WHITE PAPER

Tips for Deploying Wireless Networks for AS/RS and AGV Systems

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Abstract

Modern factories are increasingly deploying AS/RS and AGV systems in their facilities worldwide to optimize production efficiency and reliability. This has led to an increase in industrial traffic on factory floors and within their facilities. To be able to monitor and control the AS/RS and AGV systems, as well as other moving equipment, the control centers in these factories need uninterrupted connectivity with the equipment and vehicles. Therefore, it is essential to build a wireless network that is not only stable but also optimized for the high deployment density and high-speed operations of the industrial vehicles in factories. Consequently, factory owners face the challenge of building a wireless communication system that can provide reliable wireless connectivity with sufficient coverage and which can be managed with minimal effort. In this white paper, we discuss some key tips for deploying a wireless network for AS/RS and AGV systems.

This document is meant to give you some general guidelines for deploying wireless connectivity for AS/RS and AGV systems. However, this document should not be used as a replacement for professional consultation, because each factory floor is different in its design and can present its own unique challenges. Nevertheless, here are some tips to address some common challenges. We highly recommend that you have wireless system professionals assist you with system integration, whether it is for AGV machines that you are building or for your factory.

Selecting the Right Wireless Technology

In order to perform their tasks efficiently, automated material handling (AMH) systems, such as AS/RS and AGV, need the flexibility to move around on their designated paths in a factory without obstruction while maintaining constant communication with the control center through a wireless network. Additionally, the control center needs a reliable wireless network to monitor and control the AS/RS and AGV systems, as well as sufficient bandwidth to send data and instructions to the systems and receive data without delay, including live video recordings from the IP cameras installed in these systems. How do we choose a wireless technology that is a best fit for AS/RS and AGV systems?

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Moxa is a leading provider of edge connectivity, industrial networking, and network infrastructure solutions for enabling connectivity for the Industrial Internet of Things. With over 30 years of industry experience, Moxa has connected more than 50 million devices worldwide and has a distribution and service network that reaches customers in more than 70 countries. Moxa delivers lasting business value by empowering industry with reliable networks and sincere service for industrial communications infrastructures. Information about Moxa's solutions is available at www.moxa.com.

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The table below provides a comparison of the wireless technologies available today:

Wireless Technology	WPAN	WLAN	WWAN
Range	< 100 m	> 100 m	> 10 km
Speed	High	Higher	Medium
Cost	Medium	Medium	High
Deployment complexity	Low	Medium	Low
Spectrum usage	2.4 GHz	2.4 GHz and 5 GHz	800 MHz, 900 MHz, 1800 MHz, and 2.1 GHz
Mobility	Poor	Good	Good

A quick look at the table, without considering the operating environment, indicates that WLAN technology should be an ideal choice for AS/RS and AGV systems for the following reasons:

In a typical warehouse setup, the aisles can be spread over a few hundred meters with the mobile vehicles moving rapidly on these paths to retrieve or store goods. In this scenario, WPAN technology will not be able to provide sufficient range and has the drawback of interference due to its inflexibility in spectrum usage (can only use 2.4 GHz). WWAN provides a far better range, but the operation costs are too high as each wireless node will require a subscription, leading to costs accumulating over time.

The Challenges with WLAN

WLAN technology could pose some challenges to building a reliable communication infrastructure on a factory floor when it is used to bridge the link controlling the AS/RS and AGV systems.

The key challenges include:

1. Planning and deploying the wireless solution
2. Optimizing communication reliability for mobile applications running continuously
3. Dealing with harsh environmental conditions

Proper consideration of the above challenges will save you a lot of troubleshooting headaches in the future when your AS/RS or AGV systems are in operation.

1. Plan Before You Deploy Your Wireless Solution

Before you start installing access points in your facility, you must carefully plan the wireless network that you want to build. Many times, people make the mistake of installing without planning, only to realize that the equipment is wrongly deployed. Some of the common issues seen in an unplanned network include access points (APs) not placed at the right locations to provide sufficient coverage, the wrong antenna type used, and channel interference issues not mitigated properly. As the wireless medium is invisible and operates over a frequency spectrum, it is crucial that proper analysis of the radio frequency spectrum is done to ensure that the wireless communication takes place over a relatively clean environment with sufficient

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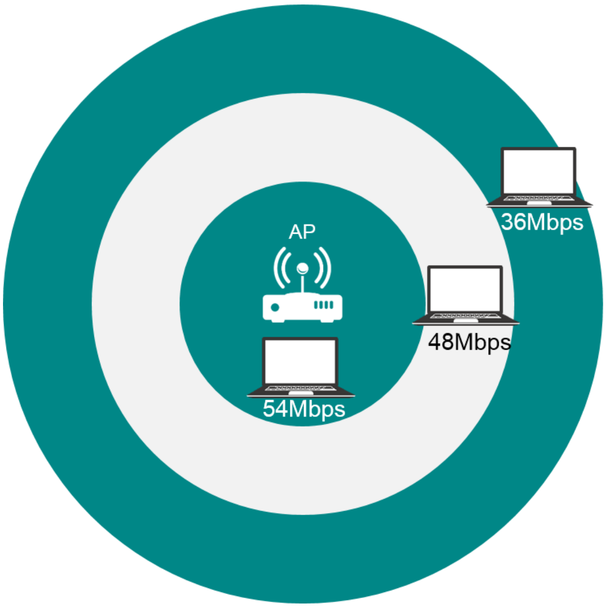
signal coverage. Some key network parameters that need to be considered in your network plan include:

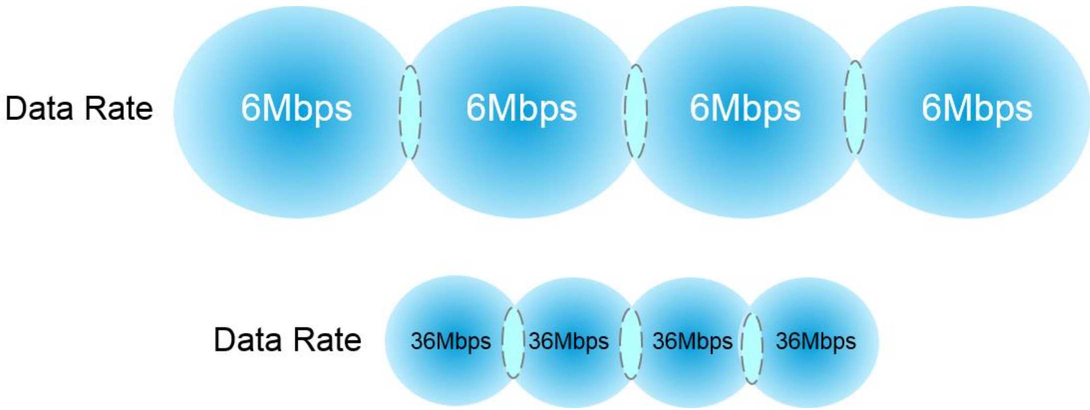
A. Data Rate / Coverage/Maximum Clients per AP

Evaluating the data rate and coverage required for your application is the first step in setting up a good Wi-Fi network. For example, the data rates supported in 802.11g networks are in the range 6 to 54 Mbps. If the data coverage circle of an AP is smaller, a client device that connects to the AP will benefit from a higher data rate. However, it is difficult to implement a specific data coverage circle for different data rates because the values may vary. Depending on the transmitter power (e.g., 1 to 17 dBm in APs with 2.4 GHz) in APs and the actual dB loss value on-site, wireless clients will receive different signal strength, which in turn will determine the data rate.



IEEE 802.1g Typical Data Rate (Mbps)
6
9
12
18
24
36
48
54

Since a set of network parameters may give different results in different environments, overlapping the network coverage areas (circles) so that each coverage circle overlaps with the previous one at a certain ratio can help keep clients, installed on moving equipment, connected at all times. Restricting the maximum number of clients that can connect per AP also helps maintain stable connections.



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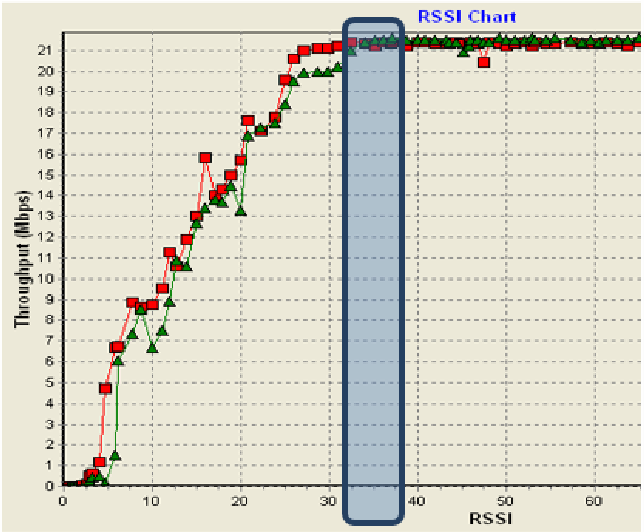
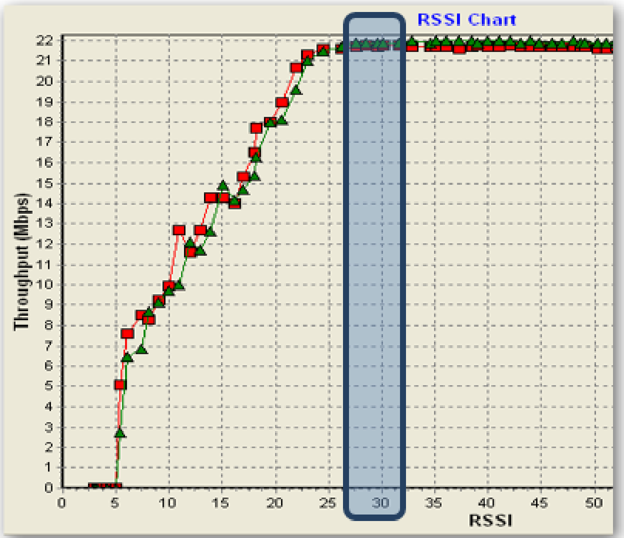
B. Throughput vs. RSSI

Throughput is related to Signal-to-noise ratio (abbreviated SNR or S/N), which is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels. The SNR of an access point is a measurement of how well your device can hear a signal from an access point. It's a value that is useful for determining if there are enough signals to get a good wireless connection. Therefore, if you define the coverage threshold in your cell too low, you will get low throughput while your client is disconnecting from an AP and connecting to the next AP. Typically, AGV & AS/RS application data could be around 1 Mbps. Thus it is not difficult for access points to support this bandwidth/throughput. However, in some extreme cases, for example when IP cameras are installed on AGVs for viewing the field site to avoid accidents, the SNR needs to be maintained at a certain level to keep the throughput above a certain bandwidth. As shown in the graph below, in general, the maximum data rate in 802.11a or 802.11g devices is 54 Mbps. Even though, theoretically, the throughput is around half the date rate, our tests show that the real throughput is lower than half the data rate. The throughput gets saturated in the range 21 to 22 Mbps at RSSI= 35 (802.11b/g mode) or RSSI=30 (802.11a mode)*. Therefore, you could define Wi-Fi coverage using the edge value of a cell. For example, if you want to maintain 16 Mbps in the 802.1b/g mode, the edge of one cell should be over SNR=20.



Roaming



Roaming

*This test result is just for your reference and is based on tests conducted using Moxa's Industrial Wireless Access Point AWK-3121/4121/5222/6222 Series.

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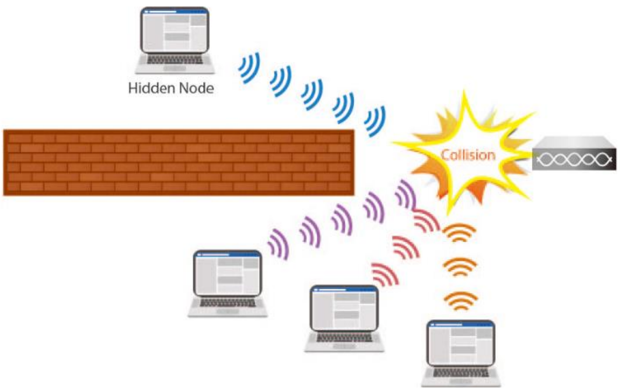
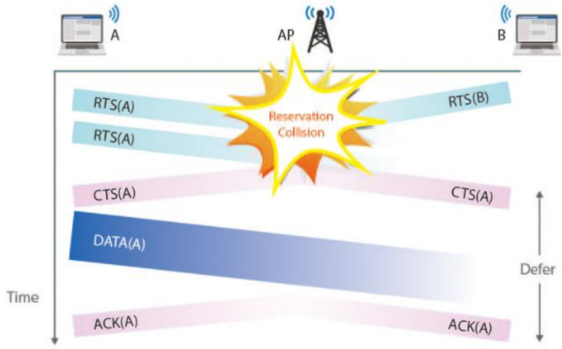
C. Tackling the Hidden Node Issue

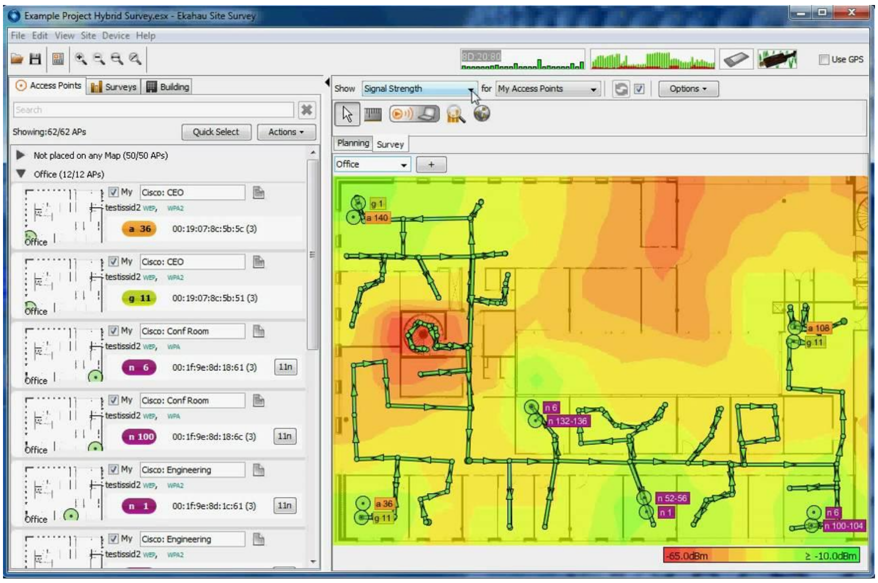
Even when the Wi-Fi coverage is good and the RF signal is strong, you may not get good throughput. Physical obstacles, such as walls, in your factory may be preventing some APs and client from "hearing" each other, leading to collision of Wi-Fi signals. The RTS/CTS exchange mechanism can be used to avoid collision between the AP and client signals.





Using Network Planning Tools

Many tools are available that can perform such planning and analysis (also known as site survey). A popular Wi-Fi planning and site survey software is Ekahau (https://www.ekahau.com/). Tools such as Ekahau can help you reduce the time needed for the Wi-Fi design cycle and provide more accurate simulation. The tool uses information, such as the floor plan of the factory, obstacles on the floor, frequency of use, and the type of wireless devices, to simulate a network model. You can use this model to generate heat maps for radio coverage and use them to determine where the APs should be placed to optimize coverage.



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2. Validate Your Network Plan

Once the planning is done, the next step is to use wireless equipment to validate the design. Start with a small area and test your network plan. You can use wireless sniffer tools within the area to trace various Wi-Fi spots to map out the actual profile of the radio coverage. More often than not, you will need to fine-tune the network design after an on-site survey. Another critical component to optimize the radio coverage is the antenna. Selecting the right antenna, as well as installing it with the right mounting angle, is the key to ensure that there are no blind spots in the path of the moving vehicles to ensure minimum communication breaks.

3. Deploy Antennas Correctly

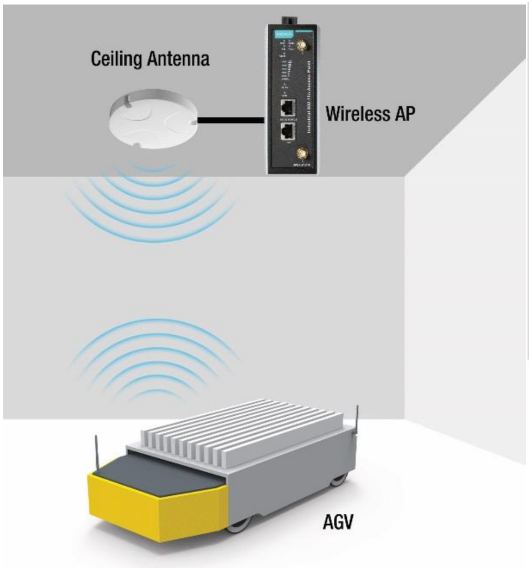
Selecting the right antenna type for the APs and the clients installed on moving vehicles, such as an AGV, is a key factor in building stable Wi-Fi networks.

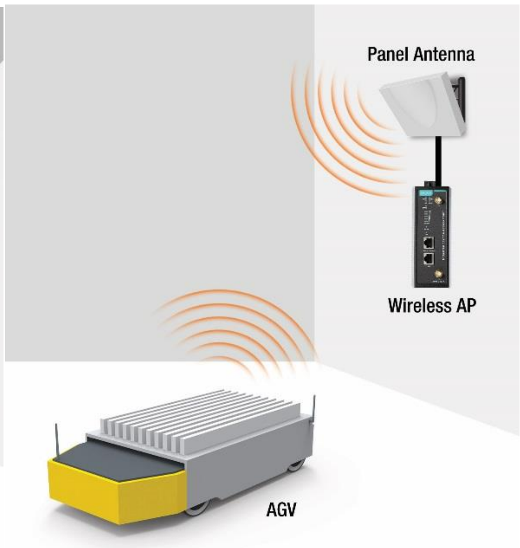
First, let us discuss the considerations for selecting the antennas for APs. It is not always possible to change the type or orientation of the antennas of APs that are already part of the existing network. But when you install new devices and antennas, it is important that you leverage different types of antenna for different areas in your factory. The main principle to be followed when installing antennas, be it for a rack structure or moving path/direction of the vehicle, is to provide adequate coverage to ensure reliable communication so that the radiation planes of the transmitting and receiving antennas overlap at all times.

Here are some examples:

a. An open space with AGVs operating on floor level

In this case, the AGVs are moving on a horizontal plane where other machinery can become potential obstacles blocking the radio signal. A ceiling-mount antenna is the ideal choice to provide the coverage needed. The ceiling-mount antenna has a downward omni-directional radiation pattern that can provide a wide coverage from the top. Since the coverage is from the top, it is unlikely to be blocked by obstacles at the floor level. If it is not possible to mount antennas on the ceiling, an alternative is to use panel antennas with a wider radiation angle (> 30 degrees), tilted slightly downwards to maximize the coverage area.





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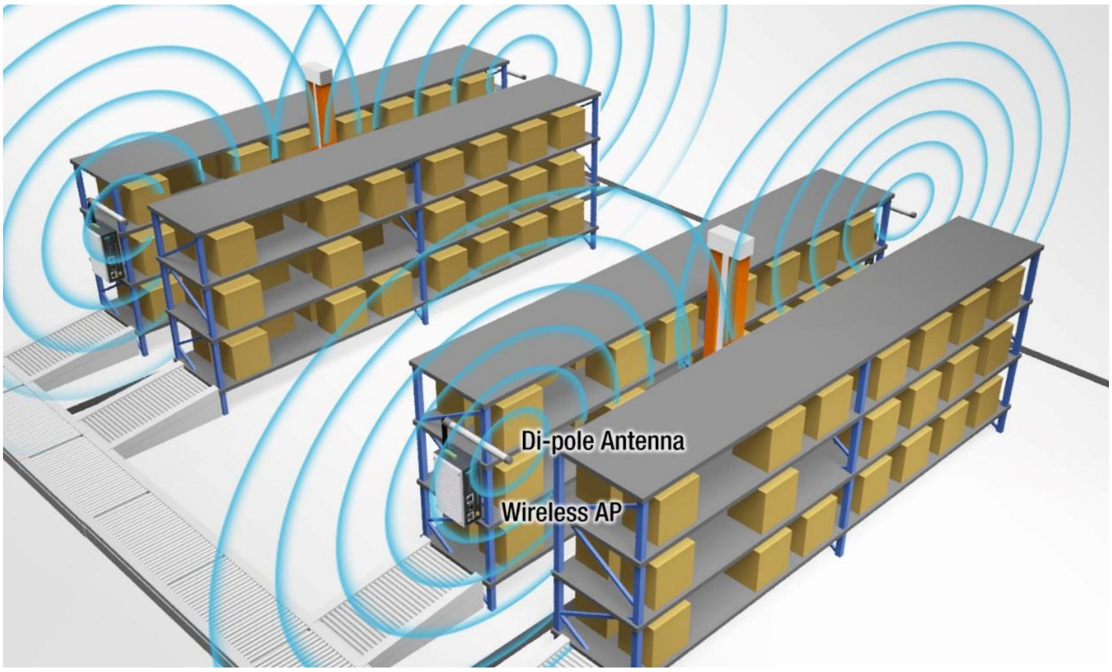
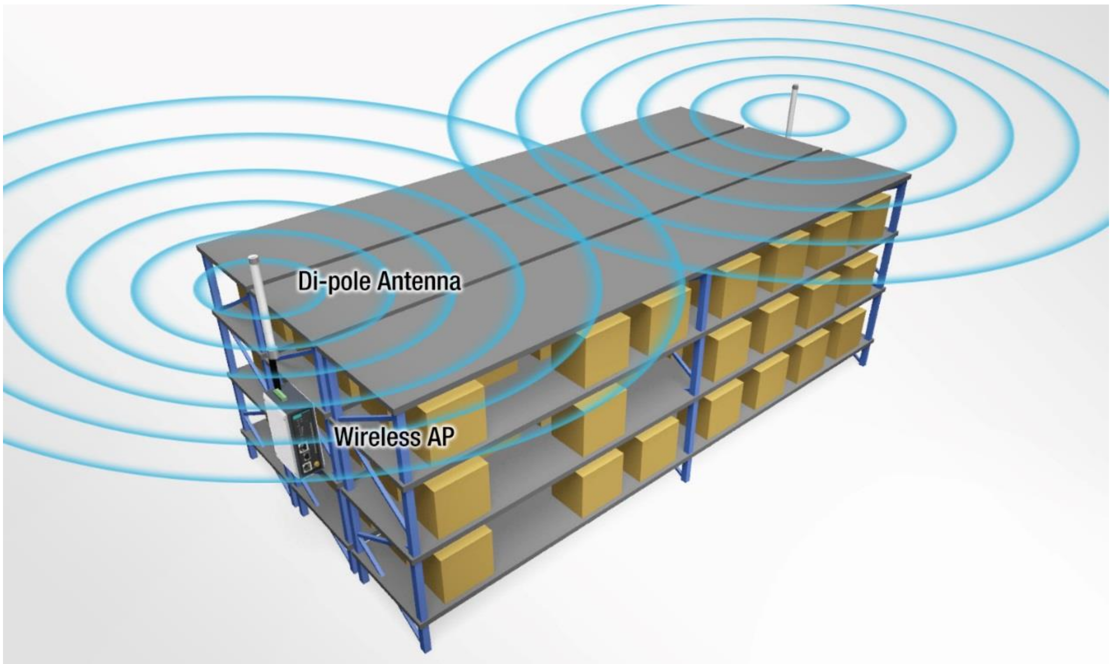
b. Horizontal plane in storage racks

The goal here is to maximize the horizontal coverage area so that shuttles (clients) in the AS/RS system that are moving on the horizontal plane have Wi-Fi coverage at all times. The ceiling-mount antenna is not a good option here as multiple layers of racks will block the signal from the top. Therefore, it is best that the radio signal comes from the side of the rack. Di-pole omni-directional antennas are the typical choice here. A 360-degree horizontal coverage with a large radiation angle is ideal for this case. A single di-pole antenna can cover multiple rack levels. If the vehicles are moving on a vertical plane along the rack, the omni-directional antenna can also be placed with a different orientation to service that need.



The vehicles are moving on a vertical plane along the racks.



The vehicles are moving on a horizontal plane along the racks.

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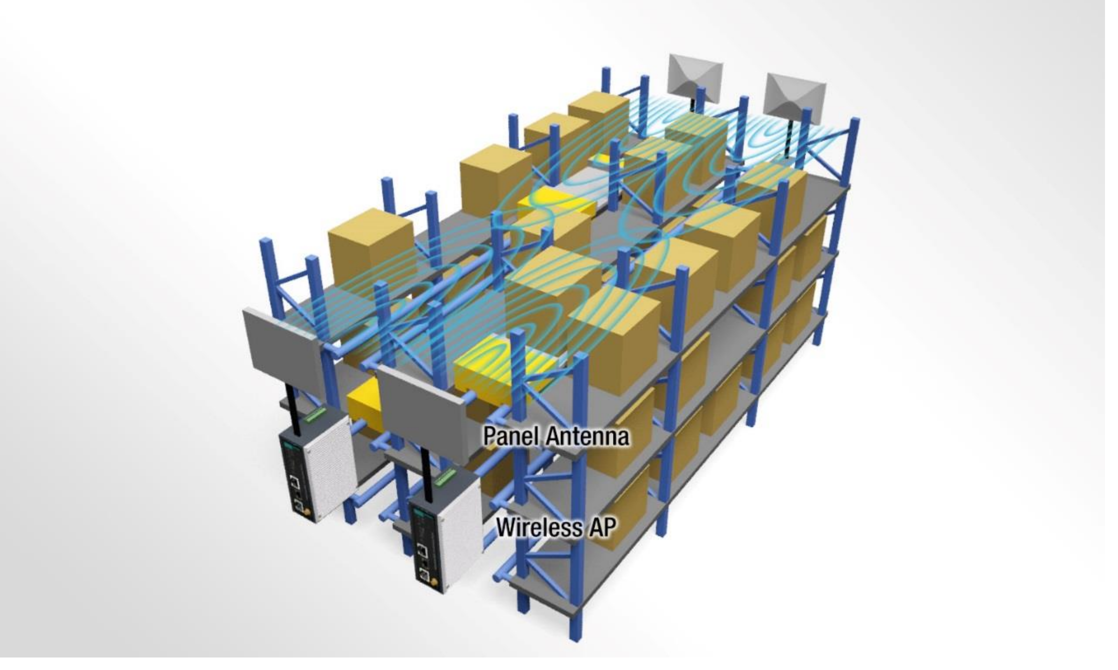
c. Straight-through tracks along the rack aisles

The material-handling robots can travel along a rail track, which is embedded along different aisles between the racks. Using an omni-directional antenna in this case may not be ideal as the signal could be blocked by the material stored. Panel antennas that point down toward the aisles can be used to provide coverage for each lane.

Also, if a warehouse is too large that a directional antenna at one side is not sufficient to provide enough coverage, then another panel antenna can be placed at the other end to enhance the signal.



These examples cover some typical AGV and AS/RS structures that are deployed, but there could be other structures that are not covered here.

Before we move on to the antennas on the vehicles, a Wi-Fi technique worth mentioning is the use of MIMO (multiple input multiple output) antennas. It is helpful to connect multiple inputs from the radios to the antenna to enable MIMO, which can mitigate the impact of distorted signals during multipath communication and provide better signal quality.

The antennas on the vehicles need to be small due to the space constraints on the vehicle, but should be powerful enough to provide enough coverage so that they can pick up signals from the APs from all directions.

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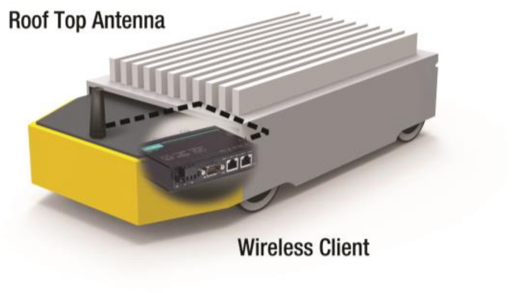
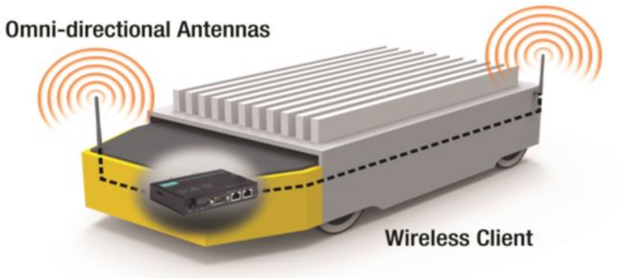
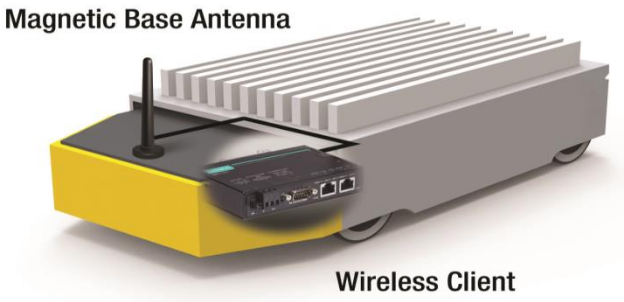
The type of antenna you choose is however restricted by the design of the AGV.

 Some AGVs that allow an antenna opening on the top of the roof can be installed with a rooftop antenna.	 Some AGVs have openings on the side of the vehicles, which facilitates the installation of omni-directional di-pole antennas. If the AGV allows for multiple antenna openings on the vehicle (ideally at the front and back of the vehicle), you can take advantage of MIMO technology to further improve the signal reception, especially if one antenna on the vehicle is blocked by an obstacle at a certain point in its path.
	As a suggestion, in order to find the optimal location to install the antenna on the AGV, one can first use a magnetic-based antenna as a test piece to try and identify the spot with the best reception.

In addition to choosing the right type of antenna, it is also important to adjust the transmitting power of radios so that the coverage is just right. Ensure that there are no weak spots or signal saturation. You want the signal coverage overlap between the APs to be just right so that the communication performance is as uniform as possible.

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4. Optimize Communication Reliability for Mobile Conditions

Once the wireless infrastructure deployment is complete, further fine-tuning of the radios is required in order to optimize the communication reliability and ensure that the client radios on the AGV can roam smoothly among the APs with minimum data loss. Loss of communication with the AGVs can result in data loss, which can result in system downtime.

The network optimization consists of fine-tuning the radio parameters. The key settings you can adjust are transmitting power and the MIMO antenna. Another important parameter is the channel setting. The radio channel determines the frequency that the device radios use to send and receive data. A “clean” channel facilitates uninterrupted communication, whereas a crowded channel will lead to low throughput and data loss due to congestion. This is why site survey is important, and if it is done properly, it can help identify channel interference and the correct frequency channel to use for the location.

It is not always possible to have multiple “clean” channels at a given location. Besides, identical channels used adjacent to each other will result in co-channel interference. The best practice here is to plan multiple frequency channels so as to increase channel availability, but, at the same time, avoid co-channel interference. Frequency channels abide with the frequency regulation in different countries. Some channels allow different transmission power (may depend on indoor or outdoor usage) while some channels may require additional regulations such as DFS (Dynamic Frequency Shift) to force a channel change in the event a radar signal is detected on a channel. Therefore, before committing to a channel plan, you must check the regulation requirement regarding the frequency usage in your country.

Apart from the basic radio settings, the client radios must support fast roaming in order to roam seamlessly among the APs. In Moxa’s AWKs, this feature is called Turbo Roaming. Turbo Roaming must be enabled and configured according to the radio coverage strength to achieve maximum data reliability. Turbo Roaming allows client radio handoff from AP to AP within a few milliseconds. In addition, it also triggers roaming at the right moment, that is, before the signal level drops too low for good overall data throughput performance.

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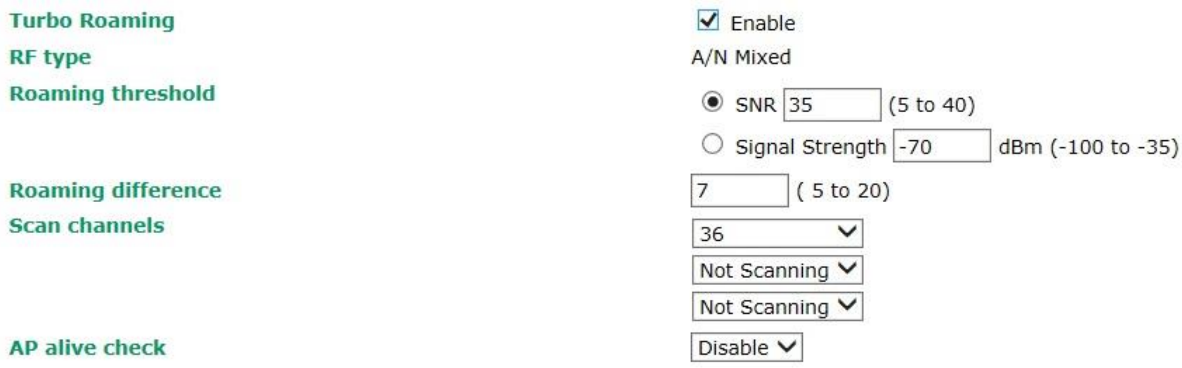
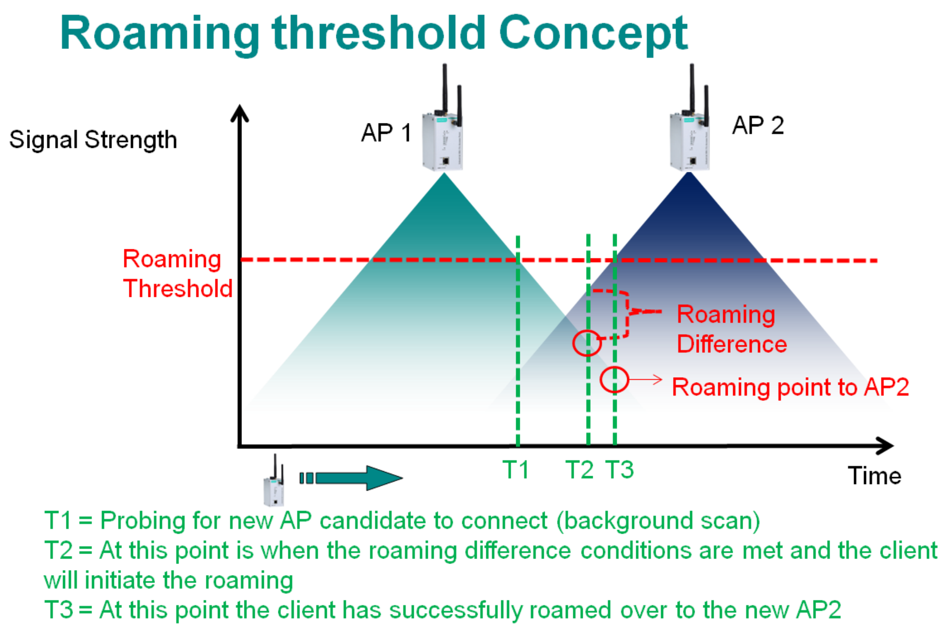
Configurable Roaming Parameters

Roaming parameters, such as "Roaming threshold", allow the user to define when the client radio should start looking for the next AP. The "Roaming difference" setting lets the user define the signal-level criteria for the next available AP. Setting and maintaining these parameters at a certain level will ensure that the client is aware of the spectrum changes and actively looks out for a better AP to connect to.



Because system integrators have to meet communication needs in various operating environments, the roaming parameters should be configurable so as to increase roaming reliability for clients. For example, when an AS /RS system is already deployed, the speed at which the moving parts operate and the transmitter power of the APs deployed on the access points are fixed. In this case, it is simpler to change the roaming threshold flexibly to make client roam to next AP easily and precisely. If a wireless client finds that the signal strength of the connected AP is below the Roaming Threshold that is set, the wireless client will start to look for new AP candidates. The signal strength of the new AP candidates must be better than the current APs signal strength by at least the "roaming difference" dB value.



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Support Multiple Frequency channels Scanning

Due to the limited bandwidth available on each channel frequency, system integrators must use multiple frequency channels to avoid channel congestion. The wireless-roaming technology should be able to provide smooth roaming between different APs using different channels.

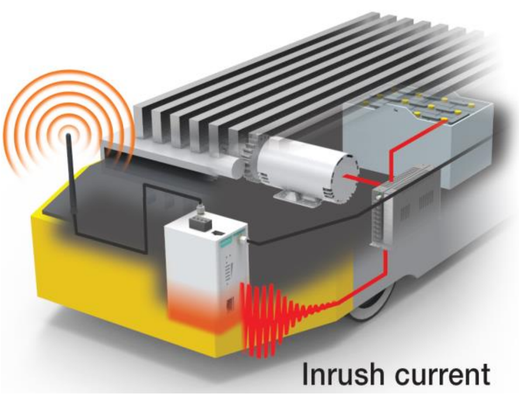
Best Wireless Encryption without Impacting Roaming Performance

Since wireless architecture is radio wave over the air (space), there are several vulnerabilities that can be used to hack into the network. Wireless networks require high data security mechanism, such as using encryption protocols WPA2. However, when using WPA2 encryption protocol, it could cause delay during the security key exchange procedure when the client connects to the next access point. There are some roaming functions available that can provide millisecond-level handoff recovery time even when the wireless security is set to WPA2 encryption.

5. Consider the Impact of Harsh Environmental Conditions

For a wireless system to perform at its best, you must mitigate the effects of the operating environment and ensure that the electrical parts in the equipment can function without interference. Some AGVs operate under harsh environmental conditions, such as in a cold-storage warehouse where the electrical equipment needs to be able to operate at sub-zero temperatures.

Another potential environmental hazard is the stability of the power motors on the AGVs. The power supply on the AGVs may not always be capable of providing a steady current to the radio equipment with the best grounding paths. Therefore, it is essential that you use isolation protection at the power input and sometime also on the antenna ports as electrical interference can damage the mobile radios. In an ideal scenario, the radios themselves should be robust enough to withstand these disturbances.



Other environmental conditions such as vibration, dust, and humidity can impact the performance of Wi-Fi devices and networks.

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Summary

Deploying a wireless network on a factory floor or in an automated warehouse is not an easy task and requires in-depth RF domain knowhow and also some IT knowledge. However, understanding basic wireless principles and key challenges can go a long way in determining the success of the implementation. Moxa is committed to providing easy-to-use and easy-to-deploy radio equipment that will help you build efficient wireless networks for your AS/RS and AGV systems.

Moxa's Solution

The AWK Series AP/bridge/client solution offers the following capabilities that can help develop reliable wireless solutions for your AS/RS and AGV systems.

- Client-router mode in devices to simplify network deployment
- Interoperability with existing third-party APs
- 5 GHz DFS support for noise-free Wi-Fi channels
- 802.11n 2x2 MIMO technology for Wi-Fi coverage over a wide area
- Data rates of up to 300 Mbps
- 150 ms client handoff with Turbo Roaming technology
- -40 to 75°C operating temperature range
- A selection of antennas fit for AGV and AS/RS applications, such as omni-directional, rooftop, magnetic-based, and panel antennas.

Moxa's Wi-Fi solution for AS/RS and AGV is successfully deployed around the world. For complete details, download our Success Stories brochure https://www.moxa.com/en/literature-library/industrial-wireless-solutions-in-manufacturing

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