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CableLabs®

Mobile Wi-Fi

Making Wi-Fi Work for Users on the Move

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Executive Summary

Wi-Fi has become the ubiquitous means through which consumers and their plethora of clients access the internet and each other—both at home and on the go. As the number of clients within the home and the average sizes of these homes have grown, consumers have increased coverage and capacity by adding more Wi-Fi access points (APs) to their home networks. Consumers routinely shift from the coverage of one access point to another, either within their homes or when moving between home, work, and elsewhere. The study of these motions, however, reveals a significant deficiency in current Wi-Fi operations, namely that the client (smartphone, tablet, wearable, and more) remains connected to an AP well beyond the ability for that AP to serve the needs of that client. This causes tremendous frustration for users, who expect Wi-Fi to roam with the same seamlessness as their cellular handsets.

Mobile Wi-Fi solves this critical issue by creating a virtual basic service set (VBSS) for each roaming client. VBSS is a technology that CableLabs has developed and contributed to standards organizations (Wi-Fi Alliance). CableLabs has also submitted a corresponding reference implementation to the prplMesh project. Control of which access point is assigned the VBSS for each roaming client happens at the access point, not at the end-user client, which allows the consumer client to roam freely, with the controller ensuring the client is connected to the optimal AP and optimal radio on that AP. It also can release the client when the local Wi-Fi network can no longer support its connectivity needs. A key feature of this innovation is that it requires no changes on the client side, allowing it to work seamlessly with legacy clients, such as older model smartphones or existing smart home clients (e.g., robotic vacuum cleaners). Mobile Wi-Fi will improve user experiences in homes, apartment complexes, businesses, and, eventually, in a citywide manner to ensure completely seamless Wi-Fi mobility.

Introduction

When Wi-Fi was first created as a wireless protocol equivalent to Ethernet, Wi-Fi roaming was not even a consideration. The challenges of Wi-Fi roaming did not appear first in the home but, rather, in the office and at similar venues where multiple APs were installed on the same network. Within the last five years or so, many homes have added multiple APs, and this trend will continue. When there are multiple APs on one network with multiple users moving throughout that network using real-time applications over Wi-Fi, there can be Wi-Fi roaming issues.

The number of clients moving about homes and offices, either attached to the person or under their own mobility, has grown exponentially over the last decade. What started as inclusion of Wi-Fi radios on smartphones and music players such as the iPod Touch has expanded to include fitness clients, pet trackers, tablets such as the iPad or the MS Surface, lower priced laptops such as Chromebooks, robot vacuums, home security cameras, smart speakers, and, most recently, VR headsets like the Meta Quest 2. Many of these clients have use cases where they are in heavy active use as users move through their homes or workspaces. Back when the most taxing bandwidth use was something like checking text email on a Blackberry handset, issues with Wi-Fi handoffs were few and rarely noticed by users. Now, as users stream video content as they move through their homes and out the door, or as families use VR headsets or handheld gaming clients in different rooms of the house, these “smart” clients actually exhibit a very unintelligent relationship with Wi-Fi.

1. Understanding the Problem

Simply put, the Wi-Fi roaming problem that we are addressing in this paper is when a client is connected to a suboptimal AP or band rather than the optimal AP or band. For example, as a client is moved around a multi-AP home, it should transition from AP to AP so that it is always connected to the “best” AP. The “best” AP may mean the one with the highest signal strength, but it could also mean the AP with the lowest congestion. The decision to transfer to a better AP is usually controlled by both the client and the network, with the network suggesting an AP transition to the client, and the client acting (or not) on that suggestion. In practice, this leads to a variety of roaming implementations among clients and inconsistent behavior for users. A common problem is when a client refuses to transition to a better AP and remains connected to a suboptimal AP. For example, a client is on a video call over Wi-Fi and the user moves from one room to another, which takes the client from one AP's coverage to another. If the client remains connected to the original AP, the physical distance may be such that it no longer has the throughput to continue the call. Ideally, Wi-Fi roaming would transition the client to a closer AP, but this frequently does not occur. Clients tend to hold onto a particular access point even when it no longer serves the bandwidth needs of the client (a.k.a. "sticky client"). To the user, this appears as a degraded or unresponsive application or experience because of the very low throughput.

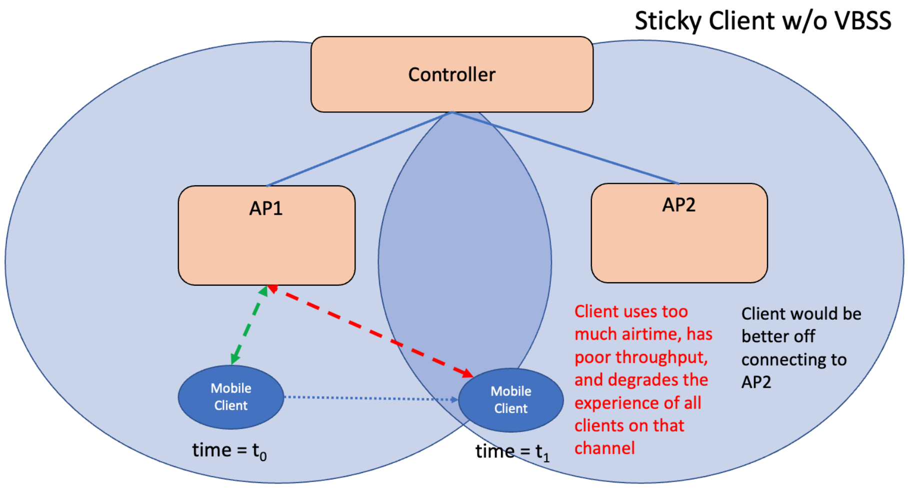

Figure 1. Illustrative Example of the "Sticky Client" Problem

A similar problem occurs when there is no suitable AP to transition to when a client reaches the edge of coverage of an AP. In this case, the best course of action for the client would be to terminate the Wi-Fi connection altogether and switch to a different interface, such as cellular. However, clients often stubbornly cling to a Wi-Fi connection that no longer serves their needs. For example, a user gets in their car while still on the video or teleconference they started at home on their phone and starts to drive away. Instead of switching to the cellular interface, the phone clings to the fading Wi-Fi signal, resulting in a frozen conferencing application.

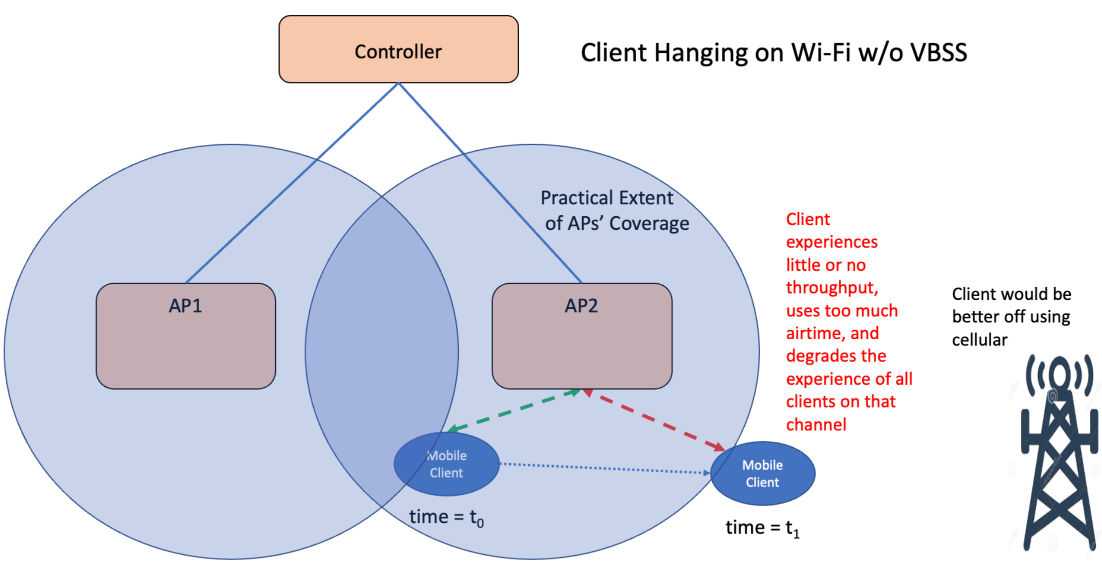

Figure 2. Illustrative Example of a Mobile Client Remaining on an AP Outside of the Wi-Fi's Optimal Coverage

Other optimizations are possible—for example, a client might be better served on the 5 GHz band rather than on the 2.4 GHz band. Though the 2.4 GHz band tends to reach farther than the 5 GHz bands, it is also usually more congested with more overlapping Wi-Fi “cells.” A client will often have a better experience if it is able to connect to a 5 GHz network than if it had connected to a 2.4 GHz network.

These issues affect network operators along with network users. Users tend to blame Wi-Fi problems on the network itself rather than on their clients. As a result, network operators not only lose customer satisfaction and suffer increased customer service calls, but the users also often turn off the Wi-Fi interfaces on their mobile clients, leading to decreased Wi-Fi offload and higher cellular costs and usage for mobile virtual network operators (MVNOs) and mobile network operators (MNOs).

1.1. HarrisX December 2020 Overnight Poll Reports Woes with Extenders

To obtain real-world data on the extent of consumer Wi-Fi roaming problems, CableLabs deployed a survey to Wi-Fi consumers in December 2020, asking a group of almost 2,000 respondents about their experiences and strategies when dealing with Wi-Fi issues, such as dropping clients, bandwidth issues, or connectivity woes, as well as the steps they took to address the issues.

The respondents were split into two groups: those with boosters/extenders (just under 40%) and those without (just above 60%). Overall, more than one in four respondents had issues with their clients being connected to Wi-Fi but having poor or non-functioning Internet connectivity. Almost half of those respondents that have boosters/extenders are represented in this number, indicating that clients are having issues moving between the disparate access points within their homes. More than one in three of the total number of respondents reported poor Wi-Fi experiences, with almost half of those having extenders/boosters.

This survey was done during the height of the COVID-19 pandemic, when a large number of people were working, learning, and playing at home. During this time, as consumers moved around their homes with their handsets, laptops, and other mobile clients, the sticky nature of Wi-Fi clients impacted a significant portion of the population.

Further, of those who experienced issues, one in five turned off the Wi-Fi on their clients and instead relied on their cellular connections, and another 10% connected with their personal hotspots, bypassing their Wi-Fi networks altogether. These percentages were higher for consumers with more than one access point in their homes. Incredibly, these customers were willing to forgo using their home broadband networks in favor of their smartphones because of Wi-Fi issues.

Almost one in four respondents called their service providers when a problem with their Wi-Fi arose. The most common suggestion was to reboot or restart their entire Wi-Fi networks, with more than one-third of respondents resorting to this disruptive practice. Experiences like this bring consumers closer to deciding they can do without home broadband and can rely exclusively on their cellular connections.

When asked what steps they were likely to take in the future with respect to addressing Wi-Fi issues, almost 90% of respondents said they would first restart their Wi-Fi networks. Nearly nine out of ten would restart Wi-Fi on their clients, and more than four out of five would reboot the clients. These approaches can be successful because they force the client to rethink how it is connected to the Wi-Fi network and to reconnect to a more appropriate access point, though restarting the entire network or Wi-Fi interface is clearly a disruptive and arduous experience for consumers. In fact, almost four out of five of those surveyed said they would switch their connectivity to cellular if Wi-Fi issues came up again. In sum, issues with Wi-Fi add friction to subscribers’ lives, increase demand on customer service to solve issues that seemingly disappear and reappear randomly, and increase loads on cellular networks when consumers give up on their Wi-Fi networks.

1.2. Consumer Review Insights Highlight Impacts on Returns and Support

There is also evidence in online consumer reviews of rising frustrations around both Wi-Fi extenders and the standalone mesh Wi-Fi networks. Below is a discussion based on samples of consumer reviews sharing issues that typically led to the customers returning their purchases, driving up costs for retailers and manufacturers alike. These samples came from market leading consumer Wi-Fi retail reviews on the bestbuy.com website.

1.2.1. Wi-Fi Extenders

Among those consumers using extenders, there are stories of devices connecting to the access points but lacking connectivity. Consumers cite routine issues of mobile devices connected to an extender experiencing reduced or “zero Internet capabilities.” Others mention outward indications of “full bars” and extremely slow connections to their phones. In addition to the issues with setting up extenders on existing network, extender issues also trigger client devices to rapidly switch between access points. Consumers report experiences of their phones trying to switch back and forth between the main signal and the extender. Consumers also share that “sometimes a phone will connect through the extender, sometimes not.” These problems are experienced by multiple client devices in the home, not just mobile handsets. Mobile Wi-Fi would eliminate these problems entirely on a home network.

1.2.2. Mass Market Mesh Wi-Fi Router

The advanced mesh Wi-Fi equipment now available is not immune from the issues consumers face when trying to use their handheld devices in dynamic settings around the home. The problems occur when the devices are routinely moved around the home; for example, one user reports their children “having connection issues streaming videos to iPads, laptops and phones.” Restarting access points and turning Wi-Fi on devices off and back on are common yet undesirable remedies used by consumers facing issues that can be addressed by Mobile Wi-Fi. Restarting networks forces client devices to reassociate with the nearest access points, but if the clients and APs are both restarted, the problems can arise again.

The issue is “resolved,” albeit temporarily, when the user turns their client device Wi-Fi off and back on. Doing this forces the device to reattach to the nearest and, ideally, the best access point. With mesh systems, because they all have the same service set identifier (SSID), the user does not realize that their device might be latched to the farthest away access point, knowing only that cycling the device’s Wi-Fi seems to “fix” the problem. Many mobile users report having to “turn off the Wi-Fi at times to allow our phones to work,” relying on cellular backhaul to support mobile Internet experiences. This action not only builds frustration for the users but also increases operator OpEx, using the more expensive cellular systems to support at-home Internet use. Users are further confused when their mobile devices are within close proximity of a known access point, not realizing that their mobile devices are actually connected to farther away, less-than-optimal access points on their mesh networks.

The effects of reviews like these include slower adoption of products, creation of more overhead (from higher support costs) for retailers and manufacturers, increased returns, and other woes. Eventually, retailers work to push these returned, gently used devices back to the manufacturers that then struggle to find new homes for them.

1.3. Significant Numbers of Wi-Fi Users Suffer Unnecessarily

Stickiness to access points creates significant frustration for the end users of Wi-Fi systems. The adoption of Mobile Wi-Fi would not only enable home networks to function as expected, but there would be significant positive impact for the companies that make, sell, and support these networks. The December 2020 poll of Wi-Fi users found that almost 20% of those users that had Wi-Fi issues switched to rely on their smartphone hotspot feature instead of Wi-Fi, opening the way to canceling their broadband service in the future. Based on the consumer reviews, Mobile Wi-Fi would reduce returns and support costs for retailers and manufacturers. MSOs would not only see these benefits but also potentially reduce churn for those users who, as they move through their homes with their Internet-enabled devices, are frustrated that their service seemingly degrades for no good reason.

2. Previous Attempts to Solve the Problem

Ever since Wi-Fi evolved—from a point-to-point wireless equivalent of a wired connection at a desk into a network of wireless access points providing coverage for mobile users—Wi-Fi roaming has been its Achilles Heel. This section details past attempts to improve Wi-Fi roaming.

2.1. Pre-Standard Roaming

From the mid to late 2000's, companies on both sides of the Wi-Fi link (AP and client manufacturers) have seen the need and tried to improve the Wi-Fi roaming experience. Back when most people had just one AP in their homes, businesses were installing enterprise WLANs, and enterprise AP vendors tried all sorts of things to fix roaming, including the two examples described below.

- Distributed antenna systems, which allowed a single AP to cover an entire building, but were deficient in terms of capacity
- Key caching, which could eliminate the lengthy key exchange (but only in some cases)

On the client side, manufacturers have worked to optimize client scanning algorithms to try to reduce the time spent looking for the next AP. Some clients have taken advantage of features of 802.11e, which was introduced to reduce power usage in battery-operated clients. The idea behind doing this was to spend the time that the AP thought the client was sleeping to instead search for the next AP. However, none of these non-standard solutions addressed the indeterminate roaming times that clients still experienced. Eventually, the standards organizations stepped in.

2.2. Standards Organizations Address Roaming

Wi-Fi standards organizations have been working to solve Wi-Fi roaming issues for more than 14 years. In 2008, the 802.11r Fast BSS Transition amendment was introduced, which shortened reauthentication time during movement between APs in a Wi-Fi enterprise security network. Also in 2008, the 802.11k Radio Resource Measurement (RRM) amendment was ratified, which allowed neighboring Wi-Fi clients to report out the networks that were available in a given area. In 2011, BSS Transition in 802.11v was introduced and further refined in Wi-Fi Agile Multiband, which allows APs to suggest that clients move to another BSS. 802.11v BSS Transition was the last amendment to address roaming, but others have been introduced to improve onboarding and initial link connection times (e.g., 802.11ai Fast Link Setup).

Coordination between APs is critical in the decision-making process to determine when and where to steer clients, and solutions already exist to solve this part of the problem. In enterprise environments, WLAN controllers, either local or cloud based, fill this coordination role. In the home environment, there are a few standards for providing this coordination: Wi-Fi CERTIFIED™ EasyMesh, OpenSync, and other cloud-based self-optimizing network (SON) solutions.

With the introduction of both 802.11v BSS Transition and neighbor reports, the messaging is available to significantly reduce, or even eliminate, the time clients would need to spend looking (scanning) for their next AP connections. These did nothing, however, to eliminate the reassociation time when a client agreed to roam. Therefore, problems still exist even with these standards being available.

Though BSS Transition Management, a part of the IEEE802.11v and Wi-Fi Alliance Multiband Operation standards, does attempt to address the key Wi-Fi roaming problems targeted in this paper, it does not go far enough. As mentioned above, the AP can only suggest that a client move to another BSS, and even though the AP can notify the client that it will be forcibly disassociated if it does not leave its current connection, the client can ignore the suggestion and may even attempt to simply reassociate with the previous AP (behavior that we have observed time and time again by clients in our testing). No current standard requires clients to roam to the BSS to which they are steered.

In addition to the problem of getting the client to move when it should, the reassociation time that happens with any roam, including through BSS Transition Management, is still significant and completely indeterminate (30 ms in a best-case scenario to multiple seconds in some situations). Though transition times of under 100 ms are sufficient for most real-time traffic streams (i.e., the user will not notice the communication gap), longer transition times greatly disrupt any activity on the mobile client. In addition, highly latency-sensitive traffic (e.g., mobile gaming) can be heavily impacted by even 50 ms of disruption.

2.3. Virtual BSS

The standards section above focuses on ways to make a client move from a network on one AP to a network on a different AP or radio. An alternative to this is to move the network itself from one AP to another, with the client staying connected throughout the process. This is the concept of a virtual BSS—a BSS that is not tied to a particular AP but, rather, can be moved without the client disconnecting.

The concept of a virtual BSS that follows a Wi-Fi client around actually has already been explored. In 2016, the Wi-5 Project worked on creating an open-source implementation for enterprise WLANs, but sources close to the project say that it suffered from extremely low throughput. In addition, there is a paper that focuses on the personal virtual AP (PVAP) idea, which presented the idea of moving a private BSS around in an enterprise WLAN setup; however, CableLabs could not find any implementations of it.

Both of these previous efforts focused on enterprise WLANs because (1) WLAN controllers are present in enterprise networks to manage the movement of the BSSs, and (2) historically, enterprise networks were the only place where multiple APs on the same SSID were typically installed. However, in an enterprise environment, scalability becomes a problem because of the limited number of BSSs that current chipsets can support (e.g., 16 BSSs per radio). The home is a more attractive target for virtual BSS implementations, given the lower number of BSSs required.

2.4. New Paradigm

In a majority of cases, having the Wi-Fi client itself decide which Wi-Fi radio it should connect to is problematic. The client ends up using more power than necessary scanning for its next, best AP, and it results in a bad user experience. We believe that a new paradigm is required—one that puts the line-powered infrastructure of APs in charge of making sure Wi-Fi clients get the best experience.

3. How Mobile Wi-Fi Solves the Problem

CableLabs Mobile Wi-Fi technology is a VBSS solution that has been developed over the last few years and has reached a certain level of maturity. Mobile Wi-Fi was included in the fifth release of Wi-Fi EasyMesh, and a reference implementation has been submitted to the prplMesh codebase. However, the technology is not specific to EasyMesh and can be used in any multi-AP management system. The technology has been proven to work and is now ready for commercial adoption.

Like other VBSS solutions, Mobile Wi-Fi creates a special VBSS for each client and moves that VBSS across APs and radios as the client moves to ensure the best radio is serving the client. A central controller manages the transitions between APs. The central controller can either run on its own platform or on one of the APs.

Clearly, a VBSS that moves from AP to AP can only serve one connected client. To ensure this, the VBSS not only does not respond to probe requests from clients other than its intended client, but it also uses unicast management and control frames (including beacons) to ensure that only the intended client hears the VBSS.

The life cycle of a VBSS is as follows: a VBSS is created on an AP via a command from the controller. The VBSS initially uses broadcast beacons and responds to all probe requests. Any client can sign onto it, and when a client signs onto the VBSS, the VBSS becomes dedicated to that client, in that beacons switch to being unicast and probe responses are suppressed unless the probes come from the connected client.

Once the VBSS has a connected client, the controller continually decides which AP will best serve that client; the best AP may not be the AP that the client originally signed onto. The controller receives the received signal strength indicator (RSSI) and other information about the client from all nearby APs, not just the connected AP. Using the information that it receives, the controller chooses the best AP, and if it is not the connected AP, then the controller initiates a transition of the VBSS to the new AP. Clearly, if several APs are comparable in their ability to serve the client, hysteresis must be used to prevent repeated unnecessary transitions between APs.

Once a transition is started, the controller

1. retrieves the security context from the source AP and sends it to the target AP,

2. instructs the source AP to turn off block-acks on the connection,

3. creates the VBSS on the target AP (with the client association already in place),

4. instructs the source AP to send out a CSA pointing to the target channel/band (if the target channel/band is different than the source channel/band), and

5. destroys the VBSS on the source AP (without disconnecting the client).

At the end of the transition, the client is unaware that the VBSS is now being served from a different AP or radio, and any network activity that the client is engaged in is not interrupted. There is a small window of time between steps (3) and (5) where the VBSS is present on both APs, but in practice, that window of time is small enough to not cause any disruption. In experiments with a CableLabs VBSS implementation, this window of time was typically 5–10 msecs.

Occasionally, the source and target APs are on different channels or bands. In this case, a channel switch announcement is used to prompt the client to switch from the source channel or band to the target channel or band (this is step (4) above).

To complete the life cycle, when a client disassociates from a VBSS, the controller instructs the AP to destroy the VBSS. Similarly, if the RSSI of the client on the connected AP goes below a useful minimum (indicating that the client cannot get usable throughput on the network), then the controller instructs the AP to forcibly disconnect the client and destroy the VBSS.

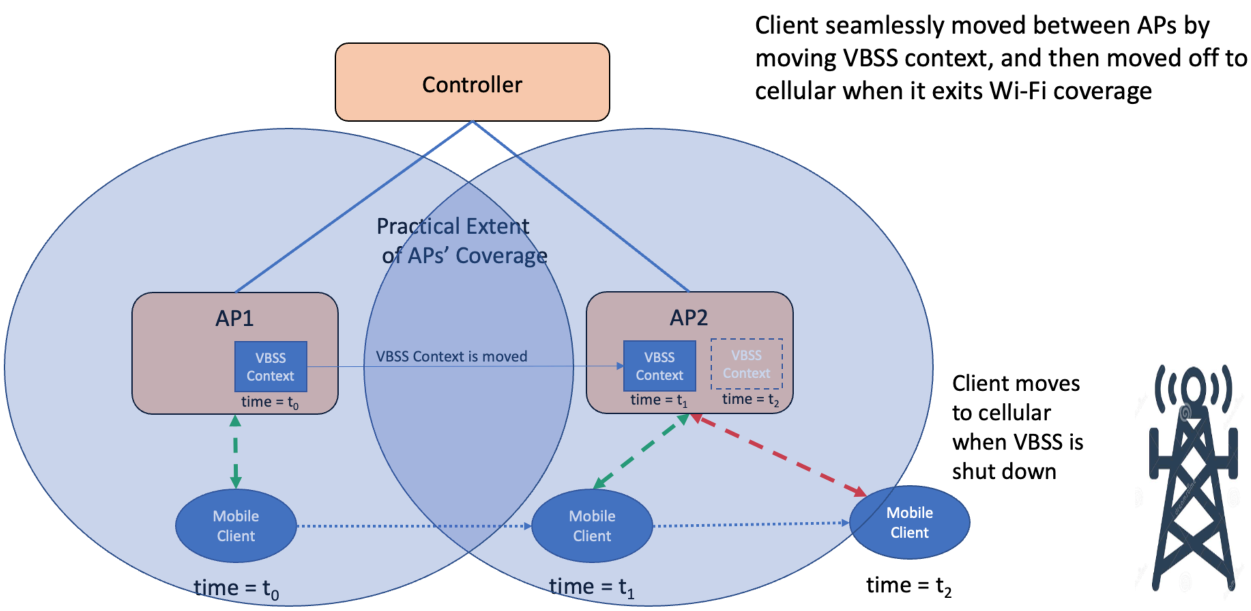

Figure 3. Illustration Showing How the VBSS Is Moved Between APs

Note that the above procedure does not need to associate a client by a fixed MAC; the sign-on process allows any client to sign on. In this way, Mobile Wi-Fi is robust in handling random MAC implementations on clients. This is especially valuable because the clients using random MAC addresses (typically phones) are also those that will benefit the most from the mobility conferred by Mobile Wi-Fi.

Clients using Mobile Wi-Fi enjoy a seamless roaming experience—because the controller controls the roaming, the user's experience is the same, regardless of which phone is being used, unlike previous efforts at Wi-Fi roaming. Furthermore, by keeping the mobile client on the best radio, the client should rarely see the need to go off channel and scan for a better AP, allowing the client to instead go into WMM power save mode and save battery power. This requires no change to the client, as most clients only start scanning if their Wi-Fi experiences go bad in some way.

3.1. How Well Does it Work?

One of our members tested CableLabs' proof of concept in an RF anechoic chamber with a Galaxy S10 smart phone and two 3x3 Wi-Fi 5 APs on which Mobile Wi-Fi could be either enabled or disabled. Their signals could be selectively attenuated in a controlled repeatable fashion because the system had attenuators in line with the APs' antennas. This allowed repeated "roaming" of the phone back and forth between the APs.

The results of the roaming tests without and with Mobile Wi-Fi enabled are shown in Figures 4 and 5, respectively. The top halves of both figures show the RSSI over time for the two APs in the test setup from the view of the Galaxy phone, with AP1 in red and AP2 in yellow. The bottom halves of both figures show a graph of the throughput that the Galaxy phone is able to achieve over time, with a starting value around 60 Mbps. The Galaxy phone starts near AP1 and then "moves" toward AP2. Halfway through the test, the phone starts "moving" back to AP1, away from AP2.

What is apparent from Figure 4 is that without Mobile Wi-Fi, the Galaxy phone gets into and remains in a bad Wi-Fi state, with its throughput dropping to near zero for about 40 seconds, while away from AP1. As the phone "moves" from AP1 toward AP2, the RSSI of AP1 drops off and the RSSI of AP2 increases, yet the phone does not decide to associate to AP2; it remains on AP1, even at an RSSI approaching -80 dB.

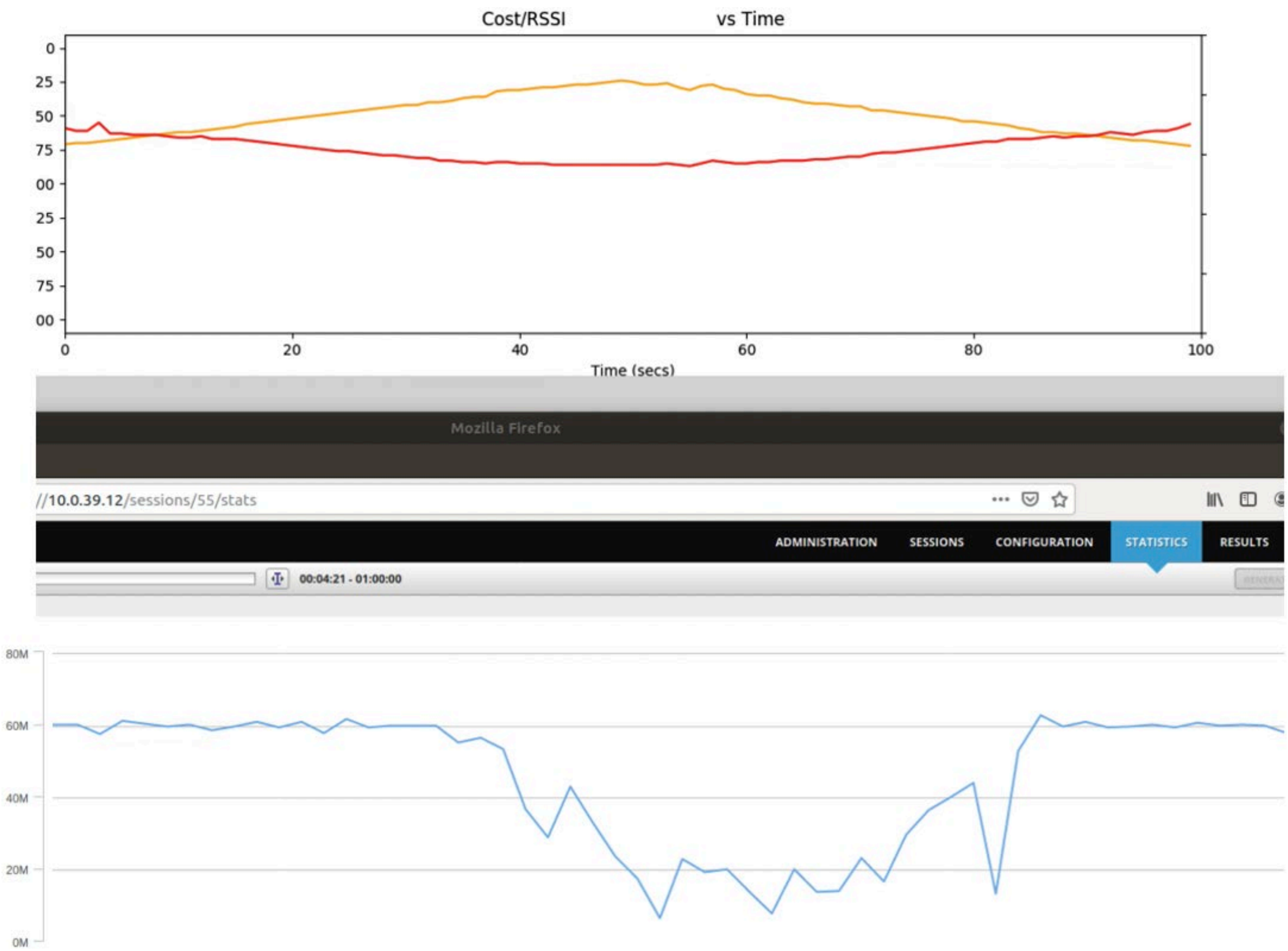

Figure 4. Galaxy Phone Roaming Without Mobile Wi-Fi

Figure 5, with Mobile Wi-Fi, shows a much better experience for the user. The Galaxy phone starts off on AP1, and as it “moves,” the controller transitions the VBSS to AP2. This occurs at roughly t=22, where there is a vertical dotted line on the RSSI graph. The phone continues to move closer to AP2 and farther from AP1. Halfway through the test, the phone starts “moving” back to AP1, away from AP2, and at roughly t=92 (at the second vertical dotted line on the RSSI graph), the controller decides that AP1 is now better suited to serve the phone, and the VBSS is switched to AP1. The throughput graph of Figure 5 shows that the throughput is unaffected by the VBSS transitions, remaining steady with no decline.

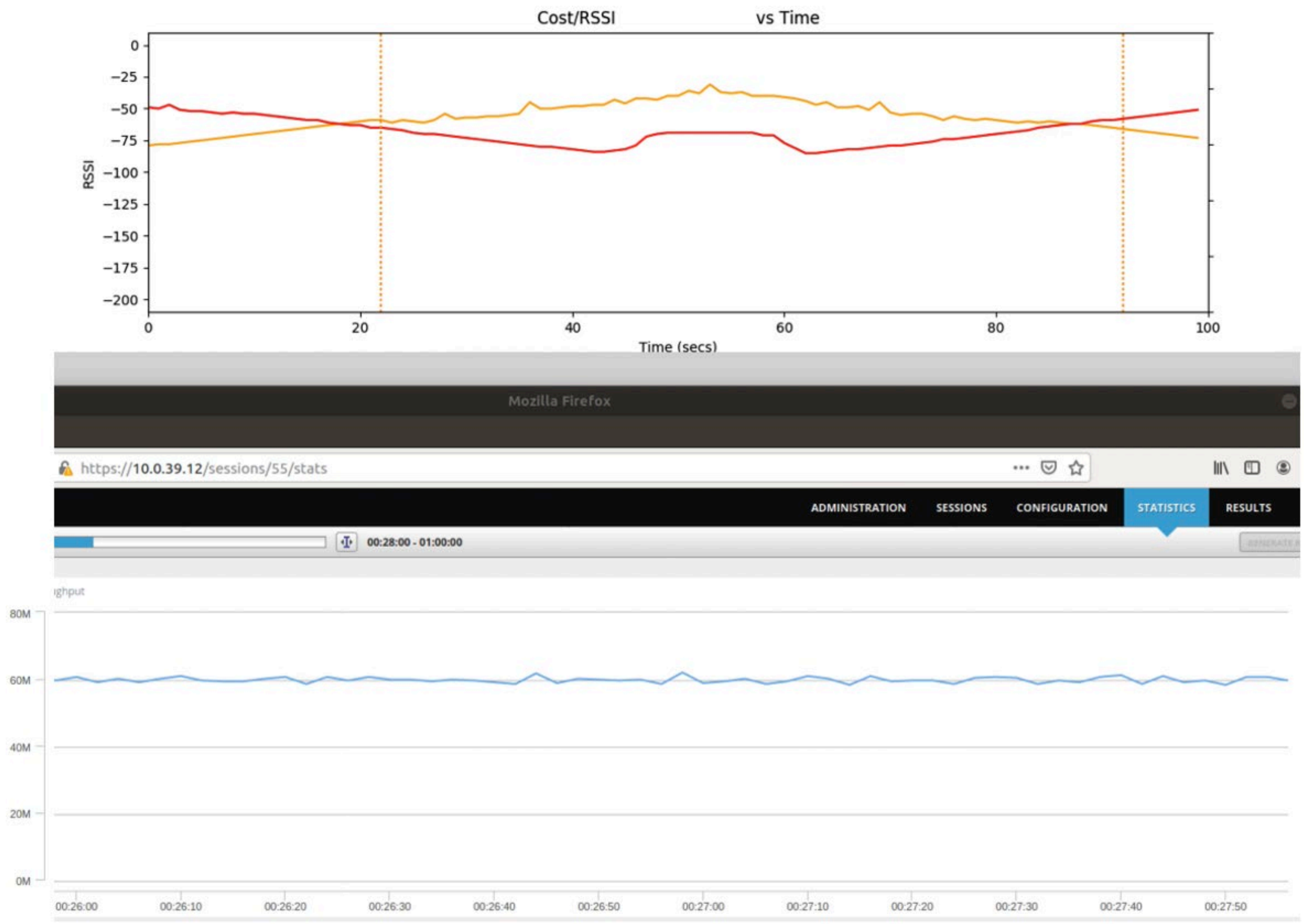

Figure 5. Galaxy Phone Roaming with Mobile Wi-Fi

4. Current State of Mobile Wi-Fi and Next Steps

CableLabs created a Mobile Wi-Fi proof of concept using four Wi-Fi access points running WPA2-PSK security and showed the ability to move mobile clients from one AP to another. A Zoom call was shown to have no dropped audio or video when running on a variety of mobile clients, including iPhone 4/5/6/8 and Samsung Galaxy 6/7/8 phones. BSS transfer time (time from last packet on source AP to first packet on target AP) was shown to be 50 ms or less.

After this proof-of-concept success and discussions with our member and vendor partners, CableLabs contributed the Mobile Wi-Fi technology to the fifth release of the Wi-Fi CERTIFIED™ EasyMesh specification. It was a natural fit, given that EasyMesh manages multiple APs with a central controller. The Mobile Wi-Fi technology is included as an optional feature, termed Virtualized BSSs for AP Coordination. CableLabs joined the prplFoundation and has developed a reference implementation of Mobile Wi-Fi using the prplMesh implementation of EasyMesh. Note, however, that Mobile Wi-Fi is not specific to EasyMesh and can be used in any multi-AP management system.

The concept of virtual BSSs has been introduced a few times into IEEE802.11, and CableLabs will be working toward getting the Mobile Wi-Fi technology into the 802.11 standard. The timing may be ideal, as a number of upcoming new features are focusing on high reliability and multi-AP operation.

CableLabs continues to work with its member and vendor partners to help them see how Mobile Wi-Fi technology would fit into their roadmaps.

5. How to Get Involved

CableLabs is actively seeking partners in deploying Mobile Wi-Fi into the market. We are excited to work with hardware and software vendors, as well as service providers, to understand how Mobile Wi-Fi can deliver on the promise of a seamless whole-home Wi-Fi experience. Though a reference implementation has been successfully created using prplMesh, CableLabs stands ready to support integration of the technology into whatever stack you require to reduce the frustrations your end users are facing with current Wi-Fi solutions. If you are a network operator, CableLabs is delighted to support conversations with your preferred vendor partners to build out your adoption roadmap, learning from our extensive experience in implementing this technology. If you are a vendor for the Wi-Fi market, CableLabs welcomes the opportunity to aid you in integrating this compelling technology, providing you with a competitive edge. If you are part of a Wi-Fi development team and would like to review the reference implementation in prplMesh, you can find it here: https://gitlab.com/prpl-foundation/prplmesh/prplMesh.

Kick off your journey to integrate Mobile Wi-Fi into your architecture and address the serious shortfalls subscribers are suffering from today. You can contact CableLabs Mobile Wi-Fi team lead, Dr. Steve Arendt, at s.arendt@cablelabs.com.