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Automatic Adjustment of Wireless Access Point Settings Based on Client-side RF Measurements

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ABSTRACT

In settings where multiple access points (APs) provide WiFi coverage, the radio frequency (RF) environment experienced by a client device is non-stationary due to various factors such as the emergence and disappearance of hotspots; spectrally uncoordinated APs; the number of clients; the sensitivity of client devices to noise; the mutual distances between clients, RF noise sources, and metallic structures; etc. Since the RF environment experienced by a client device is materially different from that experienced by an AP, attempting to optimize network parameters based on measurements at the AP frequently fails or further degrades WiFi service. This disclosure describes techniques to automatically control and adjust the settings of a network of APs to optimize WiFi coverage and quality based on measurements made by external devices. The measurements include factors such as the RF noise, RSSI, and SNR ratio at locations close to client devices in the WiFi coverage area. Network optimization is carried out based on the measurements, ensuring settings selection in a client-centric, rather than AP-centric, manner.

KEYWORDS

- Wireless access point
- 802.11
- Noise floor
- RF interference
- Received signal strength indicator (RSSI)
- Signal-to-noise ratio (SNR)
- RF environment

BACKGROUND

With WiFi now nearly ubiquitous, a high-quality WiFi connection has come to be expected; indeed, in most work environments, it is essential to complete work tasks. A poor-quality WiFi connection (or no WiFi connection at all) can negatively impact productivity, delay essential work tasks, block certain operations and/or software tools that rely on a WiFi connection, etc.

Multiple access points (APs) are typically used to cover a large area with WiFi. For optimal operation, the network of APs works cohesively, without APs interfering with each other. The design, deployment, and configuration settings of an AP, which include transmit power, operating channel, channel bandwidth, etc., are usually organized based on the physical and radio frequency (RF) environment. However, in many cases, the RF environment in the area covered by the WiFi may change over time due to factors such as local variations in the RF noise floor. Moreover, the RF environment as seen by an AP may be different from the RF environment as seen by a client device.

For example, the RF noise characteristics and levels generated by electronic devices, although compliant with regulatory standards, can change rapidly due to the introduction of new devices and technologies; clients, e.g., smartphones or other mobile devices, used as hotspots occupying WiFi spectrum; transient RF emissions due to external factors; outside-network APs (e.g., controlled by different providers and hence spectrally uncoordinated with network APs); a change in the physical architecture where the APs are housed (e.g., a change in the layout of a warehouse-type environment); the number of client devices; the sensitivity of client devices to noise; the type of WiFi client devices; the software version installed on client devices, the distance between the client devices and the RF noise sources; the introduction of metal structures and/or partitions (which act as RF reflectors); etc. Such changes can significantly affect the quality and the coverage area of the WiFi service.

The aforementioned time-changing factors and variables are uncontrolled; consequently, it can be difficult to reproduce, determine root cause, and debug a WiFi problem reported by a user. Redesign of the AP network can be costly, may present logistical problems, introduce WiFi interruptions, and may be time-consuming. As a result, many WiFi problems go unreported or unfixed until the problems are substantial enough to have significant operational impact.

To alleviate the described problems, some access point vendors have introduced software that tries to optimize the overall WiFi quality by automatically changing AP settings based on the environment in which an AP operates. Such software uses the AP as an RF receiver, measures the RF environment from the perspective and location of the AP, and changes the AP settings to try to improve WiFi coverage and quality. The software does not account for external RF measurements or cause other radio sources to adjust their settings, as there is no view of the client RF environment which can be different from the AP view. The variance between the client and AP views of the RF environment becomes especially problematic in areas where the coverage areas of different APs overlap.

The automated AP setting adjustments introduced by AP vendors may perhaps work adequately in relatively open architectural environments with low RF noise and a relatively small number of APs in the network. However, they fail in situations with a large number of APs placed in complex architectural and physical environments; in situations with multiple metal structures or other RF reflectors; in situations with diminished direct line of sight between APs; in situations with relatively high environmental RF noise in-band with WiFi frequencies; in situations with large numbers of APs (co-channel interference between APs operating in the same channel); in situations with a non-uniform distribution of RF noise sources; etc. In such situations, automated adjustments of the AP settings may actually degrade WiFi quality. In fact, in many cases, technicians disable the automated AP-settings software intended to optimize WiFi coverage and revert to a fixed, manual configuration.

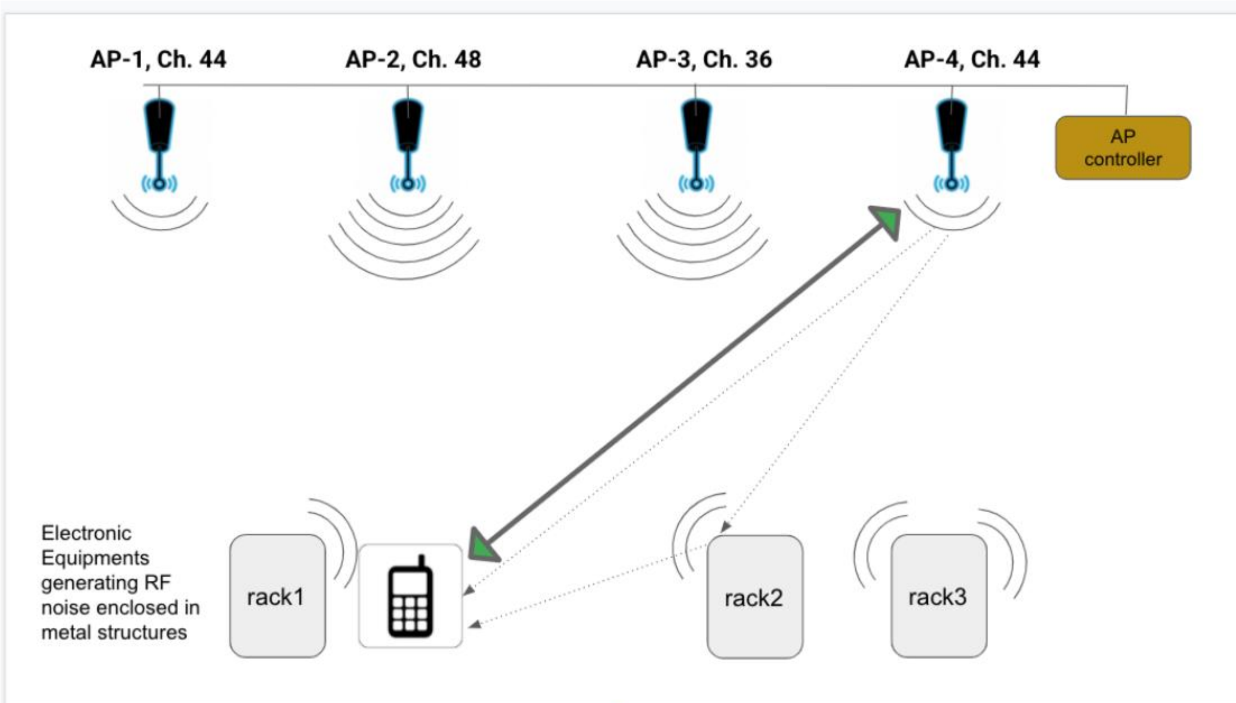


Fig. 1: The RF environment experienced by a client device can be very different from the RF environment measured by an AP

Fig. 1 illustrates an example where the RF environment experienced by a client device, e.g., a mobile device, is very different from the RF environment measured by an AP. Multiple APs (AP-1 through AP-4) cover a data center, operating, as far as possible, on different channels to minimize interference. However, for various technical constraints, e.g., due to a limited number of channels, AP4 and AP1 operate on the same channel (Ch. 44). To minimize interference between AP4 and AP1, the transmit power of these two APs is limited by automated configuration setting procedures running within the APs.

A mobile device is connected to the WiFi network through AP4. If the mobile device is located in an area where the RF noise is low, the WiFi connectivity can be acceptable even if AP4 is transmitting relatively low amounts of power. However, if the mobile device is located close to an RF noise generator, e.g., a rack of electronic equipment, the noise generated by the rack can be substantially higher than the signal transmitted from the AP4. The WiFi signal from AP4 is drowned out and connectivity disrupted.

In the example of Fig. 1, the closest AP (AP1) operates on a channel affected by high RF noise. Once the WiFi connectivity is lost, the mobile device scans (listens on all channels) to regain connectivity. Even if the mobile device can see multiple AP beacons, by virtue of its location, the beacons are impacted by RF noise coming from the closest racks. The mobile device tries to reconnect to AP4 again or to some other nearby AP, but that neighboring AP also operates on a frequency with a high in-band noise floor, potentially resulting in failure of the reconnection attempt.

The main parameters defining the quality of WiFi service are the received signal strength indicator (RSSI) or signal level and the RF background noise level. Good wireless communication becomes possible when the RSSI is higher than the RF noise. The ratio between the RSSI and the RF noise is called signal-to-noise ratio (SNR). APs typically measure parameters such as RSSI and noise floor to derive the SNR at the *location of the AP*. However, client devices are typically located away from the APs, and RF measurements taken at the AP are unrepresentative of conditions at the client. The exponential decay of RF fields with distance practically ensures a complete decorrelation of RF conditions at the client and the AP. Consequently, software that adapts AP configuration based on measurements taken at the AP can generate suboptimal, inadequate, or counter-productive settings for the client devices, resulting in degradation of WiFi service. In this context, note that most client devices (e.g., smartphones, laptops, etc.) do not communicate to APs their received SNR and RF noise because their WiFi chipsets can only measure received power in the channel and lack the capability of distinguishing WiFi signals from unwanted RF noise.

Some example scenarios when automated configurations-settings software can produce suboptimal, inadequate, or counterproductive results include:

- Large areas covered by multiple relatively closely spaced APs, including APs controlled by different providers, e.g., warehouses, commercial centers, data centers, airports, hotel lobbies, etc. Different APs operating on the same channel interfere with each other. Automated configuration software tries to assign different channels to APs operating in close proximity. However, the number of available channels is limited, and, if a large area needs to be covered, some sharing of channels between APs becomes inevitable or at least more probable. In this case, the transmit power of the APs may be reduced to a level compatible with the coexistence of different APs working on the same channel, which, however, creates WiFi dead spots and low RSSI for clients.
- Relatively high in-band RF noise, e.g., areas with multiple WiFi services controlled by different providers and devices that can interfere (e.g., video cameras, microwave ovens, etc.); data centers; industrial environments; locations close to airports or military bases; etc. Automated configuration software tries to move WiFi communications to channels where there is less RF noise. This may increase the coexistence problem (co-channel interference) between APs operating on the same limited number of channels. Furthermore, configuration-setting software may not include noise sources as inputs and may end up choosing other channels with large amounts of noise or interference. The

software may try to increase transmit power to increase the SNR and overcome RF noise. This may exacerbate coexistence problems between APs. Also, as clients receive signals of increasing strength from different APs, roaming (frequent switching between APs) and connection (clients unable to process signals from different APs) problems arise.

- RF noise can occur close to the clients but relatively far away from the APs, e.g., in data centers, industrial environments, regions with a high density of client hotspots, etc. Since APs lack information about the RF noise received by the clients, the AP transmits at a suboptimal power level, and the RSSI (e.g., SNR) received by the client is insufficient, manifesting as WiFi dead spots or low-quality WiFi.
- Presence of large metallic structures close to the client devices, e.g., in data centers, warehouses, commercial buildings, etc. Metallic structures act as RF reflectors and exacerbate the discrepancies between RF measurements at the AP location and at the client location. Metallic structures may also propagate WiFi signals from one AP to many other distant APs, leading to suboptimal transmit power and channel selection settings at the APs. WiFi dead spots and roaming problems result.

Generally, not accounting at the AP for signal conditions (e.g., RSSI, RF noise, SNR) experienced by the client device makes automated configuration settings (or adjustments) at the AP suboptimal, inadequate, or counterproductive.

DESCRIPTION

This disclosure describes techniques to automatically control and adjust the settings of a network of APs to optimize WiFi coverage and quality. The adjustments are based on measurements made by external devices of the RF noise, RSSI, and/or SNR ratio at locations close to clients in the WiFi coverage area.

The external devices that make the RF measurements can be dedicated APs used as receivers, RF receivers, WiFi cards, or other devices capable of measuring RF noise in WiFi spectra of interest (2.4 GHz, 5 GHz, 6 GHz, etc.). The external measuring devices can be connected to RF equipment to ensure sufficient dynamic range and sensitivity. For example, a pre-amplifier and a band-pass filter can be connected to an AP used as a receiver to measure the RF noise in the WiFi band. Software tools can separate transient WiFi signals from the background broadband noise generated by other devices. The measuring devices can be stationary or mounted on automated guided vehicles (AGVs) to scan the entire WiFi-covered area. RF equipment mounted on AGVs collect RF data and location information to create WiFi heat maps; verify WiFi coverage; measure RSSI signals and RF noise levels; detect possible malfunctions of APs; etc.

The collected data is streamed to computational modules that determine the root cause of potential WiFi problems (low RSSI, high level of RF noise, roaming problems, etc.); adjust the AP settings to overcome the problems; and, to close the loop, send the AGV to verify that the new AP settings have fixed the problems and/or the WiFi quality is as expected. Thus, the AP settings are adjusted based on RF measurements *at client locations*, not AP locations. APs receive active feedback from the measuring devices in multiple locations of the WiFi covered area to optimize the WiFi signal and quality. This is in contrast to existing automated AP procedures, which do not have any feedback to verify the effect of the new settings.

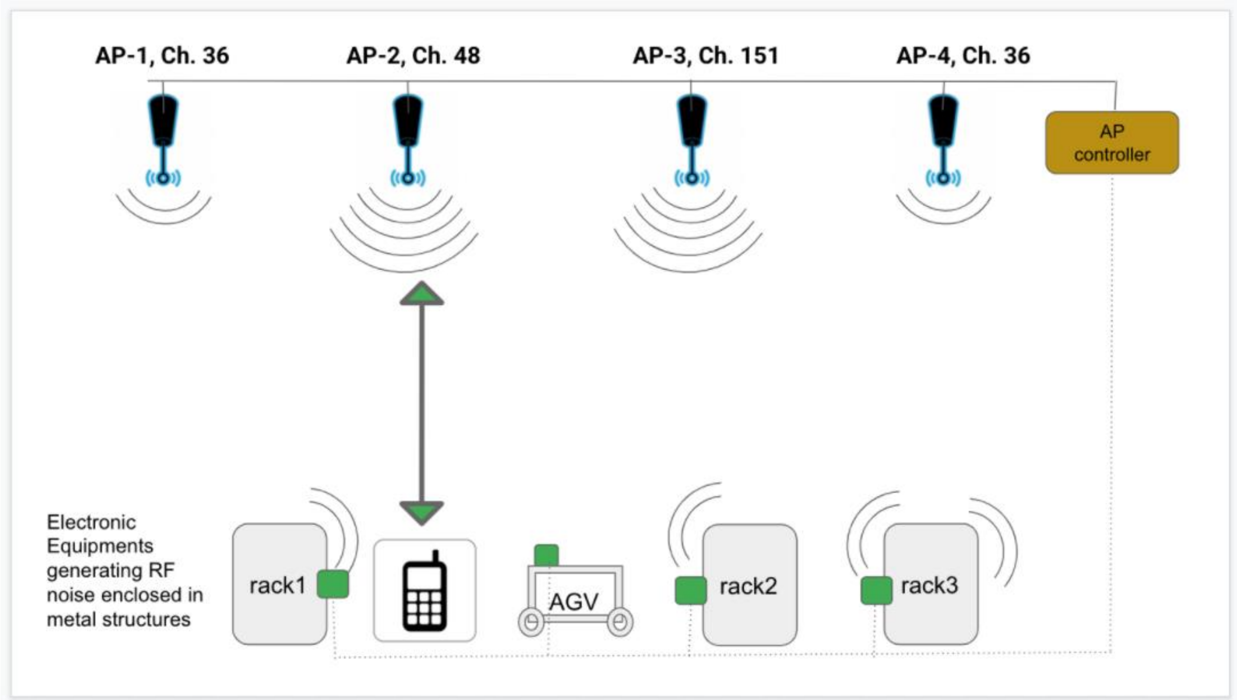


Fig. 2: AP settings are adjusted based on the RF environment experienced by client devices

Fig. 2 illustrates adjustment of the settings of an AP based on the RF environment experienced by client devices. The data center floor in the example of Fig. 2 is equipped with external devices (green boxes). The external devices capable of measuring the RF noise and WiFi signals act as WiFi clients positioned in fixed locations, or, alternatively, they are mounted on automated guided vehicles (AGVs), placed on carts, or implemented in the WiFi cards of the client devices. The external devices measure the RF noise generated by nearby racks of electronic equipment. The RF measurements from these devices are analyzed to adjust and optimize the RF configuration, e.g., channel, transmit power (effective isotropic radiated power, or EIRP), channel bandwidth, etc. of APs in a predefined RF zone, e.g., a building or a floor in a building.

Basing the RF configuration of the APs on measurements obtained from external devices ensures a sufficient SNR for client devices while minimizing the possibility of co-interference with other APs. The external devices can also verify that the wireless connectivity has been optimized by the new AP settings. The advantage of having external RF-measuring devices is that they feed into an AP channel-selection procedure the RF noise and RSSI levels as seen by the client devices, e.g., in locations in close proximity to the area of operations. AP settings are thereby optimized for the wireless clients, not for the APs. Effectively, noise sources are identified, and their effects mitigated.

Example use case: Data center

In a data center, electronic modules in the aisle are close to the WiFi clients, which operate near the data center floor, far away from the APs, typically located on the ceiling or above the aisles. Aside from a high noise RF environment, WiFi clients in a data center also operate in the presence of large metallic structures, e.g., machine racks, cooling structures, metallic partitions between aisles, etc.

A data center floor is typically covered by multiple APs, which therefore have a substantial chance of interfering with each other if the channel selection and the transmit power are not carefully selected. A data center thus represents a difficult WiFi environment, e.g., one where AP settings adjustment based solely on AP measurements is likely to fail, and even further degrade service quality. WiFi issues, even once reported, can be difficult to reproduce and fix due to the non-stationarity of the RF environment in a data center. WiFi coverage and noise measurements are time consuming and logistically complex tasks since specialized equipment and engineers may have to travel to the data center locations. Similar issues may also be present in warehouses, offices, and other settings where multiple APs increase co-channel interference.

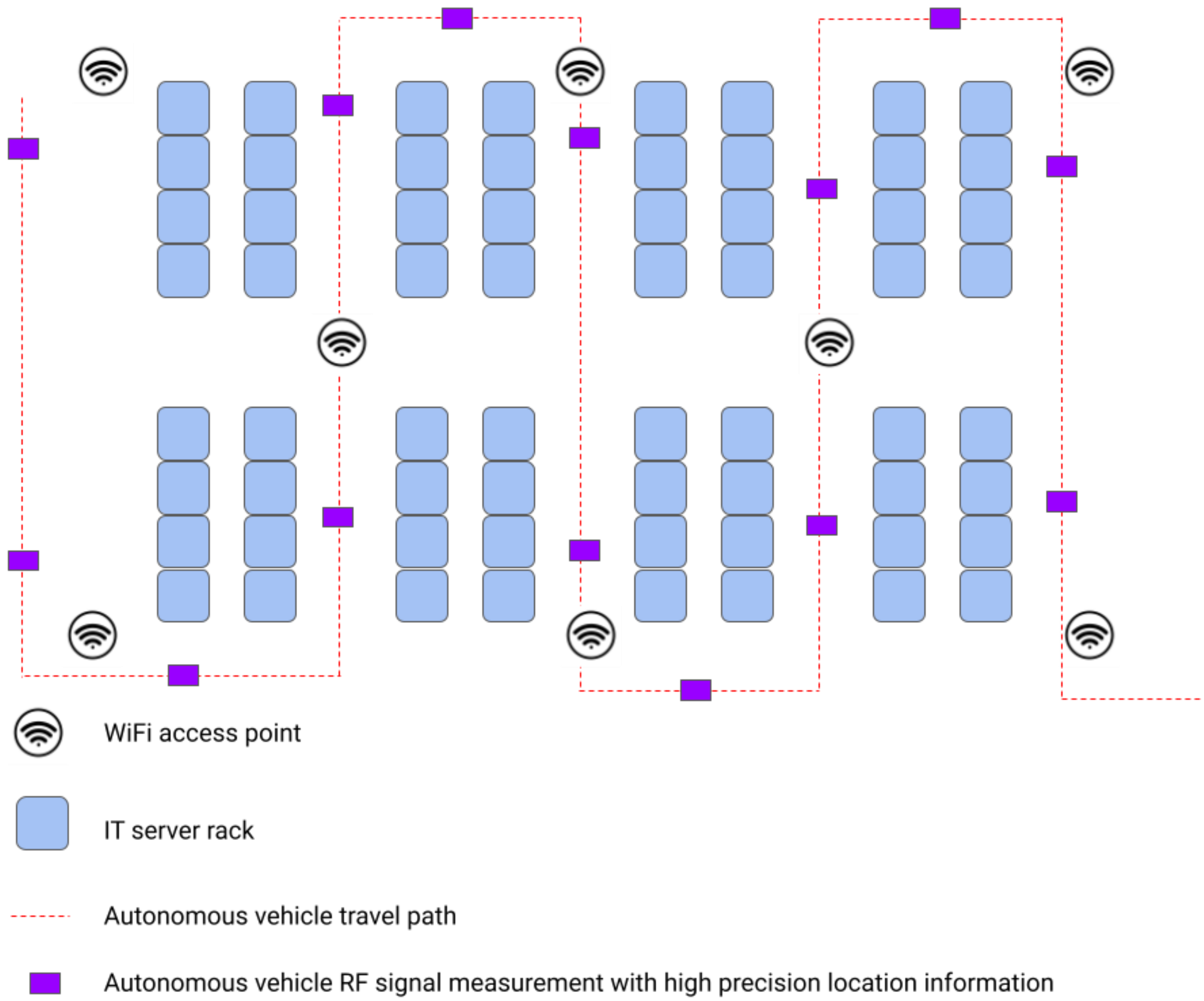
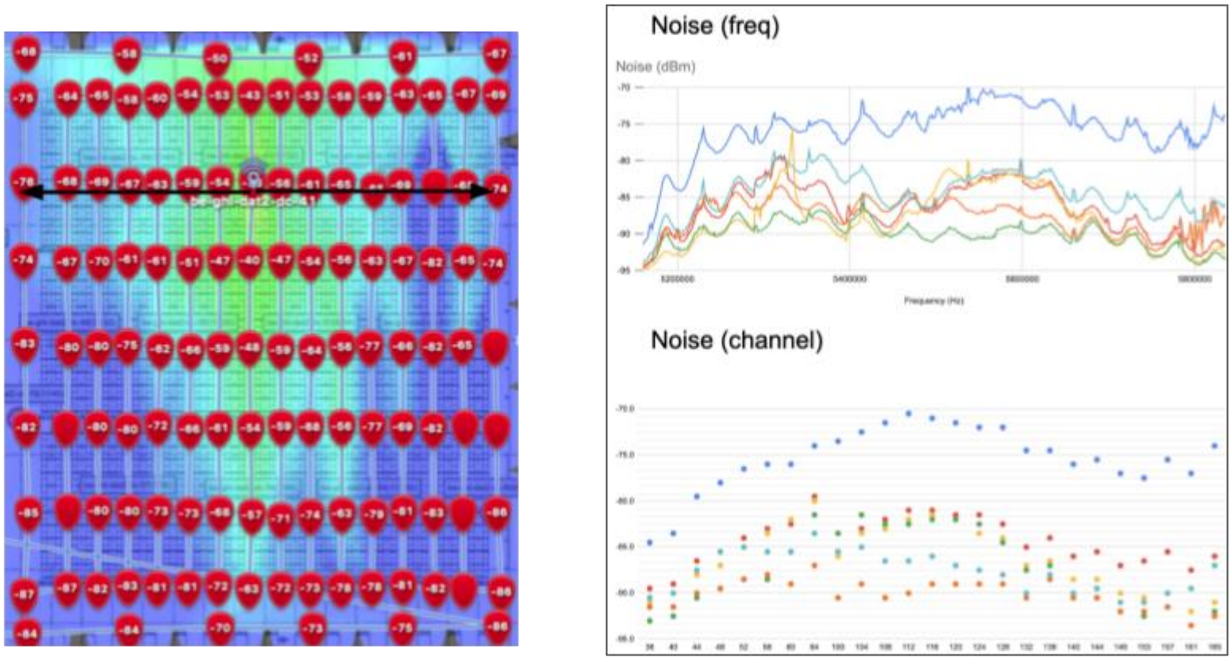


Fig. 3

Per the techniques described herein, a network of relatively cheap external RF devices collect data as seen by WiFi clients and drive the AP configuration to improve WiFi reliability, coverage, and speed. As illustrated in Fig. 3, autonomous vehicles roam the data center measuring and mapping the RF environment to location, to generate RF data (such as the heat map of RSSI (Fig. 4a) or noise power spectral density (Fig. 4b) as seen by WiFi clients.



(a) **(b)**

Fig. 4: (a) A heat map of WiFi signal quality across a coverage area (blue represents low signal quality; green represents high signal quality. Numbers in red location markers indicate RSSI in dBm; (b) Noise power spectral density at a particular location

With real-time data, e.g., as illustrated in Fig. 4, a determination can be made of the SNR of WiFi channels at particular client locations. Configurations of APs throughout the network can be optimized in a client-centric manner. WiFi network quality is optimized without physically changing the APs, e.g., their locations or number, and without costly and time-consuming RF surveys such as the ones conducted before and after a significant AP network rework.

The described techniques can detect and prevent WiFi coverage and quality issues before they are experienced by the wireless clients and guarantee good quality of WiFi service even during transient RF noise events such as RF noise coming from intentional or unintentional radiators not considered during the design of the wireless network such as a new machine deployed in the data center that may have more-than-expected emissions under a specific load or hardware combination.

Additionally, the techniques can be used to design wireless client devices (laptops, phones, tablets, etc.) and compatible APs such that they can communicate and exchange data in order to improve the WiFi experience. Wireless client network cards can be designed to integrate the wireless capabilities necessary to communicate the RF noise data to the APs. Such RF-environment data originating from wireless clients can be used to optimize the AP network based on the client and the RF noise as seen by the clients.

CONCLUSION

This disclosure describes techniques to automatically control and adjust the settings of a network of APs to optimize WiFi coverage and quality based on measurements made by external devices. The measurements include factors such as the RF noise, RSSI, and SNR ratio at locations close to client devices in the WiFi coverage area. Network optimization is carried out based on the measurements, ensuring settings selection in a client-centric, rather than AP-centric, manner.