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TECHNICAL SPECIFICATION

**Broadband Radio Access Networks (BRAN);
Multiple Access Points Performance Testing**

Reference

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Broadband Radio Access Networks (BRAN).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1   Scope

The present document provides a set of test cases to verify the performance (coverage, throughput, roaming time, etc.) of the multiple Access Point (multiple AP) networks in the home. Each test case consists of testing environment setup, device and equipment configuration, test procedures, and pass/fail metrics.

2   References

2.1   Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference.

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The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2   Informative references

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NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1]   IEEE 802.11ac™-2013: "IEEE Standard for Information technology--Telecommunications and information exchange between systems-Local and metropolitan area networks--Specific requirements--Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications--Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz".

[i.2]   IEEE 802.11ax™-2021: "IEEE Standard for Information Technology--Telecommunications and Information Exchange between Systems Local and Metropolitan Area Networks--Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 1: Enhancements for High-Efficiency WLAN".

[i.3]   IEEE 802.11k™-2008: "IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 11: Wireless LAN Medium Access Control (MAC)and Physical Layer (PHY) Specifications Amendment 1: Radio Resource Measurement of Wireless LANs".

[i.4]   IEEE 802.11v™-2011: "IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment 8: IEEE 802.11 Wireless Network Management".

3   Definition of terms, symbols and abbreviations

3.1   Terms

Void.

3.2   Symbols

For the purposes of the present document, the following symbols apply:

B	byte
dB	decibel
dBm	dB relative to 1 mW
dB/s	decibel per second
GHz	gigahertz
MHz	megahertz
Mb/s	megabits per second
min	minute
ms	millisecond
Nss	number spatial stream

3.3   Abbreviations

For the purposes of the present document, the following abbreviations apply:

AES	Advanced Encryption Standard
AP	Access Point
DUT	Device Under Test
GUI	Graphical User Interface
LAN	Local Access Network
MCS	Modulation and Coding Scheme
OTA	Over The Air
PPS	Packets Per Second
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
S2L1	STA to Leaf_1 node
S2L2	STA to Leaf_2 node
S2R	STA to Root node
SSID	Service Set Identifier
STA	Station
UDP	User Datagram Protocol
WPA	Wi-Fi® Protected Access
WPA2	Wi-Fi® Protected Access 2
WPA3	Wi-Fi® Protected Access 3

4   Equipment Features

4.1   Device Under Test (DUT) and Station (STA)

4.1.1   Device Information

Table 1 and Table 2 are intended to provide test engineers and readers of the test report with sufficient information about the DUT and connected STAs in order to assure repeatability of results.

Table 1: DUT Information

DUT system vendor	
DUT system firmware version	
DUT chipset vendor	
DUT chipset firmware version	

Table 2: STA Information

STA type (e.g. PC, mobile phone, etc.)	
STA system vendor	
STA system firmware version	
STA chipset vendor	
STA chipset firmware version	
Supported IEEE specification by STA	

4.1.2   Management of the DUT and STA

The DUT shall support a DUT Northbound management protocol or local Graphical User Interface (GUI) that allows the ability to configure and retrieve the settings. The management protocol is DUT vendor discretionary.

The STA shall support a STA Southbound management protocol that is required for execution of this test plan except as required to configure the STA to pass Ethernet traffic between the STA and Local Area Network (LAN) interface(s).

4.2   Testing Equipment and Components

This clause includes tables to record information of testing equipment and components that are used in the test.

Table 3: Traffic Generator/Analyser Information

Manufacturer	
Equipment model	
Code Version	

Table 4: Attenuator Information

Manufacturer	
Component model	
Supported frequency range	
Attenuation value used in the test	

Table 5: Test Chamber Information

Manufacturer	
Equipment model	

Table 6: Additional Antenna Information

| Manufacturer	
Component model	
Where it is used (On test chamber/etc.)	

5   Test Environment

This clause describes the performance test environment, which includes test configuration, test setup characteristics, and device settings.

Root node, first stage leaf node, and second stage leaf node constitute a multi AP application scenario. The root node connects to the broadband network. The first stage leaf node and the second stage leaf node connect to the root node, and to each other, via wireless or wired backhaul channels (Optical fibre/Ethernet networking). The roaming STA is able to connect to any of the nodes (root, first leaf, or second leaf) via a wireless access channel.

Under the test environment, the traffic generator/analyser simulates the broadband network and multiple terminals. Figure 1 presents a schematic diagram of the test environment for two stage networking throughput performance.

If using iPerf3 to generate the traffic, the parallel parameter instructs iPerf3 to run ten measurement streams at the same time between the APs and STAs. This improves the overall accuracy of the measurement.
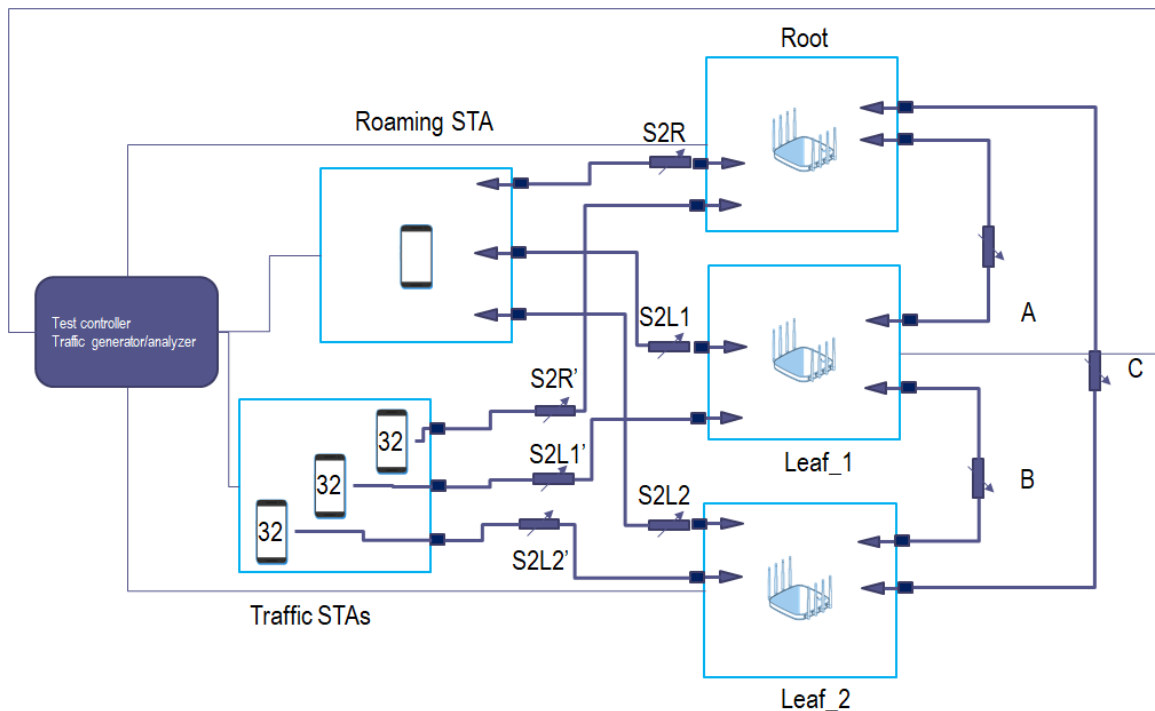
Figure 1: Test Environment for multiple access point performance testing

A brief overview of this configuration follows:

1)   There are three (3) RF chambers labelled "Root", "Leaf_1", and "Leaf_2" which hold the three nodes of the multiple access point system under test. These are the Root device (which in a deployment would have the gateway connection to the wider world, for example the Internet), and the two leaf or extender devices (which in a deployment would provide connections back to the Root).

2)   The multiple AP devices (root and leaves) are connected to each other using three (3) programmable attenuators A, B, and C. These are the "backhaul" attenuators, and for a static mesh (in which the root and leaf nodes do not move relative to each other) those attenuations would typically not change for the duration of a single test. Changing these attenuators changes the relative "distances" between the mesh nodes, hence, it changes the topology of the mesh system under test.

3)   There is one (1) RF chamber labelled "Roaming STA" which holds the STA device used to test the multiple AP system under test. This chamber is connected to each of the mesh nodes via a programmable attenuator. Attenuator "S2R", for example, connects the STA to the Root. Attenuators S2R, S2L1, and S2L2 connect the roaming STA to the mesh nodes, and the settings on these attenuators define how "close" the roaming STA is to each mesh node. These attenuators will change during any test in which roaming is being simulated.

4) There is one (1) RF chamber labelled "Traffic STAs", which holds STAs (or devices that can generate virtual STAs) used to create load on each of the mesh nodes. A set of STAs (or virtual STAs) is connected directly from this chamber to one of the mesh nodes; that is, the devices in the "Traffic STAs" chamber are not expected to participate in roaming across the mesh nodes. They are used only to generate static load on the nodes in the mesh. These traffic STAs are connected to the chambers through the attenuators S2R', S2L1', and S2L2', but these attenuators do not necessarily need to have programmability. Static attenuation may be acceptable for these connections.

Important notes about the design shown in Figure 1:

1) This figure is not intended to require a specific testbed configuration to be used for testing compliant with the present document.

2) Any testbed that can support the tests as designed may be used for testing.

How to understand the purpose of the diagram shown in Figure 1:

1) Figure 1 represents a design to be used throughout the present document.

2) A single diagram used to illustrate each test case makes it easier for readers to understand the tests. Readers do not have to adapt to a new diagram for each test.

3) The diagram is intended to act as a guide for testers intending to create tests compliant with the present document.That is, although this specific testbed configuration is not a requirement, it is an example configuration that can be used as a starting point.

4) The diagram acts as a guide for the consideration of new tests which may be proposed as an addition to the present document.

This is not to imply that the diagram should act as a limit to the proposal of new tests. It is to suggest, however, that due considering should be given to the practicality of the tests.

6   Multiple Access Points Performance Test Cases

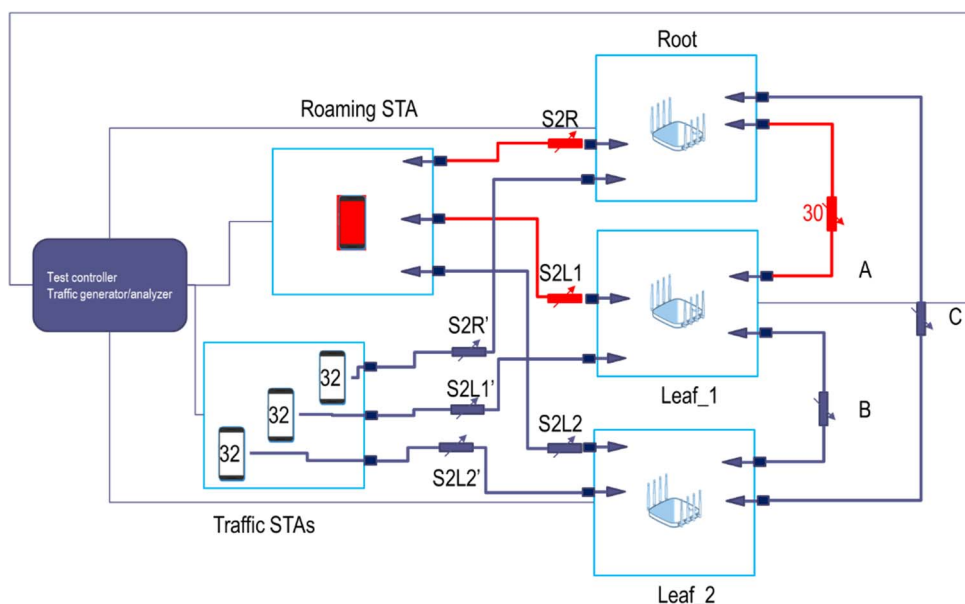## 6.1   Roaming Experience

6.1.1   Roaming Time

6.1.1.1   Introduction

This test case attempts to measure the roaming time of STA between wireless connections of the root node and the leaf node.

This test shall be MANDATORY for the test plan.

6.1.1.2   Setup

The test setup (Red Connections) based the testbed shown in Figure 2 shall be used for this test.

Figure 2: Test Environment for Roaming Time

6.1.1.3   Device Under Test (DUT) Configuration

The test shall run under the following configuration.

Table 7: General configuration for spatial consistency test

Wireless configuration (Root node)	Wireless configuration (Leaf_1 node)	Wireless configuration (peer STA)	Bandwidth (MHz)
IEEE 802.11ac [i.1] (5 GHz, Nss = 2)	IEEE 802.11ac [i.1] (5 GHz, Nss = 2)	IEEE 802.11ac [i.1] (5 GHz, Nss = 2)	80
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	20
IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80
NOTE: IEEE 802.11ac [i.1] or IEEE 802.11ax [i.2] appearing in all the tables only represent the working mode of DUTs.			

Additional attenuations for RF chain during the test:

a)   Initial attenuation of A: 30 dB at 2,4 GHz band, 30 dB at 5 GHz band.

b)   Initial attenuation of S2L1: 40 dB at 2,4 GHz band, 40 dB at 5 GHz band.

c)   Initial attenuation of S2R: 0 dB at 2,4 GHz band, 0 dB at 5 GHz band.

d)   Any attenuator not specifically mentioned should be set to its maximum (highest attenuation) value.

e)   Root node, Leaf_1 node and the STA are configured to be single-band only.

f)   Security settings:

    i)   Authentication Mode: WPA2/WPA3;

    ii)   Encryption Mode: AES;

    iii)   WPA PreShareKey: Defined by test agent;

    iv)   WPA Group Key Regeneration Interval: 3 600 seconds.

NOTE: Same security settings are used for the following test case.

6.1.1.4 Procedures

Place the root and leaf_1 nodes and STAs in three shielding boxes. The root node and the leaf_1 node can be connected in the following ways:

1) Wi-Fi wireless networking.

2) Set the STA support IEEE 802.11k [i.3] and IEEE 802.11v [i.4] roaming functions.

3) In wireless networking, set the initial attenuation of A (between Root node and Leaf_1 node): 30 dB at 2,4 GHz band, 30 dB at 5 GHz band, to ensure that the RSSI range is between -60 dBm and -70 dBm.

4) Set the STA to connect to the root node.

5) Use the traffic generator to send 1 460 B UDP packets to the STA with 1 000 PPS. With 1 dB/s frequency, increase the attenuation (S2R) until the attenuation from the STA to root node reaches 40 dB, and decrease the attenuation (S2L1) from the STA to the leaf_1 node until it reaches 0 dB. Then calculate the number of lost packets, the roaming time is lost packets/packet rate.

6) Wait for 1 min, with 1 dB/s frequency, decrease the attenuation (S2R) from the STA to the root node until the attenuation from the STA to the root node reaches 0 dB, and increase the attenuation (S2L1) from the STA to the Leaf_1 node until it reaches 40 dB. Then calculate the number of lost packets, the roaming time is lost packets/packet rate.

7) Change the attenuation frequency to 2 dB/s and 3 dB/s, and repeat steps 5 and 6.

8) Replace the STA with one STA that does not support IEEE 802.11k [i.3] and IEEE 802.11v [i.4] roaming functions, and repeat steps 3 to 7.

6.1.1.5 Metrics

Record the roaming test results and fill in Table 8.

Table 8: Test results of roaming time

Roaming Time (ms)	STA connect to Root node -> STA connect to Leaf_1 node			STA connect to Leaf_1 node -> STA connect to Root node		
	1 dB/s	2 dB/s	3 dB/s	1 dB/s	2 dB/s	3 dB/s
STA support 802.11 k/v						
STA not support 802.11 k/v						

6.1.2 Roaming Throughput

6.1.2.1 Introduction

Test network throughput performance while roaming.

6.1.2.2 Setup

The test setup (Red Connections) shown in Figure 3 shall be used for this test.
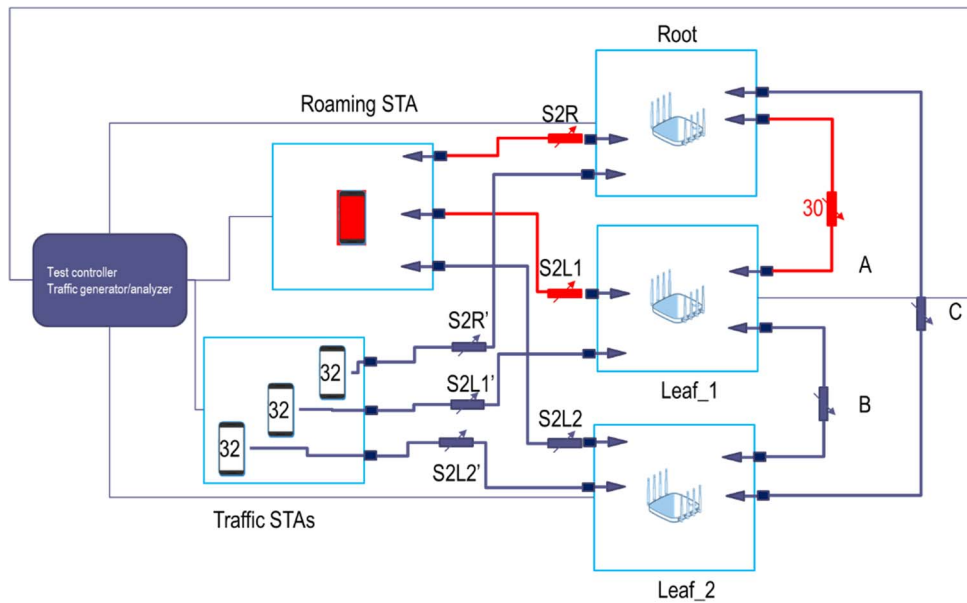
Figure 3: Test Environment for Roaming Through

6.1.2.3   DUT Configuration

The test shall run under the following configuration.

Table 9: Test configuration for roaming throughput performance

Wireless configuration (Root node and Leaf_1 node)	Wireless configuration (STA)	Wireless configuration (STA)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)		20
IEEE 802.11ax [i.2] (5 GHz, Nss = 2)		IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80
NOTE: See clause 6.1.1.3 for the initial value of variable attenuator.			

6.1.2.4   Procedures
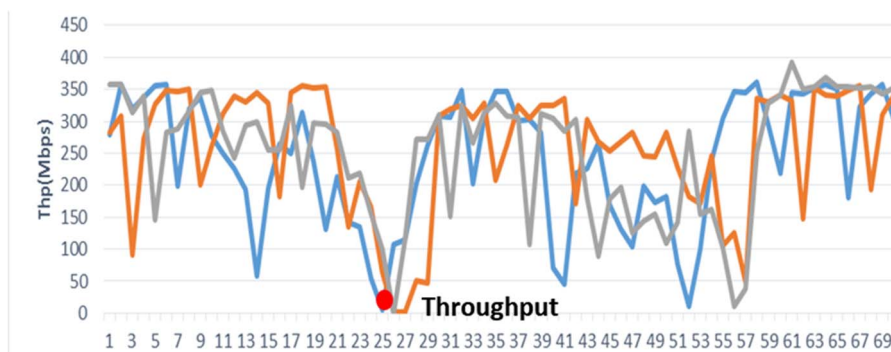
Figure 4: Example of roaming throughput performance Curve

Testing procedure described as following:

1)   Configure the antenna attenuation. For example, the attenuation from the STA to the Root node, S2R is 20 dB smaller than that of the attenuation of S2L1 from the STA to Leaf_1 node.

2)   The STA goes on line and definitely select the Root Node for initial login.

3) Then, traffic at maximum rate is sent between the Root Node and STA.

4) Increase the attenuation of S2R and decrease the attenuation of S2L1 until the STA roams from Root Node to Leaf_1 Node.

5) Record the throughput changes during roaming.

6) The higher the roaming throughput, the better the roaming throughput test.

6.1.2.5 Metrics

Record the test results and fill in Table 10.

Table 10: Test results of roaming throughput performance

Test scenarios	Uplink throughput（Mb/s）	Downlink throughput（Mb/s）
Roaming Throughput performance of STA at 2,4 GHz		
Roaming Throughput performance of STA at 5 GHz		

6.2 Networking Throughput

6.2.1 One-stage Networking Throughput

6.2.1.1 Root Node Networking Throughput Test Procedure

6.2.1.1.1 Introduction

Test the root node networking throughput performance.

6.2.1.1.2 Setup
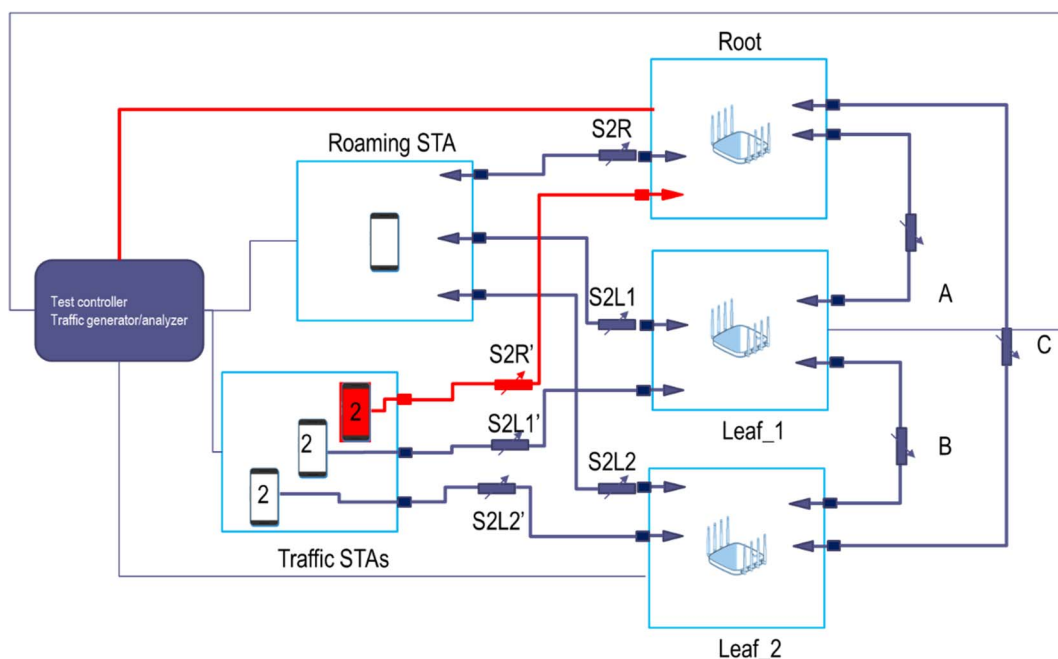
Figure 5: Root node networking throughput performance test

In Figure 5, Leaf_1 node is the first stage node, Leaf_2 is the second stage node. In this test case, Leaf_1 and Leaf_2 are not used.

Root node and STAs are deployed in a shielding box, the test controller and the traffic generator/analyser can be placed outside the shielding box. Root node is connected to the traffic generator/analyser through network cable. Root node, traffic STA1 and traffic STA2 are configured with the same SSID.

6.2.1.1.3 DUT Configuration

The test shall run under the following configuration.

Table 11: Test configuration for root node networking throughput performance

| Wireless configuration (Root node)	Wireless configuration (STA1)	Wireless configuration (STA2)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)		20
IEEE 802.11ax [i.2] (5 GHz, Nss = 2)		IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80
NOTE: See clause 6.1.1.3 for the initial value of variable attenuator.			

6.2.1.1.4 Procedures

1) The instrument configures a terminal (Traffic STA1), which accessed to Root node on the 2,4 GHz band. The attenuation on S2R' should be at its minimum value (presumably 0 dB.) The expectation in this test is that the link between the traffic STAs and the Root node is "optimal", in the sense that the best RF performance is possible (expected bandwidth, maximum MCS, expected number of streams, etc.)

2) The instrument configures 1 460 B UDP packet, builds traffic at maximum rate between Root and Traffic STA1, and records uplink test results and downlink test results.

3) The instrument configures a terminal (STA2), which accessed to Root node on the 5 GHz band.

4) The instrument configures 1 460 B UDP packet, builds traffic at maximum rate between Root node and Traffic STA2, and record uplink test results and downlink test results.

5) The instrument configures two terminals (Traffic STA1, Traffic STA2), which accessed to Root node on the 2,4 GHz and 5 GHz band.

6) The instrument configures 1 460 B UDP packet, builds traffic at maximum rate between Root node and Traffic STA1/STA2, and record uplink test results and downlink test results.

6.2.1.1.5 Metrics

Record the test results and fill in Table 12.

Table 12: Test results of root node networking throughput performance

Test scenarios	Uplink throughput（Mb/s）	Downlink throughput（Mb/s）
Throughput performance of terminal access root node (2,4 GHz)		
Throughput performance of terminal access root node (5 GHz)		
Throughput performance of terminal access root node (2,4 GHz + 5 GHz)		

6.2.1.2 First Stage Node Networking Throughput Test Procedure

6.2.1.2.1 Introduction

Test the first stage node networking throughput performance.

6.2.1.2.2 Setup
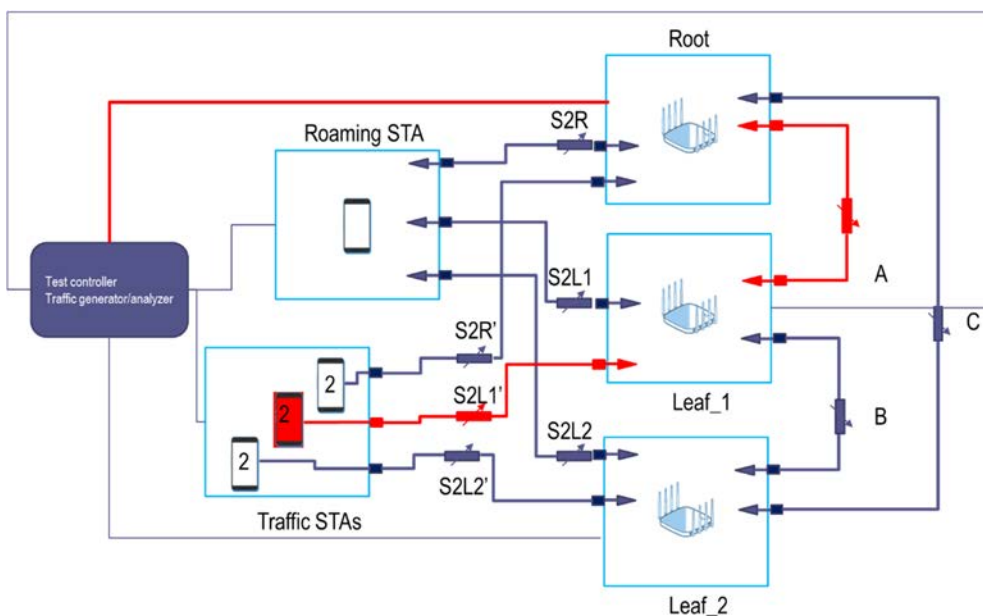
Figure 6: Test Environment for first stage node networking throughput performance

In Figure 6, Leaf_1 is First stage node, Leaf_2 is Second stage node. In this test case, Leaf_2 is not used.

Root node, Leaf node and STA are deployed in a shielding box, the test controller and the traffic generator/analyser can be placed outside the shielding box.

Root node is connected to the traffic generator/analyser through network cable. Leaf_1 node, Traffic STA1 and Traffic STA2 are configured with the same SSID. Leaf_1 node is connected to Root node through wireless, as a backhaul path, Root node and Leaf_1 node wireless backhaul paths are configured with the same SSID.

6.2.1.2.3 DUT Configuration

The test shall run under the following configuration.

Table 13: Test configuration for first stage node networking throughput performance

Wireless configuration (Root node)	Wireless configuration (Leaf_1 node)	Wireless configuration (Traffic STA1)	Wireless configuration (Traffic STA2)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)		20
IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)		IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80
NOTE: See clause 6.1.1.3 for the initial value of variable attenuator.				

6.2.1.2.4 Procedures

1) The instrument configures a terminal (Traffic STA1), which accessed to Leaf_1 node on the 2,4 GHz band.

2) The instrument configures 1 460 B UDP packet, builds traffic at the maximum rate between Leaf_1 node and Traffic STA1, and record uplink test results and downlink test results.

3) The instrument configures a terminal (Traffic STA2), which accessed to Leaf_1 node on the 5 GHz band.

4) The instrument configures 1 460 B UDP packet, builds traffic between Leaf_1 node and STA2, and records uplink test results and downlink test results.

5) The instrument configures two terminals (Traffic STA1, Traffic STA2), which accessed to Leaf_1 node on the 2,4 GHz and 5 GHz band, respectively.

6) The instrument configures 1 460 B UDP packet, builds traffic at maximum between Leaf_1 node and Traffic STA1/STA2 respectively, and records uplink test results and downlink test results.

6.2.1.2.5   Metrics

Record the test results and fill in Table 14.

**Table 14: Test results of first stage node (Leaf_1 node) networking throughput performance**

Test scenarios	Uplink throughput（Mb/s）	Downlink throughput（Mb/s）
Throughput performance of terminal access Leaf_1 node (2,4 GHz)		
Throughput performance of terminal access Leaf_1 node (5 GHz)		
Throughput performance of terminal access Leaf_1 node (2,4 GHz + 5 GHz)		

6.2.1.3   One-stage Networking Throughput Test Procedure

6.2.1.3.1   Introduction

One-stage networking throughput performance includes the root node throughput and the first stage node throughput.

6.2.1.3.2   Setup
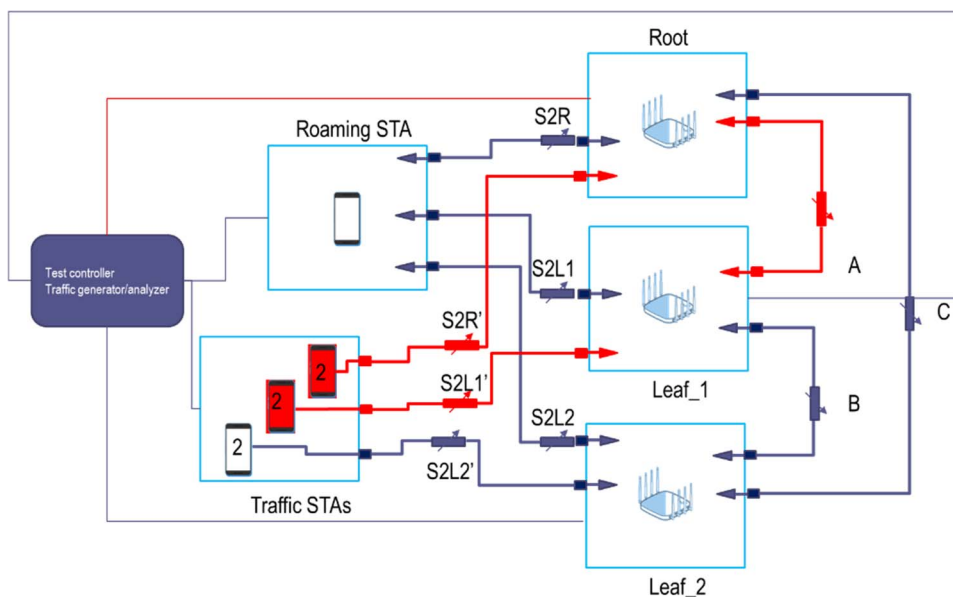
Figure 7: One-stage networking throughput performance test

In Figure 7, Leaf_1 is First stage node, Leaf_2 is Second stage node. In this test case, Leaf_2 is not used.

Root node, Leaf node, and STAs are deployed in a shielding box, the test controller and the traffic generator/analyser can be placed outside the shielding box.

Root node is connected to the traffic generator/analyser through network cable. Root node, Traffic STA1 and Traffic STA2 are configured with the same SSID; Leaf_1 node, Traffic STA3 and Traffic STA4 are configured with the same SSID. Leaf_1 node is connected to Root node through wireless, and as a backhaul path, Root node and Leaf_1 node wireless backhaul paths are configured with the same SSID.

6.2.1.3.3   DUT Configuration

The test shall run under the following configuration.

Table 15: Test configuration for One-stage networking throughput performance

Wireless configuration (Root node)	Wireless configuration (Leaf_1 node)	Wireless configuration (STA1)	Wireless configuration (STA2)	Wireless configuration (STA3)	Wireless configuration (STA4)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)		IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)		20
IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)		IEEE 802.11ax [i.2] (5 GHz, Nss = 2)		IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80
NOTE: See clause 6.1.1.3 for the initial value of variable attenuator.						

6.2.1.3.4   Procedures

1)   The instrument configures two terminals (Traffic STA1, Traffic STA2), which accessed to Root node on the 2,4 GHz and 5 GHz band respectively, and configures two terminals (Traffic STA3, Traffic STA4), which accessed to Leaf_1 node on the 2,4 GHz and 5 GHz band respectively.

2)   The instrument configures 1 460 B UDP packet, builds traffics at maximum rate between the APs (Root and Leaf_1 nodes) and Traffic STA1 ~ STA4, and records uplink test results and downlink test results.

6.2.1.3.5   Metrics

Record the test results and fill in Table 16.

Table 16: Test results of one-stage networking throughput performance

Test scenarios	Uplink throughput（Mb/s）	Downlink throughput（Mb/s）
Total throughput performance of terminal access Root node and Leaf_1 Node (2,4 GHz + 5 GHz)		

6.2.2   Two-stage Networking Throughput

6.2.2.0   Introduction

Two-stage networking consists of root node, first stage leaf node and second stage leaf node. The throughput performance of root node has been discussed in clause 6.2.1.1, and the throughput performance of first stage leaf node has been discussed in clause 6.2.1.2. This clause mainly discusses the throughput performance of second stage leaf node and two-stage networking.

6.2.2.1   Second Stage Node Networking Throughput Test Procedure

6.2.2.1.1   Introduction

Test Leaf_2 node throughput performance.

6.2.2.1.2   Setup
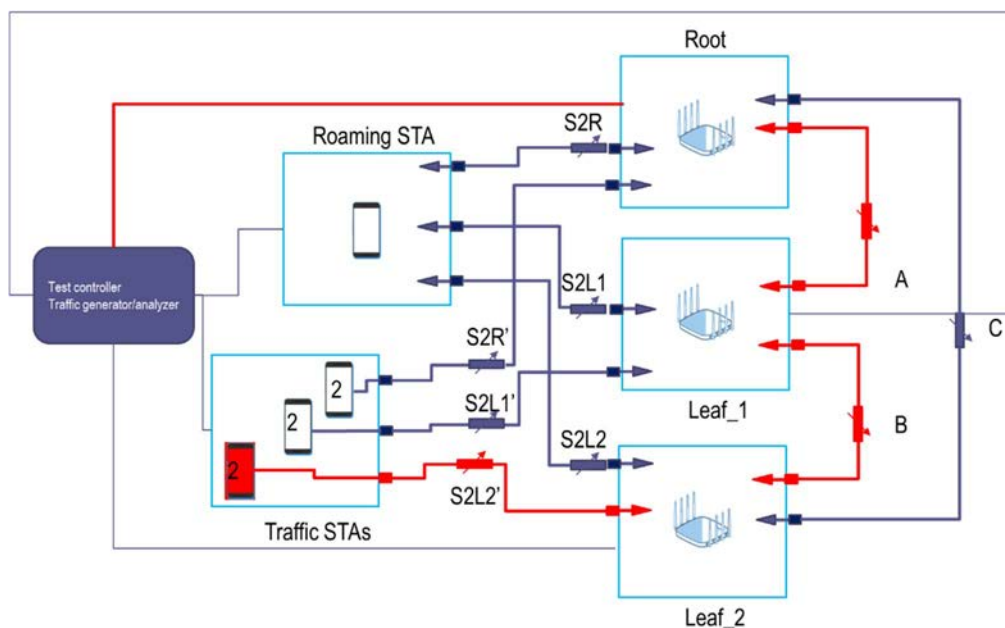
Figure 8: Test Environment for Leaf_2 node throughput performance

In Figure 8, Leaf_1 is First stage node, Leaf_2 is Second stage node.

Root node, Leaf_1 node and Leaf_2 node are deployed in three shielding boxes respectively, the test controller and the traffic generator/analyser can be placed outside the shielding boxes.

Root node is connected to the traffic generator/analyser by network cable. Leaf_2 node and corresponding traffic STAs are configured with the same SSID.

Leaf_1 node accessed to Root node by wireless as the backhaul channel of Leaf_1 node, Leaf_1 nod and Root node are configured with the same SSID; Leaf_2 node accessed to Leaf_1 node by wireless as the backhaul channel of Leaf_2 node, Leaf_2 node and Leaf_1 node are configured with the same SSID.

6.2.2.1.3   DUT Configuration

The test shall run under the following configuration.

Table 17: Test configuration for second stage leaf node throughput performance

Wireless configuration (Root node)	Wireless configuration (Leaf_1 node)	Wireless configuration (Leaf_2 node)	Wireless configuration (STA1)	Wireless configuration (STA2)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)		20
IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)		IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80
NOTE: See clause 6.1.1.3 for the initial value of variable attenuator.					

6.2.2.1.4   Procedure

1)   The instrument configures a terminal (Traffic STA1), which accessed to Leaf_2 node on the 2,4 GHz band.

2)   The instrument configures 1 460 B UDP packet, builds traffic at maximum rate between Leaf_2 node and Traffic STA1, and records uplink test results and downlink test results.

3)   The instrument configures a terminal (Traffic STA2), which accessed to Leaf_2 node on the 5 GHz band.

4) The instrument configures 1 460 B UDP packet, builds traffic at maximum rate between Leaf_2 node and Traffic STA2, and records uplink test results and downlink test results.

5) The instrument configures two terminals (Traffic STA1, Traffic STA2), which accessed to Leaf_2 node on the 2,4 GHz and 5 GHz band, respectively.

6) The instrument configures 1 460 B UDP packet, builds traffic at maximum rate between Leaf_2 node and Traffic STA1/STA2, and records uplink test results and downlink test results.

6.2.2.1.5 Metrics

Record the test results and fill in Table 18.

**Table 18: Test results of second stage leaf node throughput performance**

Test scenarios	Uplink throughput (Mb/s)	Downlink throughput (Mb/s)
Throughput performance of terminal access Leaf_2 node (2,4 GHz)		
Throughput performance of terminal access Leaf_2 node (5 GHz)		
Throughput performance of terminal access Leaf_2 node (2,4 GHz + 5 GHz)		

6.2.2.2 Two-stage Networking Throughput Test Procedure

6.2.2.2.1 Introduction

Two-stage networking throughput performance includes the root node throughput, the Leaf_1 node throughput and the Leaf_2 node throughput.

6.2.2.2.2 Setup
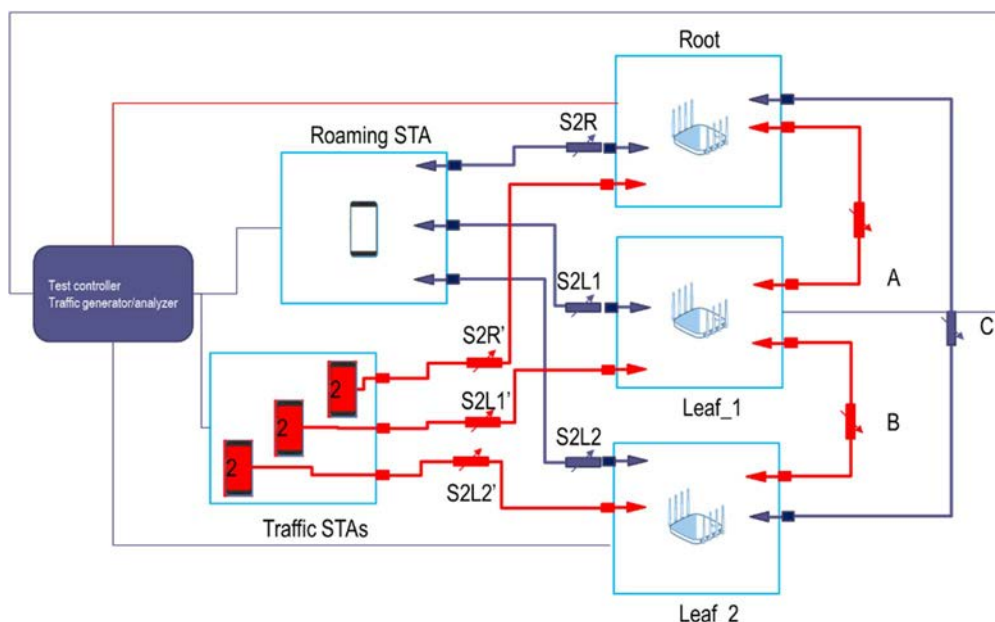
Figure 9: Test Environment for two-stage leaf node throughput performance

In Figure 9, Leaf_1 is First stage node, Leaf_2 is Second stage node.

Root node, Leaf_1 node and Leaf_2 node are deployed in three shielding boxes respectively. The test controller and the traffic generator/analyser can be placed outside the shielding boxes.

Root node is connected to the traffic generator/analyser by network cable. Leaf_1 node accessed to Root node by wireless as the backhaul channel of Leaf_1 node Leaf_1 node and Root node are configured with the same SSID; Leaf_2 node accessed to Leaf_1 node by wireless as the backhaul channel of the second stage leaf node, Leaf_2 node and Leaf_1 node are configured with the same SSID.

6.2.2.2.3 DUT Configuration

The test shall run under the following configuration.

Table 19: Test configuration for two-stage networking throughput performance (AP)

Wireless configuration (Root node)	Wireless configuration (Leaf_1 node)	Wireless configuration (Leaf_2 node)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	20
IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80

Table 20: Test configuration for two-stage networking throughput performance (STA)

Wireless configuration (Traffic STA1)	Wireless configuration (Traffic STA2)	Wireless configuration (Traffic STA3)	Wireless configuration (Traffic STA4)	Wireless configuration (Traffic STA5)	Wireless configuration (Traffic STA6)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)		IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)		IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)		20
	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)		IEEE 802.11ax [i.2] (5 GHz, Nss = 2)		IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80
NOTE: See clause 6.1.1.3 for the initial value of variable attenuator.						

6.2.2.2.4 Procedure

1) The instrument configures two terminals (Traffic STA1, Traffic STA2), which accessed to Root node on the 2,4 GHz and 5 GHz band respectively, and configures two terminals (Traffic STA3, Traffic STA4), which accessed to Leaf_1 node on the 2,4 GHz and 5 GHz band respectively, and configures two terminals (Traffic STA5, Traffic STA6), which accessed to Leaf_2 node on the 2,4 GHz and 5 GHz band respectively.

2) The instrument configures 1 460 B UDP packet, builds traffics at maximum rate between the APs (Root, Leaf_1 and Leaf_2 nodes) and Traffic STA1~STA6, and records uplink test results and downlink test results.

6.2.2.2.5 Metrics

Record the test results and fill in Table 21.

Table 21: Test results of two-stage networking throughput performance

| Test scenarios	Uplink throughput (Mb/s）	Downlink throughput (Mb/s）
Total throughput performance of terminal access Root node, Leaf_1 node and Leaf_2 node (2,4 GHz + 5 GHz)		

6.3   Networking Time

6.3.1   Configuration Time

6.3.1.1   Introduction

This test case aims to verify that the root node automatically sends the new parameter information to the leaf node for synchronization and records the synchronization time when wireless parameters such as the SSID, authentication mode, encryption type, and password of the root node change in a level-1 or level-2 network.

6.3.1.2   Setup

The test setup (Red Connections) shown in Figure 10 shall be used for this test.
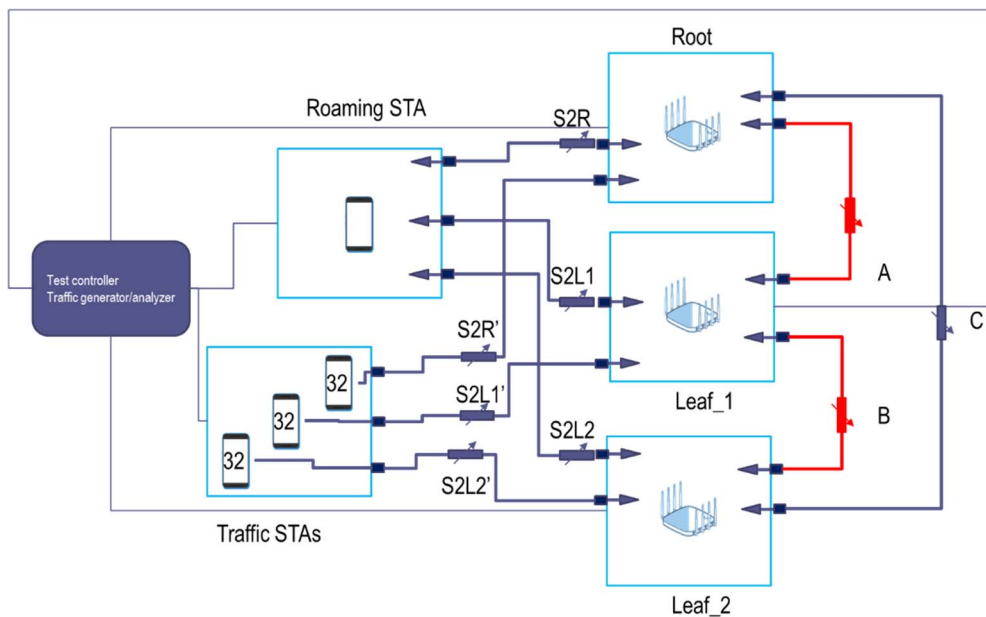
Figure 10: Test Environment for Configuration Time

Level-1 Networking Configuration: As shown in the preceding figure, the root node, and Leaf_1 node form a chain topology. Variable attenuators A is used to control path attenuation between APs. Set A = 30 dB.

Level-2 Networking Configuration: As shown in the preceding figure, the root node, Leaf_1 node and leaf_2 node form a chain topology. Variable attenuators A, and B are used to control path attenuation between APs. Set A = 30 dB, and B = 30 dB.

6.3.1.3   DUT Configuration

The test shall run under the following configuration.

Table 22: Test configuration for root node networking throughput performance

Wireless configuration (Root node)	Wireless configuration (Leaf_1 node)	Wireless configuration (Leaf_2 node)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	20
IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80

6.3.1.4   Procedure

1) Two wireless configuration templates are preset on the Controller:
    Template A: SSID name 1 + Password1 + Authentication mode A.
    Template B: SSID name 2 + password2 + Authentication mode B.

2) The Root node and Leaf nodes form a one-level cascading network. Set up the template A to Root node. Set up SSID and security to the STA, and associate STA to Leaf 1 node.

3) Preconfigure the new Template B to the STA.

4) Push the new configuration (Template B) to the Root node, record the time to T1.

5) Wait until the STA is associated to the Leaf_1 node, again, record the time to T2.

6) Calculate the configuration time: T2 - T1.

7) The root node and two leaf nodes form a level-2 topology. Repeat steps 2 to 6.

6.3.1.5   Metrics

Record the test results and fill in Table 23.

Table 23: Test results of the network configuration time

| Test scenarios	Configuration time
Level-1 Cascading (2,4 GHz)	
Level-2 Cascading (2,4 GHz)	
Level-1 Cascading (5 GHz)	
Level-2 Cascading (5 GHz)	

6.3.2   Self-healing Time

6.3.2.1   Introduction

This test case aims to test the service recovery time of the entire network when the intermediate node recovers from a fault (using power-off and power-on simulation) in a chain topology.

6.3.2.2   Setup

The test setup (Red Connections) shown in Figure 11 shall be used for this test.
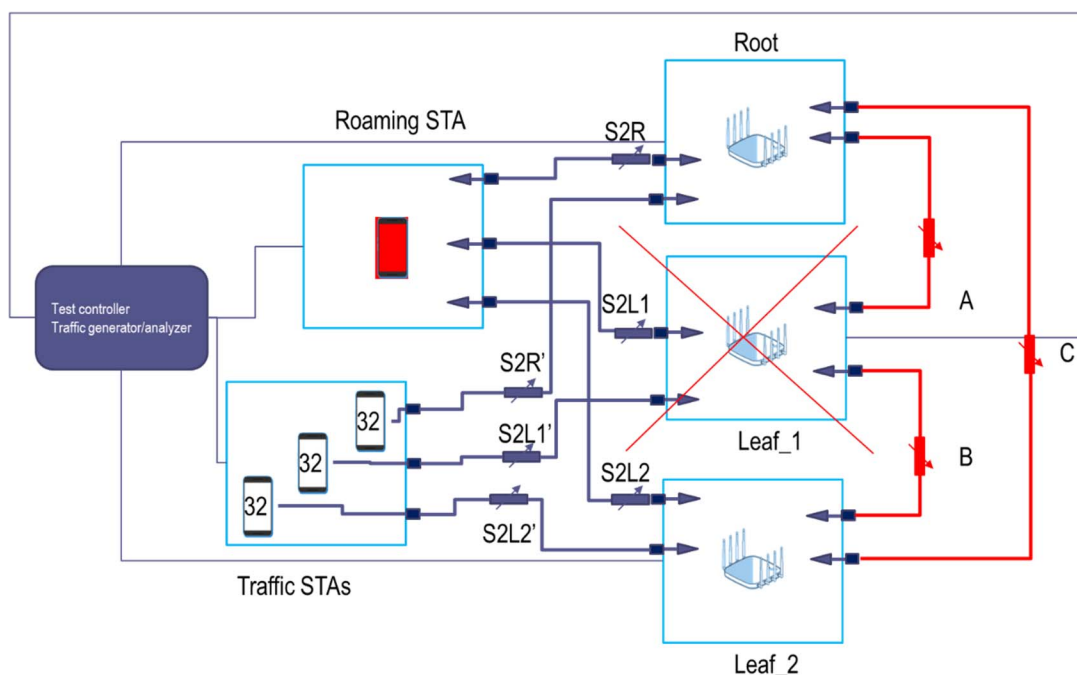
Figure 11: Test Environment for Self-healing Time

As shown in the preceding figure, the root node, leaf_1 node and leaf_2 node form a chain topology. Variable attenuators A, B and C are used to control path attenuation between APs. Set A = 30 dB, B = 30 dB, and C = 60 dB (assume that the link has inherent insertion loss: 10 dB (attenuator) + 5 dB (cable) and the OTA attenuation at both ends is 50 dB (using gain directional antennas)). The root node and leaf_2 node are invisible to each other because the fixed attenuation is large.

6.3.2.3   DUT Configuration

The test shall run under the following configuration.

Table 24: Test configuration for root node networking throughput performance

Wireless configuration (Root node)	Wireless configuration (Leaf_1 node)	Wireless configuration (Leaf_2 node)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	20
IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80

6.3.2.4   Procedure

1) Associate the roaming STA with Leaf_2 node and run traffic. This traffic should be going from Leaf_2 node to Leaf_1 node and then from Leaf_1 node to the Root node.

2) Use the traffic generator to construct 1 000 PPS UDP flows for 5 mins. When the traffic is sent for 1 min, power off Leaf_1 node and quickly power on it. Collect statistics on packet loss on the traffic receiving port within 5 mins.

3) The time between service interruption and recovery is calculated by dividing the packet loss rate by the packet sending rate.

6.3.2.5   Metrics

Record the test results and fill in Table 25.

Table 25: Test results of the network self-healing time

| Test scenarios	Network self-healing time
Network self-healing time (2,4 GHz)	
Network self-healing time (5 GHz)	

6.3.3   Automatic Networking Time

6.3.3.1   Introduction

This test case aims to verify the root node and leaf nodes automatically networking when they are powered on for the first time and records the automatic networking time in a level-1 or level-2 network.

6.3.3.2   Setup

The test setup (Red Connections) based the testbed shown in Figure 12 and Figure 13 shall be used for this test.
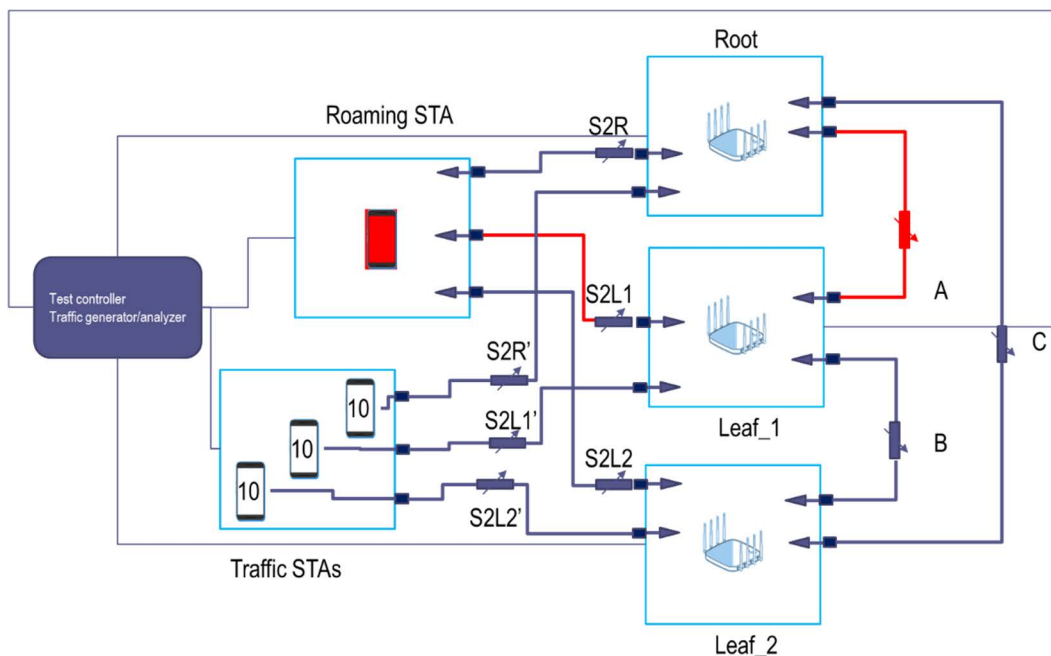
Figure 12: Test Environment for Level_1 Automatic Networking Time

Level-1 Automatic Networking Time Test: As shown in the preceding figure, the root node, and leaf_1 node form a chain topology. Variable attenuators A is used to control path attenuation between APs. Set A = 30 dB. PC is connected to the Root node through network cable. STA is associated to the leaf_1 node by wireless.
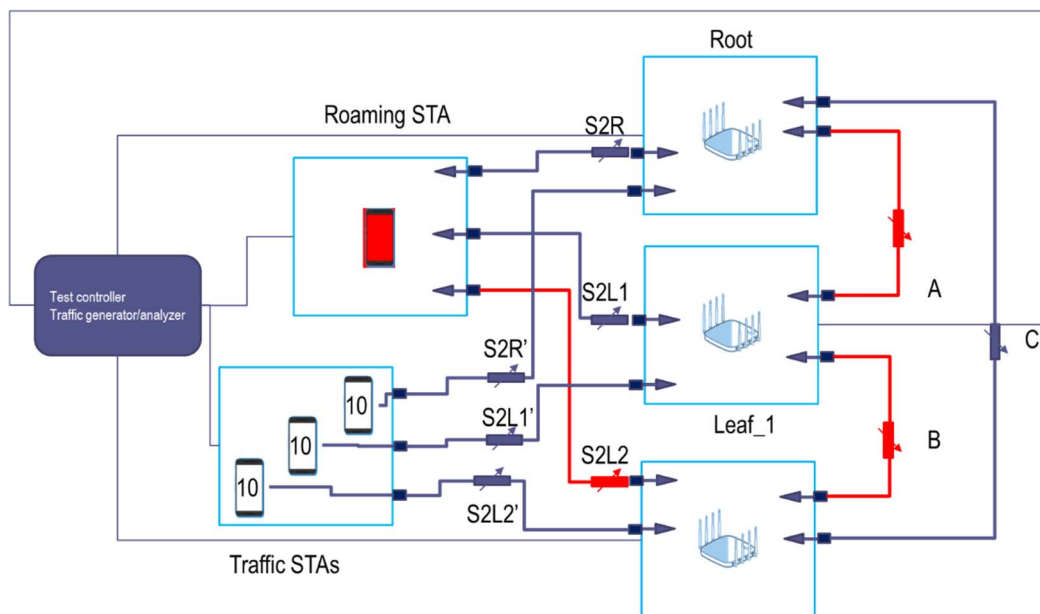
Figure 13: Test Environment for Level-2 Automatic Networking Time Test

Level-2 Automatic Networking Time Test: As shown in the preceding figure, the root node, Leaf_1 node and Leaf_2 node form a chain topology. Variable attenuators A, and B are used to control path attenuation between APs. Set A = 30 dB, and B = 30 dB. PC is connected to the Root node through network cable. STA is associated to the Leaf_2 node by wireless.

6.3.3.3   DUT Configuration

The test shall run under the following configuration.

Table 26: Test configuration for automatic networking time

Wireless configuration (Root node)	Wireless configuration (Leaf_1 node)	Wireless configuration (Leaf_2 node)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	20
IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80

6.3.3.4   Procedures

1) The default key wireless parameters such as the SSID name, encryption authentication mode, and password of the root node are pre-set on the STA.

2) Test configuration according to Figure 12, the root node and leaf_1 node form a one-level cascading network. Set the root node and leaf nodes to factory settings and turn off the power.

3) Turn on the power of the root node and leaf_1 node and record the timer to T1.

4) Scan the SSID names on the STA. After the SSID names are scanned, perform the association operation. Use STA ping PC, when STA received the response of PC, record the timer to T2.

5) Calculate the time for automatic networking: T2 - T1.

6) Test configuration according to Figure 13, the root node and two leaf nodes form a level-2 topology. Repeat steps 1 to 5.

6.3.3.5 Metrics

Record the test results and fill in Table 27.

**Table 27: Test results of the network configuration time**

Test scenarios	Automatic networking time
Level-1 Cascading (2,4 GHz)	
Level-2 Cascading (2,4 GHz)	
Level-1 Cascading (5 GHz)	
Level-2 Cascading (5 GHz)	

6.4 Band steering

6.4.1 Introduction

Band steering performance test refers to testing the functionality of the root node, the first stage leaf node and the second stage leaf node's support for band steering.

6.4.2 Setup
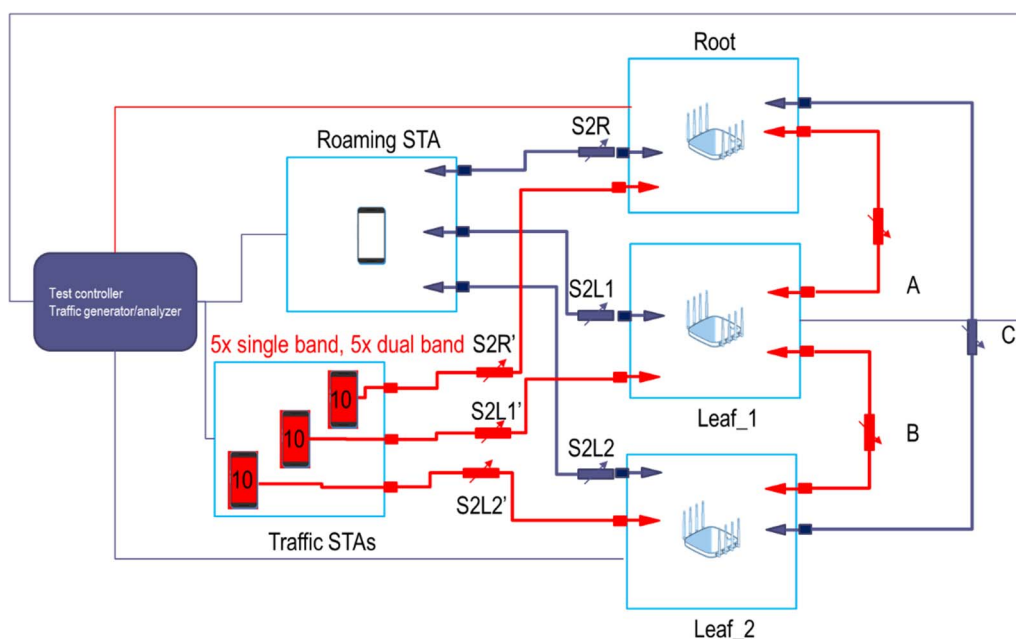
Figure 14: Test Environment for Band Steering

In Figure 14, Leaf_1 is First stage node, Leaf_2 is Second stage node.

Root node, Leaf_1 node and Leaf_2 node are deployed in shielding box 3, the test controller and the traffic generator/analyser can be placed outside the shielding boxes.

Four 2,4 GHz single-band terminals (Traffic STA1~ STA4), while four 2,4 GHz/5 GHz dual-band terminals (Traffic STA5~ STA8).

Four 2,4 GHz single-band terminals (Traffic STA9~ STA12), while four 2,4 GHz/5 GHz dual-band terminals (Traffic STA13~ STA16).

Four 2,4 GHz single-band terminals (Traffic STA17~ STA20), while four 2,4 GHz/5 GHz dual-band terminals (Traffic STA21~ STA24).

Root node and Traffic STA1~ STA8 are configured with the same SSID; Leaf_1 and Traffic STA9~ STA16 are configured with the same SSID; Leaf_2 node and Traffic STA17~ STA24 are configured with the same SSID.

Root node is connected to the traffic generator/analyser by network cable. Leaf_1 node accessed to Root node by wireless as the backhaul channel of Leaf_1 node, Leaf_1 node and Root node are configured with the same SSID; Leaf_2 node accessed to Leaf_1 node by wireless as the backhaul channel of the Leaf_2 node, Leaf_2 node and Leaf_1 node are configured with the same SSID.

6.4.3   DUT Configuration

The test shall run under the following configuration.

Table 28: Test configuration for Band Steering function (AP)

Wireless configuration (Root node)	Wireless configuration (Leaf_1 node)	Wireless configuration (Leaf_2 node)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	20
IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80

Table 29: Test configuration for Band Steering function (STA)

Wireless configuration (Traffic STA1~STA4, STA9~STA12, STA17~STA20)	Wireless configuration (Traffic STA5~STA8, STA13~STA16, STA21~STA24)	Bandwidth (MHz)
IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	IEEE 802.11ax [i.2] (2,4 GHz, Nss = 2)	40
	IEEE 802.11ax [i.2] (5 GHz, Nss = 2)	80
NOTE: See clause 6.1.1.3 for the initial value of variable attenuator to ensure both terminals and APs receiving strong signals from each other.		

6.4.4   Procedures

1) Band steering for Root node, Leaf_1 node and Leaf_2 node respectively, namely, dual-band terminals are preferentially accessed to 5 GHz band.

2) Four 2,4 GHz single-band terminals STA1~ STA4, and four 2,4 GHz/5 GHz dual-band terminals STA5~ STA8 are connected to Root node respectively.

3) Four 2,4 GHz single-band terminals STA9~ STA12, and four 2,4 GHz/5 GHz dual-band terminals STA13~ STA16 are connected to Leaf_1 node respectively.

4) Four 2,4 GHz single-band terminals STA17~ STA20, and four 2,4 GHz/5 GHz dual-band terminals STA21~ STA24 are connected to Leaf_2 node respectively.

NOTE: The band steering tests on each node may be performed simultaneously or separately.

6.4.5   Metrics

Record the frequency band associated with the STA and check the corresponding band column in Table 24.

Table 30: Test results of two-stage networking Band Steering function

STA	Band	
	2,4 GHz	**5 GHz**
STA1		
STA2		
STA3		
STA4		
STA5		
STA6		
STA7		
STA8		
STA9		
STA10		
STA11		
STA12		
STA13		
STA14		
STA15		
STA16		
STA17		
STA18		
STA19		
STA20		
STA21		
STA22		
STA23		
STA24		

Annex A (informative):
Link Budget

Figure A.1 shows the link budget for the attenuations.

There is OTA loss in each box, and insertion loss for the attenuator. In this test case, the OTA loss is 25 dB, and insertion loss is 10 dB.
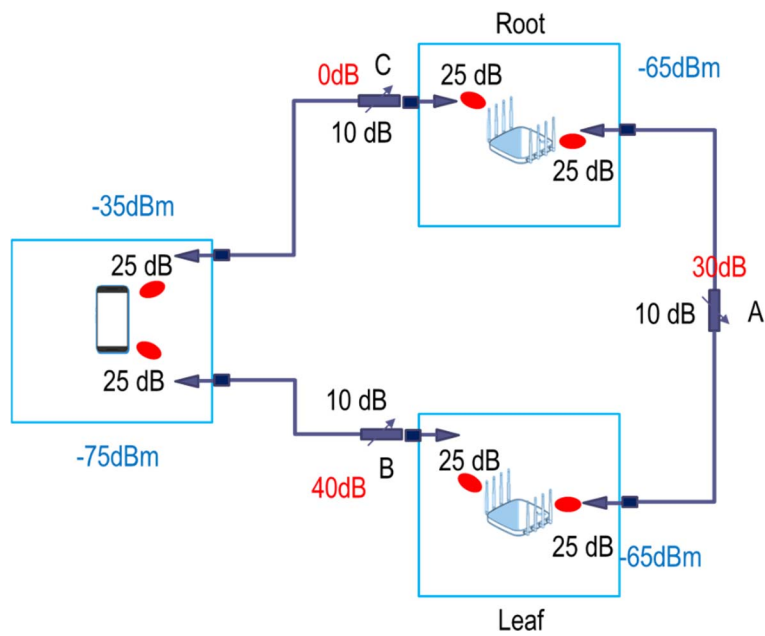

Figure A.1: Link Budget for Roaming Time Test Case

History

Document history		
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