Licensed Assisted Access (LAA)

Test Report

HTCL

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1. Overview

1.1) Introduction of Licensed Assisted Access ("LAA")

According to the Statement ("Statement") made by the Communications Authority ("CA") on 4 June 2018, total 580 MHz of spectrum in the 5 GHz band (consisting of four sub-bands of frequencies in 5150 – 5250 MHz, 5250 – 5350 MHz, 5470 – 5725 MHz, and 5725 – 5850 MHz) (the "5 GHz Shared Band") would be made available in Hong Kong for the provision of public mobile services on a shared basis.

There are a number of technologies being developed and implemented by the global telecommunications industry to enable the use of the 5 GHz Shared Band to provide public mobile services, such as Licensed Assisted Access ("LAA"), LTE-Unlicensed ("LTE-U"), LTE Wi-Fi Aggregation ("LWA") and MulteFire, among which the development of LAA is supported by a large number of overseas markets including the United States, Italy, South Africa and South Korea etc.

LAA is a technical standard developed by the international standardization body, 3rd Generation Partnership Project ("3GPP"), in which Release 13 covers the downlink operation of LAA using the 5 GHz Shared Band, while Release 14 includes uplink support. In essence, the standard requires the use of one or more ordinary 4G LTE carrier(s) in the licensed mobile spectrum as the Primary Component Carrier(s) ("PCC") for control and signaling, aggregating with one or more LTE carriers in the 5 GHz Shared Band as the Secondary Component Carrier(s) ("SCC") as Carrier Aggregation ("CA"). The combined data transmission capacity via CA of the PCC and the SCC will enable the provision of higher speed mobile data services to end users.

1.2) Test Motivation

To facilitate the coming LAA deployment in Hong Kong, HTCL has conducted deployment of a LAA testbed and performed trial test in 1H-2018.

The motivation of this trial test is as below:

- Assessing LAA performance under standalone scenario.
- Assessing performance of LAA and Wi-Fi under their coexistence scenario.
- Assessing under which radio environment would the deployment of new LAA base stations be an effective solution for improving end user's Quality of Experience ("QoE").

2. Test Scope

2.1) Test Equipment, Setup and Configuration

A) Test Equipment List

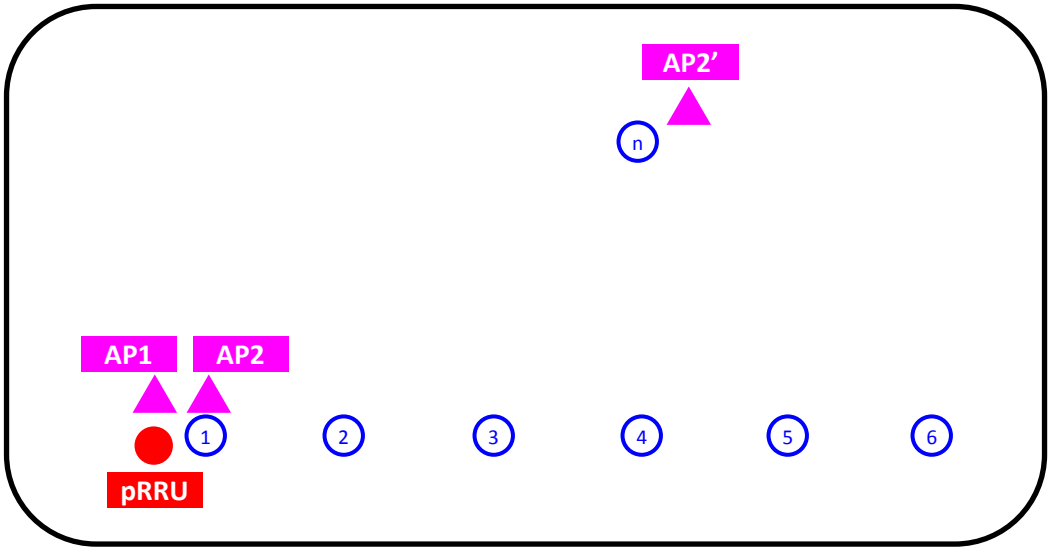
- LAA base station : 1 piece (pRRU)

Technical standard	LTE 3GPP Release 13
Working frequency band and Max transmit power	LTE Band 1 : 2x 100mW LTE Band 3 : 2x 100mW LTE Band 46 : 2x 20mW
Frequency channel bandwidth	LTE 10MHz, 15MHz, 20MHz

- Wi-Fi Access Point ("AP") : 2 pieces (AP1, AP2/AP2')
- Testing device : 1 piece supporting LAA & Wi-Fi (UE1)
  : 1 piece supporting Wi-Fi (UE2)
- Wi-Fi servers (Laptop) : 2 pieces, using FTP at FileZilla for speed tests

AP2 and AP2' refer to the same AP equipment, installed at different locations as shown in each test scenario below.

B) Test Setup at the office and lab area of a commercial building.



- Total 7 locations are marked in the test area, i.e. 1, 2, 3, 4, 5, 6, n.
  The distance between locations
  - From 1 to 6 : around 20 meters

- From 1 to n : around 15 meters

- The location of each Test Equipment:

	pRRU	AP1	AP2	AP2'
location 1	✓	✓	✓	
location n				✓

C) Test Configuration

- In this test, LAA is configured as 3CC (1+2) CA by aggregating 1 piece of PCC at Band 3 and 2 pieces of SCC at Band 46.

- Listen Before Talk ("LBT") is a useful function to alleviate mutual co-channel interferences from the time domain's perspective. As an essential part of the 3GPP standardization as well as CA's requirement as stipulated in the Statement, LAA mandates the implementation of the LBT feature to ensure compatibility and effective sharing of the 5 GHz Shared Band with other apparatus operating in the same band such as Wi-Fi.

  According to the specifications in 3GPP and testing equipment, there are several types of LBT configurations for LAA as shown in the table below, in which the configuration #3 is used in this test and turned on in all test scenarios.

#	Max Channel Occupancy Time (MCOT)	Discovery Reference Signal (DRS)	Ratio of transmission time (%)
1	2 ms	every 40 ms	47.5%
2	3 ms		64.2%
3	8 ms		85.0%
4	10 ms		87.5%

- In addition to LBT, the LAA equipment used in this test also has another function, Frequency Channel Selection ("FCS").

  FCS is capable of mitigating interference from the frequency domain's perspective by auto detecting interference within the 5 GHz Shared Band then prioritizing and selecting the frequency channel(s) with the lowest interference for the LAA SCC to use. The effect of this feature is also evaluated in this test.

2.2) Test Phase, Items and Procedures.

A) Test Phase

There are 2 Phases of test proposed as shown in the table below.

Phase	Configuration	LAA standalone	Wi-Fi standalone	LAA & Wi-Fi coexistence
1	3GPP Release 13	✓	✓	✓
2	3GPP Release 14	✓	✓	✓

This trial test here would only focus on Phase 1 which is based on 3GPP standards Release 13, i.e. LAA as Supplementary Downlink ("SDL").

The Phase 2 of testing eLAA as Dual Connectivity ("DC") as specified in 3GPP Release 14 is targeting to be arranged in late 2018 or early 2019, subject to the development status of network equipment and devices.

B) Test Scenarios

Total 6 types of scenarios are tested as shown below:

<table>
<tr><th colspan="2">Testing Scenarios</th><th>Channel Number</th><th>Equipment's Separation Distance</th><th>FCS</th></tr>
<tr><td>1a</td><td>LAA Standalone (1pcs)</td><td>PCC : 1751
SCC1 : 52740
SCC2 : 52941</td><td>N/A
(pRRU)</td><td rowspan="4">n/a</td></tr>
<tr><td>2a</td><td>Wi-Fi Standalone (1pcs)</td><td rowspan="3">AP1 : 153
AP2 : 153
AP2' : 153</td><td>N/A
(AP1)</td></tr>
<tr><td>2b</td><td rowspan="2">Wi-Fi Standalone (2pcs)</td><td>Near
(AP1, AP2)</td></tr>
<tr><td>2c</td><td>Far
(AP1, AP2')</td></tr>
<tr><td>3</td><td rowspan="4">LAA (1pcs) and Wi-Fi (1pcs) Coexistence</td><td rowspan="4">PCC : 1751
SCC1 : 52740
SCC2 : 52941

AP1 : 153
AP2' : 153</td><td>Near
(pRRU, AP1)</td><td rowspan="2">Off</td></tr>
<tr><td>4</td><td>Far
(pRRU, AP2')</td></tr>
<tr><td>5</td><td>Near
(pRRU, AP1)</td><td rowspan="2">On</td></tr>
<tr><td>6</td><td>Far
(pRRU, AP2')</td></tr>
</table>

Under scenarios of LAA and Wi-Fi Coexistence above (3, 4, 5, 6), the SCC2 and the AP1/AP2/AP2' are operated at the same frequency channel (5755-5775 MHz).

3. Test Procedures and Results

3.1) Impact from Wi-Fi to LAA (speed)

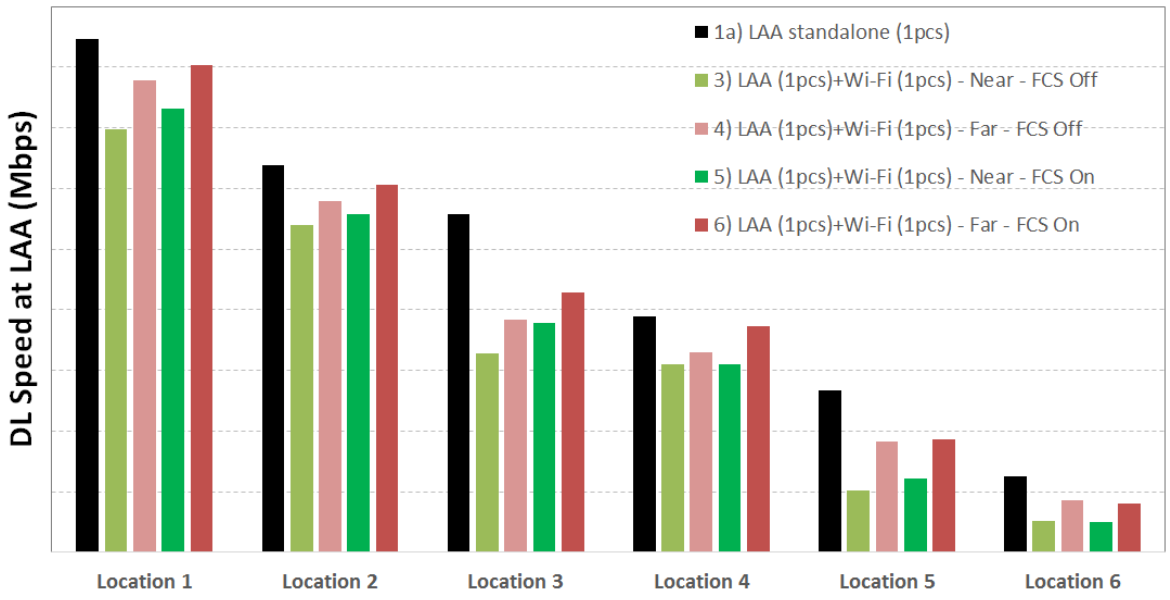
The objective of the tests is to evaluate the impact from Wi-Fi to LAA, i.e. the speed variation at LAA device under LAA standalone as well as types of LAA and Wi-Fi coexistence scenarios.

A) Testing Procedures

Please refer to Section 2.1, A) and B) on the test equipment and setup.

Testing Procedures		Testing Scenarios				
		1a	**3**	**4**	**5**	**6**
1	Using UE1 to start DL speed test under pRRU	Y	Y	Y	Y	Y
	Using UE2 to start DL speed test under AP1		Y		Y	
	Using UE2 to start DL speed test under AP2’			Y		Y
2	Moving UE1 from location 1 to 6	Y	Y	Y	Y	Y
	Keeping UE2 at location 1		Y		Y	
	Keeping UE2 at location n			Y		Y
3	Recording the DL speed for UE1 at each test location	Y	Y	Y	Y	Y

B) Testing Results – Downlink speed at LAA device (UE1)



- Performance Ranking : 1a > 6 > 4 > 5 > 3

Scenario	Performance Ranking
1a	Baseline
6	Baseline x 88%
4	Baseline x 83%
5	Baseline x 76%
3	Baseline x 72%

- Co-channel operated Wi-Fi AP would cause interference and consequently performance degradation on LAA pRRU, i.e. the nearer the worse.

- In testing scenarios 5 and 6, the Channel Number of 2 pieces LAA SCCs are swapped from 52740 and 52941 to 53340 and 53541 under FCS function, which proves it is useful to further eliminate interference from Wi-Fi to LAA.

3.2) Impact from LAA to Wi-Fi (speed)

The objective of the tests is to evaluate the impact from LAA to Wi-Fi, i.e. the speed variation at Wi-Fi device under Wi-Fi standalone as well as types of LAA and Wi-Fi coexistence scenarios.

A) Testing Procedures

Please refer to Section 2.1, A) and B) on the test equipment and setup.

(i) Part 1 – Measure of download speed of UE2 (over Wi-Fi) in the presence of UE1 (over LAA)

Testing Procedures		Testing Scenarios				
			3	**4**	**5 ***	**6 ***
1	Using UE1 to start DL speed test under pRRU		Y	Y	Y	Y
	Using UE2 to start DL speed test under AP1		Y		Y	
	Using UE2 to start DL speed test under AP2’			Y		Y
2	Keeping UE1 at location 1		Y	Y	Y	Y
	Keeping UE2 at location 1		Y		Y	
	Keeping UE2 at location n			Y		Y
3	Recording the DL speed for UE2 at locations 1 and n		Y	Y	Y	Y

(ii) Part 2 – Measure of download speed of UE2 (over Wi-Fi) in the presence of UE1 (over Wi-Fi)

Testing Procedures		Testing Scenarios				
		2a	**2b**	**2c**		
1	Using UE1 to start DL speed test under AP1	Y	Y	Y		
	Using UE2 to start DL speed test under AP2		Y			
	Using UE2 to start DL speed test under AP2'			Y		
2	Keeping UE1 at location 1	Y	Y	Y		
	Keeping UE2 at location 1		Y			
	Keeping UE2 at location n			Y		
3	Recording the DL speed for each UE at locations 1 and n	Y	Y	Y		

B) Testing Results - Downlink speed at Wi-Fi devices

(i) Part 1 – Measure of download speed of UE2 (over Wi-Fi) in the presence of UE1 (over LAA)

Testing Scenario	**UE & location** [#]	**Equipment's Separation Distance**	**FCS at LAA**	**Performance Ranking**
3	UE2 at location 1	Near	Off	Baseline x 50% ~ 60%
4	UE2 at location n	Far	Off	Baseline x 70% ~ 80%
5 *	UE2 at location 1	Near	On	Baseline x 100%
6 *	UE2 at location n	Far	On	Baseline x 100%

(ii) Part 2 – Measure of download speed of UE2 (over Wi-Fi) in the presence of UE1 (over Wi-Fi)

Testing Scenario	**UE & location**	**Equipment's Separation Distance**	**FCS at LAA**	**Performance Ranking**
2a	UE1 at location 1	n/a	n/a	Baseline
2b	UE1 at location 1	Near	n/a	Baseline x 50% ~ 60%
	UE2 at location 1	Near	n/a	Baseline x 50% ~ 60%

2c	UE1 at location 1	Far	n/a	Baseline x 70% ~ 80%
	UE2 at location n	Far	n/a	Baseline x 70% ~ 80%

- The Co-channel operated LAA pRRU would cause interference and consequently performance degradation on Wi-Fi AP, i.e. the nearer the worse. Nevertheless, such impact is similar to that when another Wi-Fi AP was added at the same location with co-channel operations.

- (*) The testing results for scenario 5 and 6 shown in the table above refer to the results when LAA SCC frequency channels are reselected to be different with that on the Wi-Fi AP. Consequently the Wi-Fi speed performance was soon increased, i.e. resumed to the same level of that in the testing scenario 2a.

  These results demonstrated the effectiveness of FCS function to further eliminate interference from LAA to Wi-Fi.

4. Conclusions and Way Forward

The performance of LAA under standalone scenario is assessed, from which demonstrated the technology can be adopted as an alternative (supplemental DL via Carrier Aggregation) for improving customer's quality of experience (QoE) while enjoying mobile broadband services.

The performance of LAA and Wi-Fi under their coexistence scenario is also assessed. When the two types of equipment & technologies are located near to each other and operated at the same frequency channel(s), mutual co-channel interference would inevitably cause performance degradation on either of them, the nearer separation the worse performance. Nevertheless, the level of performance degradation on the Wi-Fi AP would be the same in the case of adding another radio node operated at the same channel nearby, regardless of using either Wi-Fi or LAA technology.

In addition to implement the mandate function LBT on LAA to ensure compatibility and effective sharing of the 5 GHz Shared Band with other apparatus operating in the same band such as Wi-Fi, it is found another function FCS would also be useful to give a stable performance on both LAA and Wi-Fi by further eliminating co-channel interferences in between.

When assessing under which radio environment (e.g. Wi-Fi AP/Devices are located nearby) would still be suitable for deploying additional LAA base stations to enhance user QoE effectively, we propose to identify the Wi-Fi channels' utilization at 5 GHz Shared Band in that area, e.g. the location, the operating frequency channels, and the usage time of each Wi-Fi channels deployed there. In general, lighter utilization on Wi-Fi would facilitate a better performance enhancement by adding LAA. As a matter of fact, 5GHz Shared Band to be used under an un-protected, un-coordinated manner, there's no control over mutual interference between access points and devices, quality of experiences to achieve will subject to best effort to certain extend.

Looking forward, we're planning to extend the LAA trial and/or deployment at other environment, e.g. public shopping malls, for assessing this solution more comprehensively in terms of the aspects below:

- more types and quantity of Wi-Fi AP nearby;
- more end users and more types of end users' LAA smartphones;
- more types of technical functions and parameters:
  - ✓ different types of LBT configurations
  - ✓ different types of FCS configurations
  - ✓ different types of pRRU-to-pRRU distances
  - ✓ KPI counters and O&M
  - ✓ eLAA (3GPP Rel-14) performance as Phase 2 of the proposed test;

Overall, this trial test has successfully demonstrated the technical feasibility of using LBT based LAA as an effective alternative for enhancing end user's QoE without causing adverse impact to the existing Wi-Fi systems additionally.