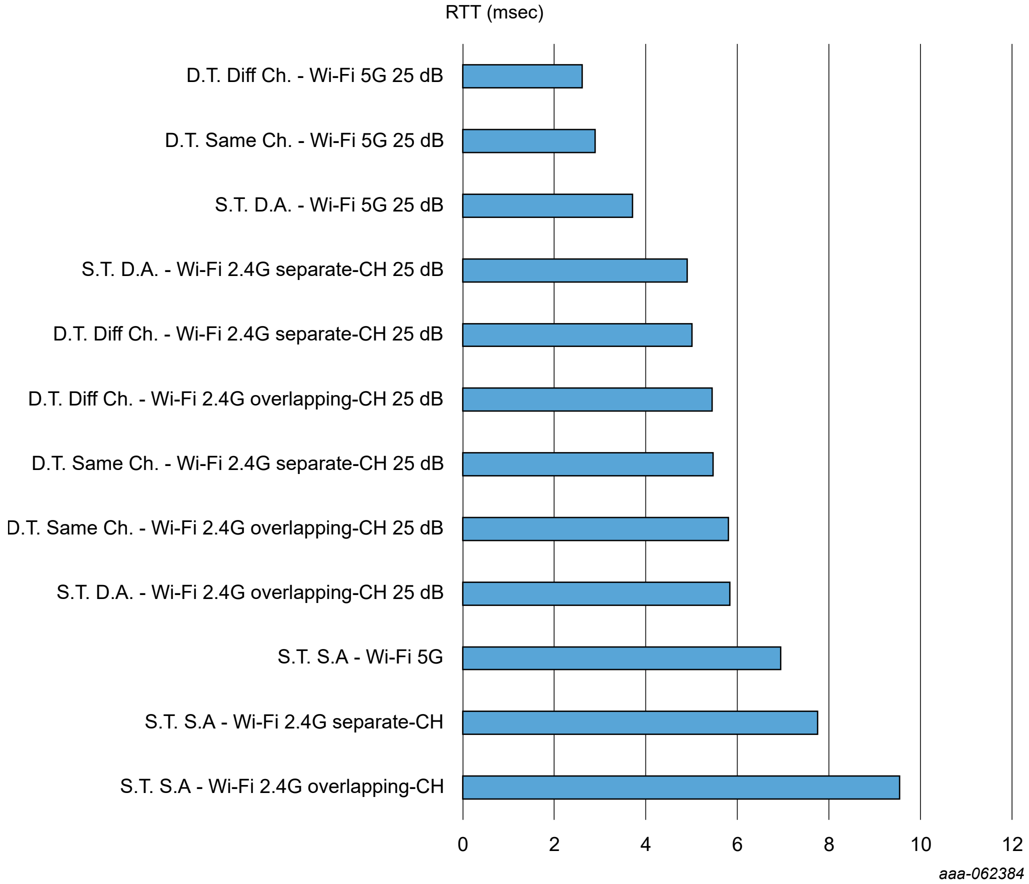

Figure 29. Wi-Fi RTT reported to antenna configuration for fixed payload size

The Figure 30 presents a more compressed view of RTT values based on the number of transceivers and antennas. Each value reflects the mean measurement for its respective combination.

Note: *'Wi-Fi 2.4G separate CH' refers to the separation between the Wi-Fi network channel and the 802.15.4 network channel, while 'Wi-Fi 2.4G overlapping CH' refers to the Wi-Fi and 802.15.4 channels having overlapping frequencies. For the DT data, 'same CH' means that the 802.15.4 PAN networks (ZigBee and Thread) are running on the same channel, while the 'diff CH' refer to the fact that Thread and ZigBee are on separate 802.15.4 channel frequencies.*

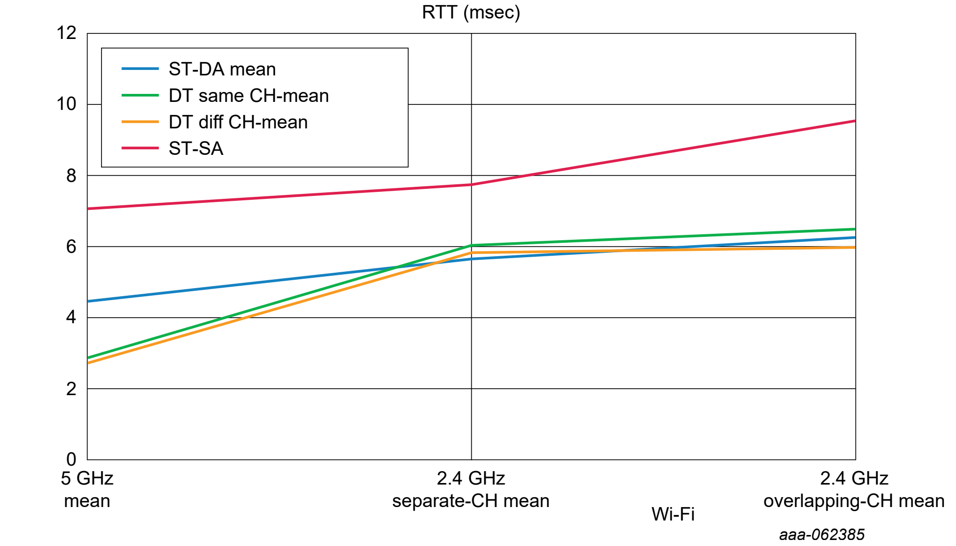

Figure 30. Wi-Fi reports the mean RTT based on the antenna configuration.

Note: *Refer to the Note to check the comments for Figure 31.*

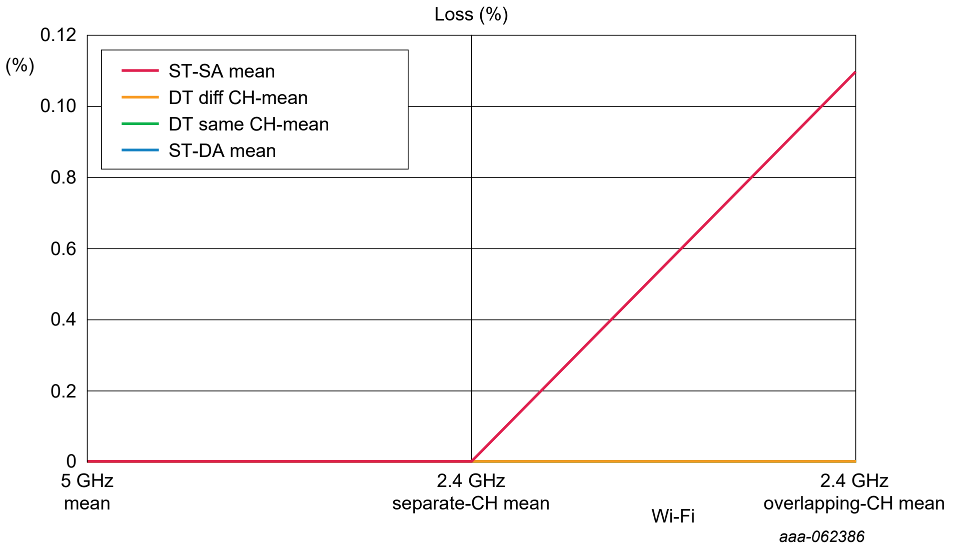

Figure 31. Wi-Fi loss reported to antenna configuration

Dual PAN performance shows impact primarily in RTT values for the two PANs. In the worst conditions, where OpenThread sends 1090 B payloads every 0.5 seconds, the system records a maximum packet loss of 2 %. Environmental factors in open office or home settings also affect performance.

On the Wi-Fi side, the single-antenna setup experiences slightly increased latency. The dual-antenna setup shows higher packet loss, depending on the Wi-Fi band, channel overlap, and antenna attenuation.

Given the minimal setup with one device per PAN, we observe increased RTTs and packet error rates on scaling up the networks. For example, when we move to a typical setup with five devices per PAN, channel utilization gets closer to its limit, which contributes to degraded performance.

Refer to the Note.

6.2 T0.1.2 Dual PAN Wi-Fi bandwidth minimal test setup results

This section summarizes the performance measurements for the KPIs of the Wi-Fi network in a minimal test setup with one OpenThread node and one ZigBee node.

Table 30. Measured bandwidth using iperf on TCP/UDP reported to antenna configuration and setting

Wi-Fi configuration	Measuring Interval [sec]	Throughput [Mbit/s]					
		TCP			UDP		
		ST-SA	ST-DA	DT	ST-SA	ST-DA	DT
5 GHz	300	201	N/A	N/A	205	N/A	N/A
5 GHz - 25 dB isolation	300	N/A	209	207	N/A	229	225
2.4 GHz separate channel	300	37.8	N/A	N/A	37.5	N/A	N/A
2.4 GHz separate channel - 25 dB isolation	300	N/A	64.1	63.3	N/A	69.9	65.4
2.4 GHz overlapping channel	300	35.9	N/A	N/A	35.2	N/A	N/A
2.4 GHz overlapping channel - 25 dB isolation	300	N/A	52.4	44.2	N/A	61.2	51.6

Table 31. Measured iperf loss on UDP reported to antenna configuration and setting

Wi-Fi configuration	Measuring Interval [sec]	UDP		
		ST-SA loss [%]	ST-DA loss [%]	DT loss [%]
5 GHz	300	0.92 %	N/A	N/A
5 GHz - 25 dB isolation	300	N/A	1.00 %	1.10 %
2.4 GHz separate channel	300	16.00 %	N/A	N/A
2.4 GHz separate channel - 25 dB isolation	300	N/A	1.60 %	2.00 %
2.4 GHz overlapping channel	300	20.00 %	N/A	N/A
2.4 GHz overlapping channel - 25 dB isolation	300	N/A	2.20 %	4.30 %

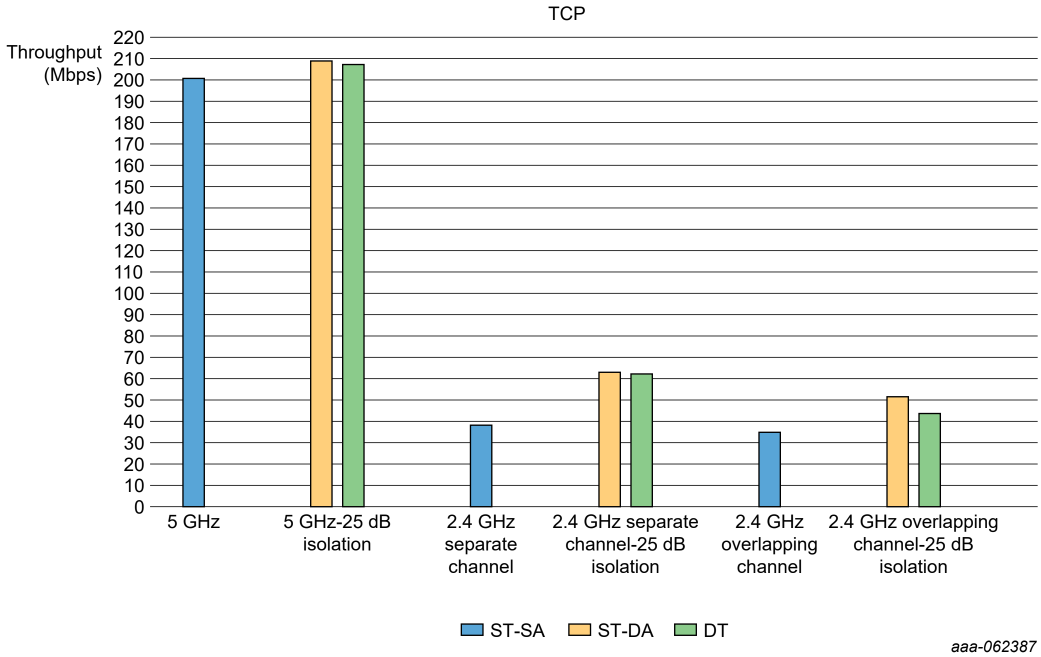

Figure 32. Iperf TCP results

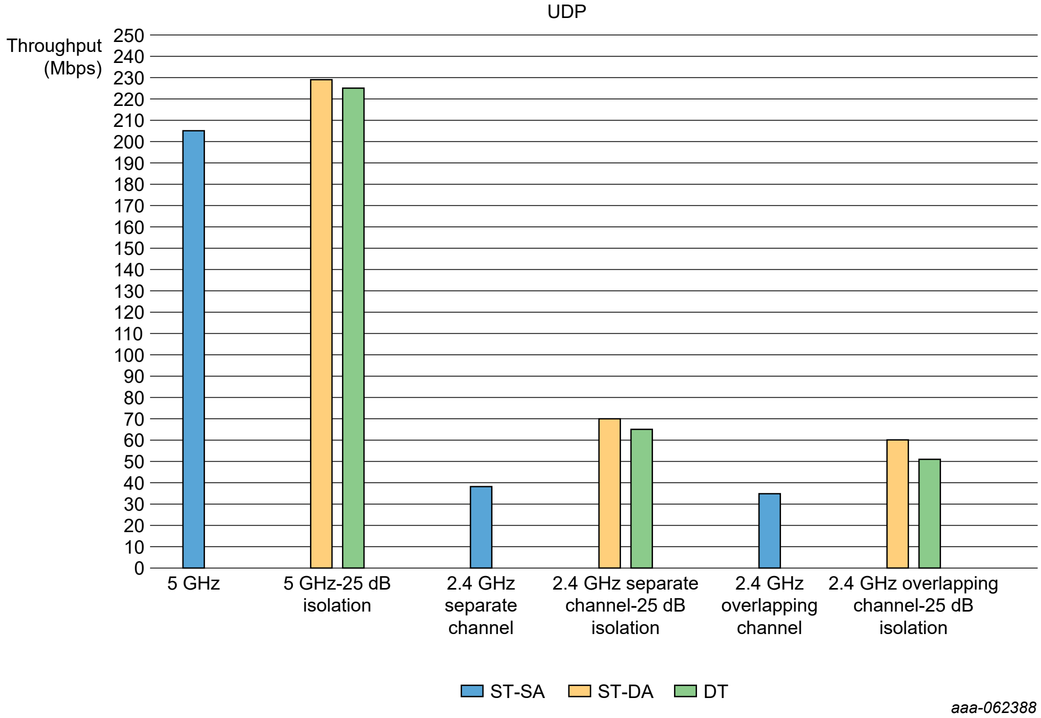

Figure 33. Iperf UDP results

6.2.1 Test conclusions

Having multiple antennas benefits all configurations, as shown in the figures of the section, Section 6.2. In multiple-antenna setups, throughput in the 5 GHz band averages about three times higher than in the 2.4 GHz band. For single-antenna configurations, the 5 GHz throughput can be up to five times greater.

The worst results are obtained using the single-antenna setup. A single antenna must multiplex signals from multiple protocols, including IEEE 802.11 Wi-Fi and IEEE 802.15.4 Thread/ZigBee, which reduces overall bandwidth.

6.3 T0.1.3 Dual PAN Wi-Fi fixed bandwidth minimal test setup results

This section summarizes the performance measurements for the KPIs of the Thread and ZigBee networks in a minimal test setup with one OpenThread node and one ZigBee node.

Table 32. OpenThread loss reported to antenna configuration for fixed Wi-Fi bandwidth of 25 Mbit/s

Wi-Fi configuration	Measuring Interval [sec]	OT loss [%]			
		ST-SA	ST-DA	DT Same Ch.	DT Diff Ch.
5 GHz	300	0.00 %	N/A	N/A	N/A
5 GHz - 25 dB isolation	300	N/A	0.00 %	0.00 %	0.00 %
2.4 GHz separate channel	300	2.30 %	N/A	N/A	N/A
2.4 GHz separate channel - 25 dB isolation	300	N/A	0.00 %	0.00 %	0.00 %
2.4 GHz overlapping channel	300	7.60 %	N/A	N/A	N/A
2.4 GHz overlapping channel - 25 dB isolation	300	N/A	0.00 %	0.60 %	0.00 %

Table 33. OpenThread RTT reported to antenna configuration for a fixed Wi-Fi bandwidth of 25 Mbit/s

Wi-Fi configuration	Measuring Interval [sec]	OT RTT [ms]			
		ST-SA	ST-DA	DT Same Ch.	DT Diff Ch.
5 GHz	300	63.18	N/A	N/A	N/A
5 GHz - 25 dB isolation	300	N/A	45.4	49.74	51.14
2.4 GHz separate channel	300	85.92	N/A	N/A	N/A
2.4 GHz separate channel - 25 dB isolation	300	N/A	48.71	54.77	51.7
2.4 GHz overlapping channel	300	108.37	N/A	N/A	N/A
2.4 GHz overlapping channel - 25 dB isolation	300	N/A	76.76	75.95	50.88

Table 34. ZigBee loss reported to antenna configuration for a fixed Wi-Fi bandwidth of 25 Mbit/s

Wi-Fi configuration	Measuring Interval [sec]	ZB Loss [%]			
		ST-SA	ST-DA	DT Same Ch.	DT Diff Ch.
5 GHz	300	0.00 %	0.00 %	0.00 %	0.00 %
5 GHz - 25 dB isolation	300	0.00 %	0.00 %	0.00 %	0.00 %
2.4 GHz separate channel	300	0.00 %	0.00 %	0.00 %	0.00 %
2.4 GHz separate channel - 25 dB isolation	300	0.00 %	0.00 %	0.00 %	0.00 %
2.4 GHz overlapping channel	300	0.00 %	0.00 %	0.00 %	0.00 %
2.4 GHz overlapping channel - 25 dB isolation	300	0.00 %	0.00 %	0.00 %	0.00 %

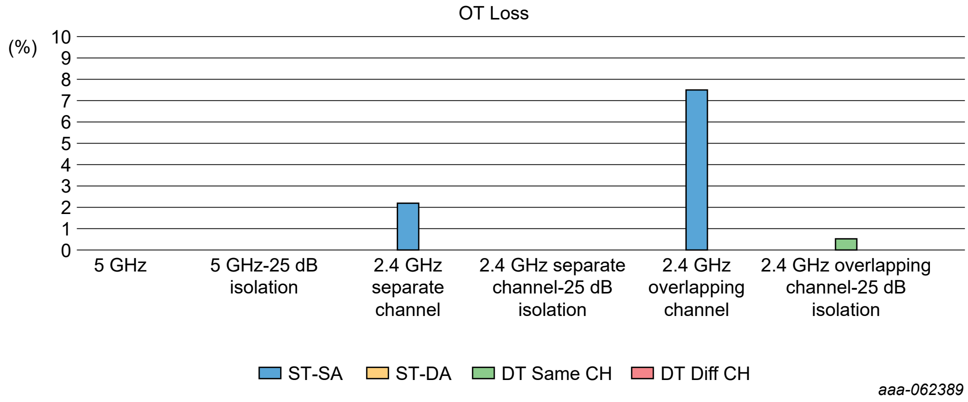

Figure 34. OpenThread loss reported to antenna configuration for fixed Wi-Fi bandwidth of 25 Mbit/s

Note: *Refer to the Note to check the comments for Figure 34.*

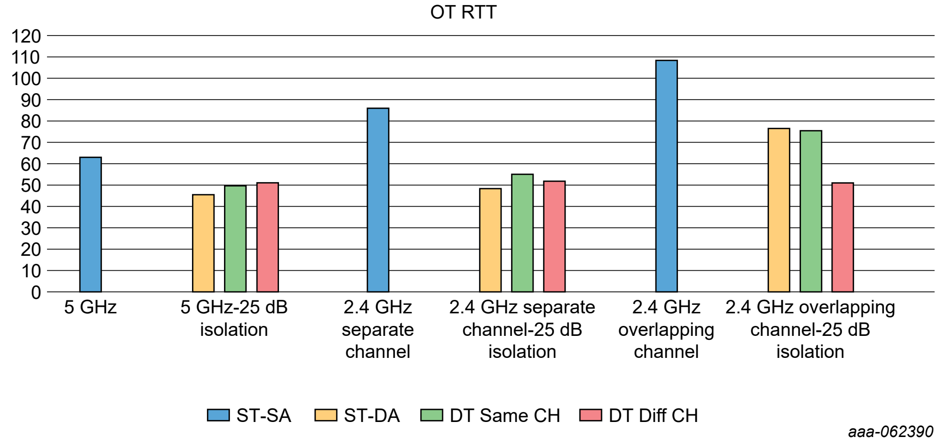

Figure 35. OpenThread RTT reported to antenna configuration for a fixed Wi-Fi bandwidth of 25 Mbit/s

Note: *Refer to the Note to check the comments for Figure 35.*

6.3.1 Test conclusions

This test reveals the limitations of the ST-SA configuration. OpenThread traffic shows the highest packet loss percentage in this setup.

The configuration multiplexes all wireless protocols through one antenna. This causes bottlenecks during transmission and reception, especially under high-throughput cases.

Wi-Fi operates at a high and constant Mbit/s rate. This leaves limited time for OpenThread and ZigBee traffic to transmit effectively.

ZigBee remains unaffected during testing. However, OpenThread encounters issues because its packet size reaches 1090 bytes, which exceeds the maximum packet size of ZigBee. These challenges become more evident in open environment conditions.

6.4 T0.2.1 Dual PAN Wi-Fi fixed bandwidth typical test

This section summarizes the performance measurements for the KPIs of the Thread and ZigBee networks in a typical test setup with five OpenThread node and five ZigBee node.

Table 35. OpenThread loss reported to antenna configuration for fixed Wi-Fi bandwidth of 25 Mbit/s

Wi-Fi configuration	Measuring Interval [sec]	OT Loss [%]			
		ST-SA	ST-DA	DT Same Channel	DT Diff Channel
5GHz	300	0.00 %	N/A	N/A	N/A
2.4 GHz separate channel	300	2.68 %	N/A	N/A	N/A
2.4 GHz separate channel - 25 dB isolation	300	N/A	0.20 %	0.00 %	0.00 %
2.4 GHz overlapping channel	300	9.90 %	N/A	N/A	N/A
2.4 GHz overlapping channel - 25 dB isolation	300	N/A	0.80 %	0.60 %	0.00 %

Table 36. OpenThread RTT reported to antenna configuration for a fixed Wi-Fi bandwidth of 25 Mbit/s

Wi-Fi configuration	Measuring Interval [sec]	OT RTT [ms]			
		ST-SA	ST-DA	DT Same Channel	DT Diff Channel
5 GHz	300	76.71	N/A	N/A	N/A
5 GHz - 25 dB isolation	300	N/A	51.77	54.71	52.9
2.4 GHz separate channel	300	120.13	N/A	N/A	N/A
2.4 GHz separate channel - 25 dB isolation	300	N/A	50.22	57.3	54.3
2.4 GHz overlapping channel	300	184.1	N/A	N/A	N/A
2.4 GHz overlapping channel - 25 dB isolation	300	N/A	90.39	78.76	59.32

Table 37. Zigbee loss reported to antenna configuration for a fixed Wi-Fi bandwidth of 25 Mbit/s

Wi-Fi configuration	Measuring Interval [sec]	ZB Loss [%]			
		ST-SA	ST-DA	DT Same Channel	DT Diff Channel
5 GHz	300	0.00 %	N/A	N/A	N/A
5 GHz - 25 dB isolation	300	N/A	0.00 %	0.00 %	0.00 %
2.4 GHz separate channel	300	0.13 %	N/A	N/A	N/A
2.4 GHz separate channel - 25 dB isolation	300	N/A	0.00 %	0.00 %	0.00 %
2.4 GHz overlapping channel	300	0.84 %	N/A	N/A	N/A
2.4 GHz overlapping channel - 25 dB isolation	300	N/A	0.00 %	0.00 %	0.00 %

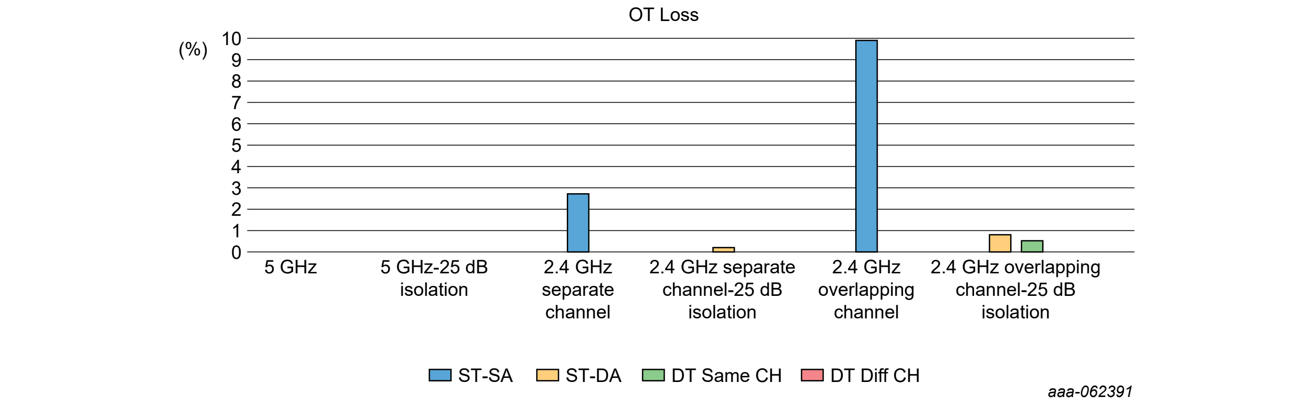

Figure 36. OpenThread loss reported to antenna configuration for fixed Wi-Fi bandwidth of 25 Mbit/s

Note: *Refer to the Note to check the comments for Figure 36.*

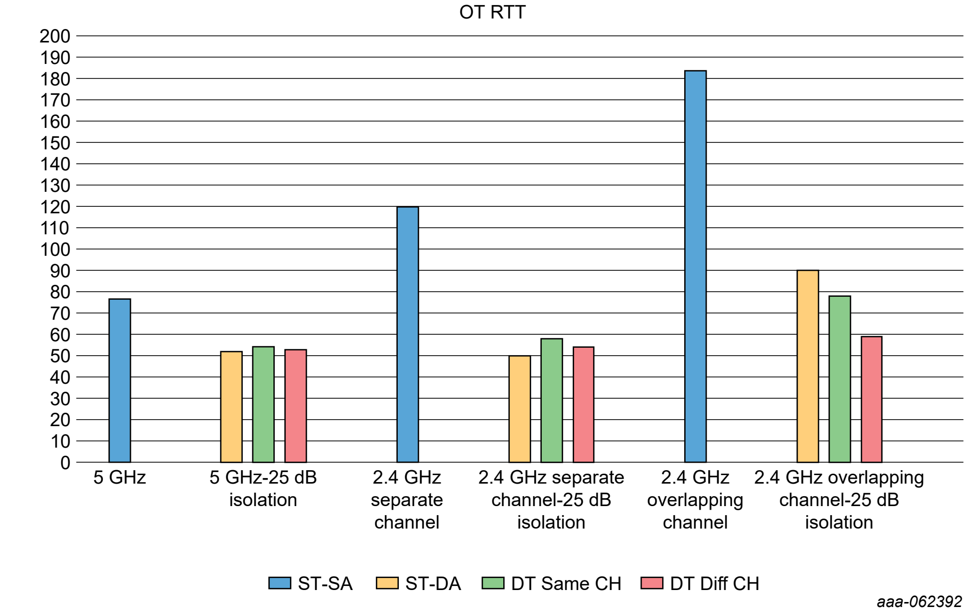

Figure 37. OpenThread RTT reported to antenna configuration for a fixed Wi-Fi bandwidth of 25 Mbit/s

Note: *Refer to the Note to check the comments for Figure 37.*

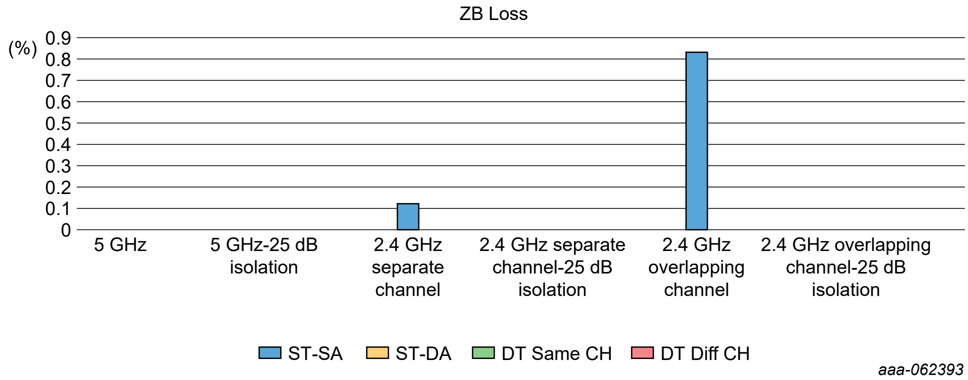

Figure 38. ZigBee loss reported to antenna configuration for a fixed Wi-Fi bandwidth of 25 Mbit/s

Note: *Refer to the Note to check the comments for Figure 38.*

6.4.1 Test conclusions

On the 5 GHz Wi-Fi band, all solutions perform similarly. No major discrepancies appear in either minimal test setups or extended 802.15.4 networks with 5 OT and 5 ZigBee devices.

On the 2.4 GHz Wi-Fi band, the ST-SA setup shows the most impact. It experiences up to 10 % OT ping loss and 200 ms OT RTT. It also starts registering ZigBee losses in typical network setups.

The ST-DA setup follows in terms of impact. Low antenna isolation affects it most when the Wi-Fi channel overlaps with the 802.15.4 channel. This highlights a limitation in the multiplexing mechanism between Zigbee and OT under high Wi-Fi interference.

The DT solution shows similar results to the ST-DA setup in most cases. However, it becomes more susceptible to OpenThread and Zigbee losses when Zigbee and OT share the same channel and antenna isolation is low.

The DT setup performs worse than ST-DA when Wi-Fi and 802.15.4 channels overlap with the 802.15.4 channel and antenna isolation is low. This setup uses three antennas compared to two in ST-DA. The results reveal the limitations of relying solely on Clear Channel Assessment (CCA) for arbitration under high interference. They also show the benefits of adding an internal arbitration mechanism.

When Zigbee and OpenThread use different channels, the DT setup performs most consistently across all use cases—even with low antenna isolation.

Testing results from T0.1.3 minimal setup and T0.2.1 typical setup reveal the expected increase in RTT and packet error rate when scaling up the network from 1 to 5 devices. This behavior is observed when using Wi-Fi in the 2.4 GHz band

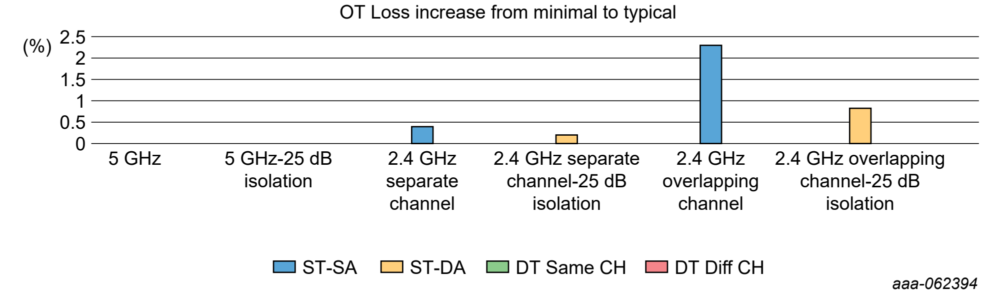

Figure 39. OpenThread loss increases from minimal setup to typical setup

Note: *Refer to the Note to check the comments for Figure 39.*

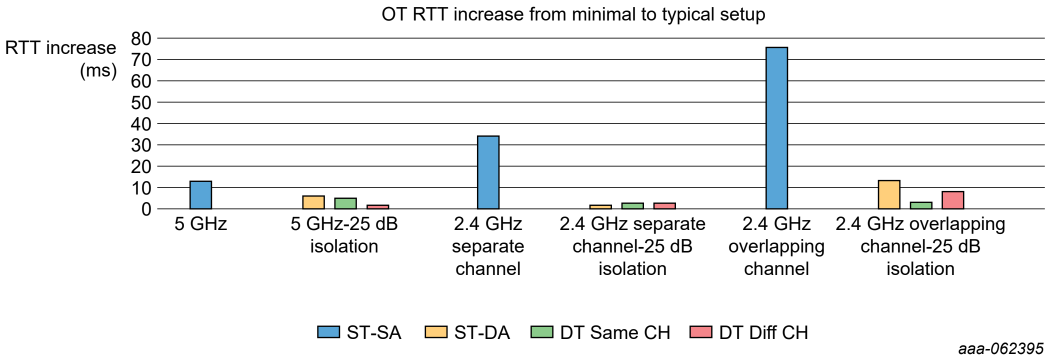

Figure 40. OpenThread RTT increase from minimal setup to typical setup

Note: *Refer to the Note to check the comments for Figure 40.*

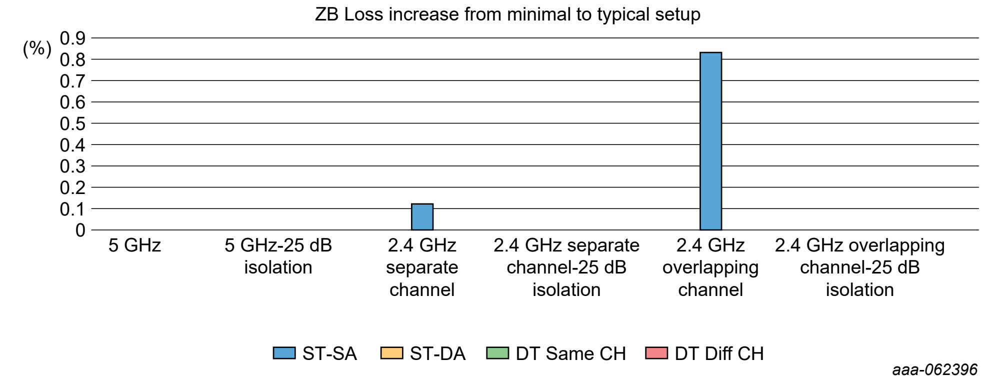

Figure 41. Zigbee loss increases from minimal setup to typical setup

Note: *Refer to the Note to check the comments for Figure 41.*

Based on current test results, all three setups offer specific use cases where they provide the best solution:

- ST-SA: When Wi-Fi operates on the 5 GHz band, it is the most cost effective. It shows minor performance differences and moderate impact on system resources.
- ST-DA: When Wi-Fi uses the 2.4 GHz band and the channel is separate from the 15.4 channel, it has similar or better performance than the other two solutions. It remains more cost effective than the dual radio solution and has the lowest impact on system resources.
- DT-TA: When Wi-Fi operates on the 2.4 GHz band and the channel overlaps with the 15.4 channel, it has the best performance. It shows the lowest increase in OpenThread loss and RTT when increasing the network sizes due to the possibility of operating the PANs on different channels. However, it involves higher costs and a greater impact on system resources.

7 MPU resource usage

Complementary to testing, CPU, and memory usage reports have been conducted to observe how each system configuration handles resources differently.

The Table 38 sums up the capabilities of the MPU platforms used in testing.

Table 38. NXP MPU capabilities

Metrics	i.MX 93	i.MX 8MM
APP CPU	2 x Arm Cortex A55	4 x Arm Cortex-A53 core running
I/O CPU	1 x Arm Cortex M33	1 x Arm Cortex-M4 core running
MEM	2 GB 16-bit LPDDR4X	2 GB 32-bit LPDDR4
Default memory utilization in idle [%]	8.96 %	17.60 %

The data in Table 39 represents the average CPU usage and memory usage in percentage at runtime.

Table 39. Average CPU and memory usage for system configurations

Wi-Fi configuration	Measuring Interval [sec]	CPU Avg Usage [%]			MEM Avg Usage [%]		
		ST-SA (i.MX 93)	ST-DA (i.MX 8MM)	DT (i.MX 8MM)	ST-SA (i.MX 93)	ST-DA (i.MX 8MM)	DT (i.MX 8MM)
5 GHz	300	79.35 %	32.58 %	58.50 %	9.72 %	18.12 %	20.57 %
2.4 GHz separate channel	300	79.98 %	32.93 %	58.38 %	9.47 %	18.63 %	20.38 %
2.4 GHz overlapping channel	300	80.07 %	33.20 %	62.18 %	9.69 %	18.28 %	20.84 %

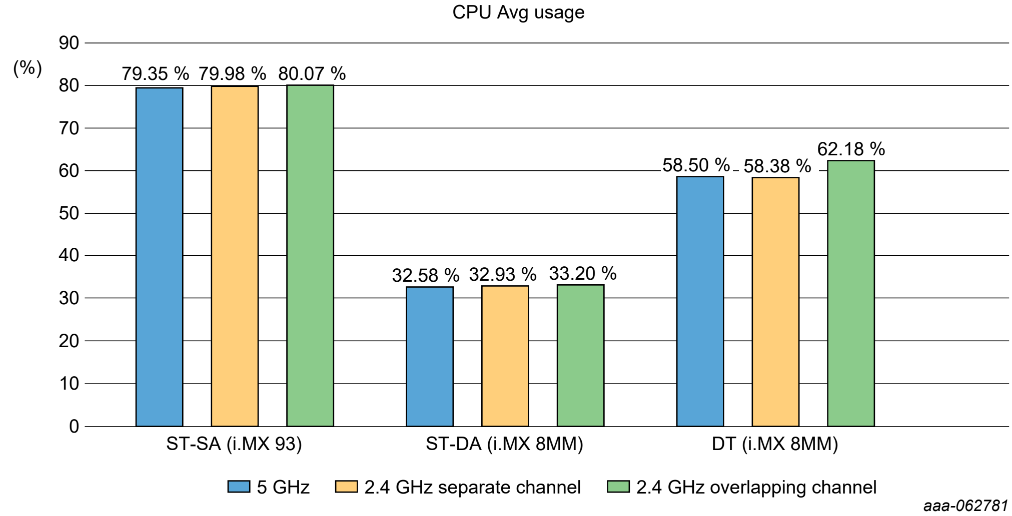

Figure 42. Average CPU for system configurations

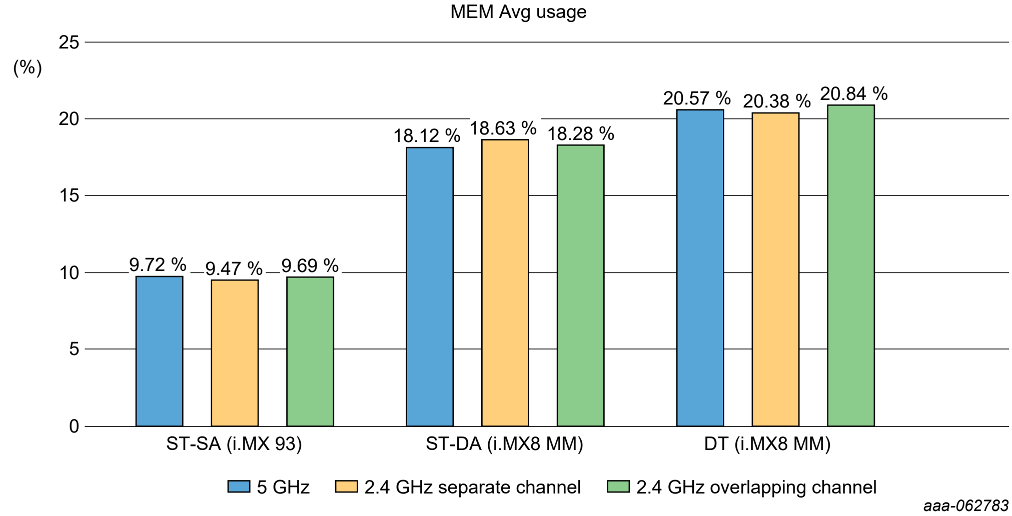

Figure 43. Average memory usage for system configurations

The average CPU load on the i.MX 93 MPU system seems higher. This happens because it has the fewer available Arm Cortex A55 cores. To compare the 2 systems clearly, there is a need to normalize the data. Using the data provided by the Arm community, you can estimate the CPU performance ratio between i.MX 93 Arm Cortex A55 and i.MX 8MM Arm Cortex A53 as being 1.18x.

The i.MX 93 has 2 x Arm Cortex A55 application cores, while the i.MX 8MM has 4 x Arm Cortex A53 application cores. As one A55 core is 1.18 times faster than one A53 core, scaling the i.MX 93 data to the i.MX 8MM can be done by using the following formula: (2 x 1.18)/(4 x 1) = *0.59. This ratio represents the theoretical CPU normalization factor.*

Applying the ratio to i.MX 93 data from the table above generates the following result: Figure 44.

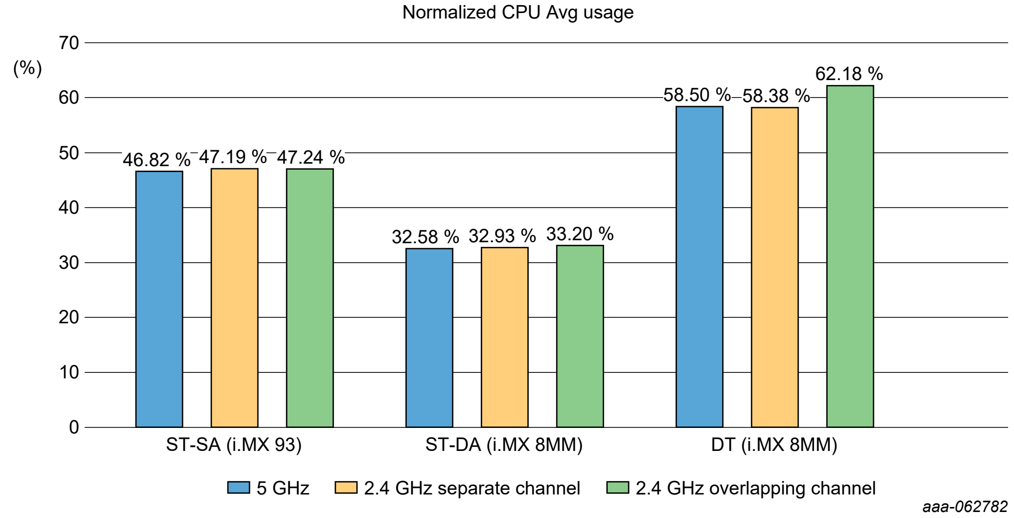

Figure 44. Normalized CPU average usage

The Figure 44 shows a comparison between the ST-SA configuration and the ST-DA configuration in terms of system load.

The DT configuration consumes more resources. The DT setup nearly doubles the CPU load compared to ST-DA and increases the CPU load by approximately 25 % compared to ST-SA.

The memory usage comparison uses a baseline defined by the memory consumed after device boot-up and upon reaching the idle task state.

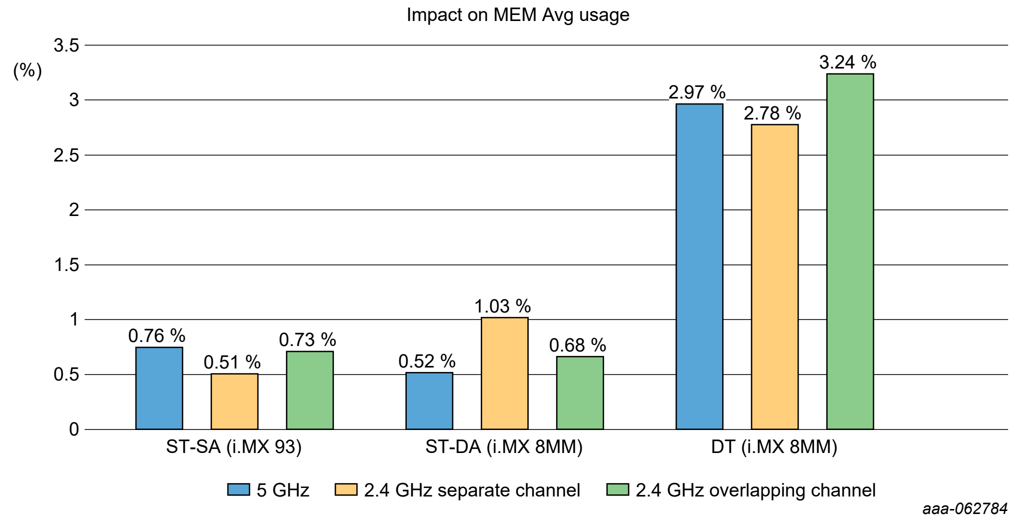

Figure 45. Impact of memory usage

The dual transceiver solution requires up to 3 % more RAM, while the average impact for the single transceiver solutions is below 1 %.

8 Acronyms

Table 40 lists the acronyms used in this document along with their description.

Table 40. Acronyms

Acronyms	Description
AP	Access Point
CCA	Clear Channel Assessment
DT	Dual Transceiver
DT-TA	Dual Transceiver Triple Antenna
DUT	Device under Test
GPIO	General-Purpose Input/Output
ICMP	Internet Control Message Protocol
IoT	Internet of Things
KPI	Key Performance Indicator
NCP	Network Coprocessor
OTBR	OpenThread Border Router
PTA	Packet Traffic Arbitration
RSSI	Received Signal Strength Indicator
RTT	Round-Trip Time
SPI	Serial Peripheral Interface
SSID	Service Set Identifier
ST-SA	Single Transceiver Single Antenna
ST-DA	Single Transceiver Dual Antenna
TCP	Transmission Control Protocol
UART	Universal Asynchronous Receiver Transmitter
UDP	User Datagram Protocol
WCI	Wireless Coexistence Interface

9 Related documentation

Table 41 lists the references used to supplement this document.

Table 41. Related documentation/resources

Document	Link/how to access
NXP Dual PAN Feature and Performance Results (document AN14476)	AN14476
Dual PAN Software User Manual for IW612 (document UM12265)	UM12265
Zigbee Software User Manual for IW612 (document UM12029).	UM12029
OpenThread Software User Manual for IW612 (document UM11844)	UM11844
Calibration Structure for AW611, IW611, and IW612 (document AN13983)	AN13983

Table 41. Related documentation/resources...*continued*

Document	Link/how to access
NXP IW612 RD board	Contact your local NXP FAE or sales representative

10 Revision history

Table 42 summarizes the revisions to this document.

Table 42. Revision history

Document ID	Release date	Description
AN14782 v.2.0	13 November 2025	Made technical changes
AN14782 v.1.0	29 September 2025	Initial public release

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