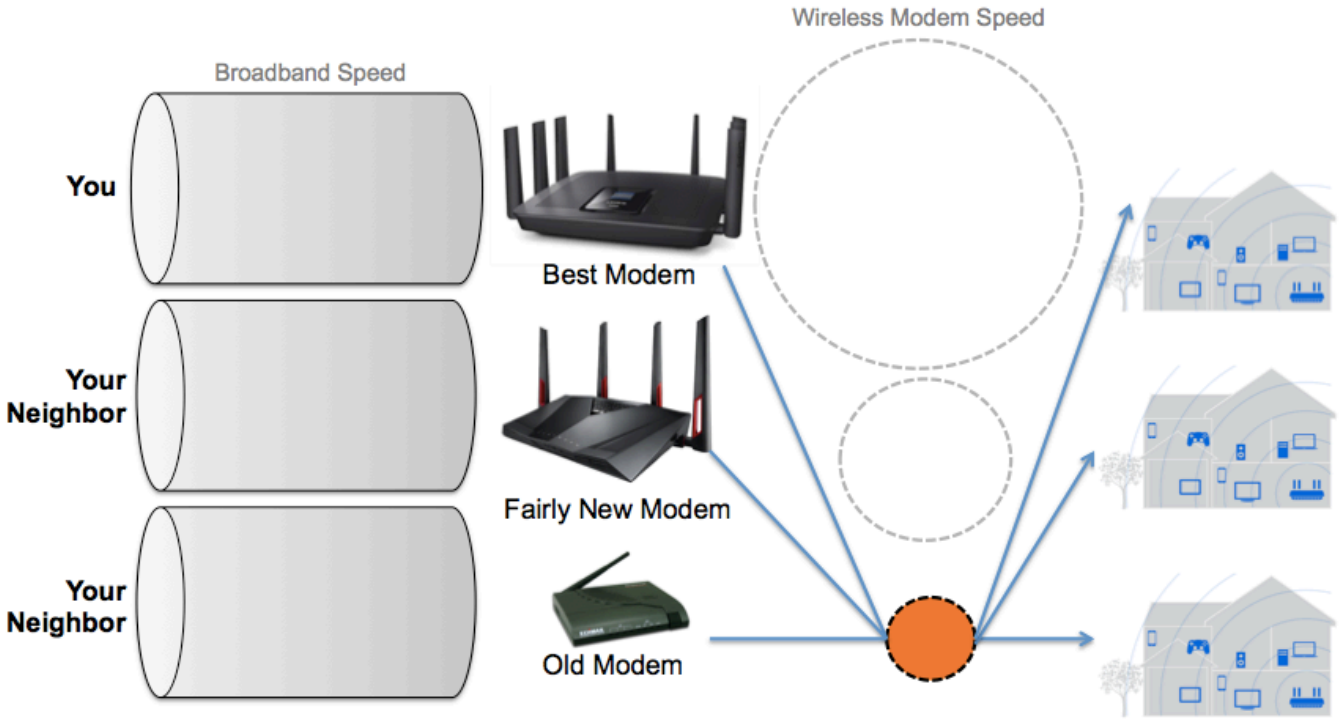
Ambeent

Tackling Wi-Fi Waste

User-centric & Collaborative

Unlicensed Spectrum Management



Ambeent's solution empowers users and service providers to unlock Wi-Fi's full potential. With our unique cloud-based, AI-powered platform, we can reach hundreds of millions of Wi-Fi access points to optimize Wi-Fi's performance globally. Our user-centric, virtualized platform does not require installing hardware/software on premises. Our solution lays the groundwork for the unlicensed spectrum in future 5G heterogeneous networks.

Use Case: we tune your Wi-Fi when you move from kitchen to bedroom

"

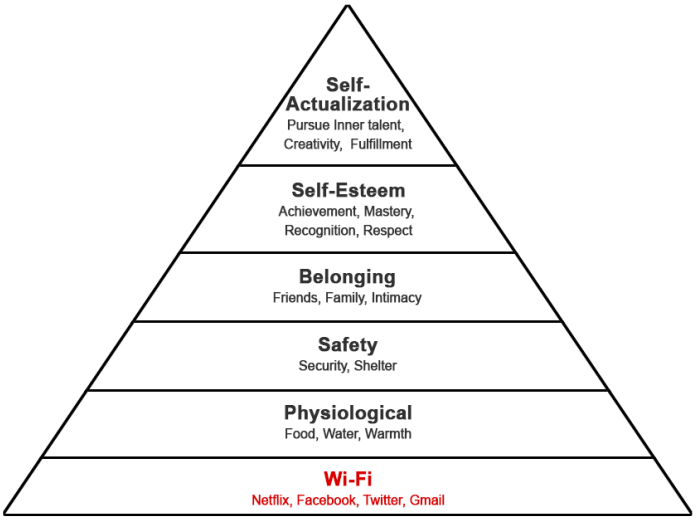
Wi-Fi ranked #2 item we don't want live without.

"

Wi-Fi is a Basic Need

The spectrum for Wi-Fi faces a challenge to respond to demands generated by emerging technologies and new usages. Due to spread of smart devices and bandwidth hungry applications, there is significant demand for ubiquitous and higher data rate wireless networks. According to the 2016 Cisco Mobile Visual Networking Index Forecast, mobile data consumption grew 18-fold between 2011 and 2016; it is expected to increase sevenfold between 2016 and 2021. Cisco, highlighting the expanding role and coverage of Wi-Fi, predicts that offloading from cellular connections to Wi-Fi will increase by 3 % by 2021, reaching 63% of total mobile data traffic from all mobile-connected devices[1]. On the other hand, new technologies such as Augmented Reality (AR)/ Virtual Reality (VR), 8K Video, Internet of Things, increasingly popular with consumers and critical for businesses, will demand ever higher data rate wireless networks, putting a strain on the available unlicensed spectrum.

As the worldwide usage of Internet continues to grow, the unlicensed spectrum represents a critical network response to rising data traffic on wireless networks. Wireless connections are either licensed or unlicensed. Internet service providers benefit from the freely available unlicensed spectrum while cellular operators pay high fees to obtain spectrum licenses. Growing number of smart



devices almost exclusively rely on the unlicensed spectrum, including the 2.4 GHz and 5 GHz frequency bands for accessing Wi-Fi. The freely available unlicensed spectrum is also gaining traction as a possible alternative to the costly licenced spectrum LTE technology. Moreover, efficiency associated with the unlicensed spectrum, is vital for meeting fifth generation (5G) network goals.

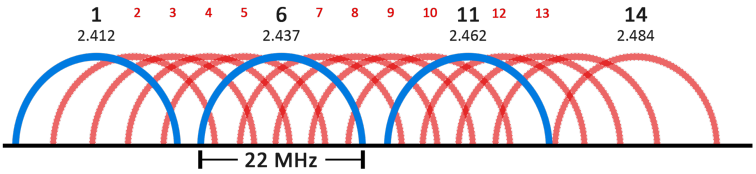
The Unlicensed Spectrum Challenge - *Comprehensive Thinking Matters*

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 growing number of Wi-Fi access points and technologies. Current applications, depending on the 802.11 protocol (b, g, a, n, ac, ax) they use,

[1] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021 White Paper.

operate on either the 2.4 GHz and 5 GHz bands. Access points (APs) and other devices (e.g. Bluetooth, Microwaves) that are connected to wireless networks on the 2.4 GHz band use the few channels available within this band. 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 1. Overlapping channels on the 2.4 GHz unlicensed spectrum



On the other hand, the 5 GHz unlicensed band, with a high number of non-overlapping channels, provides faster download speeds making it especially attractive for Wi-Fi access systems. However, the 5 GHz unlicensed band has the disadvantage of reduced coverage per cell due to its higher frequency. Furthermore, emerging technologies such as LTE-U, LAA-LTE, and MulteFire that are being developed to operate in the 5GHz unlicensed spectrum, may require further coordination. There is an ongoing debate on the fair coexistence of these technologies and Wi-Fi on the 5 GHz band.

Ambeent's Pioneering Wi-Fi Architecture

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 (QoS). 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 and fast decision–making and forecasting. The system relies on existing infrastructure sending information to the cloud to be analysed 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 analysing 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

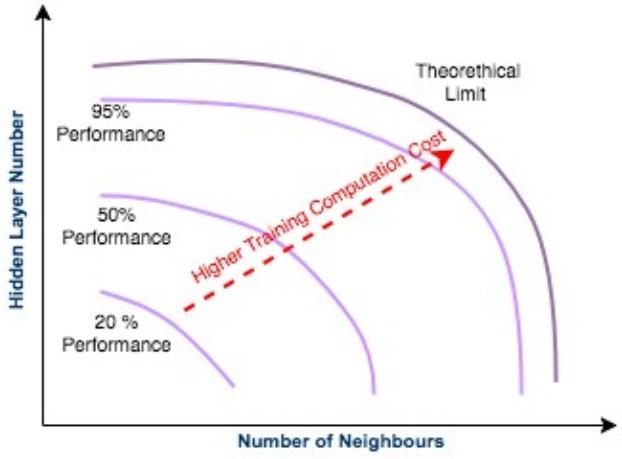
access points in a given cluster thereby optimizing channel allocation in that cluster. A number of variables (adjustable parameters), including transmission power, usage patterns, load balancing, router types and capabilities, varying backhaul capacities, are taken into consideration to contribute to optimal decision making and forecasting.

- **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.

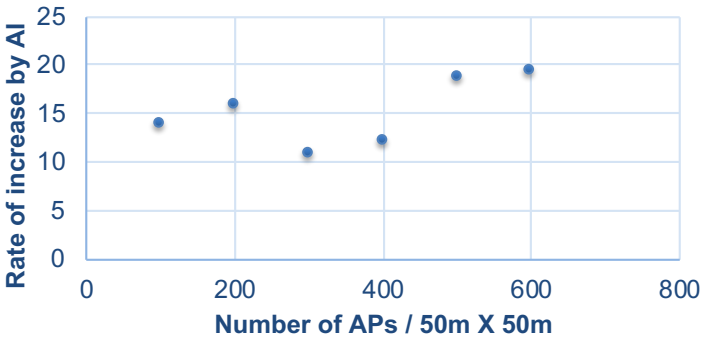
- **Artificial Intelligence (AI) technology for fast decision making and forecasting.** Ambeent uses AI for decision making to optimize channel selection and for forecasting based on user patterns and radio frequency measurements data. Ambeent's AI algorithms are 18 times faster than heuristic optimization algorithms, which utilize advanced computational tools such as parallel processing.

Figure 2. AI Performance Evaluation and Training Cost



AI training depends on many factors. Ambeent optimizes real time AI update computations based on evaluations of the marginal contribution as complexity increases. In turn, cost-effective AI can be implemented.

Figure 3. AI Computation Speed Comparison



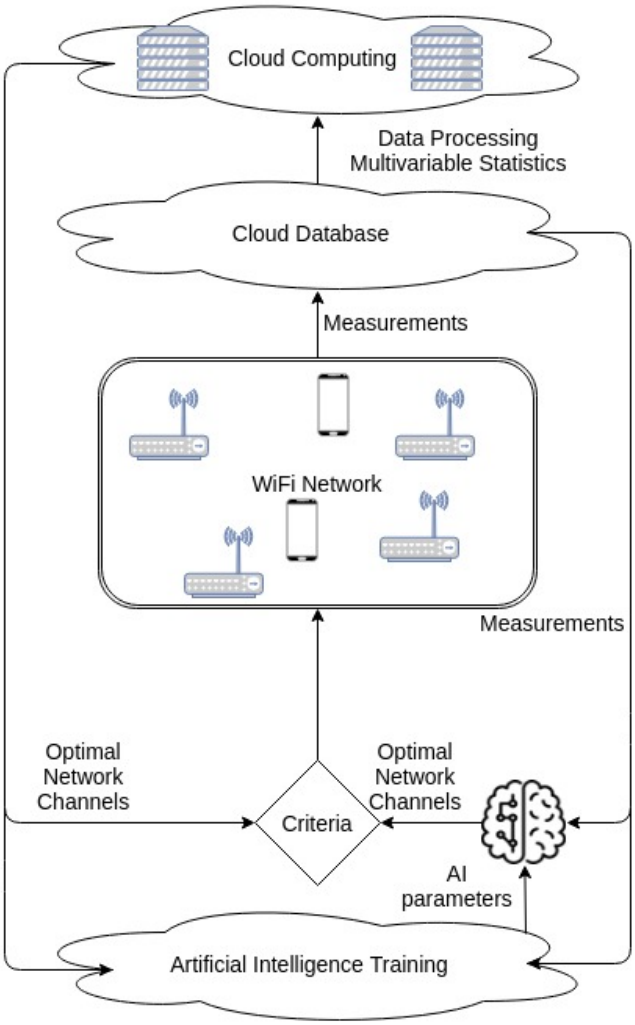
AI is significantly faster compared to traditional assignment algorithms in dealing with a high density of APs operating under dynamic network conditions.

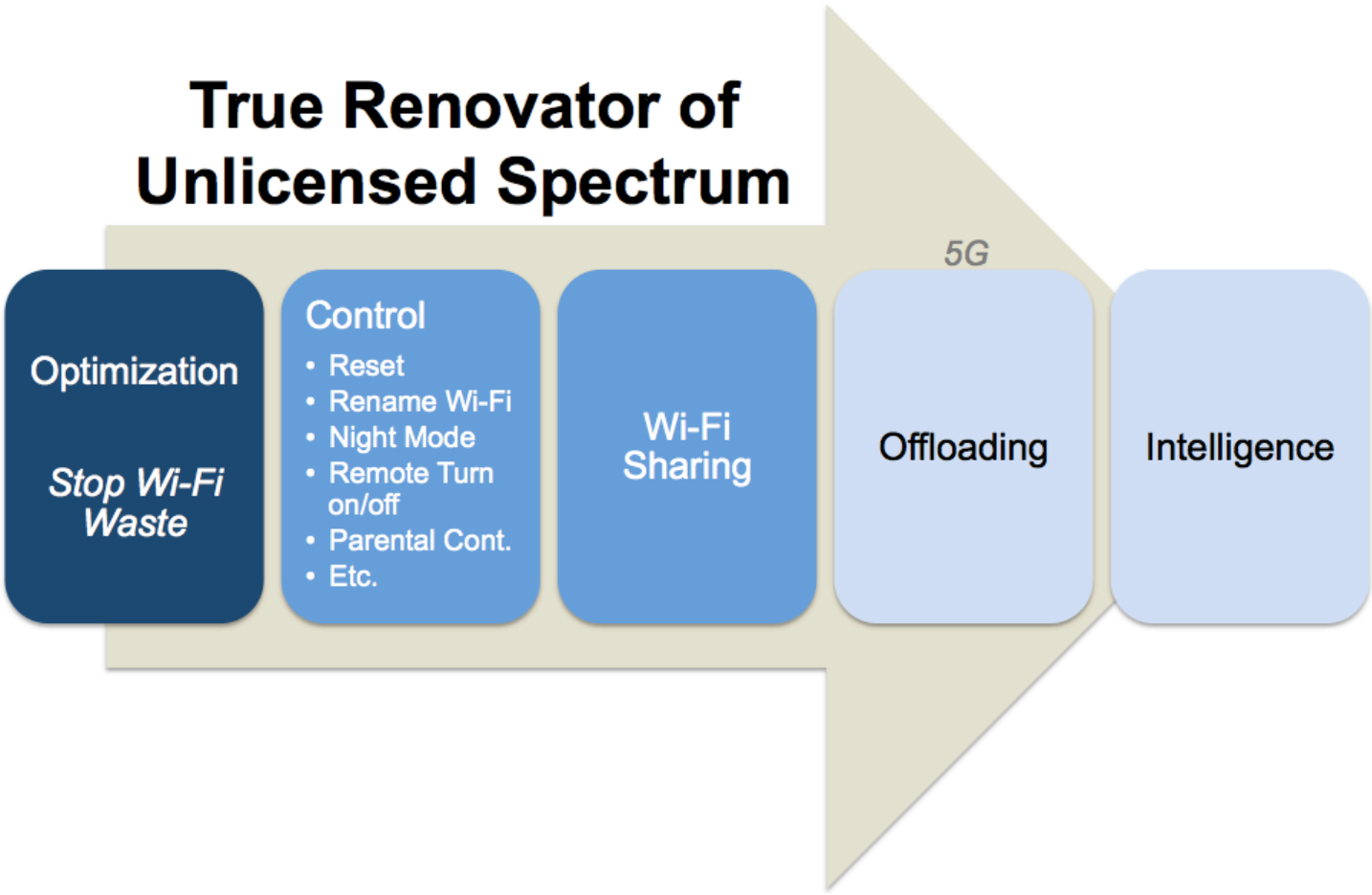
Unlocking the Global Wi-Fi Potential

The world faces ever-growing demand for Wi-Fi networks. Yet, the present wireless architecture falls short, partly due to existing Wi-Fi wastage. A fast and cost-effective solution to improve wireless operations is urgently needed to improve user experience in a world of smart devices.

Ambeent's next generation adaptive software defined network (SDN) technology rises to the challenge. Its cutting-edge machine learning tools will ensure robust and seamless user experience. Ambeent's cloud solution to Wi-Fi management does not require change in existing software or hardware making it cost-effective and easily scalable. Ambeent aspires to improve the global capacity of cellular networks through optimal utilization of wireless networks on the unlicensed spectrum.

Figure 4. Ambeent's Wi-Fi Architecture




True Renovator of Unlicensed Spectrum
5G
Optimization
Stop Wi-Fi Waste
Control
• Reset
• Rename Wi-Fi
• Night Mode
• Remote Turn on/off
• Parental Cont.
• Etc.
Wi-Fi Sharing
Offloading
Intelligence

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 and Istanbul. Ambeent Inc. has seasoned executives as well as researchers & developers from tier-1 institutions.

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