Licensed-Assisted Access (LAA)

Live Trial Report

Version 1.4
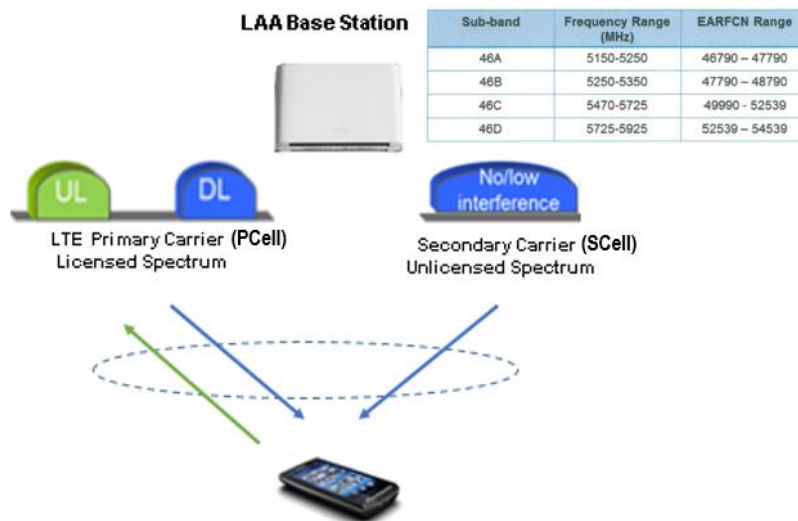
Date: 31-Aug-2018

Table of Contents

_____

1. Overview

1.1 Introduction

Licensed Assisted Access (LAA) is part of the LTE Advance Pro functionality, it was introduced in Release 13 of 3GPP (a Global standardization organization for cellular network technology). LAA offers better downlink performance through carrier aggregation of the unlicensed frequency band of 5 GHz with the licensed LTE frequency band. The topology of LAA is illustrated in Figure 1 below.   LAA helps mobile operators to utilize portions of the unlicensed frequency band to deliver a better end-user quality of experience and significant increase in the downlink data rate.

As Wi-Fi is the dominant applications on unlicensed frequency band of 5 GHz, the key operation principle is that LAA is in coexistence but fairly sharing use of unlicensed frequency band of 5 GHz with Wi-Fi. This is accomplished by dynamically selecting clear channels in 5 GHz to avoid interference with Wi-Fi users. If there is no clear channel available, LAA will share a channel fairly with others. This is accomplished by the feature called Listen Before Talk (LBT). The LBT will be used by most of technologies in unlicensed spectrum to ensure fair spectrum sharing globally.

Figure 1 – Topology of LAA

Sub-band	Frequency Range (MHz)	EARFCN Range
46A	5150-5250	46790 – 47790
46B	5250-5350	47790 – 48790
46C	5470-5725	49990 - 52539
46D	5725-5925	52539 – 54539

Source Reference: Qualcomm

1.2   Scope and purpose

The purpose of the test is to study and verify if there is any impact on Wi-Fi Network with coexistence of Licensed-Assisted Access (LAA) in live environment. It covers the following major areas:

- Measure and compare any performance difference in Wi-Fi client on coexistence of LAA and Coexistence of multiple Wi-Fi routers

- Performance impact on network connection of Wi-Fi network in coexistence of LAA

- Performance impact on VoIP applications of Wi-Fi network in coexistence of LAA

The test cases are derived with reference to similar tests done in overseas, with special emphasis on actual use cases. Wherever possible, reference is also made to similar coexistence test cases proposed by the Wi-Fi Alliance ("WFA"). However, due to limitation of test tools and live environment, some of the test cases of WFA were not included.

1.3   Disclaimer and Limitation

- Copyright – SmarTone owns the copyright for this coexistence test report and reserves all rights therein. The use, duplication or distribution of the result on this report requires the endorsement and pre-approval from SmarTone. The unauthorized use and distribution of this test report is an infringement to the copyright of SmarTone.

- The measurement and testing were focus on studying any performance difference with Wi-Fi on co-existence of LAA sharing use of unlicensed band spectrum as compare to co-existence of Wi-Fi system sharing use of spectrum. The performance measurement of LAA is not the scope of this study.

- The radio condition of the test environment is having high level of interference by third parties 5GHz band devices, best effort has been paid to achieve more accurate and consistent measurement result, but it is subjected to existence and extents of interference from third parties' devices.

- The specific measurement tools like sniffer is not available on this test, the alternative measurement methods to capture the packet loss, jitter and frame re-transmission rate through TCP ping, Wireshark trace with data transfer in TCP & UDP were adopted.

- Test tools to measure the packet loss, jitter and frame re-transmission rate on VoIP is not available, user experience test to observe the voice quality was deployed in the measurement.

_____

2. Test Tools, Methodology and Approach

2.1 Test Setup

Figure 2 – Test Setup diagram:
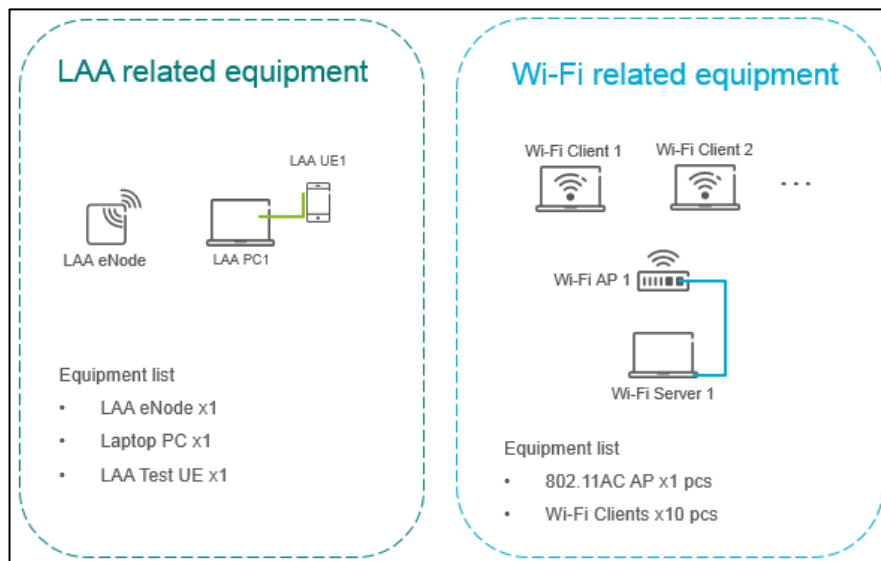
2.2 Test Equipment

2.2.1 List of Equipment:

1. 1 x LAA eNode (operating in frequency bands UNII-1 and UNII-3)

2. 1 x Wi-Fi Station (802.11ac AP)

3. 10 x Wi-Fi clients (Notebook / handset)

4. 1 x LAA UE

2.2.2 Testing Tools

Tools	Applications
Iperf	As load generator for data stream on UDP and TCP
Wireshark	Data and Log collection for Packet loss and retransmission measurement
Ping (command)	TCP Ping to local router with 1,440-byte ping size in 100 times for latency and Jitter measurement
Windows Perfmon	Data throughput Logging and monitoring
Acrylic Wi-Fi Home (PC) / WiFi Analyzer (Mobile)	Wi-Fi Scanner freeware to scan wireless network and view WLAN channel, signal before test
TEMS	Mobile test tools to monitor the data throughput on licensed band and

_____

	unlicensed band of LAA mobile.

(Remarks: Packet loss and retransmission rate was captured by Wireshark with transfer mode in TCP as transfer mode in UDP always return with zero packet loss and retransmission rate).

2.2.3 Test locations

	LAA Configuration		
Location Type	Frequency and Maximum Frequency Tolerance (MHz)	Class of Emission	Maximum E.I.R.P (in Watts)
Indoor	5150 – 5250 MHz (UNII-1) Maximum Frequency tolerance: ±0.1 ppm	20M0G7W	0.2W
Outdoor	5735 – 5850 MHz (UNII-3) Maximum Frequency tolerance: ±0.1 ppm	20M0G7W	4W

Total 3 indoor and 8 outdoor locations were tested with LAA

_____

Sample photo of LAA equipment installed at outdoor locations

_____

3. LAA and Wi-Fi Coexistence Tests

3.1 Base Line performance measurement on Wi-Fi – KPI measurement for Wi-Fi

Description:

This is the baseline performance measurement for Wi-Fi at vacant channel condition

Reference:

Coexistence Test Plan of WFA, Section 4.5 Procedure A

Test Equipment:

- 1x Wi-Fi Station
- 1x Wi-Fi Client (Notebook)

Test Configuration:

LAA Configuration	Test Setup in Wi-Fi	
LAA is Turn Off	Traffic Type	Full Buffer UDP/TCP from Wi-Fi AP to Client
	Wi-Fi Network	1x Wi-Fi Station, 1x Wi-Fi Client (Good Coverage, ~ -40 to -50 dBm)
	Channel Map	Wi-Fi (Indoor): Ch 40 UNII-1 (20MHz, 802.11ac mode) and Wi-Fi (Outdoor): Ch 157 UNII-3 (20MHz, 802.11ac mode)

Test Result:

This is the baseline reference case of the test. No Pass/Fail for this case.

Wi-Fi Client	Result with Wi-Fi in Ch40 (Indoor)	Result with Wi-Fi in Ch157 (Outdoor)
Download Throughput	93.2 Mbps	94.5 Mbps
Packet Lost	0%	0%
Retransmission	0.1%	0%
Latency	6.9 ms	7.9 ms
Jitter	3.4 ms	4.7 ms

_____

3.2   Coexistence Test with 2x Wi-Fi/LAA – KPI measurement for Wi-Fi/LAA

Description:

The test is to verify that there is no impact on Wi-Fi KPIs under coexistence of the Wi-Fi and LAA

Reference:

Coexistence Test Plan of WFA, Section 4.5 Procedure B and Procedure C

Test Equipment:

- 1x Wi-Fi Station
- 2x Wi-Fi Clients (Notebook)
- 1 x LAA eNode
- 1 x LAA UE

Test Configuration:

Item	LAA Configuration	Test Setup in Wi-Fi	
1	LAA is Turn Off (Baseline for co-existence of 2 Wi-Fi in UNII-1/UNII-3)	Traffic Type	Full Buffer UDP/TCP from Wi-Fi AP to Client
		Wi-Fi Network	1x Wi-Fi Station, 2x Wi-Fi Client (Good Coverage, ~ -40 to -50 dBm)
		Channel Map	Wi-Fi (Indoor): Ch 40 UNII-1 (20 MHz, 802.11ac mode) Wi-Fi (Outdoor): Ch 157 UNII-3 (20 MHz, 802.11ac mode)
2	LAA is Turn On Replace 1 x Wi-Fi Client with 1x LAA UE for data transfer	Traffic Type	Full Buffer UDP/TCP from Wi-Fi AP to Client
		Wi-Fi Network	1x Wi-Fi Station, 1x Wi-Fi Client (Good Coverage, ~ -40 to -50 dBm)
		Channel Map	Wi-Fi (Indoor): Ch 40 UNII-1 (20 MHz, 802.11ac mode) Wi-Fi (Outdoor): Ch 157 UNII-3 (20 MHz, 802.11ac mode)
3	LAA is Turn Off (Baseline for Co-existence of 2 Wi-Fi in UNII-1/UNII-3)	Traffic Type	Full Buffer UDP/TCP from Wi-Fi AP to Client
		Wi-Fi Network	1x Wi-Fi Station, 1x Wi-Fi Client (Good Coverage, ~ -40 to -50 dBm) 1x Wi-Fi Client (Weak Coverage, ~ -82dBm)
		Channel Map	Wi-Fi (Indoor): Ch 40 UNII-1 (20 MHz, 802.11ac mode) Wi-Fi (Outdoor): Ch 157 UNII-3 (20 MHz, 802.11ac mode)
4	LAA is Turn On Replace 1 x Wi-Fi Client with 1x LAA UE for data transfer	Traffic Type	Full Buffer UDP/TCP from Wi-Fi AP to Client
		Wi-Fi Network	1x Wi-Fi Station, 1x Wi-Fi Client (Weak Coverage, ~ -82dBm)
		Channel Map	Wi-Fi (Indoor): Ch 40 UNII-1 (20 MHz, 802.11ac mode) Wi-Fi (Outdoor 1/2): Ch 157 UNII-3 (20 MHz, 802.11ac mode)

Remark: Test items 1 – 4 were conducted at both indoor and outdoor locations

Test Result:

Performance parameter of data throughput, packet loss, latency, retransmission, jitter and network connection time of a Wi-Fi client under co-existence of Wi-Fi with LAA scenarios and co-existence of Wi-Fi clients scenarios are measured on all test items.

The test result demonstrated that there was no negative impact imposed on Wi-Fi users' experience with co-existence of Wi-Fi and LAA. All performance parameters measured are having similar or even better performance when one of the Wi-Fi client is replaced by LAA. This is valid with LAA operating in either indoor and outdoor (frequency band UNII-1 or UNII-3)

For indoor locations with Wi-Fi/LAA at good coverage, noticeable average throughput improvement (98.9%) on Wi-Fi client if one of the Wi-Fi clients was replaced by LAA UE. Total Network Throughput on 5GHz improved by 104.6%

For indoor locations with Wi-Fi/LAA at weak coverage, noticeable average throughput improvement (116.5%) on Wi-Fi Client if one of the Wi-Fi clients was replaced by LAA UE. Total Network Throughput on 5GHz improved by 42.9%

Similar test result was also observed at outdoor locations under good and weak coverage.

![SmarTone 25th anniversary logo]

_____

3.3 Wi-Fi Client Network Connection Test with existence of LAA

Description:

The test is to verify that there is no impact on the accessibility of Wi-Fi network with the existence of LAA.

Reference:

Coexistence Test Plan of WFA, Section 4.2

Test Equipment:

- 1x Wi-Fi Stations
- 11x Wi-Fi Client (Notebook / Handset)
- 1 x LAA eNode
- 1 x LAA UE

Test Configuration:

Item	LAA Configuration	Test Setup in Wi-Fi	
1	LAA is Turn Off (Base Line for accessibility on Co-existence of Wi-Fi)	Traffic Type	Full Buffer UDP from Wi-Fi AP to Client
		Wi-Fi Network	1x Wi-Fi Station, 11x Wi-Fi Client
		Channel Map	Wi-Fi (Indoor): Ch 40 UNII-1 (20 MHz, 802.11ac mode) Wi-Fi (Outdoor): Ch 157 UNII-3 (20 MHz, 802.11ac mode)
2	LAA is Turn On Replace 1 x Wi-Fi Client with 1x LAA UE for data transfer	Traffic Type	Full Buffer UDP from LAA to UE
		Wi-Fi Network	1x Wi-Fi Station, 10x Wi-Fi Client
		Channel Map	Wi-Fi (Indoor): Ch 40 UNII-1 (20 MHz, 802.11ac mode) Wi-Fi (Outdoor): Ch 157 UNII-3 (20 MHz, 802.11ac mode)

Remark: Test items 1 and 2 were conducted at both indoor and outdoor locations

Conclusion

No negative impact accessibility and setup delay with Wi-Fi connections is observed on existence of LAA with Wi-Fi.

_____

3.4   VoIP Test over Wi-Fi network with existence of LAA

Description:

The test is to verify that there is no impact on VoIP service over Wi-Fi with the existence of LAA.

Reference:

Coexistence Test Plan of WFA, Section 4.4

Test Equipment:

- 1x Wi-Fi Station
- 2x Wi-Fi Clients (Notebook Client/Handset)
- 1 x LAA eNode
- 1 x LAA UE

Test Configuration:

Item	LAA Configuration	Test Setup in Wi-Fi	
1	LAA is Turn Off- (Base Line for VoIP service on Co-existence of Wi-Fi)	Traffic Type	VoIP on one Wi-Fi Client and Full Buffer UDP download on Wi-Fi AP and Wi-Fi Client
		Wi-Fi Network	1x Wi-Fi Station, 2x Wi-Fi Client
		Channel Map	Wi-Fi (Indoor): Ch 40 UNII-1 (20 MHz, 802.11ac mode) Wi-Fi (Outdoor 1/2): Ch 157 UNII-3 (20 MHz, 802.11ac mode)
2	LAA is Turn On Replace 1 x Wi-Fi Client with 1x LAA UE for data transfer	Traffic Type	VoIP on one Wi-Fi Client and Full Buffer UDP from LAA to UE
		Wi-Fi Network	1x Wi-Fi Station, 1 x Wi-Fi Client
		Channel Map	Wi-Fi (Indoor): Ch 40 UNII-1 (20 MHz, 802.11ac mode) Wi-Fi (Outdoor 1/2): Ch 157 UNII-3 (20 MHz, 802.11ac mode)

Remark: Test items 1 and 2 were conducted at both indoor and outdoor locations

Conclusion

No negative impact on speech quality (No muting, No one way audio and No Clipping sound) was observed when a Wi-Fi client is replaced by LAA.

4. Overall Summary

It is concluded that all test cases were passed as detailed in the table below.

Test Case	Description	WFA Reference	Pass / Fail
3.1	Base Line performance measurement on Wi-Fi – KPI measurement for Wi-Fi	Section 4.5	NA
3.2	Coexistence Test with 2x Wi-Fi/LAA – KPI measurement for Wi-Fi/LAA	Section 4.3	Pass
3.3	Wi-Fi Client Network Connection Test with existence of LAA	Section 4.2	Pass
3.4	VoIP Test over Wi-Fi network with existence of LAA	Section 4.4	Pass

Based on the live trial test result at indoor and outdoor areas, it was demonstrated that existing Wi-Fi networks were not negatively affected by the coexistence of an LAA device more than an additional Wi-Fi device.

Many of the test cases were done by forcing both the Wi-Fi device and the LAA device to use the same radio channel, and this is considered the worst-case scenario. In most of the actual situation, the Wi-Fi device and LAA device will select and use different radio channels, and the interaction between the two can be avoided.

With better interference mitigation and resource sharing algorithm, LAA can improve the user throughput, overall network capacity and spectral efficiency of the unlicensed band. The overall test result under a live environment on coexistence of LAA and Wi-Fi network is positive for Wi-Fi in terms of end user applications perspective, and positive in terms of overall system perspective.