ALTAI Super WiFi

Altai Super WiFi Solution for Automated RTG Operation in Container Ports

Whitepaper

Revision 1.1

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Super WiFi

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1. Automated RTG Operation in Container Ports

Rubber-Tyred Gantry (RTG) is an important type of container handling machinery in container ports, which operates in the container stacking areas to load/unload containers to/from trucks. Currently most RTGs are manually operated by an on-board driver. But unmanned automated RTG operation has also been increasingly demanded for its greater productivity, better safety, and long-term cost-savings.

Automated RTG operation typically involves a remote operation center (ROC), RTG local execution system (including IPCams, sensors, PLCs, actuators and corresponding machineries), and a communication network connecting them, as illustrated in Fig. 1. The RTG-ROC communication network needs to provide reliable and low-latency control signal transmission as well as high-bandwidth real-time video transmission for supervision. In general, such a communication network is implemented using fiber optics, which can be bundled with the power cables that electrify the RTG. But this approach has limitations that it's applicable only to electrical RTGs (vs. diesel RTGs) and the RTGs are confined to operate only in their dedicated container stacking blocks. Apparently, if there's a wireless solution for this communication network, the limitations incurred by cabling can be avoided and more RTGs can be automated with higher mobility and flexibility.

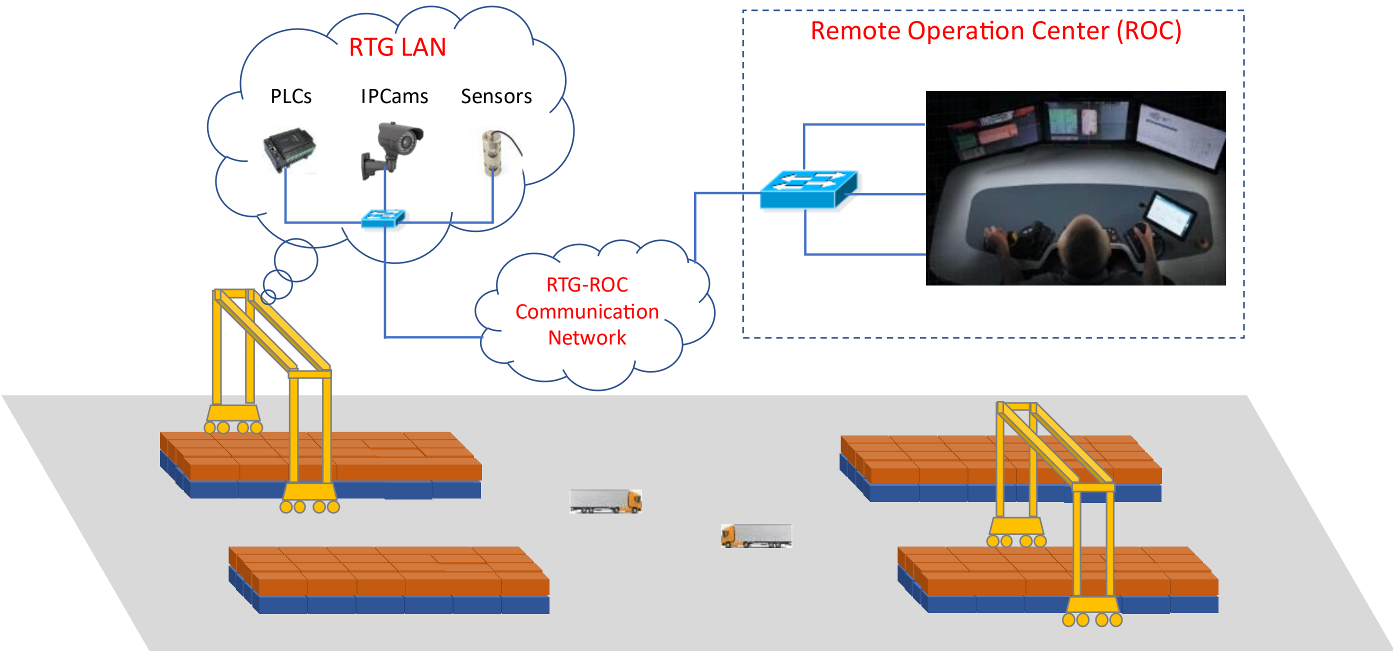


Figure 1 Automated RTG Operation

However, meeting the bandwidth and latency requirement of automated RTG operation is not easy for a wireless solution. The candidate wireless technologies mainly include WiFi, 4G (LTE), and 5G, each with its respective advantages and limitations.

WiFi is a wireless Local Area Network (LAN) technology based on IEEE 802.11 standards. It works in unlicensed Industrial, Scientific and Medical (ISM) frequency bands (2.4GHz & 5GHz). License-free use of the frequency bands makes WiFi very attractive and widely adopted for home, office, manufacturing, and even telecommunication uses. But the prevalence of WiFi equipment in general means busy channels and high interference, which have a negative impact on the communication performance and user experience. Moreover, WiFi uses a contention-based MAC-layer mechanism called Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA), where all WiFi terminals need to contend for accessing the media to transmit, without dedicated timeslots and bandwidth guarantee. In other words, generic WiFi only provides service on a best-effort basis. Another inefficiency of WiFi is in the support of seamless, fast roaming/handover. The handover time of a WiFi client from one AP to another can easily be as large as hundreds of milliseconds or even seconds, which makes delay-sensitive applications inoperable.

4G/LTE is a cellular technology which works in licensed frequency bands and can be used for both public and private communications. Working in licensed frequency bands means less interference and more predictable performance. Moreover, 4G/LTE uses a scheduling-based MAC protocol to offer better QoS guarantee, and supports seamless and fast roaming. Nevertheless, the frequency spectrum is scarce resource in licensed bands, and that available for a private 4G/LTE network in a container port in general will not be more than 20MHz, thus limiting the throughput such a network can achieve. Practically, building a private 4G/LTE network in a container port is much more costly than a WiFi solution, and the Operation Administration and Maintenance (OAM) of a private 4G/LTE network is very complicated and usually beyond the expertise of the IT staff of a container port, thus requiring constant support from the solution provider which leads to high OPEX.

5G shares the most advantages as well as limitations of 4G/LTE. It can provide a higher throughput than 4G/LTE. But it still needs to be tested and tweaked under various application scenarios before being mature enough.

Altai has been a veteran in providing WiFi solutions for various industrial applications. In this article, we present our Super WiFi solution for automated RTG operation and explain how it has overcome the limitations of traditional WiFi.

2. Altai Super WiFi Solution

Altai Technologies is the world-leading large-coverage outdoor WiFi solution provider. Altai owns various patents in smart antenna and wireless signal processing, which form the foundation of its Super WiFi solution. Now we apply our Super WiFi technology and products to container ports for automated RTG operation. In particular, we address the following challenges as previously described:

- Containing the channel interference;
- Maintaining high performance/QoS level of the wireless link;
- Support of seamless and fast roaming.

2.1. Use of Waveguide for High-Quality WiFi Transmission

Waveguide is a special type of transmission line in the form of a hollow metal tube, with electromagnetic waves transmitted inside by successive reflections from the inner walls of the tube. When perforated with slots in certain pattern, a waveguide can become a leaky-wave antenna. When RF signal is fed into the waveguide, it will leak through the slots along the waveguide. An example is illustrated in Figure 2.

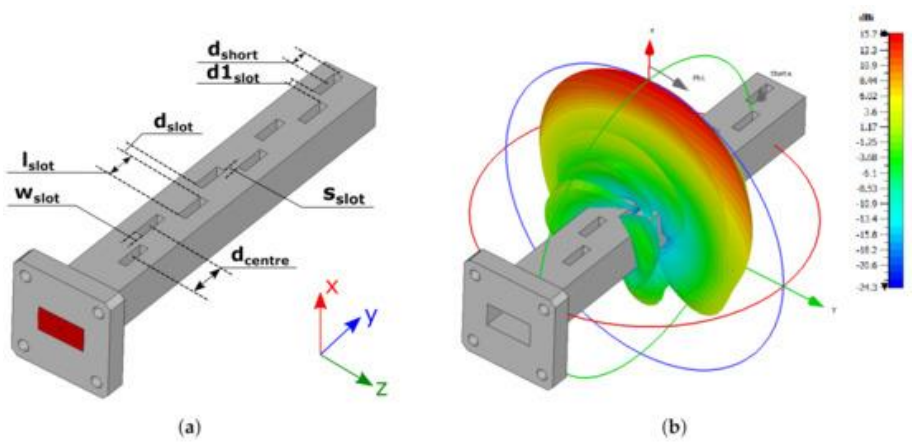


Figure 2 A Slotted Waveguide Antenna
(Picture courtesy of Telecom 2021, 2, 42–51. https://doi.org/10.3390/telecom2010004)

Slotted waveguide antennas typically have such advantages as easy to manufacture, low signal loss, able to handle large power, etc., which help them find application in many fields like UHF TV signal transmission, cellular base stations, and marine radars. In container ports for automated RTG operation, we use slotted waveguide for the following reasons:

- Laying waveguide is practically feasible (and relatively easy) because it can be laid together with the conductor rail system which is used for electrifying the RTGs;
- Slotted waveguide can confine the RF signal emission in the vicinity of the waveguide. A counterpart antenna can be put close to the waveguide (e.g., 20~30cm), thus forming a short-range wireless link which is much less prone to the impact of environmental interferences;
- Slotted waveguide has slow signal strength attenuation (e.g., 16 dB/km), thus able to maintain a high level of signal strength even when the RTG (with CPE) moves far away from the AP that feeds signal into the waveguide.

An actual deployment is shown in Fig. 3. An AP that connects to the backend network (i.e., the remote operation center) is installed at one end of the waveguide (not shown in the figure) and feeds WiFi signal in. On the other hand, a WiFi CPE is installed on the RTG with antenna pointing to the waveguide, thus setting up an AP-CPE wireless link for the communication between RTG's local network and the remote operation center.

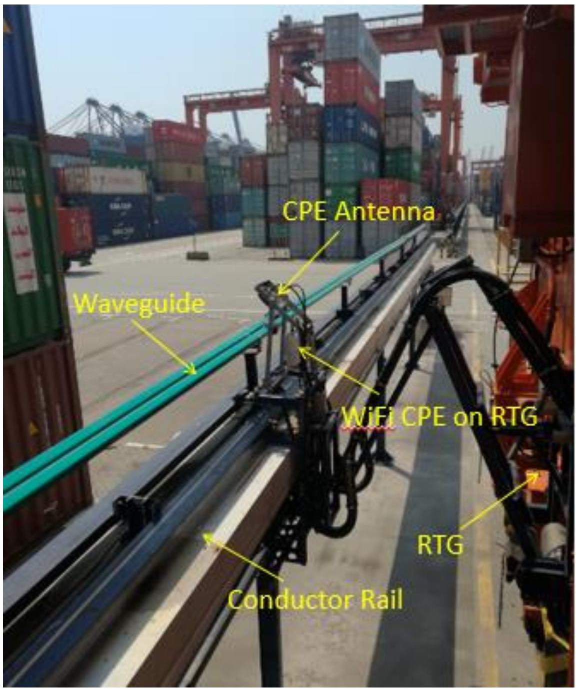


Figure 3 A Waveguide Deployment Example

2.2. Link Redundancy for High Reliability and Seamless Roaming

Automated RTG operation demands high reliability of the communication network, because a loss or delayed reception of an operation command might cause misplacement or even collision of containers. Although use of waveguide can ensure strong SNR in WiFi signal transmission and less interference from the environment, which improves the reliability of the WiFi network, such faults as AP/CPE power outage, cable disconnection, or even hardware failure have not been handled. To meet the customer's increasingly stringent requirement on reliability and contain such faults that render the wireless link inoperable or simply disconnected, Altai has developed a "AlwaysConnected" solution with redundant links.

Altai "AlwaysConnected" link redundancy solution can support 1 active link + N standby links (typically N = 1 or 2), with link switching time < 10ms. In the case of automated RTG operation, there can be totally 3 wireless links. Two of them are for redundancy when the WiFi transmission is through the waveguide, while the third one is for seamless roaming when RTG needs to move from one container stacking block to another, where the WiFi transmission needs to be switched from waveguide to open air and switched back. One such example is illustrated in Fig. 4. There are totally three WiFi CPEs installed on the RTG. Two of them are connected to two WiFi APs installed on the ground in some IT cabinet via the waveguide, respectively. The third CPE is equipped with omni antennas and connected to another AP, which may be installed on some high light mast to cover the inter-block passageway, via the open air.

When the RTG operates in the container stacking blocks, the two waveguide AP-CPE links work in an active-standby mode. The active link is selected based on preset priority, and performance metrics like SNR and throughput. When the active link's quality/performance drops below certain threshold while the standby link becomes a better option, active link switching will be completed within 10ms, so that RTG-ROC communication quality can be maintained for smooth and accurate operation. When the RTG moves close to the edge of the stacking blocks, the air AP-CPE connection can be set up and work in standby mode for potential link switching. Similarly, when at a certain point the air link becomes a better option than the waveguide links, active link switching happens, and the RTG-ROC communication will be through the air link. When the RTG arrives at the next stacking block and new waveguide AP-CPE links are set up and later become better than the air link, the active link switches to one of the waveguide links.

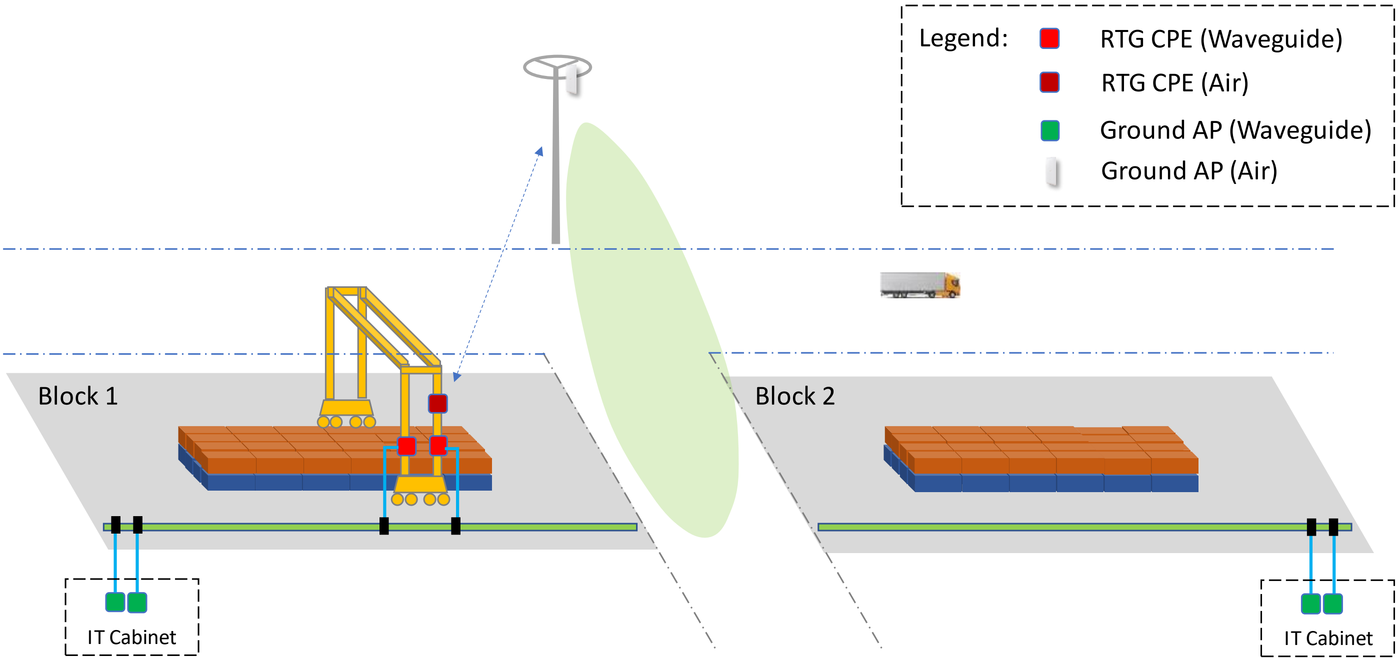


Figure 4 Altai "AlwaysConnected" Link Redundancy for Automated RTG Operation

In the above example, the whole WiFi network is configured with three different SSIDs, two for waveguide connections (primary and backup) and one for the inter-block air connection. Neighboring APs are configured with different operating channels to minimize the co-channel interference. With such a 1 + 2 redundancy configuration, the RTG-ROC communication network becomes "AlwaysConnected" and highly reliable in providing bandwidth and latency guarantee, even when RTG moves between container stacking blocks.

2.3. Enabling Transmission Priority per Traffic Types

The RTG-ROC communication involves different types of traffic, e.g., PLC control, IPCam video streaming, sensor status update, and log/file transfer. Different types of traffic have different requirements on reliability and timeliness. For example, PLC control is directly related to container movements and hence demands high reliability and low latency, while log/file transfer can tolerate retransmissions and delays. When such mixed types of traffic are transmitted via WiFi, a priority scheme is desirable to help meet their respective performance requirements.

WiFi starts to support QoS/Priority transmission since the advent of 802.11e/WMM, in which four access categories (ACs) are defined, i.e., Background (BK), Best-Effort (BE), Video (VI), and Voice (VO), with increasing transmission priority. How to map the traffic coming from the wired side into the four ACs in wireless transmission is up to the design of the WiFi equipment. Typically, DSCP field of the IP header and Priority field of the VLAN header are used to determine the mapping.

In the RTG operation case, PLC control is generally implemented using PROFINET protocol, which has a VLAN priority of 6, as shown in Fig. 5, and is mapped to the VO category. For IPCam video traffic, the packets can be tagged by switches before entering the AP/CPE, for example, with either a VLAN priority of 5 or a DSCP of 40, which both are mapped to the VI category. For other traffic that do not have stringent latency requirement, the packets are not specially tagged and simply mapped to the BE category.

Altai APs and CPEs support both IP- and VLAN-based priority, and hence can easily realize such differentiation among different traffic types.

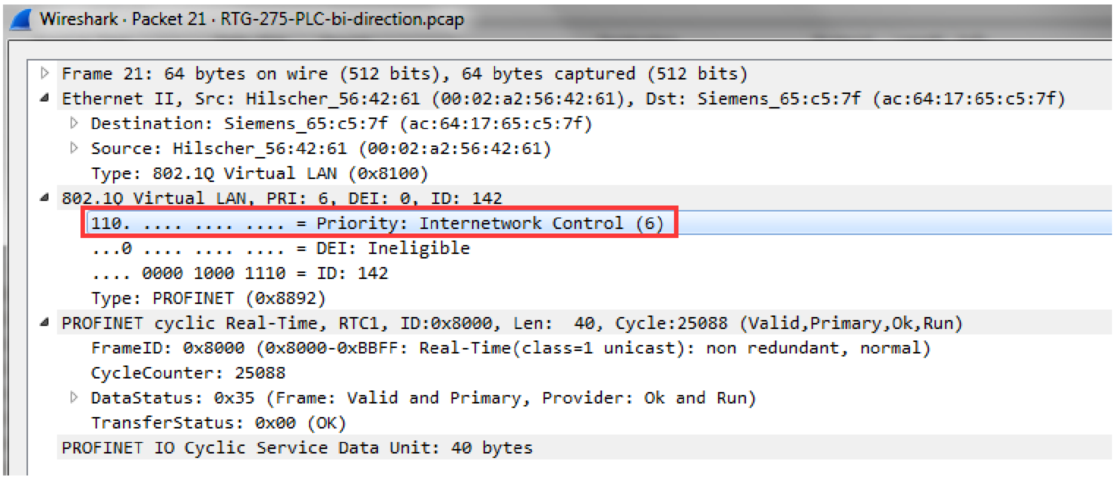


Figure 5 PLC Control (PROFINET) Packet with VLAN Priority

2.4. Proper Bandwidth and Capacity Planning

In RTG-ROC communication, video transmission of the IPCams on the RTG contributes most of the bandwidth consumption. There can be easily more than a dozen of cameras on an RTG. With different cameras serving different purposes and having different requirements on definition/bandwidth, a total bandwidth of 50Mbps is generally enough for one RTG per current practices.

One thing to note is that the video transmission is from RTG to ROC, or from CPE to AP from WiFi perspective, i.e., in the uplink direction. Given the contention-based CSMA/CA mechanism of WiFi, multiple uplink high-bandwidth traffic streams from different clients (CPEs) might cause severe contention, especially when the clients could not hear each other thus forming a hidden-node scenario, which would decrease the transmission efficiency and overall throughput significantly. With the use of waveguide, however, all CPEs attached to the same waveguide can hear each other and hidden-node scenario can be avoided.

Altai offers A2x WiFi AP/CPE, which supports 2x2 802.11ac and has a maximum link data rate of 867Mbps, to be used with the waveguide. Considering the environmental impact and MAC layer efficiency drop under multi-user condition, we suggest limiting the total throughput of a waveguide AP to be no more than 300Mbps, i.e., no more than 6 RTGs work on the same waveguide simultaneously.

For the AP that covers the inter-block passageway and transmits over the air, Altai offers A3-Ei, which supports 3x3 802.11ac and has a maximum link data rate of 1300Mbps. Since in general it does not take long (e.g., a few minutes at most) for an RTG to move from one block to another, the chance that the air AP needs to serve multiple RTGs is low, and hence bandwidth is normally not a problem. Instead, good signal coverage to maintain a reliable wireless connection is important for the air AP. Altai A3-Ei has superior coverage capability with a built-in 13dBi 5GHz sector antenna, and is a perfect choice for the air AP.

Detailed specifications of A2x and A3-Ei can be found in the Appendix.

2.5. Network Security

For information security, the SSIDs for RTG CPEs should enable authentication and encryption. In general, it is recommended to use WPA2-PSK authentication + AES encryption.

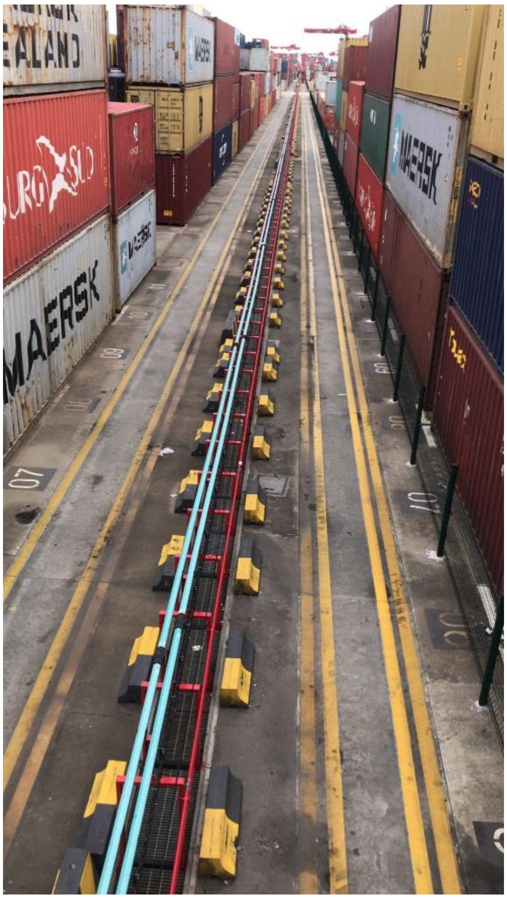
For further security as well as performance protection, by preventing non-working WiFi terminals (e.g., personal smartphones of the workers in the ports) from connecting to the SSID, MAC access control list (ACL) function can be enabled with black and white lists properly set.

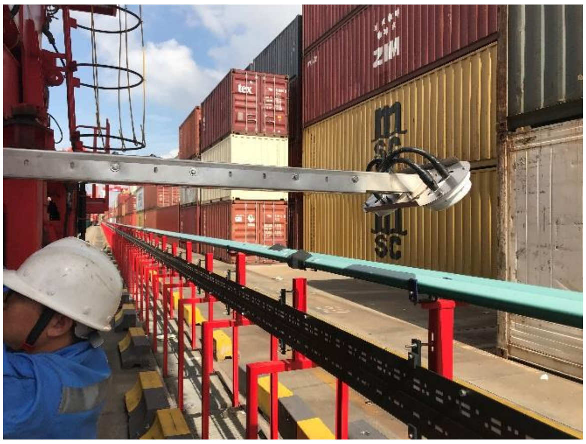
3. Reference Cases

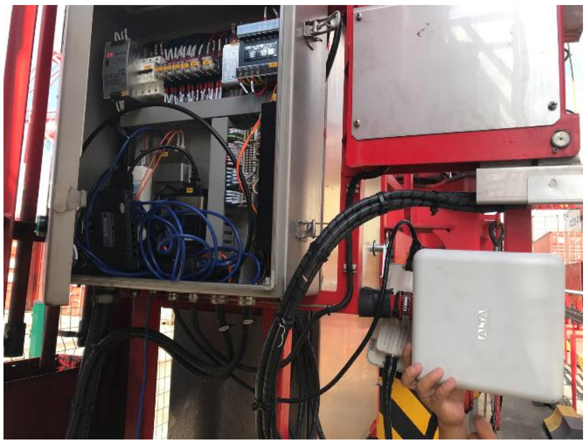
Case 1: A Fully Automated Container Port in Eastern China

- 5 waveguide lines* serving 5 container stacking blocks;
- Link redundancy: 2 ground APs (A2x) for each waveguide line, and 3 CPEs (A2x) on each RTG;
- Seamless roaming for inter-block transition: 4 ground APs (A3-Ei) to cover the passageways between the 5 blocks;
- Phase 2 expansion is under way.

(* Each line is composed of a pair of waveguides for 2x2 MIMO transmission)

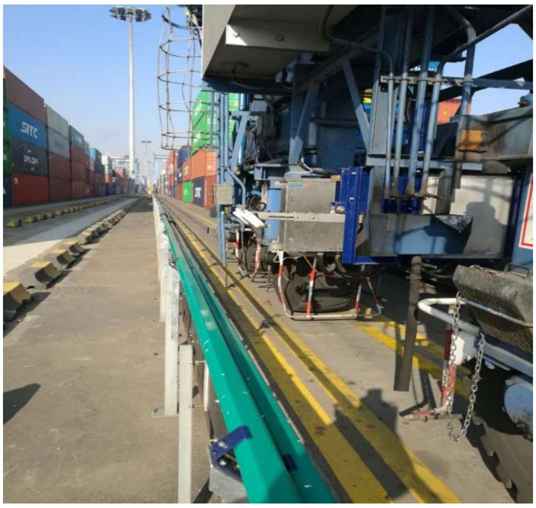






Case 2: A Container Port in Northeast of China

- 15 waveguide lines serving 30 container stacking blocks;
- 1 ground AP (A2x) for each waveguide line, 1 CPE (A2x) on each RTG;
- System upgrade to have link redundancy and passageway coverage is under planning.




4. Appendix: Altai AP/CPE Datasheets

4.1. A2x 2x2 802.11ac WiFi AP/CPE

A2x WiFi Access Point/Bridge
Outdoor 802.11ac AP with External Antennas

Wireless Interface

802.11b/g/n (2x2:2) Radio

- Operating Mode — Access Point/CPE/Bridge/ Repeater
- Standard — IEEE 802.11b/g/n
- Operating Frequency — 2.400 – 2.835 GHz (Ch 1-13)
- Transmit Power — 28 dBm (Max.) 25 dBm (Per Chain)
- Receiver Sensitivity (Typical)

802.11b	11 Mbps	-89 dBm;	1 Mbps	-99 dBm
802.11g	54 Mbps	-79 dBm;	6 Mbps	-90 dBm
802.11n	HT20	-90 dBm;	HT40	-86 dBm

802.11a/n/ac (2x2:2) Radio

- Operating Mode — Access Point/CPE/Bridge/ Repeater
- Standard — IEEE 802.11a/n/ac
- Operating Frequency — 5.150 – 5.250 GHz; 5.250 – 5.350 GHz; 5.470 – 5.725 GHz; 5.725 – 5.850 GHz
- Transmit Power — 28 dBm (Max.) 25 dBm (Per Chain)
- Receiver Sensitivity (Typical)

802.11a	54 Mbps	-79 dBm;	6 Mbps	-93 dBm
802.11n	HT20	-93 dBm;	HT40	-90 dBm
802.11ac	VHT20	-92 dBm;	VHT40	-89 dBm
	VHT80	-87 dBm		

For both 2.4 and 5 GHz

- 32 SSID (16 SSID per Radio)
- 802.11h, 802.11k, 802.11r, 802.11v, 802.11w
- Passpoint (Release 2)
- Fast Roaming
- Multi-AP Steering
- Smart Load Balancing
- Smart Mesh Networking*
- Altai *AirFi*™ Throughput Optimization
- WMM (802.11e)

Antenna

2.4 GHz Antenna

- Antenna Connector — 2 x N-Female

5 GHz Antenna

- Antenna Connector — 2 x N-Female

Networking

- Switch (Bridge) and Gateway Mode
- IPv4/ IPv6 Dual-Stack
- NAT
- DHCP Client/ Server
- PPPoE Client
- Soft-GRE
- VLAN
- Bandwidth Control Per VAP/ Client
- Multicast Rate Filter/ IGMP Snooping

Security

- Authentication – Open, Shared key, WPA/ WPA-PSK, WPA2/ WPA2-PSK, , WPA3*, 802.1x (EAP-PEAP/ TLS/ TTLS/ SIM/ AKA)
- Encryption – WEP, TKIP, AES
- Client Isolation
- MAC-Based Access Control (White/ Black List)
- RADIUS
- Active Directory
- Firewall
- WIPS* – Denial of Service, Rogue AP Detection, Alerting and Reporting

Management

- Management Platforms – Standalone, AltaiGate, AltaiCare cloud service, AltaiCare On-Premise Virtual Appliance
- Web User Interface
- Command Line Interface (SSH)
- SNMP v1/ v2c / v3
- MIB2/ IF-MIB/ Altai Enterprise MIB
- Syslog
- Remote Factory Reset
- Auto Channel Selection and TX Power Control
- Spectral Analysis*
- KPI Monitoring*
- Client OS Detection

Physical Specifications

- Dimension — 220 x 220 x 60 mm
- Weight — 1.3 kg (Unit Weight)
- Mounting — Pole/Wall-Mounted
- Network Interface — 1 x 1GbE Port

Environmental Specifications

- Operating Temperature — -40 °C to +60 °C
- Storage Temperature — -40 °C to +80 °C
- Humidity — Up to 95 % (Non-Condensing)

Power Supply

- Power Supply — 802.3at PoE PD or 56 VDC Passive PoE PD
- Power Consumption — 10 W (Typical) / 20 W (Max.)

Certification

- FCC / CE / SRRC /Others*
- RoHS Compliance

Product Ordering Information

A2x (Part No.: SD.A2AC-2224-000)

- A2x Wi-Fi Access Point/Bridge (Model No.: AP5822)
- Mounting Accessories

Optional Accessories

- 56 VDC Passive PoE Injector
- External Omni or Sector Antennas

Contact Us

- Email: sales@altaitechnologies.com

A2X-PB201117

** Will be available in future.*
All specifications are subject to change without notice

4.2. A3-Ei 3x3 802.11ac AP

Altai A3-Ei Dual-band 3x3 802.11ac WiFi AP

Outdoor 802.11n/ac, Built-in 2.4 GHz and 5 GHz Sector Antennas

Wireless Interfaces

802.11b/g/n (3x3:3) Radio

- Operating Mode: AP/CPE/Repeater
- Standard: IEEE 802.11b/g/n
- Operating Frequency: 2.400 – 2.484 GHz (Ch 1-13)
- Transmit Power: 30 dBm (Max.), 25 dBm (Per Chain)
- Receiver Sensitivity (Typical)

802.11b	11 Mbps	-90 dBm;	1 Mbps	-100 dBm
802.11g	54 Mbps	-79 dBm;	6 Mbps	-92 dBm
802.11n	HT20	-92 dBm;	HT40	-88 dBm

802.11a/n/ac (3x3:3) Radio

- Operating Mode: AP/CPE/Bridge/Repeater
- Standard: IEEE 802.11a/n/ac
- Operating Frequency: 5.150 – 5.350 GHz, 5.470 – 5.725 GHz, 5.725 – 5.850 GHz
- Transmit Power: 30 dBm (Max.), 25 dBm (Per Chain)
- Receiver Sensitivity (Typical)

802.11a	54 Mbps	-79 dBm;	6 Mbps	-93 dBm
802.11n	HT20	-94 dBm;	HT40	-90 dBm
802.11ac	VHT20	-93 dBm;	VHT40	-90 dBm
	VHT80	-87 dBm		

For both 2.4 and 5 GHz

- 32 SSID (16 SSID per Radio)
- WMM, 802.11h, 802.11k, 802.11r, 802.11v, 802.11w
- Passpoint (Release 2)
- Fast Roaming
- Band Steering/Multi-AP Steering
- Smart Load Balancing
- Dual-Radio 1+ 1 Redundancy*
- Smart Mesh Networking*
- Auto Channel Selection and TX Power Control
- Bandwidth Control Per SSID/Client
- Altai *AirFi*™ Throughput Optimization

Antennas

2.4 GHz Antenna

- Built-in Antenna: 12 dBi Sector
- Frequency: 2.4 – 2.5 GHz
- Polarization: 3x3 MIMO Spatial Polarized
- Horizontal Beamwidth: 60° (-3 dB)
- Vertical Beamwidth: 25° (-3 dB)
- VSWR: 2 (Max.)

5 GHz Antenna

- Built-in Antenna: 13 dBi Sector
- Frequency: 5.150 – 5.875 GHz
- Polarization: 3x3 MIMO Spatial Polarized
- Horizontal Beamwidth: 80° (-3 dB)
- Vertical Beamwidth: 12° (-3 dB)
- VSWR: 2 (Max.)

Networking

- Switch (Bridge) and Gateway Mode
- IPv4/IPv6 Dual-Stack
- NAT
- DHCP Client/Server
- PPPoE Client
- Soft-GRE
- VLAN
- Multicast Rate Filter/IGMP Snooping

Security

- Authentication – Open, Shared key, WPA/WPA-PSK, WPA2/WPA2-PSK, WPA3*, 802.1x (EAP-PEAP/TLS/TTLS/SIM/AKA)
- Encryption – WEP, TKIP, AES
- Inter/Intra-SSID Client Isolation
- MAC-based Access Control (White/Black List)
- RADIUS/Active directory
- Dynamic VLAN Assignment
- Firewall
- WIDS/WIPS
- Broadcast/Multicast/Unicast Flooding Control

Management

- Management Platforms: Standalone, AltaiGate, AltaiCare, AltaiCare Appliance
- Web User Interface
- Command Line Interface (SSH)
- Remote Factory Reset
- Trusted Management IP List
- SNMP v1/v2c /v3
- MIB2/IF-MIB/Altai Enterprise MIB
- Syslog
- Spectral Analysis*
- KPI Monitoring*
- Client OS and Hostname Detection

Physical Specifications

- Dimension: 491 x 221 x 73mm
- Weight: 2.1 kg (Without Mounting Kit)
- Mounting: Pole or Wall-mounted
- Network Interface: 10/100/1000 Mbps Ethernet Port

Power

- Power Supply: 802.3at PoE PD or 56 VDC Passive PoE PD
- Power Consumption: 10 W (Typical)/25 W (Max.)

Environmental Specifications

- Operating Temperature: -40 °C to +60 °C (Ambient)
- Storage Temperature: -40 °C to +80 °C
- Humidity: Up to 95% (Non-Condensing)
- Lightning Protection: EN 61000-4-5
- Wind Loading: Up to 216 km/h (134 mph)
- Weatherproof: IP67 Compliant

Certifications

- FCC/CE/Others
- RoHS Compliance

Product Ordering Information

A3-Ei (Part No.: SD.A3-EH00-00)

Standard Package

- A3-Ei Dual-band 3x3 802.11ac WiFi AP with Built-in 2.4 GHz and 5 GHz Sector Antennas (Model No.: WA3311NAC-E)
- Mounting Kit

Accessories

- 56 VDC Passive PoE Injector (Optional)

Contact Us

- Email: sales@altaitechnologies.com

A3Ei-PB-191213

*Will be available in the future.
The coverage range will vary depending on NLOS and interference conditions
The transmit power may vary according to country regulation

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