

In-Home Wi-Fi Multi-AP Solutions Trial Report

WBA NextGen Work Group



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1 Executive Summary

With the advent of widespread video streaming and video conferencing, the demand for bandwidth within the home has increased significantly and a Wi-Fi connection of just a few Mbps to any one device is no longer adequate for many consumers. The present goal for in-home Wi-Fi providers is to provide 10s or even 100s of Mbps to any device in any room in the house, and even beyond the garage/garden, and in many cases, this cannot be achieved with a single Access Point. As a result, multi-AP Wi-Fi in the home is becoming an essential proposition to meet customers' expectations. Customers also expect that Wi-Fi will be easy to set up and operate even if they have no knowledge or understanding of the technology¹ and multi-AP systems are quite different in this respect from simply plugging in a single AP and using default configuration.

To help operators and other providers of in-home Wi-Fi understand the advantages and differences of multi-AP systems, this 'In-Home Wi-Fi Multi-AP Solutions Trial' report examined only those features beyond the capability of a single AP that are specific to multi-AP systems. The key areas of testing relate to the installation, ease of onboarding additional APs and client devices, automatic network optimizations and problem remediation, and ongoing management and diagnostics.

There are new standards and corresponding certification programs, such as Wi-Fi CERTIFIED EasyMesh™, Wi-Fi CERTIFIED Data Elements™ and Wi-Fi CERTIFIED Easy Connect™, that are starting to work their way into products. Most existing systems use a mixture of established standards, with proprietary protocols and management systems to achieve their capabilities.

Certain features are important in multi-AP Wi-Fi deployments, such as channel management based on RF environments, client steering, update management, and access to network state for diagnostics; while others are important in some cases depending on the target market (e.g., AP placement guide, loop-prevention, detection of unmanaged APs in the LAN).

Operators providing self-installation systems may wish to focus on systems/features that guide users/installers in AP placement and notifications to users of network device issues via a smartphone App. Operators who provide managed and supported systems are likely to want diagnostic information such as Wi-Fi Data Elements to give the operator visibility of the network configuration (including topology), and various KPIs reflecting performance and device connectivity issues.

End-users may want to use a smartphone App to check on their Wi-Fi system status and do some rudimentary controls. Solutions that provide more control allow savvy users to make

¹ For many users, 'Wi-Fi' is now synonymous with 'in-home connection to the internet' and Wi-Fi is blamed for broadband and cable problems, the reverse of the situation a few years ago.

use of advanced features such as separate guest networks and scheduled access for specific devices, along with the opportunity to self-solve some issues.

There are different levels of multi-AP equipment available to target the full range of markets, from off-the-shelf self-install and self-administer with limited local management, through to professional install with full remote management capabilities requiring no end-user intervention, and various stages in between. Most multi-AP systems are proprietary at present and so it is to be expected that they will allow feature to differing levels of capability, functionality, and user interaction. There are also features that might make using a multi-AP system easier for the user; such as Wi-Fi Easy Connect that are not widely available yet.

Operators wanting to provide a managed Wi-Fi offering need to pay close attention to those features that provide remote diagnostics and configuration so that problems can be detected and resolved.

This report provides testing and analysis of all these multi-AP features and capabilities.

2 Introduction

As the demand within the home for networked devices, data usage by those devices, and the capacity of the home internet connection have increased, the throughput and coverage available from using a single Wi-Fi Access Point (AP) to cover the whole home is often no longer acceptable to the users. The solution is to provide multiple APs to meet the demand, but those APs need to form a single network to ensure continuity of service for mobile devices - a multi-AP network. Users or operators are moving towards installing multi-AP systems to address the need, but these systems have varying capabilities and features.

Multi-AP networks, often based around a separate controller, have been available for many years in enterprise networks but the typical home has neither the budget nor the resources to operate such a network, so something more economical must be provided. As a result, there are now diverse systems designed for home use that offer different levels of functionality, management, and diagnostic capability; sometimes depending on budget and the availability of technical resources.

This project provides test results that examine the behavior of several multi-AP systems to provide a guide to the type of features and functionality that are available for these home networks.

The tests and use-cases have been selected by this group to examine the way in which multi-AP home networks can provide a better coverage in the home, as compared to a single-AP home, and address the issues and complexities specific to connecting multiple APs to make up a single coordinated network.

The “In Home Wi-Fi Multi-AP Solutions Trial Use Cases Scope Document” [1] was written by WBA to describe features that should be found in multiple-AP-capable home systems and thereby highlight some of the advantages of adopting them. The Test Plan document [2] was then written, and finally, the report below aggregates the summary of the field trial results.

3 About the Test Cases

The test cases are designed to cover all of the use-cases that are currently testable. Each test case may test a component of a use case, an entire use case, or even a combination of several test cases.

The test cases aim to test the capabilities of multi-AP systems in the areas that are most important to operators. These include both operator capabilities, but also the solution’s features that are end-user visible. In addition, other test cases focus on features that prevent problems from ever occurring in the first place.

The test cases are focused on functional testing, rather than performance testing. While some tests (e.g., client steering) could be seen as testing performance, we focused on how the systems steered clients, and not how well. This is important since the actual performance of client steering still depends heavily on the behavior of the clients being steered.

3.1 Table of Test Cases (TC)

TC ID	TEST CASE NAME	TEST DESCRIPTION
COM-01	This case provides the common set-up steps used by most test cases	N/A
DEP-01	IoT device onboarding via Wi-Fi Easy Connect smartphone	Wi-Fi Easy Connect offers a simple way to install IoT devices. This examines a smartphone user adding a headless IoT device with a QR code sticker to a Wi-Fi network.
DEP-02	AP onboarding via Wi-Fi Easy Connect AP and Wi-Fi Easy Connect smartphone	This examines a Wi-Fi Easy Connect smartphone user adding a Wi-Fi Easy Connect AP with a QR code sticker to an existing Wi-Fi network.
DEP-03	Onboarding Wi-Fi Easy Connect smartphone to an Wi-Fi Easy Connect AP	This examines a Wi-Fi Easy Connect smartphone user onboarding their phone to a Wi-Fi Easy Connect AP.
DEP-04	Initial install of multi-AP network by end-user	This examines a user installing a multi-AP network, adding APs to an existing multi-AP network, and connecting a client.
DEP-05	Initial install of multi-AP network by professional installer	This assesses a user ordering internet service with whole-home Wi-Fi or requesting an additional AP for coverage, with installation performed by a technician.

DEP-06	Channel allocation and selection by APs	Users require a good overall Wi-Fi experience including coverage and available bandwidth, even in the presence of neighboring Wi-Fi networks. This examines assignment of frequency slots to each of the APs toward achieving the highest available medium accessibility.
DEP-07	Adding an AP to an existing multi-AP system	The addition of an AP sometimes involves a different and possibly more complicated process from the initial installation of a set of APs, which could be pre-configured. This examines a user adding an AP to an existing multi-AP network.
DEP-08	Identify and specifying location for APs	User needs guidance on where to place APs in a multi-AP system; operator needs information if locations can be optimized. Correct positioning of APs is important for throughput and coverage. This use-case assesses the assistance provided for placing the AP.
DEP-09	Network Loop Prevention	With a multi-AP setup, it is possible for there to be more than one path between some APs in the network. This examines handling network loops if the user creates one using an Ethernet connection.
DEP-10	Onboarding Wi-Fi Easy Connect devices to a Wi-Fi Easy Connect AP	This examines a user using an App from the AP-supplier on their smartphone to onboard a Wi-Fi Easy Connect device: client, IoT or AP.
OPS-01	Self-healing for fixing channel interference issues	User requires a good overall Wi-Fi experience including coverage and available bandwidth, even in the presence of increasing interference from neighboring Wi-Fi networks. This looks at how a network handles those changes when they start to have an impact on the performance of the network.
OPS-02	Handling Orphaned APs in the system	An end-user can remove or "orphan" a specific AP. This examines a user changing wireless security while one or more APs in a multi-AP network are powered off.
OPS-03	Detection and Handling of Unmanaged APs using the same SSID as the multi-AP network	A user paying for a managed multi-AP network wants to reap the benefits of a fully managed network. This examines connectivity and reporting of the connection of new unmanaged AP with the same SSID as the installed network.
OPS-04	Client Steering	Users want consistent Wi-Fi service as they roam around their house. This examines how the network manages transitions of clients between one AP and another AP within the network.
OPS-05	Coordinated Firmware Upgrade	Multi-AP networks should be able to apply upgraded firmware in a way that doesn't break the end-user experience. This looks at managing firmware upgrades while maintaining connectivity.
OPS-06	Network Topology control and optimization	Multi-AP networks must be able to adapt to changing conditions and maintain a good end-

		user experience. This examines how a change in network topology is handled.
MAN-01	End-User Smartphone App Capabilities	The end-user wants the ability to monitor and do simple diagnostics of their multi-AP system using an app on their smartphone. This examines the functionality of such an app provided to an end user.
MAN-02	Proactive Diagnostics and Analytics for Operator	When the network is managed by an operator, the operator wants to be able to identify and sometimes fix issues in the subscriber's multi-AP system before the end-user notices them. This examines the Wi-Fi diagnostics system.
MAN-03	Topology Management by Operator	When the network is managed by an operator, the operator wants to be able to reconfigure the backhaul topology of their managed multi-AP networks to ensure the best user experience in the presence of changing RF conditions. This examines how the AP topology is managed and presented.

Table 1 - Table of Test Cases

4 Trial Results

4.1 Table of Results – MediaTek EasyMesh R2 System

The MediaTek system is an OpenWRT based development kit for operators and OEM vendors that supports the Wi-Fi EasyMesh R2 specification, include two Wi-Fi 6 radios (2.4/5 GHz) each with 4 spatial streams (4x4:4) and has a separate DFS sensing radio and DFS channel support. Each unit can act as an EasyMesh Controller and Agent or just an EasyMesh Agent.

TC ID	FEATURES	EXPECTED RESULTS	RESULTS	TAKE-AWAYS FOR OPERATORS
DEP01	IoT device onboarding via Wi-Fi Easy Connect smartphone	N/A	Not run due to lack of Wi-Fi Easy Connect smartphone	It is taking longer than expected for Wi-Fi Easy Connect enabled devices to appear in the market. However, Wi-Fi Easy Connect has the potential to greatly reduce onboarding time and end-user intervention. Zero-touch configuration could be provided for service provider supplied equipment.

DEP02	AP onboarding via Wi-Fi Easy Connect AP and Easy Connect smartphone	N/A	Not run – Solution does not implement Wi-Fi Easy Connect in APs	It is taking longer than expected for Wi-Fi Easy Connect enabled devices to appear in the market. However, Wi-Fi Easy Connect has the potential to greatly reduce onboarding time and end-user intervention. Zero-touch configuration could be provided for service provider supplied equipment.
DEP03	Onboarding Wi-Fi Easy Connect smartphone to a Wi-Fi Easy Connect AP	N/A	Not run due to lack of Wi-Fi Easy Connect smartphones	It is taking longer than expected for Wi-Fi Easy Connect enabled devices to appear in the market. However, Wi-Fi Easy Connect has the potential to greatly reduce onboarding time and end-user intervention. Zero-touch configuration could be provided for service provider supplied equipment.
DEP04	Initial install of multi-AP network by end-user	AP onboarding over Ethernet and Wi-Fi happens quickly and is smooth	Onboarding happened flawlessly	Wi-Fi EasyMesh onboarding is zero-touch with Ethernet connection and works smoothly with WPS pushbutton over Wi-Fi (user presses two buttons)
DEP05	Initial install of multi-AP network by professional installer	Solution is development kit and thus not tailored for professional installer, but many tools are available via OpenWRT and Wi-Fi EasyMesh	Onboarding and configuration worked well, even though no AP placement guidance was provided	OpenWRT and Wi-Fi EasyMesh provide the hooks and status to provide a professional installer real-time view of the network and flexibility to create multiple networks for end-user
DEP06	Channel allocation and selection by APs	Solution picks channels that provide optimal bandwidth for client devices	All APs picked the best channel based on lowest airtime utilization	In a multi-AP system, each AP may pick the same fronthaul channel initially, if only one channel is quiet. But a system should have the ability to re-assess the fronthaul channels for each AP if RF conditions substantially change in the future, either due to external or internal changes in channel utilization

DEP07	Adding an AP to an existing multi-AP system	Additional APs added to the network are onboarded and configured seamlessly.	All APs picked the best channel based on lowest airtime utilization	While important that radios pick the best channel at boot, it is also important to adapt to changing RF conditions (see OPS1 test case)
DEP08	Identify and specifying location for APs	AP placement assistance app is provided to guide users where to place their APs relative to each other	The product tested is a reference design for integrators, it is not a retail product. AP Placement assistance tools would be provided by the integrator.	AP placement is key to good home Wi-Fi and good tools will reduce truck-roll and end-user install time
DEP09	Network Loop Prevention	Multi-AP systems are expected to detect and resolve loops formed by multiple (Wi-Fi + Ethernet) backhaul connections between APs	After Wi-Fi backhaul connection is established and the Ethernet cable is plugged in to establish an additional backhaul connection, for a short transient time there is ping loss, but then the network recovers and eliminates the loop by dropping the Wi-Fi backhaul and keeping the Ethernet backhaul	Non-network savvy users may connect Ethernet cables in addition to the existing Wi-Fi creating loops and a solution needs to be able to keep working and, if possible, take advantage of the best path
DEP10	Onboarding Wi-Fi Easy Connect devices to a Wi-Fi Easy Connect AP	AP can onboard a device to a WPA2/3-Personal Wi-Fi network using Wi-Fi Easy Connect	N/A The Multi-AP system tested is a Wi-Fi EasyMesh system, which uses PBC/WPS as onboarding mechanism	It is taking longer than expected for Wi-Fi Easy Connect enabled devices to appear in the market. However, Wi-Fi Easy Connect has the potential to greatly reduce onboarding time and end-user intervention. Zero-touch configuration could be provided for service provider supplied equipment.

OPS1	Self-healing for fixing channel interference issues	Reallocation of the operational channels of the multi-AP network in case of interference on the operational channels	After 92% of airtime interference was introduced in the operating channels, the multi-AP system changed both the backhaul and the fronthaul channels.	It is important for a system to re-assess the fronthaul channels for each AP and reconfigure them if RF conditions substantially change
OPS2	Handling Orphaned APs in the system	Multi-AP network has a re-onboarding procedure in place to allow orphaned APs to re-join the system	UI for Wi-Fi EasyMesh Controller shows network topology and that the orphaned AP is no longer part of the network. Manual push button by the user allows the orphaned AP to re-join the network.	Notifications to users of issues with network devices is important to allow remediation. Capabilities such as Wi-Fi Data Elements also gives the operator visibility into network issues.
OPS3	Detection and Handling of Unmanaged APs using the same SSID as the multi-AP network	A multi-AP system under test implements a detection and reporting mechanism for APs that use the same SSID as the multi-AP system but are not part of it.	User can visualize the managed APs Controller UI and could determine that the unmanaged AP is “missing” from the network. No automation is present in the reference design.	It is important that unmanaged APs are detected by the multi-AP network so that the user can be advised to remove/reconfigure said APs.
OPS4	Client Steering: a) Band steering b) AP Steering	When devices move about the home, each Wi-Fi client device to roam/be steered to the best AP/band.	BTM steering was used to steer the client to another band on the same AP and to another AP belonging to	Steering mobile clients in the home is key to good Wi-Fi user experience and goes a long way to keeping users from turning off Wi-Fi

			the multi-AP system.	
OPS5	Coordinated firmware upgrade	Support automated (remote) coordinated firmware upgrade of the APs in the network.	Not supported by the reference design	N/A: not tested
OPS6	Network topology control/optimization	Network topology is reconfigured when needed	New APs got onboarded automatically and topology changed accordingly whenever a new AP was introduced to the multi-AP system. Topology change when one AP was relocated could not be tested in the test house.	Topology can be managed effectively locally by a multi-AP system without user intervention
MAN01	App provided to end-user	Multi-AP system to provide an interface to end user to manage the network	The multi-AP system tested provides a WebUI for the end users to monitor run time topology, connected clients, operational channels, settings, KPIs.	Support for smartphone Apps is advantageous to enable end-users to monitor Wi-Fi system status and do rudimentary control. Operators should consider multi-AP systems that provide a method to integrate with operator's existing UI channels?
MAN02	Proactive Diagnostics and Analytics by Operator	Diagnostics can be provided from the multi-AP network across a WAN to a remote diagnostic system	WFA DE Data is collected on MAP Controller and solution supports JASON format. WEB GUI can be used for GUI display of DE data real time.	Fully managed Wi-Fi is a differentiator and systems need to provide the ability to interface with operator management systems.
MAN03	Topology Management by Operator	The multi-AP system can report topology	Topology Information is accessible via	While topology can be effectively managed locally, operator support agents

		information to a management system. The management system should also be able to configure the backhaul topology of the multi-AP system.	WEB GUI on controller/agents. Controller acts as management system. WebUI of Controller presents topology in graphical format, all WFA DE R1 KPIs for each radio in the AP are included.	also need the ability to view Wi-Fi KPIs and change topology in case of more complex Wi-Fi environments (e.g., MDUs).
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Table 2 - MediaTek Test Results

4.2 Table of Results – AirTies 4930 Mesh System

The AirTies system is a proprietary Hybrid-Mesh utilizing Wi-Fi and Ethernet, containing two Wi-Fi 5 radios (2.4/5 GHz) with 2 spatial streams (2x2:2) on 2.4 GHz and 4 spatial streams (4x4:4) on 5 GHz with DFS channel support. It was tested with a preview version of the AirTies Vision Android application.

TC ID	TEST CASE FEATURES	EXPECTED RESULTS	RESULTS	TAKE-AWAYS (FOR OPERATORS)
DEP01	IoT device onboarding via Wi-Fi Easy Connect smartphone	N/A	Not run due to lack of Wi-Fi Easy Connect smartphone	It is taking longer than expected for Wi-Fi Easy Connect enabled devices to appear in the market. However, Wi-Fi Easy Connect has the potential to greatly reduce onboarding time and end-user intervention. Zero-touch configuration could be provided for service provider supplied equipment.
DEP02	AP onboarding via Wi-Fi Easy Connect AP and Wi-Fi Easy Connect smartphone	N/A	Not run – Solution does not implement Wi-Fi Easy Connect in APs	It is taking longer than expected for Wi-Fi Easy Connect enabled devices to appear in the market. However, Wi-Fi Easy Connect has the potential to greatly reduce onboarding time and end-user intervention. Zero-touch configuration could be provided for service provider supplied equipment.

DEP03	Onboarding Wi-Fi Easy Connect smartphone to a Wi-Fi Easy Connect AP	N/A	Not run due to lack of Wi-Fi Easy Connect smartphone	It is taking longer than expected for Wi-Fi Easy Connect enabled devices to appear in the market. However, Wi-Fi Easy Connect has the potential to greatly reduce onboarding time and end-user intervention. Zero-touch configuration could be provided for service provider supplied equipment.
DEP04	Initial install of multi-AP network by end-user	AP onboarding over Ethernet and Wi-Fi happens quickly and is smooth	Onboarding worked well whether Ethernet or Wi-Fi was used	End users may try connecting APs via Ethernet and a solution should handle that automatically and shouldn't require the user to do anything further. Visual feedback of Ethernet connection on APs is important.
DEP05	Initial install of multi-AP network by professional installer	Solution should guide installer to best first approximation location for APs	Solution guided installer using # APs, home type and # floors by presenting a graphic showing placement recommendations. Guest network setup worked well. Network performance tools help verify installation.	Customized guidance for installers speeds up the process and improves the final outcome
DEP06	Channel allocation and selection by APs	Solution picks channels that provide optimal bandwidth for client devices	Solution picked the lowest utilized 5 GHz channel, and picked an overlapping 2.4 GHz channel (Chan 2)	Initial and ongoing channel selection is one of the most important aspects of multi-AP systems especially if deployed in any kind of urban or sub-urban environment
DEP07	Adding an AP to an existing multi-AP system	Solution should make adding an AP as simple as possible	Onboarding additional AP worked well	Adding an AP ideally should be as simple as plugging it in
DEP08	Guiding an end-user to install APs in a good location	Solution should guide the user to place additional APs in a location that extends coverage without adding performance issues	Not run as functionality not provided.	N/A: not tested
DEP09	Detection and mitigation of	Solution should detect network loops caused by	Wireless-connected APs switch to using Ethernet when connected. There is	Non-network savvy users may connect Ethernet cables in addition to the existing Wi-Fi creating loops and a solution

	network loops	Ethernet cables and use those connections	no packet loss, and latency is considerably reduced.	needs to be able to keep working and, if possible, take advantage of the best path
DEP10	Onboarding clients using Wi-Fi Easy Connect	Guide the user through onboarding client	Test Not Run. Extenders use a QR code and early version of DPP, but support for Wi-Fi Easy Connect clients is not provided.	It is taking longer than expected for Wi-Fi Easy Connect enabled devices to appear in the market. However, Wi-Fi Easy Connect has the potential to greatly reduce onboarding time and end-user intervention. Zero-touch configuration could be provided for service provider supplied equipment.
OPS01	Self-healing in presence of interference	Solution should move its channels away from persistent interference, if possible	Channel does not change on a short-term basis. Channel is selected on startup and may be changed based on predictions from long-term observations.	Whilst it is important that channels with significant interference should be avoided, frequent short-term changes are not desirable, and long-term channel prediction is an appropriate solution.
OPS02	Handle orphaned APs	APs should rejoin the network and get updated configurations if orphaned	AP orphaned by update whilst turned off is automatically re-onboarded after around 2 minutes.	Reacquiring an orphaned AP ideally should be as simple as turning it back on
OPS03	Handling Rogue APs	User should be notified of, and provided guidance for, APs operating in the same network that are not managed	AP with same SSID and Passphrase as test network but not part of the network is detected and reported to the management system.	Reporting that there is a duplicate SSID not part of the network will assist the user to avoid misconfiguring APs and experiencing poor client behavior
OPS04	Client Steering	Solution should guide clients to a better AP/Radio, if one exists	For Band steering, client moved from 2.4 to 5GHz radio and back. 'BTM was seen for the 5GHz to 2.4GHz transition but not the 2.4-5GHz transition. For AP steering, BTM observed for both transitions in both directions between AP1 and AP2	AP and Band steering are important to try to keep the clients associated to the most appropriate radio for good performance.
OPS05	Coordinated Firmware Updates	Solution should handle firmware	System performs a coordinated update of	Ideally a firmware update should have minimal impact on the use of the network, and should be able

		updates in a manner so that end-user is not bothered or impacted	firmware to all APs in approximately 4 minutes.	to happen without user intervention
OPS06	Network Topology Optimization	Solution should be able to optimize its network topology if warranted	APs can be connected and disconnected from the network, and the topology reflects this. Throughput measurements show that the packet routing changes when APs disappear and rejoin.	If the network loses an AP it should continue working if possible. Dynamic changes to topology are important to maintain a stable network in the event of connection failure.
MAN01	End-user Management Smartphone App	Solution should provide an App the shows system performance, status and provides configuration	Topology and connected status of all devices is shown, both wired and wireless. Private and guest networks can be configured and managed - SSIDs and passwords changed, guest network enabled and disabled	Being able to see the network state and control features such as an isolated guest network will be important to some users.
MAN02	Proactive analytics and diagnostics for Operators	Systems provide analytics and diagnostics data over WAN to operator	A remote management system is accessible using a web browser. Topology is updated immediately. Other data defaults to 10min interval. Diagnostics data includes associated clients (including device identification), client Wi-Fi capabilities, firmware versions of APs, channel utilization, operating channels including length of time seen, installation alarms, client warnings, DFS usage, rogue APs, authentication issues, node placement issues, interference, coverage issues	Systems that provide extensive analytics and diagnostics information allow for better proactive management and quicker resolution of customer issues.
MAN03	Topology status and configurability for Operator	Solution allows Operator to see and possibly change network topology	The topology is correctly represented graphically. The network is a fully connected mesh, so change of topology is not relevant. Packets are routed individually.	A fully connected mesh removes the requirement to manage the topology of the network.

Table 3 - AirTies Test Results

5 Discussion of the Results

5.1 What the results show

Fully managed Wi-Fi is a differentiator and systems need to provide the ability to be managed remotely by the operator. Both proprietary and standards-based multi-AP systems can provide the features necessary for operator-managed Wi-Fi in the home.

It seems to be taking longer than expected for Wi-Fi Easy Connect-enabled devices to appear in the market and thus it is unclear when this onboarding enhancement standard will make an impact. However, WPS seems to work well and, while not as secure, provides some physical and temporal security for onboarding.

Certain features are critical for successful Wi-Fi deployments (e.g., initial and ongoing channel selection based on RF environments) while others are important in certain cases (e.g., loop-prevention and detection of unmanaged APs in the LAN).

Operators who are keen on reducing truck rolls and installer time spent in subscribers' homes should focus on systems/features that guide users and installers in AP placement. Support for Wi-Fi Data Elements gives the operator visibility into the home environment and enable notifications to users of network device issues via a smartphone App. Visual feedback of Ethernet connection on APs is important. End-users expect to be able to use a smartphone App to monitor Wi-Fi system status and do some rudimentary control. Systems that provide more advanced control allow savvy users to self-solve some issues.

While topology can be effectively managed locally, operator call-center agents also need the ability to view Wi-Fi KPIs and change topology in case of certain Wi-Fi problems. Steering mobile clients in the home is key to good Wi-Fi user experience and goes a long way to maintaining customer satisfaction.

5.2 Why the results show what they do

There are different levels of multi-AP equipment available to suit a range of markets and budgets. These differences in target market are reflected in the variations in the results. For example, operator-targeted systems must provide interfaces to allow operators to integrate their own back-end systems (OSS/BSS).

There are new and existing standards and corresponding certification programs, such as Wi-Fi EasyMesh, Wi-Fi Data Elements and Wi-Fi Easy Connect, that are starting to work their way into products. Most systems use a mixture of established standards, with proprietary protocols and management systems to achieve their capabilities.

6 Conclusions & Recommendations

Most multi-AP systems are proprietary at present and so it is to be expected that they will all feature differing levels of capability, functionality, and user interaction.

There are different levels of multi-AP equipment available to target the full range of markets, from off-the-shelf self-install and self-administer with limited local management, through to professional install with full remote management capabilities requiring no end-user intervention, and various stages in between.

There are features that a user might like to see in home-orientated multi-AP systems such as Wi-Fi Easy Connect that are not widely available yet. Operators wanting to provide a managed Wi-Fi offering need to pay close attention to both the customers' expectations and their own network management and operational requirements.

7 Next steps for the In-Home Wi-Fi work

In-Home Wi-Fi undoubtedly plays an important role within the telecommunications sector, being a core revenue generator for many worldwide carriers that provide services in the residential domains.

For that reason, WBA Members continue to discuss and strategize ways to help the different types of residential Wi-Fi participants provide an overall better service to end-users. From operators to infrastructure and service providers to research labs, all participate and are welcome to join the work.

WBA originally launched its [Industry Guidelines \[3\]](#) deliverable back in 2019, followed in 2020 and now in 2021 by the comprehensive analysis on [multi-AP needs \[1\]](#), use cases, and performance results for the home domain.

Given the importance of In-Home Wi-Fi for the overall industry, a set of topics are being outlined for an assessment that will take place over the next few months, within the scope of WBA's yearly call for projects.

In-Home Wi-Fi 6E

- One of the first themes immediately raised relates to the expected impact of the 6GHz band within the residential domain. It's an opportunity to provide a cleaner and better service, but that comes with certain questions such as automatic channel selection and how to achieve this in a secure and seamless way.

Wi-Fi EasyMesh Certification

- A second theme relates to the possible limitations of the Wi-Fi EasyMesh certification. The team believes that given the level of proprietary systems being sold in the market,

and available to the end customers, there may be some existing gaps in the Wi-Fi EasyMesh certification that WBA could help identify and solve.

Avoiding interference from residential networks in close proximity

- A third topic discussed by the team focuses on the conflict and overlapping of signals that are frequent in residential buildings. Is there a way to develop a standard or guidelines to avoid friction and noise from different network providers in close range? What would be the criteria to balance and optimize the signal broadcast? Is Wi-Fi 6 BSS coloring an implementable and sufficient solution?

Joint cloud – local control and management

- Another theme is cloud control and management of Wi-Fi. A LAN-local controller is valuable for rapid actions such as station steering. Cloud diagnostics and control can complement a local controller, with long-term historical data and data across multiple residences. A Wi-Fi cloud controller can also easily interface with network providers' other systems. Some interfaces between cloud controllers and local controllers are developing in Wi-Fi Data Elements and BBF TR-181, but are these sufficient and how does the architecture separate cloud and local functions?

Reference architecture for operator managed In-Home Wi-Fi

- Following the previous years' work focused on helping operators providing overall better residential Wi-Fi, and in light of the increased pressure verified in home networks due to post-covid pandemic reinforced applications, it is paramount for the operators to develop and deploy a sustainable managed Wi-Fi home solution.

OpenRoaming for In-Home Wi-Fi

- Finally, another area of possible critical impact is the extension of seamless and scalable roaming capabilities to homes. WBA OpenRoaming™, a federated service that is focused on making the bridge between identity and network providers, on the public and enterprise sectors, can also play an important role within the home domain, not only to allow faster and secure authentication, but possibly to explore community Wi-Fi services.

WBA welcomes your organization to join the discussion, express your thoughts and guidance in any of these or other proposed topics. Please contact the WBA Project Management Office for collaboration pmo@wballiance.com.

REFERENCES

- [1] WBA, “In Home Wi-Fi: Multiple-AP Solutions Trial Use Cases Scope Document,” May 2020. <https://wballiance.com/in-home-wi-fi-use-cases-public-executive-summary/>
- [2] WBA, “In-Home Multi-AP Trial: Test Cases,” March 2021. <https://wballiance.com/in-home-wi-fi-multi-ap-solutions-trial-final-report-executive-summary/>
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ACRONYMS AND ABBREVIATIONS

ABBREVIATION / ACRONYM	DEFINITION
AP	Access Point – Wi-Fi device that provides connections to a Wi-Fi network
App	Application – often used to refer to a program on a Smartphone
BBF	Broadband Forum – A telecommunications standards organisation
BSS	Basic Service Set – the network service of a single AP
BTM	BSS Transition Management
DFS	Dynamic Frequency Selection – a mechanism to avoid Wi-Fi interfering with radar systems
GUI	Graphical User Interface
IoT	Internet of Things
KPI	Key Performance Indicator – (one of) a measure of some aspect of a system intended to reflect the system performance
LAN	Local Area Network – a single local network
MAP	Multi-AP
MDU	Multi-Dwelling Unit – a block of homes
Multi-AP	A single Wi-Fi network with more than one AP
OpenWRT	An operating system widely used for APs
OSS / BSS	Operations / Business Support Systems
QR code	Quick Response code – a 2 dimensional (matrix) barcode
RF	Radio Frequency
UI	User Interface
WAN	Wide-Area Network
WBA	Wireless Broadband Alliance
WFA	Wi-Fi Alliance – a Wi-Fi standards organisation
WGC	Wireless Global Congress
Wi-Fi 6	The 6 th Wi-Fi standard as defined by 802.11AX
Wi-Fi 6E	The 'E' indicates Wi-Fi 6 in the 6GHz RF band
Wi-Fi CERTIFIED™ Data Elements (DE)	Standard from the WFA for formatting W-Fi diagnostics information
Wi-Fi CERTIFIED™ Easy Connect	Standard from the WFA for authorising devices to join a Wi-Fi network.
Wi-Fi CERTIFIED™ EasyMesh	Standard from the WFA for multi-AP networks
WLAN	Wireless LAN – often Wi-Fi
WPS / PBC	Wi-Fi Protected Setup - Push-Button Connection of a Wi-Fi device to an AP

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