ADVANCED WIRELESS POSSIBILITIES

Carol Ansley
ARRIS

Abstract

Wireless connectivity is a constant expectation from modern consumers. They expect their devices to work seamlessly everywhere: at their workplace; on their commute; and in their home, even as they might be migrating from an enterprise Wi-Fi system at work to a cellular system on the road to a consumer class Wi-Fi solution at home. Broadband providers must be ready to meet these needs today and tomorrow.

This paper considers how consumers are using Wi-Fi today at home and extrapolates about how Wi-Fi services will be used in the future. Alternative home networking architectures are discussed with attention to how they can meet the needs of new services and new devices. A closer look is given to the capabilities of 60 GHz Wi-Fi® and how it may become the centerpiece of a new wireless home strategy.

INTRODUCTION

Wireless connections are ubiquitous in the consumer world, particularly Wi-Fi. A consumer expects to access any entertainment content on any device without thought to where they are or what the device is. Outside of entertainment, most general computing devices offer Wi-Fi connectivity options, such as printers or laptops. Even more generic consumer goods, such as refrigerators or dryers, are becoming a part of the Wi-Fi universe within the world of use cases generally called the Internet of Things. Home security systems are also moving into Wi-Fi-enabled devices to reduce the installation complexity and provide superior services, such as full-motion video recording coupled with motion detection sensors.

We will review recent Wi-Fi data for insights into how Wi-Fi is being deployed within the home in 2016. These results will be compared with results from similar studies a year earlier, where relevant.

Next, we will consider how consumers may want their Wi-Fi and wireless services to evolve within their homes over coming years. As a part of examining those services, we will also examine alternative architectures for future Wi-Fi and wireless deployments.

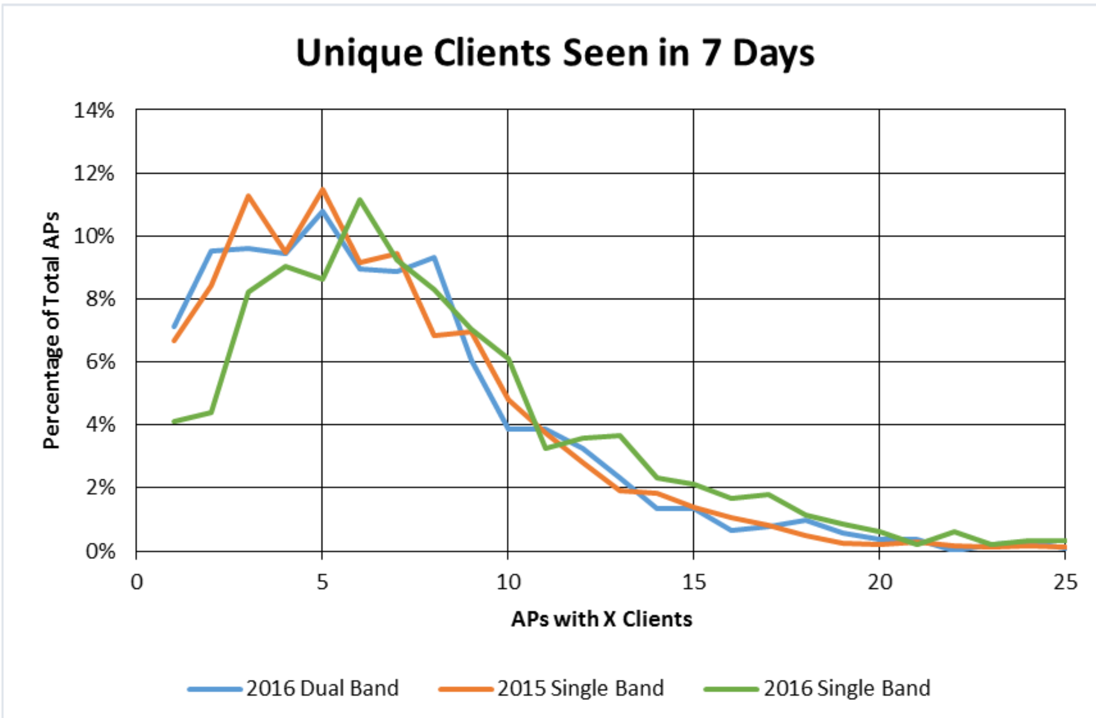
The potential of 60 GHz Wi-Fi, or WiGig, in future wireless architectures deserves a closer look. WiGig has been lurking in the background as a potentially significant technology for several years and finally had some significant announcements at CES 2016. We will provide a brief overview of the advantages and tradeoffs inherent to 60 GHz Wi-Fi networking.

TODAY'S RESIDENTIAL WI-FI USAGE

Many operators around the world are deploying DOCSIS gateways with embedded Wi-Fi Access Point (AP) technology. Most new deployments are using dual band concurrent APs with a 2.4 GHz radio and a 5 GHz radio, but a substantial population of single band AP gateways, usually 2.4 GHz, is also still deployed. In the larger consumer marketplace, stand-alone APs with two 5 GHz radios have also appeared on the market.

In a population of operator-provided APs studied recently, the presence of dual band radios versus single band radios in APs did not impact the number of clients used by a home, though it did appear to improve the quality of service seen by those clients since splitting traffic across two bands significantly reduces the overall congestion.

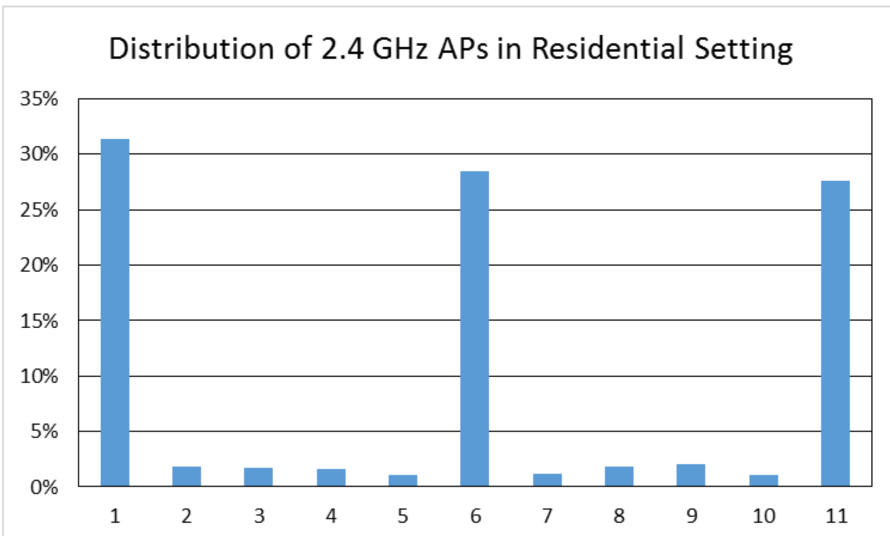
Each AP typically supported an average of just under 7 clients in both surveys, but the number of clients on any one AP varied widely as seen in the following graphic with some households seeing 20 clients or more. Also, interestingly, the distribution of clients per AP was very similar to that seen a year ago, suggesting the constant year over year growth in Wi-Fi clients may be slowing. The 2016 Single Band client count did show a higher mean. This may suggest that when users move to a new AP, they may not carry over all of their older devices, but while they remain on an AP, they do not bother to explicitly remove little used devices.



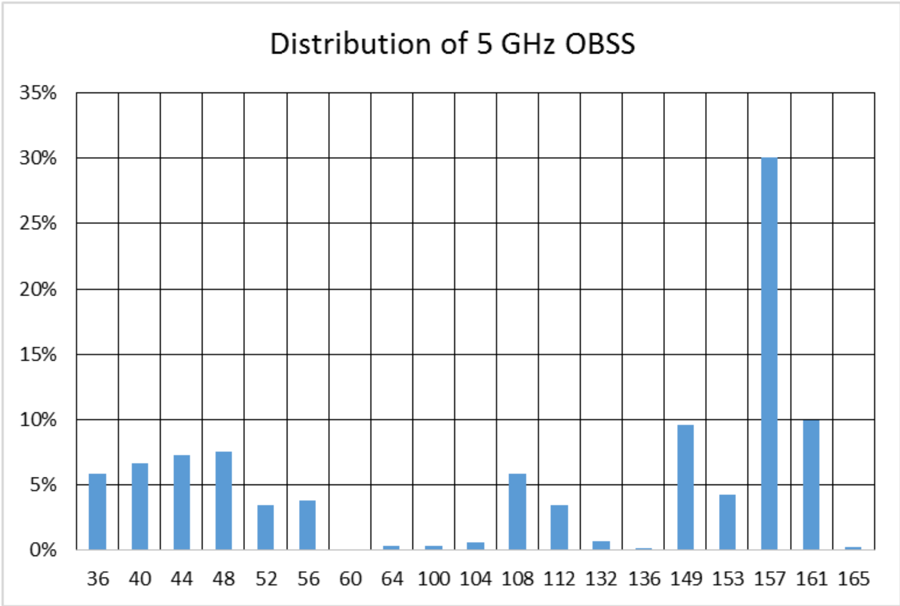
Present Wi-Fi deployments are primarily in support of high speed data deployments, with operator-deployed video set-top boxes just beginning to find widespread use. On the consumer side, however, video is already the dominant use for all Internet traffic, and in-home wireless video distribution to mobile devices and even some stationary devices within the homes. Returning to the 2016 survey of Wi-Fi usage mentioned earlier, over 55% of the devices connected to home APs were mobile phones or tablets. These mobile devices also tended to connect preferentially to the 5 GHz band when they were new enough to have a 5 GHz radio available.

The other service quality consideration for current AP deployments is the amount of overlap between different APs and their associated clients. When two or more APs and their associated clients share a channel, all the clients experience increased congestion causing difficulty sending and receiving data. The 2.4 GHz band in North America has only enough bandwidth allocated to it to support 3 non-overlapping channels. Comparing 2015 to 2016, the 2.4 GHz band has only gotten more crowded. Data from 2015 found about 20% of GW APs with no overlapping 2.4 GHz traffic, but that dropped to only 3% in 2016. The 5 GHz band has fewer instances of overlapping APs in the residential environment, largely thanks to its inherent propagation limitations. The 5 GHz band is also significantly wider, allowing more 5 GHz systems to coexist without overlapping. In 2016, 65% of the GW APs surveyed did not report any overlapping transmissions in the 5 GHz band.

This data suggests that in the future wider bands with more channels to spread out competing traffic is important for continuing reliability of Wi-Fi services. It also suggests that higher frequency bands with poor long-distance transmission characteristics may offer advantages to keep neighboring APs from causing congestion in the home. Channel usage data can also offer hints for future optimization. Generally, 2.4 GHz APs will perform at least a basic level of channel search trying to find the least loaded channel. This graphic shows that overall, 2.4 GHz APs are well distributed across the 3 non-overlapping channels.



Comparing the 2.4 GHz distribution to the 5 GHz distribution illustrates a potential problem. In the region where this data was gathered, one provider appeared to have a fixed frequency assignment for its APs, resulting in an uneven distribution of APs across the 5 GHz band.



A LOOK INTO THE FUTURE OF WIRELESS SERVICES

Many new services are rolling out into the market which could substantially affect consumer demand for Wireless connectivity. The wireless standards community is also moving along at full speed expanding the technology choices for future home architectures.

Future Use Cases

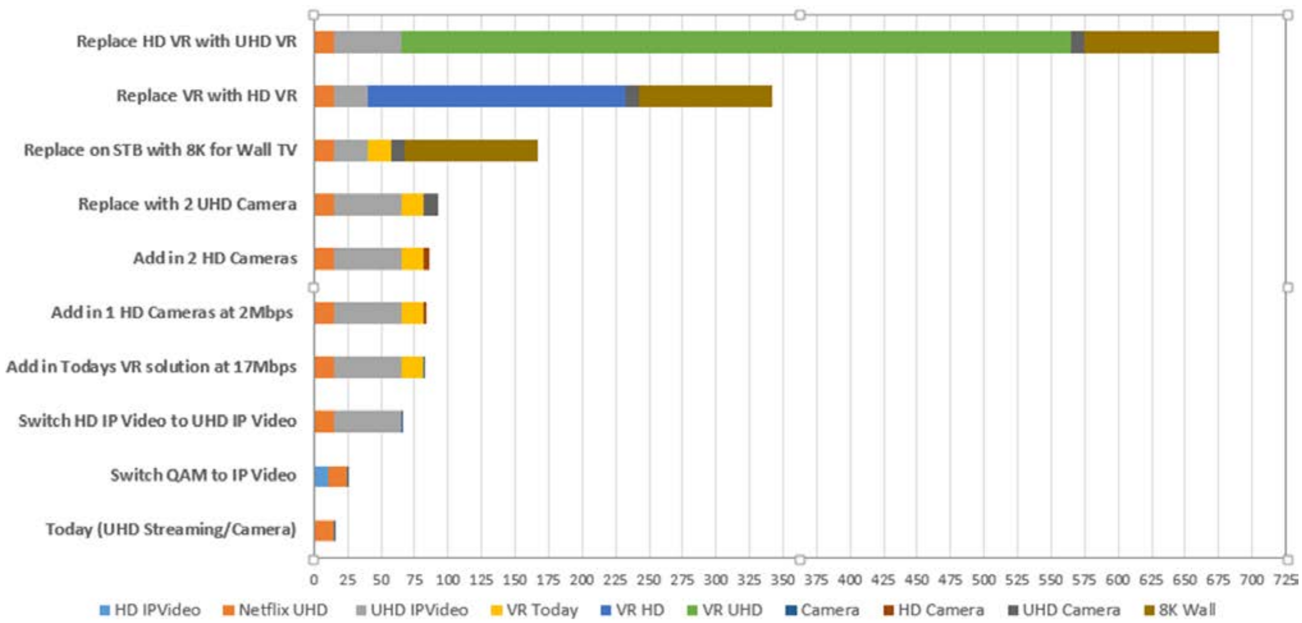
The future directions for wireless connectivity are moving in two separate directions: low power low bit rate, and high performance high bit rate. We will consider two areas, Internet of Things (IoT) and virtual reality, as examples.

The nascent IoT marketplace is driving a lot of innovation. One prominent IoT use case is home sensing and security. Some potential devices within this use case demand low power so that non-power line devices can have a long service life, such as door locks or window sensors. Some other devices might demand long range, but require only a nominal bit rate, such as a motion sensor placed on the perimeter of a home. Whenever video comes into play, such as for security cameras, higher bit rates and low latency are generally required.

To provide thorough coverage of IoT devices, multiple radio bands will probably be needed as well as potentially multiple wireless protocols. Within Wi-Fi, 802.11ah® can provide low power long range coverage at 900 MHz, as can 802.15.4 variants such as Zigbee® as 2.4 GHz. The crowded field at

2.4 GHz currently suggests that moving IoT devices to another band may be useful to ensure quality of service. IoT devices that require higher bit rates may be usefully served with the current Wi-Fi band choices of 2.4 GHz and 5 GHz.

Turning to future entertainment use cases, bandwidth growth is a virtual certainty (pun intended). The consumer electronics industry is already well into a switch-over to Ultra High Definition (UHD) televisions with 4K resolution. Television manufacturers have been showing 8K televisions for several years, though real volume market introduction is probably several years away. However, virtual reality (VR) shows signs of becoming popular in a way that other new viewing modes, such as 3D, have not. It differs from other video services because it requires a uniquely personal stream delivered with low latency to each user. Even if several people are sharing a VR experience, each one would require a different feed as they turn their head to different angles to see different parts of the VR experience. From a technology perspective, an ideal wireless distribution system must be capable of supplying multiple high bit rate streams with very low latency. Using the current 2.4 GHz and 5 GHz bands to support these new services, or others like them, may be problematic, since they are already challenged with the current traffic loads. The graphic below illustrates the potential growth in bandwidth related to VR and UHD usage.



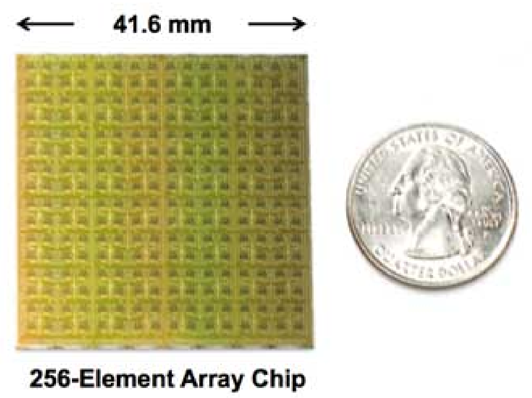
New wireless options, like 60 GHz Wi-Fi, a.k.a. WiGig, may hold the answer to keeping entertainment traffic flowing smoothly in the home of the future. Transmission of 60 GHz signals is highly attenuated by anything solid, so transmissions tend to stay mostly within the space where they originated, and neighboring systems in other rooms do not tend to interfere. For rooms with devices that demand high bit rates, such as VR or 8K displays, going wireless by way of WiGig in-room hot spot/APs may be the future.

A Closer Look at 60 GHz WiGig

WiGig was mentioned earlier as offering a promising option for high bit rate wireless connectivity. The 60 GHz ISM band offers over 8 GHz of bandwidth, as opposed to 79 MHz in the 2.4 GHz band and about 600 MHz in the 5 GHz band. The current 11ad products can use that bandwidth to provide high speed (over 6 Gb/s) mostly point-to-point links in indoor settings. Next generation products will provide higher throughput and more flexibility to support indoor multi-user scenarios as well as outdoor scenarios. As an example, the first 11ad router was announced at CES 2016 earlier this year. The Wi-Fi Alliance has also announced that they will begin certifying WiGig products for interoperability this year as well. The IEEE 802.11 standards committee is already working on the next generation of 60 GHz, currently known as amendment 11ay. It is projected for completion in 2020, but early pre-standard products will probably appear sooner.

On the technical side, using the 60 GHz band for high bit rate connections imposes interesting constraints. This high frequency band is blocked or heavily attenuated by most solid objects. A clear line of sight connection between the transmitter and the receiver provides the best throughput. Non-line-of-sight (NLOS) transmission is possible, but requires a high dynamic range from the transmitter/receiver pair. A mix of LOS and NLOS targets can be challenging because of the need for gain control or other means of enabling the high dynamic range needed.

Antenna selection and design is very important in WiGig. The optimal antenna elements are very small due to the high frequency/short wavelength. Because of the small antenna size, power transmission characteristics can be challenging. To overcome these disadvantages, antenna arrays are the favored implementation for 60 GHz. With the small individual element size at 60 GHz, antenna arrays can still be smaller than the current 2.4 or 5 GHz antennas. Shown below is a 256 element array that might be suitable for an AP. Smaller arrays may be more suitable for client devices.



Antenna arrays have the advantage of improving overall reception, but they also require more pre and post processing than current Wi-Fi solutions. Highly focused antenna patterns can provide high gain, but also narrow the useful angular window. If an AP supports clients scattered across a wide area, multiple arrays may be required to achieve uniform coverage, or the placement of the AP will need careful consideration. For example, a 60 GHz AP may be best placed in a corner of a room so that the AP sees clients distributed across 90^{o} in the horizontal plane. It may be best placed near the ceiling, so that the clients are within a 90^{o} spread in the vertical plane. These challenges imply that in the long term, WiGig APs may have a different form factor than today's Wi-Fi APs. On the next page is a graphic of a potential WiGig AP designed to light up a room with high bit rate services.

FUTURE WIRELESS HOME ARCHITECTURES

Putting these different threads together suggests that the home wireless networks of the future will have a complex network of wireless APs, serving different bands and potentially different use cases throughout the home. All the low power IoT devices may be served from one central IoT 900 MHz AP or if 2.4 GHz IoT devices are being used, then several APs may need to service IoT devices. Higher speed low latency services are best served with several distributed APs, perhaps even with one per room in the most frequented areas of the home.

Backbone Networking

The entertainment and Internet data we have discussed will enter the home from a broadband access network that could be wired, cable or fiber, or even wireless, but will probably be physically present at a single point at the edge of the home. That flood of data must be distributed around the home to the appropriate devices. While an IoT hub might be located near the broadband access point to serve the low power low data rate devices spread throughout the home, because of the challenges discussed earlier, high bit rate services would probably be more efficiently served by a network of APs. The APs could perhaps be controlled or directed to offer specific services within specific rooms. These APs would still need to be connected together by a backbone data network that reaches back to the broadband access entry point.

The backbone data network in the home is an important part of this distributed future wireless architecture. A wireless back bone might be used, if the transmission challenges can be met. A 60 GHz backbone with highly focused beams could be used, but to achieve the highest bit rates, line of sight transmission would be needed. Companies have also proposed using a wireless mesh to pass data around the home, when a single connection does not reach far enough, but the current 5 GHz and 2.4 GHz meshes have serious capacity problems when one tries to extend them to the data rates that will be required in the UHD VR future.

Wired backbones are also possible. MoCA and G.hn networks are flirting with Gigabit speeds today and will probably continue to improve with time. The biggest challenge that a wired backbone poses is how to get the data into the APs. A G.hn power line system might provide the data over the power line connection. A MoCA system might provide the MoCA data signal along with a center core power connection to minimize wiring for the distributed nodes.

Future Wireless Concerns

The unlicensed bands discussed in this paper have also attracted the attention of cellular operators. They offer the mobile operators available spectrum without the governmental regulations and high fees of their current licensed spectrum. The reason to note this alternative development is that it may affect the success of the deployment of the future wireless networks we have discussed. If a home user has an LTE-U home hotspot that operates in the 5 GHz band, then, the homeowner's use of the 5 GHz band for services over regular Wi-Fi may be affected and vice versa. As consumers use all wireless services more and more, this issue of shared spectrum may become challenging.

CONCLUSION

The wireless systems of the future may not resemble the systems of today since they will need to support radically increased amounts of data and new use cases. The consumer appeal of UHD and VR may determine how much the current systems have to change to ensure that there is enough bandwidth to satisfy the end users. New wireless technologies, like 60 GHz WiGig, offer interesting capabilities that can be used to meet those new challenges. Other new services, like LTE-U, may provide additional challenges to maintain and improve wireless data service within the home. Operators will need to monitor the growth of new use cases, and decide how best to keep the consumer's wireless connections on-line.