Multi-AP Performance Testing with Spirent TestCenter WLAN

Introduction

A typical single Wi-Fi Access Point (AP) cannot achieve the goal of whole house coverage for many large homes or multi-room dwellings. Users want to enjoy high-performance Wi-Fi throughout the entire house with a good connectivity and fast throughput without experiencing frequently random disconnects from the internet. For those larger houses, multi-level or multi-room apartments, lack of complete connectivity along with network interruptions is often caused by weak RF signal strength in either the receiver or transmitter side of a Wi-Fi client, due to relatively far distance or obstacles between an AP and clients. A new wave of multi-AP networking solutions are now available that claim to improve on every aspect of the home Wi-Fi experience with adequate coverage, giving consumers more options than ever before for whole home connectivity. This is good news for many consumers whose access to the internet is wireless and who want to have access from everywhere within their homes.

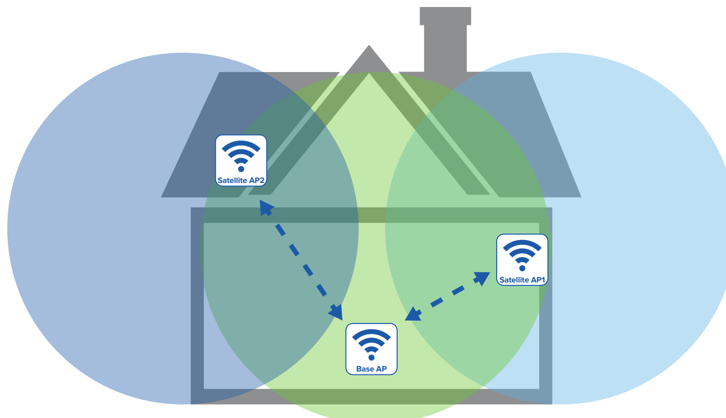

Figure 1. Multi-AP Wi-Fi mesh networking for home

It is recommended to have a multi-AP network for a home larger than 3,000 sq ft, a home more than two levels, or a multi-room apartment complex, a high-rise building or for dwellings with dense walls, multiple floors, metal and concrete substructures, or other structural impediments. Early solutions for those scenarios include range extenders or repeaters that re-transmit the Wi-Fi signal to further their distance or these usually require a wired connection to the main router. Both solutions come with a cost of reduced channel accessibility and typically create a new network SSID that users must log into in order to move from one area to another. Recently, it has become evident that Wi-Fi networking consisting of a multiple APs architecture is an easy and cost-effective solution that can be deployed by spreading APs around a bigger house or multi-room apartment unit to provide the best Wi-Fi coverage service in terms of throughput and connectivity. A multi-AP network with a strong RF signal, can deliver a strong Wi-Fi connection across a whole house. Any good multi-AP Wi-Fi network should have some networking capabilities such as self-healing, self-organizing for an optimal connection, and self-coordination amongst the multi-APs.

In this solution brief, we will discuss how to test the multi-AP networking throughput performance and subsequently provide guidance on testing configurations in a lab setting to test multi-AP units, including both a base (also called master or controller) AP and multiple satellite (also called slave or agent) APs. The focus of this solution brief is on the performance testing of multi-AP system, not on the conformance testing that are mainly on the control plane features. The discussion on these tests for multi-APs will focus on features such as reliable inter-AP Wi-Fi RF connections, maximum throughput, Band Steering and client steering. Starting with some basic information needed to understand multi-AP networking technology and design, this paper will then detail how to setup test beds to validate the throughput performance gain from various multi-AP networking configurations. The testing methodology presented will explore the benefits of implementing multi-AP networking for a complex large home environment which involve multiple device clients sharing the same multiple wireless interface. The benchmarks or expected throughput performance numbers discussed for specific test cases are also listed as a reference for comparison purposes. Discussions on the topics of how to test some advanced features such as Band Steering, inter-AP roaming, and Dynamic Frequency Selection (DFS) feature are also included in this solution brief.

Spirent TestCenter WLAN: Multiple Platforms

Spirent TestCenter WLAN offers a single user interface (GUI) for multiple hardware platforms, as shown in Table 1. The solution platforms combine both the latest IEEE 802.11 WLAN interface cards or modules and the new 100Mbps/1Gbps/2.5Gbps/5Gbps/10Gbps (5-Speed) Base-T Ethernet solutions. These solutions support the highest performing and most realistic Wi-Fi RF interface emulation, for the best possible traffic throughput testing. With a unique multi-radio design, the same platforms can support, simultaneously multi-client and AP emulation for direct functionality and performance testing of multi-AP solutions that involve both AP and client interface for a mesh networking. More specifically, the following general Wi-Fi test scenarios can be performed:

- AP Personal and Enterprise security (802.1x) type
- Medium capacity and maximum client loading
- Wi-Fi stability testing
- Interwork with various mixes of different 802.11 mode clients
- Benchmark or baseline for throughput, forwarding rate, and latency performance
- RFC-style testing with across APs and clients through the RF interface
- Throughput vs packet size, throughput vs client numbers, IPv4, IPv6, DHCP scale and performance, etc.
- Band Steering, Inter-AP roaming testing, and DFS testing
- Rate vs range testing

Spirent TestCenter C1 WLAN

- Integrated 4-port 100Mbps/1Gbps/2.5Gbps/5Gbps/10Gbps (5-Speed) Ethernet
- IEEE 802.11 a/b/g/n/ac 2.4GHz/5GHz, 4x4 MIMO, MU-MIMO

Spirent TestCenter C50 WLAN

- Integrated 4-port 100Mbps/1Gbps/2.5Gbps/5Gbps/10Gbps (5-Speed) Ethernet
- IEEE 802.11 a/b/g/n/ac 2.4GHz/5GHz, 4x4 MIMO, MU-MIMO
- Integrated Radar signal emulation for DFS Testing

MX2 WLAN Test Modules

- IEEE 802.11 a/b/g/n/ac 2.4GHz/5GHz, 4x4 MIMO, MU-MIMO
- Integrated Radar Signal Emulation for DFS Testing

Table 1: Spirent TestCenter WLAN Platforms

Basic Working Mechanism of Multi-AP Networking

Typically, there is just one wired Ethernet connection conveniently available to connect to an AP in a home where a multi-AP network is needed. This wired network cable connection to an external high-speed network is then connected to the base AP unit of the multi-AP. Such a multi-AP system can be designed in full mesh networking in principal where the APs can communicate amongst each other. A fully-meshed network may reduce traffic bandwidth and increase latency if traffic needs to travel from a few satellite APs and ultimately reach the base AP as shown Figure 2. A simplified multi-AP design for consumer home deployment can also use inter-AP communication only between the base AP and the satellite APs and all traffic then connects to the Internet through the base AP. As shown in Figure 3, the communications between the base AP and other satellite APs are usually using Wi-Fi to ensure the fastest possible connection between multi-APs, where the base AP acts as a normal AP and the satellite APs act just like clients to the base AP. Ideally, there is a dedicated Wi-Fi connection, usually on a less congested 5GHz band for a good backhaul connection, between the base AP and the satellite APs that does not handle any other traffic. Moreover, the base AP serves its clients on different channels with different radios on both 2.4GHz and 5GHz, and the satellite APs also uses different channels with different radios on both 2.4GHz and 5GHz than the one used to communicate with the base AP to provide Wi-Fi coverage to their clients. It can also be implemented as a full mesh version, as shown in Figure 3, where the satellite AP communicates to the base AP just as a client, and there are communications between all APs. In this full mesh design, each satellite AP has a backhaul and a fronthaul communications with other APs. Obviously, the full mesh Wi-Fi networking with multi-AP networking increases the complexity of communications amongst all APs.

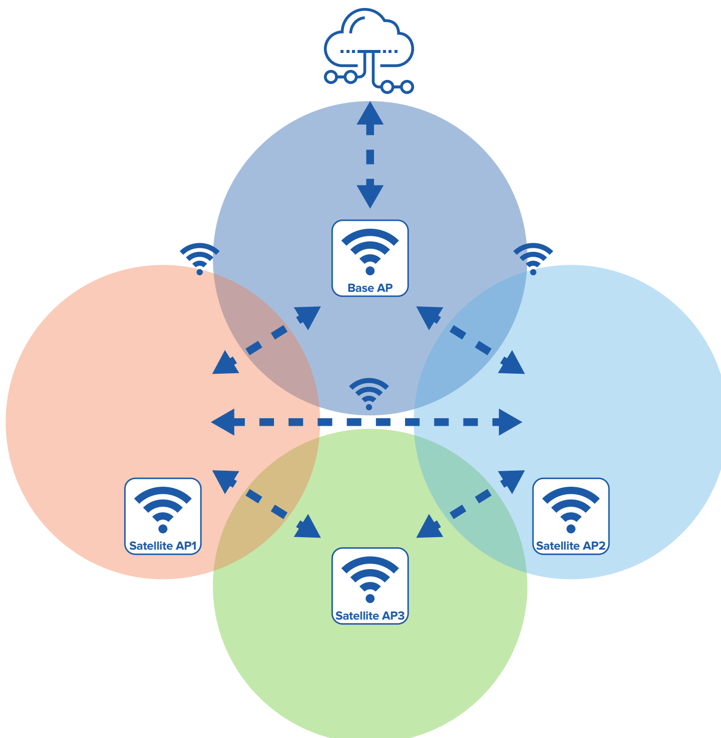

Figure 2: Multi-AP mesh networking architecture with a base AP and multiple satellite APs.

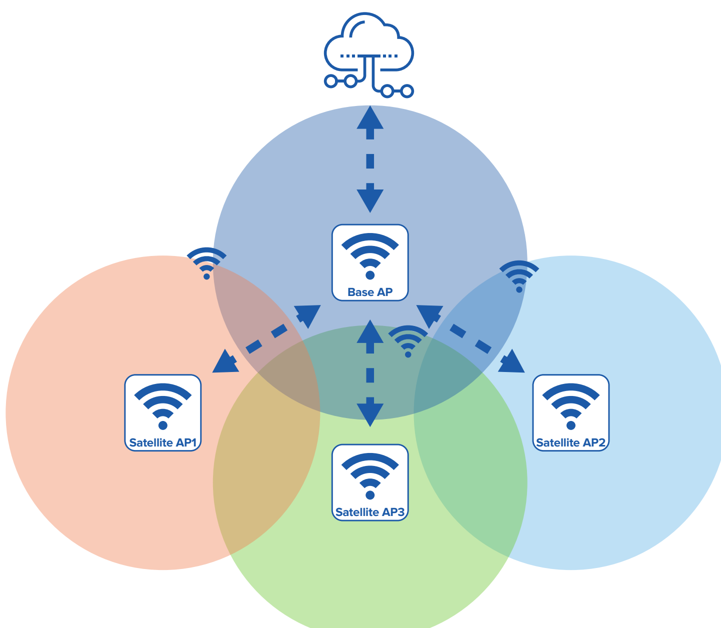

Figure 3: Multi-AP architecture with a base AP and multiple satellite APs.

There is currently no industry standard for designing a multi-AP network, especially on the control channel or communication mechanism between APs. It is acknowledged that the Wi-Fi Alliance (WFA) is currently working on some proposals to standardize the multi-AP design with a common control protocol based on IEEE Std 1905.1TM-2013 for the inter AP communications. The solutions usually come with a bundled system with multiple APs including one base unit and the multiple satellite units working together for a whole house Wi-Fi coverage. The networking architecture is fully expendable, as all APs are usually set to use the same SSIDs, and the satellite APs are add-on devices and the number of those satellite units depends upon the size of a home. A number of commercially available home multi-AP Wi-Fi systems include AmpliFi HD from Ubiquiti, Netgear Orbi from Netgear, Google Wi-Fi Home from Google, Linksys Velop from Linksys, Samsung's Whole Home Wi-Fi, and EERO Home Wi-Fi System. All of these come with this type of multi-AP design, with some vendor proprietary implementations mainly focused in the control protocols between APs. More and more enterprise Wi-Fi features, such as Band Steering, client steering, dynamic frequency selection (DFS), are being re-used for consumer grade multi-AP solutions. Wi-Fi Alliance (WFA) has estimated that about 30% APs sold for consumer market is multi-AP devices today. We should see many more multi-AP solutions with enhanced features becoming available off-the-shelf very soon. One popular design for each of the APs, for a multi-AP system, includes three radios concurrently working within every AP. One of those three radios is used dedicatedly on 5GHz supporting 802.11 a/n/ac/ax modes for inter AP connections, one on 5GHz supporting 802.11 a/n/ac/ax modes for client Wi-Fi service, and one on 2.4GHz supporting 802.11 b/g/n/ax also for client service. Here, two 5GHz channels are configured un-overlapped to avoid RF interference between each other. With this design, it is not uncommon that any one of those APs can be configured as either a base AP or a satellite AP.

Multi-AP Networking Testbed Design

Testing and benchmarking throughput for each AP, of a multi-AP system, within a WLAN network is extremely valuable to any AP vendor whom wishes to quantify good quality of service (QoS) or good quality of experience (QoE). In addition to simply checking the physical layer's parameters, RF signal level, and connectivity. Remember, it is essential for a successful product to define a well-prepared test bed setup which can be especially difficult to do within complex RF environments. Once these test bed requirements are fully understood, only then can the testing engineers design a well-defined test plan, then execute to that plan in a fully automated fashion. Spirent TestCenter WLAN solutions are designed to meet those testing requirements to enable testers to easily execute test cases in a lab environment.

Single AP Testbed

To ensure that this multi-AP mechanism, consisting of both the base AP and the satellite APs can work efficiently to cover the entire home with a good traffic throughput, one can consider testing each of those multi-APs as a single AP used in an emulated environment for achievable, acceptable performance levels. It should be first examined whether or not the communications between the base AP and the satellite APs can support a good throughput bandwidth, where the satellite APs use a Wi-Fi connection with the base AP as an uplink for uplink for Internet access.

An AP configured as a base AP should support at least two un-overlapped 5GHz channels and one 2.4GHz channel all in AP mode. To test a base AP, a good testing platform needs to support multiple independent Wi-Fi interfaces with at least two on 5GHz and one on 2.4GHz and all must support multiple client emulation. Spirent TestCenter WLAN is able to support such emulation and then is able to generate a performance metric between hard-wired Ethernet ports and emulated Wi-Fi clients. Figure 4 shows a simple setup for a single AP testbed where the AP as a Device Under Testing (DUT) is placed within a RF enclosure to avoid any unwanted RF interference.

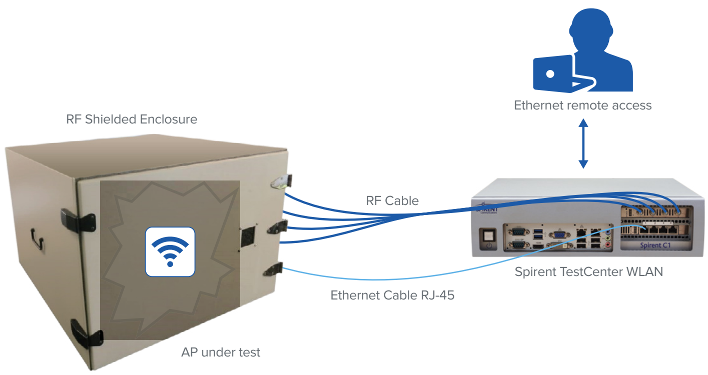

Figure 4: Testbed setup with Spirent TestCenter WLAN: Single AP

Symmetrically, an AP configured as a satellite AP should support two un-overlapped 5GHz channels and one 2.4GHz channel, where one 5GHz channel is in client mode to communicate with the base AP, and another 5GHz channel is in an AP mode along with a channel on 2.4GHz for client Wi-Fi access. However, there is no direct Ethernet link to the satellite APs. To test a base AP, the testing equipment, such as Spirent TestCenter WLAN, needs to support multiple independent Wi-Fi interfaces with at least two on 5GHz and one on 2.4GHz. One 5GHz channel is in an AP mode to emulate a base AP for the mesh networking, while another 5GHz and 2.4GHz are used for multi-client emulation. A closed loop traffic scenario can be created between the emulated AP and clients for a performance testing. Wired Ethernet traffic is not required in this testing scenario. The maximum physical layer rates are given in Table 2 and 3 for IEEE 802.11 n/ac modes.

IEEE 802.11N with MIMO, 40MHz Channel, Short Guard Time	**Maximum PHY Rate (Mbps)**	**MCS Type**	**Achievable UDP Throughput (Mbps)** (Assume 85% MAC Efficiency)
1x1	150.00	MCS7	127.50
2x2	300.00	MCS15	255.00
3x3	450.00	MCS23	382.50
4x4	500.00	MCS31	510.00

Table 2: Maximum PHY Rates for 802.11n Mode

IEEE 802.11AC with MIMO, 80MHz Channel, Short Guard Time	**Maximum PHY Rate (Mbps)**	**MCS Type**	**Achievable UDP Throughput (Mbps)** (Assume 80% MAC Efficiency)
1x1	433.55	MCS9	364.40
2x2	867.10	MCS9	693.68
3x3	1,300.65	MCS9	1,064.52
4x4	1,734.20	MCS9	1,387.36
8x8	3,468.40	MCS9	2,774.80

Table 3: Maximum PHY Rates for 802.11ac Mode

In the following examples, the test goals in terms of validation for maximum achievable PHY rates and UDP traffic throughput are discussed at a high-level for a few typical multi-AP designs.

Test Case 1 (Enter level System, popular design): AP supports one 2x2 MIMO on 5GHz band in 802.11ac for inter-AP backhaul connection, one 2x2 MIMO on 5GHz in 802.11 a/n/ac modes, and another 2x2 MIMO on 2.4GHz in 802.11 b/g/n modes. The important test case requirement to note here is to ensure that the AP under test can support the maximum possible UDP throughput from all three channels concurrently. The maximum PHY rates and the UDP throughput are aggregated as shown in the table below:

Supported Wi-Fi Interface	Maximum PHY Rate (Mbps)	Achievable UDP Throughput (Mbps) (Assume 80% MAC Efficiency)
Radio 1: 11AC 2x2, 5GHz	867.10	693.68
Radio 2: 11AC 2x2, 5GHz	867.10	693.68
Radio 3: 11N 2x2, 2.4GHz	300	255.00
Aggregated per AP		1,642.36

Table 4: An Enter Level Multi-AP Throughput Performance Goal

The test cases with multiple clients for one 5GHz channel and one 2.4GHz channel can also be used to test more realistic applications. For those two channels, the emulated client numbers can vary amongst 1, 5, 10, and 20. Here, the number of emulated clients may not need to be very high for home applications.

Test Case 2 (Common Design): AP supports one 4x4 MIMO on 5GHz band in 802.11ac for inter-AP connection, one 2x2 MIMO on 5GHz in 802.11 a/n/ac modes, and another 2x2 MIMO on 2.4GHz in 802.11 b/g/n modes. The important test instance to note here is to ensure that the AP can support the maximum possible UDP throughput from all three channels concurrently. The maximum PHY rates and the UDP throughput are aggregated as shown in the table below:

Supported Wi-Fi Interface	Maximum PHY Rate (Mbps)	Achievable UDP Throughput (Mbps) (Assume 80% MAC Efficiency)
Radio 1: 11AC 4x4, 5GHz	1,734.20	1,387.36
Radio 2: 11AC 2x2, 5GHz	867.10	693.68
Radio 3: 11N 2x2, 2.4GHz	300	255.00
Aggregated per AP		2,335.68

Table 5: A Common Multi-AP Design Throughput Performance Goal

Test Case 3 (Advanced Solution): AP supports one 4x4 MIMO on 5GHz band in 802.11ac for inter-AP connection, one 4x4 MIMO on 5GHz in 802.11 a/n/ac modes, and another 4x4 MIMO on 2.4GHz in 802.11 b/g/n/ac modes.

The important point to remember here is to ensure that the AP can support the maximum possible UDP throughput from all three channels concurrently. The maximum PHY rates and the UDP throughput are aggregated as shown in the table below:

Supported Wi-Fi Interface	Maximum PHY Rate (Mbps)	Achievable UDP Throughput (Mbps) (Assume 80% MAC Efficiency)
Radio 1: 11AC 4x4, 5GHz	1,734.20	1,387.36
Radio 2: 11AC 4x4, 5GHz	1,734.20	1,387.36
Radio 3: 11N 4x4, 2.4GHz	600	510.00
Aggregated per AP		3,284.72

Table 6: An Advanced Multi-AP Design Throughput Performance Goal

Multiple AP Testbed

To test multi-AP architecture, it requires a testbed setup with multiple APs to fully test an multi-AP networking environment. If one can reasonably assume that the communications between APs are in a good connection state as the APs are usually installed in the fixed locations in a home, we can have multiple APs configured as one base AP and a few satellite APs, and all are placed in a single RF shielded enclosure as shown in Figure 5. In this testing scenario, Spirent TestCenter WLAN emulates Wi-Fi clients on different frequencies and data traffic is generated between the wired Ethernet port connected to the base AP and emulated clients connected to multiple APs. With this testbed, we could then experiment with the range between an AP and connected clients, emulated by adding attenuations between the APs and emulated clients.

As shown in Figure 6, a more complex setup can be proposed with two RF shielded enclosures, one for a base AP and another for a satellite AP, and a programmable 4x4 attenuator used to emulate the range between the APs for the inter-AP communications. One may add more RF shielded enclosures to accommodate more APs, but this quickly increases the setup complexity. Spirent TestCenter WLAN also emulates Wi-Fi clients on different frequencies and data traffic is then generated between the wired Ethernet port connected to the base AP and emulated clients connected to multiple APs.

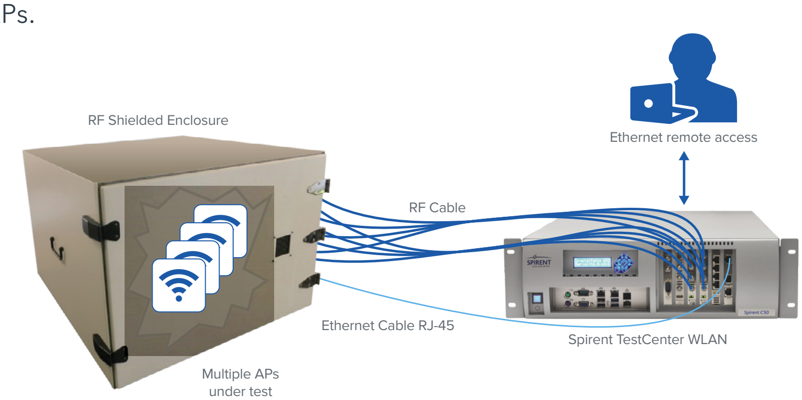

Figure 5: Testbed setup with Spirent TestCenter WLAN: Multiple APs in a single RF enclosure

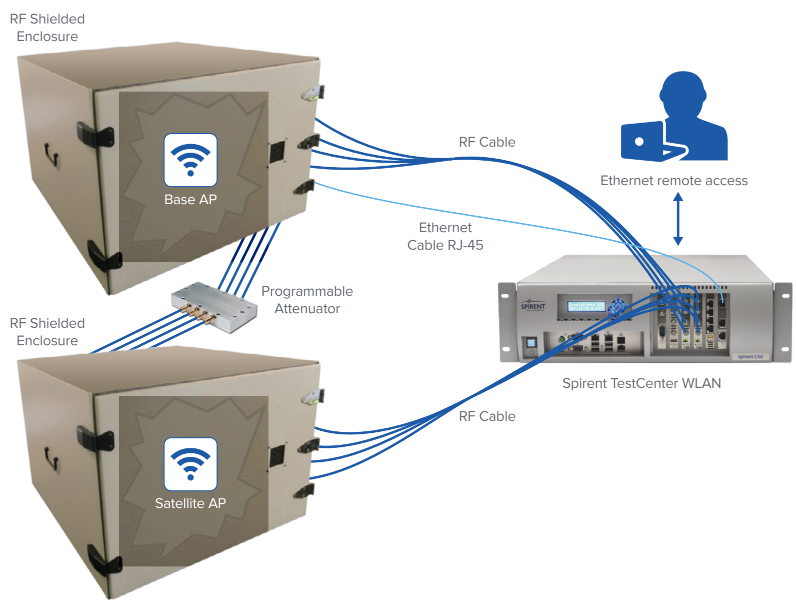

Figure 6: Testbed setup with Spirent TestCenter WLAN: Multiple APs in separate RF enclosures

Band Steering

The purpose of Band Steering is to move and keep a Wi-Fi client on the best frequency band.   It is a technique used only during the association or connection stage in dual-band Wi-Fi deployments to encourage dual-band client devices, such as most modern smartphones, tablets, laptops, and PCs, to use the less-congested and higher-capacity 5GHz band. This is usually advantageous because 5GHz frequency band tends to be better for Wi-Fi performance as it has more and wider channels available and tends to have less overall interference from both neighboring Wi-Fi and non-Wi-Fi sources.

There is no "standard" for Band Steering to steer dual-band clients to the 5GHz band, and each vendor implements Band Steering differently, with some vendors doing it better than others. It is known that Wi-Fi channel access is all contention based amongst multiple APs and clients on the same channel. On a given channel and any given time, if two clients are all trying to transmit, they will collide with each other and the backoff mechanism will be triggered, and this costs an overhead. If all APs of a mesh network are configured with the same SSID, security type and settings, VLAN assignments, and so forth, including all channels on either 2.4GHz and 5GHz bands, then, Band Steering can be a useful feature of the APs to reduce possible access collisions by properly placing clients on different frequency bands during each association process.

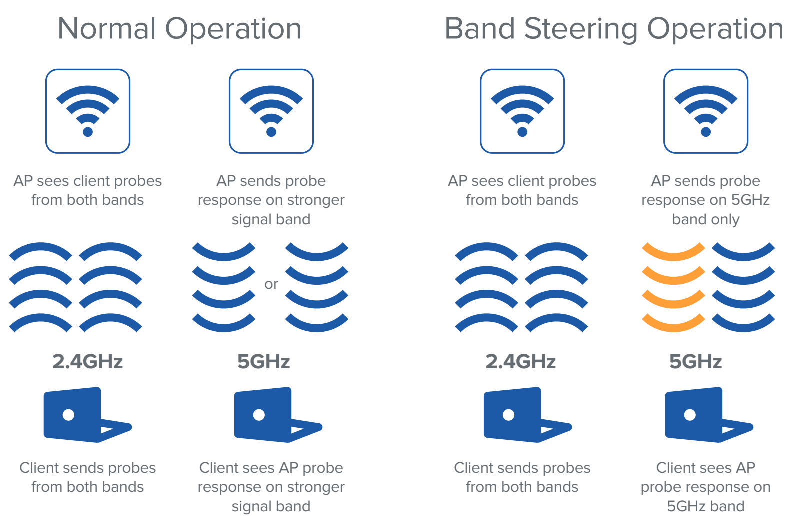

Figure 7: Band Steering to bring more clients on 5GHz band

As shown in Figure 7, an AP is able to identify dual-band client devices from their probe requests and then preferentially respond to them, only on the 5GHz band, so that clients do not see the 2.4GHz network and then just connect to the 5GHz network. Since client devices use the same MAC address on both the 2.4GHz and 5GHz bands, it's fairly easy for an access point to identify dual-band capable client devices. Wi-Fi devices use two kinds of scanning techniques: passive and active. In a passive scan, the Wi-Fi client quickly sweeps each channel listening for beacon frames sent by the APs. In an active scan, the Wi-Fi client sends probe requests on each channel to solicit a probe response from APs. With Band Steering enabled, the AP's beacon frames do not advertise the unwanted wireless network. Client devices performing a passive scan will qualify the SSID as hidden. If the AP hears a probe request from the same client on both 2.4GHz and 5GHz, it will only send a probe response advertising the wireless network in response to the 5GHz probe. This steers the client to the 5GHz band. If the AP hears probes from a wireless client on 2.4GHz only, it will respond with a probe request advertising the network.

The feature of Band Steering may not be enabled by default setting of an AP, so users may need to explicitly set it up.

One example is shown in Figure 7, where an AP can be set up to support different configurations and the Band Steering needs to be enabled. Best practices dictate that when using Band Steering, your SSIDs and all their parameters must match identically.

Another feature that must be enabled is to set the emulated clients as dual-band clients for Spirent TestCenter WLAN testing solutions, as shown in Figure 8. Test cases can be designed to include multiple emulated clients that support dual-band and can be set up to be associated with an AP that supports Band Steering. These testing scenarios also provide a flexibility to create a few testing environments such as:

- All dual-band clients to connect to an AP. There are a few scenarios that the clients should get connected to an AP under test: 1: all clients associated on 5GHz channel; 2: some of them are on 2.4GHz, and the most of them on 5GHz band;
- A mix of signal band and dual band clients. Expect to see all dual band clients connected to 5GHz band;
- Many pro-loaded clients on a band, and additional dual band clients to examine loading balance capability of an AP. In environments with a high density of client devices, it may be advantageous to balance connections between 2.4GHz and 5GHz bands.

Although Band Steering is primarily designed to select prefer 5GHz for dual band capable clients, it is desirable to have some tunable options for Band Steering. This can be useful to make clients connect normally on 5GHz band, but also allow them to connect on 2.4GHz in areas where 5GHz coverage is weak but 2.4GHz coverage is still adequate.

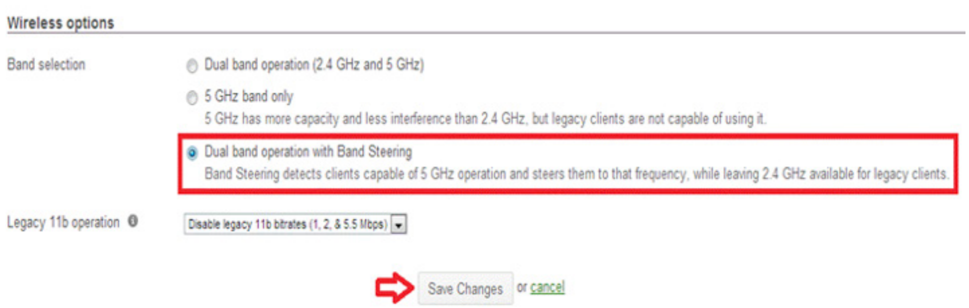

Figure 8: AP Band Steering Setting: An Example

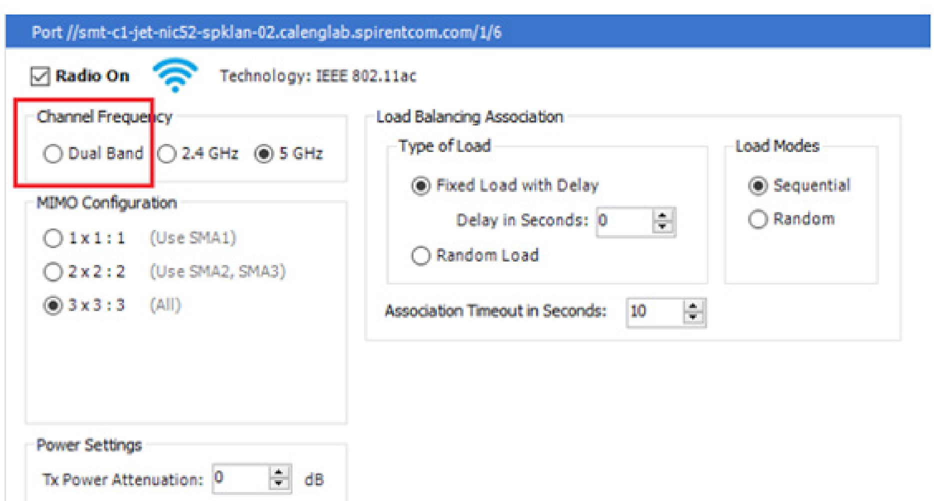

Figure 9: Spirent TestCenter WLAN Band Steering Feature

Client Steering and Roaming

As discussed in the previous section, Band Steering places a client on a preferred band like 5GHz during the connection process, the client steering feature is used to move and keep a Wi-Fi client on the best AP in each location during operation. For enterprise APs, this is a post-association technique with a feature called inter-AP Fast Transition (FT) roaming. The roaming for enterprise Wi-Fi is mainly based on 802.11 k/v/r protocols and involves an assisted operation with the access controller. For some of multi-AP design, the base AP acts like a controller for other APs and therefore FT roaming can be retained. Otherwise, a client can also perform a drop and reconnect process to a new AP based on a preset threshold value. This is a completely drop and reconnect process with an interrupted service, although the interruption can be very short and may be unnoticeable from a user prospective.

Fast Transition (FT) Roaming

Assume that a multi-AP mesh networking can fulfill the inter-AP Fast Transition (FT) roaming protocol like 802.11 k/v/r. Here Fast Transition means that an initial handshake with the new AP occurs before client roams to the target AP. This is a non-interruptible, fast, and seamless process in terms of traffic with a client requested and AP initialized roaming from one AP to another AP. As shown in Figure 10, a client is in an overlap area between the base AP and the satellite AP. At first, it is connected to the satellite to the satellite AP, when the client moves towards another side of the house, it gets closer to the base AP with a stronger RF signal. When the client senses a stronger RSSI from the base AP, and the signal level from the satellite AP becomes lower than a threshold, the client will then request a transition to the base AP without an interruption in the traffic service.

The pre-roaming initial handshake allows the client and APs to do Pairwise Master Key (PMK) process in advance. Once the client performs the re-association request or response exchange with the new AP, the PMK keys are applied to the client and AP.

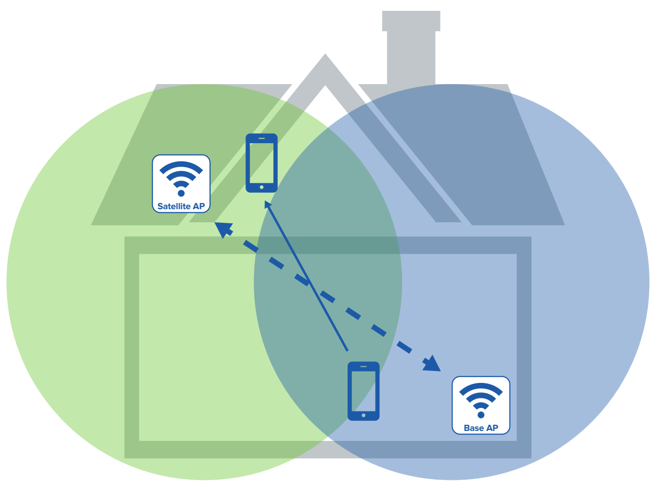

Figure 10: Seamless Roaming between APs

The operation mode of 802.11k consists of the following steps to complete a fast BSS (Basic Service Set) transition to a new AP:

- AP determines that a client is moving away from it
- Informs client to prepare to switch to a new access point
- Client requests list of nearby APs
- Client moves to a best AP based on report

Here 802.11v allows client devices to exchange information about the RF environment. 802.11r based fast transition roaming goes through a few steps such as

- Scanning for other APs in the area
- Exchanging 802.11 authentication messages with the target AP
- Exchanging re-association messages to establish connection at target AP

Spirent TestCenter WLAN supports an inter-AP fast transition roaming testing for the APs as shown with the following detail procedures:

- Single or multiple clients simultaneously roaming
- Support single or continuous roaming amongst APs
- Support both sequential and random roaming modes
- Report roaming related statistics such as roaming delay (min, max, and average), traffic info (throughput and packet loss), etc
- Support both GUI based manual operation and automated test fashion
- Support both Over-The-Air and Over-The-DS fast transition and can perform the following inter-AP roaming testing scenarios:
  - Roaming for single or multiple clients emulated with a radio amongst APs with the same channel;
  - Roaming for single client emulated with a radio amongst APs with the same of different channels;
  - Single or continuously roaming amongst APs

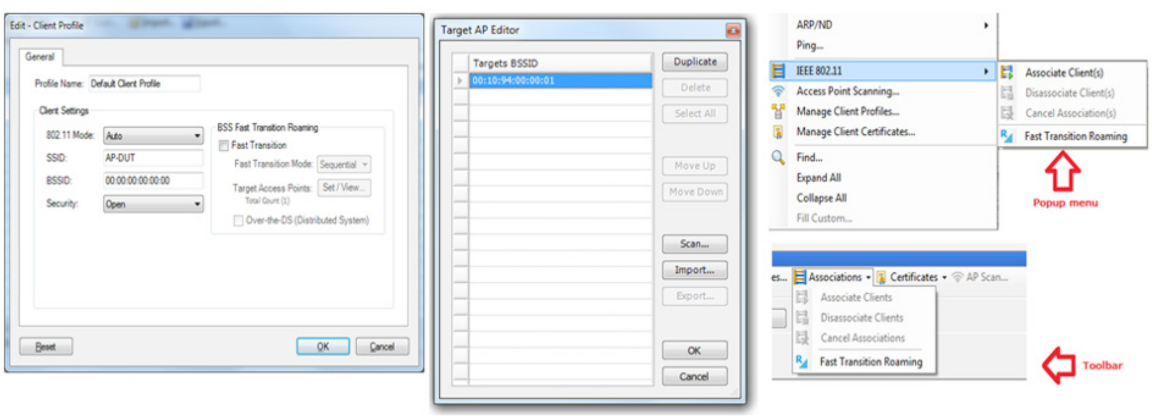

Figure 11: Inter-AP Seamless Roaming

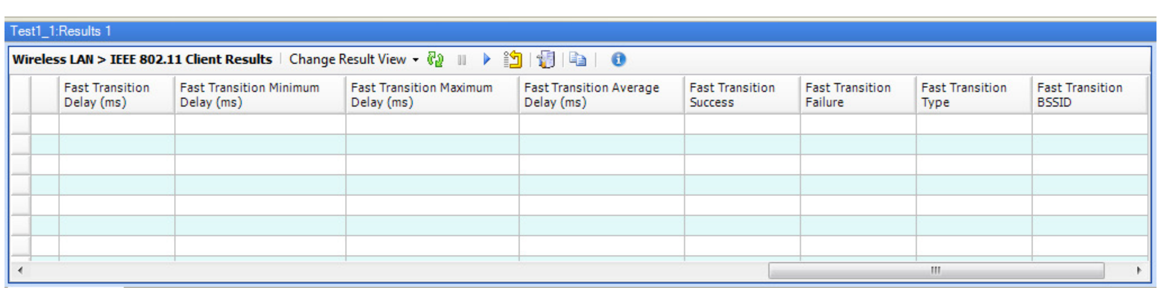

Figure 12: Seamless Roaming Results Report

Client Assisted Roaming

Unlike high-end enterprise Wi-Fi applications, APs for multi-AP Wi-Fi networking may not be managed with an access controller to fulfill a full coordination between APs. The roaming to a new AP with a re-connect mechanism solely resides on a client. The algorithm is vendor specific, and is usually just RSSI level based with a rescanning logic design. This simple roaming solution with a drop and then reconnect process may come with a cost of a short interruption for the traffic, since a re-authentication is usually needed after a re-association. The length of this transition process is dependent on the performance of a Wi-Fi client. Some client devices are able to complete this process fast enough so that the traffic interruptions are not even noticeable, while other devices need a bit more time to complete this process.

As shown in Figure 10, two APs are installed to cover an entire home with an overlapped area. A client is in an overlap area between the base AP and the satellite AP. At first, the client is connected to the satellite AP, when the client moves towards another side of the house, it gets closer to the base AP with a stronger RF signal while the signal from the satellite AP becomes weaker. This situation could trigger a roaming for the client's connection from the satellite AP to the base AP.

A roaming logic can be designed such that when the signal level from the AP for the current connection becomes lower than a so-called drop out threshold (DROP_OUT_THRESHOLD) (For example -70 dBm used by iPhone), then the client starts to sense a stronger RSSI from the other APs to see if the signal levels from other APs can be higher than the current signal level with a pre-selected roaming threshold (ROAMING_THRESHOLD) (For example 8 dB better in traffic mode, and 12 dB better in idle mode). Once it finds those candidate APs, the client will then drop out the current connection with the AP and re-connect with a new AP with the best RSSI value. A re-scanning process by a client is triggered by the RSSI threshold. This means that if the connected AP signal is lower than the threshold, the client believes that the AP is not usable and decides to roam, and this causes the client to start to scan for available APs. This scanning keeps going until it finds a BSSID with RSSI difference greater than the ROAMING_THRESHOLD or until the current AP signal goes back above the drop out threshold.

Spirent TestCenter WLAN can be used to emulate multiple clients that roam from one AP to another by changing RSSI levels of multi-AP networking with multiple APs involved, where all APs come with the same SSID and the different BSSIDs.

There are some important facts to be aware of for this type of the client roaming feature that is solely driving by the client itself based on the RSSI level:

- There must be an overlapped area so that a client can scan and detect both of APs simultaneously to evaluate and then choose the best wireless network to roam on.
- Wi-Fi clients are responsible for deciding it needs to roam, and then detecting, evaluating, and roaming to a new AP.
- A client must support roaming mechanism such as a RSSI based or other algorithm based. Different wireless client vendors may have different roaming algorithms, and there is no standard from WLAN standard bodies (such as IEEE) and industry bodies (such as the Wi-Fi Alliance)
- Usually, mobile phones are enabled for roaming by default, although there are third party apps for Android for controlling roaming behavior.
- For laptops, some Wi-Fi NIC vendors do give some mechanism to control its roaming behavior with an interface allow users to select a parameter called roaming aggressiveness.
- Single or multiple clients can perform independent and simultaneous roaming

DFS Channels on 5GHz Band

Multi-AP mesh networking uses multiple channels on 5GHz band, and those channels should not be used by any nearby APs to avoid unnecessary channel sharing and collision. It is a fact that many consumer grade APs are not using those DFS channels on 5GHz to avoid required regulatory compliance testing for DFS feature. AP vendors simply block out those DFS channels to avoid the complexity of the required DFS channel requirements, consequently, limiting the users' flexibility to use different channels on 5GHz to avoid interference.

Generally speaking, an AP product needs to support DFS functionalities including radar signal detection and auto channel switching, if those DFS channels are selectable. From a testing and validation point of view, there is a need with an automated and simple-to-use application that tests compliance of Wi-Fi APs to the Dynamic Frequency Selection (DFS) regulations.

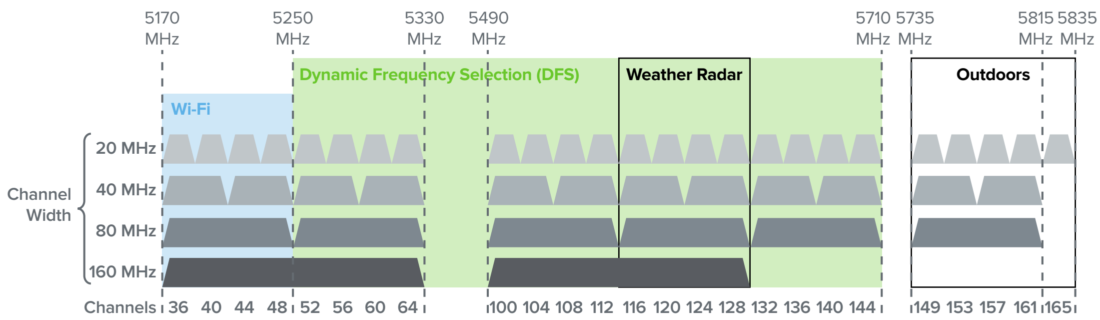

Figure 13: DFS Channels on 5GHz Band

Spirent TestCenter WLAN solutions have two major components for the DFS feature testing. First, it offers the emulated clients that are able to auto switch to a different channel on 5GHz band during the association seamlessly, if it's requested by the AP associated. Second, it has an integrated radio that generates regulatory-specified radar signal pulses. The testing setup can measure and evaluate an AP's response to these radar pulses, while providing a real-time feedback, as well as detailed reports documenting the AP's behavior in the presence of radar pulses. The radar signal generation logic is fully integrated with the WLAN NICs used for the client emulation and is controlled with the same GUI, while the radar signal is sharing the same RF medium with the WLAN connections for the client emulation.

In summary, the capability of the DFS testing solution tool to test compliance of 802.11 access points (APs) to Dynamic Frequency Selection (DFS) feature on 5GHz band includes the following:

- Generate radar signals required by the FCC/ETSI/MIC
- Testing in statistically radar signal detection capability
- Record the timing of the AP channel switching
- Fully integrated DFS testing along with traffic testing simultaneously
- Programmable radar signal pulse generation

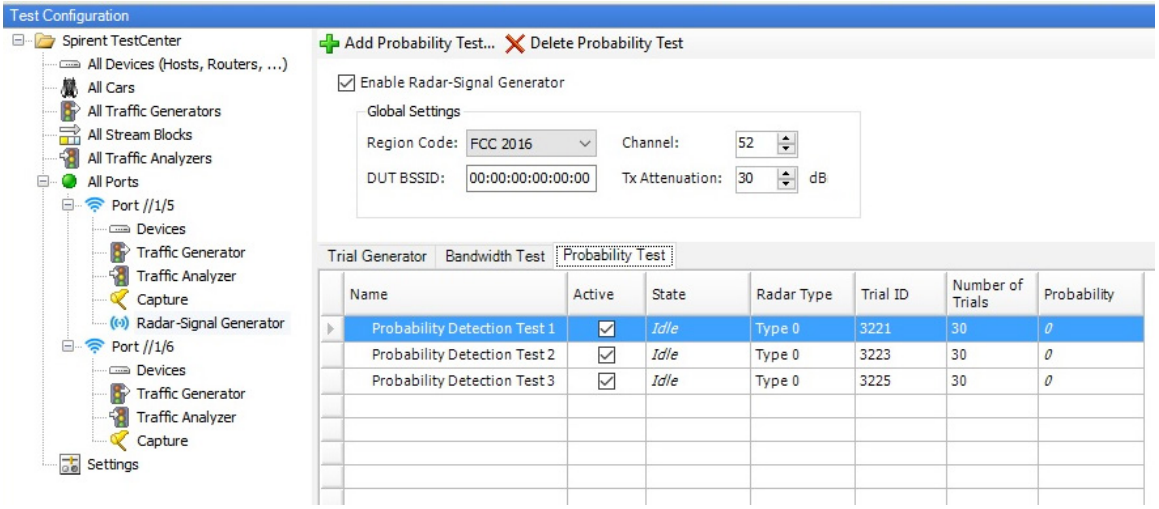

Figure 14: Spirent TestCenter WLAN for DFS Testing

Conclusions

Multi-AP networking solutions with the latest 802.11 Wi-Fi technologies such as 802.11ac Wave-2 are now available to consumers to achieve the goal of 'everywhere' and 'no dead zone' internet access at home. Consumers now have more options than ever when it comes to whole home Wi-Fi networking with a new wave of multi-AP networking solutions that claim to improve on every aspect of the home Wi-Fi experience with adequate coverage. This provides a new thrust for the explosion in popularity of smart home devices and countless streaming media services. Whole-house Wi-Fi coverage has become a must. The expectation for those new multi-AP solutions are largely improving on coverage, capacity, performance, reliability, and security.

Since end-users expect WLAN technologies to be ubiquitous, it is vital for AP manufacturers to test their new multi-AP solutions with the latest WLAN multi-client emulation testing tool available on the market today. Spirent TestCenter WLAN has a unique multi-NIC and multi-radio design to concurrently test multi-band support for functionality and performance. It is patricidal to complete an in-lab testing for various multi-AP designs to ensure that the promised performance can ultimately be delivered to the end-user.

In addition the conformance testing to be defined by Wi-Fi Alliance, testing and benchmarking throughput performance for each AP of a multi-AP system within a WLAN network is extremely valuable to any AP vendor to quantify good quality of service (QoS) or good quality of experience (QoE) in various realistic environments, in addition to simply checking the physical layer's parameters, RF signal level, and connectivity. Remember, it is essential for a successful product to define a well-prepared test bed setup which can be especially difficult to do within complex RF environments. Once these test bed requirements are fully understood, it is only then that the test engineer can design a well-defined test plan, then executes to that plan in a fully automated fashion. Spirent TestCenter WLAN solutions are designed to meet those testing requirements to enable testers to easily execute testing cases in a lab environment.

For more detailed information, download the Spirent TestCenter WLAN data sheet at
https://www.spirent.com/Products/TestCenter/Platforms/Modules

About Spirent Communications

Spirent Communications (LSE: SPT) is a global leader with deep expertise and decades of experience in testing, assurance, analytics and security, serving developers, service providers, and enterprise networks.

We help bring clarity to increasingly complex technological and business challenges.

Spirent's customers have made a promise to their customers to deliver superior performance. Spirent assures that those promises are fulfilled.

For more information, visit: www.spirent.com

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