The Plume Adaptive WiFi™ Advantage

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ABSTRACT:

Wi-Fi is the predominate way we connect to the internet and access our mobile digital lives. Customer experience is directly proportional to the speed and reliability of the Wi-Fi connection, and the mobility of devices we use to consume content requires Wi-Fi to reach every corner of the home. Traditional centralized Wi-Fi routers fail to provide adequate coverage for the whole home, and accompanying Wi-Fi repeaters or extenders fail to reliably extend the Wi-Fi connection. In order to completely solve the Wi-Fi problem, a new architecture is required. This architecture requires a deeply distributed Wi-Fi access network with a centralized, intelligent controller to manage the delivery of Wi-Fi speed, reliability, and coverage. Each network must be customized for each customer's home size, environment, and usage-based on current client device usage and historical insights of customer patterns. The benefits of such an architecture, called Plume Adaptive WiFi, are compared against traditional Wi-Fi systems and also against newer mesh-based Wi-Fi systems.

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Introduction

Today, in their homes, people are consuming ever more content, interacting via richer communication mediums, and relying on various internet-delivered applications and services to make their lives more comfortable and safer.

Led by the emergence of HD and UHD video-on-demand and IoT connected devices, consumers are using the corresponding applications and devices at even more places in the home, and Wi-Fi is becoming the standard way these devices and applications are connecting to the internet. The broadband internet connection available in most homes today is extremely reliable and consistent with 99.9% uptime, moreover, the upstream infrastructure and resources–compute, storage, CDN, DNS, and other cloud platform services–are even more reliable with a 99.99% uptime. However, today, the consumer internet experience in most homes is often frustrating with choppy video, dropped sessions, and inconsistent speed. This problem is largely due to the Wi-Fi network inside the home, the last few meters of the connection. Some of the key factors of this inconsistent performance are wireless interference, congestion, coverage impairments, and device (mis)behavior.

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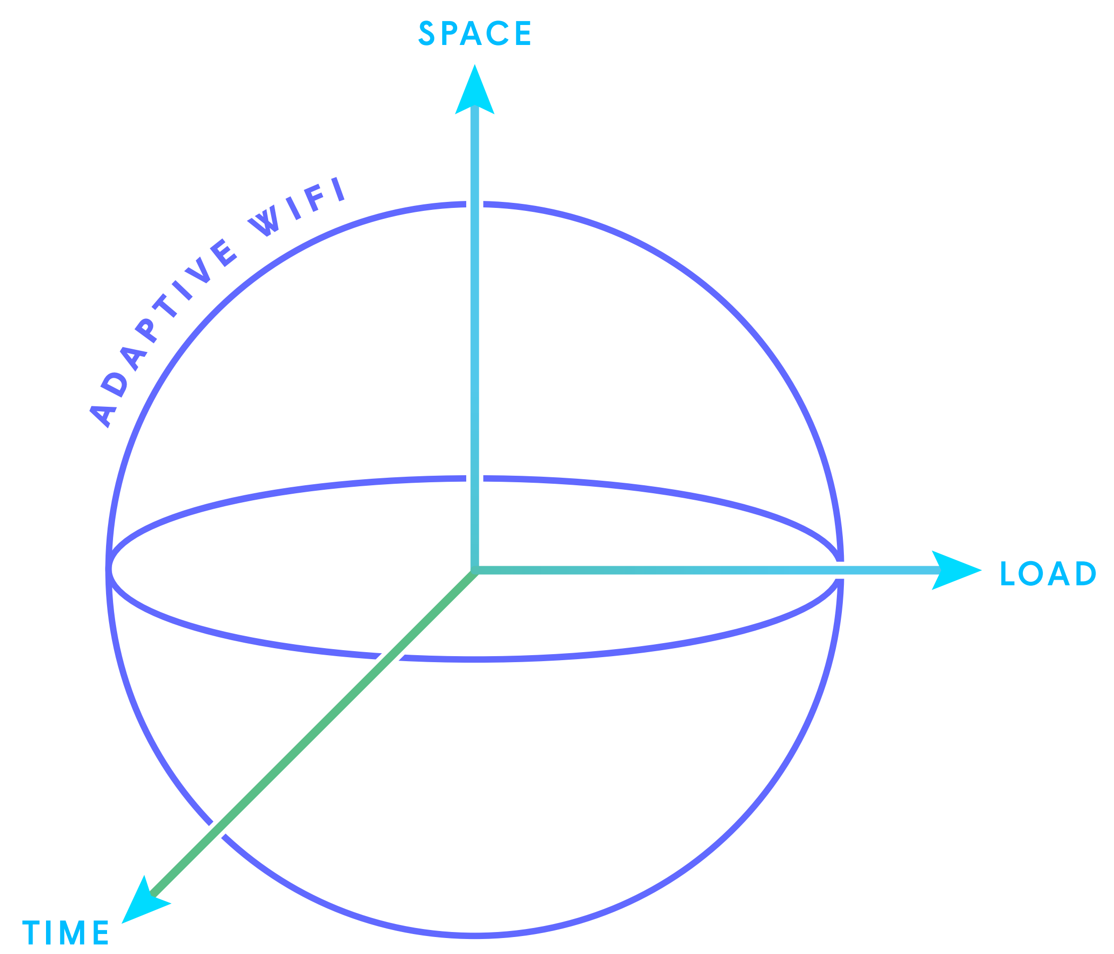
Today, home Wi-Fi works well only in some places, some of the time.

Current systems focus development and marketing efforts on performance in terms of single application speeds and feeds without close regard to the requirement for a high-quality experience across many simultaneous applications through whole-home Wi-Fi coverage. Bringing a high-performing, consistent, and reliable Wi-Fi experience to every corner of the home requires a completely new architecture and delivery model which we call Plume Adaptive WiFi™. Plume Adaptive WiFi adds the space and time dimension to high-performance Wi-Fi, as illustrated in figure 1, by replacing or complementing the centralized home router with a set of distributed, cloud-controlled, simple-to-install Wi-Fi nodes or Pods[1]. These beautiful and small Wi-Fi access points are placed at optimal locations around the house. While traditional Wi-Fi is centralized and static, relying on local control, Plume Adaptive WiF is deeply distributed throughout the home and delivered as a cloud service that continuously adapts to the needs of the home and its occupants.

1 The term “Pods” is used to refer to the complete ‘family’ of Plume’s Wi-Fi access points including Pods, PowerPods™ and SuperPods™.

1



PLUME ADAPTIVE WIFI DIMENSIONS

While traditional Wi-Fi is centralized and static, relying on local control, Plume Adaptive WiFi is deeply distributed throughout the home, and delivered as a cloud service that continuously adapts to the needs of the home and its occupants.

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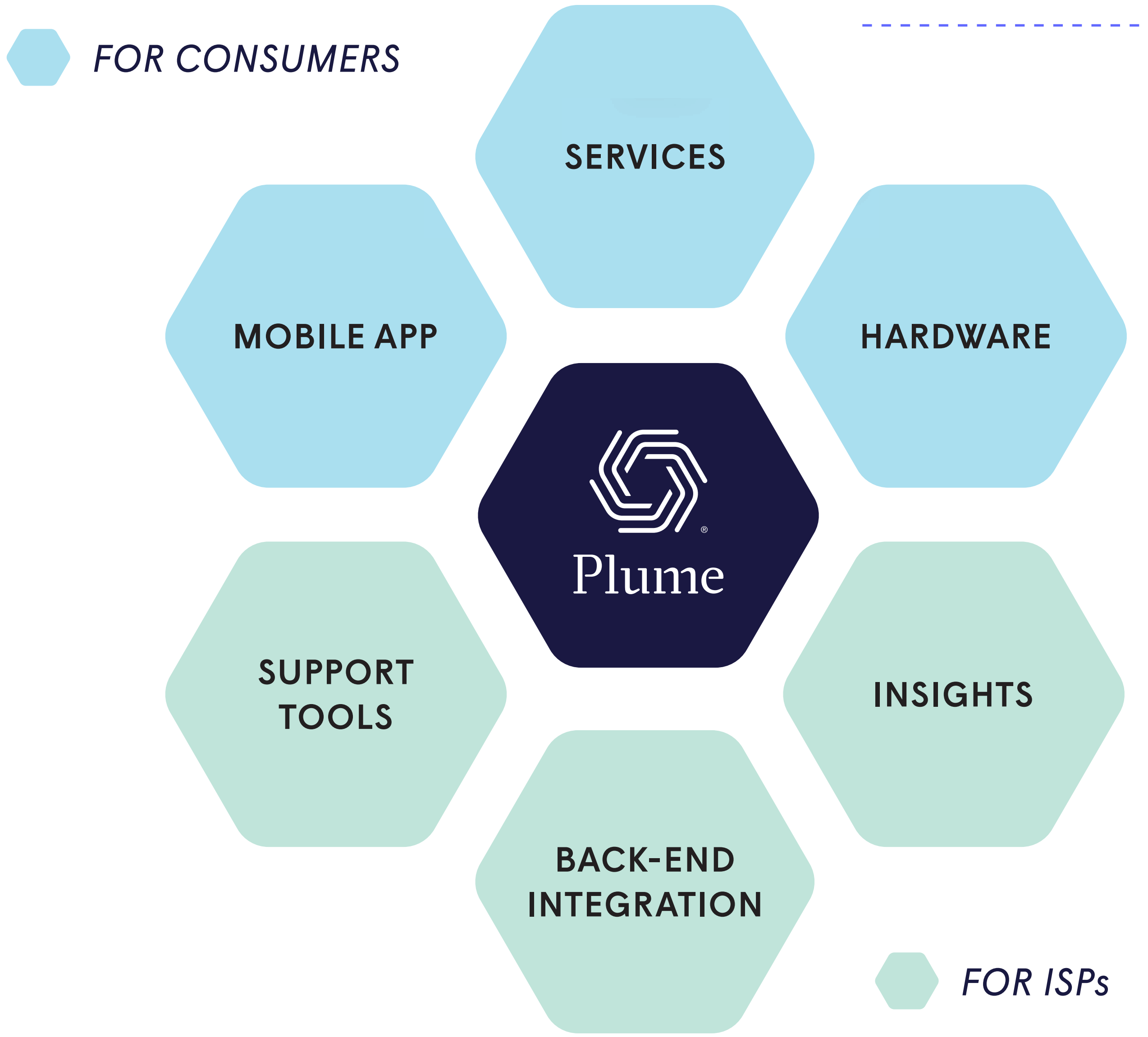
Beyond the consumer, there are many others with a vested interest in high-performing, consistent Wi-Fi around the home:



SERVICE PROVIDERS

The over-the-top Service Provider (OTT-SP) ecosystem relies increasingly on consistent, high-performance Wi-Fi for adequate delivery of their content, customer satisfaction, and retention.

MSO & TELCO SPs

As the “last few meters” of their broadband access infrastructure, the MSO and Telco SPs need managed, high-performance, and consistent home Wi-Fi for delivery of video-over-wireless, data, and other services to a multitude of wireless devices.

IoT & SMART HOME DEVICE MAKERS

The rapidly emerging IoT and Smart Home category requires Plume Adaptive WiFi as a fundamental enabler to handle the growing number of connected devices consistently and reliably. The distributed nature of Plume Adaptive WiFi ensures that the distance (range) between IoT devices and the home infrastructure is always short. Such an architecture is critical for IoT devices which are small and low-powered, and cannot afford to transmit signals all the way across a home to a single Access Point (AP). Easy and secure onboarding, configuration of smart devices, and reliable connectivity for data collection are core elements of the Plume Adaptive WiFi architecture.

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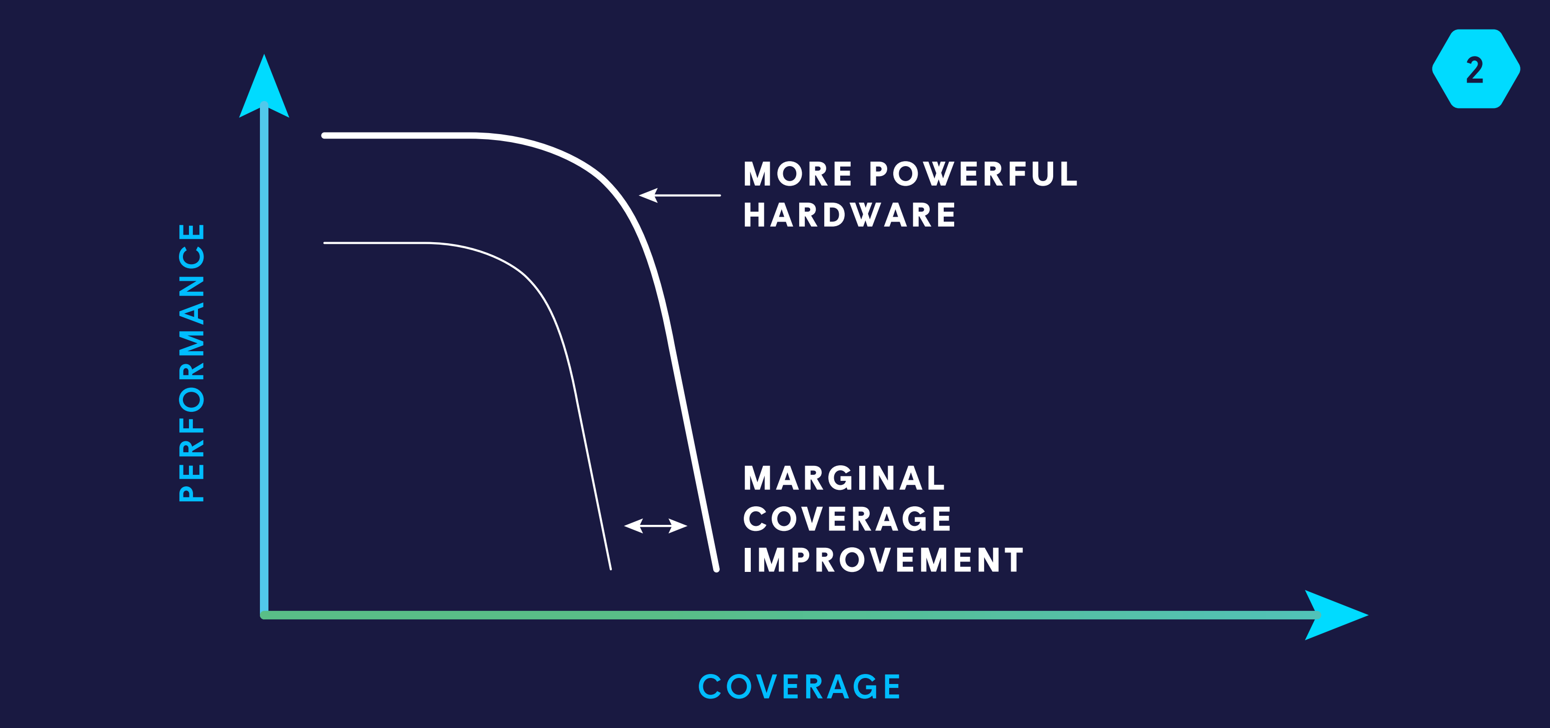
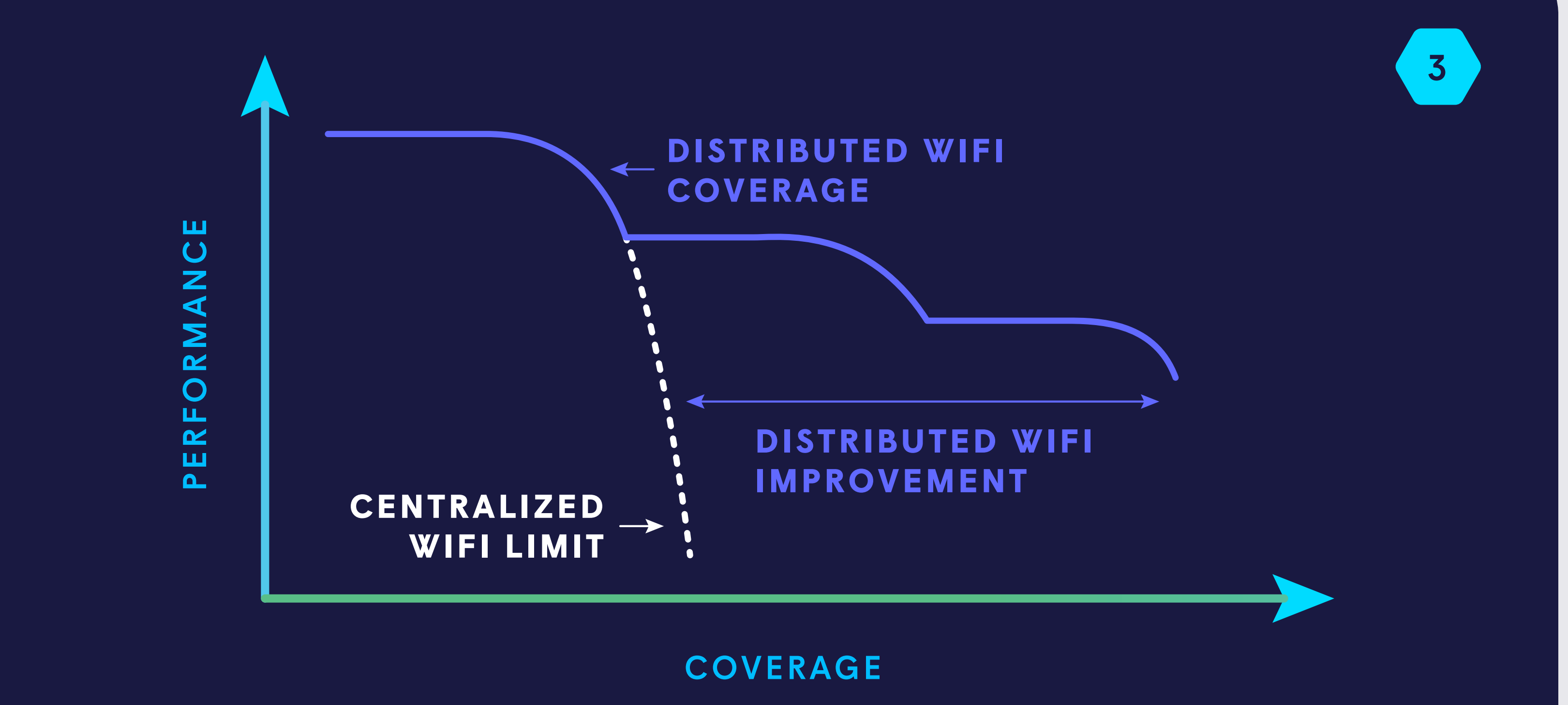
Design Approach

Why is Plume Adaptive WiFi distributed?



COVERAGE IMPROVEMENT WITH SINGLE WI-FI ROUTER HW IMPROVEMENT



COVERAGE IMPROVEMENT WITH DISTRIBUTED WI-FI SYSTEM

Wireless signals degrade with distance, more so when passing through walls made of common construction materials. This attenuation is particularly dramatic if the walls are brick or stone (common in Europe), contain wire mesh (traditional plaster), or metal foil (common in insulation in newer homes). The wireless signal corresponding to the Wi-Fi 11ac and 11ax standard degrades even more rapidly with distance since it uses the 5GHz spectrum as compared to the 2.4GHz spectrum used by earlier, slower versions of the standard.

As the consumer is starting to use ever-increasing bandwidth-hungry Wi-Fi devices at more and more places in the home, the approach taken by the high-end routers is to use increasingly powerful hardware in the router in the hopes of driving the Wi-Fi signal to more places in the home. More powerful hardware means using more radio chains (antennas) with sophisticated signal processing (MIMO) and higher-power amplifiers to generate a stronger signal. This approach leads to higher cost, size, and consumption. In addition, very few client devices are able to fully use the MIMO capabilities. In all cases, the increase in range that can be achieved this way is relatively incremental and reflects diminishing returns for larger increments in power and complexity. Figure 2 above shows the resulting improvement in coverage achieved by such higher-end routers. As distance increases, the rate of performance of the Wi-Fi signal is greatly diminished, and expensive increases in signal power and parallel transmissions provide only marginal Wi-Fi performance at distance.

Figure 3 above highlights a more sophisticated distributed Wi-Fi approach, in which coverage is improved by sprinkling the smaller, lower power AP hardware (Pods) across the home.

The Wi-Fi signal is forwarded across the Pods optimally placed around the home to reach all clients. With a sufficient number of Pods (depending on the size of the home), the Wi-Fi signal never needs to travel very far between Pods, or from the last Pod to the final client device. By substantially shortening the distance the Wi-Fi transmissions need to travel, this solution dramatically reduces the degradation of the Wi-Fi signal, allowing substantially higher data rates throughout the entire home.

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A distributed Wi-Fi system has several advantages over a single router:

With a single router, the Wi-Fi performance at different places in the home will vary based on the placement of the router since there is only one way for the signal to get from the router to a given client. With a distributed Wi-Fi system, the signal can take several paths to get to the client, and therefore the system can be optimized to choose the most effective path.

MAXIMIZE CONFIGURATION

Most Wi-Fi clients (e.g. phones, PCs, TV boxes, IoT devices) use one or two antennas and do not benefit from the >4 radio chains built into the most powerful routers. A distributed Wi-Fi system can use a similar radio configuration as supported by clients to avail a significant cost advantage without losing performance on the client connection speed.

MULTIPLE PODS, ANY NUMBER OF CHANNELS

A centralized Wi-Fi router can only use a limited number of channels, and those channels have to bear the load for all the clients on the home network. The multiple Pods of a distributed Wi-Fi network can operate over any number of channels, thereby spreading the radio spectral load without causing interference. The distributed network also benefits from load balancing, allowing clients to be distributed among the multiple APs in the home, relieving congestion in the AP to client links.

MU-MIMO TECHNOLOGY IS LIMITED

Some of the recently launched 11ac wave2 routers use MU-MIMO technology to allow a single router to send traffic to multiple clients in parallel by using different subsets of its multiple radio chains. Similarly, upcoming 11ax routers will use OFDMA technology to communicate with multiple devices in parallel. However, the resulting capacity increase is modest due to operating in the same channel from the same radio when compared to the significant capacity gain achieved from separating the multiple radios of a distributed Wi-Fi network in frequency and space. MU-MIMO gains are further limited by the fundamentally fragile nature of the nulling based technology.

LEVERAGE SOFTWARE TO MANAGE COMPLEXITY

The proliferation of Wi-Fi nodes, or Pods, throughout the home provides large degrees of freedom for traffic routing between the end-device and internet gateway connection. The number of potential connections between nodes increases by N(N-1), greatly increasing the ability to deliver a reliable, high-performance Wi-Fi service.

Distributed Wi-Fi networks are more complex to configure and manage, specifically to deliver the optimal performance commensurate with their capability. This complexity is best handled with a centralized software entity with knowledge across the entire network. In essence, a distributed Wi-Fi approach achieves a superior wireless system by shifting the complexity from hardware to software.

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What are the pitfalls of Wi-Fi repeaters or mesh?

Wi-Fi repeaters can be used to extend coverage similar to the distributed Wi-Fi approach, but repeaters act as independent nodes and do not coordinate with the central router or other repeaters (nodes) in the system. Therefore, unintelligent repeaters cannot adapt to the changing needs from the wireless network and can only be used to boost (repeat) the signal from the central router. Some Wi-Fi repeaters repeat the signal on the same channel, thereby reducing the overall capacity of the network by introducing self-interference. Even in the case where a repeater attempts to repeat the Wi-Fi signal onto a different frequency channel, it requires sophisticated management by the user to optimize performance. Any configuration created by the user will be a single static configuration, unresponsive to changing conditions or interference from neighbors. Moreover, in traditional repeater-enhanced Wi-Fi networks, the selection of the connecting Wi-Fi node per client device is completely controlled by the client.

Devices operating on their own free will often not choose the path of maximum performance. For example, customers can experience extremely poor performance when clients "stick" to a distant repeater rather than connecting to the nearby router. Finally, coordination of changes in the Wi-Fi network, such as channel or SSID changes, are hampered by the lack of a centralized authority. Typically, consumers changing their Wi-Fi network name or password end up in a tangle of reboots, disconnected devices, and partially connected networks. In net, the use of Wi-Fi repeaters or extenders to increase range often leads to inconsistent results and often lessens the performance of the network.

A new class of Wi-Fi products form a mesh network to coordinate with each other to increase the Wi-Fi range. Current mesh routing protocols are designed to provide reachability of traffic between mesh nodes, only ensuring that the traffic makes it to the internet gateway in some way. This focus of mesh routing on the survivability of the backhaul traffic between mesh nodes largely ignores the routing demands of the connected devices. These unsophisticated routing protocols do not address application performance or wireless network capacity to achieve the desired customer QoE. In fact, most mesh systems available today operate on a single channel backbone thereby significantly limiting the overall capacity while being prone to self-generated interference. Additionally, the locally managed traditional distributed control plane mesh routing architecture increases the complexity of each individual node making it difficult to continue to add capabilities by adding additional nodes and routes to the mesh system.

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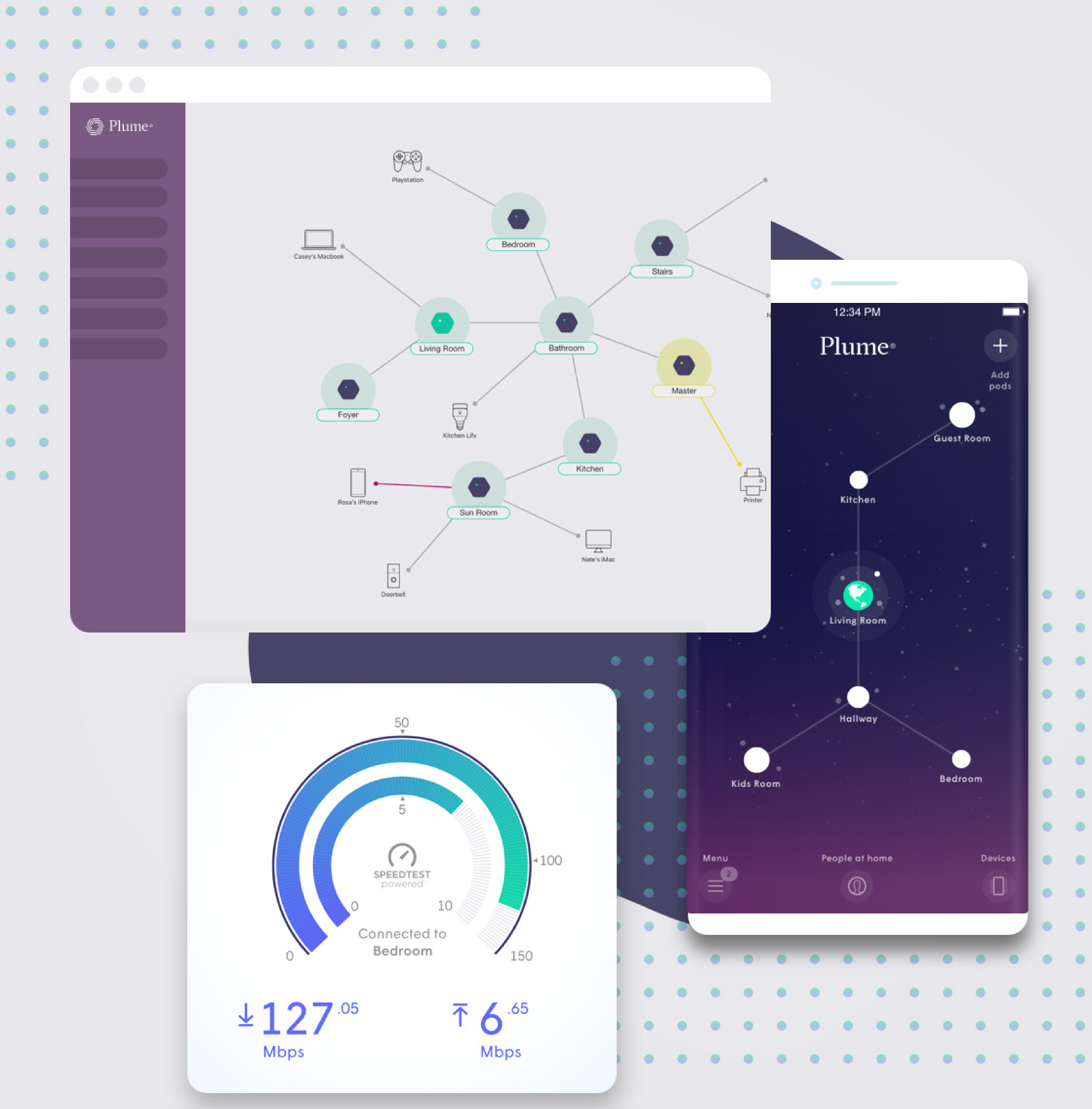
How is Plume Adaptive WiFi different?

The Plume Adaptive WiFi system continuously adapts to the environment and user behavior to optimize the overall network capacity and application performance.

Some of the differentiating aspects of Plume Adaptive WiFi compared to repeater or mesh systems are:



- Continuous monitoring and avoidance of interference from neighboring networks
- Leveraging multiple, non-interfering channels to operate the network routing paths thereby increasing capacity
- Routing algorithms designed to balance the network load, maximize the network capacity, and optimize end-application performance based on client device requirements
- Traffic shaping/prioritization for application-level performance
- Ability to optimize network performance by steering clients to different Pods in the system consistent with the optimized route topology
- Fast client hand-off across nodes for application survivability and quality of experience

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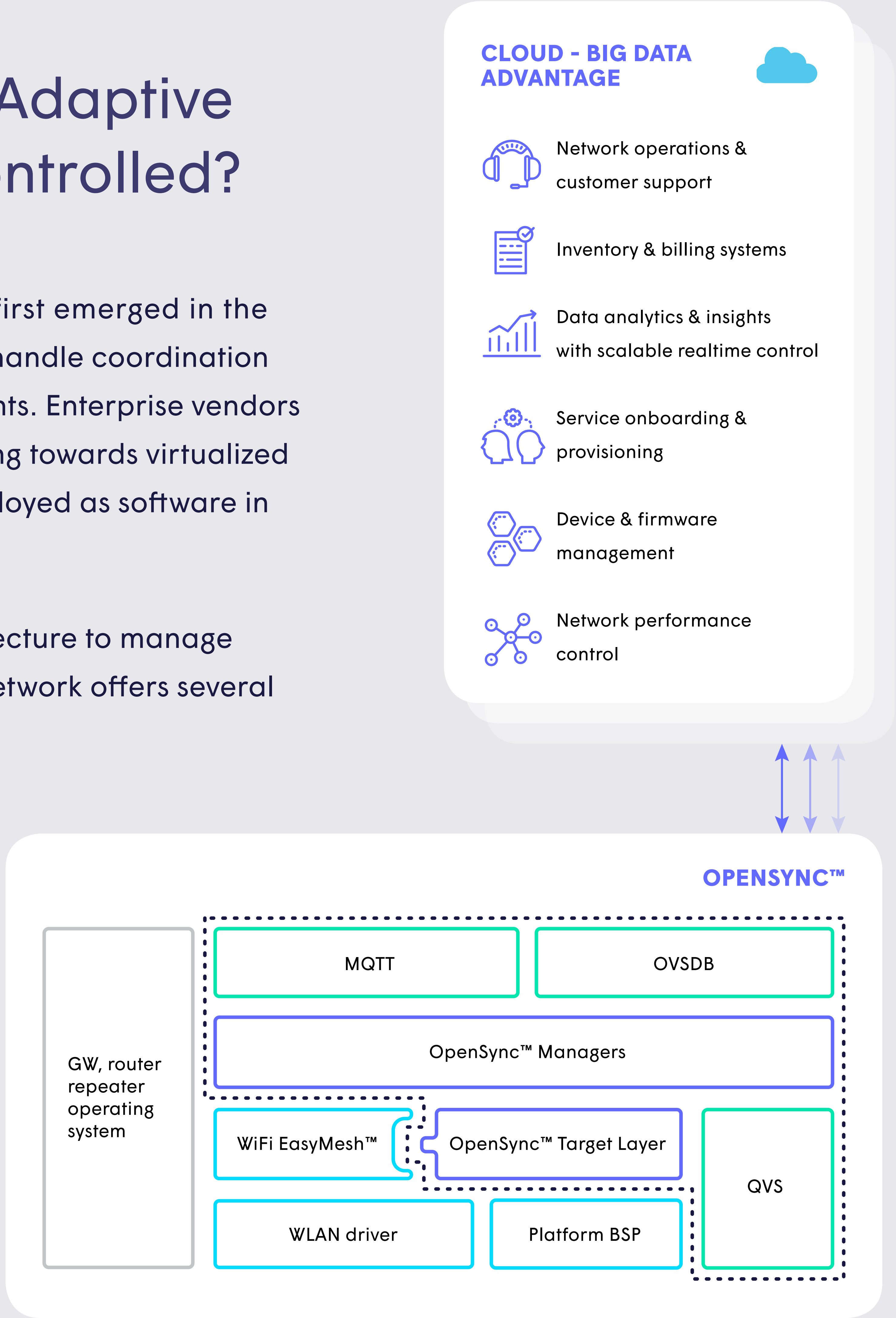
Why is Plume Adaptive WiFi cloud-controlled?

Wi-Fi network controllers first emerged in the enterprise environment to handle coordination among multiple Access Points. Enterprise vendors have been steadily migrating towards virtualized controllers (controllers deployed as software in the cloud).

Leveraging a similar architecture to manage a distributed Wi-Fi home network offers several advantages:



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CLOUD-BASED NETWORK-AS-A-SERVICE STACK

- Centralized management simplifies coordination among distributed nodes, and can more readily apply global optimizations across multiple customers. These optimizations can span large apartment complexes, or even entire regions of cities.
- Similar to channel frequency and bandwidth assignment, the assigning of client devices to Pods (client steering) can be done more effectively with a centralized global view of the network including all client devices.
- Roll-out of new features and services is simpler, faster, cheaper, and less risky by updating the centralized cloud controller, without having to update the firmware on the in-home devices themselves.
- Network stability issues are eliminated with a centrally controlled network. Optimization is performed in the cloud, the result is configured in the network, and the network will remain in that state until the cloud decides to modify the configuration. This alleviates the problems experienced with distributed mesh systems in which each of the nodes are running independent algorithms, making localized decisions with arbitrary timing, thereby creating inconsistent and unpredictable network behavior.
- A cloud-based management system is able to aggregate data from many homes for analysis and learning. Improved methods for network optimization, client behaviors and bugs, and typical device/user patterns and behaviors can be extracted from such a cloud-based centralized database.
- The compute, storage, and memory complexity of each individual node is reduced, making the nodes smaller, less power-hungry and easier to develop and deploy. The cloud, with virtually unlimited compute power and memory, can run arbitrarily complex algorithms to learn and optimize.

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What are the key attributes of our user-focused design?

As a consumer electronics product, end-user experience is the most important design aspect. An easy and intuitive installation process including the onboarding of nodes is critical. The Plume Adaptive WiFi solution is mobile-first, enabling customer action through iOS and Android applications.

In designing the application and flows, the focus was placed on the consumer activity rather than packaging the system mechanisms. For the first time in consumer Wi-Fi, customers are in control over the performance of, and access to, their home Wi-Fi. Cloud-enabled features such as one-touch guest network access, remote performance monitoring and troubleshooting, IoT device auto onboarding, parental controls, and advanced AI security are features which can be continuously rolled out via the cloud platform over the life of the product without having to compromise due to legacy local controllers or hardware.

Plume Adaptive WiFi shifts the focus of wireless performance from the prevalent speed and feeds paradigm to one focused on the quality of the user experience. As such, focus is placed on whether the consumer can get the internet performance he/she requires everywhere in the home. Plume Adaptive WiFi ensures application performance, reliability, and coverage through cloud-controlled network optimization on a continuous basis.

Visibility and support is the third key attribute of a great consumer Wi-Fi system. The consumer is provided beneficial performance metrics, status indicators, and data insights for each client device and the internet connection with in-app troubleshooting to assist with inquiries when things are not working well, for example, “is it your internet, or is it your Wi-Fi?” Additionally, online or call support is provided by the ISP with the ability to visualize the customer network and related Wi-Fi and ISP KPIs from the cloud fed operations center.

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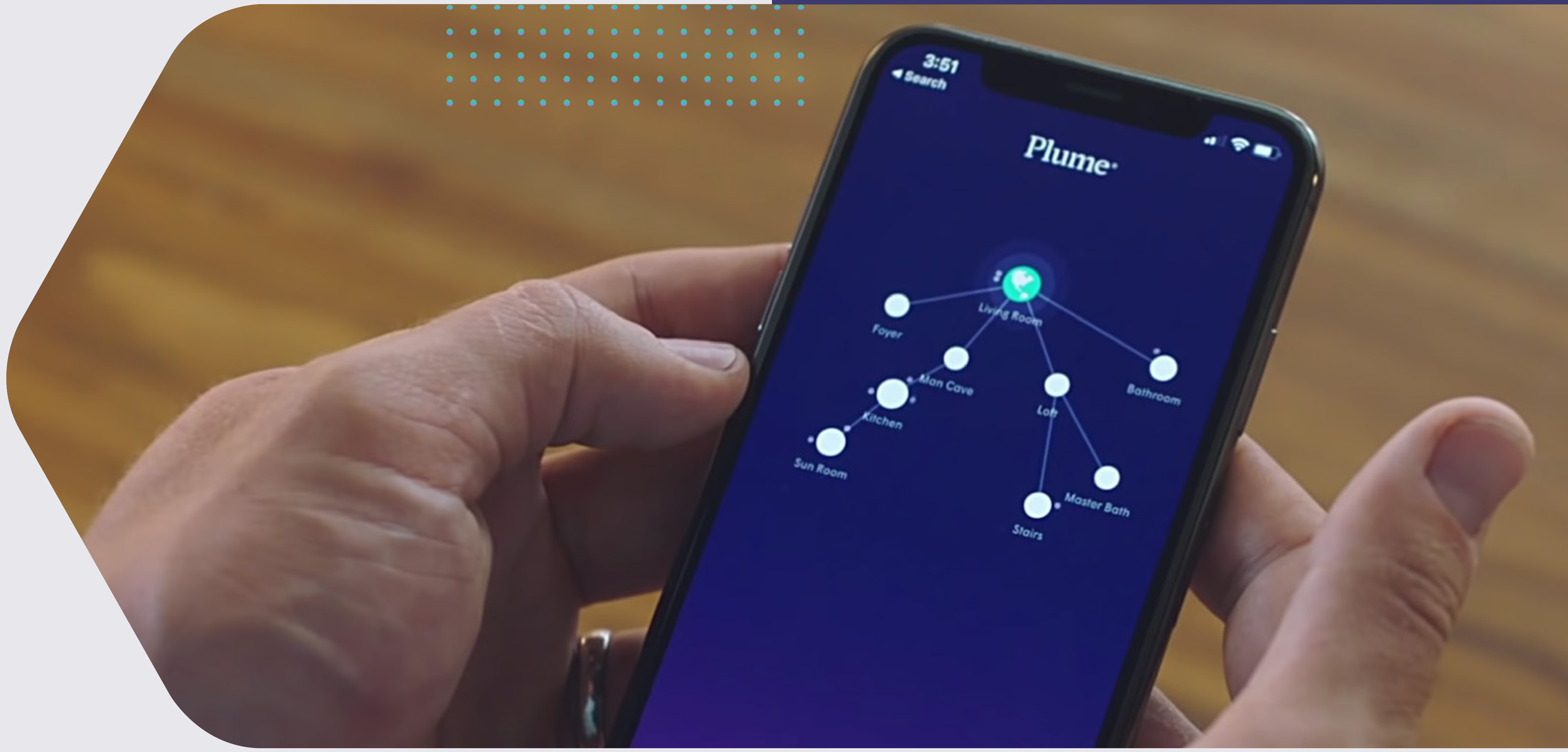

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Conclusion

The unique capabilities of Plume Adaptive WiFi, a distributed, dynamic Wi-Fi system with cloud-based control, provides the best quality of customer experience when compared to other available Wi-Fi architectures.

The advantages can be seen in the network topologies themselves, including the use of multiple frequency channels in the backhaul, optimized selection of the number of hops, and channel frequency assignments planned across entire apartment complexes. It can also be seen in the management of the client devices in the networks, including simple onboarding, and coordinated client steering. Finally, the approach brings network management advantages including superior visibility and support, and the ability to easily upgrade and enhance capabilities changing cloud software, rather than code on an in-home device.

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