



**A Novel Approach to
Tackle Home Wi-Fi Waste
Inter-Home Wi-Fi
Performance Solution.**



WHITE PAPER

Table of Contents

Executive Summary	04
The Role of Wi-Fi in the 5G Home	05
The Home Wi-Fi Performance	07
Limitations of the Gateway Approach	08
Long Deployment Cycle	09
Mixed Footprint	09
Neighbor Interference	10
A Novel Approach	11
Smart Separation of Channels	11
User-Centric and Location Aware	12
Collaborative	13
Application-Aware Optimization	13
Deployment Scenario	14
Conclusions	15
About Ambeent	16
About the Author	16



Executive Summary

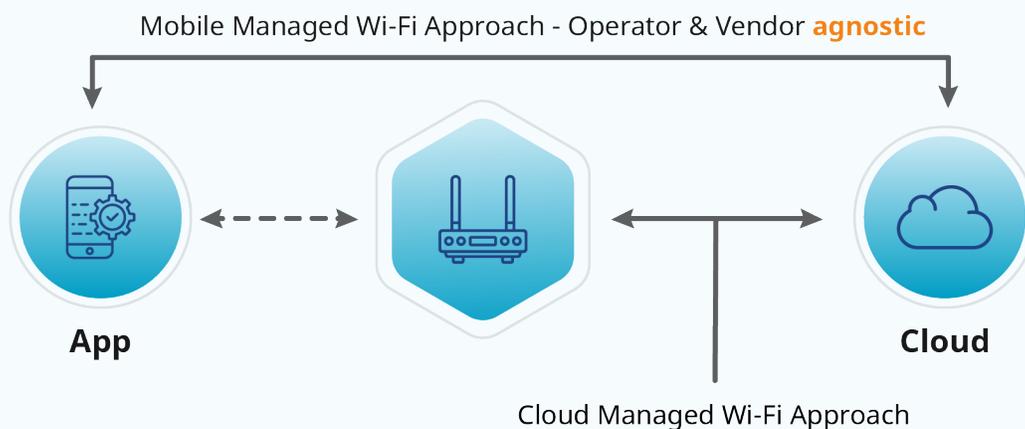
Wi-Fi has become king in the home with an ever-increasing number and type of devices connected to Wi-Fi. Therefore, the need for a solid home Wi-Fi foundation has never been so great. Unfortunately, a number of factors affect Wi-Fi performance and hence the quality of experience, not least, **neighbor interference which is out of the hands of the home broadband operator**. Often neighbors end up using the same channel creating an avoidable congestion. As these neighbors share the same channel, the throughput for all users is greatly reduced.

So far, the main approach to solve the home Wi-Fi performance has been driven by the integration of additional software in the middleware gateway in hopes to address the issues of coverage and congestion. However, this approach has fallen short of addressing the issue of neighbor interference which requires a smart way to allocate channels. Ambeent¹ proposes a novel device-centric way to solve the neighbor interference problem. This approach is **location** and **application aware** and empowers users to take their Wi-Fi destiny into their own hands without having to rely on complex and lengthy decisions from their service providers. It is a mobile-managed approach which combines the power of cloud-based computing and artificial intelligence with the simplicity and elegance of a device application.

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Neighbour interference is out of the hands of the home broadband operator.

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Source: Ambeent

¹Selected as the top five startup in Mobile World Congress two years in a row. MWCA 2018, MWC Shanghai 2019.

The Role of Wi-Fi in the 5G Home

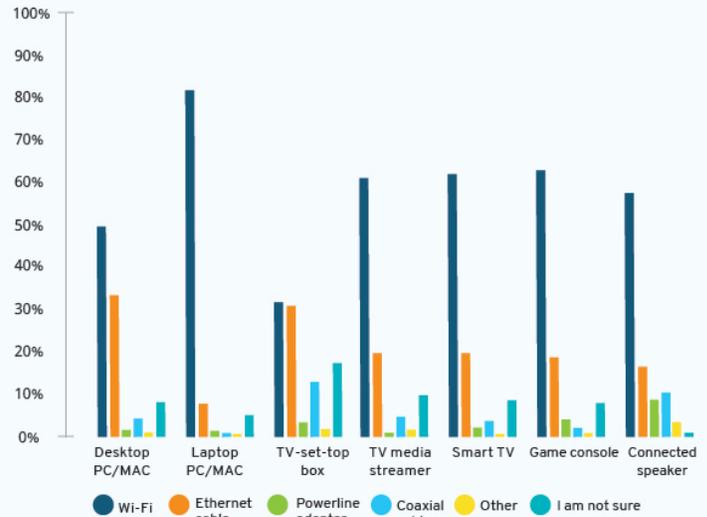
Simply said, we live with Wi-Fi in the home. Today consumers experience their home broadband mostly through Wi-Fi. As indicated on the graph on the right, home devices from Smart TVs, to game consoles and thermostats are connected mostly through Wi-Fi. Therefore, in the minds of consumers, Wi-Fi is broadband and vice versa and they will measure the quality of the broadband experience all the way to their devices.

As a result, service providers are pressured to take responsibility for the in-home Wi-Fi experience through some managed, organized and secure way. The proliferation of home devices will only increase the need for more managed Wi-Fi. Figures vary by region but in North America the average number of devices per home is already higher than 10 and will double in the next 4 years.

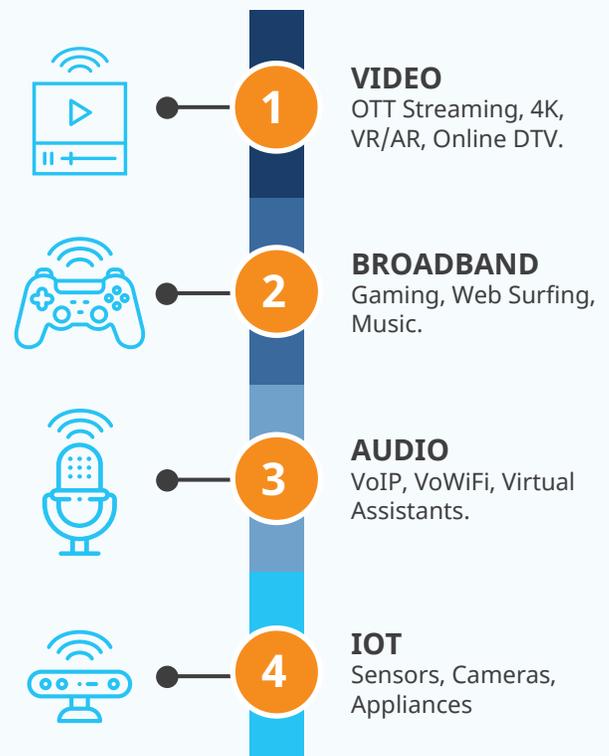
Another important factor is that delivering greater bandwidth alone is not enough anymore. As the bandwidth requirements increase exponentially with 4K video streaming, VR and online gaming, lower latency and stability are becoming essential requirements to enable a good quality of experience in the home.

Gigabit broadband is also forcing service providers to make home Wi-Fi better because clients who pay for higher broadband speeds will expect those same speeds on the device and in this context the emergence of Wi-Fi 6 will help provide more efficiency to the equation.

In this context, 5G will build on technologies and architectures which have been evolving in the unlicen-



Source: Ovum

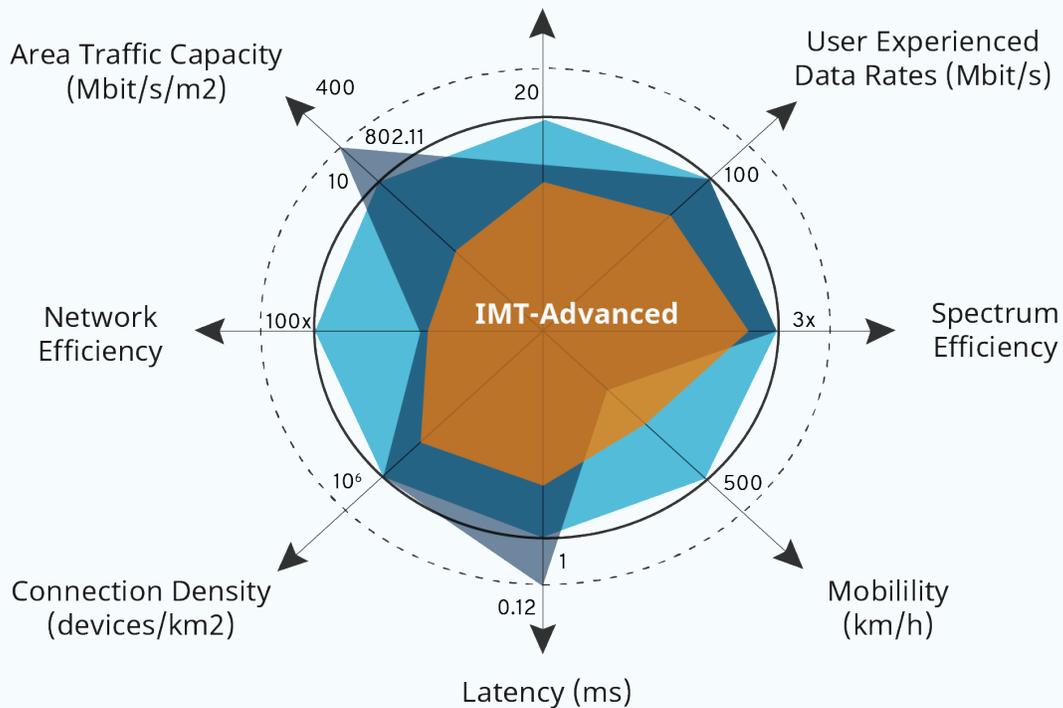


Source: Ambeent

sed spectrum world, especially in Wi-Fi, as much as in cellular. Indeed, unlicensed spectrum technologies will play a major role in 5G. We don't believe 5G will compete with Wi-Fi but rather complement it in areas where wireline technologies are not providing the expected speeds and QoS because of poor infrastructure or lack of it. One scenario would be that Wi-Fi becomes the bottleneck to gigabit speeds which would then fall over to 5G, but that scenario is unlikely as both wireline technology and Wi-Fi 6 reach gigabit speeds.

The Wireless Broadband Alliance (WBA) has identified areas where 802.11 technologies outperform the base requirements for IMT-2020 (5G), and ones where future work will be needed to bring Wi-Fi into line with 5G cellular. Wi-Fi can outperform the IMT-2020 requirements related to area traffic capacity and latency. But, while network efficiency values are above those associated with IMT-Advanced, they do not meet the target requirements for IMT-2020.

This is summarized in the figure below, with each technology having its own strengths and weaknesses.



Source: Wireless Broadband Alliance

Wi-Fi has a role to play in the 5G vision, one that leverages its formidable existing indoor footprint and ecosystem. But it cannot get too comfortable, as new LTE-based technologies will increasingly compete for a share of usage in the unlicensed spectrums.

The Home Wi-Fi Performance

Historically, operators have had little visibility of what is happening in the Wi-Fi home network and, therefore, have been unable to diagnose and/or solve Wi-Fi-related issues. Furthermore, differentiation of Wi-Fi-related degradations from other causes of poor customer experience has also been problematic.

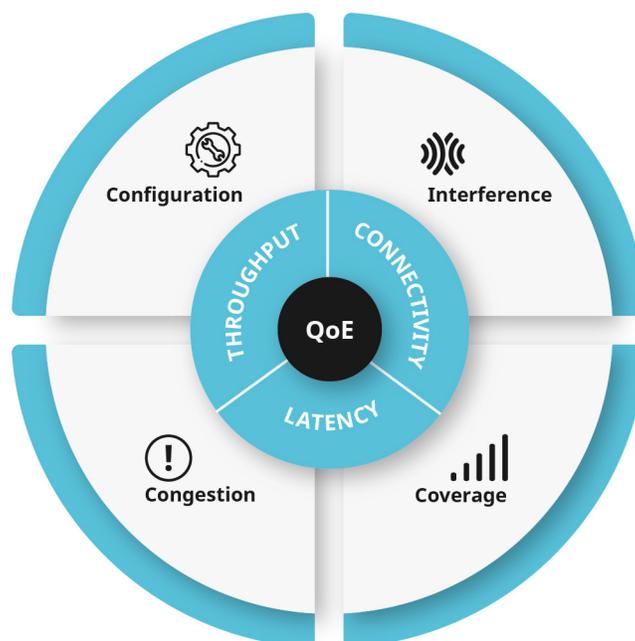
Maravedis survey of service providers reveals that the top 3 factors affecting home Wi-Fi experience are poor CPE placement, dead zones due to poor coverage and **neighbor interference**. In this context, the use of Multi-Access points including a range of one or more extenders is becoming increasingly popular. However as we shall see, adding access points will not be of much help to resolve neighbor interference.

All these top factors result in a poor quality of experience measured in terms of throughput, latency and stability of the connection. And when QoE

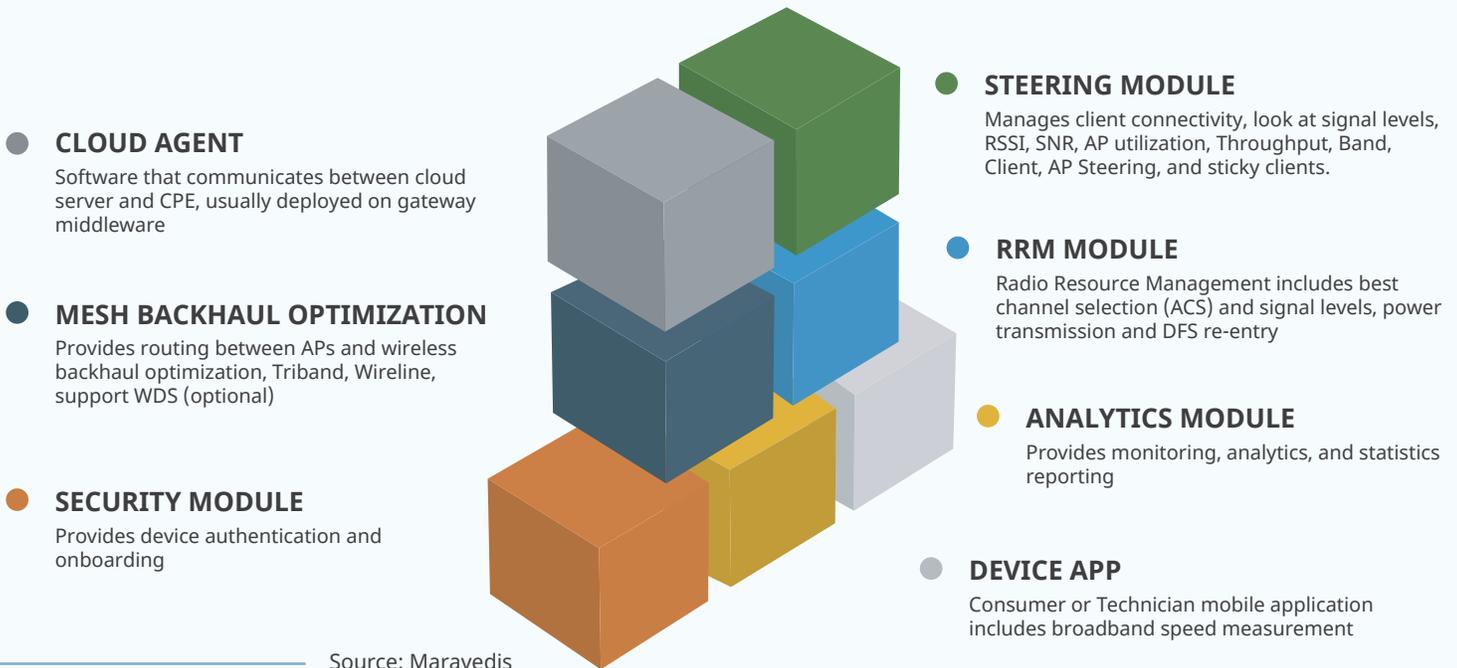
does not match customer expectations they will blame service providers for that.

This poor QoE, results in calls made to service providers. It is estimated that between 30-and 50% of calls made to service providers are Wi-Fi related, although numbers vary by service provider. Among those calls, half result from the inability to connect perhaps because the device is sticking to the wrong AP or because there is congestion caused by too many legacy devices operating at 2.4GHz. The potential reasons are many, the point being that service providers and the users need all the help they can get to reduce the sources of friction in the home Wi-Fi experience.

The service calls can be quite expensive to operators with an average call costing over \$30 per hour when all expenses are included, while a truck roll would range between \$150 to \$350 in the USA according to various sources.



Limitations of the Gateway Approach



Managing home Wi-Fi is more complex than it appears from the outsider perspective. In fact, it involves many aspects, and the corresponding technology solutions in supply reflect this complexity. There is no one single approach to solve all coverage and performance problems that would fit them all. Consequently, service providers can opt for various approaches to resolving fronthaul and backhaul issues. Some operators, Maravedis spoke to, e.g., Comcast or Bell Canada, are in favor of a multi-AP strategy where a 4X4 radio is complemented with a number of extenders backhauled wirelessly with a dedicated channel. By contrast, European service providers have traditionally opted for a wireline backhaul and a limited number of access points.

There are different approaches and elements to solving the home Wi-Fi performance and coverage issues. Each vendor has its own approach and “secret

sauce” comprised of algorithms sold in modules to perform the essential functions needed to solve emerging problems. In the graph above, we summarize these functions. Some functions are essential for resolving performance within a single access point (intra-AP), while others are core to enabling the coverage and roaming (inter-AP). Each software module is destined to perform a particular function or set of functions. Where specifically in the network each module resides, as well as how it is implemented, varies across vendors and/or according to service provider preferences.

However, all these approaches involve three pieces: a software embedded in the home gateway, a cloud-based platform and an app on the device. Although the modem/router/gateway approach brings a number of benefits, it also comes with its own set of drawbacks.



Long Deployment Cycle

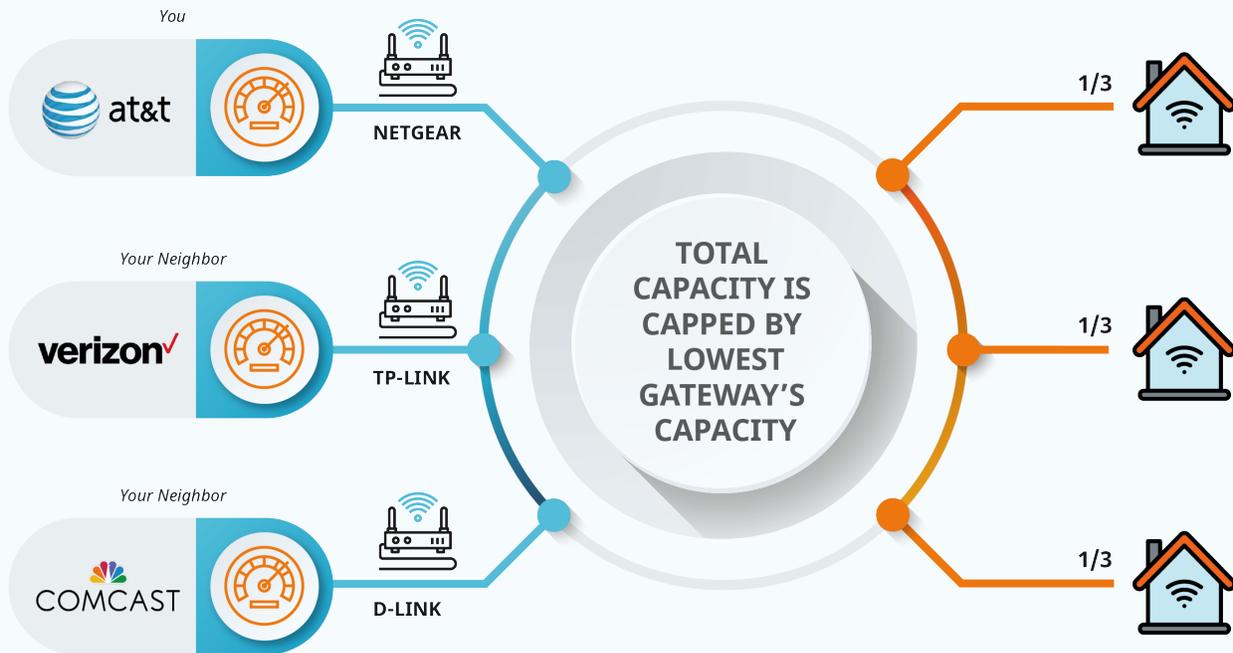
Operators are notorious for being very diligent about introducing a new technology which translates into very long deployment cycles of 18-24 months typically. This is a long time for a technology that evolves very quickly with ongoing innovations. The operator must invest quite some time performing integration both at the gateway and central level to ensure the new software runs smoothly and delivers on its promises.

Mixed Footprint

Operators especially the large ones have a mixed bag of gateways deployed over time. They often end up with several vendors, each with several generations of gateways (b, g, a, n, ac, ax versions of 802.11) deployed, especially when acquisitions have taken place. This creates a headache for operators as they look to deploy new services and features on top of such a disparate footprint and limits at what speed they can scale their new deployments. It is estimated that an operator has to deal with between ten and twenty models of gateways from different vendors in its broadband network.



Neighbor Interference



Source: Ambeent

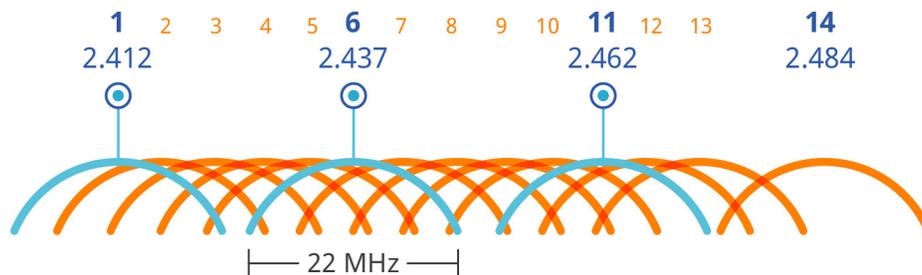
The gateway approach is one where the gateway is managed by the service provider. As a result, a given service provider **A** can manage what belongs to its footprint and its hands are tied when it comes to managing the interference coming from a neighbor who is a customer of service provider **B**. If a neighbor is using the same channel, then the throughput will be reduced as the medium is shared between the two neighbors, thus generating a waste in this precious spectrum resource. Given the fact that neighbor interference is one of the top 3 causes of poor Wi-Fi performance, this is a serious limitation of the gateway driven approach.

Not only would these neighbors share the same channel, they will be limited to the lowest common denominator, that is the gateway with the lowest capacity and throughput because of the longer airtime that old generation gateway will require to transmit the same number of bits.

A Novel Approach

While data traffic and demand using the unlicensed spectrum is growing, the present wireless network architecture on this spectrum suffers from uncoordinated spectrum utilization in a growing number of Wi-Fi access points and technologies. Insufficient coordination among a large number of APs that use overlapping channels leads to interference among them resulting in reduced efficiency and lower data rates. Inefficiency also results in re-transmissions, which not only reduces throughput but also wastes energy.

Figure: Overlapping channels on the 2.4 GHz unlicensed spectrum



Source: Ambeent

Smart Allocation of Channels

We already indicated that the number of devices in the home is exploding, thus creating more competition to access this limited unlicensed spectrum in the 2.4GHz and 5GHz bands. That demand will be further aggravated by the emergence of LTE technology using the 5GHz band and will increase the need to perform dynamic channel management.

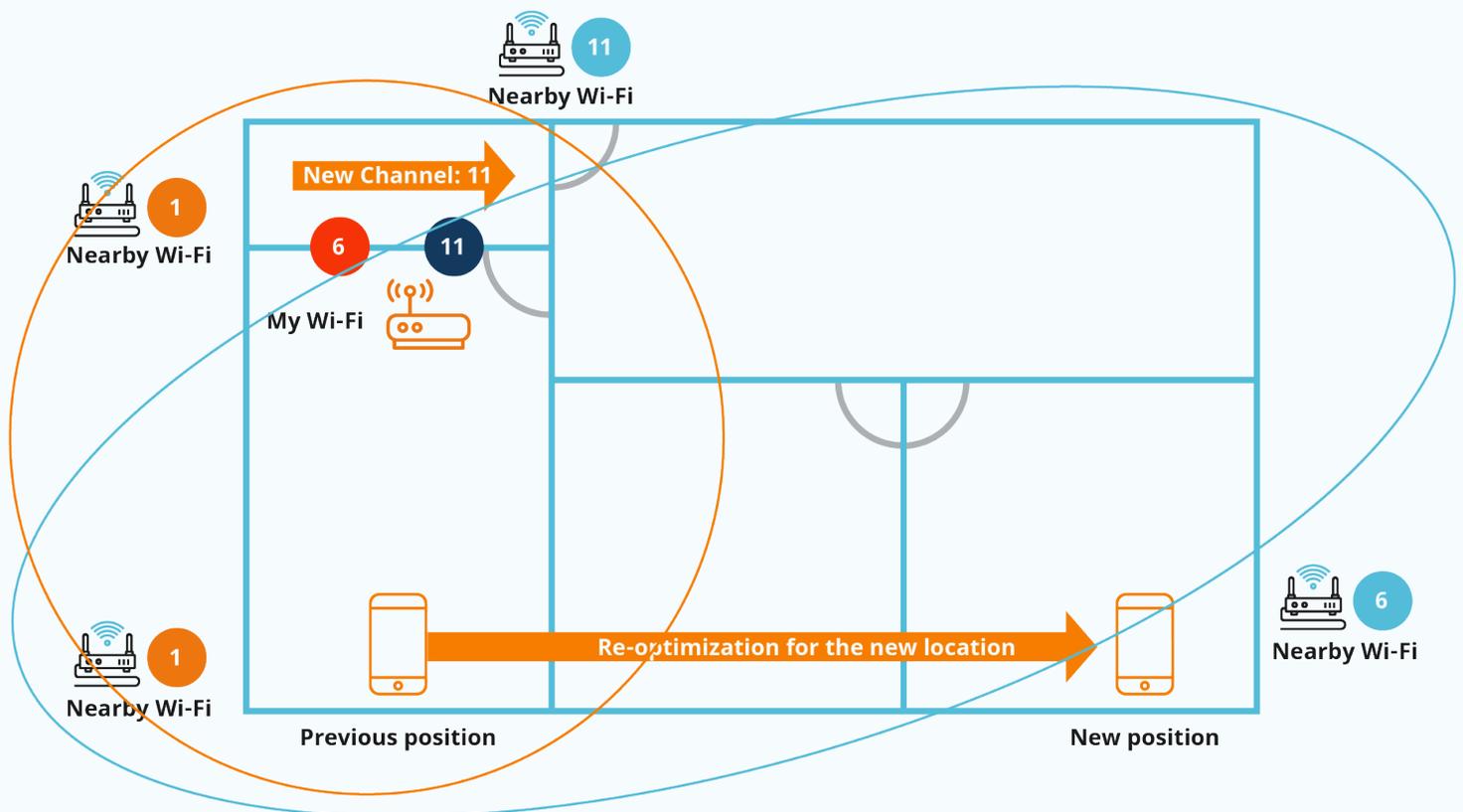
Shift from a decentralized to a centralized management system on the unlicensed spectrum is critical to obtain the maximum possible degree of efficiency and to increase overall wireless quality of service (QoS). What is needed is a smart and dynamic allocation of the channels based on a number of parameters which we will detail now.



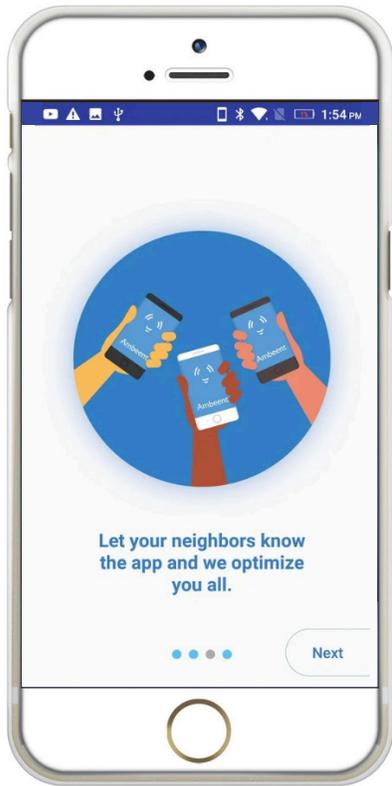
User-Centric and Location Aware

By having the device and thus the user scan the immediate channel conditions instead of relying on a centralized gateway, the system is much more precise and dynamic. If for example, the user is using channel 6, and walks to the kitchen where the neighbor also uses channel 6, the algorithm will tell the device to move to another channel such as 11 as shown in the figure below.

Managing Inter-home Wi-Fi Interference



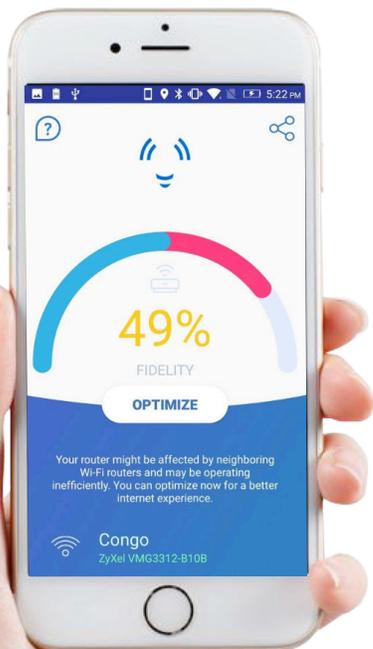
Source: Ambeent



Collaborative

Because this innovative approach enables the first user to enjoy the benefits of smart allocation of channels, it is incentivized to spread the word to its neighbors and friends and generate a viral spread of the solution without having to resort to the operator's permission or involvement. This is a very low-cost entry which is self-driven by positive results.

As explained in the next section on the deployment scenario, the shift from a decentralized to a centralized management system on the unlicensed spectrum is critical to obtaining the maximum possible degree of efficiency and to increase overall QoS. It works with the combination of application on the device which configures the router and signals that it must send the user to another channel. All of the data is sent to the cloud to feed a central repository and machine-learning algorithms.



Application-Aware Optimization

The solution is also application aware to take into account throughput requirements of each user or device in the home. When neighbors exceed the number of overlapping channels, the need to allocate channels according to session types is inevitable.

Indeed, a 4K TV streaming video will have different throughput and latency needs than web browsing or email activity and therefore applications requiring high throughput will require a priority access to clean channels, which will result in a better quality of experience overall.

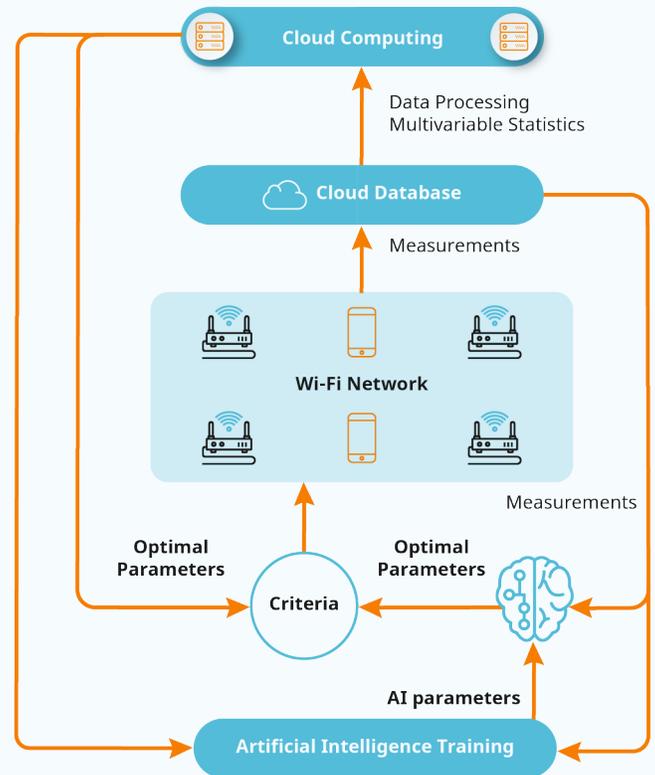
Deployment Scenario

Ambeent’s patent-pending adaptive software defined network (SDN) algorithms offer smart solutions to ensure optimal management of Wi-Fi and LTE network parameters on the entire unlicensed spectrum. The cloud based integrated spectrum management system uses machine learning tools for real-time adaptable & fast decision-making and forecasting. The system relies on existing infrastructure sending information to the cloud to be analyzed with AI algorithms, therefore, accessible and web scalable.

Ambeent’s unique architecture can be summed up as follows:

- A cloud-based centralized system allowing large scale data management.** The cloud feature makes Ambeent’s system both agile and web-scalable allowing for large scale decision-making and for analyzing multiple Wi-Fi metrics. Cloud based data management will also prepare the groundwork for 5G network demands. Ambeent’s agnostic cloud solution will leverage aggregated information (generated by operators, vendors and individual customers that use Ambeent’s applications) to improve end-user experience.
- Integrated management of a range of variables.** The system takes into account the real-time requirements of not one but all Wi-Fi access points in a given cluster thereby optimizing channel allocation in that cluster. A number of variables (adjustable parameters), including transmission power, usage patterns, load balancing, router types and capabilities, varying backhaul capacities, are taken into consideration to contribute to optimal decision making and forecasting.

Figure: Ambeent’s Wi-Fi Architecture



Source: Ambeent

Figure: Multi-dimensional Optimization Parameters

User Location	Wi-Fi Generation
User Demand	Transmit Power
Backhaul Capacity	2.4/5 GHz
QoS	DFS/Country Specific
5G/LTE Unlicensed	Carrier Agregation
MU-MIMO	FUTURE

Source: Ambeent

- **Compatibility with LTE and DFS on the 5 GHz band.** Ambeent's technology also focuses on the development of mechanisms to ensure co-existence of Wi-Fi and emerging technologies such as LTE-U, LAA-LTE, and MulteFire, which are being developed to operate in the 5GHz unlicensed spectrum. The impact of Dynamic Frequency Selection (DFS) on wireless systems operating in 5GHz are resolved through machine learning tools.
- **Compatibility with all Wi-Fi protocols and country regulations on the unlicensed spectrum.** The self-organizing network (SON) feature takes into account capabilities of all existing and future 802.11 protocols, which are subject to different restrictions in different countries.
- **Artificial Intelligence (AI) technology for fast decision making and forecasting.** Ambeent uses AI for decision making to optimize channel selection and for forecasting based on user patterns and

radio frequency measurements data. Ambeent's AI algorithms are 18 times faster than heuristic optimization algorithms, which utilize advanced computational tools such as parallel processing.

- **Ambeent's device side can be standalone or embedded into existing apps.** It provides Level 0 support by reducing neighbor interference at the source and fast Level 1 support by making ready poor CPE placement and coverage problem indicators along with Wi-Fi-only throughput at the call center.

Ambeent already supports gateways for a number of operators including AT&T, Verizon, Comcast, Time Warner, Turkcell, Turk Telekom, Millenicom, Turk-net and many others. Ambeent's differentiated value proposition is to be operational in less than a month with no change in core network or access points. The company also provides alternative revenue sharing and licensing models with partners and customers.

Conclusions

In this paper, we looked at the predominance of Wi-Fi usage in the home, a situation only becoming more acute with the proliferation of devices and IoT. We discussed the various factors affecting Wi-Fi performance including neighbor interference and how the modem/gateway approach falls short at addressing and solving the negative impact of neighbor interference on quality of experience. Poor Wi-Fi performance not only affects users but also results in higher costs for the operator in the form of higher service calls and truck rolls.

We then presented and made the case for an innovative approach to tackle this Wi-Fi waste that is device-based. This solution offered by Ambeent enables smart channel allocation that is location and application aware and lends itself to a collaborative approach. The result is an average 40% performance gain in throughput and quality of experience.



About Ambeent

Ambeent, Inc. develops cloud platforms for 5G networks. The company's patent-pending adaptive software defined network (SDN) algorithms use machine learning tools for better Wi-Fi user experience in the unlicensed spectrum servicing all operators, vendors and users with regard to emerging unlicensed LTE technologies. Its strong cloud computing capabilities that enable effective handling of global scale operations and its novel methods that allow for zero cost integration into existing deployments make the company's solution unique, web scalable and monetizable. The company was founded in 2016 and is operating in San Francisco. Ambeent Inc. has seasoned executives as well as researchers & developers from tier-1 institutions.

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*From Managed Home
Wi-Fi to Enabling the
Secure Smart Home
2018-2023.*

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