CONSUMER NETWORKING GAINS WI-FI MESH

ENTERPRISE TECHNOLOGY HELPS FILL THE GAPS IN HOME ENVIRONMENTS

EXECUTIVE SUMMARY

Consumers traditionally deploy a single Wi-Fi router for the home and adapt their usage around the router. But, changing needs are rendering this strategy unworkable for many homes as the coverage area needs are increasing, the prevalence of mobile devices is changing the access patterns and a host of consumer Internet of Things (IoT) devices are now entering the home. Commercial Wi-Fi mesh technology has been available for years and can address these needs. Because of these changing needs, consumer networking companies are beginning to bring those technologies to the consumer market to bring a better Wi-Fi experience into the home.

TODAY'S CUSTOMER NEEDS

When Wi-Fi first made the jump from commercial environments into the home, most PCs were desktops; Wi-Fi was chiefly used to connect a few notebooks to the network for web surfing across a (lower performance) shared connection. Speed and coverage were not critical considerations for consumers as the shared broadband connection was typically slower than the 11Mb/s that 802.11b Wi-Fi delivered at the time.

Wi-Fi access is now a staple for device connectivity, growing from linking one or two notebooks to no linking other compute devices including desktops, smartphones and tablets. Additionally, entertainment devices like smart TVs, DVD players and streaming devices (Apple TV, Roku, Sonos, etc.) are now connecting to the network to provide music and video around the house. With the rapid growth of home IoT devices, in the form of doorbells, alarms, thermostats, door locks, security systems, video cameras and more, Wi-Fi connectivity needs to reach to the far edges of the home, into places where wires could never allow. It is increasingly difficult for a single router to effectively handle the range of device and location demands of the modern home.

Wi-Fi has progressed over the years, with much focus being on performance, increasing the throughput from a paltry 11Mb/s with 802.11b to the latest 802.11ac which can reach 433Mb/s. But those speeds are for a single channel. 802.11ac is being deployed with multiple channel and multiple antenna configurations, increasing the performance for a single client up to a theoretical 1.27Gb/s. In actual usage, the typical client will rarely see performance at this level because both the ideal situation rarely occurs in today's crowded homes and the backhaul (the connection between the wireless access point and the physical network) is typically 1Gb/s at most.

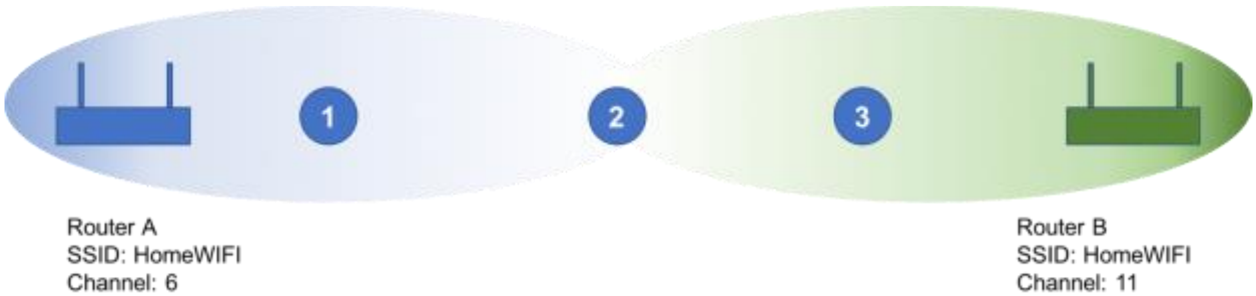
MU-MIMO (multi-user, multiple input, multiple output) is a terminal/antenna scheme that enables a larger number of users to simultaneously access the wireless router. While the actual PHY layer may only allow for 1Gb/s of upstream connectivity, the MU-MIMO architecture enables a larger number of devices to connect at higher speeds, so that when each needs to transmit/receive data they are not being limited as much as if there was only one antenna and one layer for the wireless to wired translation. MU-MIMO speeds can be deceiving; these refer to an aggregate capability for the device, not the connection speed of a single device. Consumers buying the latest AC5300 Wi-Fi routers do not receive over 5Gb/s of bandwidth per connection, that is the aggregate of all the different radios and channels combined; the upstream connection is still only 1Gb/s.

As Wi-Fi standards continue to increase performance, they do it by shrinking the wavelength and increasing the channel count. With each generation, higher performance can be reached, but only with proximity. 802.11N is still the "workhorse" of home networking as its wavelength allows it to penetrate walls, doors and other obstacles, enabling the widest coverage and still decent performance. 802.11ac, the latest standard for consumers, brings greater performance, but the coverage often begins dropping after users move more than 2 rooms away from the router. This makes the lower performing 802.11N the preferred standard for low bandwidth IoT devices that are literally at the edge of the network, in the furthest spots in the home.

Mesh Networking vs. Traditional Routers

Traditional routers have strong coverage close to the device but as distance increases the signal strength (%) and connection throughput (Mb/s) begins to degrade, eventually dropping completely. Many consumers have tried to resolve this issue by adding a second Wi-Fi router, utilizing the same SSID (Wi-Fi network name) on a different channel (to prevent channel conflict.) However, each router operates in a vacuum, unaware of the other. In this environment, the router works to maintain the connection with the client, so as it moves from point 1 to point 2 and eventually point 3 in the diagram below, it maintains its connection to the first router (often called "stickiness"), despite the stronger signal with the same network name that is being output by the second router. The solution is to temporarily turn off the client network services, and restart them - the device will then connect to the stronger second router signal. However, in practice this rarely happens as consumers would be constantly turning devices on and off to optimize their connection – something that they are loathe to do.

FIGURE 1: TRADITIONAL WI-FI AND "STICKY" CLIENTS



(Source: Moor Insights & Strategy)

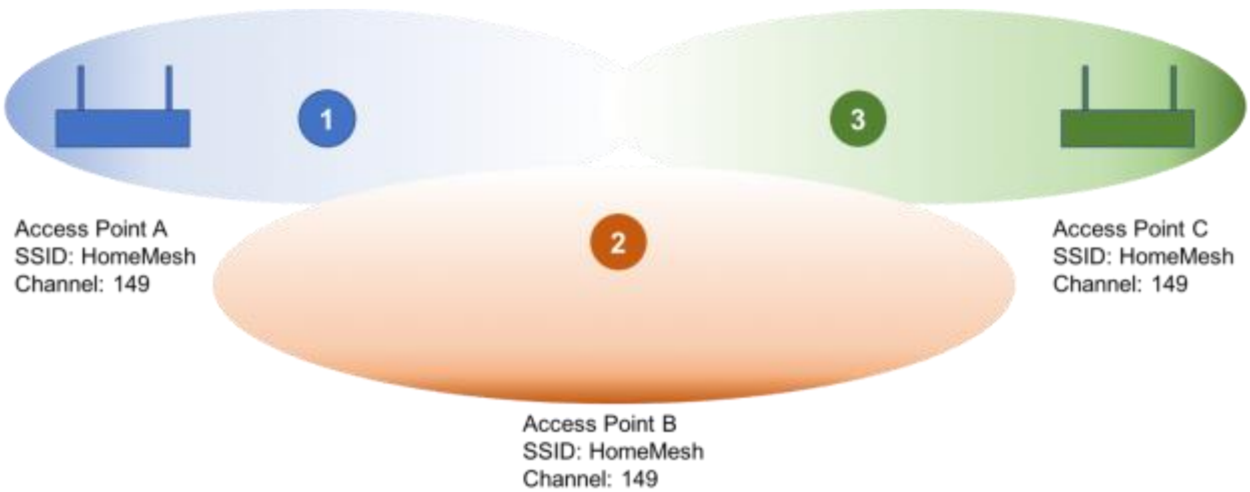
In contrast, commercial Wi-Fi solutions utilize technologies that enable the creation of a mesh network for Wi-Fi where each access point communicates back to a centralized controller, indicating the connected clients' location and signal strength. This enables the controller to handoff clients to a different access point with a stronger signal as they move through the network.

"Self-organizing networks (SONs) enable access points (APs) and clients to work in unison, shuffling around neighboring sources of interference to match clients to the best AP" said Kenneth Fernandes, of networking company ADTRAN. "Our technologies enable commercial APs to provide a consistent, predictable Wi-Fi Quality of Experience." ADTRAN sells to commercial customers, but believes that these commercial technologies will make their way into consumer homes in both retail products that consumers may buy or in products delivered by ISPs into homes. "We can see applications for our DynamicRF Radio Resource Management and DynamicSteering technologies in residential Single Family and Multi-dwelling Units, allowing ISPs to bring more sophisticated offerings, introducing SONs into the home"

Mesh networks will typically have less signal strength per access point because the mesh requires them to cover a smaller amount of area and handoffs are encouraged. In a mesh, the access points are arranged in a SON, allowing them to communicate client status between the access points, handing off where appropriate. Because of the network coordination in a mesh, all access points will share the same channel, typically 802.11AC, which enables a mesh to deliver greater connection speed and provide the coverage that is needed throughout the house without fear of signal degradation. This degradation is the most common AC problem for clients as they move away from the AP. 802.11N networks tend to maintain their signal strength better as devices move away.

In the example below the client begins connected to the first access point in the mesh. As it moves closer to the second access point, the connection is handed off from access point A to access point B, increasing the signal to the client. As the client then moves to the third position, it is again handed off to the third access point, enabling the device to maintain the strongest signal. Handoffs are done automatically with no user interaction required. To maintain a balance between optimizing the handoff and maintaining the signal, access points typically will wait a bit between handing off to minimize network churn. Clients remain connected to the other access point (at lower speed) for continuity during the handoff, which can be as little as a few seconds or up to a minute.

FIGURE 2: MESH NETWORK



(Source: Moor Insights & Strategy)

BACKHAUL CONNECTIVITY: A CRITICAL MESH CONSIDERATION

Another significant consideration with multiple access points is what is referred to as the "backhaul" – the connectivity between the access points. Backhaul can either be wired or wireless, with the former delivering more performance and better management while the latter provides more convenience and flexibility. Wired backhaul includes:

- **Ethernet**. Utilizing Cat 5/5e/6 cabling, Ethernet connectivity is the easiest wired backhaul as it does not require the signal to be translated over any physical interface; everything can flow easily between the different network devices. Most home routers support Gigabit Ethernet, with throughput of roughly ~950Mb/s.
- **Powerline**. Powerline adapters can transmit Ethernet signal over a home's electrical wiring infrastructure, enabling signal to be delivered to any location in

the home. Speeds from Powerline adapters are typically 200, 500 or 600Mb/s with newer models claiming 1 or 1.2Gb/s speeds. However, because of noise in the electrical system, speeds rarely achieve the advertised rate.

- **MoCA**. MoCA (Multimedia over Coax Alliance) utilizes the coaxial cable found in many cable TV systems to transmit data. The smaller and more optimized cable TV grid in the home generally helps MoCA deliver higher performance than Powerline with less impact from interference. But with fewer cable outlets, MoCA tends to be less flexible than Powerline where AC sockets are plentiful.

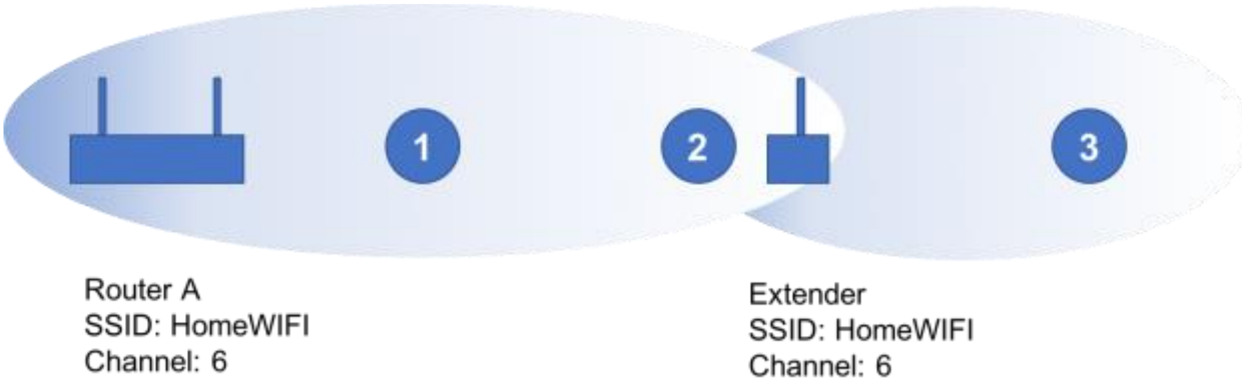
Any of these three technologies can allow a mesh network to be established with high speed, but not every application requires the highest speed, some demand the widest coverage area, and for those environments, a wireless backhaul may make sense.

Wireless backhaul typically uses one band (802.11N) for communication between the access points and the other band (802.11AC) for communication with the client devices. While this strategy enables devices to connect and show an apparently high signal, their actual *throughput* is gated by the 2.4GHz speeds of 802.11N, leaving the bandwidth closer to 80-90Mb/s. This disparity is like Wi-Fi extenders, products that were designed to extend a Wi-Fi signal, but rarely did. Both give the illusion of a stronger connection, but typically reserve bandwidth from the main router to maintain the connection, dropping the overall performance for all network clients.

Wi-Fi Extenders: The Illusion of Higher Throughput

In the example below, a client attached to the router might show a signal strength of 80% at position one, which drops to 20% at position 2 but then increases back to 80% if it is connected to the extender. But the extender is essentially masking the poor performance, giving the illusion of boosting the signal, but because the backhaul is wireless, this is just a larger signal percentage, not an actual increase in performance. Extenders may help in environments where a device may be just outside the reach of a router, but they only extend connectivity, they do not boost performance for further out clients. Many extenders are eventually returned when consumers thought the extender would increase performance only to find out that this is not the case. One industry expert estimated that more than half of the extenders sold are eventually returned, a statistic that we cannot confirm, but one could understand how this data point could be plausible. We believe that the advent of mesh networks will greatly shrink the extender market as their cost and limitations will make them a poor alternative to a true mesh system.

FIGURE 3: WI-FI EXTENDER

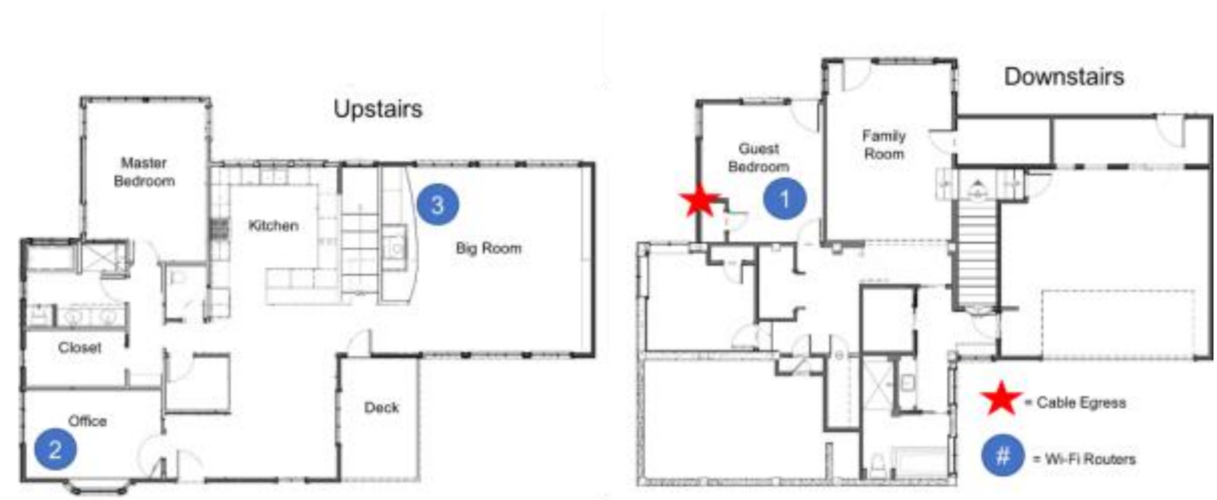


(Source: Moor Insights & Strategy)

TESTING MESH SYSTEMS

To truly understand how mesh systems operate, we looked at two to assess their throughput and ease of use. In both cases, we utilized the same home environment, a two-story house with over 30 different wired and wireless network devices. The ISP provides 300Mb/s Internet via fiber, with 3 unmeshed Wi-Fi routers. The cable egress is marked along with the locations of the previous network routers, all of which all share the same SSID on different channels (non-meshed), connected via Gigabit Ethernet. All throughput measurements were performed with iPerf3 running on Mac OS 10.12.2.

FIGURE 4: EXISTING WI-FI CONFIGURATION



(Source: Moor Insights & Strategy)

Most of the network usage occurs in the big room with the master bedroom and the office being secondary and tertiary locations. While the original configuration brings plenty of bandwidth throughout the house, clients moving between the different zones often hang or remain stuck to their older routers – something a mesh should correct.

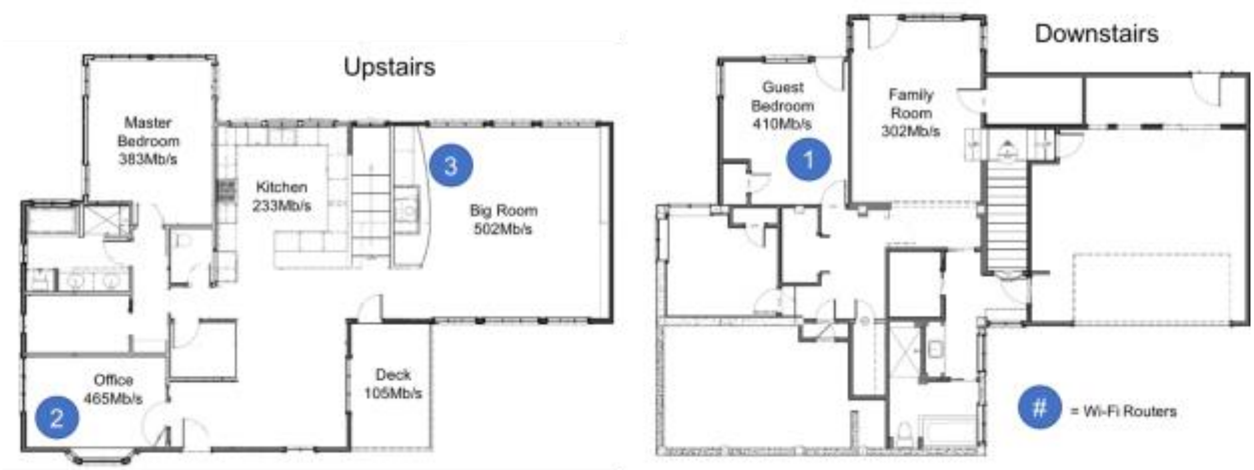
GOOGLE WI-FI

Google Wi-Fi ($299) is a compelling product for those with higher throughput requirements, but falls down a bit in its manageability. Based on a circular design that looks like an overgrown white tuna can, each unit has a very strong Wi-Fi output with two wired Gigabit Ethernet ports on the bottom for handling backhaul and/or connecting wired clients. In a wireless backhaul the Google Wi-Fi has the performance of a standard N router, but when the 3 units are connected via Ethernet cables, they hit 400-500Mb/s performance in the same room and even 200-300Mb/s from a room away.

(Source: Moor Insights & Strategy)

Unfortunately, the manageability is lacking as Google masks many of the configuration parameters from the owner. DHCP is not configurable and you're stuck with an odd IP range that cannot be configured (192.168.85.X), meaning any existing static IPs will need to be set up as reserved IPs instead. The management console is via a smartphone app and tied to a single Google login; there is no web-based management console. The app is only functional when there is internet connectivity, hindering troubleshooting. Google collects plenty of data about clients, access and quality, but allegedly does not track actual web usage; interestingly, there is no way to view usage logs or pull other data from the system yourself.

FIGURE 5: GOOGLE WI-FI CONFIGURATION



(Source: Moor Insights & Strategy)

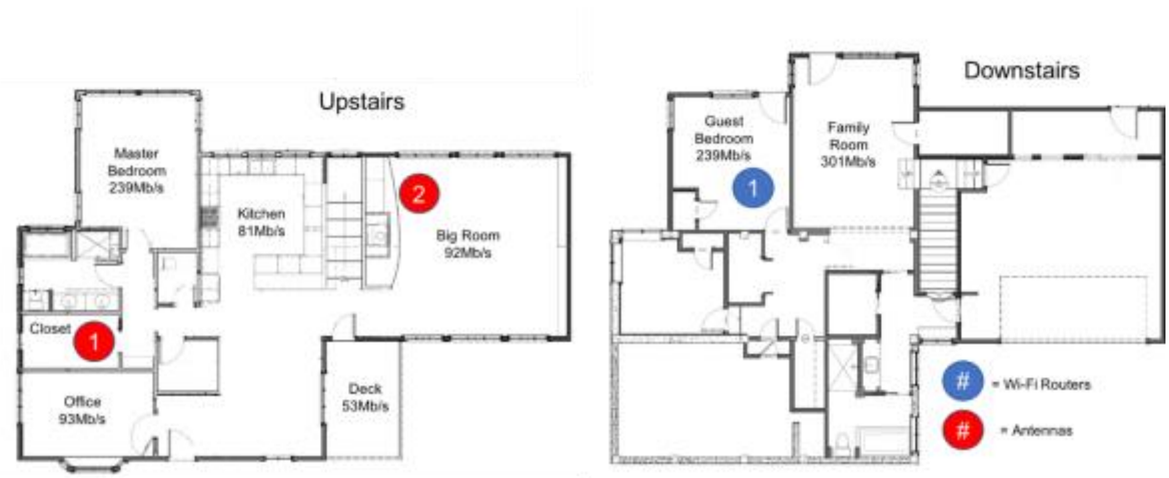
AMPLIFI HD

Amplifi is the consumer brand of Ubiquiti Networks, well known for their commercial mesh networks. The Amplifi HD ($349) brings style and design with a primary base station that does not need to be hidden away in a closet. Instead of a wired backhaul, Amplifi chooses to utilize a wireless-only strategy, and while it does mean that performance is a bit lacking from the satellite antennas, they are much more flexible and can be placed closer to where they will perform the best. The system is clearly targeted at those who are less comfortable setting up networks. While it is easier to get up and running, optimizing for the best performance takes more time because the antennas are more sensitive to position and the actual remote performance is lower than a wired backhaul. It took some time to optimize, eventually locating one antenna in a closet to get the most even coverage for the areas that needed signal. The main unit has significantly strong performance, so if your cable connection is near the primary usage area and the antennas are only needed for lighter duty away from the base, this system should work fine. If, however, most of your access is far from the base unit location as ours is, the overall performance will be lacking.

(Source: Moor Insights & Strategy)

Amplifi also utilizes a smartphone app for configuration, which is limiting, but Amplifi allows for configuration of many parameters that Google locks down. I could access the system via a browser, but was not able to get beyond the first step of configuration. Amplifi indicated that this is all that they have now and that in the future there may be more functionality. I could set the system up with my preferred IP address and set up the DHCP range outside of the static IPs that already existed on the network.

FIGURE 6: AMPLIFI HD CONFIGURATION



(Source: Moor Insights & Strategy)

OTHER MESH CHOICES

These are not the only two mesh systems on the market today and with the 2017 Consumer Electronics Show just wrapping up, we have the following options now in the market (by vendor) or planned for release this year.

Vendor	Price	Description
Asus HiveSpot	$399 (for 3)	AC2200 mesh, not currently shipping
Asus HiveDot	$299 (for 3)	AC1300 mesh, not currently shipping
Amped Ally Plus	$379 (for 2)	AC1900 mesh, wireless only backhaul
Eero	$499 (for 3)	AC1200 mesh wired/wireless backhaul
Linksys Velop	$499 (for 3)	AC2200 mesh, wired/wireless backhaul
Luma	$299 (for 3)	AC1200 mesh, wired/wireless backhaul
Netgear Orbi	$399 (for 2)	AC3000 mesh, wired/wireless backhaul
TP-Link Deco	N/A	N/A

Clearly vendors are all zeroing in on the sweet spot of the market – the $300-$400 range is equivalent to the cost of 2 higher end Wi-Fi routers, the solution most have used to tackle the coverage challenges. Most of the mesh systems, except for the Netgear Orbi and the Amplifi HD, have only two Gigabit Ethernet ports for attaching to a single wired client and providing a wired backhaul. Given the number of wired connections in the average home, this oversight presents two problems. First, it requires additional Ethernet switches to be installed in the network to attach wired clients. But the second problem is more challenging. While it would be very convenient to add a Wi-Fi mesh on top of an existing wired network, products like Google Wi-Fi do not easily enable this, instead forcing customers to make the Google Wi-Fi mesh point the primary router for the network. One can overcome this buy putting the mesh units into "bridge mode" be when this occurs, they lose the ability to handoff to each other, which is the whole purpose for a mesh in the first place. Google claims that they are investigating this capability but it is a big gap in the product. Because a large portion of consumer network devices still connect via wires, this will continue to be a need for some time.

I have not had an opportunity to work with many of the other systems, but some, such as Eero, appear to have this capability – an acknowledgement that we don't live in a wireless-only world.

One of the other interesting areas of integration will likely come from home automation and personal assistants. Linksys is touting its connection to Amazon Echo with its Alexa voice service. We expect to see others try to become a hub for IoT and home automation as time moves on and technologies consolidate.

CALL TO ACTION

Based on the dynamics of today's consumer Wi-Fi environment, the upgrade from a traditional router to a mesh network is an easy decision. With more devices and usage models in the home, these mesh systems can alleviate the problems that traditional router installations experience. Consumers with more complex environments (i.e. larger homes, mobility "dead zones" and IoT devices on the edge) should consider mesh systems to overcome these challenges and deliver a better experience.

There is on "one-size fits all" solution for home mesh networks. Because the choices are varied, we recommend that buyers consider their backhaul and usage needs before deciding. Usage area, the distance between access points, bandwidth requirements, technical expertise and the ability to backhaul over cabling should all weigh into the decision. Sophisticated consumers that require high bandwidth throughout the house should be focused on wired backhaul solutions. Users that need adequate coverage but don't want to deal with the infrastructure requirements or have non-flexible home layouts might find wireless solutions easier and more flexible to deploy. Either way, a mesh system stands to make wireless networking easier and more stable for the typical home.

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