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# **Coexistence Test Plan**

**Version 0.8.4 (Alpha)**

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# 1 Overview

Recently there has been great interest in the cellular community in making use of the 5 GHz unlicensed bands to offload LTE traffic from the licensed bands. The leading two approaches to make use of the unlicensed 5 GHz spectrum are: LTE-U developed by the LTE-U Forum, and LTE-LAA currently being discussed in 3GPP.

LTE-LAA may use a listen-before-talk (LBT) mechanism similar to the Wi-Fi Carrier Sense Medium Access (CSMA) where the medium is sensed and transmission only occurs when the medium is free, subject to some back-off rules.

LTE-U uses a Carrier Sensing Adaptive Transmission (CSAT) scheme to share the channel. This technology attempts to assess average activity on the channel and arrange its transmission to take a fair share of the channel by multiplexing its transmissions in the time domain. While CSAT periodically assesses the medium and adjusts the periods of time it transmits on the channel, there are widely differing implementations of how to access the medium.

## 1.1 Scope and Purpose

The purpose of this document is to verify the performance of coexistence algorithms such as CSAT and to measure the impact of unlicensed LTE on a Wi-Fi network to determine the unlicensed LTE device coexistence behavior in an unlicensed spectrum. It is not yet determined whether this test plan applies to LTE-LAA.

The definition of fair sharing is outlined in [1] and the scope of allowable tests includes any situation where the impact of LTE-U operation in the unlicensed band could adversely affect the Wi-Fi user experience.

This test plan contains procedures, expected results, and pass/fail criteria designed to determine whether an LTE network impacts a Wi-Fi network any more than a Wi-Fi network impacts another Wi-Fi network. Results of these tests apply only to the device that has been tested and configured, and cannot be generalized to configurations or devices that have not been tested.

The test equipment, configurations, procedures, expected results, and pass or fail criteria were carefully selected with this goal in mind. Any coexistence tests performed should adhere precisely to all guidance herein to enable replicability and confidence in results. Furthermore, the tests described in this document are intended to represent a complete set, and all tests are considered equally important and mandatory to demonstrate reliable coexistence. Any divergence from this document, or any incomplete demonstration of coexistence, is not deemed to be reliable.

This test plan will be validated by performing detailed testing with real equipment. This validation process will illuminate tests that may be difficult to execute reliably and will provide information on how to determine the overall pass/fail criteria for the equipment under test. It is anticipated this overall pass/fail determination could be applied by executing all applicable tests, recording the results, and then making a final determination taking the entirety of the test results into account.

NOTE: As of this writing, the tests within the test plan have not undergone validation for feasibility, correctness, or repeatability. It is therefore incomplete and cannot be used to determine unlicensed LTE coexistence until approved in its entirety by the Wi-Fi Alliance board.

## 1.2 References

The documents listed in this section are included in requirements made in the body of this test plan. Knowledge of their contents is required for the understanding and implementation of this test plan. If a listing includes a date or a version identifier, only that specific version of the document is required. If the listing includes neither a date nor a version identifier, the latest version of the document is required.

- [1] Coexistence Guidelines for LTE in Unlicensed Spectrum Studies, <https://groups.wi-fi.org/apps/org/workgroup/coex/download.php/66096/latest>
- [2] AT4 wireless Performance Test Tool, <http://www.at4wireless.com/it-services-solutions/at4wireless-performance-test-tool.html>
- [3] IEEE 802.11-2012 “Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications”, March 2012
- [4] Wi-Fi CERTIFIED Voice-Enterprise Test Plan v1.1, <https://www.wi-fi.org/file-member/wi-fi-certified-voice-enterprise-test-plan>

## 1.3 Acronyms and Abbreviations

The acronyms, terms and definitions presented throughout this document are defined in Acronyms. Some acronyms are commonly used in publications and standards defining the operation of wireless local area networks, while others have been generated by Wi-Fi Alliance. Refer to the [Wi-Fi Alliance Acronyms Terms Definitions](#) document for a complete list of approved acronyms.

**Table 1. Acronyms and abbreviations**

Acronym	Definition
CCA-ED	Clear Channel Assessment, Energy Detect
CSAT	Carrier Sensing Adaptive Transmission
DHCP	Dynamic Host Control Protocol
DL	Downlink
EIRP	Equivalent Isotropic Radiated Power
EUT	Equipment Under Test
ETH	Ethernet
KPI	Key Performance Indicator
LTE	Long Term Evolution
MTU	Maximum Transfer Unit
OS	Operative System

Acronym	Definition
OTA	Over the air
RSSI	Received Signal Strength Indication
RAT	Radio Access Technology
TCP	Transport Control Protocol
UDP	User Datagram Protocol
UL	Uplink
WLAN	Wireless Local Area Network

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## 2 Test Tools, Methodology and Approach

This section defines the tools, methodology, and approach used for executing this test plan.

### 2.1 Test Setup

#### 2.1.1 Test Environment

Each test case contains a configuration diagram of the devices and test equipment. The practical implementation of the test setup is not mandated by this test plan. Instead, the test lab shall choose a setup that provides an interference free environment with accurate signal levels. Wi-Fi Alliance is currently evaluating a hybrid cabled/OTA test setup using semi anechoic shielded boxes. Standard procedures should be used to validate accurate setup and calibration of the test equipment.

In this test plan, the tests are performed at three different signal levels at which the EUT hears the Wi-Fi nodes and vice-versa.

Test Level 1 (-50 dBm)

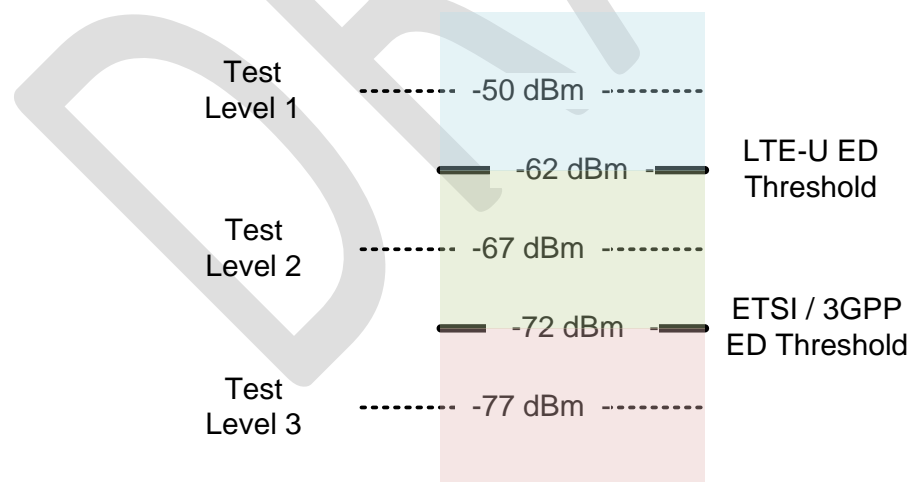
- Good signal level enables higher MCS rates
- Used to verify basic functionality

Test Level 2 (-67 dBm)

- 5 dB below LTE-U ED for setup margin
- Used to verify basic “Below ED” functionality

Test Level 3 (-77 dBm)

- 5 dB below ETSI / 3GPP ED for setup margin
- Used to verify enhanced “Below ED” functionality



**Figure 1. Signal test levels**

## 2.2 Test Equipment

### 2.2.1 Traffic Generator Performance Analysis Tool

A wireless performance test tool shall be used to generate test data and analyze performance of the devices in the networks. The wireless performance tool also captures RAT and system information from the device and reports standard Wi-Fi information such as channel, BSSID, RSSI and PHY Rate from the client perspective.

Some of the test cases in this test plan collect the most relevant key performance indicators (KPIs), such as:

- Throughput
- Latency (one way delay)
- Jitter (latency variation)

This test plan does not mandate a specific traffic generator and wireless performance test tool for carrying out testing. Below is the set of minimum requirements the tool shall support:

- Multiple endpoints running simultaneously to address testing requirement
- Collection of key performance indicators (KPIs) such as throughput, latency and jitter
- Collection of RAT and system information and standard Wi-Fi information such as channel, BSSID, RSSI and PHY rate

Wi-Fi Alliance is evaluating a Performance Test Tool provided by AT4 wireless. The tool comprises of two main parts, the Test Controller running in a server machine under Windows 2012, and client agents running on each of the clients in the test.

Additional information about the tool can be found in [2]

### 2.2.2 Access Point and Station Devices

Table 2 lists the minimum capabilities required on the Access Point and Station devices selected to execute Wi-Fi Coexistence test plan. All selected station devices shall be identical to eliminate variability and shall be chosen to be representative of real-world device implementations.

**Table 2. Access point and station device capabilities**

Feature	Description
PHY support	802.11a/n/ac
Security	WPA2-AES
Spatial Stream	2 SS
MIMO	MIMO capable
Channel Width	20/40/80 MHz
Interface	Rich UI for configuration

### **2.2.3 DHCPv4 Server**

A DHCPv4 server is used in this test plan to provide unique IPv4 addresses for station devices that are configured to obtain IPv4 addresses using DHCP.

### **2.2.4 Sniffer**

A sniffer test tool is used in this test plan to capture and analyze data over the wireless medium. The sniffer shall be capable of capturing and decoding 802.11n and 802.11ac frames over the air.

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## 3 LTE-U and Wi-Fi Coexistence Test Requirements

### 3.1 Applicability of Tests

The applicable tests for LTE-U and Wi-Fi coexistence are specified in Table 3.

**Table 3. LTE-U and Wi-Fi coexistence tests**

Test Case Description	M/O	Test Plan Section
LTE-U Channel Selection Test	M	4.1
LTE-U Allowing New Wi-Fi Network Connection Test	M	4.2
LTE-U Medium Usage Adapting to Changing Channel Loading Test	M	4.3
LTE-U Node Impact on Latency Sensitive Wi-Fi Traffic Test	M	4.4
LTE-U Node Impact on Wi-Fi Throughput Performance Test	M	4.5
LTE-U UE and Wi-Fi Station In Device Coexistence Test	M	4.6

### 3.2 Equipment Under Test Declaration

In this document, the term EUT is used to represent the unlicensed LTE equipment under test. Prior to submission for testing, the implementer shall complete the following declaration table for use in execution of this test plan.

**Table 4. Equipment Under Test Declaration**

Item	Vendor Response	Expected Maximum Value
Does the EUT support CCA-SD with preamble detect?	Yes/No	Not applicable
The maximum possible time period allowed on the EUT to initiate scan for available channels in the order of minutes (Tscaninterval)	Value	5 minutes
The time required by the EUT to scan available channels in the order of seconds (Tscan)	Value	30 seconds
The time identified by the vendor as appropriate to achieve reliable test runs (Tmargin)	Value	< Tscaninterval
The time required by the EUT from boot up to become operational	Value	
The maximum nominal duty cycle at which the EUT can operate	Value	

Medium Usage adaptive response time in the order of milliseconds	Value	
TBD		

### 3.3 Wi-Fi Device Configuration Requirements

#### 3.3.1 Access Point Configuration

Access points shall be configured with the default configuration except for the modifications listed in Table 5.

**Table 5. Access point configuration**

Characteristic	Value
Channel	157
Security mode	WPA2-AES
Encryption Key	12345678
Channel bandwidth	20 MHz
802.11ac	Enabled
2.4GHz band	Disabled
SSID	Name customized per router to distinguish between the APs
DHCP Server	Disabled

#### 3.3.2 Station Configuration

The station device shall be configured with the default configuration except for the modifications listed in Table 6.

**Table 6. Station configuration**

Characteristic	Value
Channel	157
Security mode	WPA2-AES
Encryption Key	12345678
Channel bandwidth	20 MHz

Characteristic	Value
802.11ac	Enabled
2.4GHz band	Disabled
SSID	As per access point configuration
DHCP Client	Enabled

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## 4 LTE-U and Wi-Fi Coexistence Tests

The test cases in this section validate the coexistence of unlicensed LTE equipment with Wi-Fi equipment when the LTE and Wi-Fi equipment can hear each other at the signal levels defined in section 2.1.1. Each test case includes multiple procedures that are labeled alphabetically. For all test cases in this section, the term EUT is used to represent the unlicensed LTE equipment under test.

The EUT shall be configured once prior to the test case execution and shall not be altered between the test case procedures unless otherwise stated in the test plan. Manual or electronic intervention or adjustment of the unlicensed LTE equipment under test is not permitted between procedures or within a procedure of a given test case unless explicitly stated otherwise. This will ensure that the dynamic qualities of the LTE coexistence features are properly tested.

### 4.1 LTE-U Channel Selection Test

#### Purpose and Description

This test verifies that the EUT can identify and report:

1. A vacant unlicensed channel when all but one of the unlicensed channels have active Wi-Fi nodes. The EUT shall sense the spectrum to identify the vacant channel and begin operating in the vacant channel.
2. The least utilized unlicensed channel when all unlicensed channels have active Wi-Fi nodes, intra-operator and inter-operator LTE-U nodes. The EUT should sense the spectrum to identify that there are no vacant channels available for its use, employ CSAT to assess the load on each channel, and determine the least utilized channel.

Unlicensed channels in the U-NII-1 (5150 MHz -5250 MHz) and the U-NII-3 (5725 MHz -5825 MHz) bands are used for this test.

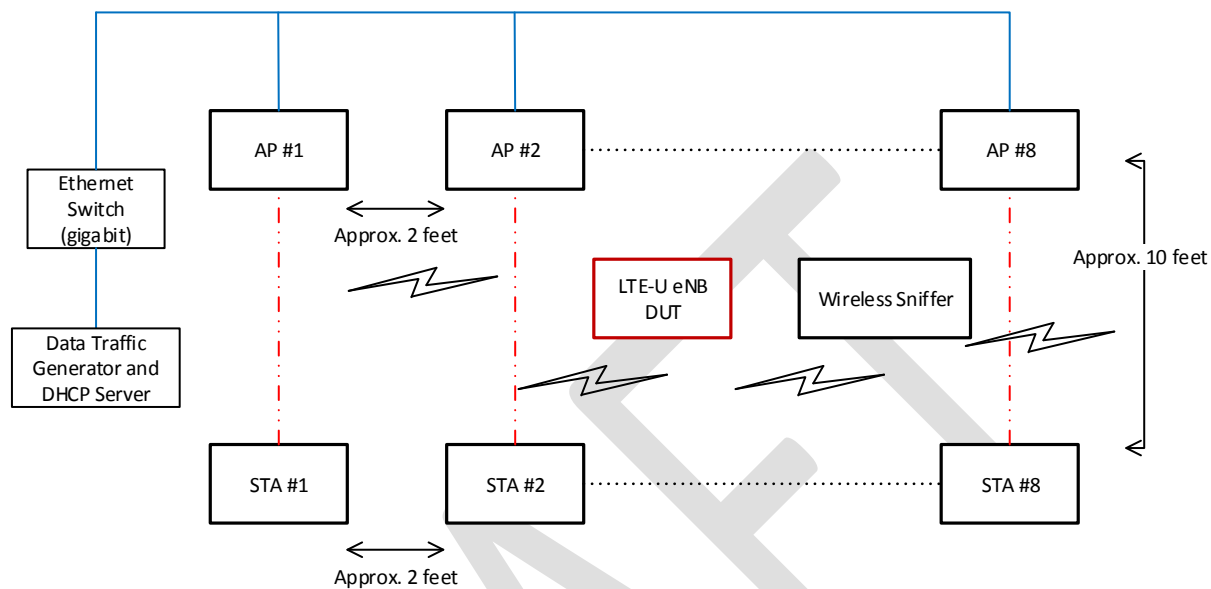
#### References

- TBD

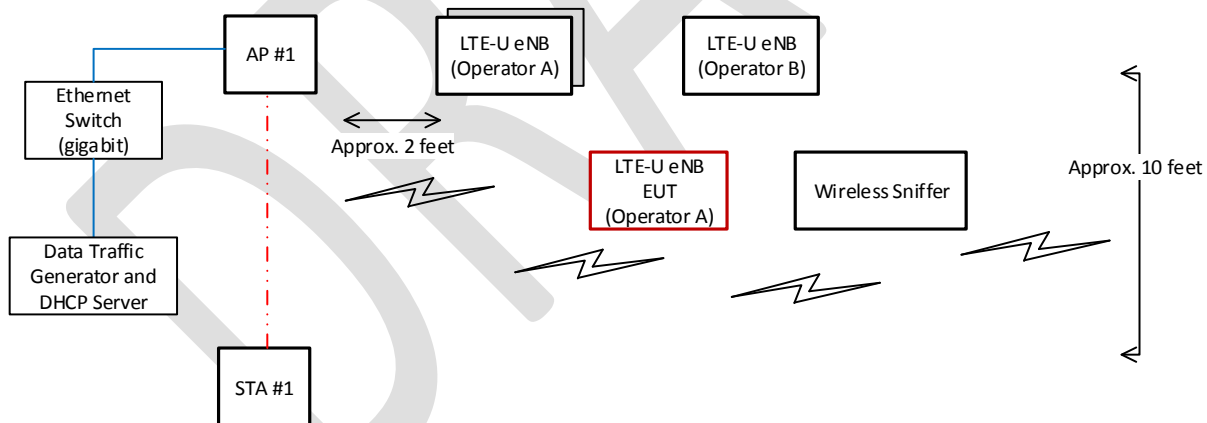
#### Test Environment

- EUT (1)
- LTE-U eNodeB (4) - operating as test bed device
- UE (5) - operating as test bed device
- Wi-Fi CERTIFIED ac access point (8) - capable of operating in 11a only and 11n mode
- Wi-Fi CERTIFIED ac station (8)
- Wireless sniffer
- Wi-Fi data traffic generator
- DHCP server

Figure 2, Figure 3, Figure 4 depicts the test bed schematic to be deployed for the LTE-U Channel Selection Test. Blue lines depict the physical connection between Wi-Fi access points to the data traffic generator and DHCP server through an Ethernet switch. Red dashed lines depict the Wi-Fi network connection between the access points and station devices.

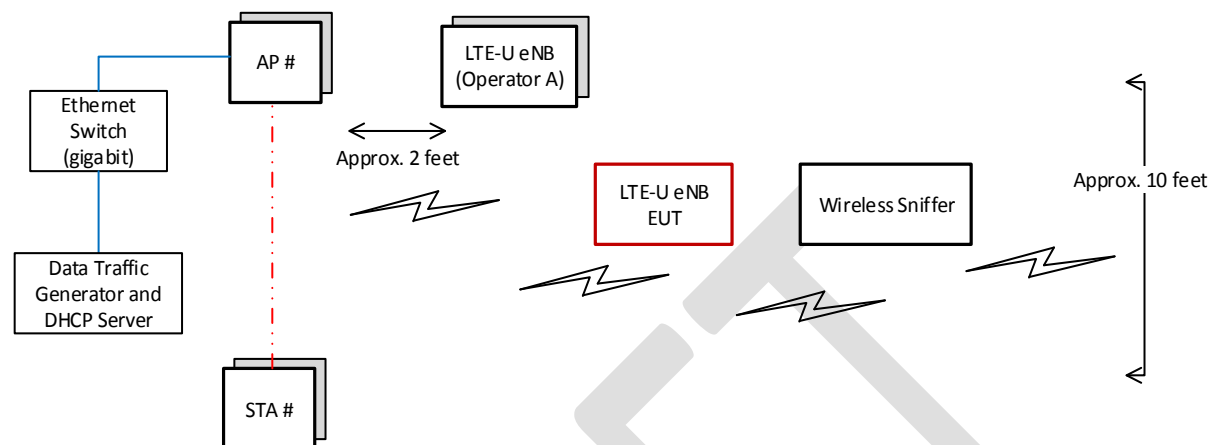


**Figure 2. LTE-U channel selection test setup**



**Figure 3. LTE-U behavior in the presence of inter-operator LTE-U, and Wi-Fi network test setup**





**Figure 4. LTE-U behavior in the presence of intra-operator LTE-U, and Wi-Fi network test setup**

### Test Configuration

Refer to Table 5 for access point configuration. Refer to Table 6 for station device configuration.

Table 7 lists the additional test configuration for each of the procedures that comprise this test case.

Note: Prior to start of each test procedure execution, the test bed devices are switched off unless otherwise stated in the test case procedure.

**Table 7. LTE-U channel selection test configuration**

Procedure	EUT Configuration	Test Bed Configuration	
Procedure A (Vacant channel selection)	Configure the EUT to perform automatic channel selection every Tscaninterval minutes, where Tscaninterval is the maximum possible time period allowed on the EUT to initiate scan for available channels in the order of minutes.  Vendor shall state time required to scan all channels (Tscan) in the order of seconds	Traffic type	No traffic
		AP channel width	All 8 APs are configured to 20 MHz (11ac mode)
		STA configuration	Wi-Fi turned OFF
		Vacant channel	Every (Tscaninterval + Tscan + Tmargin) time, Wi-Fi network is re-configured to provide a new vacant channel, where  Tscaninterval is the maximum possible time period allowed on the EUT to initiate scan for available channels in the order of minutes Tscan is the time required by EUT to scan available channels in the order of seconds Tmargin is the time identified as appropriate to achieve reliable test runs  The procedure is repeated 5 times without interruption
Procedure B	<TBD>	Traffic type	Full buffer Wi-Fi uplink traffic (Table 30)

Procedure	EUT Configuration	Test Bed Configuration																														
(Vacant channel selection)		AP channel width	4 APs covering 8 channels. AP1 (11a only) and AP2 (11ac) in 20MHz, AP3 (11n) in 40MHz, AP4 (11ac) in 80 MHz with supported primary and secondary channel																													
		Vacant channel	36																													
Procedure C (Least utilized channel selection)	<TBD>	Traffic type	TCP, Wi-Fi downlink and uplink traffic (Table 30) Duration: Tscaninterval + Tscan + Tmargin after transmission starts																													
		AP channel width	All 9 APs are configured to 20 MHz (11ac mode)																													
		Channel load	Traffic on each channel with fixed medium usage ranging from 20% to 100% as specified in the table below: <table><tr><td>AP#</td><td>AP1</td><td>AP2</td><td>AP3</td><td>AP4</td><td>AP5</td><td>AP6</td><td>AP7</td><td>AP8</td><td>AP9</td></tr><tr><td>Load</td><td>80%</td><td>80%</td><td>50%</td><td>80%</td><td>100%</td><td>100%</td><td>80%</td><td>80%</td><td>100%</td></tr></table>										AP#	AP1	AP2	AP3	AP4	AP5	AP6	AP7	AP8	AP9	Load	80%	80%	50%	80%	100%	100%	80%	80%	100%
		AP#	AP1	AP2	AP3	AP4	AP5	AP6	AP7	AP8	AP9																					
		Load	80%	80%	50%	80%	100%	100%	80%	80%	100%																					
Least utilized channel	44 (AP3 operating channel)																															
Procedure D (Least utilized channel selection)	<TBD>	Traffic type	Full buffer Wi-Fi uplink traffic (Table 30) Duration: Tscaninterval + Tscan + Tmargin after transmission starts																													
		AP channel width	2 APs covering 8 channels (11ac mode, 80MHz, Channel 36 and Channel 149). AP1 and AP2 in 80MHz in U-NII-1 and U-NII-3 bands. AP3 (11ac mode) in a 20 MHz channel																													
		Channel load	Traffic on each BSS with fixed medium usage ranging from 20% to 100% as specified in the table below: <table><tr><td>AP#</td><td>AP1</td><td>AP2</td><td>AP3</td></tr><tr><td>Load</td><td>50%</td><td>100%</td><td>20%</td></tr></table>										AP#	AP1	AP2	AP3	Load	50%	100%	20%												
		AP#	AP1	AP2	AP3																											
		Load	50%	100%	20%																											
Least utilized channel	165 (AP3 operating channel)																															
Procedure E (Least utilized channel selection)	<TBD>	Sample set	Only 4 channels available (36, 40, 44, 48)																													
		AP configuration	AP1 operating in channel (36, 1), 40MHz, with channel 40 as 20MHz secondary channel AP2 operating in channel (44, 1), 40MHz, with channel 48 as 20MHz secondary channel																													
		Traffic type	AP1 - STA1 (40Mhz capable): 75% of the channel capacity (UL + DL, TCP) AP2 - STA2 (40MHz capable): 25% of the channel capacity (UL + DL, TCP) Duration: Tscaninterval + Tscan + Tmargin after transmission starts																													
		Channel load	Traffic on each BSS with fixed medium usage as specified in the table below: <table><tr><td>AP#</td><td>AP1</td><td>AP2</td></tr></table>										AP#	AP1	AP2																	
		AP#	AP1	AP2																												

Procedure	EUT Configuration	Test Bed Configuration				
			Load	75%	25%	
		Least utilized channel	AP2 operating channel			
Procedure F (Intra-Operator)	<TBD>	LTE-U eNodeB (Operator A)	1 node operating in CH-A LTE-U node configured to fixed medium usage as specified below: Medium usage @ 50%			
		Wi-Fi network	4 Wi-Fi ESS (1 AP and 1 STA each) Operating channel: CH-B, CH-C, CH-D, CH-E Traffic on each channel with fixed medium usage ranging between 50% to 80% CH-B @ 80% CH-C @ 50% CH-D @ 50% CH-E @ 80%			
Procedure G (Inter-Operator)	<TBD>	LTE-U eNodeB	Operator A LTE-U node is configured to operate as below: 1. Operating channel: CH-A 2. Medium usage @ 30% Operator B LTE-U node is configured to operate as below: 3. Operating channel: CH-B Medium usage @ 100%			
		Wi-Fi network	3 Wi-Fi ESS (1 AP and 1 STA each) Operating channel: CH-C, CH-D, CH-E Traffic load: 50%, 75%, 100% respectively			

## Test Procedure

### Procedure A and B:

1. Set up an operational Wi-Fi network comprising multiple APs, each operating in an unlicensed channel and connected to a STA device with the traffic load specified in Table 7.
  - a. Set the channel bandwidth for all APs to 20MHz initially and later configured as required by the test configuration in Table 7
  - b. Verify that all Wi-Fi nodes are heard at the signal levels specified below by the LTE-U node and vice versa:
    - Run 1: Test Level 1
    - Run 2: Test Level 2
    - Run 3: Test Level 3
  - c. Of the available channels {36, 40, 44, 48, 149, 153, 157, 161, 165}, one channel in U-NII-1 or U-NII-3 band is left vacant from Wi-Fi activity.
2. Once the Wi-Fi network is operational, configure the EUT and turn it on.

3. For procedure A only, re-configure the Wi-Fi networks during the test execution as defined in Table 7 without changing the initial EUT configuration to test EUT's automatic channel selection feature.
4. For each procedure, record the time taken by the EUT to select the vacant channel.

#### Procedure C, D and E:

1. Set up operational Wi-Fi network comprising multiple APs, each operating in an unlicensed channel and connected to a STA device, and each operating with the traffic load as specified in Table 7.
  - a. All channels {36, 40, 44, 48, 149, 153, 157, 161, 165} must be occupied with Wi-Fi activity.
  - b. Set the channel bandwidth for all APs initially to 20 MHz and later configured as required by the test configuration in Table 7.
  - c. Verify that all Wi-Fi nodes are heard at the signal levels specified below by the LTE-U node and vice versa:
  - d. Run 1: Test Level 1
  - e. Run 2: Test Level 2
2. Once the Wi-Fi networks are operational, configure the EUT and turn it on.
3. Record the time taken by the EUT to switch to the new channel.
4. Execute procedures C through E sequentially without interruption and without reconfiguring the EUT.

#### Procedure F and G:

1. LTE-U eNB equipment from operator 1 (PLMN ID: x) and/or operator 2 (PLMN ID: z) is configured as defined in Table 7 and then turn them on to operate in multiple channels. The medium usage of these nodes serving multiple LTE-U UE devices is specified in Table 7.
2. Configure the Wi-Fi networks comprising of multiple APs and STAs and make operational in multiple channels with the traffic load specified in Table 7.
3. At this point, both LTE-U and Wi-Fi nodes should be operating exclusively in different channels.
4. Configure the EUT from operator 3 (PLMN ID: y) and turn it on.
5. Ensure that all Wi-Fi nodes are heard at signal levels specified below by the LTE-U node and vice versa:
6. Run 1: Test Level 1
7. Record the EUT's assessment of the channel utilization on all channels.
8. Record the time taken by the EUT to select the operating channel.

### Test Results

The test case is considered PASSED if the EUT identifies and reports the correct channel as specified in Table 8.

**Table 8. LTE-U channel selection test expected results**

Procedure	Expected Results
Procedure A (Vacant channel selection)	EUT shall select the correct vacant channel for LTE-U operation each of the 5 times within (Tscaninterval + Tscan) time after Wi-Fi network is re-configured
Procedure B (Vacant channel selection)	EUT shall select channel 36 for LTE-U operation within the manufacturer declared time as specified in Table 4
Procedure C (Least utilized channel selection)	EUT shall report load assessment on each channel and select channel 44 for LTE-U operation within (Tscaninterval + Tscan) time after the Wi-Fi network and traffic is re-configured

Procedure	Expected Results
Procedure D (Least utilized channel selection)	EUT shall report channel assessment on each channel and select channel 165 for LTE-U operation within (Tscaninterval + Tscan) time after the Wi-Fi network and traffic is re-configured
Procedure E (Least utilized channel selection)	EUT shall report channel assessment on the available channels and select AP2 operating channel for LTE-U operation within (Tscaninterval + Tscan) time after the Wi-Fi network and traffic is re-configured
Procedure F (Intra-operator)	EUT (Operator A) shall select CH-A for LTE-U operation within the manufacturer declared time
Procedure G (Inter-operator)	EUT (Operator C) shall select one of the channels (CH-A, CH-B) for LTE-U operation within the manufacturer declared time

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## 4.2 LTE-U Allowing New Wi-Fi Network Connection Test

### Purpose and Description

This test verifies that the EUT operating in an unlicensed channel allows a new Wi-Fi network to become operational. The test environment includes a set of STAs which scan and discover the Wi-Fi network(s), establish and maintain the connection in the presence of the EUT operating at full capacity. Unlicensed channels in the U-NII-1 (5150 MHz -5250 MHz) and the U-NII-3 (5725 MHz -5825 MHz) bands are used for this test.

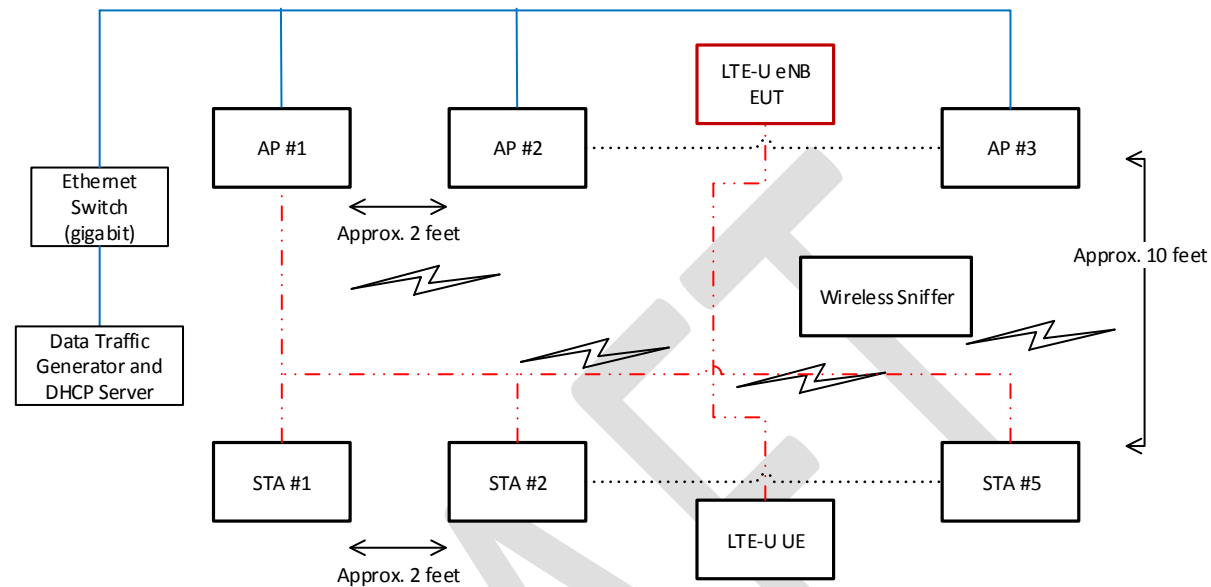
### References

- TBD

### Test Environment

- EUT (1)
- LTE-U UE (1)
- Wi-Fi CERTIFIED ac access point (3)
- Wi-Fi CERTIFIED ac station (6)
- Wireless sniffer
- Wi-Fi data traffic generator
- DHCP server

Figure 5 depicts the test bed schematic to be deployed for the LTE-U Allowing New Wi-Fi Network Connection Test. Blue lines depict the physical connection between Wi-Fi access points to the data traffic generator and DHCP server through an Ethernet switch. Red dashed lines depict the Wi-Fi network connection between the access points and station devices.



**Figure 5. LTE-U allowing new Wi-Fi network connection test setup**

**Test Configuration**

Refer to Table 5 for access point configuration. Refer to Table 6 for STA device configuration

Table 9 lists the additional test configuration for each of the procedures that comprise this test case.

Note: Prior to start of each test procedure execution, the test bed devices are switched off unless otherwise stated in the test case procedure.

**Table 9. LTE-U allowing new Wi-Fi network connection test configuration**

Procedure	EUT Configuration	Test Bed Configuration	
Procedure A Part 1	Manufacturer declares the maximum nominal duty cycle at which it can operate. EUT is configured and turned on. Full buffer DL from EUT to LTE-U UE in a clean channel	Not applicable	
Procedure A Part 2	Not applicable	# of BSSs	BSS #1: AP1 - STA1 on Channel 48 BSS #2: AP2 - STA2, STA3, STA4, STA5, STA6 on Channel 48
		AP channel width	20MHz, 11ac mode
		Traffic type	Full buffer Wi-Fi uplink traffic (Table 30) on BSS #1

Procedure	EUT Configuration	Test Bed Configuration	
		Sequential execution	BSS #1 is operational with traffic when AP2 is configured and turned on in the same channel. STA2 - STA6 are configured to discover and associate to AP2
Procedure B	<TBD>	# of APs	AP1 on Channel 48
		AP channel width	20MHz, 11ac mode
		# of STAs	5, all STAs to connect to AP1
		Traffic type	Full buffer Wi-Fi uplink traffic (Table 30)
Procedure C	<TBD>	# of APs	AP1 (Channel 149), AP2 (Channel 36), AP3 (Channel 36). AP1 and AP2 in same ESS
		AP channel width	20MHz, 11ac mode
		# of STAs	3 STAs to transition from AP1 operating in channel 149 to AP2 which is operating in channel 36 (LTE-U operating channel) 2 STAs to connect to AP3 which is operating in channel 36
		Sequential execution	AP3 is turned on 15 seconds after 3 STAs successfully transition to AP2 in Channel 36 and initiate data transfer. STA4 and STA5 should scan and associate to AP3
		Traffic type	Full buffer Wi-Fi uplink traffic (Table 30)

### Test Procedure

For this test case, the EUT is reconfigured at the start of each procedure.

1. Configure and execute test procedure A part 1 to record the baseline EUT performance in terms of maximum medium usage in a clear channel.
2. Configure and execute test procedure A part 2 to record the Wi-Fi baseline connection setup time in the presence of only Wi-Fi nodes. The AP is heard by its respective STAs (and vice versa) at -80 dBm.
3. Turn off all Wi-Fi APs and STAs. Then configure the EUT and turn it on.
4. Connect an LTE-U UE to the EUT.
5. Restrict the EUT to operate only on one channel. Load the EUT with full buffer traffic and measure the medium usage. It is expected that the EUT will utilize the channel to the maximum extent allowable by transmitting DL traffic to connected UE.
6. Turn on Wi-Fi APs. Configure the Wi-Fi APs to operate in the same channel as the EUT as specified in Table 9. The Wi-Fi APs are configured to transmit Beacon frames at 24 Mbps rate and the lowest basic rate is set to 24 Mbps (as is common for high density deployments). Each AP is heard by its respective STAs (and vice versa) at -80 dBm.
7. Turn on Wi-Fi STAs. Configure multiple Wi-Fi STAs to initiate a Wi-Fi connection with the Wi-Fi APs as defined in procedure B and procedure C in Table 9.
8. For procedure B and procedure C, verify that all Wi-Fi nodes are heard at signal levels specified below by the LTE-U node and vice versa:  
Run 1: Test Level 1  
Run 2: Test Level 2  
Run 3: Test Level 3



9. The Wi-Fi STAs should scan and discover the available Wi-Fi networks and successfully complete a connection setup with the respective APs. Measure the time required to completely setup the Wi-Fi connection, including achieving IP connectivity by obtaining the IP address from the DHCP server and (if implemented) probing it using ARP.

### Test Results

The test case is considered PASSED if the STA logs indicate the presence of Wi-Fi network(s), the EUT allows the Wi-Fi STAs to establish new Wi-Fi network connections as specified in Table 10, and the EUT's RF activity measurements indicate appropriately adjusted medium usage.

**Table 10. LTE-U allowing new Wi-Fi network connection test expected results**

Procedure	Expected Results
Procedure A	Part 1: EUT's medium usage of unlicensed band shall match the maximum nominal duty cycle declared by the manufacturer. Part 2: The recorded connection setup time for each STA2, STA3, STA4, STA5, and STA6 forms the Wi-Fi - Wi-Fi baseline.
Procedure B	EUT operation shall allow all 5 STAs to successfully connect to AP1 and initiate data transfer The complete connection setup time for each STA shall not exceed max (5 seconds, Wi-Fi - Wi-Fi baseline in Procedure A - Part 2)
Procedure C	EUT operation shall allow STA1,STA2,STA3 to transition from AP1 to AP2 and allow STA4, STA5 to associate with AP3 and initiate data transfer The complete connection setup time for each STA shall not exceed max (5 seconds, Wi-Fi - Wi-Fi baseline in Procedure A - Part 2)

## 4.3 LTE-U Medium Usage Adapting to Changing Channel Loading Test

### Purpose and Description

This test verifies that the CSAT operation adapts to the change in channel utilization with respect to Wi-Fi traffic load. When one or more Wi-Fi networks are operating co-channel with the EUT, the LTE-U eNB should adapt its channel usage based on the detected channel usage.

This test also verifies the ability of LTE-U operating in 40Mhz transmission to adjust and properly contend with each Wi-Fi 20Mhz channel occupying the same spectrum. Procedure A and procedure F are applicable only to LTE-U systems capable of 40Mhz channel operations.

Unlicensed channels in the U-NII-1 (5150 MHz -5250 MHz) and the U-NII-3 (5725 MHz -5825 MHz) bands are used for this test.

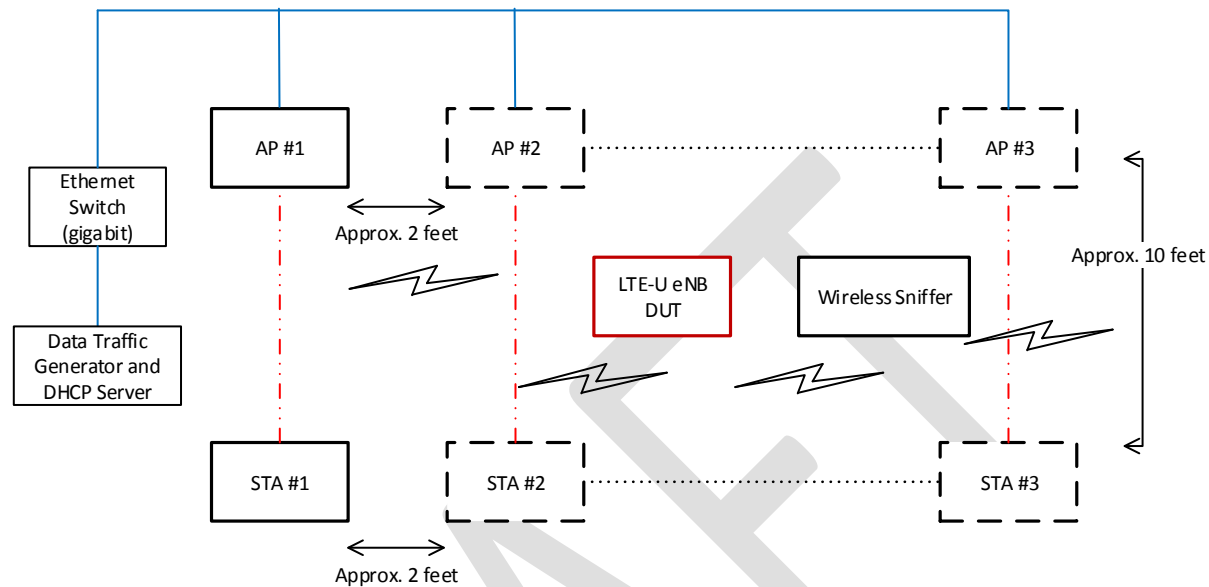
### References

- TBD

### Test Environment

- EUT (1)
- LTE-U UE (1)
- Wi-Fi CERTIFIED ac access point (5)
- Wi-Fi CERTIFIED ac station (5)
- Wireless sniffer
- Wi-Fi data traffic generator
- DHCP server

Figure 6 depicts the testbed schematic to be deployed for this test. Blue lines depict the physical connection between Wi-Fi access points to the data traffic generator and DHCP server through an Ethernet switch. Red dashed lines depict the Wi-Fi network connection between the access points and station devices.



**Figure 6. LTE-U medium usage adapting to changing channel loading test setup**

## Test Configuration

Refer to Table 5 for access point configuration. Refer to Table 6 for station device configuration

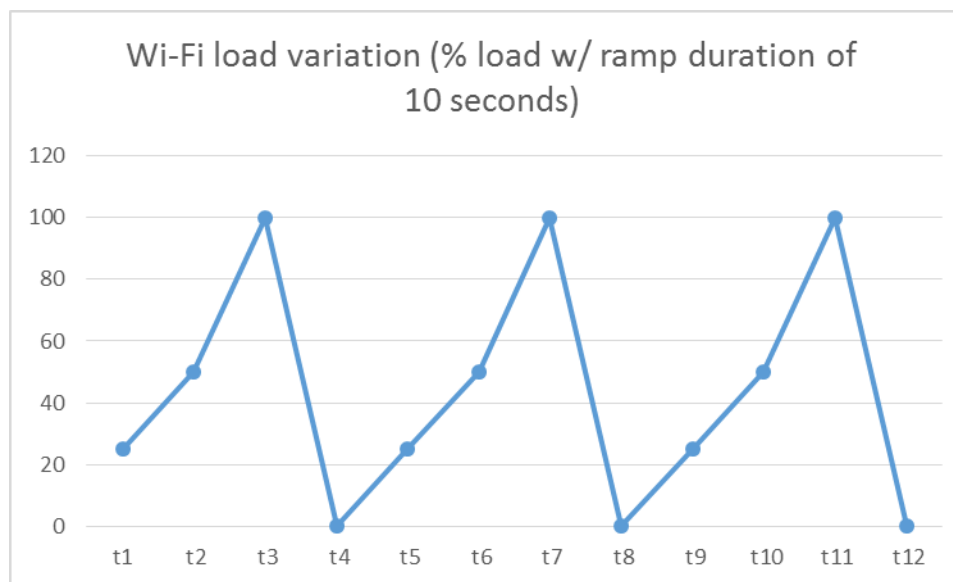
Table 11 lists the additional test configuration for each of the procedures that comprise this test case.

Note: Prior to start of each test procedure execution, the test bed devices are switched off unless otherwise stated in the test case procedure.

**Table 11. LTE-U medium usage adapting to changing channel loading test configuration**

Procedure	EUT Configuration	Test Bed Configuration	
Procedure A	Part 1: Configure EUT to operate in a single 20MHz unlicensed channel, full buffer  Part 2: If EUT supports channel aggregation, configure the EUT to operate at 40MHz (Two 20MHz unlicensed contiguous or non-contiguous channels) with one of these two channels being the operating channel of AP1, full buffer  Note: The other 20 MHz EUT operating channel shall be clear of non-EUT signals	# of BSS	1 (AP1 and STA1)
		AP channel width	20MHz, 11ac mode
		Traffic type	Bidirectional, TCP (Table 30)  Traffic is configured for 120 seconds as per Figure 6
Procedure B	<TBD>	# of BSS	1 (AP1 and STA1/STA2/STA3/STA4/STA5)

Procedure	EUT Configuration	Test Bed Configuration	
		AP channel width	20MHz, 11ac mode
		Traffic type	Only Wi-Fi uplink traffic, AC Best Effort profile, full buffer (Table 30) 5 phases 60 seconds each (P1: Only 1 STA transmitting, P2: 2 STA transmitting..., P5: All 5 STA transmitting) performed in serial order
Procedure C (Inter-operator scenario)	EUT1 (Operator A) serving 1 UE, full buffer DL EUT2 (Operator B) serving 1 UE, full buffer DL	# of BSS	1 (AP1 and STA1/STA2/STA3)
		AP channel width	20MHz, 11ac mode
		Traffic type	Only Wi-Fi downlink traffic, AC Video profile, full buffer (Table 30) All 3 STAs receiving DL traffic
Procedure D	<TBD>	# of BSS	5 (AP1 and STA1, AP2 and STA2, AP3 and STA3, AP4 and STA4, AP5 and STA5) APs not broadcasting SSID in the Beacon (hidden SSID mode)
		AP channel width	All APs configured in 20MHz (11ac mode) same operating channel
		Traffic type	Bidirectional, TCP, full buffer (Table 30) 5 phases 120 seconds each (P1: Only 1 BSS operational, P2: 2 BSS operational..., P5: All 5 BSS operational) performed in serial order
Procedure E	<TBD>	# of BSS	3 (AP1 and STA1, AP2 and STA2, AP3 and STA3)
		AP channel width	20MHz (11ac mode)
		Traffic type	2 phases 120 seconds each (P1: Only 1 BSS operational with 25% load, P2: All 3 BSS operational with full buffer load) performed in serial order
Procedure F	40Mhz EUT operation: EUT1 (Operator A) serving 1 UE, full buffer DL. The EUT is configured for a single 40Mhz channel that contends with both the two 20Mhz Wi-Fi channels being tested.	# of BSS	5 (AP1 and STA1, AP2 and STA2, AP3 and STA3, AP4 and STA4, AP5 and STA5)
		AP channel width	Two 20Mhz adjacent channels are used for the test: channel 153 and 157 AP1 and AP2 occupy channel 153 @ 20MHz AP Channel Width AP3, AP4, AP5 occupy channel 157 @ 20MHz AP Channel Width
		Traffic type	Phase P1: From zero to 60 seconds: AP1 is full buffer. AP2 is off. AP3, AP4 and AP5 are full buffer. Phase P2: From zero to 60 seconds: AP1, AP2 and AP3 are full buffer. AP4 and AP5 are off.



**Figure 7. Wi-Fi load variation (% load with ramp duration of 10 seconds)**

### Test Procedure

1. Wi-Fi calibration test is executed before each procedure:
  - a. No LTE-U equipment should be operating during the calibration
  - b. Record the Wi-Fi calibration result for each procedure
  - c. An 802.11ac AP operating at 40Mhz is used for calibration in procedure F in order to provide a comparison between 40Mhz LTE and 40Mhz 802.11ac
2. Restrict the EUT to operate on only one channel as specified in Table 11, except for procedure A Part #2 and except as described in procedure F.
3. Measure and record the EUT's medium usage when it is loaded with full buffer traffic. It is expected that the EUT will utilize the channel to the maximum extent allowable.
4. Configure one or more Wi-Fi networks to operate in the same channel(s) as the EUT as specified in Table 11. Load the Wi-Fi operating channel by introducing the Wi-Fi traffic specified in Table 11. Each AP is heard by its associated STAs (and vice versa) at <TBD> dBm.
5. Verify that all Wi-Fi nodes are heard at the test signal levels specified below by the LTE-U node and vice versa:
  - Run 1: Test Level 1
  - Run 2: Test Level 2
  - Run 3: Test Level 3
6. Measure and record the Wi-Fi throughput achieved during each test procedure in the presence of the EUT.

### Test Results

The test case is considered PASSED if the EUT employs CSAT to sense the medium and adapt its medium usage in response to Wi-Fi usage, and the expected results listed in Table 12 are met.

**Table 12. LTE-U medium usage adapting to changing channel loading test expected results**

Procedure	Expected Results
Procedure A	EUT shall adjust its medium usage from time $(T(n) + \text{TBD ms})$ based on varying channel load and shall be $\leq 50\%$ air time each period from $T(n) + \text{TBD ms}$ to $T(n+1)$ . EUT operation shall allow Wi-Fi network to achieve average throughput (Mbps) corresponding to Table 15
Procedure B	EUT shall adjust its medium usage from time $(T(n) + \text{TBD ms})$ based on varying channel load as per Table 13 and Table 14 throughout each phase $P(n)$ $T(n)$ - time at which phase $P(n)$ begins EUT operation shall allow Wi-Fi network to achieve average throughput (Mbps) corresponding to Table 15
Procedure C	EUT1 (Operator B) and EUT2 (Operator A) shall adjust its medium usage from time $(T(n) + \text{TBD ms})$ based on varying channel load as per Table 13 throughout each phase $P(n)$ $T(n)$ - time at which phase $P(n)$ begins EUT operation shall allow Wi-Fi network to achieve average throughput (Mbps) corresponding to Table 15
Procedure D	EUT shall adjust its medium usage from time $(T(n) + \text{TBD ms})$ based on varying channel load as per Table 13 and Table 14 throughout each phase $P(n)$ $T(n)$ - time at which phase $P(n)$ begins EUT operation shall allow Wi-Fi network to achieve average throughput (Mbps) corresponding to Table 15
Procedure E	Let $T_1$ - time at which phase $P_1$ begins, $T_2$ = time at which phase $P_2$ begins. EUT Medium Usage shall be $< 75\%$ throughout the period from time $T_1$ to $T_2$ . EUT Medium Usage shall be $< 25\%$ throughout the period from time $(T_2 + \text{TBD ms})$ until the end of phase $P_2$ EUT operation shall allow Wi-Fi network to achieve average throughput (Mbps) corresponding to Table 15
Procedure F	In phase $P_1$ , Wi-Fi throughput of each AP shall be within 10% of the calibrated Wi-Fi only values. EUT medium usage on channel 153 $\leq 50\%$ . EUT medium usage on channel 157 $\leq 25\%$ In phase $P_2$ , Wi-Fi throughput of each AP shall be within 10% of the calibrated Wi-Fi only values. EUT medium usage on channel 153 $\leq 33\%$ and EUT medium usage on channel 157 $\leq 50\%$ throughout the period from time $(T_2 + \text{TBD ms})$ until end of phase $P_2$ EUT's medium usage parameters shall be measured as per Table 14

Table 13 defines the channel usage based on Wi-Fi activity. The number of Wi-Fi links represents the number of medium contenders with full buffer load (AP or STA).

**Table 13. EUT varying usage load**

Scenario	Expected Result
1 Wi-Fi link	EUT Medium Usage $\leq 50\%$
2 Wi-Fi links	EUT Medium Usage $\leq 33\%$

Scenario	Expected Result
n Wi-Fi links	EUT Medium Usage $\leq 1 / (n + 1) \%$

Table 14 gives the expected EUT medium usage.

**Table 14. EUT medium usage criteria**

Parameter	Expected Result	Description
Medium Usage	$\sum e(t) / T \leq \text{TBD} \%$	e(t) is the total T(on) duration over a period of time T is the measurement sample in seconds <TBD>
Medium Usage adaptive response time	<TBD> milli seconds	The EUT shall adjust its medium usage within <TBD> ms of each phase start time
T(on)	4ms $\leq$ T(on) $\leq$ 20ms T(on) $\leq$ 1ms (if only MIB or LDS is being transmitted)	T(on) is the SCell ON-state duration
T(off)	T(off) $\geq$ 1ms	T(off) is the SCell OFF-state duration

Table 15 provides the expected Wi-Fi throughput achieved during the test procedure in presence of the EUT.

**Table 15. Wi-Fi throughput expectation**

Scenario	Expected Wi-Fi Throughput
1 Wi-Fi link only	100%
1 Wi-Fi link + LTE-U	50%
n Wi-Fi links + LTE-U	$1 / (n + 1) \%$

## 4.4 LTE-U Node Impact on Latency Sensitive Wi-Fi Traffic Test

### Purpose and Description

This test determines the impact of LTE-U node operation on latency sensitive Wi-Fi applications such as VoIP. The test records the variations in KPIs in presence and absence of a EUT under different load conditions. Unlicensed channels in U-NII-1 (5150 MHz -5250 MHz) and U-NII-3 (5725 MHz -5825 MHz) bands are used for this test.

This test case and expected results are based on WFA Voice Enterprise test plan that provides the data for one way delay, jitter, packet loss for uplink and downlink Wi-Fi traffic. The Wi-Fi APs and STAs used in this test case are WFA Voice Enterprise Certified devices.

### References

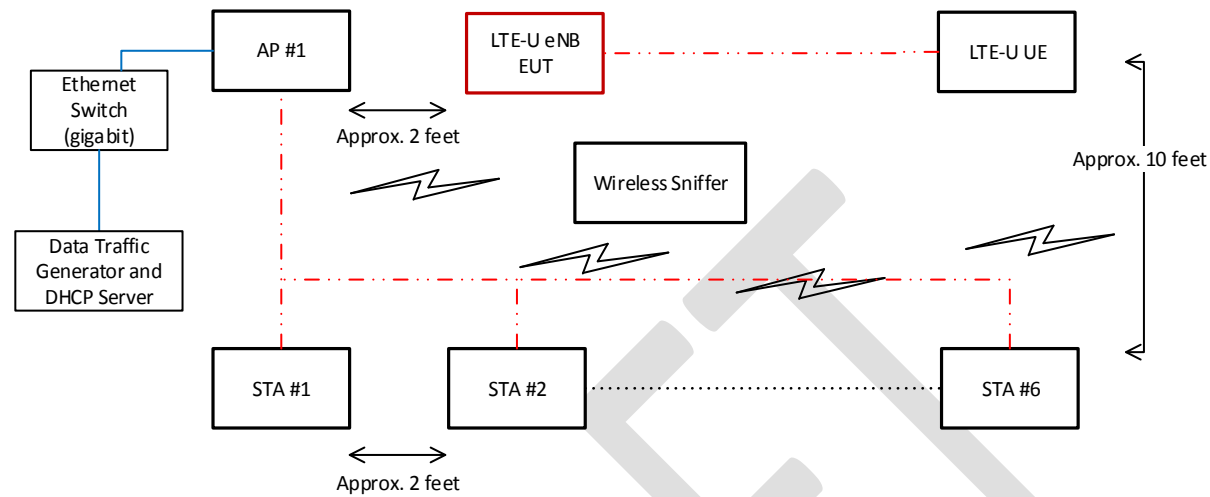
- WFA Voice Over Wi-Fi Enterprise Certification Program Test Plan v1.1

### Test Environment

- EUT (1)
- LTE-U UE (1)
- Wi-Fi CERTIFIED ac access point (2) - WFA Voice Enterprise Certified
- Wi-Fi CERTIFIED ac station (6) - WFA Voice Enterprise Certified
- Wireless sniffer
- Wi-Fi data traffic generator
- DHCP server

Figure 8 depicts the test bed schematic to be deployed for the LTE-U Node Impact on Latency Sensitive Wi-Fi Traffic Test. Blue lines depict the physical connection between Wi-Fi access points to the data traffic generator and DHCP server through an Ethernet switch. Red dashed lines depict the Wi-Fi network connection between the access points and station devices. The EUT is shown as the red entity.





**Figure 8. LTE-U node impact on latency sensitive Wi-Fi traffic test setup**

### Test Configuration

Refer to Table 5 for access point configuration. Refer to Table 6 for station device configuration.

Table 16 lists the additional test configuration for each of the procedures that comprise this test case.

Note: Prior to start of each test procedure execution, the test bed devices are switched off unless otherwise stated in the test case procedure.

**Table 16. LTE-U node impact on latency sensitive Wi-Fi traffic test configuration**

Procedure	EUT Configuration	Test Bed Configuration	
Procedure A	LTE-U small cell turned off	# of BSS	3 (AP1 and STA1/STA2/STA3/STA4, AP2 and STA5, AP3 and STA6)
		Traffic profile	Individual traffic profiles are configured as per <TBD> AP1 to STA1: 1 Voice stream (g.711 64kbps voice codec, UDP, bidirectional) AP1 to STA2, STA3, STA4: 3 Voice streams EACH (g.711 64kbps voice codec, UDP, bidirectional) AP2 to STA5: Traffic load @ ~50% of the total channel capacity AP3 to STA6: Full buffer, Downlink, UDP Duration: 120 seconds
Procedure B	EUT is configured and turned on Full buffer DL from EUT to LTE-U UE	# of BSS	1 (AP1 and STA1/STA2/STA3/ STA4)
		Traffic profile	Individual traffic profiles are configured as per <TBD> AP1 to STA1: 1 Voice stream (g.711 64kbps voice codec, UDP, bidirectional)

Procedure	EUT Configuration	Test Bed Configuration	
			AP1 to STA2, STA3, STA4: 3 Voice streams EACH (g.711 64kbps voice codec, UDP, bidirectional) AP2 to STA5: Traffic load @ ~50% of the total channel capacity Duration: 120 seconds
Procedure C	EUT configured and turned on. LTE-U UE connected to EUT.  EUT traffic type has 3 phases 120 seconds each (P1: full buffer load. P2: 50% load, P3: zero load)  Load definitions are specified in Table 21	# of BSS	1 (AP1 and STA1)
		AP channel width	20MHz (11ac mode)
		Traffic type	Wi-Fi traffic type is Bidirectional, AC Voice profile, G.711 (64 kbps) voice codec (Table 30)
			Duration: 300 seconds

### Test Procedure

This test is limited to one available unlicensed channel.

#### Procedure A:

1. Configure Wi-Fi networks comprising three APs and six STAs and make them operational in the available channel. Verify each AP is heard by its associated STAs (and vice versa) at -80 dBm. Introduce the traffic load of 10 VO streams in BSS#1, ~50% in BSS#2 and 1 full buffer, with the UDP downlink in BSS#3 for these networks as specified in Table 16. Note that the traffic load on BSS#1 and BSS#2 combined should be not more than 50% of the channel capacity.
2. Measure and record the Wi-Fi network KPIs in Table 18.
3. Calculate the delay, jitter and packet loss count using the Received Packet Time Stamp (RPTS) method.

#### Procedure B:

1. Turn off AP#3 BSS and verify that AP#1 BSS and AP#2 from procedure A is still operational.
2. Configure the EUT and turn it on so that it operates in the available channel.
3. Connect an LTE-U UE to the EUT. Configure the LTE-U network and initiate a continuous full buffer DL on the LTE-U network.
4. At this point, both LTE-U and Wi-Fi nodes should be operating on the same channel.
5. Ensure that all Wi-Fi nodes are heard at the signal levels specified below by the LTE-U node and vice versa:  
 Run 1: Test Level 1  
 Run 2: Test Level 2  
 Run 3: Test Level 3
6. Introduce the Wi-Fi traffic streams as specified in Table 16. Each AP is heard by its associated STAs (and vice versa) at -80 dBm.
7. Calculate the delay, jitter and packet loss count using the Received Packet Time Stamp (RPTS) method. Record the Wi-Fi network KPIs in Table 18.

#### Procedure C:

1. Configure the EUT to operate on only one channel with the traffic load defined in Table 16.
2. Configure one Wi-Fi network as defined in Table 16 to operate in the same channel as the EUT. Initiate Wi-Fi traffic 60 seconds after configuration.
3. Ensure that all Wi-Fi nodes are heard at the signal levels specified below by the LTE-U node and vice versa:

## Run 1: Test Level 1

4. Measure the EUT medium usage. The EUT should deploy CSAT to sense the medium and operative parameters be adaptively tuned, in response to its own load.

**Test Results**

The test case is considered PASSED if the EUT in procedure B and procedure C adjust its medium usage characteristics depending on its assessment of Wi-Fi network load as specified in Table 17. For Procedure B, Wi-Fi network KPIs are measured and compared as specified in Table 14.

**Table 17. LTE-U node impact on latency sensitive Wi-Fi traffic test expected results**

Procedure	Expected Results
Procedure A	KPIs are measured and recorded in Table 18. Ensure the test environment is configured and setup appropriately to fulfil measurement criteria listed in Table 19.
Procedure B	Measure and record the impact of LTE-U operation on Wi-Fi performance based on network KPIs as per Table 18. Measured Wi-Fi KPIs in Procedure B $\leq$ max(Wi-Fi KPIs recorded in Procedure A, Table 19)
Procedure C	Let T2 = time at which phase P2 begins, and T3 = time at which phase P3 begins EUT Medium Usage shall be $<50\%$ throughout the period from time (T2 + TBD ms) until the end of phase P2 EUT Medium Usage shall be $<1\%$ throughout the period from time (T3 + TBD ms) until the end of phase P3, in addition to potential MIB and LDS broadcasts <TBD> - shall be as per the manufacturer declared time

**Table 18. LTE-U node impact on latency sensitive Wi-Fi traffic test record**

Parameter	Stream	Procedure A	Procedure B
One-Way Delay	AC-VO		
Jitter	AC-VO		
Lost Packets	AC-VO		
	AC-VO		

**Table 19. Measurement criteria**

Parameter	Stream	Measurement/Pass/Fail
One-Way Delay	AC-VO	1. $\geq 95\%$ , not more than 50ms, Downlink AP1 to STA1 2. $\geq 95\%$ , not more than 50ms, Uplink STA1 to AP1
Jitter	AC-VO	Jitter (delay variation) maximum 3. $\geq 95\%$ , not more than 50ms for Downlink AP1 to STA1

		4. $\geq 95\%$ , not more than 50ms for Uplink STA1 to AP1
Lost Packets	AC-VO	1. Not more than 1%, for Downlink AP1 to STA1 2. Not more than 1% for Uplink STA1 to AP1
	AC-VO	1. Not more than 3 consecutive lost packets on Downlink 2. Not more than 3 consecutive lost packets on Uplink

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## 4.5 LTE-U Node Impact on Wi-Fi Throughput Performance Test

### Purpose and Description

This test determines the impact of LTE-U node operation on Wi-Fi throughput performance with various LTE-U traffic loads. The test is performed for various simulated path losses between two coexisting networks. The test records the variations in Wi-Fi throughput when the EUT coexists with a Wi-Fi network, and when a Wi-Fi network coexist with another Wi-Fi network.

The test also determines that the CSAT operation adapts to change for a variety of LTE-U loads in the presence of high load Wi-Fi traffic. Unlicensed channel in U-NII-1 (5150-5250MHz) band is used for this test.

### References

- TBD

### Test Environment

- EUT (1)
- LTE-U UE (1)
- Wi-Fi CERTIFIED ac Access Point (2)
- Wi-Fi CERTIFIED ac Station (2)
- Wireless Sniffer
- Wi-Fi Data Traffic Generator
- DHCP Server

### Test Configuration

Refer to Table 5 for Access Point configuration. Refer to Table 6 for STA device configuration.

Table 20 lists the additional test configuration for each of the procedures that comprise this test case.

Note: Test bed devices are operational during the test execution and shall not be turned off between procedures.

**Table 20. LTE-U Node Impact on Wi-Fi Throughput Performance Test Configuration**

Procedure	EUT Value	Test Bed Configuration	
Procedure A	LTE-U Scell is turned off	Wi-Fi network	1 AP and 1 STA connected
		Traffic profile	Traffic is downlink full buffer UDP from AP to STA
Procedure B	LTE-U Scell is turned off	Wi-Fi network	Two Wi-Fi networks that each contain one AP connected to one STA
		Traffic profile	For the first Wi-Fi network, traffic is downlink full buffer UDP from the AP to the STA. For the second Wi-Fi network, UDP traffic load from the AP to the STA has 3 phases, each 120 seconds. Phase 1: full buffer load Phase 2: 25% load

Procedure	EUT Value	Test Bed Configuration	
			Phase 3: 10% load
Procedure C	EUT is configured and turned on EUT traffic type has 3 phases, each 120 seconds. Phase 1: full buffer load Phase 2: 25% load Phase 3: 10% load	Wi-Fi network	1 AP and 1 STA connected
		Traffic profile	Traffic is downlink full buffer UDP from AP to STA

### Test Procedure

This test is limited to a single available unlicensed channel. The Wi-Fi equipment used for the test shall be selected such that the throughput in Procedure B for full-buffer shall be not less than 40% of the reference throughput in Procedure A.

#### Procedure A:

1. Configure and make operational a Wi-Fi network comprising one AP and one STA in the available channel.
2. Verify that the AP is heard by the STA (and vice versa) at -80 dBm.
3. Record the throughput results in Table 23.

#### Procedure B:

1. Configure and make operational a second Wi-Fi network comprising one AP and one STA operating in the same channel as the first.
2. Verify that the AP is heard by the STA (and vice versa) at -80 dBm.
3. Configure the UDP traffic on the second network with each of the traffic loads specified in Table 21 for each phase. Verify that the nodes of the second network are heard by the nodes of the first network (and vice versa).  
Run 1: Test Level 2  
Run 2: Test Level 3
4. Record the throughput results in Table 23.

#### Procedure C:

1. Remove the second Wi-Fi network.
2. Configure and make operational an LTE-U network comprising a EUT and LTE-U UE.
3. Configure the UDP traffic of the LTE-U network with each of the traffic loads specified in Table 21 for each phase. Verify that the EUT is heard by the nodes of the Wi-Fi network (and vice versa).  
Run 1: Test Level 2  
Run 2: Test Level 3
4. Record the throughput and EUT medium usage results in Table 23.
5. Verify that the EUT deploys CSAT to sense the medium and adaptively tunes the appropriate parameters in response to its own load.

Table 21 defines the traffic loading terms used in this test case.

**Table 21. Load definitions**

Type of Load	Description
Full buffer load	Full buffer traffic
25% load	Traffic that would consume 25% of the airtime if the LTE-U network were alone (i.e. if no other BSS or LTE-U networks present)
10% load	Traffic that would consume 10% of the airtime if the LTE-U network were alone (i.e. if no other BSS or LTE-U networks present)

**Test Results**

The test case is considered PASSED if the expected results listed in Table 22 are met, the measured Wi-Fi performance and EUT medium usage entered in Table 23 meets the expected results listed in Table 24, and EUT medium usage meets the criteria listed in Table 25.

**Table 22. LTE-U node impact on Wi-Fi throughput performance expected results**

Procedure	Expected Results
Procedure A	Measure reference throughput for single Wi-Fi network with high load. This result is the benchmark comparison for the other procedures in the test.
Procedure B	Measure the reference throughput for the two coexisting Wi-Fi networks as a benchmark comparison for Procedure C. Measure the throughput in each of the 3 phases with different loads on second Wi-Fi network.
Procedure C	<p>Let:  T2 = time at which phase 2 begins  T3 = time at which phase 3 begins</p> <p>Measure the impact of LTE-U operation on the LTE-U network. Measure the Wi-Fi throughput for each of the 3 phases with different loads.  EUT medium usage shall be <math>\leq 20\%</math> throughout the period from time (T2 + TBD ms) until the end of phase P2  EUT medium usage shall be <math>\leq 10\%</math> throughout the period from time (T3 + TBD ms) until the end of phase P3</p>

**Table 23. LTE-U node impact on Wi-Fi performance test record**

Parameter	Received signal strength of nodes of first Wi-Fi network at the nodes of second network (Wi-Fi or LTE-U)	Procedure A	Procedure B: Phase P1	Procedure B: Phase P2	Procedure B: Phase P3	Procedure C: Phase P1	Procedure C: Phase P2	Procedure C: Phase P3
Wi-Fi Throughput (Mbps)	Test Level 2 = -67 dBm							
EUT medium usage	Test Level 2 = -67 dBm	N/A	N/A	N/A	N/A			

Parameter	Received signal strength of nodes of first Wi-Fi network at the nodes of second network (Wi-Fi or LTE-U)	Procedure A	Procedure B: Phase P1	Procedure B: Phase P2	Procedure B: Phase P3	Procedure C: Phase P1	Procedure C: Phase P2	Procedure C: Phase P3
Wi-Fi Throughput (Mbps)	Test Level 3 = -77 dBm							
EUT medium usage	Test Level 3 = -77 dBm	N/A	N/A	N/A	N/A			

Table 24 provides the expected Wi-Fi throughput achieved during the test procedure in presence of the EUT.

**Table 24. LTE-U node impact on Wi-Fi performance test expected results**

Parameter	Received signal strength of nodes of first Wi-Fi network at the nodes of second network (Wi-Fi or LTE-U)	Full buffer (Phase 1)	25% traffic load (Phase 2)	10% traffic load (Phase 3)
Wi-Fi Throughput	Test Level 2 = -67 dBm	No more than 5% reduction in Procedure C throughput compared with Procedure B	No more than 5% reduction in Procedure C throughput compared with Procedure B	No more than 5% reduction in Procedure C throughput compared with Procedure B
EUT medium usage	Test Level 2 = -67 dBm	No more than 50% medium usage from TBD ms after the start of the phase	No more than 20% medium usage from TBD ms after the start of the phase	No more than 10% medium usage from TBD ms after the start of the phase
Wi-Fi Throughput	Test Level 3 = -77 dBm	No more than 5% reduction in Procedure C throughput compared with Procedure B	No more than 5% reduction in Procedure C throughput compared with Procedure B	No more than 5% reduction in Procedure C throughput compared with Procedure B
EUT medium usage	Test Level 3 = -77 dBm	No more than 50% medium usage from TBD ms after the start of the phase	No more than 20% medium usage from TBD ms after the start of the phase	No more than 10% medium usage from TBD ms after the start of the phase

Table 25 lists the expected EUT medium usage criteria.

**Table 25. EUT Medium Usage Criteria**

Parameter	Expected Result	Description
Medium Usage	$\sum e(t) / T \leq \text{TBD} \%$	$e(t)$ = Total T(on) duration over a period of time $T$ = Measurement Sample in seconds <TBD>



Parameter	Expected Result	Description
T(on) in Procedure C	$4\text{ms} \leq T(\text{on}) \leq 20\text{ms}$	T(on) = SCell ON-state duration
T(off) in Procedure C	$T(\text{off}) \geq 1\text{ms}$	T(off) = SCell OFF-state duration

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## 4.6 LTE-U UE and Wi-Fi Station In Device Coexistence Test

### Purpose and Description

This test verifies that the EUT, which is a combined UE and Wi-Fi STA operating in LTE-U operations in an unlicensed channel, provides an accurate status of the available Wi-Fi networks available to the EUT user. Furthermore, this test verifies that the EUT allows the user to select a Wi-Fi network for data connections and that LTE-U operations is terminated when the user selects an SSID for connection.

Unlicensed channels in the U-NII-1 (5150 MHz -5250 MHz) and the U-NII-3 (5725 MHz -5825 MHz) bands are used for this test.

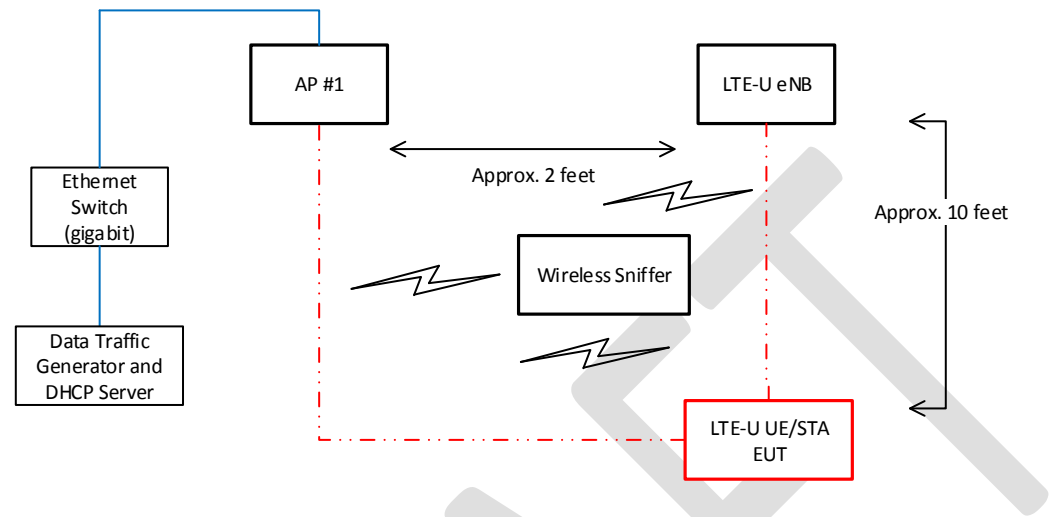
### References

- TBD

### Test Environment

- LTE-U eNodeB (1)
- EUT: a combined LTE-U UE and Wi-Fi STA (1)
- Wi-Fi CERTIFIED ac access point (3)
- Wireless sniffer
- Wi-Fi data traffic generator
- DHCP server

The figure below depicts the test bed schematic to be deployed for the test. Blue lines depict the physical connection between Wi-Fi access points to the data traffic generator and DHCP server through an Ethernet switch. Red dashed lines depict the Wi-Fi network connection between the access points and station devices.



**Figure 9. LTE-U allowing new Wi-Fi network connection test setup**

**Test Configuration**

Procedure A and B are for establishing the baseline for LTE-U and Wi-Fi performance respectively.

In Procedure C and D, Equipment Under Test (EUT) is the UE/STA.

Refer to Table 5 for access point configuration. Refer to Table 6 for STA device configuration

Table 34 lists the additional test configuration for each of the procedures that comprise this test case.

All procedures use 20MHz Wi-Fi channels.

**Table 26. LTE-U allowing use to Detect and Selection Wi-Fi SSID for Data Connections**

Procedure	EUT Configuration	Test Bed Configuration
Procedure A	Manufacturer declares the maximum nominal duty cycle at which it can operate.  LTE-U eNodeB is configured and turned on and operates on channel 153.  UE/STA is turned on and connected to the LTE-U eNodeB on channel 153.	Wi-Fi networks are OFF

Procedure	EUT Configuration	Test Bed Configuration	
	Full buffer DL from LTE-U eNodeB to UE/STA in a clean channel		
Procedure B	LTE-U eNodeB has no DL data configured UE/STA has Wi-Fi turned on out-of-box	# of BSSs	Channel: 153: AP1 is configured with SSID1
Procedure C	Channel 153 Full buffer DL traffic from LTE-U eNodeB to UE/STA	# of BSSs	Channel: 153 After 60 seconds: AP1 is turned on and configured with SSID1
Procedure D	Channel 153 Full buffer DL traffic from LTE-U eNodeB to UE/STA	# of BSSs	Channel: 157 After 60 seconds: AP1 is turned on and configured with SSID1

### Test Procedure

For this test case, the LTE-U eNodeB and UE/STA are reconfigured at the start of each procedure.

#### Procedure A:

1. Configure and execute to record the baseline LTE-U downlink performance in terms of maximum medium usage in a clear channel.
2. Connect an LTE-U eNode B to the UE/STA.
3. Load the LTE-U eNodeB with full buffer DL traffic and measure the medium usage. It is expected that the LTE-U eNodeB will utilize the channel to the maximum extent allowable by transmitting DL traffic to connected UE/STA.

#### Procedure B:

1. LTE-U eNodeB device is turned off.
2. Turn on and configure Wi-Fi AP1.
3. Configure UE/STA and then check the status of the UE/STA UI to ensure SSID1 is listed.
4. UE/STA is connected to Wi-Fi AP1 and full buffer DL data is transmitted.

#### Procedure C:

1. Turn off Wi-Fi AP1.
2. LTE-U eNodeB is connected to UE/STA and full buffer DL data is configured for transmission with maximum medium usage in a clear channel.
3. Turn on and configure Wi-Fi AP1 as per Table 26. Check the Wi-Fi SSID status on the UE/STA's UI.
4. Select SSID1 on the UE/STA Wi-Fi status UI and ensure that the UE/STA associates with AP1.
5. Full buffer data is sent from AP1 to UE/STA.

#### Procedure D:

1. Turn off Wi-Fi AP1.
2. LTE eNodeB is connected to UE/STA and full buffer DL data is configured for transmission with maximum medium usage in a clear channel.
3. Turn on and configure Wi-Fi AP1 as per Table 26. Check the Wi-Fi SSID status on the UE/STA's UI.
4. Select SSID1 on the UE/STA Wi-Fi status UI and ensure that the UE/STA associates with AP1.

5. Full buffer data is sent from AP1 to UE/STA.

For procedure C and procedure D, verify that all Wi-Fi nodes are heard at signal levels specified below by the LTE-U node and vice versa:

- Run 1: Test Level 1
- Run 2: Test Level 2
- Run 3: Test Level 3

### Test Results

The test case is considered PASSED if the LTE-U meets the expected results listed in Table 27.

**Table 27. LTE-U allowing use to Detect and Selection Wi-Fi SSID for Data Connections expected results**

Procedure	Expected Results
Procedure A	LTE-U eNodeB and UE/STA's medium usage of unlicensed band shall match the maximum nominal duty cycle declared by the manufacturer.
Procedure B	User checks Wi-Fi network status on UE/STA. The UE/STA Wi-Fi SSID status UI shows SSID1 listed. Record the time required for UE/STA to discover and report Wi-Fi network to user Wi-Fi throughput is recorded as baseline
Procedure C	Verify that LTE-U is at maximum duty cycle prior to Wi-Fi AP being turned on. User checks the Wi-Fi network status on UE/STA. The UE/STA Wi-Fi SSID status UI shows SSID1 within max (5 seconds, recorded time in Procedure B) of AP1 becoming operational LTE-U operation shall allow Wi-Fi network to achieve average throughput (Mbps) not less than 50% of Procedure B
Procedure D	Verify that LTE-U is at maximum duty cycle prior to Wi-Fi AP being turned on. User checks the Wi-Fi network status on UE/STA. The UE/STA Wi-Fi SSID status UI shows SSID1 within max (5 seconds, recorded time in Procedure B) of AP1 becoming operational LTE-U operation shall allow Wi-Fi network to achieve average throughput (Mbps) not less than 95% of Procedure B

## Appendix A Test Bed Products (Normative)

### A.1 Test Bed Equipment

This section provides the test bed equipment for Wi-Fi Coexistence tests in this test plan.

**Table 28. Test bed access points**

Vendor	Product	Software Version(s)	Contact

**Table 29. Test bed stations**

Vendor	Product	Software Version(s)	Contact

## Appendix B Reference Data (Informative)

<TBD>

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## Appendix C Traffic Profiles (Normative)

Table 30 lists the traffic profiles used for all test cases.

Editor's note: To be updated

**Table 30. Traffic profiles**

Traffic Profile ID	Transport Protocol	Traffic Direction	Duration (s)	Packet Rate (pkts/s)	Packet Size (Bytes)	Data rate (Mbps)	TCP Streams	Other Settings
TCP_DL	TCP	DL	60	Continuous	131,072	Max. Link Capacity	1	TCP Streams = 1 Tx/Rx Buffer = OS Default
TCP_UL	TCP	UL	60	Continuous	131,072	Max. Link Capacity	1	TCP Streams = 1 Tx/Rx Buffer = OS Default
UDP_DL	UDP	DL	60	450	278	1	N/A	Allow IP Frag. = Disabled Max. MTU = 1500B
UDP_UL	UDP	UL	60	450	278	1	N/A	Allow IP Frag. = Disabled Max. MTU = 1500B



## Appendix D Document Revision History (Informative)

**Table 31. Document revision history**

Version	Date YYYY-MM-DD	Remarks
0.8	2016-02-08	Initial draft release.
0.8.1	2016-02-29	<ol style="list-style-type: none"> <li>1. Consolidated all channel selection tests in v0.8 of test plan, <ol style="list-style-type: none"> <li>a. 4.1 - LTE-U Vacant Channel Selection Test</li> <li>b. 4.2 - LTE-U Least Utilized Channel Identification Test and</li> <li>c. 4.6 - LTE-U Behavior in Presence of Intra-operator LTE-U, Inter-operator LTE-U and Wi-Fi Network Test</li> </ol> into test case 4.1 and renamed the test to LTE-U Channel Selection Test </li> <li>2. V0.8 - Test case 4.1 - procedure A, procedure B, procedure E removed</li> <li>3. V0.8 - Test case 4.2 - procedure A, procedure B, procedure D removed</li> <li>4. V0.8 - Test case 4.6 - procedure A and procedure B removed</li> <li>5. Consolidated and merged test case 4.9 - LTE-U Opportunistic SCell OFF Test in v0.8 of the test plan into test 4.8 and 4.10</li> <li>6. Test case 4.3 (LTE-U Medium Usage Adapting to Changing Channel Loading Test) Procedure F added for LTE-U multicarrier operation verification</li> <li>7. Test case 4.6 (LTE-U UE and Wi-Fi Station In Device Coexistence Tests) added for verifying in device coexistence behavior of LTE-U UE</li> </ol>
0.8.2	2016-03-04	Added reference to definition of fair sharing.
0.8.3	2016-03-31	<ol style="list-style-type: none"> <li>1. Qualified the Traffic type duration time with "after transmission starts" for procedures C, D, and E of the LTE-U channel selection test configuration.</li> <li>2. For the LTE-U Medium Usage Adapting to Changing Channel Loading Test, changed the phase P2 traffic type "6 sec to 120 sec" to "zero to 60 sec". And changed "<math>\leq 50\%</math> throughput" to "<math>\leq 50\%</math> air time" in the description for Procedure A</li> <li>3. For the LTE-U UE and Wi-Fi Station In Device Coexistence Test, clarified eNodeB and STAs in the Test Configuration and Test Procedure. Also added " Verify that LTE-U is at maximum duty cycle prior to Wi-Fi AP being turned on" to the Test Results in Procedures C and D.</li> </ol>
0.8.4	2016-03-31	Modified the note at the end of section 1.1 Scope and Purpose.