Augmented Reality Can Improve Wi-Fi Installation In Homes

A Technical Paper prepared for SCTE•ISBE by

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1. Introduction

Wi-Fi is a physical medium that is impeded by distance and materials that cause interference. In order to ideally place access points (APs) the physical space needs to be understood. Relevant variables much as spacing, shape of the space, and interfering objects need to be consistently measured. Measuring and evaluating all of these variables creates challenges for technicians to properly optimize networks. APs may be placed optimizing for either cost to the consumer and service provider or coverage. We have built an application that will help a technician or customer design an ideal Wi-Fi space. This paper will outline design issues in Wi-Fi and how an augmented reality application can solve them.

Traditional Wi-Fi design utilizes a meter to collect data about the behavior of the electromagnetic radio waves within a physical space. This provides the technician insight into variables that impact radio waves that are hard to visualize. Interference from other radios and the differing amount of signal degradation caused by materials the radio waves pass through can be interpreted using a Wi-Fi meter. Our AR application combines the traditional data that would be collected using a Wi-Fi meter with additional information about the space such as the area and shape that require coverage.

Additional AP hardware is expensive for service providers and too much coverage overlap can cause negative network performance for clients. If the APs aren't placed close enough together then clients will experience low signal or loss of signal. It is ineffective to train technicians and customers to measure and consider so many variables in order to decide where to place their APs. Instead, service providers may utilize augmented reality to gather data about the physical world and feed that data to systems that may make informed and consistent decisions about how the APs should be placed.

A customer's living space contains three key components of relevant data when deciding where to place APs. The most important factor for effective mesh Wi-Fi design is distance between APs. If the distance is too great dead zones are created and mesh steering becomes ineffective. Conversely, when APs are placed too close to each other interference may be caused on overlapping channels. The service provider also incurs expense due to the additional hardware they are utilizing to cover the space.

The shape of the living space is also an impactful factor when considering AP placement. Wi-Fi radios can cover different shapes based on their design, and location of APs is important to make sure the coverage is complete. For example, if a space has a room adjacent to the square common space, that room may be outside of the coverage for the rest of the living space. As shown in figure 1, non-uniform environment layout can lead to difficult design choices when placing APs. Radios often cover a omni-directional space uniformly meaning that if a space is not uniform in its shape there will be regions that require a different coverage solution.

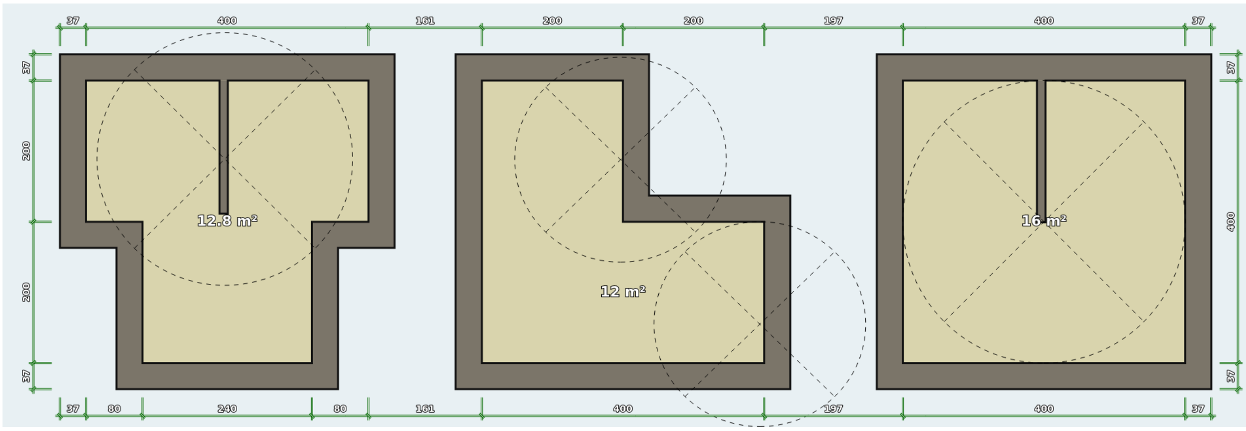

Figure 1 - APs in different shaped environments

The last relevant variable to be considered is noise and interference caused by foreign materials and appliances. There are some common materials such as mirrors and concrete that can cause a high degree of Wi-Fi attenuation and reflections. Detecting and designing a Wi-Fi system around them is important. The most common device that can cause interference is the microwave, although devices like cordless phones can also cause problems. Locating potential trouble devices and accounting for them can help alleviate problems. This type of interference is hard to visually detect and is often measured through a Wi-Fi meter.

Designing Wi-Fi coverage is not as simple as adding more antennae. It is a problem of design, consideration, and optimization. To design a Wi-Fi system the variables must be known, measured, and weighted. This is a process that is very difficult and not practical for consumers. Technicians are able to be trained as to what variables are important, general guidelines for what thresholds indicate for each variable, and the importance of each. This results in installations that are more efficient than if the customer were to perform the installation, but leads to inconsistencies as much is left to the discretion of the technician. Technicians must spend time measuring and designing the Wi-Fi, which increases the amount of time spent in the home and reduces the number of home installations per day.

2. Overview of the Wi-Fi Augmented Reality Application

The augmented reality application is designed to assist with Wi-Fi AP setup by guiding the user to collect all required data. The user is guided through the room and instructed to tap on the borders of the room as well as locating relevant connected devices and APs. Upon opening the application, the user is asked to move through each room, position the camera to view the corners, and then tap on the corner. The user is also prompted to tap on any connected network devices or APs. As the user tags each border or device the augmented reality application will place a virtual tag over the feature, showing the user where the application understands the feature to be. While the user navigates through space the device location and its current RSSI are recorded. After the user has successfully tagged all of the corners and devices they may move their device around the room to see the virtual overlay of how the application understands the environment. This displays to the user the dimensions of their environment and where the variations in signal strength are.

The principles described in this paper have been implemented as a proof of concept application by Charter's Emerging Technology group. The application is an iOS app utilizing ARKit APIs in order to gather relevant data. The application measures the path that the user walks through the home, timestamps associated with points of the walk, and the relative location of all data points. Once the features have been captured all of the data is sent to a cloud for processing and use by other applications. The APs are also configured to collect high definition RSSI measurements for the AR device during the walk, allowing the device to act as a Wi-Fi meter.

Currently many technologies exist that could make the design of the user interface more accessible for users. The user interface accepts touch input to identify corners defining a room as well as allowing the user to tap on any device in their home that is connected to their network. These events can be seen from an interface perspective in figure 2. This however could be enhanced and even automated using plane detection to automatically locate the intersection between three planes. In an implementation following that pattern, the user would simply move through the space and the layout would be generated as they pass the camera over features. The user could after the fact, or while moving through the space, make any adjustments to correct where the plane detection is erroneous.

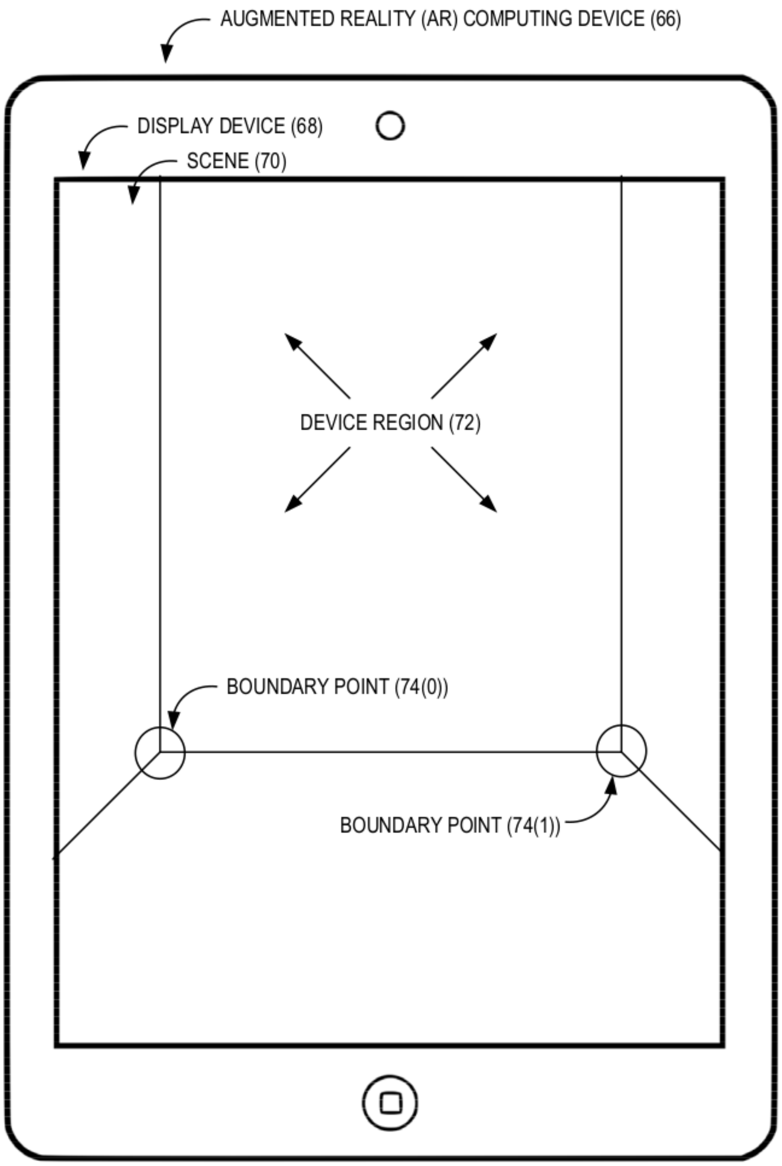

Figure 2 - Edge Detection

Machine learning can also help automate the placement of network devices. The augmented reality application samples the environment and identifies features including devices. The current implementation allows the user to tap on any device that is currently connected to their network and a list is then provided of currently connected devices for them to select from. This interface is seen in figure 3. Instead of requiring user interaction to select which device is present, image recognition could be employed to match images of known network devices against devices seen in the camera of the augmented reality device.

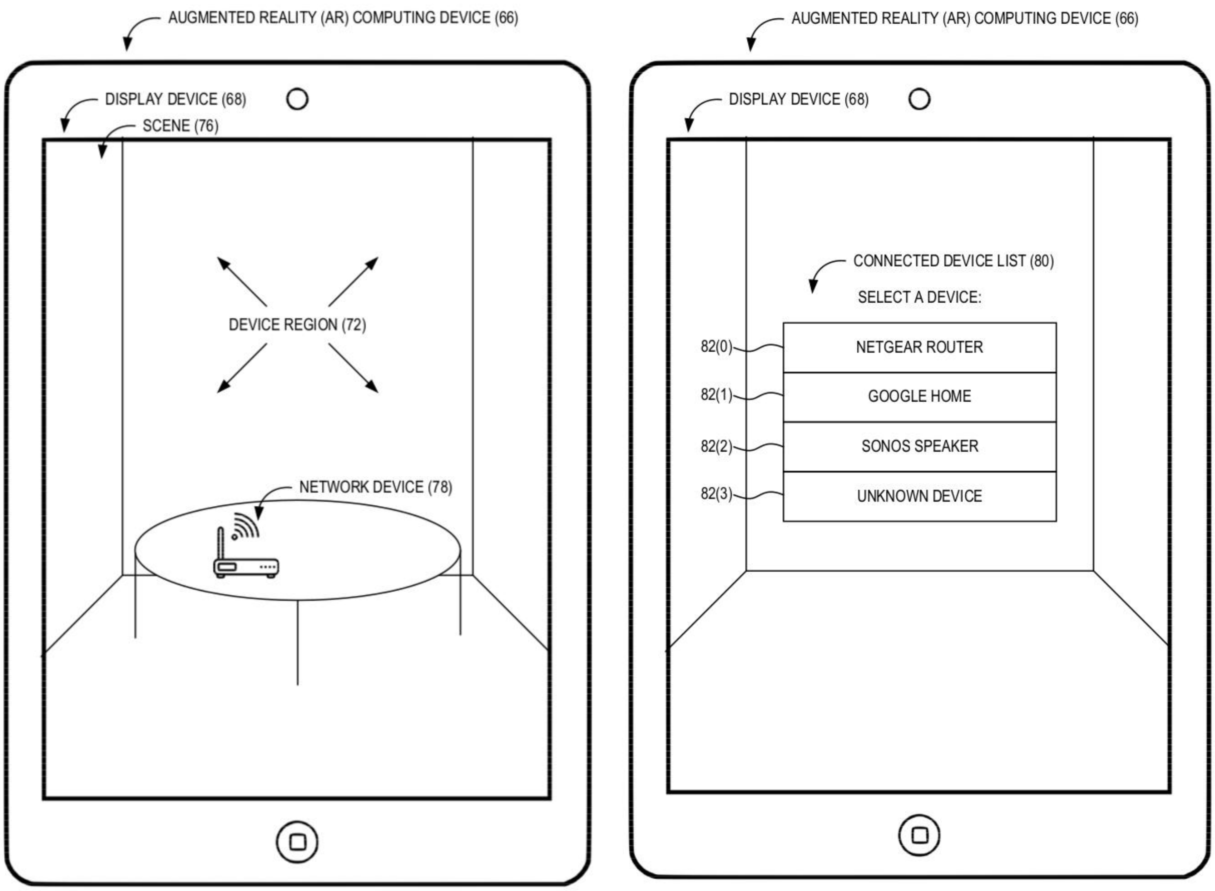

Figure 3 - Viewfinder and device selection

A great benefit of collecting information about the layout of a space and devices within is to enable cloud applications with extensive features. Currently, an application has been developed to consume the input data and render a floor plan for the user and to show their currently connected devices. Many next steps involve the development of new applications using the data, such as an application that would make recommendations for AP placement given the spatial and RSSI variables. Future iterations would also look to expose rules to automation systems like If This Then That or SmartThings in order to provide the ability to interact with their devices based on room or location.

The current working implementation has a lot to expand upon, but even the initial state helps to bring great benefit to the technicians and users. With real data available about the space they are installing APs in, a technician will be able to make a more informed decision about how to design a Wi-Fi system. As the current system doesn't include an engine in the cloud to recommend the location of APs, the technician will follow a process similar to the current process for assessing placement. With the addition of this application technicians will have access to more granular data that maps directly to the criteria they are asked to assess.

3. Setting up effective Wi-Fi

Wi-Fi installation is approached differently based on the environment and requirements. Two approaches of relevancy are enterprise installations and retail installations. Enterprise installations are buildings such as restaurants, office spaces, and hotels. Retail installations are environments such as homes and apartment buildings. The enterprise approach uses an array of tools to gather data about the premises, considers the use cases and number of clients, and utilizes floor plans to add context to the data. In retail installations a technician uses a Wi-Fi meter to map out RSSI in the space and then place an AP if the RSSI falls into the 'weak' category. The first approach considers the shape and size of a space and then allows the engineer to design a system based on the data they have gathered. The second approach uses a very simple system to address poor signal allowing for an easily replicable process.

Enterprise grade Wi-Fi installations start with data collection, often move off site for design and architecture, and then conclude with installation and validation. The engineer will either be provided floorplans, or they will create their own by tracing the building. The engineer moves through the building measuring the radio signals and recording them in relation to their location on the floor plan. This is a slow and manual process as the engineer populates the floor plan with all of the measurements. The engineer will also take notes about potential interference locations such as thick walls, concrete structures, etc.

Once all of the data is compiled it will be correlated with information about the use cases the business will experience. This involves understanding the number of clients that will be interacting with each AP and the manner of those interactions. Radios can support different numbers of clients 'transmitting' and 'receiving' simultaneously. The MIMO configuration allows for fewer or more concurrent clients, and the common radio configurations range from (2x2) MIMO to (8x8) MIMO. In addition to the number of transmitters and receivers, enterprise grade installations need to consider the directionality of the radio. Radios may come as either omni-directional, meaning they cover a 360 degree radius, or directional meaning they cover a longer range in a specific direction. Omni-directional radios are best placed on interior walls and spaced to allow for clients to cleanly be transitioned between APs. Once the engineer has considered all of the measured variables they place their hardware configuration choices onto the floor plan. They return to the site and install the APs based on their architecture documentation. Generally a final sweep is done to verify the design choices and measure the new radio signals.

Retail grade Wi-Fi installations have some shared principles with enterprise, but the process is more rigid and leaves fewer design choices to the technician. In a retail installation a technician is sent to the customer's home where the Wi-Fi connectivity troubles are being experienced. They will then use a meter to conduct Wi-Fi analysis of the premises and then use a guide to determine whether an AP is necessary. Technicians are asked to rank RSSI in four categories ranging from excellent when greater than -50dBm to weak when less than -70dBm. The technician is asked to determine whether network extenders would remedy a poor network, and in the case that they would they are asked to determine the number of extenders and the location. General rules are provided to the technician in the form of a short video during their training. Technicians are asked to consider the square feet of the building and the shape of the building. No firm guidelines are given, however the technician is informed to distance APs twenty to thirty feet apart when through walls, and thirty to fifty feet apart when in an open space. In their training they are told to consider client usage, density of walls, and to be wary of common objects such as mirrors and household appliances.

Common themes are apparent in both enterprise and consumer grade AP installations. In both situations, the data that is gathered is generally not available after the installation has been completed. This means that there is no easy way of knowing the distance between APs and their efficacy after the fact in both enterprise and retail. The real differences in process are the data that is available to the installer and their level of expertise. Creating a uniform and optimized on boarding experience for enterprise and retail involves making sure the same data points are available to the system that is deciding how to design a Wi-Fi space, and creating a standard method for choosing AP locations.

4. Impact of Augmented Reality

In order to optimally place Wi-Fi APs a myriad of data needs to be gathered; The shape and size of the space, RSSI levels at locations within the space, and client use cases are all necessary for effective Wi-Fi design. The augmented reality application asks the user to move through the customer home and move the view over each corner that exists. A user will get within a few feet of the corner and then tap on the corner to record the its location in space. A very similar path needs to be walked to generate a floor plan as is required to sample RSSI. These tools can be combined and provided to the technicians, so they have similar efficacy as enterprise installations. Giving the same tools to technicians that exist in enterprise enriches the data they have access to. Ensuring that the data is stored in a standard way allows the process to get smarter and improved based on past installations.

Augmented reality allows a user to view their environment through a device that overlays relevant metadata into the space. For example, the user is able to point their device at an object, tap on it, and then a virtual tag is added to the object and its location is recorded. The user can visualize all of the recorded tags as virtual stickers they can see when looking through their device at the location.

This interface directions the user to navigate through the space and locate the corners of each room. As corners are identified, a virtual marker is placed over the identified corner and lines are created on the edges. This process gradually builds up a virtual representation of the space the user is navigating through, recording all of the nodes within a relative Cartesian space. These recordings are precise enough to allow for distance and area calculations, meaning that upon completion a record of square footage and shape of the location is fully available as data that can be fed into other systems.

Understanding the physical layout of an environment is critical to effective Wi-Fi design. Measuring the current RSSI helps account for an array of variables that confound proper design, such as interference from appliances and structures. As the user walks through the space to record the relevant corners, they walk a relatively complete path through the environment. As the device moves through the building it's RSSI is recorded by the AP it is connected to. The location measured by the device is correlated to the RSSI recorded by the AP using a synchronized clock allowing the floor plan to be enriched with the data about the radio signals in the space.

In an enterprise system, the architect manually combines the location they take the measurement and RSSI data. They then compare the radio topology with the client use cases, such as number of expected connections. Most modern network installations gather data about what devices are connecting to the network and measure the amount of traffic transmitted and received. These same data points are used by an engineer to decide the proper MIMO configuration for a given space. As the augmented reality application is used to map the environment, network devices may also be identified through image recognition or manual user input. Identified devices may be cross correlated with the devices known to be on the network and then placed into the space. This allows for understanding potential sources of interference, assistance for troubleshooting performance, as well as allowing other applications to integrate with the data. When this data is combined with the data provided by the augmented reality walk, a retail Wi-Fi design may now be as efficient, effective, and fine-tuned as an enterprise installation.

The last variable that differentiates a consumer grade install and an enterprise installation is the knowledge of the installer. The data recorded by the AR application is encapsulated in a standard format and then stored in the cloud. This allows for developers to consume the data after the fact to create models to better advise AP topologies in a space. This removes the potential for human error from the design and allows providers to algorithmically select the variables they would like to optimize for, be it the cost of the hardware or the performance of the Wi-Fi system.

5. Extra Use Cases

The data that can be gathered by an augmented reality device is quite useful for Wi-Fi design and optimization of hardware, but it's use cases extend further. The application provides relative spatial information for the devices on a network, borders for each room, and distances between all devices and APs. This data can be sent to the cloud and added to the other associated information known about a user's home such as the network devices and known users. Applications can be built to utilize this extra set of metadata to either enrich existing features or curate a new feature set.

One such application is Wi-Fi based presence detection. This is a technology that exploits multipath reflections and other data from the Wi-Fi radio to detect movement between two APs. This allows users "peace of mind" security to be notified when there is activity within their home. One element that is missing from this solution is the difficulty in communicating to the user the location of detected motion. An application such as this could hook into the data provided by the augmented reality application to show the user the room or predicted area where movement was detected between two APs. Currently the platform just simply alerts the user of activity on an unidentified link between two APs. Visible in figure 4 is a home layout with configured APs. This layout shows that a movement between two nodes in this design would indicate movement in a specific room. Providing the user with a graphical representation of their space helps to empower the user and give credibility to applications built on top of the technology.

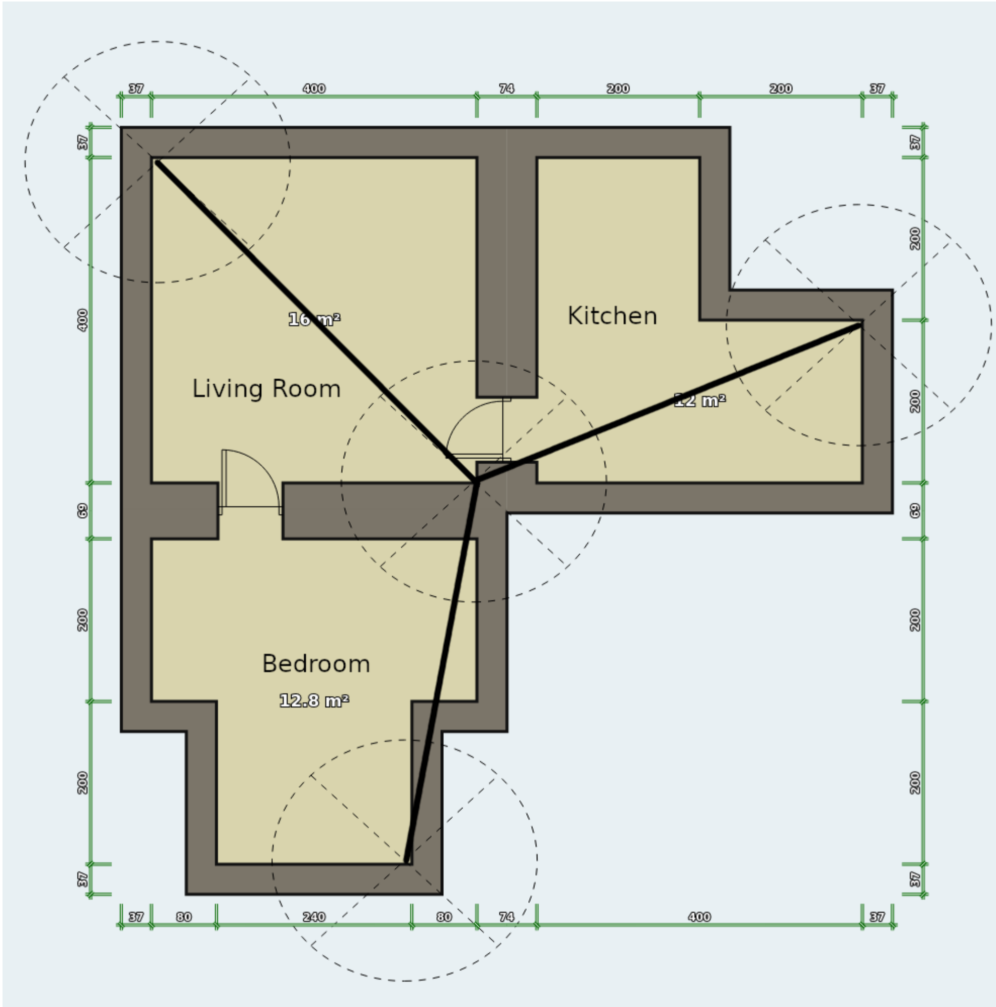

Figure 4 - Presence Detection in home

The Internet of Things (IoT) space can also benefit from the addition of location based metadata to devices and the rooms they exist within. Users are often guided through a cumbersome process of selecting their devices, creating groupings for them, and then naming the groups to indicate where the devices are connected. This is a manual process and is often required to be repeated for every application that contains connected devices. With a service provider able to expose information about what rooms exist in the home and the locations of the devices, IoT applications would be able to automate the forming of groups and creation of rules. IoT applications could now expose rules such as “when a user enters the Living Room, turn on all lights within” and “when movie night is run, dim all lights within ten feet of the television.”

Building metadata about rooms and device location into the dataset for a user is useful for designing a powerful network, yet also provides foundational building blocks for new applications. When enterprise Wi-Fi data is sampled and utilized it’s generally discarded after the topology is designed. Creating a standard system that works in enterprise as well as retail and exposing that data to other applications allows for intelligence to be brought into many feature sets.

6. Conclusion

Wi-Fi design is critical to get right when providing service to any customer base. There is a gap between the highest quality Wi-Fi design in enterprise and the methods used to design systems in a consumer's home. This gap may be overcome when augmented reality is used effectively benefiting both enterprise and retail. Proper use of this data enables cloud systems to learn from previous recommendations and grow in capacity to make placement decisions. New systems can be built to help show the customer their environment, communicate where their devices are, and understand their network on a new level. Instead of a user understanding their network as a list of MAC addresses with current DHCP assignments, the user can gain real world context to what is active and where it exists in their home.

Enriching the data that a service provider associates with devices is key to building smarter networks and a broader feature set. In an effort to achieve this, it's important to standardize the approaches taken to design systems and remove as many variables as possible from the system. Instead of giving a technician a set of rules to attempt to apply to a new location, we can gather the data and allow an engine to build the Wi-Fi system. This approach allows the user to better understand their network, empowers the service provider, and gives the technician access to the same tools used by enterprise Wi-Fi architects.

The tools accessible within a mobile device or tablet have evolved to a high degree, it's important to audit new tools as they are available and assess how they can complement service offerings. The processes described in this paper are immediately and directly expected to enhance the capabilities of technicians. A sufficiently intelligent interface should give an end user similar capabilities as a technician in terms of troubleshooting and designing a Wi-Fi network. An external application may make recommendations for where the APs should be placed. The AR application collects and exports all relevant data for designing a network topology. The requirements for running this application are enough compute power to handle augmented reality and a sophisticated enough camera array. This technology has become standard among consumers in the form of their mobile device or tablet. This means that instead of requiring special technology used by technicians, anyone with a modern device can exercise this approach.

Abbreviations

AP	access point
IoT	Internet of Things
DHCP	Dynamic Host Configuration Protocol
AR	augmented reality