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# Generating a Map of Wireless Signal Quality Using Autonomous Vehicles

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ABSTRACT

Radio-frequency noise generated by equipment in the server halls of data centers can degrade WiFi access within the data center, thereby hampering the ability of personnel to complete their tasks. An up-to-date, detailed, and accurate heatmap of WiFi signal quality enables planners to plan WiFi coverage within server halls. This disclosure describes techniques to generate a heatmap of WiFi signals and electromagnetic noise in closed spaces such as warehouses, server halls of data centers, etc. using autonomous vehicles. The techniques enable the continuous and accurate automated collection of data pertaining to the evolving WiFi environment within the server hall.

KEYWORDS

- WiFi heatmap
- Data center
- Server hall
- Radio-frequency noise
- Electromagnetic noise
- Autonomous vehicle
- Automatic guided vehicle

## BACKGROUND

Data center server halls are designed with wireless networks to provide personnel working in the data center with access to the tools and services needed for their tasks. The information technology (IT) equipment in a server hall generates high levels of electromagnetic (radio frequency) noise that can interfere with WiFi access. Further, WiFi signal quality can degrade if new IT equipment is added to the server hall. Electromagnetic noise in a data center is dependent on the load profile of the IT equipment and hence exhibits short-term variability with time. An up-to-date, detailed, and accurate heatmap of WiFi signal quality, e.g., received signal strength, electromagnetic noise levels, etc., enables planners to plan WiFi coverage within server halls, e.g., the locations of access points, the spectral band-combinations of the access points, etc.

Existing WiFi signal analysis tools require a user to trace a specified route through a server hall to create a snapshot of WiFi coverage. When the environment changes the user must retrace the original route in order to record changes in the signal-quality map. Besides being cumbersome, the retracing of a route by a human operator is subject to imprecision. Current procedures for recording the signal-quality map are tedious and manual and, by virtue of their need for human operators, imprecise and error-prone.

DESCRIPTION

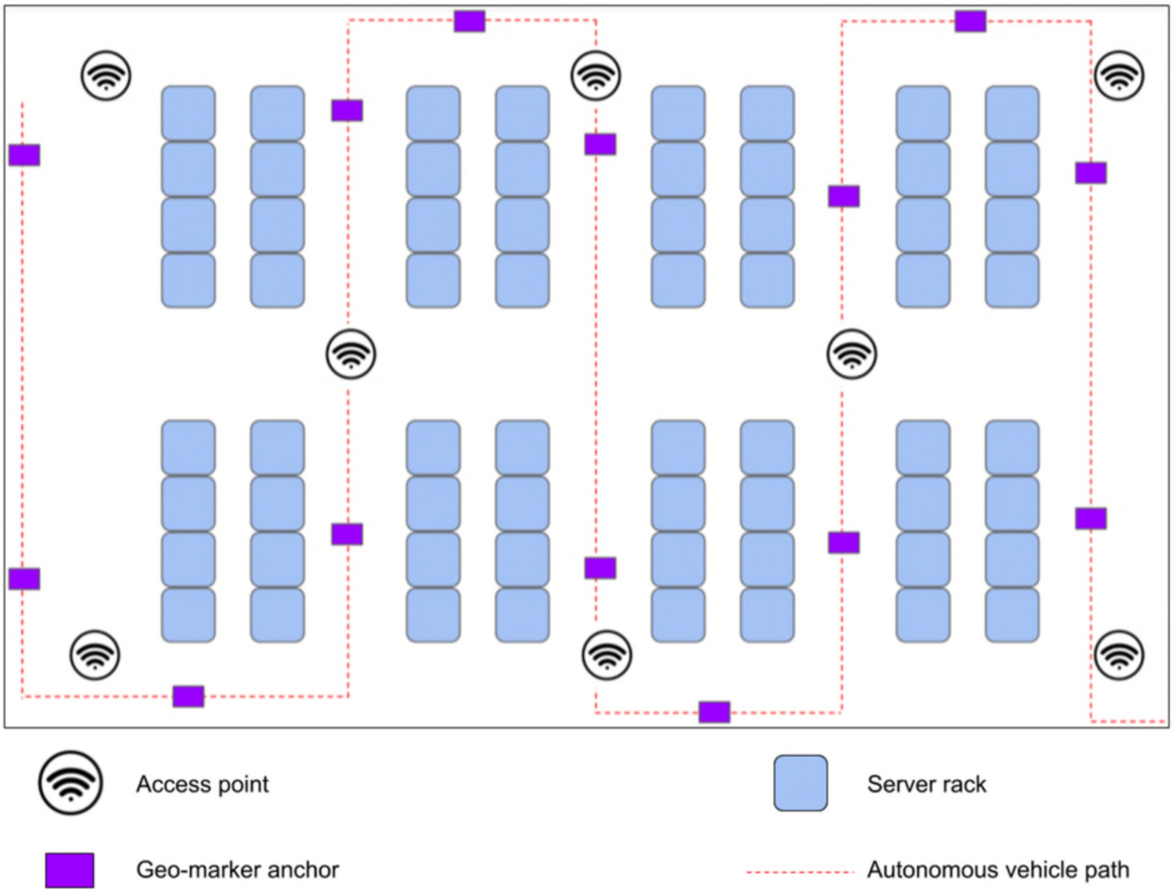


**Fig. 1: Mapping wireless signal quality with autonomous vehicles**

This disclosure describes techniques to generate a heatmap of wireless, e.g., WiFi, signals and electromagnetic noise in closed spaces such as warehouses, server halls of data centers, etc. using autonomous vehicles or automated guided vehicles (AV). Per the techniques, an autonomous vehicle is equipped with a local positioning system, a radio-frequency (RF) power meter, a signal-strength meter, a spectral analyzer, an inertial measurement unit (IMU), etc. As illustrated in Fig. 1, the AV travels through a server hall or other indoor space and collects data pertaining to electromagnetic noise and WiFi signal quality, and associates such data with the location and time of data capture.

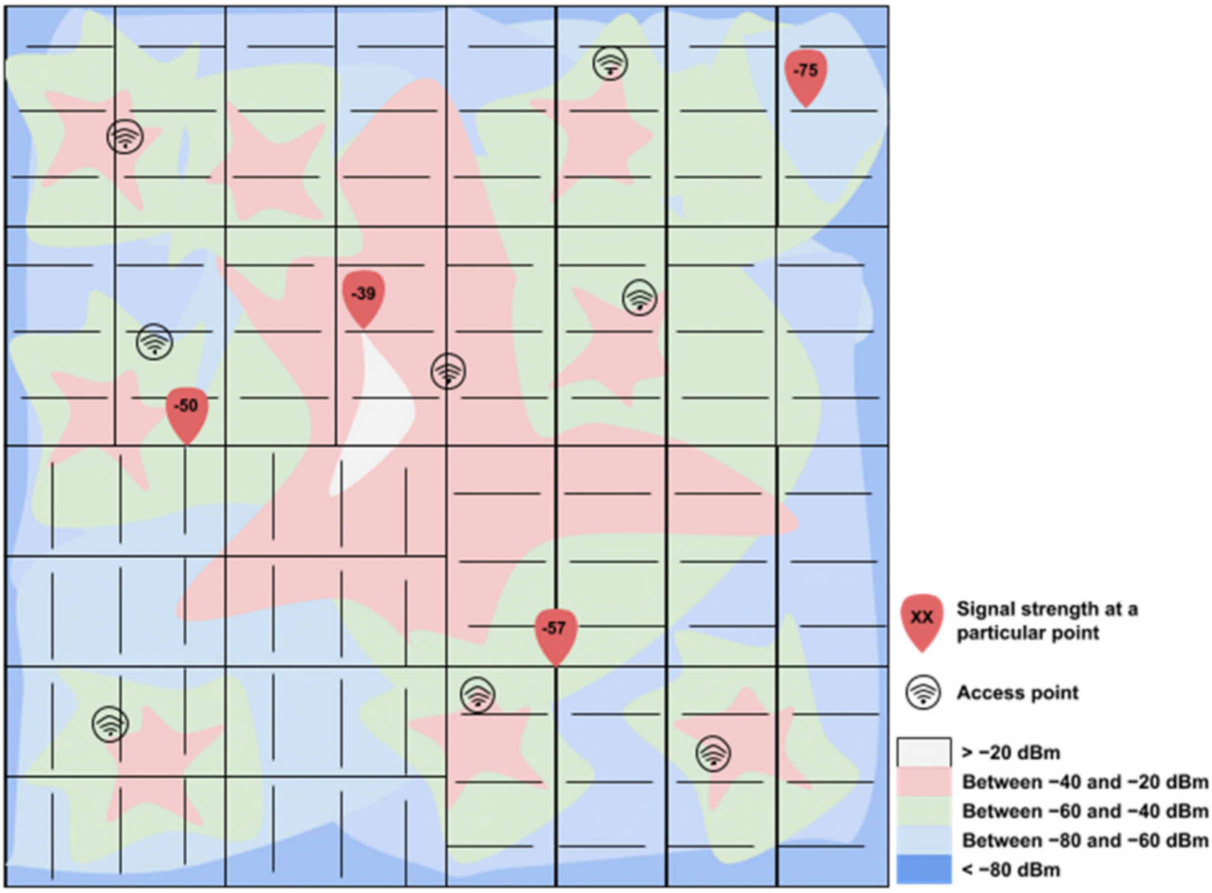


**Fig. 2: An example heatmap of wireless signal strength**

Fig. 2 illustrates an example WiFi heatmap for a server hall generated by collating data generated by the autonomous vehicle.

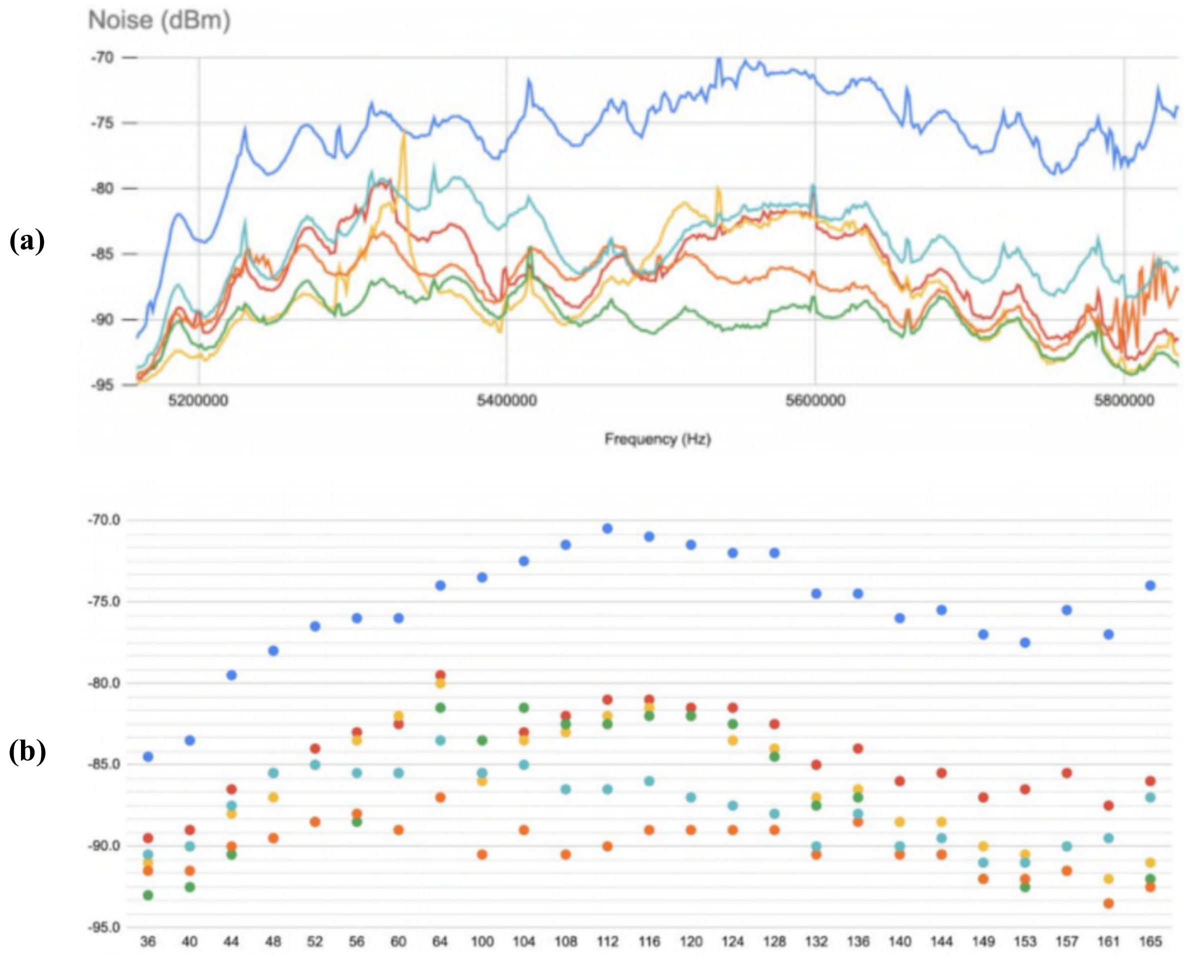


**Fig. 3: Signal or noise measurements at a particular location: (a) Noise versus frequency (noise power spectral density); (b) Noise power versus WiFi channel number**

Signal and/or noise measurements can be examined in detail at a particular location. Fig. 3 illustrates such an example measurement at particular locations. Fig. 3(a) illustrates the noise power spectral densities (noise power versus frequency) at various locations indicated by the colors blue, red, green, etc. Fig. 3(b) illustrates the noise power versus WiFi channel number at various locations indicated by the colors blue, red, green, etc.

The AV can position itself using geo-markers, which are anchors with positions known to high accuracy. When the AV passes a geo-marker, it scans the geo-marker to update its position. Between geo-markers, the AV determines its position using deduced reckoning, simultaneous localization and mapping (SLAM), or other techniques based on accelerometer, gyroscope, and other inertial measurement unit (IMU) data. Other examples of local positioning techniques include indoor GPS, techniques based on computer vision, etc.

The use of AVs enables continuous (or periodic) and accurate automated collection of data pertaining to the evolving WiFi environment within the server hall, even as the IT equipment in the server hall changes with time. The collection of WiFi data can be an additional activity performed using AVs that rove through the hall for other scheduled activities. AVs are particularly suited for WiFi heatmap generation because they can precisely and repeatedly trace predictable routes; can self-determine their location with sub-centimeter accuracy; and can be outfitted with equipment and software needed to measure intentional and unintentional RF signals.

## CONCLUSION

This disclosure describes techniques to automatically generate a heatmap of WiFi signals and electromagnetic noise in closed spaces such as warehouses, server halls of data centers, etc. using autonomous vehicles. The techniques enable continuous and accurate automated collection of data pertaining to the evolving WiFi environment within the server hall.