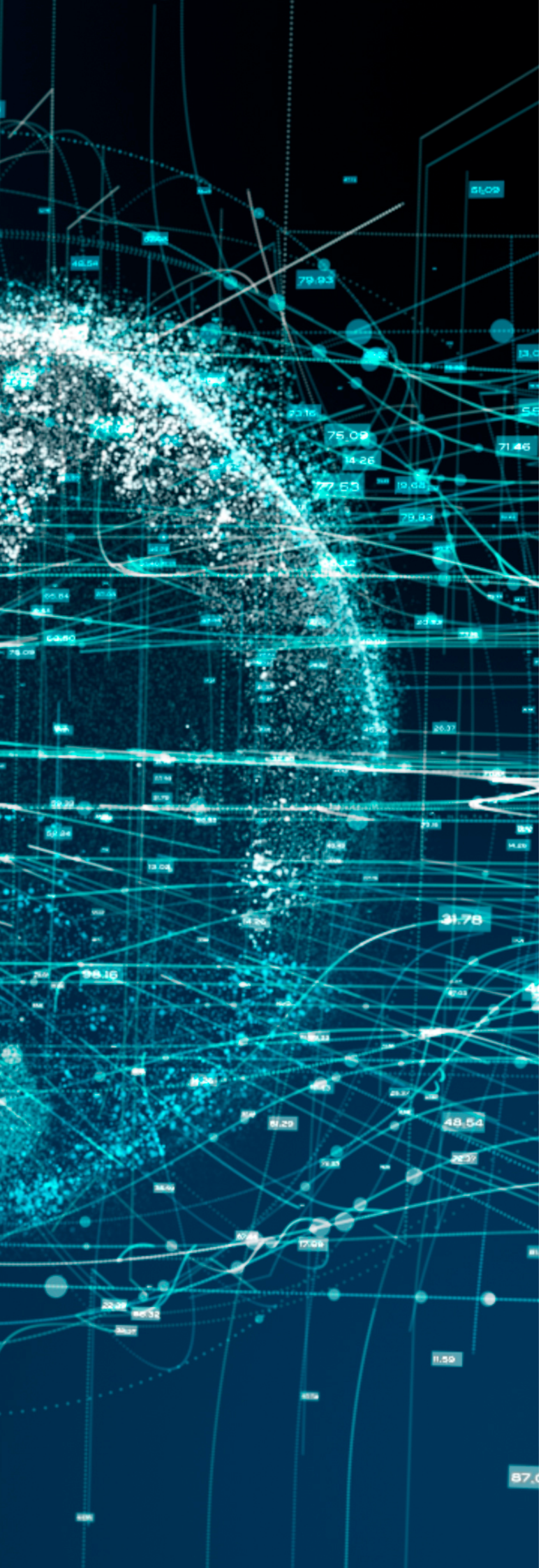

WIRELESS BROADBAND ALLIANCE

DRIVING NEXT WIRELESS EXPERIENCE

# WBA Annual Industry Report

2020


**Source:**
Wireless Broadband Alliance

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**Issue date:**
October 2019

**Version:**
Final

## ABOUT THE WIRELESS BROADBAND ALLIANCE

Founded in 2003, the vision of the Wireless Broadband Alliance (WBA) is to drive seamless, interoperable service experiences via Wi-Fi within the global wireless ecosystem. WBA's mission is to enable collaboration between service providers, technology companies and organizations to achieve that vision. WBA undertakes programs and activities to address business and technical issues, as well as opportunities, for member companies.

WBA work areas include advocacy, industry guidelines, trials and certification. Its key programs include NextGen Wi-Fi, 5G, IoT, Testing & Interoperability and Roaming, with member-led Work Groups dedicated to resolving standards and technical issues to promote end-to-end services and accelerate business opportunities. WBA's membership is comprised of major operators and leading technology companies, including Broadcom, BSNL, Orange, Facebook, Google, HPE Aruba, Huawei, Microsoft, NTT DOCOMO, Ruckus, Shaw, SK Telecom and T-Mobile US.

The WBA Board includes AT&T, Boingo Wireless, BT, Cisco Systems, Comcast, Deutsche Telekom AG, GlobalReach Technology, Intel and KT Corporation. For a complete list of current WBA members, click here.

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For the Wi-Fi industry, 2020 will be a landmark year as next generation Wi-Fi platforms drive a whole new generation of use cases and revenues. The impact from innovation, investment and hard work by companies involved with the Wi-Fi industry, standards bodies and alliances including the Wi-Fi Alliance, Wireless Broadband Alliance and others will be powerfully felt.

In our 2020 Industry Report, we once again look back and highlight the important milestones which have been crossed during the past year, as we move into the 5G era. Many of these will be crucial in the '5G era' which is opening up. From Wi-Fi 6, which provides a step change in functionality and performance, to deep cooperation with other bodies such as the NGMN Alliance, the WBA is playing a key role in shaping next generation wireless.

And of course, the Report looks ahead, to the opportunities that new era of wireless platforms will open up for the Wi-Fi community with the advent of Wi-Fi 6 and other enhancements, as well as the challenges which must still be addressed by the WBA working groups and the wider industry.

**Key Takeaways from the 2020 Report:**

- This year's WBA Industry Survey gained inputs from across the ecosystem, including many kinds of service providers, as well as equipment and device vendors. The results showed that confidence in investing in license-exempt spectrum technologies has risen sharply since last year's survey, with 79% of survey respondents saying they had more confidence than a year ago, or the same level. Key factors behind this progress include the advent of Wi-Fi 6, and the prospect of additional license-exempt spectrum especially in the 6 GHz band. In total, 90% of the survey base plan to deploy Wi-Fi 6 at some point, 66% starting in 2019 or 2020. And 78% said the 6 GHz extension was very important or important to their current or future network strategy. In considering that strategy for "network evolution and 5G", 46% said the role of Wi-Fi/ unlicensed spectrum was the most important criterion, compared to 15% for the roadmap and standardization of 5G NR.

- Certification and deployment of Wi-Fi 6 networks started and will play a highly significant role in enabling transformative wireless services in many sectors from 2020 onwards. The Report examines the WBA's critical work in providing deployment blueprints, field trials and other resources to accelerate the industry's roll-out; and analyses the future part Wi-Fi 6 will play in the wider wireless platform, and in industries, such as manufacturing and automotive, with challenging requirements.

- The WBA built on core activities in roaming and security, with achievements such as a new release of WRIX (Wireless Roaming Intermediary eXchange) standards. The Report keeps us informed of the importance of these foundational work items, while demonstrating how they drive forward an ever-changing set of business cases. The WBA's work directly enables new services and experiences in areas where Wi-Fi is

dominant, such as the home, to those where it interworks with other technologies as part of a broad connectivity platform, such as smart cities.

- The WBA is also contributing to best practices in in-home Wi-Fi with a set of guidelines detailed in a recent white paper. The WBA identifies the gaps in current in-home Wi-Fi standards and highlights the need for intelligent network optimization. The WBA has proposed key recommendations for different functional areas and identifies future lines of work and possible directions the In-Home Wi-Fi network may take.

- This Report, like the WBA's work, is firmly grounded in real world use cases and market requirements. A rich set of case studies exemplifies the breadth and commercial relevance of its scope. They range from Deutsche Telekom's deployment of in-flight Wi-Fi; to Mettis Aerospace's use of Wi-Fi 6 for enterprise and industrial IoT; to the role of Wi-Fi in Hong Kong's ambitious and multi-faceted smart city project; and others.

**Other Key Survey Findings (full results in section 8):**

- 40% of the respondents have deployed NGH/Passpoint by 2019 or plan to do so in 2020, while a further 37% do plan to implement the technology, but have not set a firm date.

- In-home Wi-Fi and general enterprise requirements were the top-placed Wi-Fi segments by providers, and in the enterprise category, the most significant verticals were office buildings (22% placed in their top three priorities), hospitality (21%); industrial (15%); and healthcare (13%).

- In terms of monetizing these sectors, the top three for current networks are Wi-Fi analytics (56% placed it in their top three), enterprise services (46%) and Wi-Fi roaming (43%). For the future, the top spot is taken by location-based services (49%), followed by roaming and analytics on 40% each.

- In three years' time, a different picture is seen – IoT and vertical industry applications are expected to become the leading revenue driver, with 45% placing these in their top three. These are followed by cloud/AI-based Wi-Fi services (33%) and city-wide services (27%).

**Other Report Highlights:**

- Interviews with WBA chairman JR Wilson of AT&T, and eight detailed case study interviews with deployers in different industry sectors.

- Detailed analysis of the Wi-Fi 6 roadmap, and how it relates to service provider business models, and to the wider next generation wireless platform, including details of the WBA's ground-breaking work on RAN convergence.

- Overview of the 2019 market landscape, including the latest developments in roaming, security, Wi-Fi offloading, mesh and other key enablers. As well as moving these technologies forward, the WBA has carried out high-impact work in applying them to important markets such as in-home networks.

- Forecasts and roadmaps for next generation Wi-Fi enabled services and their impact on key industries from aerospace to healthcare, and how Wi-Fi can work with complementary technologies in unlicensed spectrum.

- An analysis of the current and future spectrum position for Wi-Fi and unlicensed technologies, including the potential impact of emerging spectrum sharing mechanisms.

All these topics and more are covered in this year's Report. We hope it provides a valuable guide to the varied and influential work the WBA carries out in the world of Wi-Fi and unlicensed spectrum technology; and inspires you to take part in the rich and business-critical agenda that lies ahead in 2020.

## 2. A Year in Wi-Fi… Interview with JR Wilson, Chairman of the Wireless Broadband Alliance

In this interview, JR Wilson, the Chairman of the WBA, talks about this year's achievements at the WBA, and about what we should expect from the WBA and the Wi-Fi ecosystem in the next year.

**Question:** Looking back over the past year, what do you consider to be the biggest achievements of the WBA?

**JR:** As the demand for Wi-Fi and broadband continues to growth exponentially, an important role of the WBA is to make Wi-Fi roaming easier by defining a standard set of service specifications to facilitate commercial roaming between operators through WRIX (Wireless Roaming Intermediary eXchange). This year we made an important update to the WRIX standards to better outline support for EAP authentication methods. We updated the WRIX Interconnection and Clearing specifications as well as providing updated templates for the bilateral roaming agreements, the TED (Technical Exchange Document) and CBED (Commercial Business Exchange Document). This is a vital benefit we provide to our membership – a common set of standards that speeds up time to market when implementing roaming agreements. Those documents are important to help members manage authentication methods, billing issues, streamline roaming standards and specifications to make it easier for operators to establish roaming agreements.

In addition, the WBA is championing the concept of a roaming federation to unite public hotspots with NGH in order to resolve some of the remaining friction.
Some hotspot federations are already operating but need a common framework to minimize operational complexity. Simplifying the process by which a city, venue, or any sort of network is able to implement roaming is key to accelerate and facilitate the adoption of a best in class

Wi-Fi experience: automatic authentication, seamless and secure connection, across home and visited networks.

We also released the In-Home Wi-Fi Industry Guidelines this year which address the challenges that contribute to inconsistent Wi-Fi performance in the home. This is an area that impacts millions, so we thought it an important topic for the WBA to tackle and outline the way to a better experience. The purpose of these guidelines is to serve as an industry go-to reference when preparing for 'Smart Home' deployments. The guidelines identify gaps in current in-home Wi-Fi standards and services and highlight the need for intelligent network optimization. We believe the work the WBA has done is already making a difference in the end-user experience. Many in the industry are excited about the arrival of Wi-Fi 6 to say the least. The WBA's Wi-Fi 6 Deployment Guidelines provide tools that operators, enterprises and cities can use to embrace and deploy Wi-Fi 6 as it becomes commercially available this year. The paper provides guidelines for RF planning and design, while addressing ways that Wi-Fi 6 deployments can provide seamless mobility and backward compatibility with previous Wi-Fi generation technology.

For a number of years, the WBA has been working on defining and enabling the role of Wi-Fi in cellular networks. The WBA has accumulated know how regarding RAN convergence which is reflected in the joint work with NGMN in defining how RAN Convergence can be achieved and what the necessary steps are to bring it to fruition.

**Question:** What will be the biggest challenges for the WBA to address in the year ahead, and how will these be best met?

**JR:** Always a priority is ensuring we continue to grow and provide value to our membership. We want to remain the trade association that provides the tools and resources our members need to drive real business results. That is why we continue to focus on things like WRIX standards to make roaming easier, providing a resource to make in-home Wi-Fi a better experience and Wi-Fi 6 guidelines that include an emphasis on backwards compatibility.

I think we will continue to focus on RAN convergence to address the challenges and solutions for converged RAN deployments of Wi-Fi 6 with 5G. RAN convergence is a complex issue. The goal of this work is to help ensure the best customer experience using both Wi-Fi and cellular and to examine the business opportunities this convergence might enable for our members. The technology has to be agile and flexible to enable service providers, mobile or fixed, to pursue their business models.

**Question:** What are the most important evolutions in the Wi-Fi technology, which will expand business opportunities in the 2020s?

**JR**: One area we will be keeping a close eye on is opening of the 6GHz band in support of Wi-Fi 6. Many believe that if Wi-Fi 6 is to reach its full potential, there is need for additional unlicensed spectrum. Wi-Fi 6 will enable new use cases for industrial IoT, smart homes and support for high-density deployments, to name a few, but access to wider channels is needed to support these new use cases. Indeed, some estimate that Wi-Fi needs will exceed its capacity on 2.5GHz and 5GHz in 2020. At the same time, this must be balanced with the needs of the current users of 6GHz – public utilities, public safety and wireless backhaul – all of whom currently use 6GHz band for vital microwave communications. The FCC in the US, Ofcom in the

UK and the CEPT in Europe are all actively looking at how to open up 6GHz for unlicensed use while protecting the incumbent users. We will be keeping an eye on how this evolves and the implications for our members.

**Question:** The WBA has had a strong position on driving Wi-Fi services like NGH-Passpoint technology over the last years. Can you update us on its progress and key objectives for 2020?

**JR:** NGH is a focus on the end-to-end Wi-Fi experience that includes authentication using Hotspot 2.0/Passpoint combined with the WRIX framework for roaming. Over the past few years we've seen NGH penetration increase dramatically. For example, there are now an estimated 650+ types of AP's and routers, 1600+ devices (smartphones, tablets, laptops) and 200+ IoT devices that support Passpoint. At Mobile World Congress we've seen a 40% compound annual growth rate in the number of attendees attaching to NGH since 2014 and a 522% YOY growth in the most recent year driven by the number of operators that have adopted NGH. As I mentioned before we updated the WRIX guidelines this year to better outline support for EAP methods of authentication – a key element to NGH. The Hotspot 2.0 specification from the Wi-Fi Alliance (WFA) has continued to evolve over the years, with Release 3 just published. As Wi-Fi evolves to support Wi-Fi 6 capabilities, the need for a seamless and secure method of authentication doesn't go away – in fact it becomes even more important given the type of mission critical applications that are envisioned for industrial IoT, smart cities and connected homes.

**Question:** How is WBA helping AT&T to support and develop its mobility business, including Wi-Fi Offload and Wi-Fi Roaming?

**JR:** One of the main drivers behind AT&T's participation in the WBA was the resources available to support and drive a standard set of guidelines for Wi-Fi roaming. This work has given us the leverage to significantly expand our Wi-Fi roaming relationships both domestically and abroad. Those standardized approaches are also helping the overall ecosystem. We believe that NGH (Next Gen Hotspot) delivers the Wi-Fi roaming experience we want for our customers – seamless, secure and interoperable. We made the decision over a year ago to focus all our Wi-Fi roaming efforts on Passpoint (i.e. HS 2.0/Next Gen Hotspot) capable roaming partners because of the superior, frictionless customer experience that Passpoint delivers. In the US we use Passpoint Wi-Fi roaming to add capacity (as needed/ on demand) in high density venues like airports, convention centers and stadiums. This is automatically available to all AT&T Mobility customers with a Passpoint capable Smartphone. Internationally for customers with an AT&T International Day Pass, in addition to their cellular allowance we make Passpoint Wi-Fi roaming available in France, Thailand, Chile and Brazil to name a few places. As a result, NGH is giving our customers more coverage in more places to fill critical gaps.

**Question:** With Wi-Fi 6 and 5G both going into commercial deployment this year, how do you envisage them working together in the '5G era'? In which scenarios will they be complementary to one another, for service providers?

**JR:** I think the case of convergence is clear. The drive towards 5G technologies – both Wi-Fi 6 and cellular 5G – is driven by consumer demand, ever-increasing video consumption, the growth in IoT, to name a few. I don't think convergence is an option, I think it is a "must do" to meet customer expectations. RAN core becomes increasingly important with the emergence

of Wi-Fi 6 and 5G. In that context, we have developed at AT&T tools to manage traffic between cellular and Wi-Fi networks. And while there is still work to do defining the best way for convergence to happen, good progress is being made. 3GPP Releases 15 and 16 provide interworking between the 5G and Wi-Fi networks by enabling access to the 5G Core via untrusted and trusted non-3GPP access networks such as Wi-Fi. The WBA is working with NGMN to highlight some of the requirements and key challenges that need to be addressed to realize service and network convergence over 3GPP Access and Wi-Fi.

**Question:** How significant will the extension of unlicensed spectrum into the 6 GHz band be to the Wi-Fi industry, and will it enable new use cases?

**JR:** Like I said before, we will keep a close eye on opening of the 6GHz band in support of Wi-Fi 6. Many believe that if Wi-Fi 6 is to reach its full potential, there is need for additional unlicensed spectrum. More spectrum means faster speeds, lower latency and more users. It's easy to forget that is has been over 15 years since the last 5 GHz band was opened in 2003. Certainly, if Wi-Fi 6 at 6 GHz gets more channels that are 160 MHz wide, this will enable many more simultaneous users to transmit and receive data at very fast speeds. Wi-Fi 6 will enable new use cases for industrial IoT, smart homes and support for high-density deployments, to name a few, but access to wider channels is needed to support these new use cases. Indeed, some estimate that Wi-Fi needs will exceed its capacity on 2.5GHz and 5GHz in 2020. At the same time, this must be balanced with the needs of the current users of 6GHz – public utilities, public safety and wireless backhaul – all of whom currently use 6GHz band for vital microwave communications.

**Question:** What are the other significant developments in unlicensed spectrum, for Wi-Fi or other technologies? Do you believe global harmonization of these bands is essential, and is it improving?

**JR:** I think the WBA announcing earlier this year the world's first Wi-Fi 6 Industrial Enterprise and IoT trial, as part of its ongoing Wi-Fi 6 program, is a significant development. During this trial, Mettis Aerospace, a designer and manufacturer of precision-forged, machined and sub-assembled components, primarily for the aerospace and defense industry, will work with WBA members to test several use cases on a Wi-Fi 6 network at its 27-acre West Midlands facility. The trial will enable the use of augmented reality, real-time monitoring of equipment, and a host of other applications in an enterprise network environment designed to digitize Mettis' production line. Harmonization helps to reach economies of scale from an equipment perspective but also helps provide a more harmonious and predictable experience for end users and things, as they travel and move around. However, global harmonization of bands, may not be an entirely realistic goal. Every county and region has their own governing body and incumbent users of existing frequencies. In terms of unlicensed, I do think the fact that the FCC, Ofcom and CEPT in Europe are all actively looking at how to open up 6GHz for unlicensed use while protecting the incumbent users is a promising development.

**Question:** How do you see Wi-Fi working with other radio and wireline technologies in the IoT, and what will be the WBA's role to facilitate that?

**JR:** We want to make Wi-Fi better, faster, more efficient, and more focused on the customer experience. Not only for the phone or tablet users, but also for IoT applications. At the WBA, we are working towards a solid framework for IoT and this work will continue in 2020. We are

working on streamlining authentication and interoperability, on improving security, and offering a seamless experience. Another thing that comes to mind is the impact that Wi-Fi 6 will have IoT. It is estimated that by 2021, machine to machine (M2M) IoT connections will account for more than half of all wireless connections. IoT devices already outnumber smartphones; in fact, it's estimated that the number of IoT devices will be twice that of smartphones by 2020. Wi-Fi 6 will improve signal strength to support IoT deployments, support always-on devices and reduce overcrowding of resources with high-capacity networks. IoT devices will be able to send more information and use less power.

**Question:** Finally, when we come to write the 2021 industry report, what do you most hope will have been achieved by the WBA, and in the wider Wi-Fi community?

**JR:** My vision is that we have robust, growing and active WBA that continues to add value to our membership by delivering projects that equip them to drive real business results. From an industry perspective, that the WBA has an active role in adoption and advancement of Wi-Fi 6 and convergence with 5G, fulfilling the promise of delivering better coverage, lower latency, and higher throughput. I also expect that the WBA will continue to advocate NGH, and we will see that most carriers and Wi-Fi providers have adopted NGH as the preferred method of authentication on Wi-Fi networks in the next 12-24 months. We will continue to work with other trade associations to reach our ultimate common outcome of a better user experience.
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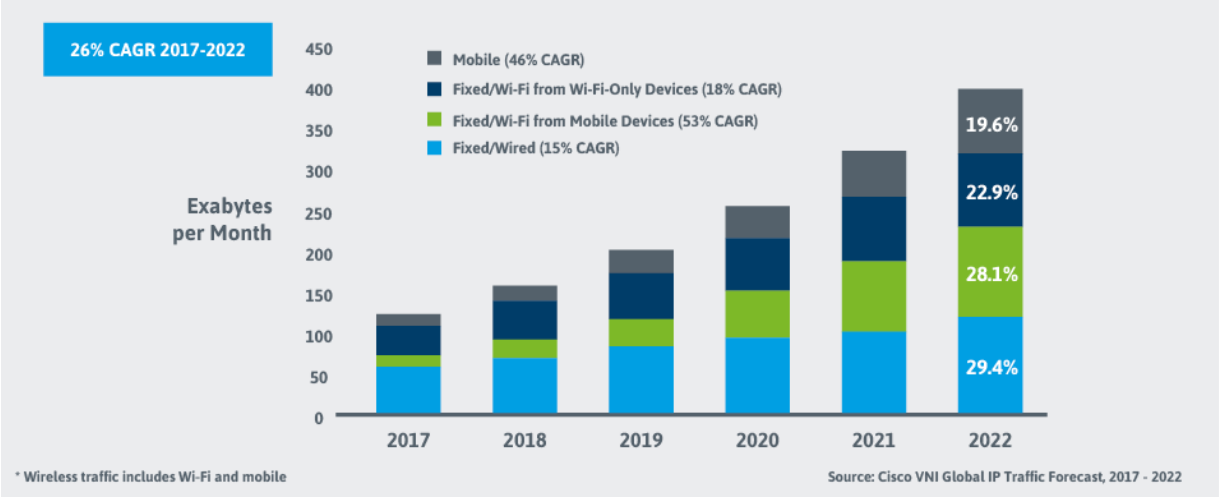
## 3. The Wi-Fi Key Market Segments and Business Models

Wi-Fi has become the dominant indoor wireless technology in homes, offices, businesses, and increasingly public spaces. Wi-Fi serves all market segments, and service providers have been keen to find ways to monetize it. Traffic from wireless and mobile devices will account for 71 percent of total IP traffic by 2022 according to Cisco's latest VNI index. By 2022, wired devices will account for 29 percent of IP traffic, and Wi-Fi and mobile devices will account for 71 percent of IP traffic. Wi-Fi in particular accounted for 43 percent of total global IP traffic which is 5 times more than IP traffic running on mobile networks.

***Figure 1: Global IP Traffic, Wire and Wireless***



The WBA has been very active in helping its members and the industry at large to identify new Wi-Fi uses cases and business models from Wi-Fi roaming and offloading to in-flight connectivity and home Wi-Fi. In this section, we will review various case studies about how Wi-Fi is used and monetized in the four main market segments: Carrier Wi-Fi, in-Home, Enterprise and city Wi-Fi.

## 3.1. Carrier Wi-Fi Trends

The past few years have seen a massive expansion of public Wi-Fi around the world and the technology platform has been evolving rapidly. Next generation hotspots (NGH) are now emerging as a fully carrier-grade network, poised to revolutionize the services and business models which they can support. As these networks have become increasingly robust, with higher levels of security, QoS and bandwidth they have provided a platform for service innovation and development. Among the most notable uses cases for NGH are roaming and offloading which we will look in detail in the following sections.

### 3.1.1 Wi-Fi Roaming

Wi-Fi access has been widely accepted by operators globally, and it has evolved to complement mobile networks and is used for offloading from more costly cellular networks on to lower-cost-per-bit Wi-Fi networks. The WBA has done significant work to facilitate seamless Wi-Fi roaming between the various stakeholders. Its work includes the WRIX (Wireless Roaming Intermediary eXchange) which offers a modularized set of standard service specifications to facilitate commercial roaming between operators.

Essential attributes of carrier-grade Wi-Fi – such as wider roaming, subscriber management, and improved QoS and security – will enable new services including high quality voice services, location and proximity, smart city, consumer IoT, quad play services and HetNets . Non-carrier-managed Wi-Fi such as hotels, cities and public venues will be able to join the federation without having to worry about all the technical work only the commercial agreement. The following case study with AT&T presents a clear example of how Wi-Fi roaming can be used to improve the bottom line.

#### Case Study: Wi-Fi NGH Roaming with AT&T

AT&T has been a highly enthusiast adopter of NGH Wi-Fi roaming and has garnered great results from its roaming business. As a market leader in all things roaming, AT&T has been offering innovative international roaming packages.

**A Focus on NGH Wi-Fi Roaming**

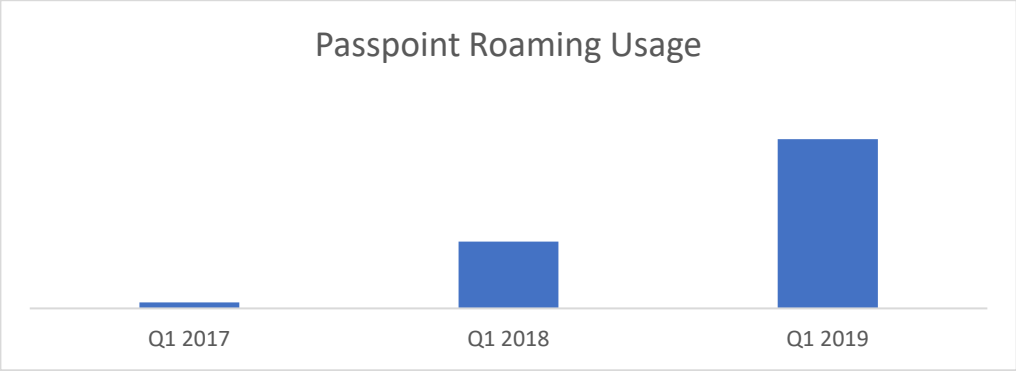
Over a year ago, AT&T made the decision to focus all its Wi-Fi roaming efforts on Passpoint-capable roaming partners (i.e., Hotspot 2.0/Next Gen Hotspot)because of the superior, frictionless customer experience that NGH delivers—i.e. a seamless and secure experience for its customers.

- In the USA, AT&T uses NGH Wi-Fi roaming to add capacity as needed in high density venues like airports, convention centers, and stadiums. This is automatically available to all AT&T Mobility customers with a Passpoint-capable smartphone—which today is virtually all smartphones, both Android and iPhone. In early 2019, AT&T announced eighty-plus venues that are HS2.0 capable, including thirty airports (Boingo) and military bases.

- Internationally for customers with an AT&T International Day Pass®, in addition to their cellular allowance, AT&T makes NGH Wi-Fi roaming available in France, Thailand, Chile, and Brazil, to name a few places.

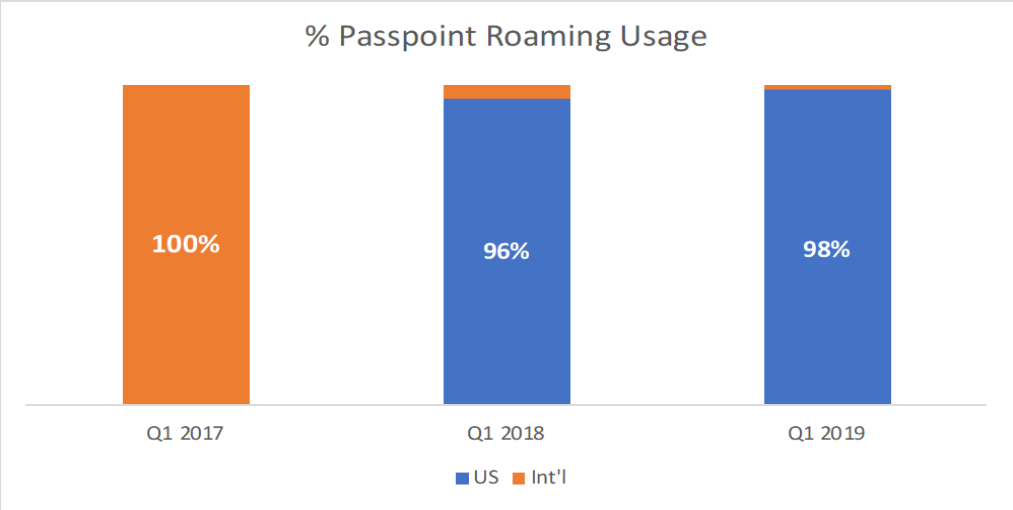
NGH is an important tool to improve indoor coverage and capacity when needed, especially at high density venues—to use in concert with the cellular tools such as DAS, small cells, or coverage from the macro network. As the exhibit below shows, Passpoint roaming usage has been growing since its introduction, and the trend is continuing with more venues enabled in the U.S.

***Figure 2: Passpoint Roaming Usage***




*Source: AT&T*

***Figure 3: Passpoint Roaming Usage (By Percentages)***




*Source: AT&T*

For NGH Wi-Fi roaming to make sense, it is needs to be:

- Inexpensive: Compared to cellular roaming, i.e., the cost needs to be less than cellular on a per-unit basis.
- Efficient: Using intelligent routing, Passpoint/NGH Wi-Fi can be used to add capacity during times at which the cellular network is experiencing peak traffic levels.
- Reliable and Fast: Wi-Fi needs to produce throughput that is at least on par with LTE to ensure our customers have a good experience.

A Passpoint 2.0 access point does not guarantee high throughput, and therefore must be tested and validated before commercial launch or inclusion in the AT&T footprint.

**Coexistence with Cellular**
AT&T views Wi-Fi roaming as a complement to cellular and has included Wi-Fi along with cellular in its international roaming offers for many years. There are different ways in which including Wi-Fi is a complement to cellular:

- Wi-Fi can be included to make the overall cellular offer more attractive.
- Wi-Fi can be included on higher end plans to make those plans more attractive.
- Wi-Fi can be included to lower the overall wholesale cost structure.

**The Road Ahead**
To expand its footprint, AT&T needs more NGH-capable roaming partners, and for those partners to offer wholesale roaming rates that make economic sense when compared to alternatives. AT&T is also evolving its intelligent routing capabilities to more dynamically route traffic based on network loading information.

Implementing new roaming deals remains a hurdle, and certainly proceeds much faster with roaming partners that have the requisite WBA industry standard documents ready and updated ([1]CBED/TED) and comply with the WBA's WRIX standards for record exchange. Many partners already have the appropriate equipment to upgrade to Passpoint/NGH, but as yet have not fully made the transition.

Passpoint enables customers to connect seamlessly and securely to Wi-Fi, and that need will remain the same in the 5G world. Wi-Fi roaming will remain an important and effective way to address coverage and capacity, especially indoors. Obviously as cellular gets faster with lower latency, Wi-Fi has to do the same, and with Wi-Fi 6, is certainly on the path to do so.

### 3.1.2 Wi-Fi Offloading

In the last several years, carrier Wi-Fi has become a natural part of network and business strategies, both for mobile network operators (MNOs) and wireline or converged operators, such as cable providers. For the latter, with the proliferation of managed homespots and public hotspots, Wi-Fi has taken the center stage in wireless/mobility strategies, particularly in the U.S. and Western Europe. The WBA is championing the concept of a roaming federation to unite these hotspots with NGH in a way that resolves all the remaining frictions including network discovery phase when a device is trying to connect to an SSID.

The following case study with SKT presents a clear example of how Wi-Fi offloading can be used to improve the operator's bottom line, while preserving the overall quality of experience.

[1] CBED refers to Commercial Business Exchange Document while TED to the Technical Exchange Document

We had the pleasure to speak with Youngseok Oh, senior manager of 5GX Labs under ICT R&D Center at SKT.

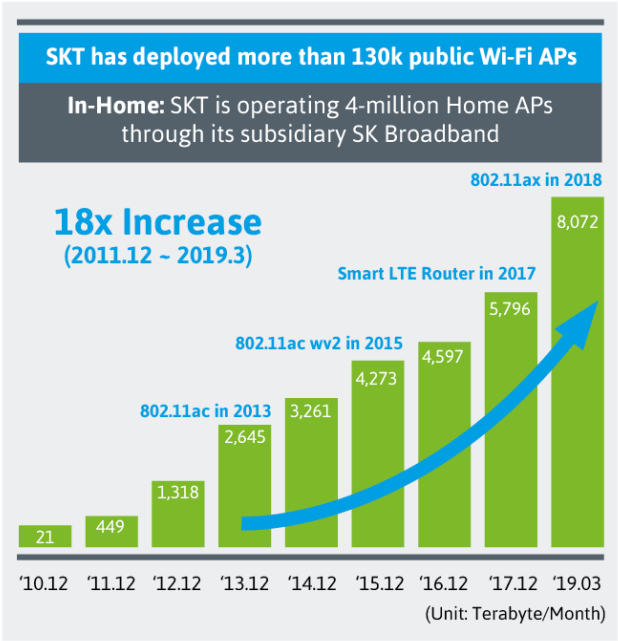
## Case Study: Wi-Fi Offloading with SKT

**Please tell us about your Wi-Fi offload strategy.**
SK Telecom has deployed a nationwide cellular network. To cope with the explosive growth of traffic, we started to deploy Wi-Fi hotspots nationwide and devoted efforts to provide reliable services to our customers through Wi-Fi offloading. To provide services to more customers, SK Telecom strategy is to first deploy Wi-Fi networks in crowded hotspots (e.g., subways, stadiums, complex malls, etc.), and then extend them to public venues. Currently, SK Telecom is operating about 130,000 public Wi-Fi access points nationwide.

**What benefits did you see from offloading cellular data to Wi-Fi?**
In a hotspot such as a crowded subway or a stadium with a big game, if all traffic is concentrated only on the cellular network, the quality of the cellular service will deteriorate. Deploying and efficiently operating Wi-Fi access points can effectively offload traffic in those hotspots. As a result, we can provide better service to customers with the combination of cellular and Wi-Fi networks.

**Please describe in which environments you offload the most?**
SK Telecom's public Wi-Fi traffic has increased rapidly—about eighteen times since 2011. SK Telecom's customers mainly use public Wi-Fi in the subway. When we consider traffic from the train and platform, the total traffic from the subway represents about 40% of the total traffic. The other demanding environments are: hospitals, universities, and busy shopping malls.

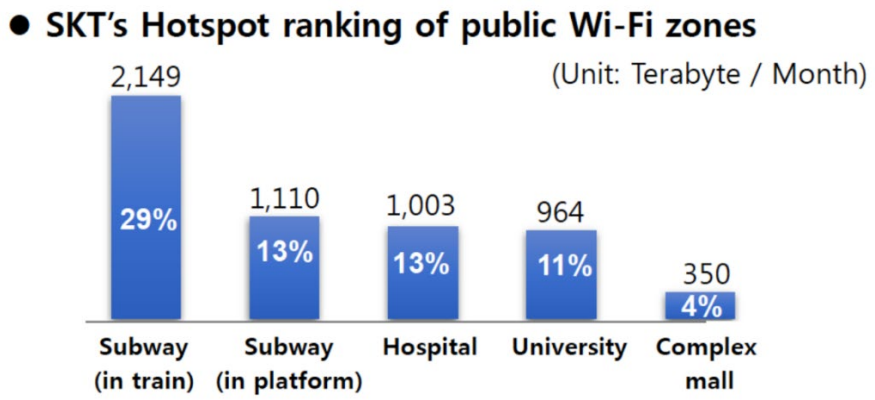
***Figure 4: SK Telecom's Public Wi-Fi Traffic Trend***




*Source: SKT*

**Did you quantify the benefits of Wi-Fi offloading? Can you provide some stats?**
Wi-Fi offload is meaningful in places with high traffic. As of April 2019, the offloading rate in a subway is about 20%. The Wi-Fi offload rate increases to about 40% including traffic from in-train. But we don't regard all that traffic as offload because Wi-Fi in train uses LTE backhaul. During the opening of Korean baseball games, the Wi-Fi offload ratio was 30%.

**Figure 5: Wi-Fi Offloading Rate in Hotspots (April 2019)**




*Source: SKT*

**What lessons have you learned so far from Wi-Fi offloading?**
Wi-Fi offload is a key element to provide a better mobile service to our customers. Offload is substantial in public venues with high traffic. Thanks to Wi-Fi offload, we can provide more reliable mobile services to our customers in these "hotspots." However, many Wi-Fi access points need to be configured to offload traffic. In those cases—since Wi-Fi operates in unlicensed bands—know-how and fine tuning to reduce interferences between many access points and improve Wi-Fi performance simultaneously are important to ensure an optimal Wi-Fi performance and QoE.

**How do you maintain the quality of the connection?**
SK Telecom commercialized South Korea's first Wi-Fi 6 in August of 2018 for next-generation Wi-Fi service, and deployed Wi-Fi 6 access points in dense areas of Seoul and other metropolitan cities in South Korea. In addition, SK Telecom developed Wi-Fi self-organized network (SON) function to optimize various Wi-Fi parameters. This is especially needed in areas where other non-managed Aps can create interference with our network.

**What impact do you expect Wi-Fi 6 to have on offloading?**
As explained in detail in section 4.1, Wi-Fi 6 (802.11ax) made a revolutionary improvement over the current 802.11ac. The most important goal is to improve QoE in dense areas as well as ensure high throughput. The main features of Wi-Fi 6 we value the most include: a maximum PHY increase due to the sue of 1024QAM; better customer experience in dense areas due to OFDMA, BSS Color, and MU-MIMO; better outdoor environment support thanks to increased guard interval; and finally, enhancement of better battery life by supporting target wake time feature. These advanced technologies of Wi-Fi 6 can significantly improve user experience. We expect, Wi-Fi 6 to play an important role in 5G. In addition, we expect the opening of 6GHz band to boost the impact and proliferation of Wi-Fi 6 and enable new business models. We deployed Wi-Fi 6 in challenging venues, such as: COEX Mall (the largest

mall in South Korea), Sajik Stadium in Busan, and the U-Square in Gwangju. As the biggest complex shopping mall in South Korea, COEX has about 250,000 visitors per *day* on weekends, and we experienced peak throughput of 800 Mbps and 5 ms latency.

**What impact do you expect 5G to have on offload?**
In the 5G era, as new media services such as VR and 8K videos expand, faster speeds and lower latencies will be required. Then, in addition to the conventional off-loading role, Wi-Fi must be able to play complementary roles with cellular networks. We think the latest Wi-Fi 6 can play a complementary role for 5G by applying key technologies such as OFDMA and MU-MIMO, and so on.

## 3.2 In-Home Wi-Fi: Managed Wi-Fi for a Connected Smart Home

Wi-Fi is king in the home, and with the proliferation of devices, the home is rapidly becoming a dense environment requiring a new level of Wi-Fi performance and coverage. However, the wireless footprint of these devices varies considerably and, unless some order is established, is a sure way towards an inconsistent Wi-Fi experience. Wi-Fi performance—and by extension the user experience—will suffer due to many environmental factors such as: congestion, noise, and interference.

The WBA 's In-Home Wi-Fi Industry Guidelines 2019[2] identifies the gaps in current in-home Wi-Fi standards and highlights the need for intelligent network optimization. The WBA aims to tackle the challenges that have contributed to inconsistent performance in the home, including a lack of uniform coverage and visibility into the in-home Wi-Fi experience.

The paper provides an industry go-to reference when preparing for 'Smart Home' deployments. It identifies the gaps in current in-home Wi-Fi standards and services and highlights the need for intelligent network optimization. WBA proposes key guidelines and recommendations for different functional areas and identifies future lines of work and possible directions the In-Home Wi-Fi network may take.

Typically, users are unable to differentiate between these problems caused by Wi-Fi, or other problems in the access network, or in the underlying applications. Top factors affecting Wi-Fi performance include: poor CPE (Customer Premise Equipment) placement, neighbor interference, dead zones due to the layout of the home, and presence of too many legacy devices operating exclusively at 2.4 GHz.

Many residential subscribers are tackling the aforementioned problems in their own way (and at their own risk) by purchasing third-party hardware in retail stores. However, at the end, if they fail to fix their Wi-Fi issues, they will blame their service providers for it, resulting in higher service calls, churn, and OpEx (operational expenses) for the carriers. In the Comcast case study, we will see that leading operators are taking the home Wi-Fi issue very seriously.

### Comcast Case Study

Comcast is a leading MSO and the largest residential Internet provider in the United States with, as of July 2019, 25.6 million Internet customers and over 19 million Xfinity Wi-Fi hotspots. According to Comcast's latest stats, 75% of residential customers receive 100 Mbps or higher.

[2] https://wballiance.com/resource/in-home-wi-fi-industry-guidelines-2019/

**What is at stake for MSOs**

Online media continues to grow in popularity and, as a result, many wireline and cable service providers are experiencing customer churn. Millions of Americans are cancelling their pay-tv subscriptions (referred to as "cutting the cord"). As pay-tv gives way to online subscription services, the need for fast and reliable broadband Internet increases as slow Internet with low capacity results in buffering that is unacceptable to customers when watching online TV programs.

At the same time, multiple system operators (MSOs) are under threat by OTT giants like Google, Amazon, and Apple who want to control the connected smart home emerging business and are already deploying their hardware in the form of voice recognition devices and IoT devices like Nest. To enable a secure and seamless connected smart home, MSOs must leverage their position as trusted broadband providers. They know that if they are to successfully introduce and sell new services and generate new revenue streams, they need to be quick, agile, and bold. Wi-Fi is at the center of that strategy and resolving the coverage and capacity issue is the necessary first step to own the connected home experience.

MSOs must provide tools for the end users to improve their Wi-Fi experience, as well as arm themselves with the ammunition to optimize and gain a better visibility of the home Wi-Fi network so that their customer care and agents can better help their customers.

**xFi Pods**

In May of 2018, Comcast officially launched xFi pods, a whole-home mesh Wi-Fi system. xFi Pods work with the xFi Gateways to continuously monitor and optimize Wi-Fi connections to each device. Powered by a cloud-based, remote management platform, xFi Pods evaluate the Wi-Fi environment to ensure devices are using the ideal bands and Wi-Fi channel. In addition, xFi Pods self-monitor their performance, and can "heal" themselves to deliver the best Wi-Fi experience for each device. With its xFi pods, Comcast hopes to reduce churn and improve customer experience.

Comcast is an investor in Plume and an early adopter of many Wi-Fi innovations, including community Wi-Fi. Plume is at the forefront of adaptive Wi-Fi delivered as a combination of multi-access points (MAPs), extenders, or pods which are cloud-managed. Comcast made some minor modifications to the firmware as their gateways have different silicon suppliers.

**The sources of poor Wi-Fi performance in the home**

One of the top contributors to degraded Wi-Fi performance in the home is the fact that there is still a large installed base of 2.4 GHz access points that have only three non-overlapping channels. On top of that, many end users simply place their access points in a less than optimal location, which further aggravates the problem.

Comcast believes multiple access points will be needed in the home to provide the kind of coverage and performance required in a home where the average number of devices is already beyond eleven with the top 10 percent already having twenty connected devices. That's why Comcast rolled out xFi Pods. The radio resource management and other control plane functions have more value if they are cloud-based and leverage the unlimited computer power available in the web to process all the data and intelligence to evolve towards truly adaptive cognitive Wi-Fi systems. Moreover, besides performance and coverage, Comcast created xFi, a

digital dashboard for customers to manage their in-home Wi-Fi network and the devices connected to it. xFi allows customers to create parental controls, pause devices, manage and troubleshoot Wi-Fi performance, onboard devices and more.

**How managed Wi-Fi fits with Comcast's overall homespot strategy**
Comcast works with vendors to enable GRE tunneling and AAA. Generic routing encapsulation is a tunneling protocol developed by Cisco Systems that can encapsulate a wide variety of network layer protocols inside virtual point-to-point links over an Internet Protocol network. Homespots are a virtual network bringing together residential customers into a shared network by enabling a second SSID.

**About Comcast Wi-Fi 6 home strategy**
Comcast and Intel are working together to develop a Wi-Fi 6-enabled ecosystem. Comcast is evolving its network to support Gigabit Wi-Fi speeds. At CES 2019, Comcast demonstrated gigabit speeds from its xFi Advanced Gateways to PCs based on 8th Gen Intel® Core™ processors with integrated Gigabit Wi-Fi. Forthcoming advancements in Wi-Fi 6 are expected to enable a new level of home Wi-Fi that can handle the demands of many connected devices. Intel is a key technology partner as Comcast currently tests new 10 Gigabit technology in their labs and could start trialing it in customer homes as early as spring 2020.

**The role of Wi-Fi in the 5G home**
Comcast does not see 5G-based fixed wireless broadband services—or mobile substitutes—becoming major competitors to their broadband business anytime soon. For connectivity in the home, Comcast believes customers prefer the speed, coverage, and control of wireline broadband services. In late 2018, Comcast announced 1GB speeds across its entire footprint of 58 million homes passed. Comcast also doubles the capacity of its broadband network every eighteen to twenty-four months as users consume increasing amounts of data.

**About Comcast overall Smart Home as a Service (SHaaS) strategy**
Cable TV giant Comcast prepared an opening salvo in its fight to sew up the Smart Home as a Service (SHaaS) market. Comcast launched Xfinity Home in 2012 and has established partnerships with Yale and Kwikset locks, Philips Hue, Tile, Honeywell, GE Lighting, and more so customers can incorporate those devices into their smart home set up and control them with their voice or automations and scenes.

Comcast offers a curated ecosystem of the best brands designed to provide the best smart home experience. Comcast believes its customers should be able to adopt smart home products with confidence and emphasizes brand staying power and quality. Providing a reliable experience that just works increases engagement and customer stickiness and offers opportunities to sell smart home solutions that customers value. People will be less likely to churn away from the Xfinity ecosystem if it means breaking their smart home into pieces and trying to reassemble it; such is the nature of smart home hubs, currently.

The WBA is discussing the development of a roaming framework for specific IoT technologies similar to the WRIX approach for Wi-Fi Roaming. The white paper "IoT Interoperability" idea is to replicate some of the work that the WBA has done for enabling Wi-Fi roaming in the IoT space especially for moving things and adding for example LoRaWAN capabilities into Wi-Fi routers.[3]

[3] https://wballiance.com/resource/iot-interoperability-dynamic-roaming/

## 3.3 Enterprise Wi-Fi

Since the first Wi-Fi standard was released almost twenty years ago, Wireless Local Area Networks(WLANs) have become an increasingly popular form of networking technology. Today, Wi-Fi is a critical and ubiquitous aspect of enterprises of all sizes and industries, furthered by the swelling usage of Wi-Fi enabled BYODs such as smartphones, tablets, laptops, and wearables. For many businesses, Wi-Fi is mission critical to operational success. While home users may tolerate a Wi-Fi outage (albeit not without frustration), schools, hospitals, corporations, and many other organizations cannot.

### 3.3.1 The Case of Industrial Wi-Fi: Mettis Case Study

Traditionally, Wi-Fi has not been very present in the industrial environment, but things are changing thanks to the features provided by Wi-Fi 6. In the spring of 2019, the Wireless Broadband Alliance (WBA) announced the world's first Wi-Fi 6 Industrial Enterprise and IoT trial with Mettis Aerospace, as part of its ongoing Wi-Fi 6 program. We spoke to David Green, I.T. Manager at Mettis; the interview follows.

**Can you give us a background about the Wi-Fi 6 enterprise and IoT trial you are partnering with the WBA for?**

Mettis Aerospace is a designer and manufacturer of precision-forged, machined, and sub-assembled components, primarily for the aerospace and defense industry. Mettis was introduced to the Wireless Broadband Alliance (WBA) by the Worcester Local Enterprise Partnership (WLEP). The Worcestershire 5G Consortium will begin the UK's most comprehensive industrial 5G testbed trial with a team of 5G specialists and business experts pioneering the concept of 'Industry 4.0.' The consortium of partners includes local infrastructure providers, national network operators, and research and development facilities. The introduction came after an initial look at the emerging 5G network project, and Mettis came to the conclusion that Wi-Fi would be a better fit for us right now.

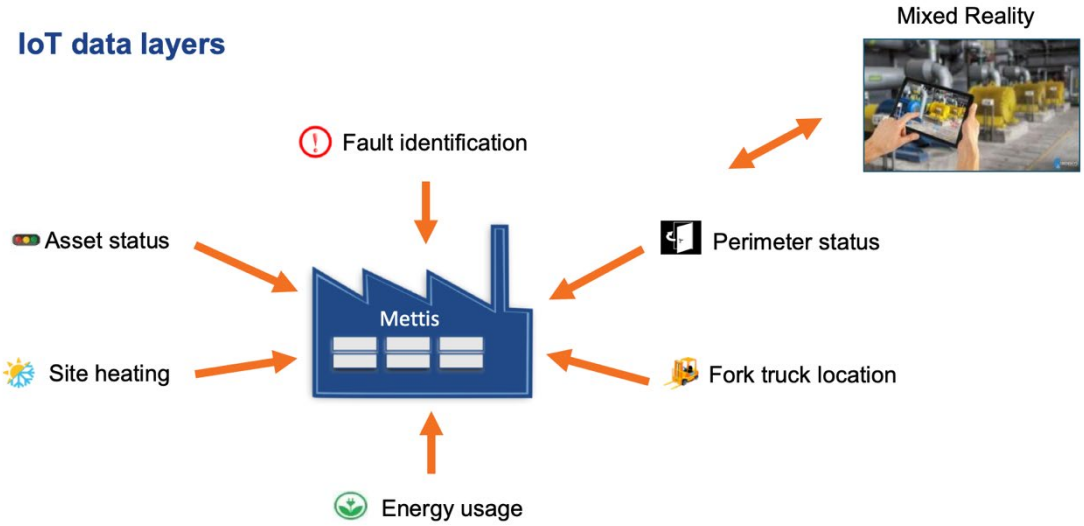
**Tell us about the role of each of the partners.**

The WBA has been doing a great job bringing all the relevant partners together to support the trial at Mettis. Cisco is fully engaged in providing the infrastructure by way of Wi-Fi 6 access points, etc. We are also engaged with other hardware providers like Broadcom and Intel together with support from iBwave from a software point of view, PTC (ThingWorx) is providing some resources to put a mixed reality demonstration together.

**What are the use cases you are testing for Wi-Fi 6 industrial enterprise and IoT trial?**

We operate in a very harsh environment that is challenging to any wireless network. Our site spreads for twenty-seven acres, comprises 3,600 assets, and employs 540 staff. Thus, we have a combination of people, fixed machines, and moving objects to connect. This industrial environment has a great variety and density of walls and obstacles composed of various materials which block the propagation of RF signals. On top of that, we have overhead cranes and moving objects which complicates where an access point must be placed for proper coverage.

**Figure 6: IoT Data Layers**




*Source: Mettis*

A few years back, we deployed 802.11b which was unable to cope with the conditions. Now, of course, the technology has evolved, and we believe Wi-Fi 6 can help us achieve our goals towards greater operational efficiency. We have identified four preliminary use cases planned that we believe will test both the capability and reliability of the Wi-Fi 6 architecture.

**1. Live video feed from a manipulator arm to forging press cab**

A camera is fixed over a manipulator which rotates 360 degrees; thus, a fixed cable to connect the camera is problematic, and the camera needs to be connected wirelessly. Wi-Fi 6 will be put to the test for high bandwidth and low latency requirements.

**2. Real time energy monitoring of our furnaces**

As part of improving operational efficiency on the furnaces, we would like our staff to be able to monitor energy usage from their mobile devices. We are looking at the possibility of controlling furnaces remotely as well. The vision in the long term is to connect these pieces of equipment so they can provide proactive alerts, monitor, and eventually self-heal, thanks to machine learning. Beyond the furnaces, we are excited about the prospect for our maintenance team to be able to manage problems more efficiently by being able to access resources such as access manuals and data onsite to fix problems more quickly.

**3. Wi-Fi machine sensors (depending on availability) to cover vibration, rotation, liquid levels, voltage, and valves**

We expect to deploy 20,000 sensors in the coming years. Some will continue to be hardwired to the network, but the majority will be wirelessly connected. One such example of connecting sensors is to connect the large entrance doors where trucks enter indoor areas. These large doors should not remain open more than necessary to avoid energy loss. An alarm would trigger an open door, and sensors would ensure doors are only open the necessary time, thus enabling huge energy savings. Wi-Fi 6 brings more efficiency into individual target wake time

(TWT) for IoT[4]. Some sensors would need to be online all the time; others wake just the necessary time needed to sense and send data back, then return to sleep mode.

**4. Mixed reality around sensor data already being collected from our 12,000-ton press**

Mixed (or augmented) reality is the most exciting use case because it can change staff's daily work lives for the better. The 12,000-ton press is just one of many possible use cases for mixed reality in our environment. One key benefit is the ability to collect data from all the machines, reuse the data within parameters, and enable a drastic reduction in rework rates which will provide substantial cost savings.

***Figure 7: Mettis Wi-Fi 6 Use Cases***

| Use Cases | High Bandwidth | Low Latency | High Security | High Mobility | Other |
|---|---|---|---|---|---|
| Live video feed from a manipulator arm to forging press cab. | Important | Important | | | |
| Real time energy monitoring of our furnaces. | | | | Important | |
| Wi-Fi Machine sensors (depending on availability) to cover vibration, rotation liquid levels, voltage, and values. | | | | | Power-saving |
| Mixed reality around sensor data already being collected from our 12,000 ton press. | Important | Important | | | |

*Source: Mettis*

**What are the KPIs and results expected?**
We are still in the process of defining these, but measuring latency, access point range, signal degradation, uptime reliability, and throughput will all be featured. We expect the trial to start in Q4 2019 and last three months, after which we will analyze and publish the results. We are at the planning stage of the project right now, arranging some site visits from the partners to determine physical hardware locations, etc.

The benefits for us include greater consistency in manufacturing, less downtime due to operational issues, significant energy savings through monitoring, more management information enabling decisions to be taken more quickly. New use cases and benefits will surely emerge as the technology becomes more widely adopted.

**Do you use Wi-Fi slicing?**
We are planning to segment the traffic between various stakeholders and use cases. For example, we will have a VLAN for voice, another for general data, control data, etc.
All the data stays onsite in the local network.

**How do you see Wi-Fi 6 coexisting with private LTE/5G in an industrial environment?**
I see both having a part to play in a fully connected industrial ecosystem. A lot will come down to cost, in terms of service, hardware, and deployment. In our case, Wi-Fi 6 is more convenient because we can use our existing devices—such as laptops, tablets, and handheld devices—which all have Wi-Fi. We expect to use Wi-Fi both indoor and outdoor in select areas.

**What about the EPC/core network? Do you have a data center on premise?**
Right now, a vast majority of our systems are on premise; this includes both voice and data.

[4] Individual target wake time (TWT) is a mechanism that allows scheduling of traffic exchanges between an AP and a client device. Scheduled behavior reduces the overhead and inefficiency of the channel access method for obtaining transmit opportunities and allows power-saving client devices to reduce power consumption by explicitly identifying the times when they should be awake.

Nearly all software providers are or are planning to migrate or offer a software-as-a-service model. So, I see this changing over the next five years.
Results from the initial Mettis Trial will be available by Jan 2020 via
the WBA Newsroom

### 3.3.2 Wi-Fi in the Hospitality Sector: Hilton Case Study

It has been well documented that free Wi-Fi tops the list of factors influencing booking decisions by hotel guests. But besides Wi-Fi being free, guests expect their Wi-Fi to be secure, seamless, and fast. In the following case study, we discuss guest expectations with leading hotel brand Hilton, and what is being done to meet these expectations.

Case Study 4: Hilton

Most large hotels have outsourced their Wi-Fi functions to third party managed service providers (MSPs) who manage and provide support for all things Wi-Fi related. Those same MSPs are the ones who can deploy new technologies and provide them as a new service to hotel brands. We spoke to John Flack, Senior Director Guest Facing Technology, who is responsible for Hilton's global Wi-Fi platform, TV/Video entertainment, and voice telecommunications to better understand how the vision of this major brand for the use of next generation hotspots.

**Wi-Fi Strategy**

Hilton has more than 5,700 hotels, totaling more than 900,000 guest rooms in 113 countries and territories worldwide. Wi-Fi designs are based on minimal signal and other standards Hilton established. Given Wi-Fi as one of the top amenities sought by guests, Hilton established a global Wi-Fi strategy for its hotels around three pillars:

1) Hotels can choose their own Wi-Fi support provider among fifteen suppliers/integrators.
2) Only one cloud-based authentication is used across all hotels worldwide for all Wi-Fi networks, providing a consistent guest login experience. All vendors are integrated into that global authentication platform. As a result, hotels have one common SSID, and Hilton Honors members can access the network with their last name and room number.
3) Hilton established a closely monitored equipment refreshment program, requiring hotel owners to replace their hardware systems every four to five years. Hilton notifies owners a year in advance of a required upgrade, and quality assurance teams monitor compliance.

Hilton has not deployed Hotspot 2.0 (HS2.0) but has completed trials and is enthusiastic about the merits of the technology. Hilton is currently reviewing the product, including appropriate security & privacy regulations. During Mobile World Congress (MWC) 2019, Hilton trialed Hotspot 2.0 in three Barcelona hotels with great success.

**Top Challenges**

Wi-Fi is normally free to Hilton Honors members but now all guests expect free Wi-Fi . As a result, Wi-Fi revenues are rapidly declining. At the same time, expenses are on the rise, and investment required for new technology remains.

**Recent Developments**
To enable future innovations and reduce overall technology cost for owners, Hilton is currently deploying converged network strategy (UnoNet or one network) across its properties to take advantage of an integrated dashboard to monitor network performance and analytics features. This platform will enable consolidation of several Local Area Networks (LAN), reducing cost and enabling technologies such as Hilton's Connected Room strategy. Hilton is deploying an edge controller that allows for communications with thermostats, light switches and other in-room devices. Connected Room will provide a consistent look and feel across all properties with rich content options, such as Netflix and Showtime as well as integration with the Hilton Honors application that allows guests to control TV, thermostats and light switches. In addition, Connected Room provides energy management and other operational cost savings initiatives.

**Other Digital Strategies**
In 2015, Hilton rolled out its Digital Key product allowing customers to check-in online the day before arrival and use their mobile devices to open their door lock. Today, Hilton has deployed the technology in more than 4,300 hotels around the globe with great success.

**Conclusion**
Hilton is a prime example of a business that relies heavily on Wi-Fi for both its customers and Team Members and is a great candidate to reap the benefits of the next generation Wi-Fi 6 with the integration of IoT and other innovations with its converged network strategy UnoNet. In the longer term, radio access network convergence with 5G may materialize through roaming and offloading agreements.

### 3.3.3 In-Flight Wi-Fi with Deutsche Telekom

In-flight connectivity is expanding rapidly as airlines increasingly recognize its value, leading to faster Wi-Fi connectivity speeds and better passenger experience. More speed and capacity backhaul services are enabling a more robust in-flight Wi-Fi experience capable of supporting high-bandwidth applications such as video streaming. Indeed, passengers—particularly the younger demographic (aged 18-35)—expect the same connected experience in the air as they have on the ground. There is a constant demand for real-time and sustained social and professional connectivity that will not accept potential barriers in the air.

As of early 2019, only a quarter of the airplanes in the air are actually providing some sort of connectivity to their passengers[5], either free or paid, while at least 81% of passengers globally would use in-flight Wi-Fi if it were available on their next flight. Sixty-six percent (66%) already see it as fundamental to the whole travelling experience.[6]

**Challenges Remaining**
While in-flight Wi-Fi is poised for steady growth, there are a number of technology and business standpoint challenges still ahead that need to be overcome. A fragmentation of approaches prevents airlines from deploying clear and convenient user services or understanding how to monetize in-flight Wi-Fi. The current fragmentation even prevents delivering an overall connected experience across regions. This lack of common best practices,

[5] Source: London School of Economics, Sky High Economics
[6] Source: Inmarsat Q4 2018 survey

combined with the high cost of certified wireless equipment onboard, impairs the in-flight Wi-Fi business case for the airlines. Over the next few decades, the airline industry will be forced to adapt to a scenario where connectivity can potentially become a basic and essential asset of any flight. Therefore, it has become more important than ever to understand what the options are for enabling technology and connectivity onboard, as well as how to monetize this service.

A wide range of monetization options have now been implemented by airlines over the last decade. The services vary according to region and usage (e.g., cellular access in Asia, not possible in the USA or EU). The first and arguably most generic option is simply charging the connectivity to the end user, either in the form of unlimited usage or limited to a specific data volume (e.g. MBs) consumed, but the take-rate of that offering has been very low so far (5-7% range). "Free" Wi-Fi (included in the ticket price) is also being experimented with, but the question as to who pays for the connectivity cost remains. Therefore, a "sponsored" approach is being explored along with advertising to cover these costs. Another option is to provide Wi-Fi only within select geographies—such as within the same country—to avoid complex roaming agreements. So far, no business model seems to have quite enabled a frictionless experience to travelers. To connect, passengers need to go through a number of obstacles, which include entering credit card details in the captive portal or downloading a specific application and choosing a specific plan, but all without any assurance of what speeds and quality of service they can expect.

**WBA Guidelines**

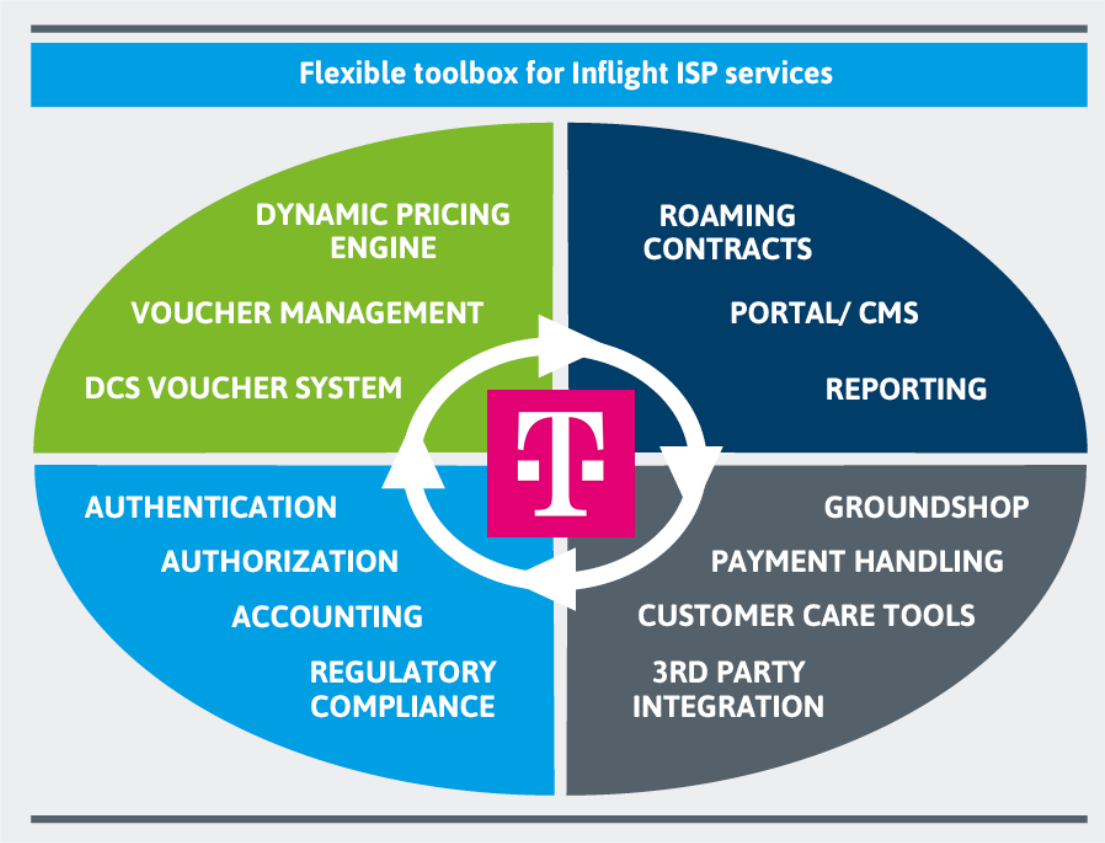
In May of 2019, the WBA released a detailed white paper[7] which lays out the different deployment scenarios and what methods can be used to improve the overall user experience on board. The paper looks at the various onboarding and authentication methods and encryption methods, as well as the overall infrastructure needed to support in-flight Wi-Fi. The ultimate goal is to enable a true next generation Wi-Fi experience, with seamless and secure onboarding across airlines and routes. The white paper also addresses the various business models that are being tried by the airlines and their partners to monetize Wi-Fi.

**The DT Example**

We spoke to Dr. Angelos Mavridis, director of Wi-Fi Roaming and Wholesale at Deutsche Telekom Global Carrier to understand the vision DT has for in-flight Wi-Fi. Deutsche Telekom is a leading in-flight and roaming provider, providing connectivity to thirteen airlines in over 500 airplanes, including Air France, Lufthansa, and Japan Airlines. DT provides connectivity support and maintenance to the airlines along with the services below:

[7] https://wballiance.com/resource/in-flight-connectivity/

*Figure 8: Deutsche Telekom Inflight ISP Services*

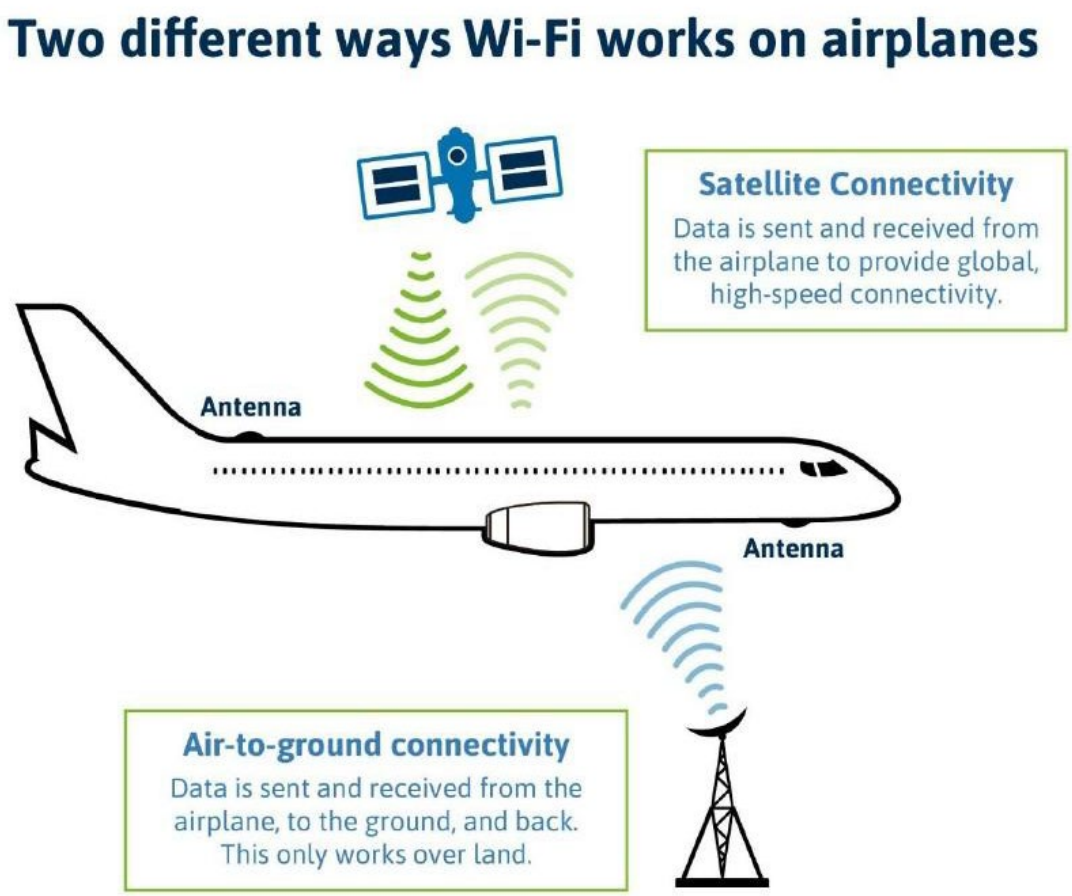



*Source: Deutsche Telekom*

**European Aviation Network with LTE Base Stations**

DT is quite bullish on the European Aviation Network which integrates satellite and air-to-ground connectivity in a large part of the European Union. The network involves thirty European countries and 300 LTE base stations providing high bandwidth, low latency in the highest flight density corridor in the world.

***Figure 9: Inflight Wi-Fi Network***




*Source: WBA*

### 3.3.4 Wi-Fi in Healthcare: Henry Ford Health System Case Study

The majority of office buildings have poor indoor cellular coverage, and mobile operators are only focusing on the largest and most profitable ones. Increasingly the argument is that building owners need to fund the in-building wireless coverage, or at least participate in the funding. However, with bring-your-own-device (BYOD), building owners and their tenants require all mobile operators to be supported inside the building. A neutral host is thus required somehow to enable access to all mobile users inside the building. Here again, the argument is that DAS is too complex and costly for smaller venues and mid-tier buildings. We now look at the specific use and requirements for Wi-Fi in the healthcare sector. We spoke to Ali Youssef, Principal Network Architect specializing in Mobility and Digital Health at Henry Ford Health System to discuss their expectations for Wi-Fi and private LTE.

The Henry Ford Health System (HFHS) covers the Detroit area and includes over 100 clinics and three hospitals. The system operates a Wi-Fi network comprised of more than 5,000 access points, the vast majority being indoor, and is considered a high-density Wi-Fi network with one

access point every 1,300 square feet. On a daily basis, the network serves 30,000 concurrent devices, half of which are guests.

The network also comprises a Digital Enhanced Cordless Telecommunications (DECT), a cordless phone system mainly used for nurses' handsets. They just upgraded their access points to 802.11ac (cycle every three to five years) and are working to move all devices to 5GHz. Current groups of HFHS users include:

- guest access
- BYOD
- medical devices
- employee devices
- handheld devices

The use of Wi-Fi in hospitals, clinics, and other health institutions is very much driven towards improving the delivery of healthcare services and staff productivity. There are a variety of applications and devices that use Wi-Fi; those include infusion pumps, oxygen monitoring devices, and smart beds, alongside mission-critical information applications such as access to electronic medical records (EMRs) and real-time access to X-rays and MRI scans. Medical telepresence delivered via Wi-Fi helps scale provision of high-quality healthcare to remote and underserved areas. Guest Wi-Fi helps healthcare IT managers eliminate the struggle associated with on-boarding of new devices, and the technology is well-suited to meet the growing connectivity demands of patients and their families in waiting rooms and lobbies.

***Figure 10: Wireless Use Cases in the Healthcare Sector***

| Customers | Staff | Contractors | Institutions |
|---|---|---|---|
| • Stay connected, informed, and entertained<br>• Navigate through hospital<br>• Improve experience while in hospital<br>• Provide timely feedback | • Stay connected, informed, and entertained<br>• Navigate through campus<br>• Improve experience | • Access patient records<br>• Track medical assets<br>• Communicate with other staff<br>• Navigate through campus<br>• Access institution central system | • Greater patient and visitor satisfaction<br>• Learn about traffic in the premises<br>• More revenues from guest Wi-Fi offering<br>• Greater staff productivity<br>• Track medical equipment<br>• Less down time<br>• Reduce capex and opex |

*Source: Datavalet*

**Challenges for Wi-Fi**

One of the biggest challenges for the network includes patchy indoor cell coverage where Wi-Fi calling is used in some instances, but is not at par with user expectations as calls drop when

users are moving around, especially in elevator shafts or in and out of buildings, stairways, etc. HFHS must also comply with a number of legal and security requirements, including:

- HIPAA Privacy Rules[8]
- HITECH (Health Information Technology for Economic and Clinical Health) Act of 2009
- ISC 8001
- PCI DSS Compliance for Healthcare

Some of these locations typically see a dense aggregation of connected devices contending for airtime, which creates a 'noisy' Wi-Fi environment, while also increasing interference and the user's experience. Wi-Fi 6 however brings many improvements. Wi-Fi 6 improves efficiency and consistency in performance by eradicating the contention-based approach of legacy Wi-Fi solutions that forces clients to randomly compete for airtime on a "first come, first served basis. As indicated in its white paper[9] "Understanding the Global Implications of Wi-Fi 6 & 6GHz", the WBA has found that more than 60 percent of those surveyed either already have or soon will roll out Wi-Fi 6 technology into their networks. Doing so will have an immediate impact on highly congested networks and will lay the foundation for supporting new use cases, such as meeting ever-increasing demand for faster multi-user data rates and IoT deployments.

**Expectations with Combined CBRS-Wi-Fi**
The expectations vis-a-vis CBRS is that it will enable good quality voice with seamless roaming in all instances at a price point way below DAS solutions. Medical staff want to use their own devices and expect quality service for both voice and data. The ideal deployment scenario is to integrate CBRS with Wi-Fi by just adding CBRS modules to existing access points powered by PoE. Their IT organization is comprised of 300 people, and they expect vendors to provide an E2E solution, including EPC for which they have no expertise at the moment. Our best bet is that CBRS will take another four to five years before it is deployed.

### 3.3.5 The Connected Vehicle

The transportation industry currently is undergoing a huge transition driven by the integration of network connectivity. Vehicles increasingly are being equipped with embedded connectivity to the extent that more than 125 million connected car shipments are expected by 2022. There has been significant industry focus on the capabilities enabled by using wide-area cellular connectivity to support connected-vehicle use cases that require always-on and ubiquitous network connectivity. However, as the recent WBA white paper entitled "The Connected Vehicle Understanding the Wi-Fi Opportunities and Use Cases" discusses, there is potential for complementary use cases in which vehicle-to-cloud connectivity can benefit from opportunistic connectivity delivered by using Wi-Fi systems. The analysis highlights striking commonalities between the requirements associated with the multi-RAT connected smartphone and the multi-RAT connected vehicle, as well as the benefits of applying well established Wi-Fi roaming concepts, originally defined for smartphone

[8] Health Insurance Portability and Accountability Act (HIPAA)—establishes national standards to protect individuals' medical records and other personal health information; applies to health plans, health care clearinghouses, and those health care providers that conduct certain health care transactions electronically. https://www.hhs.gov/hipaa/for-professionals/privacy/index.html
[9] https://wballiance.com/resource/understanding-the-global-implications-of-wi-fi-6-6ghz/

use cases, to nascent connected-vehicle roaming scenarios. Those services better served by Wi-Fi include real-time over the air updates as well as telematics, remote services and other communications to and from the vehicle.

## 3.4 Smart Cities: Connecting the IoT and the Unconnected

For many cities around the globe, Wi-Fi is a natural choice to start delivering Internet access to unconnected citizens. Wi-Fi is often the technology that is used to underpin the initial use cases and deployments in smart city projects, creating an affordable platform on which further applications can be layered and providing access to services.

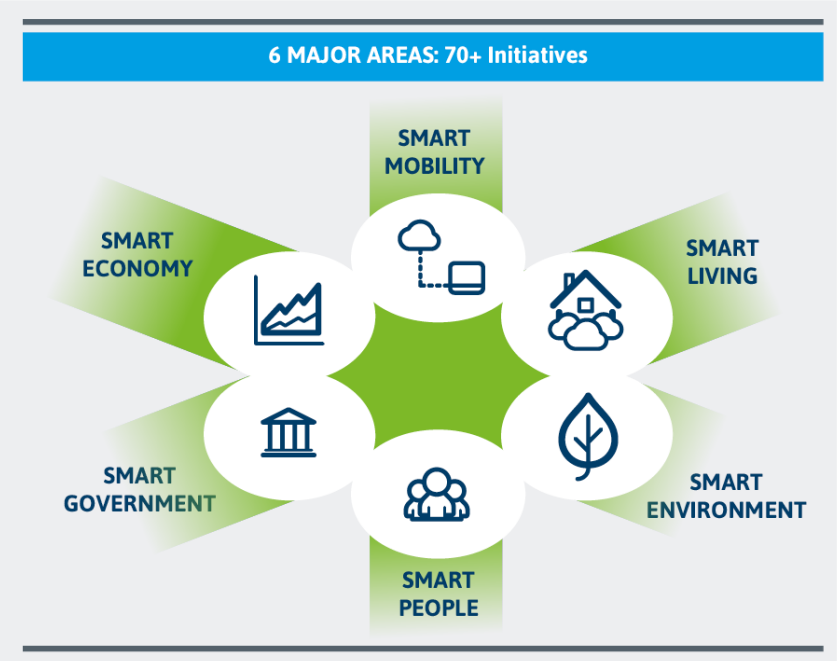
Use cases for cities are many and varied, regardless of whether or not they include some form of Wi-Fi. Cities are beginning to explore the development of wide grids of coverage by combining different networks through roaming services, given to citizens as a single credential that can be used across a variety of networks. These grids can be managed directly by the city's authorities or by a third party. For Services Providers (SPs) and cities, there is an opportunity to harness people's familiarity and acceptance of Wi-Fi to create new services and products, encouraging additional roaming usage and revenues. A managed Wi-Fi roaming service, including guest Wi-Fi for both visitors and citizens, can greatly improve the overall user experience.

### Case Study 8: Smart City Hong Kong

In December 2017, the Government released the Smart City Blueprint for Hong Kong, outlining the vision and mission to build Hong Kong into a leading smart city around the world and setting out over 70 initiatives under six smart areas:

1. Smart Mobility
2. Smart Living
3. Smart Environment
4. Smart People
5. Smart Government
6. Smart Economy

***Figure 11: Six Smart Areas***




A high-level, inter-departmental Steering Committee on Innovation and Technology, chaired by the Chief Executive, has been set up to steer development of innovation and technology and smart city projects. A Smart City Office has also been set up under the Innovation and Technology Bureau to coordinate smart city projects across different government departments and agencies in the public and private sector. A number of smart city key infrastructure projects and initiatives are now being actively taken forward by the Office of the Government Chief Information Officer ("OGCIO") as well as other government departments for improving city management and providing more efficient and reliable public services to the public. Some of the notable smart city initiatives include:

**eID**

OGCIO will be providing Electronic Identity ("eID") to Hong Kong residents to enable them to log in and use various e-Government services in a simple, convenient and secure manner. The eID system is expected to come into operation in mid-2020 with eID to be adopted in 26 e-Government services by the time including Home Ownership Scheme, eTAX, renewal of driving license, registration of outbound travel information, registration for employment services by job-seekers, etc. By mid-2021, the city expects that eID will be adopted in most (over 110) of the e-Government services. The core data (including users' personal data) in the eID system will be encrypted using Advanced Encryption Standard and stored in government data centre facilities in Hong Kong. In conformance with industry encryption standards, Transport Layer Security will also be adopted to encrypt data to ensure data security and integrity during transmission over the Internet.

**Faster Payment System**

Online and electronic payment is another essential component of e-Government services. The Hong Kong Monetary Authority ("HKMA") launched the Faster Payment System ("FPS") in

September 2018 to enable users of banks and stored value facility ("SVF") operators to make instant cross-bank/e-wallet payments easily by entering the mobile phone number or the email address of the recipient. The Government is also planning for the use of FPS to provide the public with greater convenience in paying government bills and fees including taxes, rates and water charges which is expected to be launched in the fourth quarter of 2019.

**Open Data and Related Development**

The Government firmed up the Open Data Policy on opening up government data in October 2018 where government bureaus and departments ("B/Ds") should endeavor to release their data for free public use via the Public Sector Information ("PSI") Portal (data.gov.hk) in machine-readable formats unless with justifiable reasons (e.g. involving personal privacy). Around 500 new datasets have already been released in the first half of this year and it is expected that the total number of datasets in the PSI Portal will reach 4 000 by the end of 2019. A number of public transport operators have reached agreement with the Transport Department to open up real-time arrival data in the third quarter of 2019 for free use by the public in the PSI Portal. OGCIO is also developing City Dashboards to facilitate the public to view the data in an easier manner. The City Dashboards will be rolled out in the fourth quarter of this year and anticipated that these measures and developments will help enhance the city management.

**Next Generation GovCloud and Big Data Analytics Platform**

OGCIO is establishing the next generation government cloud infrastructure ("Next Generation GovCloud") to enable B/Ds to share resources, expedite system development and enhance operational efficiency so as to cope with the growing demand for digital public services. The OGCIO is also building a big data analytics platform in order to facilitate B/Ds' transmission and sharing of real-time city data (such as traffic, weather and environmental data) and conduct big data analytics so as to adopt a data-driven approach in policymaking and service delivery for raising government operational efficiency and improving city management. The Next Generation GovCloud and the big data analytics platform are planned to be launched in the third quarter of 2020.

**Multi-Functional Smart Lampposts Pilot Scheme**

The city is also deploying about 400 multi-functional smart lampposts with sensors and other electronic devices in four urban areas (namely Central/Admiralty, Causeway Bay/Wan Chai, Tsim Sha Tsui and Kwun Tong/Kai Tak Development Area) to collect various real-time city data for enhancing city and traffic management. The smart lampposts will also use power-saving light emitting diode (LED) lighting as well as adopt intelligent management to save energy. Provision will also be made for mobile network operators to apply for installation of 5G base stations and for the provision of free Wi-Fi service. The first batch of 50 smart lampposts has been installed at Kwun Tong/Kai Tak Development Area and has come into operation in June this year. Installation of the remaining smart lampposts and the whole project is expected to be completed in 2021-22.

**Wi-Fi Connected City**

The city of Hong Kong has launched the "Wi-Fi Connected City" programme and the number of hotspots joining the "Wi-Fi.HK" brand has increased from about 21 300 in February 2018 to over 26 000 in June 2019, with the participation of more than 130 public and private organizations. The free Wi-Fi is a great amenity for both tourists and members of the public. The Government continues to invest in using fiber network and latest Wi-Fi technology

standard and as a result, connection speeds at government venues have increased to more than 10 Mbps from the previous speeds of 3-4 Mbps, leading to higher satisfaction rates. Through invitation of more organizations to join the "Wi-Fi.HK" brand, public-private collaboration and other government initiatives, the city believes the number of hotspots under the "Wi-Fi.HK" brand will exceed 34 000 by the end of 2019.

**Smart Government Innovation Lab**
The Smart Government Innovation Lab was established in April 2019 to facilitate the adoption of innovation and technology for enhancing public services. It provides a platform for inviting innovative ideas and product suggestions from the industry on operational needs of government departments and conducting proof-of-concept testing on suitable solutions. It also arranges regular technology forums to facilitate sharing and exchange with solution providers and showcases technologies that are being or have been tested by individual government departments, with a view to inspiring wider adoption within the Government.

**Pilot Blockchain Project**
OGCIO kicked off a pilot project on application of blockchain technology at the end of last year to explore the applicability, benefits and limitations of adopting blockchain technology in government services. OGCIO has discussed with four departments to jointly implement pilot projects, among which Intellectual Property Department will apply blockchain technology in the transfer of registered trademarks to facilitate the receipt and access of relevant information by concerned parties. Companies Registry, Environmental Protection Department and Department of Health will also progressively implement pilot blockchain projects that are conducive to their businesses. The first pilot blockchain project is expected to be rolled out by end 2019 while the others will be rolled out progressively in 2020.

The city of Hong Kong has a very ambitious smart city program which is already underway. As a very sophisticated city with a high concentration of mobile and tech devices, Hong Kong is a vibrant laboratory for smart city initiatives. Because it is such a dense and small environment, the citizens of Hong Kong will surely feel the impact of these initiatives very quickly in their daily lives. From being informed on environmental conditions to paying government bills and navigating through busy traffic, citizens can enjoy smart city applications and living.

## 4. The Role of Wi-Fi Among Other Radio Access Technologies and 5G

The focus of the wireless industry in 2019 has been heavily on cellular technologies because of the first deployments of 5G networks in markets like the USA and South Korea. These events have, perhaps inevitably, sparked discussion about 'standard wars'. Will 5G make Wi-Fi (and other unlicensed spectrum technologies) redundant, especially when it is standardized for unlicensed bands itself? Or conversely, is 5G too late, and facing an uphill battle to unseat Wi-Fi in the enterprise and hotspot markets on which its business case often rests?

Such discussions miss the point which stakeholders in all areas of the communications industry repeatedly make. As the Wireless Broadband Alliance put it: "Wi-Fi will be a core component of 5G communication technologies and Wi-Fi will have a significant impact on the definition of 5G, which will seamlessly integrate with future IMT-2020(5G) standards."

Given the vision that next generation wireless will be providing the connectivity for the digital society, which will mean supporting a huge variety of applications, it is clear that one radio technology will not be able to deliver that vision alone. Coexistence between different radios, spectrum bands and deployment models will be essential to deliver the full potential of wireless connectivity in the '5G era'.

Wi-Fi has blazed a trail in many areas which are now becoming a feature of the cellular market, from the technical (millimeter wave) to the commercial (neutral host providers). As the WBA has outlined in several thought leadership papers[10], these foundation stones will help to achieve wireless-based transformation more quickly and effectively.

To support this unprecedented variety of use cases, each with its own different network requirements, service providers will need to harness a variety of spectrum bands, radio technologies and ecosystems to support all the required capabilities. Increasingly, it will be more realistic to integrate Wi-Fi, cellular and wireline connectivity at multiple layers of the network, thanks to virtualized, converged cores and new network orchestration tools.

All that will culminate in network slicing, a technology that allows a particular service to call up a virtualized, dedicated network for as long as required, combining and re-combining different radio and cloud resources to achieve the optimal end-to-end connectivity. Although slicing is often associated with cellular 5G, in reality it will harness many radio technologies and types of spectrum. The WBA, as part of a series of papers on supporting '5G-like' use cases with Wi-Fi, has set out detailed guidelines on how Wi-Fi networks can be sliced, using a combination of standard features and vendor support. For instance, in 'Network Slicing: Understanding Wi-Fi Capabilities'[11], the WBA demonstrates how Wi-Fi systems can support the majority of slicing use cases, including those in access, core and transport domains.

Slicing is years away from wide-scale commercial implementation, but it is worth mentioning because it highlights the way the industry is going – towards ever-deeper convergence of cellular, Wi-Fi and wireline technologies, to create a massive pool of capacity in which the individual standards are transparent to the user or device, and even the service provider.

The WBA set out, at an early stage, to drive that process of growing convergence for the benefit of the whole wireless industry. It has worked closely with cellular standards bodies and industry organizations to define common positions and identify common requirements. Its body of work in this area, including six high impact thought leadership papers, reflects years of cooperation, deep technical work, and commercial analysis, which has made a significant contribution to the over-arching goal of universal wireless broadband connectivity for every citizen and use case. The work with 5G and Wi-Fi RAN Convergence still has a long way to go – but the collaborations in the industry are happening and operators are realizing the benefits to be had.

## 4.1 Wi-Fi Evolves 5G-Type Capabilities Within Wi-Fi 6

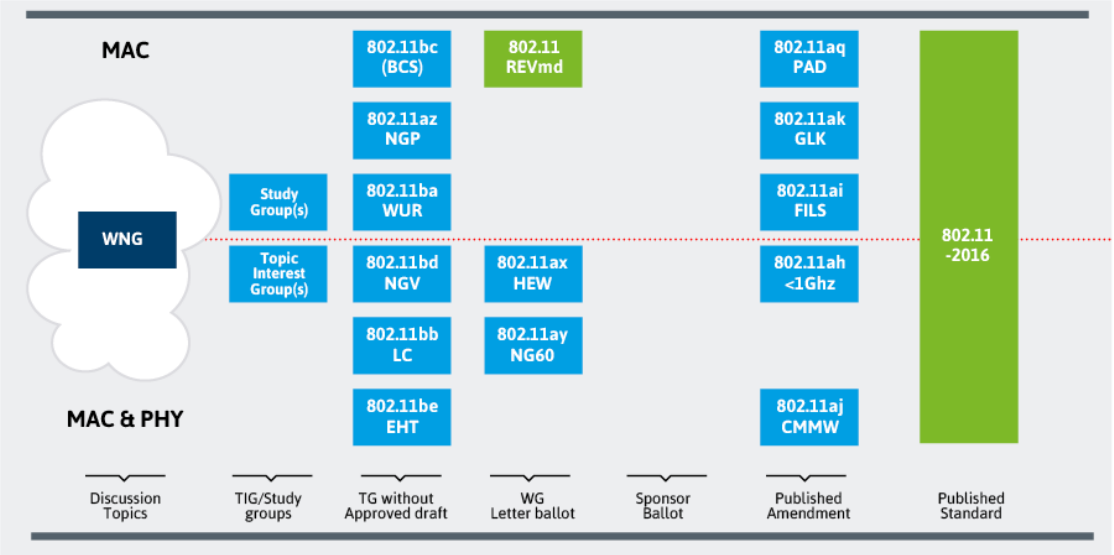
Just as the diversity of wireless use cases, and the demands they make on networks, is exploding, so a radical expansion of Wi-Fi capabilities is underway to meet those demands. The

[10] https://wballiance.com/resource/unlicensed-integration-with-5g-networks/
[11] https://www.wballiance.com/wp-content/uploads/2018/03/Network-Slicing-Understanding-Wi-Fi-Capabilities.pdf

centerpiece of this transformation is Wi-Fi 6, based on IEEE 802.11ax standards, which delivers a step change in Wi-Fi capabilities and performance.

Wi-Fi 6 has true 5G capabilities, including support for multi-gigabit speeds, massive device density and very low latency. Not only does it boost performance, but it is readily deployable for a huge array of use cases. The Wi-Fi community has worked to turn an impressive core standard into a fully deployable, monetizable platform. With publications like the new Wi-Fi 6 Deployment Guidelines and Scenarios[12], the WBA eases the path for service providers to deploy networks that are optimized for many different markets and applications, and so have far greater commercial potential than previous platforms. Networks based on Wi-Fi 6 can be sliced; they can support service level agreements (SLAs) in terms of throughput, latency, traffic prioritization and other requirements; and they remain backwards compatible with previous Wi-Fi generations, which protects investments and ensures a huge installed user base from day one.

***Figure 12: IEEE 802.11 Standards Pipeline***




*Source: IEEE, April 2019*

Wi-Fi 6 uses a combination of technologies, including OFDMA and 1024 QAM modulation to improve spectral efficiency and boost not just speed, but support for large numbers of devices in a confined area. In early trials, that capability has mainly been demonstrated in stadium environments, but device density is also important in the home, where many appliances and previously dumb devices will start to be connected to the home hub, and where several users may be consuming high quality video, gaming or AR/VR at the same time. Target wake time enables devices to determine when and how frequently they send or receive data, extending battery life for devices like IoT sensors. This is especially salient, as 26 billion IoT devices will be online by 2020. BSS coloring will enable increase capacity in dense environments by increasing frequency reuse between BSS's. BSS Coloring is a method for addressing this medium contention overhead due to overlapping basic service set (OBSS) and spatial reuse. 802.11ax radios can differentiate between BSS's by adding a number (color) to the PHY header and new channel access behavior will be assigned based on the color detected.

[12] https://wballiance.com/wi-fi-6-deployment-guidelines-scenarios/

Chipsets based on preliminary drafts of the final standards have been coming to market since early 2018 and certification by the Wi-Fi Alliance has now started (in September 2019), just ahead of final ratification of the IEEE specifications.

***Figure 13: Wi-Fi Generations of Standards***

| Protocol | Frequency | Signal | Maximum data rate |
|---|---|---|---|
| Legacy 802.11 | 2.4 GHz | FHSS or DSSS | 2 Mbps |
| 802.11a | 5 GHz | OFDM | 54 Mbps |
| 802.11b | 2.4 GHz | HR-DSSS | 11 Mbps |
| 802.11g | 2.4 GHz | OFDM | 54 Mbps |
| 802.11n | 2.4 or 5 GHz | OFDM | 600 Mbps |
| 802.11ac | 5 GHz | 256-QAM | 1.3 Gbps |
| 802.11ax | 2.4 or 5 GHz | 1024-QAM | 9.6 Gbps |

*Source: Maravedis*

Several chipset providers have already released draft-compliant 802.11ax products and many more will follow in the coming months. Quantenna (now ONSemi), Qualcomm, Intel, Mediatek and Broadcom are among the companies which have introduced Wi-Fi 6 chipsets. These chipset manufacturers have considerable influence on how new specifications are introduced in the market, as they provide drivers to the AP manufacturers to use the chipset functionality. Chip availability and certification programs will drive rapid expansion in availability of access points with many vendors planning to showcase Wi-Fi 6 products at January's Consumer Electronics Show 2020.

As indicated in figure 12, 802.11ax is at the working group letter ballot phase with draft #4 already available, and draft #5 before moving to the sponsor/association ballot phase. According to Dorothy Stanley, IEEE 802.11 Working Group Chair, publication of the standard is expected by the end of 2019. Products in the market already support the majority of features in the standard, and not all are needed.

The IEEE indicated that 802.11ax (Wi-Fi 6) meets the MAC/PHY requirements for 5G indoor hotspot test environment defined by IMT-2020. Their analysis and simulations confirm that performance of IEEE 802.11ax (Wi-Fi 6) MAC/PHY meet or exceed 5G requirements for the 5G Indoor Hotspot use case, and similar studies are underway for the dense urban test environment.

## 4.2 Other Elements of the Wi-Fi Standards Roadmap

There are other elements in the Wi-Fi standards roadmap. The various use cases keeping the IEEE busy include dense Wi-Fi deployments (802.11ax), indoor location (802.11az), and low power applications (802.11ba). The increase in technical capabilities of existing technologies also drives new standards, with technologies like MIMO and OFDMA being incorporated into new standards.

New 802.11 radio technologies are under development to meet expanding market needs and leverage new technologies:

- 802.11ax – Increased throughput in 2.4, 5 (and 6) GHz bands. Increased efficiency.
- 802.11ay – Support for 20 Gbps in 60 GHz band.
- 802.11az – 2nd generation positioning features.
- 802.11ba – Wake up radio. Low power IoT applications.
- 802.11bb – Light Communications.
- 802.11bc – Enhanced Broadcast Service.
- 802.11bd – Enhancements for Next Generation V2X.
- 802.11be – Extremely High Throughput (evolution to ax for 2.4GHz and 5/6GHz operation).

(To review each specific amendment is out of the scope of this report. Readers are invited to consult the relevant IEEE documents.[13])

In October 2018, Qualcomm was the first to announce pre-standard chipsets for the 11ay standard, which is a successor to 802.11ad/WiGig in the 60 GHz millimeter wave band. The 11ay standard adds dual-channel bonding in order to double data rates to reach almost 10Gbps over short distances (less than 50 meters), and with sustained latency as low as 3ms.

802.11be is a new amendment that builds on 802.11ax. This Extremely High Throughput (EHT) radio is projected to deliver higher throughput of up to 30 Gbps and support for low latency communications with operations in 2.4 GHz, 5 GHz, and 6 GHz bands. Its targeted completion is 2023. Some of 802.11be features under consideration include:

- 320 MHz bandwidth and more efficient utilization of non-contiguous spectrum
- multi-band/multi-channel aggregation and operation
- 16 spatial streams and MIMO protocols enhancements
- multi-AP coordination (e.g. coordinated and joint transmission)
- enhanced link adaptation and retransmission protocol (e.g. HARQ)
- adaptation to regulatory rules specific to 6 GHz spectrum
- refinements of 802.11ax features

The parallels between the two roadmaps, and the benefits of greater interworking, were highlighted in a joint report about RAN Convergence, published in 2019 by the WBA and the NGMN. The report[14] identifies various use cases where the optimal solution would be an integrated 5G/Wi-Fi approach, as well as highlighting the challenges to achieve that. The key hurdles to leap are, the report argues:

- tighter integration of Wi-Fi access within 5G networks
- network manageability and policy control,
- the enablement of Wi-Fi-only devices in a converged environment.

[13] *http://grouper.ieee.org/groups/802/11/presentation.html*

[14] https://wballiance.com/resource/ran-convergence/

The organizations state: "As society increasingly depends on fast reliable data connectivity, NGMN and WBA believe an important capability for the industry is the convergence at a network level between 5G and Wi-Fi, so that the unique and complementary capabilities of both RANs can be leveraged to provide seamless network services. Bearing in mind that a significant amount of data traffic from smartphones use a Wi-Fi access, this will lead to a better user experience and create new business opportunities for both Wi-Fi and cellular providers."

The two organizations initiated further study to identify potential solutions in four areas and a new paper, 'RAN Convergence', was published in September 2019. This examines several technical challenges, including connected cities, smart factories and next generation homes.

- Enabling Wi-Fi-only devices to connect to the 5G core
- Further progress to ensure tight integration between 5G and Wi-Fi networks
- An interface to enable a certain level of network manageability and policy control between 5G core and Wi-Fi networks
- The ability for a client to route traffic over one or more access types in an intelligent way, making optimal use of the available connectivity.

It also addresses some of the most important vertical market scenarios for converged systems, including enterprise services, in-home converged access, future factories and smart cities.

*Figure 14 summarizes some of the key targets for the current and imminent standards efforts and highlights the many parallels between the two communities.*

***Figure 14: Standard Efforts by Use Case***

| Topic | 3GPP Release 16 | 3GPP Release 17 | IEEE 802.11 roadmap |
|---|---|---|---|
| Bandwidth/speed | Multi-Gbps speeds | | Extremely high throughput |
| Media | Multimedia Priority Service, codecs | | Next generation V2X |
| mmWave spectrum | Enhanced usage at 20-50 GHz | Spectrum above 52.6 GHz | 20Gbps speeds in 60 GHz |
| Unlicensed spectrum | Unlicensed spectrum | Seamless licensed/unlicensed spectrum usage | Light communications |
| V2X | V2X application layer | V2X scenarios | Next generation V2X |
| IoT | IoT optimization | Industrial IoT<br>Ultra-low power WAN | Ultra-low power IoT |
| | | | |
| Other | 5G satellite access | 5G-enabled VR | Enhanced positioning |
| | (W)LAN support and interworking | | Enhanced bandwidth efficiency |
| | Wireless/wireline convergence | | |
| | Network automation | | |
| | Comms in vertical domains | | |
| | Enhanced security | | |
| | Network slicing | | |

*Sources: 3GPP and IEEE*

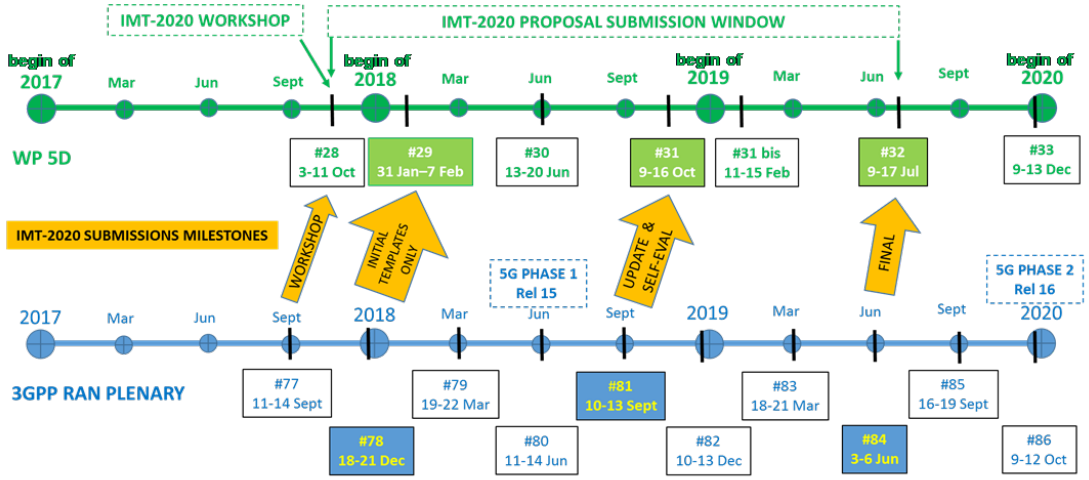
## 4.3 Standardization and the 5G Roadmap

It is no coincidence, then, that the two major next generation standards for wireless broadband, Wi-Fi 6 (IEEE 802.11ax) and 5G (3GPP 5G New Radio and Core Network), are often targeting similar capabilities, and are far closer in timescales and target use cases than previous generations. In many cases, each community draws on developments done in the other. For instance, 5G NR extends the cellular standards into millimeter wave spectrum, above 20 GHz, for the first time, but the pioneering work on mmWave wireless broadband modems was done for IEEE 802.11ad (WiGig). On the other hand, developers of the Wi-Fi 6 standards have leveraged work done on advanced modulation schemes by the cellular community. The common goals, and converging technologies, will become even more apparent when we look at the goals of the ensuing waves of standards from both communities.

On the cellular side, the first group of 3GPP 5G standards is Release 15. The first iteration was 5G New Radio (NR) Non-Standalone (NSA), which was finalized in late 2017 and specifies a 5G RAN that needs to be anchored in a 4G core. All operators which are launching 5G services in 2019-2020 plan to deploy NSA first and migrate later to the second set of standards, NR Standalone (SA), which introduces the 5G Core Network (CN). This is a virtualized, and in most cases cloud-native architecture. In both cases, core functions are run in software on off-the-shelf hardware, rather than on dedicated, integrated appliances. In cloud-native cores, the various functions are disaggregated and run as microservices, which can be mixed and matched, Lego-style, to support different use cases.

The next set of standards, Release 16, will be finalized in early 2020, and the 3GPP has recently set out a preliminary list of topics to be considered for inclusion in Release 17 standards, expected to be ratified in 2021. In all cases, commercial equipment availability usually follows ratification by 6-9 months, though many operators which are deploying NSA have not fixed a timeline to introduce a 5G Core, a major transition whose timing will be decided by business case requirements rather than equipment availability. It is important to note that enhancement of 4G (LTE) standards is continuing in parallel with 5G processes and at least two-thirds of MNOs, according to a survey by Rethink Research, plan to continue to expand 4G for at least 3-4 years after their first 5G deployments.

***Figure 15: 3GPP Standards Progression 2017 to 2020***




*Source: ETSI*[15]

## 4.4 Convergence or Diversity?

Interestingly, 3GPP Release 16 will standardize the 5G NR for unlicensed spectrum, while Release 17 proposes to develop technology to allow seamless usage of all kinds of spectrum by a single 5G connection. As with the release of 4G standards for unlicensed spectrum, such as LTE-Licensed Assisted Access (LAA), this breaks down the clear barrier between Wi-Fi and cellular – the type of spectrum.

Taken together with increasing commonality of purpose, this raises the question of whether there should just be one wireless broadband platform, with sufficient spectrum to support almost any kind of use case?

The WBA takes the view that cooperation and coexistence are more important than uniformity. The key goal is to ensure that different technologies work seamlessly together, while retaining their own unique capabilities, so that the widest range of business opportunities can be optimally addressed. The WBA believes it is important that network providers have the opportunity to use any combination of connectivity that suits their use cases or business models, with common management and orchestration (MANO) for all; and that end users are able to access the best connection for a particular application or location, with the seamless sign-in supported by NGH/Passpoint.

## 4.5 Security, Mobility and Latency – Wi-Fi 6 Addresses Three Key Wireless Challenges

Security, mobility and low latency have always been important to wireless network users, but many of the applications which are driving the new generation of connectivity make them into critical requirements. Rising use of augmented reality, many business critical IoT services, and the trend to use wireless as the default connection even for sensitive data, are all throwing a

[15] https://www.etsi.org/technologies/5g

strong spotlight on these three critical capabilities of modern wireless networks. They are also three of the biggest challenges for those designing wireless networks, and are becoming central to the business case, especially as many providers focus more heavily on mission-critical enterprise services.

Such services promise to deliver new revenue streams, often with higher margins than consumer services, but they have very demanding requirements when it comes to security, and the speed of mobile hand-off and round-trip response (latency). This is particularly true of some of the key opportunities which providers are targeting with technologies like Wi-Fi 6, such as public safety, smart cities, Industrial IoT environments.

The near future generations of Wi-Fi technology (as well as 5G), have these three capabilities at their heart. The modulation scheme in Wi-Fi 6 is central to this. It allows every individual client or transmission to have its own subset of a wireless channel, tailored for its needs. This not only supports larger numbers of users at the same time but reduces latency and helps each use case to be supported with the right set of capabilities.

**Security**

In 2018, the Wi-Fi community took one of its biggest steps forward in security when the Wi-Fi Alliance started to certify the WPA3 protocol. This replaces WPA2, which has been in use since 2004. The new protocol provides improved password protection, while limiting what hackers can see even if they do gain access. Other enhancements include forward secrecy, which prevents older data from being compromised by a later attack.

For enterprises, WPA3-Enterprise is the preferred user authentication technology for the government and finance sectors. It uses the equivalent of 192-bit cryptographic strength with a combination of four new cryptographic protocols.

**Mobility**

Fast Transition Roaming, introduced with the 802.11r standard in 2017, was an important step forward in making Wi-Fi's handoff between access points as fast as cellular's. Further enhancements have been introduced to support rapid mobile hand-off using Wi-Fi 6, and developments to enable vehicular Wi-Fi have also been important. These focus on reducing the number of messages which are necessary in the handoff process – this number has increased over the years to support new security and QoS extensions. 802.11r restores handoff to the original four-message exchange of 802.11a/b/g while retaining security and QoS support. It specifies fast Basic Service Set (BSS) transitions between access points, enabled by a new security key negotiation protocol, which allows both the negotiation and the request for wireless resources to occur in parallel. In the same time, 802.11ai Fast Initial Link Setup (FILS) addresses challenges where a large number of mobile users are continually entering and leaving a coverage area. FILS improves the way APs are discovered by clients and speeds up the link setup once a client chooses an AP to connect to. By reducing the protocol overhead of link setup, FILS enables faster connections and more efficient spectrum use.

**Latency**

The use of OFDMA in Wi-Fi 6 and beyond helps to reduce round-trip latency with the use of short data frames, which effectively pack data into the signal more efficiently. In Wi-Fi 6, the user plane latency target is 4ms uplink/downlink. Latency will be reduced further in the 802.11be specs, an extension of 11ax to support extremely high throughput.

## 4.6 Will Private LTE Displace Wi-Fi?

Many industries are interested in using 4G or 5G, alongside Wi-Fi, to support their increasingly demanding wireless applications. A multi-network connectivity strategy increases total bandwidth while combining the best strengths of each technology.

However, the industrial sectors showing most interest in adding 4G/5G to Wi-Fi - such as factory complexes, large ports and airports and transport operators - usually require levels of indoor penetration, ubiquitous coverage and quality of service that may not be available on the public cellular network. This is driving demand for private networks which can combine Wi-Fi 6 and cellular technologies according to the needs of particular applications. Wi-Fi is, of course, already widely used for private enterprise networks, and private LTE may be added directly by an enterprise or its integrator; by an external service provider; or may rely on a neutral host platform. It may use shared spectrum such as the USA's CBRS band, or private spectrum (e.g. Germany recently earmarked mid-band spectrum for industrial usage, mainly for manufacturing).

On the surface, this trend towards private cellular networks might seem to be a threat to Wi-Fi, but in fact the two are complementary. Wi-Fi already supports many enterprise networks, deployed and managed to the industry's specific requirements; and Wi-Fi 6 will greatly increase the ability to support very demanding enterprise use cases such as smart manufacturing It already addresses many of the issues which have held cellular technology back in the enterprise environment, such as:

- The weakness of the indoor deployment business case for MNOs, since most enterprises do not expect to pay for improved in-building QoS
- The need for multi-operator support to connect employees and visitors regardless of their mobile provider – this drives the industry towards a neutral host model which is immature in cellular but well-established in Wi-Fi.
- The limited device availability for specialized enterprise devices and equipment, and the misalignment of rapid cellular replacement cycles with 10-20-year cycles in factories or aircraft.

These barriers to private cellular raise a significant opportunity for non-MNO providers to support the nascent market. These may well be the same integrators and service providers which are already experienced in supporting enterprise wireless needs with Wi-Fi. This is not about displacing Wi-Fi, which addresses the great majority of enterprise requirements, and will be enhanced in that respect with Wi-Fi 6, and which always provides backwards compatibility with previous installations. It is about giving industries and their providers an additional tool which will support an even wider range of traffic behaviors.

The most-cited use cases for private cellular are industrial robots which need to move around between buildings; drones; automated industrial vehicles such as remotely controlled cranes; safety services in very rapidly moving vehicles like trains; public safety applications; augmented reality/virtual reality and digital twin applications for inspection and maintenance; and wireless access for ultra-remote sites such as mines, oil rigs and power plants.

Although private wireless networks have been in use for decades, their proprietary technology is struggling to cope with modern data requirements. In future, network slicing will potentially

allow each industry or application to have its own virtual network. Between those two phases, a common approach will be for an enterprise to have its own self-contained, location-specific access network, combining Wi-Fi and cellular potentially with its own core (local or in the cloud) and even an edge computing node to enable further use cases.

## 4.7 The Role of Wi-Fi in the IoT Space

The trend to support diversity of connectivity under a common platform is not confined to wireless broadband. As the Internet of Things (IoT) gathers pace, there will be far greater demand for machine-to-machine (M2M) connections, many of them wireless. These will have even greater varieties of performance requirements, reflecting the vast number of different use cases which may emerge under the umbrella of the IoT.

No single technology will address all these requirements, and there is a long list of wireless IoT protocols. This is likely to consolidate over time, but there will certainly be a need for at least one open, standardized technology for several key IoT profiles. These profiles vary by the degree to which they support:

- Ultra-low power vs moderate power
- Long range vs local range vs very short range
- Low data rate vs moderate data rate
- Ultra-low latency vs low latency
- Critical availability vs standard availability
- Unlicensed vs licensed spectrum

(Note: Some proprietary protocols are likely to continue to be used in specialist environments like public safety or railways.)

Wi-Fi has the advantage of addressing a very wide variety of profiles because of the proliferation of its family of standards. This means it will play a role in most IoT environments, alone or interworking with more specialized protocols, or with cellular. Some IoT applications, such as vehicular services, or video-based apps like connected security cameras, will need the bandwidth of the wireless broadband network, implemented to enable other requirements like low latency (In critical environments this may take place in a private network or slice). Wi-Fi is uniquely placed to support broadband and narrowband IoT applications from a common platform which can work at varying levels of power consumption and signal range. The next release of 5G standards, Release 16, will prioritize IoT-focused capabilities such as latency below four milliseconds and very high availability, to support emerging cases in the URLLC (ultra-reliable low latency communications) category.

*Figure 16: Relative Positioning of Selected IoT-Focused Wireless Technologies by Capabilities*

| | Power | Range | Data rate | Latency | Spectrum |
|---|---|---|---|---|---|
| Wi-Fi HaLOW | Low | Long | Moderate | Low | Unlicensed |
| Wi-Fi 5 and 6 | Moderate | Moderate to long | High | Low | Unlicensed |
| LTE Cat-M | Low | Moderate to long | Moderate | Low | Licensed |
| LTE Cat-IoT | Very low | Long | Low | Very low | Licensed |
| LoRa | Very low | Long | Low | Low | Unlicensed |
| Sigfox | Very low | Long | Very low | Very low | Unlicensed |
| Bluetooth Low Energy | Very low | Short | Low | N/A | Unlicensed |
| 802.15 – ZigBee, Thread, 6LoWPAN | Very low | Short | Low | N/A | Unlicensed |

*Source: Maravedis-Rethink*

Low power wide area network (LPWAN) connections are a particularly interesting example of the need for multiple technologies for the IoT, potentially with Wi-Fi, the most ubiquitously installed in networks and devices, as a unifying link. This is the main area, along with the well-established WPAN standards, where there are non-Wi-Fi technologies operating at scale in unlicensed spectrum. Wi-Fi and LoRaWAN are two of the most adopted unlicensed technologies and together they address a large proportion of the IoT use cases. The approaches for these technologies are disrupting private-public business models and also enabling participation in 5G success. The WBA and the LoRa Alliance have published a joint white paper to demonstrate how these two widely deployed IoT Connectivity technologies can be utilized in tandem to effectively support a vast array of use cases.

LPWAN will support applications such as intelligent transportation, smart lighting and asset tracking, to name a few examples. LPWAN provides a good example of how multiple unlicensed and licensed spectrum technologies will coexist. HaLOW, the brand name for the 802.11ah standard, allows Wi-Fi to be deployed in sub-GHz unlicensed spectrum to support LPWAN use cases. Other unlicensed spectrum options include LoRa and Sigfox, while there are two LTE-based choices for licensed bands, LTE Cat-M and LTE Cat-IoT. Each of these technologies supports a different balance between power consumption and data rates, making them optimal for different applications.

Many service providers are already deploying two or more of these technologies in tandem to support the wide diversity of services that will make up the IoT. For instance, in a complex environment like a smart city, being able to use a combination of connectivity technologies to support use cases with different requirements and integrate them all under a common management platform will be key to an economically viable and richly functional solution. While it is important to have a diversity of technologies to support the widely varying requirements of the IoT, it is also essential that these technologies can interoperate seamlessly to avoid creating islands of communication, as these would severely restrict the ability to create a broad platform in which different applications can exchange data easily.

## 4.8 Wi-Fi and Cellular 5G Interworking

Wi-Fi in general, and its latest amendment Wi-Fi 6 (based on the IEEE's 802.11ax specifications), will play a crucial role in extending high quality, high speed, low latency wireless connectivity, especially indoors. So far, the 3GPP has dominated the specifications of the 5G standard with few contributions from the IEEE.

Operators need to gain visibility into, and control of, what is happening in the Wi-Fi RAT, especially in the enterprise and public Wi-Fi areas. There is a need to be able to dynamically allocate resources from both radio access technologies according to the needs and changing requirements. For example, a common interface between Wi-Fi and 5G can be used to set Wi-Fi bandwidth dedicated for 5G service traffic, configurations and QoS settings for a Wi-Fi slice dedicated for 5G services. Such an interface can also enable enterprise Wi-Fi vendors to set policies in the 5G core for handling traffic, or request network slices, for certain enterprise users and/or applications.

There are challenges to full Wi-Fi/cellular integration, which in the past have prevented more than limited synergies, but in the 5G generation a deep level of interworking will be essential to leverage the undoubted synergies between the technologies, and to maximize the performance of wireless systems.

Cooperation between the WBA and other industry bodies such as NGMN will help to address many of the known challenges and look ahead to future and emerging technologies to ease integration. In September 2019, the WBA and NGNM co-published a ground-breaking white paper on RAN Convergence, which sets out an ambitious but achievable roadmap for Wi-Fi and 5G to work together in many ways, in order to harness the capabilities of both for a wide range of scenarios.

The paper describes environments, such as the connected city, where deep interworking of multiple RATs will be beneficial. Driven by members of both groups, the paper represents the views and commercial considerations of a wide group of service providers, including MNOs and MSOs. It sets out the key challenges of tight integration, which include:

- Access visibility, network manageability and policy control
- Enablement of Wi-Fi only devices
- Traffic routing across multiple access networks
- Multi-RAT network slicing
- Device support

And while acknowledging that these are significant issues, it makes it clear that the commercial opportunities will justify the work of addressing such challenges, and sets out the roadmap to achieve that, and so enable the start of a convergence 5G era.

## 4.9 Wi-Fi Roaming Revolution

There are millions of public and semi-public hotspots in the world from stadiums to retail stores. Unfortunately, there are in most cases like distinct islands with no connection to each

other. Two issues must be solved to enable a seamless Wi-Fi experience when roaming between hotspots:

- Discovery and onboarding are currently complex and cumbersome
- Information Exchange for AAA is done on case through tedious bilateral agreements

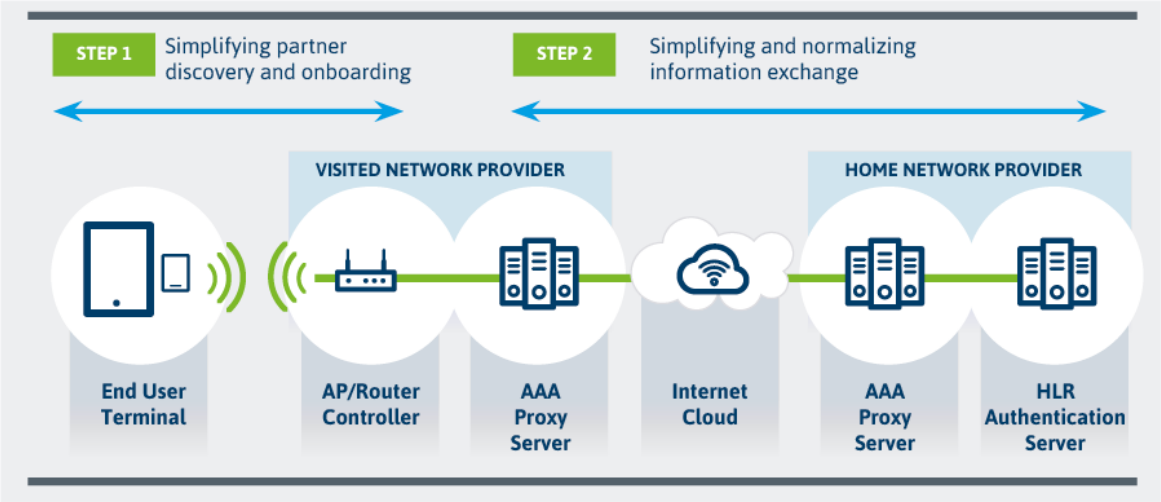
### 4.9.1 A Federation of Hotspots

The WBA is championing the concept of a roaming federation to unite these hotspots with NGH that resolves all the remaining frictions.

To that effect the WBA has acquired a Roaming Consortium Organization Identifier (RCOI) that is aimed at being used worldwide for facilitating:

- Realms configuration by operators and HUBs for Wi-Fi Roaming
- Network discovery phase when a device is trying to connect to an SSID

***Figure 17: Wi-Fi Roaming Steps***




*Source: WBA*

**The Current Paradigm**

In the current process, each venue needs to manually configure a new roaming partner in the controller which becomes unpractical (or unfeasible) when hundreds of roaming partners are considered internationally. Through the usage of a single Roaming Consortium Organization Identifier, the WBA is looking to help solving these issues for operators and roaming HUBs.

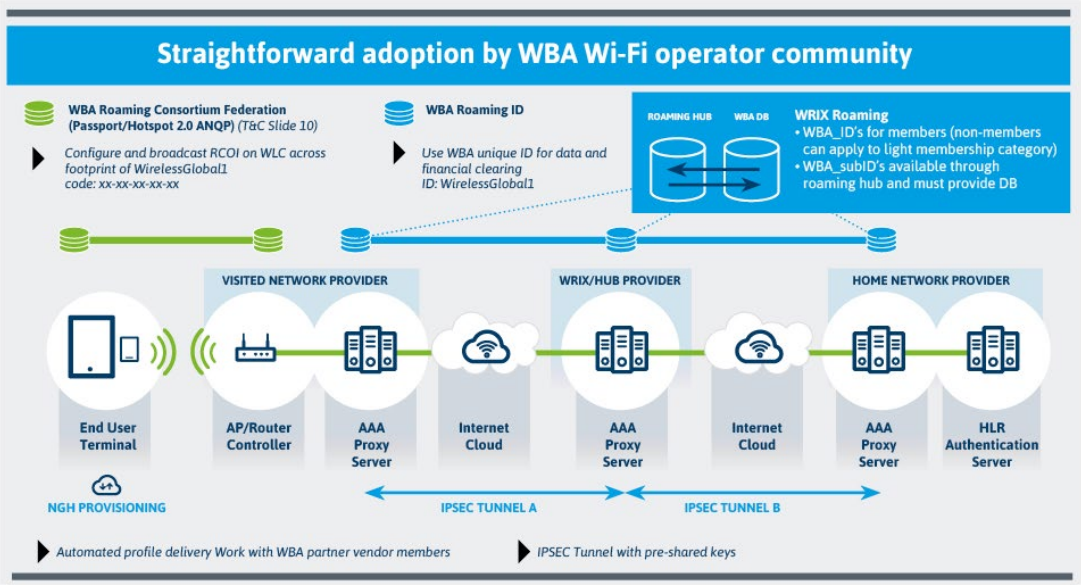
The NGH roaming federation trial, in May 2019, has been a nuclear first step towards the creation of a global roaming federation concept, where organizations have been able to use the WBA RCOI to automatically establish connections with other Wi-Fi networks across the globe, either operators, cities or venues.

**Network Identification & Data Clearing**

It has proven difficult to gain visibility and usage data on the Wi-Fi networks part of the roaming hubs in the past. One of the reasons is the networks are not well identified in the overall hub. Therefore, WBA members are leading the work in terms of mandating not only the use of the WRIX Framework for operational best practices, but also a WBA Member ID to be input in all the networks so that the organizations that run the data clearing and collect analytics can extract more relevant data to be measured and managed by their clients.

Therefore, in order to facilitate roaming and to identify the companies involved, both the VNP and the HSP must be identified as a part of all WRIX interactions through the use of an identification code as shown in the following figure

***Figure 18: Elements of the WBA Roaming Federation***




*Source: WBA*

Companies using the WRIX framework in the exchange, will have a WBA_ID assigned or use another mutually agreed identification code such as a GSMA TADIG code. The identification of roaming partners involved in each WRIX exchange is required. Each Access request sent by a visited network should contain the network's identification which will include either WBA_ID assigned to the network operator or another mutually agreed code. The WBA will act as the policy authority issuing top level certificate to the federation members part of its database of active roaming partners.

### 4.9.2 Interconnection via RadSec

Wi-Fi Roaming Interconnection has always been a complex and time-consuming process for non-telco players such as venues. RadSeC technology, supported by PKI Certificates, is seen as a good alternative to the typical challenges promoted by the use of IPSec tunnels including delays in the transfer of packets. Therefore, simplifying the process to which the city, venue, or

any sort of network, connect to the Roaming HUB is key to accelerate and facilitate the adoption of what WBA believes is the best in class Wi-Fi experience: automatic authentication, seamless and secure connection, across home and visited networks.

**WBA's WRIX Public Key Infrastructure (PKI)**

A public key infrastructure (PKI) is a set of roles, policies, and procedures needed to create, manage, distribute, use, store & revoke digital certificates and manage public-key encryption. The PKI is the foundation that enables the use of technologies, such as digital signatures and encryption, across large user populations.

WBA's WRIX architecture is used to support Wi-Fi roaming. In order for a roaming event to occur and settle, authentication, authorization and accounting (AAA) packets and data clearing/financial settlement processing must have a transport medium available between the Operators and WRIX-I Providers.

Traditionally, IPSec VPN has been the preferred connectivity method to secure the WRIX-I interfaces, ensuring data confidentiality and security, with keys being pre-shared and negotiated on a bilateral basis between WBA entities.

As the Wi-Fi roaming systems scales with increased adoption, the WBA has selected RadSec/TLS (as defined by IETF RFC 6614) to manage the security of RADIUS exchanges. This approach obsoletes the use of IP addresses and shared MD5 secrets to identify other peers, enabling the use of alternative trust models, e.g., based on X.509 certificates.

Not only does RadSec/TLS look to automate the security of the connections between RADIUS peers, but the use of TCP also provides improved timeout, reliability, and fragmentation management compared to the conventional UDP based signaling used in RADIUS.

RadSec/TLS may be configured on a RADIUS peer basis, allowing graceful introduction of the capability by WRIX defined entities. WRIX defined entities implementing RADIUS/TLS should be configured with a list of certification authorities for incoming connections.

# 5. Wi-Fi Enablers

Wi-Fi has been taking on many characteristics of cellular technologies, such as enhanced quality of service, security, and other features. As the lines between licensed and unlicensed spectrum blur, Wi-Fi will evolve alongside cellular and be part of the broader 5G platform, bringing 5G-like capabilities to non-spectrum owners—such as cable operators, city authorities, or private network providers. In this section, we review several important enablers to a smarter, more secure and adaptable Wi-Fi.

## 5.1 NGH/Passpoint 2.0

Next Generation Hotspot is WBA's accomplishment of an end-to-end Wi-Fi Roaming experience, achieving the seamless, secure and interoperable experience set as a benchmark by the Wi-Fi industry. The underlying concept is composed of:

- Hotspot 2.0 (HS2.0) specification from the Wi-Fi Alliance[16].
- Wireless Roaming Intermediary eXchange (WRIX) Framework for Roaming from the WBA

[16] As of spring 2019, the WFA had 1387 devices certified for Passpoint Release 1, and 119 devices certified for Passpoint Release 2.

As explained in a recent white paper from the WBA[17], access to Wi-Fi networks needs to be granted automatically and in a frictionless and secure way. These are the critical criteria for enhancing the usage of Wi-Fi and guaranteeing a simple user experience. This will, as a baseline, come through the adoption of HS2.0 technology in Wi-Fi networks. Secondly, the roaming procedures need to be clear and financially simple so that operators and service providers can benefit from the generated revenue streams and their own business models. The standardization of roaming practices is, therefore, critical for the development of the industry, as it enables the creation of different business models and agreements between service providers.

In light of this importance, and the hassles the roaming HUBs and service providers have been facing over the years to correctly identify traffic, the WBA Roaming Work Group has agreed on mandating the adoption of the WBA ID for anyone willing to explore the Wi-Fi Roaming technology and respective business.

On the device side, Release 2 of Passpoint introduced new capabilities that standardize the provisioning and lifecycle management of user credentials, such as how they are securely provisioned, stay valid, and are used in network selection and service policy enforcement. Release 2 also provided flexible and automatic remediation of client devices if subscriptions are updated or policy changed.

Release 3 of Passpoint, launched in April of 2019, introduced four new capabilities:

- Simplified online sign-up: drives a common provisioning methodology across vendors using a single SSID—or the "name of the network" as seen by users—to simplify deployment and configuration
- Venue-specific information: allows a device to obtain relevant local information about a venue to inform the user of available services provided by the operator
- Expanded enterprise-level security: supports WPA2™-Enterprise and next generation WPA3™-Enterprise for a strong level of authentication and connectivity
- Operator-specific policies: provides a streamlined solution for acceptance of terms and conditions when in public hotspots

## 5.2 Easy Mesh

Consumers are increasingly demanding full-coverage, efficient, self-configuring home Wi-Fi networks that require minimal work to set up and that largely maintain themselves. The industry has responded by creating proprietary solutions primarily for homes and small offices that employ multiple interconnected access points to create a single network. These products intend to deliver to users the benefits of extended Wi-Fi coverage, but do not provide multi-vendor interoperability. Wi-Fi Certified EasyMesh™ is a Wi-Fi Alliance® certification that brings a standards-based approach to multiple AP Wi-Fi networks.

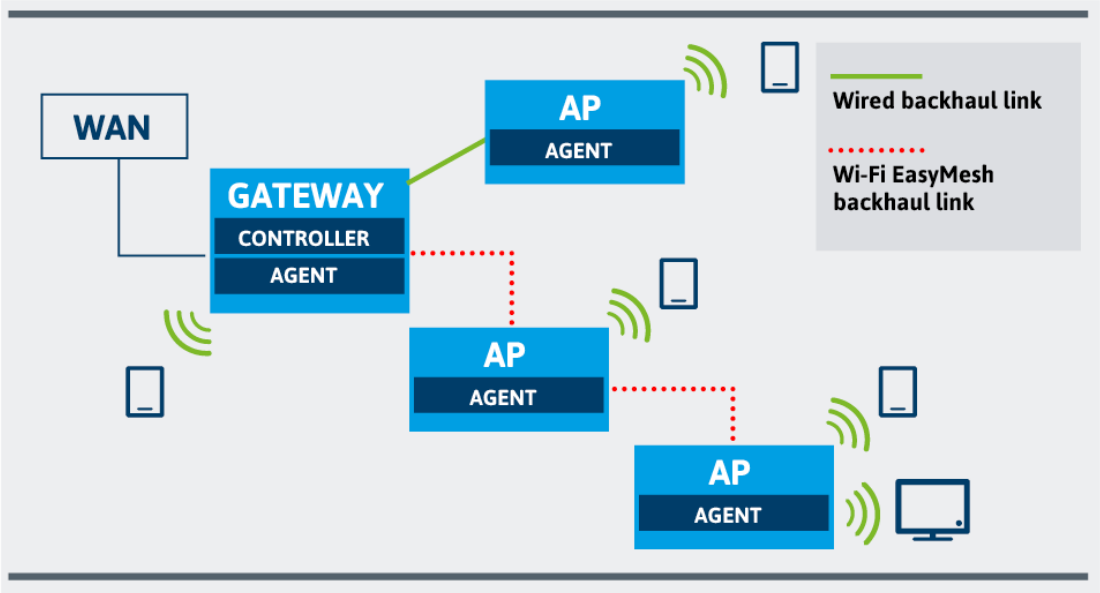
The Wi-Fi Alliance released its specification 1.0 for multi-access points (MAPs) in June of 2018. The purpose of this specification was to enable interoperability across Wi-Fi access points (APs) from different vendors in a Wi-Fi network deployment comprising multiple APs.

[17] https://wballiance.com/resource/next-generation-hotspot-ngh/

This specification defines the control protocols between Wi-Fi APs, as well as the data objects necessary to enable onboarding, provisioning, control, and management of multiple APs. This specification also defines the mechanism to route traffic between Wi-Fi access points within the multi-AP network.

One device on the network acts as a Wi-Fi EasyMesh controller—for example, a home gateway. Wi-Fi EasyMesh networks use a controller to manage the network, with agent APs connected to it. Wi-Fi EasyMesh controllers are often located in the main gateway which connects a home network to the service provider infrastructure.

***Figure 19: Easy Mesh Infrastructure***




*Source: Wi-Fi Alliance*

In its recent white paper "In-Home Wi-Fi Industry Guidelines"[18], the WBA identifies the gaps in current in-home Wi-Fi standards and highlights the need for intelligent network optimization. The paper provides an industry go-to reference when preparing for 'Smart Home' deployments. It identifies the gaps in current in-home Wi-Fi standards and services and proposes key guidelines and recommendations for different functional areas and as a follow up this paper identifies future lines of work and possible directions the In-Home Wi-Fi network may take.

## 5.3 Open Source

As gateways, routers, and set top boxes become increasingly complex with new features added at an increasing fast pace, vendors are struggling to keep pace with the cost and complexity to meet market demand and innovation pace. Thus, vendors are compelled to pool their resources and agree to share common base software platform to save time and money.

One such open source development effort is led by the prpl Foundation, which is a collaborative, non-profit foundation that strives to enable the security and interoperability of

[18] https://wballiance.com/resource/in-home-wi-fi-industry-guidelines-2019/

embedded devices. Notable founding members include Broadcom, Intel, and Quantenna, along with Arris and Technicolor.

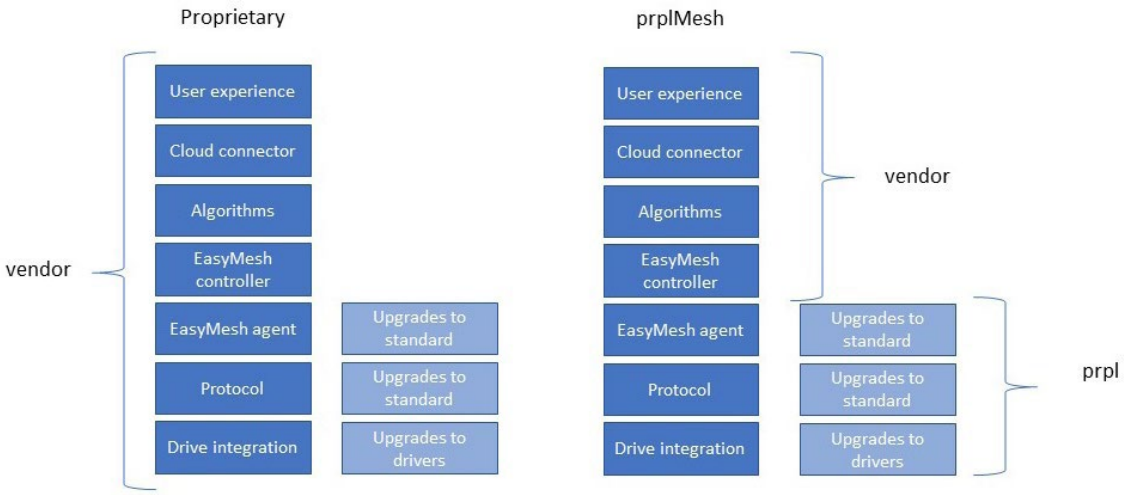
One particular working group called prplMesh will be releasing an open-source, carrier-grade, and certifiable implementation of the Wi-Fi Alliance's Multi-AP specification.

The output of the WG will be the release of a source code covering both the agent and the controller part of the Multi-AP specification. In short, the project's aim is to create a baseline for OEMs and developers to easily integrate Multi-AP into various products and platforms. Initial targets include prplWrt and RDK-B open source communities with support for Wi-Fi chipsets from almost any SoC vendor to be used in residential gateways. The project also includes Wi-Fi extenders from both retail brands and IPS managed extenders. This project is part of a wider collaboration between prpl Foundation and Broadband Forum.

The motivations to use open source include:

- faster time to market
- vendors can focus on differentiation rather than reimplementation
- shared maintenance costs and lower development costs

***Figure 20: Options for EasyMesh Implementation***




*Source: prpl Foundation*

Going open source has its pros and cons. As we saw earlier, standardization is not enough to accelerate time-to-market; every vendor has to invest much time and effort to develop code that meets the standard without adding much value in the process in a movement that would reinvent the wheel each time.

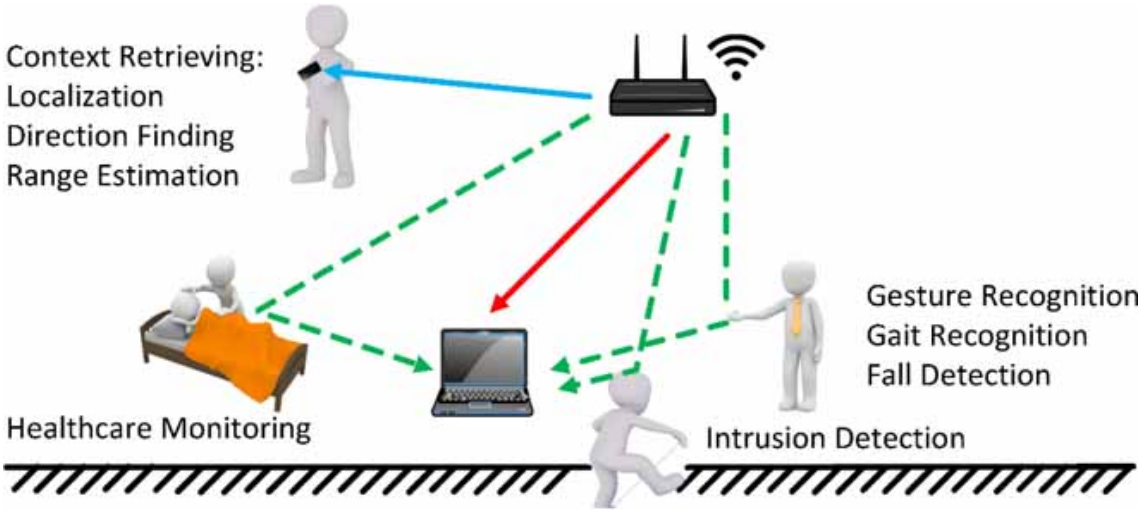
In light of the ever-growing complexity surrounding the connected home requirements where Wi-Fi is an essential, but only one, part of the equation, various organizations including the WBA are contributing to putting the pieces of the puzzle together.

## 5.4 Wi-Fi Sensing

It has been recently discovered that Wi-Fi signals can be used for the sensing purpose, as they are sensitive enough to capture environmental dynamics. In a given environment, Wi-Fi-based systems can track people using the variations in the wireless channel. The monitoring of elderly people is one example of an application for Wi-Fi-based sensing systems, as well as people counting, through-the-wall sensing, behind-the-corner sensing, gesture recognition, activity classification—amongst many others.

There are several significant features which make it an attractive option in comparison to other sensing technologies. For example, video-based sensing systems have lower localization accuracy and are computationally intensive. In addition, video-based sensing systems have limitations when in the dark, through smoke or walls, and in NLOS (Non-Line-Of-Sight) environments. Conversely, an easily accessible source of opportunity for people tracking is provided by Wi-Fi, without the limitations of video-based systems. And, Wi-Fi has longer range and higher availability than other signal-based systems (such as Ultra-Wideband (UWB)).

***Figure 21: Smart Home Based on Wi-Fi Sensing***




*Source: Smart Home Based on Wi-Fi Sensing: A Survey, IEEE*

There are three main categories of existing systems: 1. Software Defined Radio (SDR) based; 2. Received Signal Strength (RSS) based; 2. Channel State Information (CSI) based; and 3. Software Defined Radio (SDR) based.

RSS (Received Signal Strength) does not provide fine-grained information about the multipath effects, but rather only coarse-grained information about the variations of the wireless channel. In order to capture fine-grained variations in the wireless channel, CSI (Channel State Information) was introduced. RSS measurements are only a single value per packet, which represents Signal-to-Interference-Noise Ratio (SINR) over the channel. On the other hand, CSI (Channel State Information) contains the phase measurements and the amplitude for each OFDM subcarrier. SDR-based systems are low-level systems that have full access to the

received signal; therefore, they can capture more valuable information from the received signal.

**Elderly People Monitoring**
By 2030, the population of the world over the age of sixty-five is expected to grow to one billion. The majority of persons in that age group spend most of the day within their own homes. And each year, thirty-three percent of those elderly persons will fall; that percentage increases for those elderly persons living in assisted living / nursing home facilities. Often the elderly person cannot get up by themselves. Even when there is not a direct injury, approximately half of those who remained on the floor longer than an hour actually died within six months after the fall. Obviously, a fall by an elderly person can dramatically affect their quality of life, and even cause death. The immediate detection of a fall would result in the elderly receiving immediate / timely treatment, could significantly decrease medical expenses, and could save many lives. The basic concept is to be able to distinguish falls from other daily activities by analyzing the change in CSI when human activities affect the environment.

**People Counting**
People counting has become increasingly more important in a number of applications, e.g., crowd control. However, because crowd behaviors are generally unpredictable, that poses many challenges for crowd counting and/or estimation. Many applications could benefit from people counting; one such example is smart building management. In that arena, heating /cooling can be optimized based upon the number of people in a building, resulting in significant energy savings.

**Gesture Recognition**
Obviously, as computers have become more and more an integral part of most all societies, the need for novel ways to interact with the computers has increased. Specifically, there has been increased interest in creating novel user interfaces which will decrease users' dependence on traditional interfaces (like the mouse and the keyboard). One new interaction technique is gestures. For example, one could adjust their air conditioning temperature or volume of their music with just a hand motion in the air.

## 5.5 Artificial Intelligence and Machine Learning

AI applied to Wi-Fi promises to solve a significant problem which is the cost of troubleshooting the many potential connection problems that can occur from many possible sources. From RF interference, to DHCP to DNS issues, operators and IT staff are constantly challenged to monitor and identify the real source of the problem. It could be they are looking at a layer 2 issue, when in fact it is a networking problem. And of course, there are all the costs associated with troubleshooting and support calls and associated downtime for enterprises, consumers, and the service providers themselves.

RRM, client steering, roaming optimization, QoS, etc. require hundreds of parameters to adjust for optimal performance. It is simply not humanly possible to monitor and adjust these parameters in a dynamic environment—hence the need for machine learning and resolution.

The idea behind AI applied to Wi-Fi is to implement an automated management system able to monitor the network, recognize normal operations, analyze deviations from normal operations

in real time, and apply suitable solutions… sort of a real-time, self-healing system. However, things are not so simple: data flows in a Wi-Fi network are huge in number and variety, making simple performance averaging approaches ineffective.

Artificial intelligence would allow the key characteristics of problems in the Wi-Fi network to be picked out from the big data that is the mass of traffic data, fix known problems directly, analyze trends in performance, and predict future requirements to avoid problems altogether in the future. In addition, AI enables computing devices to learn as they receive new data with no need to be reprogrammed. This would allow the Wi-Fi network management system to constantly add to its knowledge base, extend its repertoire of known problems and solutions, and raise standards of user experience even higher.

### 5.6 Blockchain Developments

Since the first blockchain was implemented in 2009 with the release of the cryptocurrency Bitcoin, blockchain technology has sparked wide interest among a variety of industries. How can service providers benefit from this emerging technology?

There is no shortage of start-ups aimed at cracking the code of blockchain applied to Wi-Fi network, but they are driven by entrepreneurs wanting to break the so-called “monopoly” of the carriers rather than driven by the carriers themselves. Those start-ups include Helium, WiFicoin or Ammbr to name a few. All want to turn your regular gateway and router into a decentralized node which will earn you credits for sharing access with humans or machines independent of the traditional carriers.

At the moment, the concept of turning millions of hotpots into a virtual decentralized network is appealing but far from reality and there are both technological and business hurdles. On the business side, operators like Comcast are already offering community Wi-Fi to their home Wi-Fi and SMB customers. Moreover, hotspot aggregators such as Pareteum (ex:iPass) have spent years building a portfolio of public Wi-Fi assets under their umbrella. On the technology side, a critical mass of blockchain enabled hotspots must be reached before the system has any value at all. On the technology side, much R& D is required and a lot of it will only be possible and relevant once the decentralized network reaches that critical mass. However, a pay-as-you-go service using micropayments may be effective in emerging countries or underserved areas, where it can provide the unconnected with access and become a revenue source for the host. Smart cities may find this model useful to provide access and services without having to invest in the network infrastructure.

## 6. Spectrum and Regulatory Trends

The range of spectrum bands which will be useable by wireless broadband technologies is increasing, along with innovations in antenna design and modems. The opening of the 6GHz band for Wi-Fi is a major spectrum development which coincides with the release of Wi-Fi 6 technology. Other new bands are being freed up or shared by incumbents, like 3.5 GHz in the U.S., while others are new options, such as 60 GHz for WiGig. Systems to support interference-free shared access, such as geolocation databases and cognitive radios, will evolve into fully dynamic access platforms in future.

## 6.1 6 GHz Extension for Wi-Fi

In October of 2018, the Federal Communications Commission proposed to make up to 1200 MHz of spectrum available for use by unlicensed devices in the 6 GHz band (5.925-7.125 GHz). The proposed rules are designed to allow unlicensed devices, such as Wi-Fi, to operate in the 6 GHz band without interfering with the operation of the licensed services which will continue to use this spectrum. The WBA issued in July 2019 a white paper entitled "Understanding the Global Implications of Wi-Fi 6 & 6GHz" which describes both the regulatory and market developments making the case for the use of Wi-Fi 6 in the new proposed 6GHz band.[19]

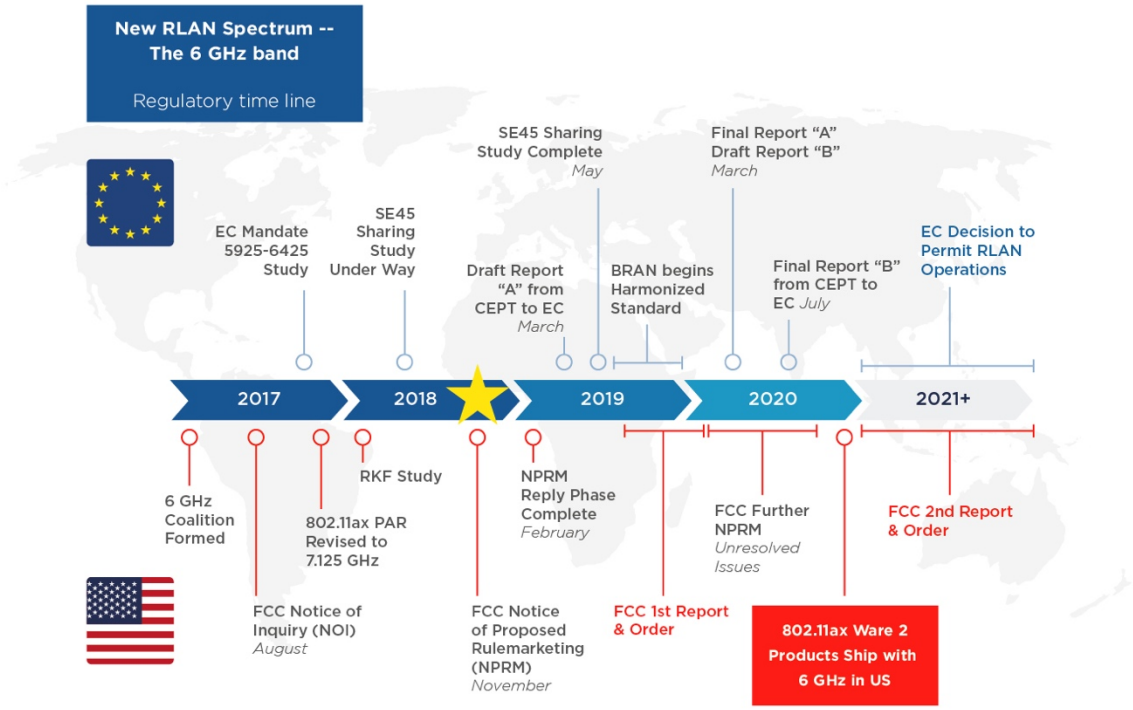
In those portions of the 6 GHz band that are heavily used by point-to-point microwave links, the Commission proposes to allow unlicensed devices to operate where permitted by an automated frequency coordination system and invites comment as to whether this is necessary for devices operated only indoors. In the other portions of the band where licensed mobile services (such as the Broadcast Auxiliary Service and Cable Television Relay Service) operate, the unlicensed devices would be restricted to indoor operations at lower power. The period of comments was extended to April 1, 2019.

In the 6 GHz band, the main existing users (in the 5.925-6.425 GHz and 6.525-6.875 GHz portions) are operators of point-to-point microwave links. The FCC proposes the use of an automated frequency coordination system to protect them from interference from unlicensed devices running Wi-Fi or other technologies (potentially, in the future, unlicensed 5G).

In the other sections of the band (6.425-6.525 GHz and 6.875-7.125 GHz), the device will be restricted to indoor operations at low power to avoid interfering with licensed mobile services in those frequencies (again, notably, the Broadcast Auxiliary Service and Cable Television Relay Service).

[19] https://wballiance.com/resource/understanding-the-global-implications-of-wi-fi-6-6ghz/

***Figure 22: 6 GHz Global Regulatory Action Timeline***




*Source: Aruba and Maravedis*

Internationally, there is no consensus to commit to unlicensed use in the 6.425-7.125 GHz band, and various groups are studying whether that band should be allocated for licensed or unlicensed use.

In June 2018, Ofcom published a document on its proposals for the bands it wants used for 5G, as well as the possibility of adopting 6GHz for use in Wi-Fi networks. This move comes as Ofcom prepares for the World Radiocommunication Conference 2019 (WRC-19), which is held every four years and enables countries to strategize the usage of radio spectrum.

Specifically, Ofcom is asking for input to better understand the advantages and challenges of opening 6GHz bands to Wi-Fi traffic. Together with its ongoing work with 5G and other spectrum issues, the information will be used by Ofcom to strategize the path forward for Wi-Fi 6 in the 6GHz band.

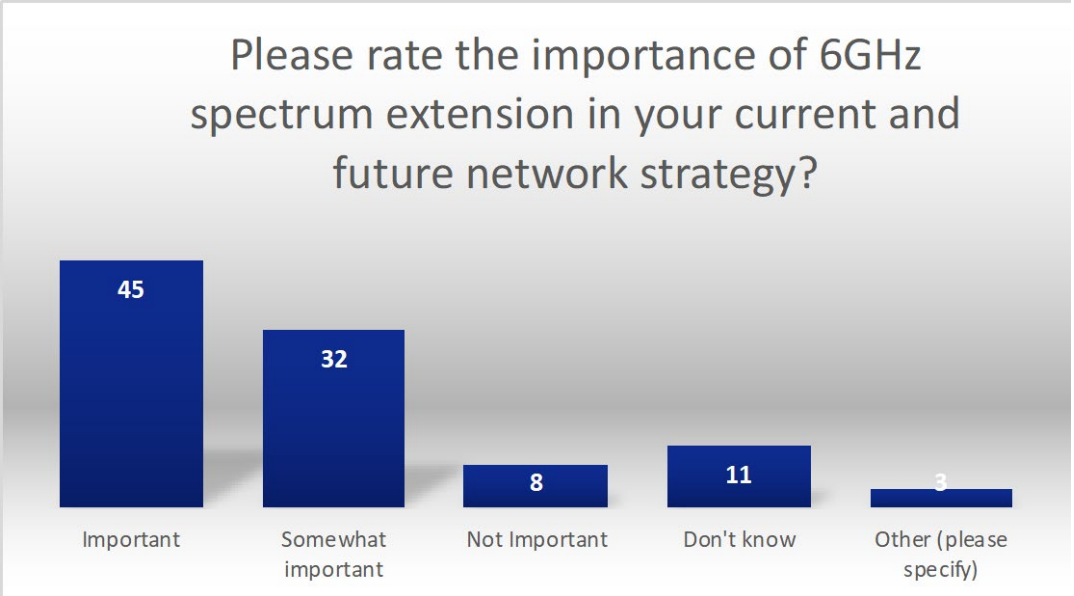
The regulatory process for releasing 6GHz spectrum to Wi-Fi in Europe is complex. CEPT issued a technical report to the European Commission, the highest regulatory authority on spectrum allocations within the EU, on the feasibility of Wi-Fi in the 6GHz band. Currently, CEPT's position is that Wi-Fi in the lower portion of the 6GHz band is possible, pending studies on potential interference.

In June 2019, the ECC opened a new regulatory work item, ECC Report 302, in support of unlicensed 6 GHz radio local area networks (RLANs). The purpose is to develop a single regulation for the 48 CEPT countries independent of the European Commission, partly in an effort to accelerate the timeline for 6 GHz Wi-Fi operations in Europe.

As such, it is feasible that 6GHz spectrum will be opened to Wi-Fi 6 before the end of 2020 in those countries. Before that happens, however, both the 48 individual country regulators and the European Commission must adopt the new rules.

The WBA survey shows that 45 percent of WBA survey respondents view 6GHz as important to their Wi-Fi business and rollout plans. Another 24 percent classified 6GHz as somewhat important, illustrating the widespread need throughout the industry for additional spectrum.

***Figure 23:Importance of 6GHz***




*Source: WBA 2019 Industry Survey*

The WBA research also shows the use cases that survey respondents believe will deliver the most benefit with the with the combination of Wi-Fi 6 and 6GHz spectrum. Seventy-two percent said the biggest consideration is that 6GHz spectrum won't have traffic interference from legacy Wi-Fi devices. More than 65 percent of respondents want to use 6GHz spectrum to enable applications that require high bandwidth and low latency, such as augmented and virtual reality (AR/VR) and gaming on Wi-Fi 6 devices.

"In some ways, we're synchronizing Wi-Fi 6 and its capabilities with 6 GHz. We're doing scheduling and frequency domain, and we're improving the deterministic capabilities of Wi-Fi. We want to achieve efficient spectral reuse and get consistent throughput. Wi-Fi 6 is very efficient, and it can run multiple streams for multiple users simultaneously by scheduling the frequency domain. That's only possible when you don't have to contend with legacy devices or other radio technologies in the same space."
**– Matt MacPherson, Wireless CTO, Cisco.**

## 6.2 License-Exempt Designations for Outdoor Operation in 28 GHz - 60 GHz

There are bands—in addition to the traditional Wi-Fi license-exempt bands—that in many countries can currently be used without a spectrum license. However, as in the case of Wi-Fi, it is required that devices receive type approval and do not transmit over certain maximum

power output levels. The 24 GHz band, the 60 GHz band (V band), and the E band (from 71 GHz onwards) are of particular interest.

The U.S. and Mexico have the most progressive of those regulations, and in 60 GHz, links of about 2 km are technically possible; some small operators could use this band to provide "fiber-like" experience to their customers. There is still a wide range of values in the regulations, though, similar to Wi-Fi. One case-in-point is in Argentina, where this band can only be used indoors. In India, the situation may change in this band; their Department of Telecommunications (DOT) has demonstrated interest in following recommendations from the Telecom Regulatory Authority of India (TRAI) that propose license-exempt use of the 60 GHz band.

This band is particularly interesting as equipment is becoming available that follows the 802.11ad, as well as the emerging 802.11ay standard, which makes Wi-Fi certification and interoperability possible. Just as with Wi-Fi, the use of the E band in some African countries requires registration with the regulatory authorities in the U.S. and Brazil.

The United States and Canada have coordinated their regulations in the 24 GHz band, both allowing license-exempt use of 200 MHz between 24.05 and 24.25 GHz for PtP links. For up to 5-6 km, this establishes another wireless alternative for fiber-like speeds. It is expected to see higher gain antennas appearing for 24 GHz equipment as well, with the requirement of the same in 60 GHz (51 vs 33 dBi). Extremely narrow beams are a result of these high gains, which makes interference with other devices extremely unlikely, in turn making licensing unnecessary.

In that vein, more policy makers and regulators are looking towards enabling the use of these bands on a license-exempt basis. Low-cost hardware for 24 GHz—similar to 60 GHz—is readily available in the market; however, there is currently no standard that will promote interoperability in the case of 24 GHz. In both cases, these hardware requirements are more expensive than devices operating in traditional Wi-Fi bands (2.4 and 5 GHz) but are still considerably less expensive than traditional microwave equipment. It is expected that their cost will ultimately go down, with more countries enabling the use of these bands on a license-exempt basis, expanding the target market for the manufacturers.

## 6.3 Regulatory and Spectrum Framework for 5G with Unlicensed Bands

Development of standards for use of unlicensed and shared spectrum has not stopped. 3GPP Release 15 covered enhancements to LTE operation in unlicensed spectrum, including enhancements to unlicensed spectrum offloading systems, as well as work on standards for use of LAA/eLAA for the CBRS band in the USA.

Work underway on 3GPP Release 16 includes standards for use of unlicensed spectrum for 5G networks. In its December 2018 meeting, 3GPP agreed to kick off a work item with a view to including support for 5G NR unlicensed spectrum (NR-U) in Release 16. The work item includes support for licensed-assisted access NR-U (using anchor channels in LTE or 5G NR) and for stand-alone NR-U (with no LTE anchor). It also covers use of unlicensed spectrum at 6 GHz, to complement the existing spectrum at 5 GHz.

Technologies in unlicensed bands such as 60 GHz for WiGig will also have an important role to play in 5G addressing many of the challenges of using mmw spectrum. 60 GHz V-Band is a particularly appealing option for FWA service providers. Unlike the lightly licensed 70/80 GHz E-Band, the 60 GHz band is unlicensed in countries like the United States, and therefore, is accessible to a wider range of providers. Additionally, the 14 GHz of contiguous spectrum in this band offers more bandwidth than any other licensed or unlicensed mmWave band. Further, the 60 GHz band has chipsets and technology currently available on the commercial market.

## 6.4 Coordinated Shared Spectrum Models

The nature of dynamic/coordinated spectrum assignment is such that its users must always vacate any frequency the primary license holder chooses to use. No interference with the activities of the primary license holder of the applicable frequencies in question is tolerated by dynamic spectrum. It strategically occupies a middle ground between traditional spectrum licensing and license-exempt spectrum. Through a database approach to validating dynamic spectrum devices, dynamic spectrum management offers the regulator some control over the use of the spectrum; however, it does not confer exclusivity in the way that licensed spectrum does. Maintaining some degree of control permits the regulator to move forward in making this spectrum available, but without the high risks involved with completely re-allocating frequencies on a long-term basis to technologies or companies which may or may not prove a success.

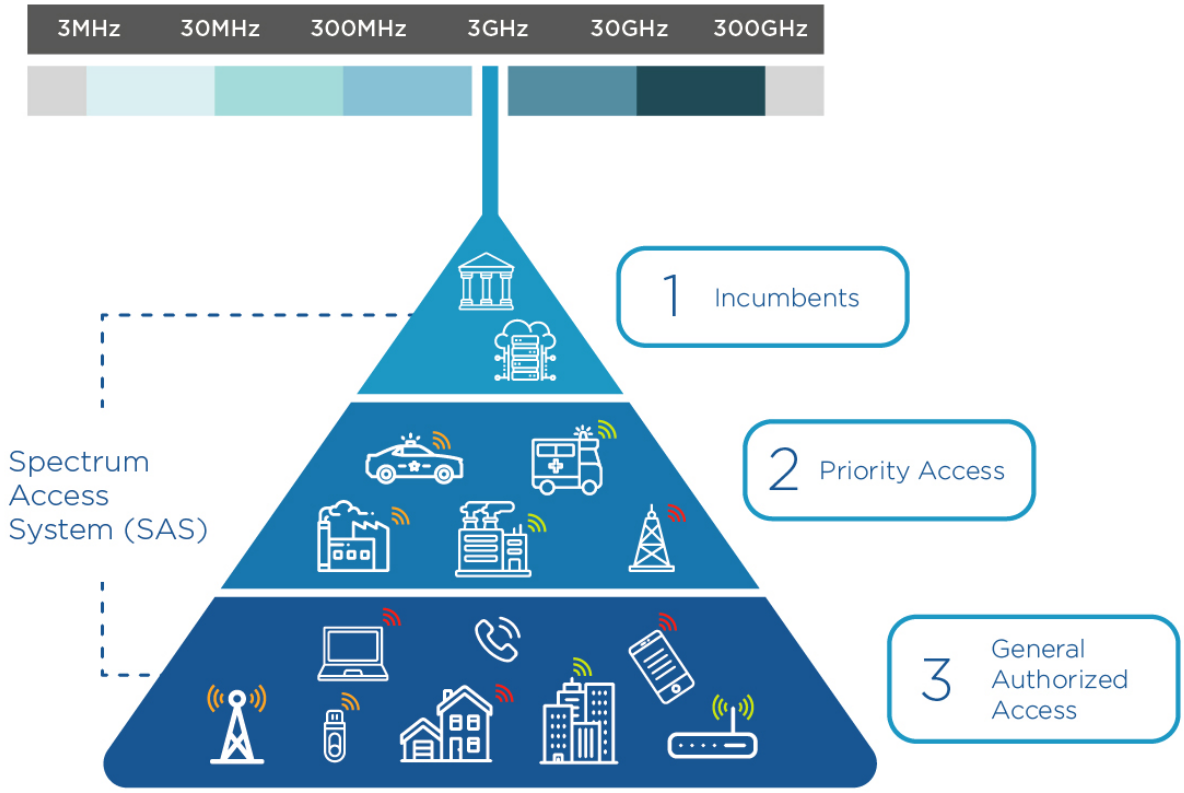
Dynamic spectrum approaches—such as Television White Space (TVWS) regulation and, more recently, Citizens Broadband Radio Service (CBRS) in the U.S.—have emerged as an alternative approach to spectrum assignment.

### 6.4.1 CBRS

In 2015, the U.S. Federal Communications Commission (FCC) approved the allocation of 150 MHz of spectrum in the 3.5 GHz band—identified as the Citizens Broadband Radio Service (CBRS) or mobile use by public and private networks. The allocation is governed under a three-tiered spectrum-sharing arrangement, with incumbent users (i.e., federal agencies and fixed satellite services), priority users, and general-access users able to operate in the band in descending order of priority, according to various regulatory criteria.

CBRS was set up by the FCC in the U.S. in April of 2016 to use the 3.5 GHz band (3550–3700 MHz) as a space where a variety of users could share bandwidth for use in their LTE networks. Access to the spectrum is prioritized for government/military users, and after them, for Priority Access Licensed (PAL) users (organizations that will acquire one of the many regional ten-year licenses in spectrum auctions), with everyone else able to request access dynamically to use the spectrum via licensed SAS (spectrum access server) operators. The CBRS Alliance is working on technical aspects of making CBRS work in the U.S., including interoperability and coexistence specifications.

*Figure 24: CBRS Spectrum Usage*




*Source: CBRS Alliance and Maravedis*

### 6.4.2 TVWS

"TV White Space" (or "TVWS") refers to the unused TV channels in the VHF and UHF spectrum—typically referred to as the "buffer" channels. The lower frequencies allocated to TV broadcasting have much better propagation characteristics than the higher frequency license-exempt bands and are thus more suited for covering longer distances to reach dispersed rural populations.

With the notable exception of a few leading countries, adoption of TVWS regulation around the world has been slow. But a number of factors may have contributed to this, such as the lack of wide availability of low-cost mass-market TVWS/dynamic spectrum devices for purchase. As manufacturers may be waiting for formal dynamic spectrum regulation to be enacted to trigger larger scale manufacturing, this may be a "Catch-22."

**United States**

The Microsoft Airband Initiative was also launched in 2017 to tackle the problem of unserved rural Americans. The Airband initiative established partnerships in 16 states that will bring broadband connectivity to more than 1 million rural residents who currently lack access using a combination of TV white spaces technologies, traditional fiber optic and satellite coverage.

### 6.4.3 New Spectrum for Industrial Use

Germany's regulator, the Bundesnetzagentur is allocating some 3.7 GHz spectrum for the country's powerful manufacturing and automotive sectors in order to support Industry 4.0 services,

The anticipated recipients are already beginning to announce their plans, particularly with 100 MHz of mid-band spectrum slated to be sold to industrial groups or their service providers. Per local media reports, carmaker Volkswagen will begin to build its own private networks in German plants as early as next year; it has already launched a tender to find its supplier. A VW spokesperson said: "We will equip the factories from 2020 onwards." The same source indicates that both Daimler and BMW are also interested in applying for the spectrum and developing their own factory networks. Other industrial groups are looking for more LTE/5G "autonomy;" these include Siemens, Bosch, Airbus, and BASF. 5G test networks have already been installed in some Siemens and Bosch plants.

There can be no question that Germany has been the most aggressive in setting aside spectrum for industrial use cases. However, others (like the UK's Ofcom) are considering a similar move in future auctions. Yet others (like the U.S.) are relying on shared spectrum to fulfill the requirements of enterprise and IoT 5G, or, (like France) are not even acknowledging the need for private networks at all. Despite its flaws and complexities, we believe that the United States' CBRS experiment is setting critical precedents which will be replicated elsewhere. But on the other hand, in just a few years' time, Germany's progressive support for industrial spectrum will enable that country to boast more wide-ranging 5G impacts than those nations which have held on to the increasingly outdated exclusive licensing model.

## 6.5 Security, Privacy and Identity Policies

Privacy and security concerns are growing everywhere as stories of massive data breaches make the headlines. Wireless as a medium is prone to breach and espionage, and both citizens and politicians are increasingly wary about privacy and security issues for both humans and connected machines.

### 6.5.1 Privacy

The EU General Data Protection Regulation (GDPR) is a law that was adopted by the European Parliament in April of 2016 and became enforceable on May 25, 2018. The regulation applies to the collection, processing, and movement of personal data for individuals residing in thirty-two European states (twenty-eight EU states + four other European states). Now, individuals must understand exactly what they have consented to, which means that an end user must give specific consent for its personal data to be collected and agree on how it will be used. GDPR impacts, for example, guest Wi-Fi practices, in that vendors will need to provide tools to get end users' consent to use their personal data for marketing. Venue managers and brands will also want to give end users transparent access to that personal information.

Databases must be classified according to the purpose they serve: legal or marketing. The collection of personal data must be performed in compliance with applicable laws, including anti-terrorist laws that require the retention of logs and their disclosure to official authorities in case of an investigation. GDPR requires vendors to erase all personal data upon request from the end user within thirty days.

Saas[20] vendors need to provide system administrators the ability to create and configure as many terms and conditions/privacy policies as required. All end users must be able to exercise their access rights through the network administrator.

All end users have the right to oppose acceptance of any previously optional Terms and Conditions/Privacy Policy. By accessing the specific end user's profile, the network administrator can view all of the Terms and Conditions/Privacy Policy that the end user has accepted. In summary, the impact of GDPR among the public is hard to predict, but one thing is certain: GDPR will force the adoption of better marketing practices.

### 6.5.2 Security

By just next year (2020), Gartner predicts that there will be 12.8 billion consumer IoT devices connected to the Internet, and further, that on average, early adopters will have as many as 16-18 connected devices per household. Homes and businesses worldwide are exposed to both new opportunities, as well as security risks, as a result of this increasing connectivity.

Unfortunately, security is not front-of-mind in the manufacture of smart devices. Low cost and speed-to-market are prioritized by manufacturers over security. Generally, it is assumed that the devices will be placed on a secure network, but most often, this is not the case.

The IoT devices which customers install in their homes impact broadband services, frequently creating new types of vulnerabilities. Home networks are particularly vulnerable to hacks, because it is not possible to install endpoint security on the majority of customers' devices. Both traditional and new / novel hacking methods are increasingly being utilized to target smart devices (TVs, DVRs, cameras).

The introduction of Wi-Fi Protected Access (WPA3) addresses the increased security requirements from user access, new use cases, and the IoT in the smart home, and in event and enterprise venue such as hotels, stadiums and airports. The WBA is actively working to extend Passpoint to IoT applications to support dynamic IoT roaming and streamline authentication and interoperability. This builds on the ranking of the IoT as the most likely application to drive the next wave of network and traffic growth. Unlike cellular, Wi-Fi 6 (802.11ax) is backwards compatible with previous devices, and the WBA believes that Wi-Fi is in a prime position to tackle continuous consumer demand for data and to power the IoT boom and the security requirements in the home, enterprise and public venues.

### 6.5.3 Digital Identity

A digital identity is the body of information about an individual, organization or electronic device that exists online. Examples of data points that can help form a digital identity include:

- Username and password
- Purchasing behavior or history
- Date of birth
- Social security number
- Online search activities, such as electronic transactions
- Medical history

[20] Software as a service

Because a profile often includes aspects of a person's actual identity, digital identities come with privacy and security risks, including identity theft. According to TechTarget, several authentication and authorization systems have been explored, but there is still no standardized and verified system to identify digital identities.

Digital identity as a dynamic authentication technology designed for businesses that transact online. It's also an anonymous authentication mechanism. Unlike authentication based on static credentials, a digital identity cannot be lost or stolen. It's also impossible to fake because it is based on hundreds of dynamic and anonymized data elements.

This new digital identity understands each user's history and the way they behave across multiple websites and applications. At the same time, to protect privacy, data elements that comprise a digital identity are anonymized using a sophisticated process called tokenization. This process replaces sensitive data with non-sensitive equivalents that cannot be converted to personally identifiable information (PII), and thus have no exploitable meaning or value.

Using behavioral history, digital identity establishes real-time, dynamic relationships between people and their associated devices, locations, credentials and offline identity details, such as billing addresses, phone numbers and shipping information.

Over time, these relationships and connections grow and evolve to form a complete and highly reliable picture of each user that can be used to verify identity and recognize returning users with up to 95-percent accuracy. Application include ecommerce, ebanking, gamming, government services or healthcare.

# 7. Important Contributions From the WBA

The challenge of addressing a wide range of vertical sectors and use cases is that the Wi-Fi industry is no longer working with a single ecosystem focused on Internet access and consumer data. Instead, players need to form an understanding of, and working relationships with, other industries which can harness wireless to improve their own productivity and services. This is one of the most important roles of the WBA, which has identified some key areas in which there are significant opportunities for Wi-Fi providers. Within those, it can help facilitate communications between vertical and wireless stakeholders as the basis for a rich ecosystem in that sector. In this report we provided a number of case studies where the WBA is playing a leading role in accompanying the introduction of Wi-Fi 6 and NGH. Those examples include the In-Home Wi-Fi Industry Guidelines, the deployment of NGH in the hospitality sector, in large public venues such as airports and stadiums and in transportation such as in-flight Wi-Fi.

## 7.1 Wi-Fi 6

### RAN Convergence (Wi-Fi 6 with 5G)

For a number of years, the WBA has been working on defining and enabling the role of Wi-Fi in cellular networks. The WBA published numerous white papers including "Roadmap for Coexistence and Convergence in 5G – Market Research"(2016) followed by " The Role of Wi-Fi

and Unlicensed Technologies (2017)". It forms part of the WBA strategy to actively embrace 5G and ensure that WBA connects cities, carriers, enterprises and Wi-Fi network operators are positioned to exploit 5G and provide the services and experiences essential to our customers and users. The WBA also published a white paper on Wi-F 6 Deployment Guidelines and possible scenarios utilizing Wi-Fi 6 technology. Operators, enterprises and cities can leverage the guidelines as the tools needed to embrace and deploy Wi-Fi 6 when it's released later this year. One concrete example is the coordination by the WBA of the adoption of Wi-Fi 6 in the context of an industrial environment with Mettis described in detail in section 3.3.1

The WBA has looked into how Wi-Fi fits with 5G from a both a business and technical perspectives through a series of marketing initiatives and partnerships with key industry bodies. This year, leveraging its accumulated know how, the WBA has partnered with the NGMN to identify areas that need to be addressed to help make the best of both technologies and include Wi-Fi in the 5G specifications—if not in Release 16, then in future releases. The two organizations issued a preliminary white paper to outline the current challenges for RAN convergence:

1. Wi-Fi-only devices cannot connect to the 5G core
2. Lack of interface to enable a certain level of network manageability and policy control between 5G core and Wi-Fi networks
3. No mechanism for a client to route traffic over one or more access types in an intelligent way, making optimal use of the available connectivity

In the last eighteen months, the WBA has done much work around the role of Wi-Fi in the 5G vision. It has laid out the merits of Wi-Fi in IMT-2020 requirements in a series of white papers.

In its most recent paper on RAN convergence published in September 2019, the WBA examines the current Wi-Fi interworking solutions available for 4G systems using either trusted or untrusted Wi-Fi access, through either Core Network based or RAN level integration. It also reviews the 3GPP 5G system approach to Wi-Fi access, which includes integration of untrusted Wi-Fi access in Release 15 and the new opportunities in Release 16 for trusted Wi-Fi access as well as wireline and cable modem access such as from a residential gateway. Release 16 specified Access Traffic Steering, Switching and Splitting (ATSSS) functionality is analyzed which enables data session over one or more concurrent accesses.

Some of the key challenges for Wi-Fi and 5G convergence are examined covering tight integration between 5G New Radio (NR) and Wi-Fi, cross network visibility, manageability and policy control, enablement of Wi-Fi only devices, traffic routing across NR and Wi-Fi, network slicing synergies and ease of adoption on the device.

A tight integration between NR and Wi-Fi could provide improved session continuity and better resource utilization between the two access networks. New business opportunities between 5G and Wi-Fi networks can be supported by defining interfaces enabling network visibility, manageability and policy control between 5G core and Wi-Fi networks.

For example, such an interface could enable the business model for cellular operators to provide Wi-Fi network management solutions for Small and Medium Businesses. It could also enable enterprise Wi-Fi networks to request access to operator-provided 5G services or 5G network slices, for certain enterprise users and/or applications as a means to provide

differentiated services. Wi-Fi operators could also provide better user experience through a standardized solution providing improved visibility and transition management in the operation of overlapping cellular and Wi-Fi networks.

Finally, taking into account the convergence use case requirements and the current set of 5G and Wi-Fi convergence solutions available, being developed and planned, this paper concludes that further action is needed to address key gaps identified. In particular some recommendations are made in areas requiring further study by the industry and standards bodies (3GPP, IEEE and/or WFA). An interesting challenge is to enable Wi-Fi only devices, with or without 3GPP identity and SIM credentials on the device, to access 5G services on PLMN networks, to expand 5G experiences to existing as well as future Wi-Fi only devices.

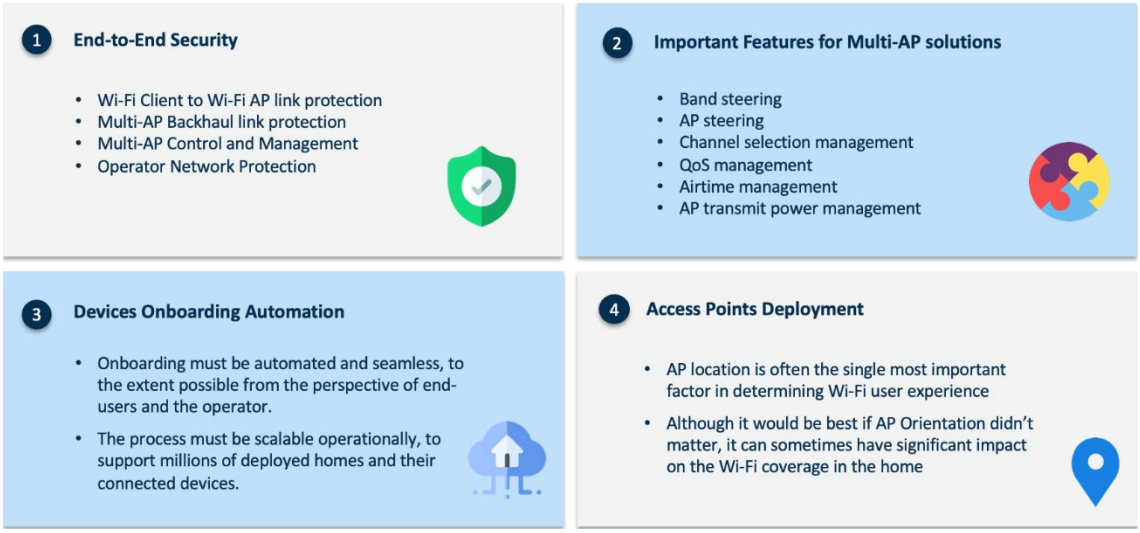
To download the RAN Convergence Interim White Paper, click here:
https://www.wballiance.com/resource/ran-convergence/

## 7.2 In-Home Wi-Fi Deployment Guidelines

A recent initiative by the WBA tackles the growing importance of home Wi-Fi for the smart home. In its whitepaper entitled "In-Home Wi-Fi Industry Guidelines," the WBA assesses and proposes the different cases and service requirements considered in the operator sector, based on the diverse set of architecture options and network types in use. It also describes key technical and deployment challenges that an operator typically encounters in managing large in-home Wi-Fi networks.

The paper also includes proposed key guidelines and recommendations for different functional areas, such as: end-to-end security, coordination of radio resource management, device onboarding and management, as well as deployment. There is also a focus on the performance testing within the home Wi-Fi environments surveying the work carried out by different organizations and suggesting a set of performance test cases in home Wi-Fi scenarios.

***Figure 25: In-Home Wi-Fi Areas of Work by the WBA***




*Source: WBA 2019, In-Home Wi-Fi Industry Guidelines*

In order to solve some of these challenges, WBA members will be assessing programs in the following areas as next steps:

- Multi-AP Solutions Trial
- Performance Testing Guidelines for In-Home Networks
- Scaling-up In-Home Networks in the IoT era
- Delivering 5G Services over an In-Home Network
- Wi-Fi & 5G Roaming

To download the In-Home Wi-Fi Industry Guidelines, click here:
https://wballiance.com/resource/in-home-wi-fi-industry-guidelines-2019/#

### 7.3 Wi-Fi Roaming Evolution

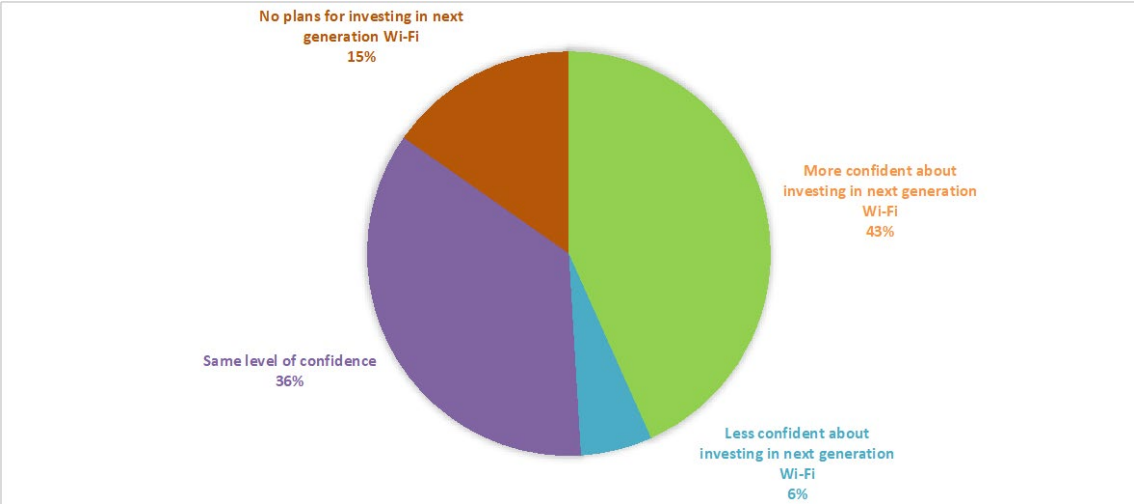
As indicated in section 4.9, the WBA is championing the concept of a roaming federation to unite these hotspots with NGH that resolves all the remaining frictions. Such federations of hotspots are already live, and the WBA is thus pursuing interoperation of these federations to ensure a critical mass of such hotspots is reached. Through the usage of a single Roaming Consortium Organization Identifier, the WBA is looking to help solving the roaming issues for operators and roaming HUBs. The WBA will act as the policy authority issuing top level certificate to the federation members part of its database of active roaming partners.

## 8. 2019 Industry Survey Results

### 8.1 Next Generation Hotspot/Passpoint

One of the most important and long-standing work items within Wireless Broadband Alliance is, of course, establishing the Next Generation Hotspot/Passpoint specifications as a standard. Support is growing – 40% of the respondents have deployed NGH/Passpoint by 2019 or plan to do so in 2020, while a further 37% do plan to implement the technology, but have not set a firm date. This reflects a growing level of confidence – 79% of respondents said they had the same or more confidence in investing in next generation Wi-Fi, including NGH/Passpoint, than a year earlier.

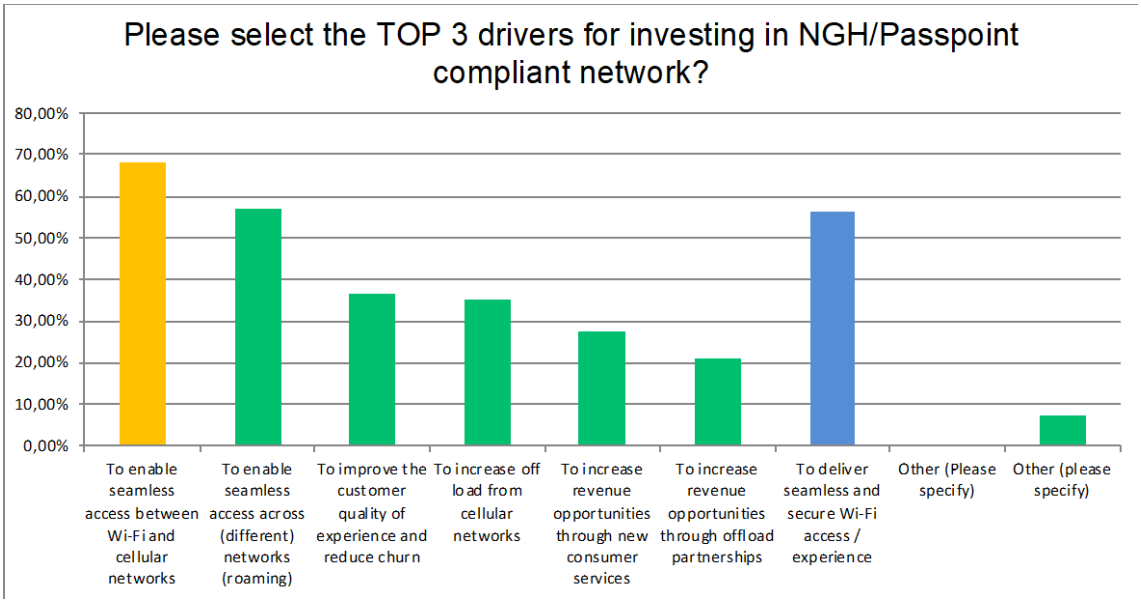
*Figure 26: Level of Confidence About Investing in Next Generation Wi-Fi/NGH*




*Source: WBA 2019 Industry Survey*

The top drivers for investing in NGH/Passpoint were led by seamless access between cellular and Wi-Fi networks, which was in the top three for 22% of respondents; followed by seamless roaming between different networks (17%); and improved customer experience, which can reduce churn (13%).

*Figure 27: Top 3 Drivers for Investing in NGH/Passpoint*

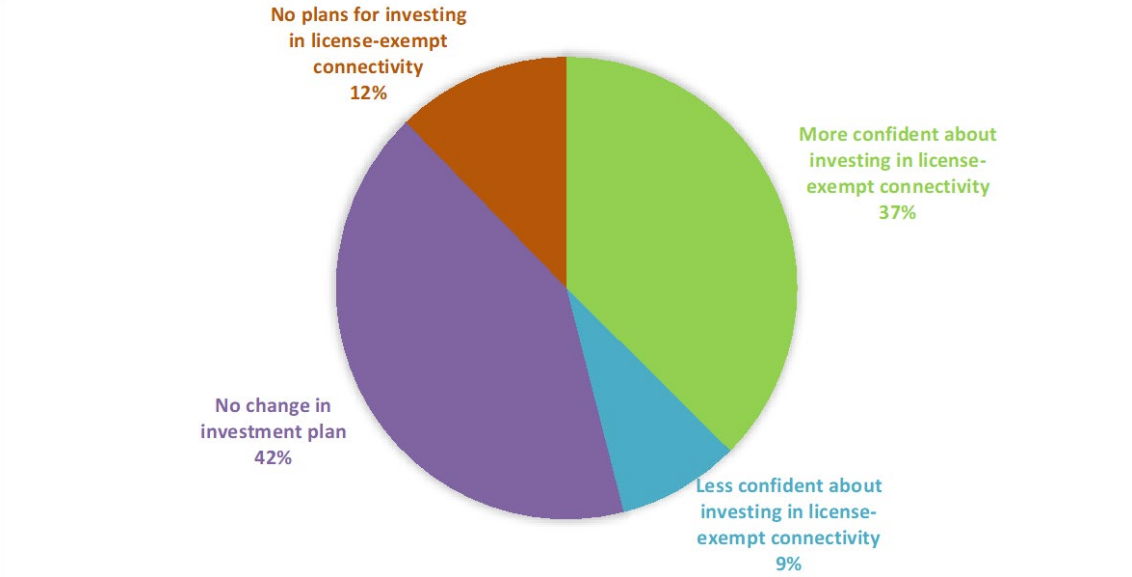



*Source: WBA 2019 Industry Survey*

**Rising confidence in license-exempt spectrum technologies:**

As for license-exempt spectrum technologies in general, confidence is also rising compared to previous studies (Figure 27). In total, 79% either had more confidence, or the same level, as they did a year earlier.

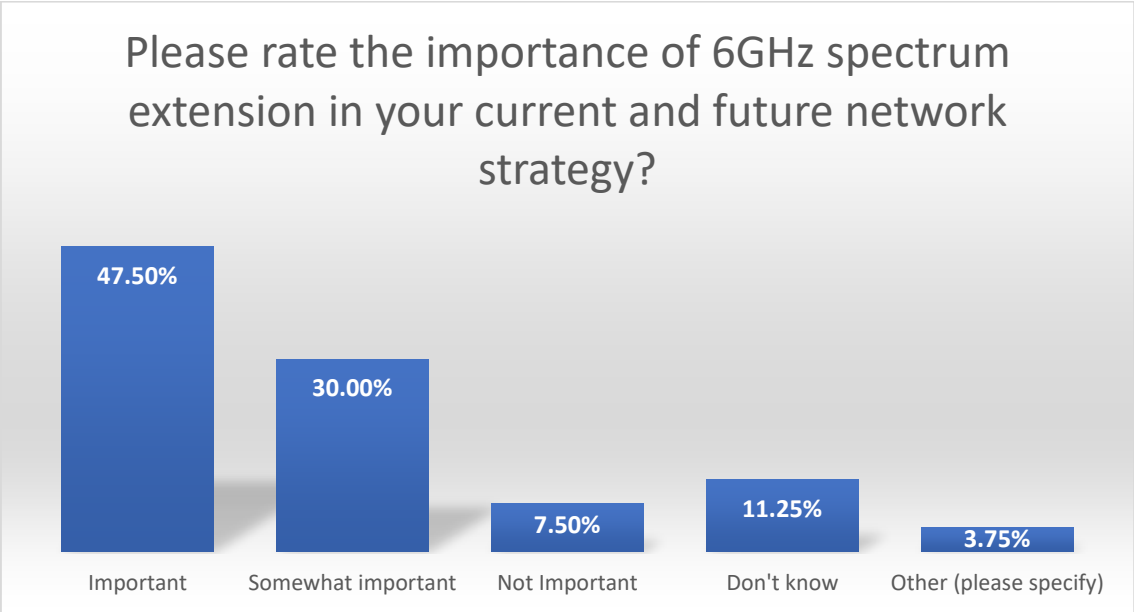
*Figure 28: Confidence Levels to Invest in License-Exempt Connectivity*




*Source: WBA 2019 Industry Survey*

Factors behind this increasing confidence, as outlined in this year's report, include increasingly powerful technologies for license-exempt spectrum, such as Wi-Fi 6; as well as the opening up of additional license-exempt capacity, notably in the 6 GHz band, led by the USA. Almost 78% of respondents said the 6 GHz extension was very important or important to their current or future network strategy. And 25% said allocation of new license-exempt spectrum was the most relevant aspect of spectrum and regulatory policy to their business (followed by 20% who chose the regulatory framework for 5G).

***Figure 29: Importance of the 6GHz Spectrum Extension***



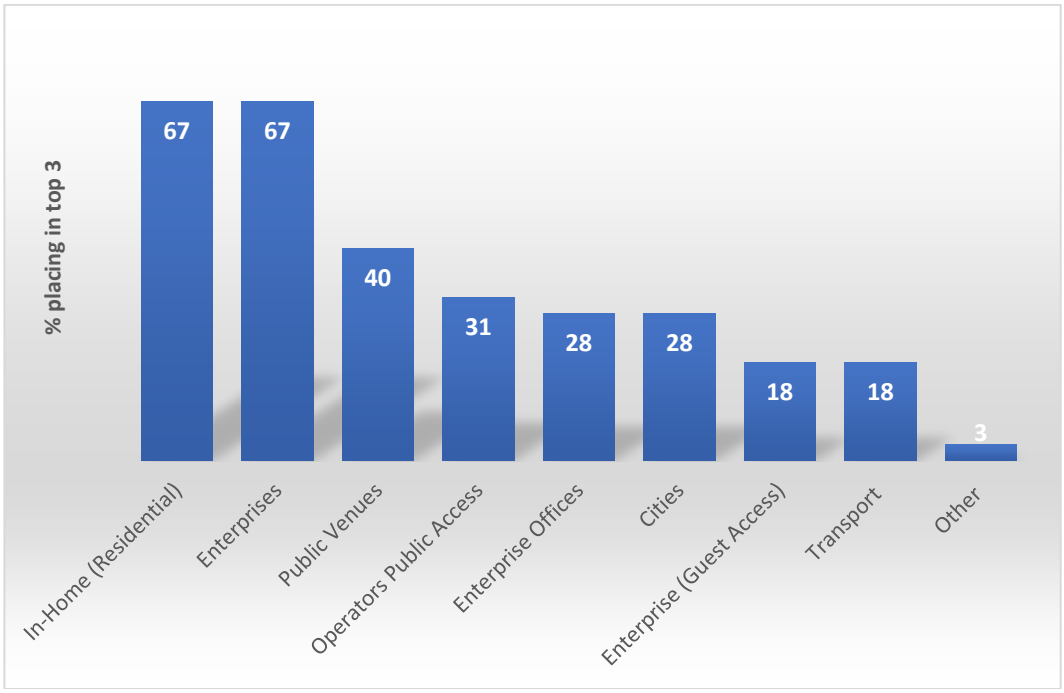

*Source: WBA 2019 Industry Survey*

Another factor is that more technologies are taking advantage of license-exempt spectrum, including low power WAN systems and LTE (57% said LTE in license-exempt bands would be very important or somewhat important to their network strategies). And there are increasingly effective ways for these to coexist with one another, and with licensed spectrum connections, and even to converge in certain points in the network platform. This coexistence of multiple technologies was rated particularly highly for its impact on customer experience management, with 44% saying it was very important for that; other highlighted functions included offload/onload and radio resource management.

## 8.2 Commercial Models for Wi-Fi

Next the survey looked at the commercial opportunities which respondents see in terms of markets, industries and use cases. In terms of Wi-Fi market segments, there was an even split between supporting in-home Wi-Fi, and general enterprise requirements, with two-thirds placing each of these in their top three targets (Figure 25). Public access, specifically in large venues, and within public operator networks, were also very important, placed in the top three by 40% and 31% respectively, while 28% prioritised the specific requirements of enterprises for office WLANs.

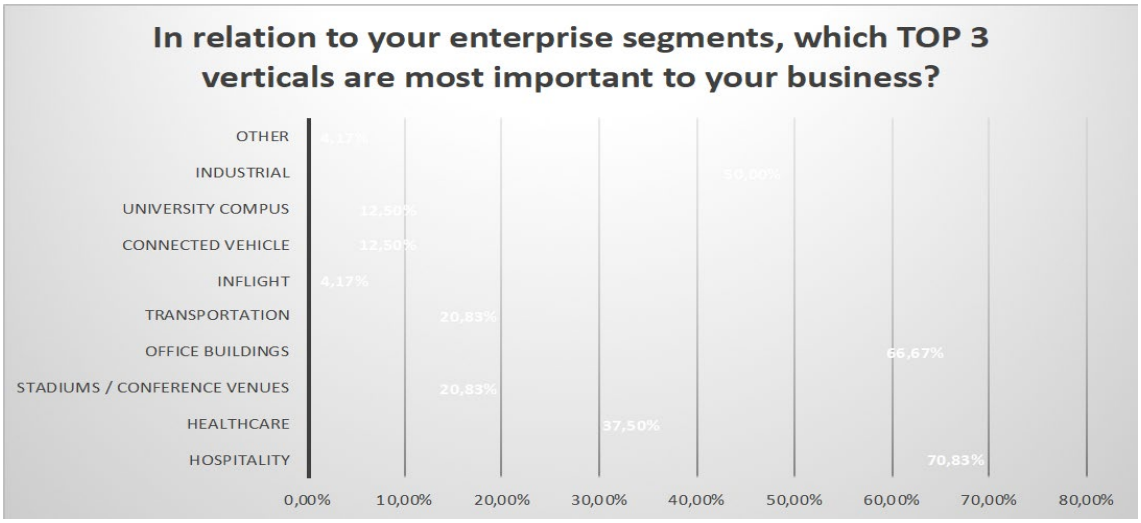
*Figure 30:Percentage Placing the Main Wi-Fi Segments in Their Top 3 Commercial Priorities*




*Source: WBA 2019 Industry Survey*

Within the enterprise category, respondents were asked to name the top three verticals in terms of importance to their business. The most significant emerged as Wi-Fi in office buildings, which was in the top three for 22%; hospitality (21%); industrial (15%); and healthcare (13%).

***Figure 31: Top 3 Verticals Most Important to Your Business***

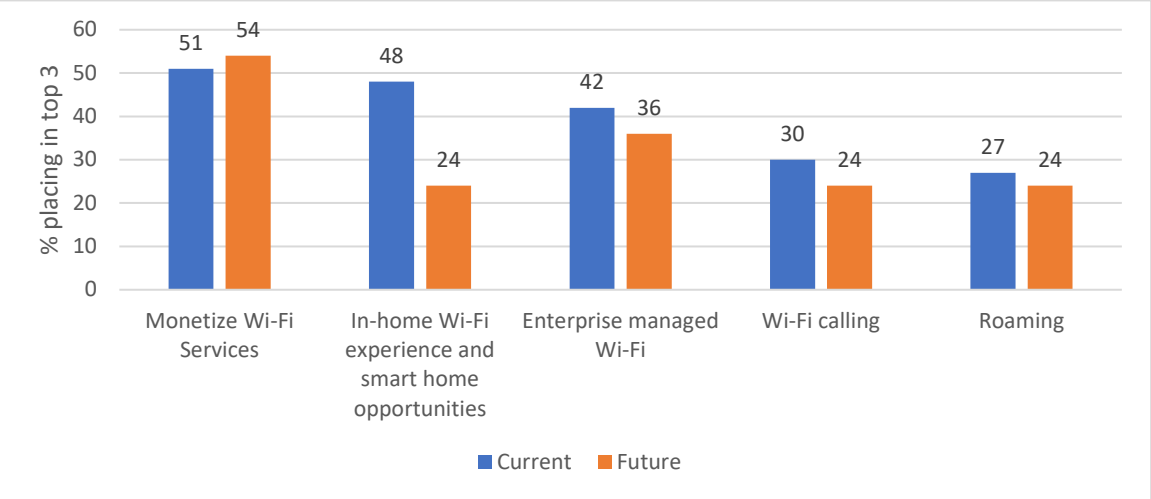



*Source: WBA 2019 Industry Survey*

The leading commercial strategies for Wi-Fi in any of these segments and industries will change slightly over the coming years, according to this study. The top five strategies – those placed most frequently in the top three priorities – remained the same when the respondents were considering their current and future business cases.

Monetizing Wi-Fi services predictably remains the leading strategy, placed in the top three by more than half the survey base. While in-home and smart home opportunities are the next most important category currently (placed in the top three by 48%), fewer see these as critical in the future – the figure falls to 24%, probably because many providers will have established their business case for the home and will be looking to expand by adopting additional strategies. So, for future business, enterprise managed Wi-Fi is ranked in second place, with 36% placing it in the top three.

***Figure 32: The Top Five Wi-Fi Business Strategies, Current and Future (% Placing in Top 3)***




*Source: WBA 2019 Industry Survey*

Within the all-important Wi-Fi monetization strategy, there are many approaches which the respondents plan to adopt. The most commonly cited in current networks are Wi-Fi analytics (56% placed it in their top three), enterprise services (46%) and Wi-Fi roaming (43%). For the future, the most popular strategies are expected to be location-based services (49% placing it in their top three, up from 26% for current networks), followed by roaming and analytics on 40% each.

The applications and services considered most likely to drive revenues in current networks are considered to be general enterprise services, placed in the top three by over half of respondents (52%), followed by in-home services and Wi-Fi calling/OTT services, with 34% each. Within the in-home category, the main use cases supported are managed Wi-Fi as a paid service (delivered by 52%) followed by parental control and guest Wi-Fi.

In three years' time, a different picture is seen – IoT and vertical industry applications are expected to become the leading revenue driver, with 45% placing these in their top three. These are followed by cloud/AI-based Wi-Fi services (33%) and city-wide services (27%).

Of course, there are always challenges when it comes to deploying powerful networks capable of supporting many services and industries. This is especially true of new networks. The main technical challenges identified by the survey were ensuring the best customer experience on a new network (63% said this was a top three issue); availability of devices (59%); and integrating licensed and unlicensed spectrum (53%).

And specific to the important in-home Wi-Fi case, there are gaps which providers see in their current platforms, many of which relate to emerging technologies or devices. Thesea are led by the ability to support proprietary multi-AP architectures, and to deliver services over Wi-Fi EasyMesh.

In terms of business challenges, the concern has swung somewhat from cost to revenue factors, compared to previous studies. Generating new revenue streams emerged as the biggest challenge, followed by capex reduction or deferral, and then by opex reduction.

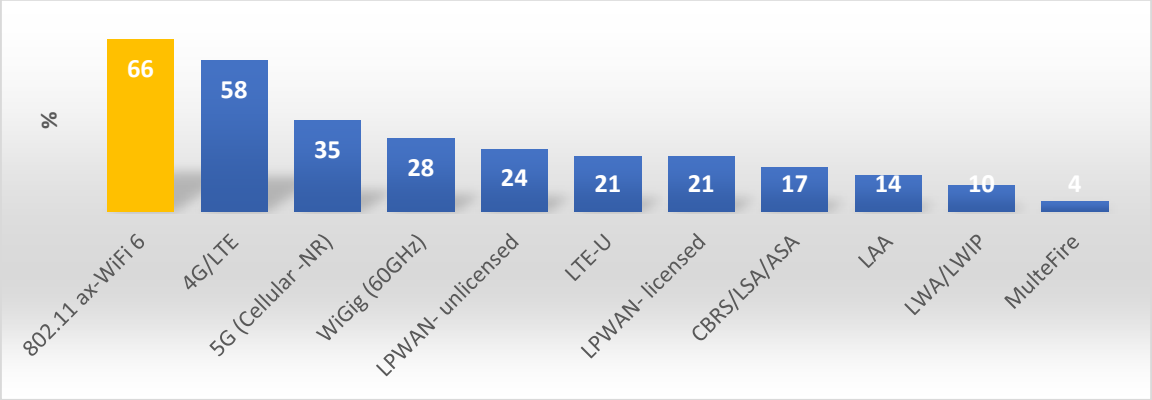
## 8.3 The Multi-Technology Network and the 5G Era

One development that could have a significant impact on the technical and commercial characteristics of next generation networks is the increasing focus on a multi-technology wireless platform, in which Wi-Fi, cellular and other connectivity options can coexist, or even converge, to support a wider variety of applications and experiences.

Respondents certainly expect to be deploying a variety of different technologies in their networks. Figure 26 shows the percentage which have already deployed each new or emerging wireless option, or plan to do so before 2021. The dominant technology in this base is Wi-Fi 6, despite its newness in the market – and when the survey looked longer term, only 10% had no plans at all to deploy Wi-Fi 6, compared to 44% for 5G NR. And when considering the top priorities for their 'network evolution and 5G strategy', 46% said the role of Wi-Fi and unlicensed spectrum was the most important criterion, compared to 15% for the roadmap and standardization of 5G NR.

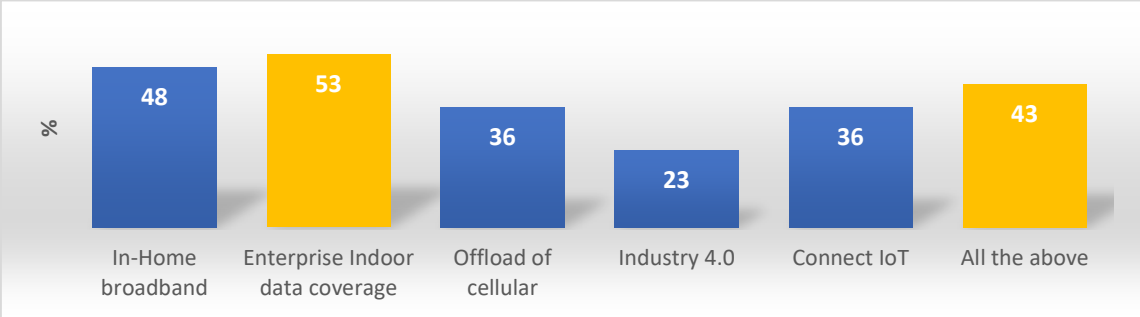
The most significant new and improved capabilities of Wi-Fi 6, which will enable it to take this key role in the connectivity landscape, were identified by the survey base. The four which were most often placed in the top three were OFDMA uplink and downlink (64%), Multi-user MIMO uplink (49%), and flexible channel sizes and self-optimizing capabilities (30% each).

*Figure 33: Percentage to Have Deployed Each Connectivity Option, or Planning to in 2019-2010*




Different connectivity technologies will have different key roles in the '5G era', and Figure 27 shows where respondents think Wi-Fi will be most important. Indoor data coverage for enterprises – often an area where cellular has been weak – was seen as a key Wi-Fi role by 53% and in-home broadband by 48%, while 43% think Wi-Fi will support all five of the main roles identified.

*Figure 34: Key Roles for Wi-Fi in "5G Era"*




This broad role for Wi-Fi in the multi-network 5G landscape will depend on improved convergence and coexistence, something which is being heavily driven by the WBA and its alliances with other groups. This work is looking to address some important challenges. The survey identified the top three:

- Wi-Fi only devices cannot connect to the 5G core
- Lack of interface to enable a certain level of network manageability and policy control between 5G core and Wi-Fi
- No mechanism for a client to route traffic over one or more access types in an intelligent way

Many tools will play a role in facilitating Wi-Fi/cellular interworking, but the respondents selected some particularly valuable ones. First, a common interface between Wi-Fi and 5G, to dedicate Wi-Fi bandwidth to 5G traffic – this was selected as useful by 55%. That was followed by ANDSF (36%), and then Wi-Fi network slicing and TWAG (34% each).

## 9. Conclusion

We have seen that for the Wi-Fi industry, 2020 will be a landmark year as next generation Wi-Fi platforms drive a whole new generation of use cases and revenues. The impact from innovation, investment and hard work by companies involved with the Wi-Fi industry will be powerfully felt.

This year's WBA Industry Survey results showed that confidence in investing in license-exempt spectrum technologies has risen sharply since last year's survey, with 79% of survey respondents saying they had the same or more confidence than a year ago, driven by the advent of Wi-Fi 6, and the prospect of additional license-exempt spectrum especially in the 6 GHz band. In 2019, deployment of Wi-Fi 6 networks started and will play a highly significant role in enabling transformative wireless services in many sectors from 2020 onwards. This year's Report examines the WBA's critical work in providing deployment blueprints, field trials and other resources to accelerate the industry's roll-out; and analyses the future part Wi-Fi 6 will play in the wider wireless platform, and in industries, such as manufacturing and automotive, with challenging requirements.

The Report details the importance of the new release of WRIX (Wireless Roaming Intermediary eXchange) standards and demonstrates how it drives forward an ever-changing set of business cases. The WBA's work directly enables new services and experiences in areas where Wi-Fi is dominant, such as the home, to those where it interworks with other technologies as part of a broad connectivity platform, such as smart cities.

Whilst in 2019 WBA work on in-home Wi-Fi has identified the gaps in current in-home Wi-Fi standards and highlights the need for intelligent network optimization, the WBA has proposed key recommendations for different functional areas and identifies future lines of work and possible directions the In-Home Wi-Fi network may take.

Wi-Fi Carriers services continue to grow and enabling factors such as AI, cloud based services and a suite of network transformation capabilities provide a tool set for continuing to improve the customer experience.

We would like to provide a special thanks to the following individuals who have contributed their time and provided useful insights for the preparation of this report.

- JR Wilson, Vice President Tower Strategy & Roaming at AT&T and Chairman of the Wireless Broadband Alliance
- Melody Eclavea, Technology Business Leader at AT&T
- Analyst Relations Team at Comcast
- Dr Angelos Mavridis, Senior Wi-Fi Roaming Manager at Deutsche Telekom
- Ali Youssef, Principal Network Architect, Henry Ford Health System
- John Flack, Senior Director - Guest Facing Technologies at Hilton Worldwide
- David Green, I.T. Manager at Mettis
- Office of the Government Chief Information Officer (OGCIO), The Government of the Hong Kong Special Administrative Region
- Youngseok Oh, senior manager of 5GX Labs
- The whole WBA team for their valuable support and contributions