Hitless Topology New Feature Whitepaper

Miguel Vicario

Steve Grau

Plume®

Overview

Your home WiFi environment is constantly evolving.

New devices joining your network, changing activity levels of nearby networks, and even interference from appliances can all impact performance. Plume's cloud-managed system acts as a **diligent monitor,** continuously analyzing these factors (including the appearance and disappearance of neighboring networks and their activity levels) and automatically adjusts your network for optimal performance. In most cases, these adjustments are minor, such as changing radio channels to avoid congestion. However, more complex changes, such as switching the backhaul connection (the high-speed link that carries data traffic between nodes), can occasionally cause disruptions lasting several seconds, which may impact the customer experience.

Plume's new Hitless Topology eliminates most of these disruptions.

Previously, in our deployment in Plume's U.S. cloud, roughly 8% of optimizations in multi-node setups resulted in disruptions. With Hitless Topology, this number drops to less than 1%. This innovative technology allows Plume to keep your network continually optimized, seamlessly adapting to changing conditions, even when new devices with limited capabilities are connected.

Hitless Topology also works hand-in-hand with the Energy Aware Adapt feature.

This new feature allows Plume to achieve significant power savings when the network is not busy[1], without compromising the industry-leading performance Plume WiFi users enjoy.

[1] Energy savings under different levels of network load can be found in the whitepaper "WiFi-6E-Competitive-Testing.pdf"

Before Hitless Topology:
An Optimized WiFi Network Topology

To fully appreciate the advancements represented by Hitless Topology, it is essential to first explore and describe the various sophisticated methods through which Plume already continuously optimizes your network. Plume's cloud-managed system tirelessly monitors your home WiFi environment, analyzing and adjusting for an array of factors.

The simple network shown below illustrates an optimized network topology, operating prior to the introduction of Hitless Topology. It shows a network with one WiFi gateway ("Living Room") and one WiFi extender ("Guest"). Both are referred to as "nodes" in the WiFi network. They are both the Plume SuperPod with WiFi 6E model. Each has three radios, one for each WiFi band: 2.4 GHz, 5 GHz and 6 GHz.

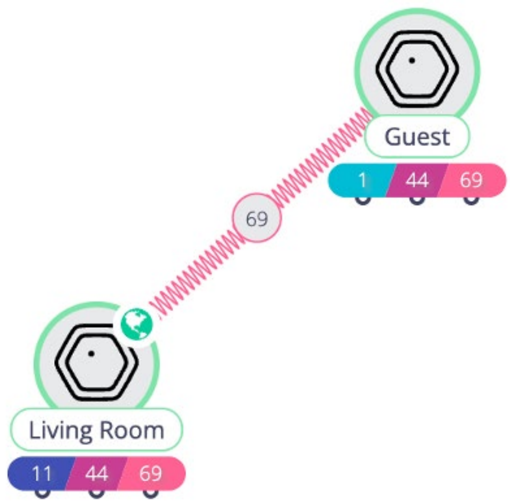


Figure 1: Figure of a 2 pod network. Under each pod we can see the 2.4GHz channel / 5GHz channel / 6GHz channel

Plume's Adaptive WiFi WLAN Optimizer automatically determined the optimal configuration for this network. Here's a breakdown of its choices:

- **Channel selection:** The optimizer tuned each of the six radios to specific channels. These channels are indicated by the colored elements and numbers below the device's names.
- **Front haul:** The optimizer determined which radios would provide service to WiFi devices (called "front haul" radios). In this case, all radios are chosen for front haul service, as depicted by the semicircles below each radio. In some setups with different node models or layouts, some radios might not be used for front haul to avoid channel conflicts.
- **Backhaul links:** These are the WiFi connections between nodes (gateways and extenders) that carry network traffic between the extenders and the internet connection. Since there's only one gateway and one extender in this example, the only option is for the extender to connect directly to the gateway.
- **Backhaul radios:** The optimizer selected the 6 GHz radios for the backhaul connection between the nodes.

Several factors influence Plume's Adaptive WiFi WLAN Optimizer selections, including:

- Physical node placement
- Building structure and materials
- Neighboring WiFi networks
- Sharing of bandwidth between nodes
- Device capabilities

Plume's optimizer leverages advanced cloud-based techniques, analyzing historical and real-time data to make the best choices for optimal service throughout your network.

Here's a breakdown of the specific choices made for the example network:

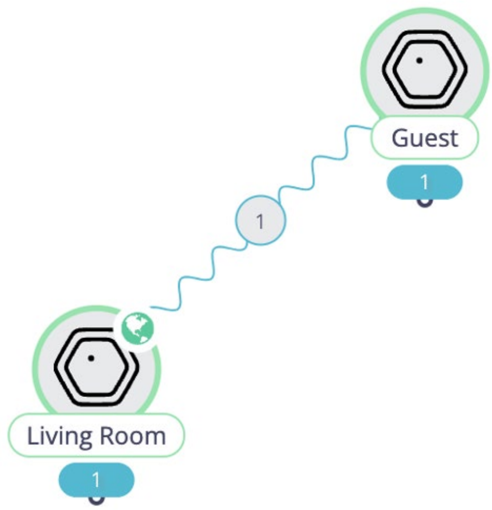
1. **6 GHz backhaul:**
   The optimizer prioritized 6 GHz for the backhaul connection because both nodes have powerful 6 GHz radios with 4 antennas each with wide channel support (160 MHz) and there were no competing networks using this band.

2. **Limited 5 GHz channels:**
   The optimizer limited channel selections in the 5 GHz band due to the presence of a Roku streaming stick with limited WiFi capabilities.

3. **Avoiding interference:**
   To minimize interference, the optimizer avoided channels 157 (5 GHz) and 6 (2.4 GHz) due to high activity from neighboring networks.

An In-Depth Example of Hitless Topology Update

The figure below shows the same network discussed previously but optimized to save power. To conserve power, the 5 GHz and 6 GHz radios were turned off. Consequently, the backhaul link switched to the 2.4 GHz radios.



Hitless Topology makes this power-saving change and the seamless return to optimal performance possible, with minimal impact on network usage. The following steps provide insight into the operations required:

- **Switching to power-saving topology:**
  - Request a topology from the WLAN optimizer that maintains the existing backhaul links but avoids using 5 GHz and 6 GHz radios.
  - Notify clients connected to the Living Room 2.4 GHz radio (channel 11) of an upcoming switch to channel 1 via Channel Switch Announcements.
  - Tune the Living Room 2.4 GHz radio to channel 1.
  - Establish a secondary backhaul link between the 2.4 GHz radios.
  - Adjust backhaul link priorities to transition traffic from the 6 GHz link to the 2.4 GHz link.
  - Disconnect the 6 GHz backhaul link and power down the 5 GHz and 6 GHz radios.
  - Notify all clients connected via 5 GHz and 6 GHz radios of the radio shutdown and steer them to 2.4 GHz alternatives.

- **Switching to optimal performance topology:**
  - Power up all 5 GHz and 6 GHz radios.
  - Request a topology from the WLAN optimizer that leverages all available radios for optimal performance while maintaining the existing backhaul link arrangement.
  - Tune all 5 GHz and 6 GHz radios to the channels specified by the WLAN optimizer.
  - Steer 5 GHz and 6 GHz-capable clients to those radios for improved performance.
  - Establish a secondary backhaul link between 6 GHz radios.
  - Adjust backhaul link priorities to transition traffic from the 2.4 GHz link to the faster 6 GHz link.
  - Disconnect the 2.4 GHz backhaul link once traffic has transitioned.
  - Tune the Living Room 2.4 GHz radio to channel 11 and notify connected clients of the upcoming channel switch via Channel Switch Announcements.

With larger networks, more operations are required but the same basic techniques are used:

- Steer clients away from radios that are being shut down.
- Steer capable clients to radios that have been brought up.
- Use “make before break” and priority adjustment to transition the backhaul links to a different pair of radios without disrupting traffic flow.

Why Update an Optimized WiFi Network with Hitless Topology?

The simple answer is because things change. Even an optimized network needs adjustments to maintain peak performance. Here are some reasons why topology updates occur:

- **Interference from busy neighbors:**
  Imagine a neighbor updating their laptop's operating system, consuming significant WiFi bandwidth. This can prompt your network to optimize for better performance.
- **Network inactivity and energy savings:**
  When everyone's asleep or away, your network can adjust to save energy.
- **Enhanced cloud optimization:**
  As cloud services improve, so too does network optimization. For instance, with better device awareness, the cloud might identify compatible devices and enable more 5 GHz channels for improved performance.
- **Extender changes:**
  The owner of the network might add a new extender or relocate an existing one to ensure optimal coverage throughout their home, especially in poorly covered areas.
- **Radar detection:**
  Homes near weather radars receive radar messages. Regulations require WiFi devices to switch channels when such radar is active, prompting a network update.

With the new Hitless Topology feature, almost all updates occur seamlessly, without disrupting users or applications. Over 80% of previously disruptive changes are now unnoticed by users. Notably, the Energy Aware Adapt feature, which would have required disruptive changes earlier, now functions smoothly thanks to Hitless Topology.

Results

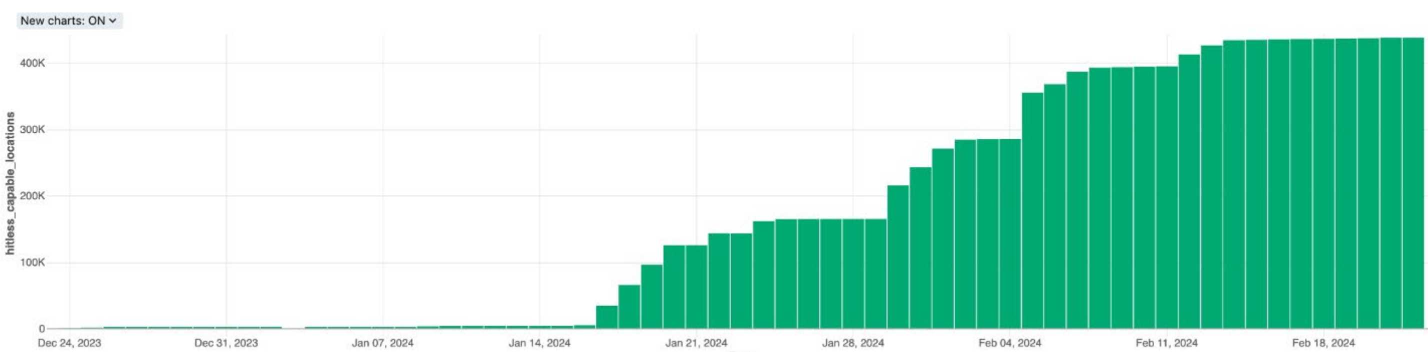
This data reflects Plume's Hitless Topology usage on February 22, 2024. It covers locations with two or more Plume SuperPods (either WiFi 5 or WiFi 6E models) running compatible firmware version 5.8 or later. There are 437,687 such locations, representing approximately 1 million nodes.

Feature Rollout Timing

The cloud software support for Hitless Topology was initially deployed with cloud release 119 on December 13, 2023. The 5.8 firmware was rolled out in stages. The initial pilot began on December 23, 2023, with 460 locations. The majority of the locations were upgraded to 5.8 firmware in four stages, as can be seen in the chart below.

Major Firmware Rollouts

1. January 17 - 25, 2024 increased to ~165,000 multi-node hitless-capable locations
2. January 30 - February 3, 2024 increased to ~285,000 locations
3. February 5 - 8, 2024 increased to ~394,000 locations
4. February 12 - 14, 2024 increased to ~435,000 locations



Reduction of Disruptive Changes

The Hitless Topology Update feature tackles two key objectives: minimizing disruptions to network traffic during topology updates and enabling the Energy Aware Adapt feature to function without requiring disruptive optimizations.

The following chart shows the total number of successful topology updates (green line). The red line shows the number of updates that involved disruptive changes, which means the backhaul connection (the high-speed link between Plume devices) was temporarily interrupted.

In late December, approximately 8% of successful updates were disruptive. This was before nearly all locations had been updated with hitless-capable firmware. The red line shows a steady decline over time, corresponding to the rollout of the new firmware. As more locations received the update, fewer topology updates resulted in disruptions.

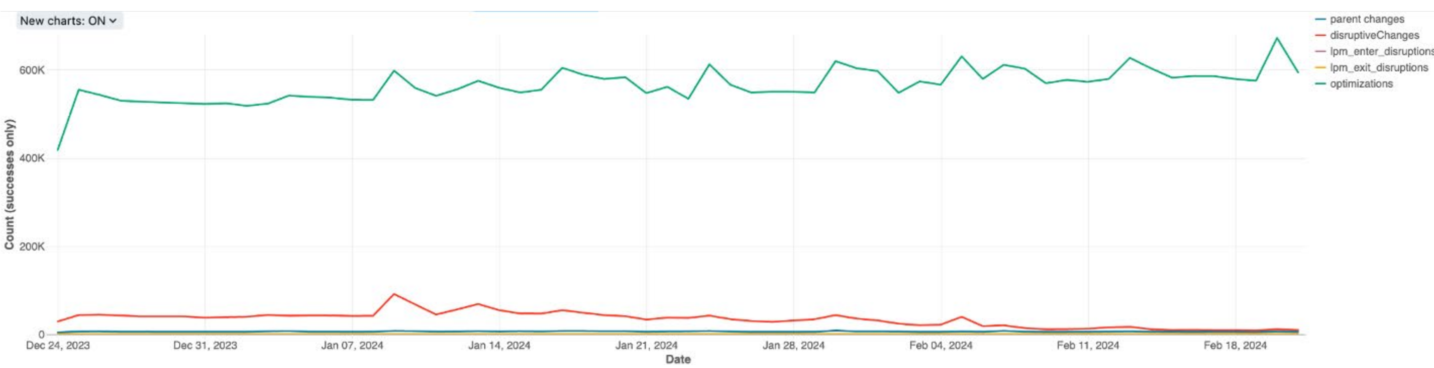


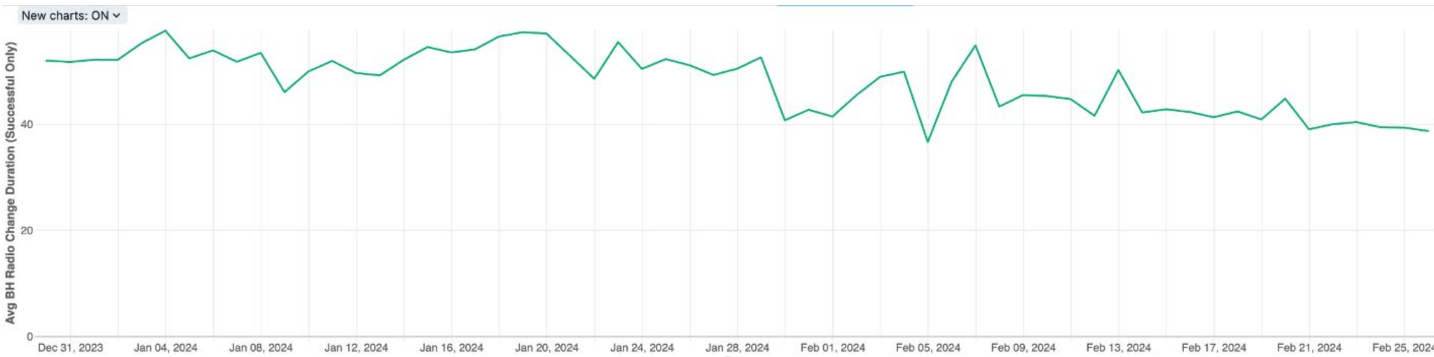
Figure 2: Graph showing the reductions of disruptive optimizations in the network

At the right end of the chart, the disruptive line trends towards the "parent change" line. This is expected because topology deployments involving a parent change (switching a child node's backhaul connection to a different parent node) are still disruptive. In contrast, Hitless Topology Change seeks to maintain seamless updates for all other topology adjustments. Future plans aim to eliminate unnecessary parent changes, further minimizing disruptions.

It's important to note that the disruptive update line and the parent change line aren't perfectly aligned in this chart. This is due to a few identified issues that require cloud software and firmware updates. These updates hadn't been deployed yet when this document was written.

Reduction in Topology Deployment Time

The chart below shows the average time (in seconds) for network updates using Hitless Topology. This applies to situations where the backhaul links stay between the same nodes but some or all of the links switch to different radio bands. For example, the backhaul might move from the lower 5 GHz band to the upper 5 GHz band on the same two nodes or vice versa.



The chart shows there has been approximately 25% reduction in topology deployment time from an average of 52 seconds to an average of 39 seconds.

Synergy with Energy Aware Adapt

One of the major benefits of Hitless Topology is that it enables the Energy Aware Adapt feature to function without causing user disruptions, as shown in Figure 2: Graph showing the reductions of disruptive optimizations in the network in order to save energy. Energy is saved by powering down radios when the network is not busy. For example, when users are sleeping. To do this, backhaul connections between nodes must be moved to different pairs of radios between the same pair of nodes as radios are powered up and down. These types of changes would be disruptive without Hitless Topology Update.

The Energy Aware Adapt feature, deployed in Gamma during the same timeframe as Hitless Topology, includes many of the locations analyzed here. As shown in the previous chart, the total number of daily optimizations (green line) has steadily increased throughout the period. This rise can be partly attributed to Energy Aware Adapt. Notably, this increase coincides with the decreasing trend of disruptive topology updates.

Conclusion

Plume's new Hitless Topology is a game-changer, reducing over 80% of disruptions that previously occurred during network optimizations, as shown in Figure 2: Graph showing the reductions of disruptive optimizations in the network. This innovative breakthrough allows Plume to keep the network optimized at all times, adapting to changing conditions seamlessly.

Hitless Topology also paves the way for significant energy savings. By adapting to network usage patterns and activity, Plume can optimize power consumption by automatically transitioning clients between different energy-efficient network configurations.