White Paper

Mobile Network
5G

Wiwynn 5G Smart Factory Solution

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1. Introduction

5G is an emerging communication standard that offers both high-speed connectivity for people, but also for the sensors, devices, and machines on the Internet of Things (IoT). With high theoretical peak data transfer rates and low latency, it can be possible to play a critical communication role that benefits Industry 4.0 applications offering high performance, reliability, and security. 5G enables new use cases because it offers different and better features and performance than other wireless technologies such as Wi-Fi.

This white paper is written to show how smart factories can use integrated application practices based on private 5G. The paper explains in detail the usage scenarios of automated optical inspection (AOI) and autonomous mobile robot (AMR), and how these applications utilize the advantages of 5G to reduce deployment and maintenance costs. In terms of AMR, each production line can reduce manual labor by several man hours per month by replacing legacy manual processes with AMR. Lastly, the paper will highlight the use of the latest Intel platform technology to build an efficient 5G platform.

Wiwynn, an Intel® Network Builders ecosystem partner, works with Intel to accelerate the development and performance of its 5G platform. Multiple Intel technologies are adapted in this platform. Please refer to chapter 3 for more technology details.

2. Architecture

This chapter goes into more details about the Wiwynn 5G platform, including the high-level architecture, hardware and software configuration, and the integration of Wiwynn 5G platform with smart factory usage scenarios. In the last section, a field site deployment will be discussed.

2.1 Wiwynn 5G Platform

With the growing demand for mobile network applications such as Industry 4.0, the mobile network is now facing the challenge of providing higher capacity, lower latency, and massive machine connection services. The revolutionary 5G network introduces architectural changes in the radio access network (RAN) and the core network. A key concept is disaggregation – that is reconstructing a proprietary legacy system (RAN, Core, etc.) into software that runs on servers based on Intel architecture CPUs. This change enables flexibility and allows manufacturers to bring forth more software and hardware to accelerate innovation.

This chapter will take a closer look at the Wiwynn 5G standalone (SA) sub-6 GHz Open RAN distributed unit (O-DU) and Open RAN centralized unit (O-CU), and third-party 5G Core solutions. The chapter will also outline the flexibility of Wiwynn DU/CU server and how this helps service providers to deploy for different scenarios and enjoy serviceability and manageability on a single hardware architecture.

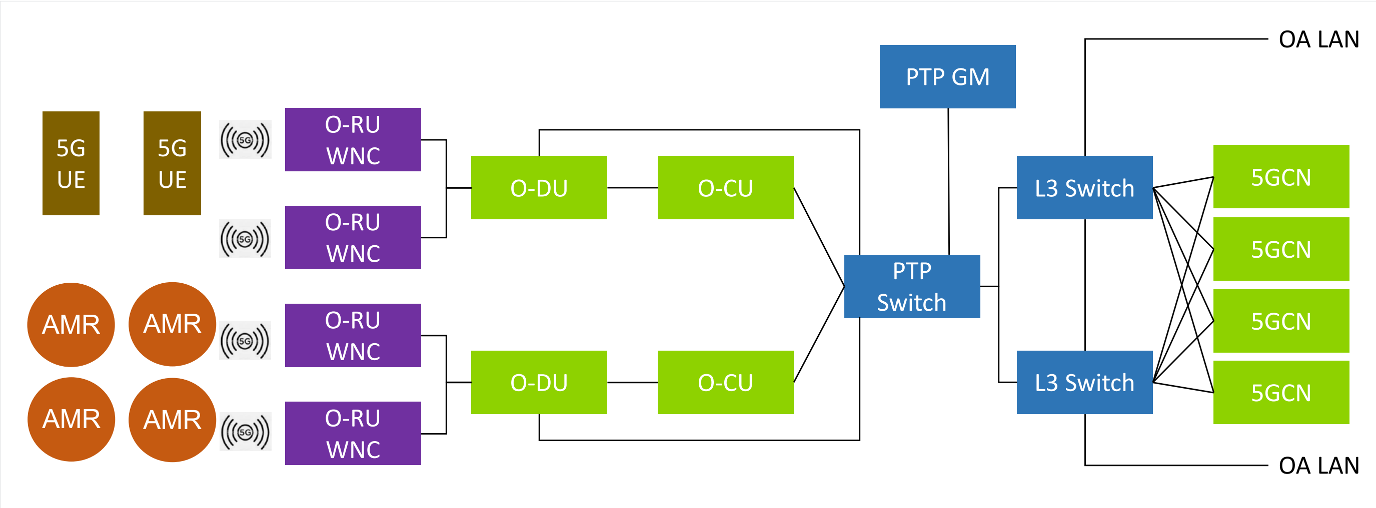


Figure 1. Wiwynn 5G platform architecture.

2.1.1 Architecture of Wiwynn 5G platform

Wiwynn's 5G SA Sub-6GHz O-DU and O-CU solution is based on O-RAN Alliance Standards and is implemented on the Wiwynn® EP100, a 3U short-depth edge server system based on the Open Compute Project (OCP) openEDGE* specification. The EP100 platform supports up to five 1U, half-width single socket server sleds. This 5G platform leverages a Wistron NeWeb Corporation (WNC) indoor radio unit (RU) to provide efficient wireless connection. To provide enterprise-level service, this 5G platform leverages Affirmed (a Microsoft company) 5G Core network function to build up high number of available clusters to reduce the service interrupt time. Figure 1 displays the high-level architecture of the Wiwynn 5G Platform.

2.1.2 Time Synchronization Function

Frequency and time synchronization of O-DUs and O-RUs is essential for data transmission. Adopting the synchronization configuration that meets telco operators' requirements is therefore the first step to building up a 5G network. Wiwynn's 5G SA sub-6 GHz solution adopts HLS option 2 as CU-DU interface and 3GPP LLS option 7-2x as DU-RU interface.

Wiwynn can support the LLS-C3 configuration when equipped with hardware supporting a Precision Time Protocol (PTP) network adapter. In addition, Wiwynn's server can also act as the PTP grandmaster when proper hardware components are installed (such as GNSS module) and using them to synchronize multiple O-RUs as described in the lower-layer split C1 (LLS-C1) and LLS-C2 configurations.

Smart factory deployments leverage a precision time protocol (PTP)-enabled switch as the PTP switch and MITS Qg2 small form factor, high accuracy multi-sync gateway as the PTP grandmaster. Therefore, the fronthaul network must have a PTP grandmaster to provide a reference clock to O-DU and O-RU. The PTP grandmaster can connect to the Ethernet switch in the fronthaul network, which supports the PTP boundary clock, to provide a reference clock throughout the network. However, since an Ethernet switch was not used between O-DU and O-RU, the GPS-synchronized PTP grandmaster clock is connected to the PTP-enabled switch to provide precise timing to the O-DU. The O-DU acts as PTP and synchronous Ethernet (SyncE) master to distribute network timing toward O-RU.

2.1.3 5G DU/CU Hardware Configuration

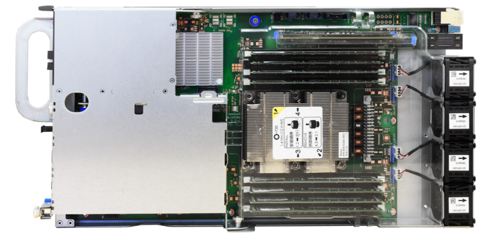
The Wiwynn® EP100 is a 3U short-depth edge system based on the OCP openEDGE specification. It is used to enable the 5G RAN DU/CU solution. This platform supports up to five 1U half-width, single-socket server sleds and each sled supports one PCIe x16 acceleration card.

In this smart factory scenario, two sleds of EP100 are dedicated for O-DU and another two are for O-CU. L1 high PHY, L2, and L3 protocol stack of O-DU and O-CU are mainly processed by the CPU. In addition to the CPU, there are other hardware functions required for O-DU and O-CU.

Wiwynn's O-DU solution adopts Intel® FlexRAN™ architecture for L1 high PHY function. The L1 high PHY processing uses the optimized software modules that leverage the Intel® Xeon® Scalable processor instruction set. In addition, the Lisbon FEC accelerator adapter based on Intel® ACC100 eASIC, an Intel® vRAN dedicated accelerator chipset, is installed in the O-DU sled for forward error correction (FEC) acceleration.

For O-CU, the CU user plane (CU-UP) and CU control plane (CU-CP) run on the same sled in the current setup. O-CU handles Packet Data Convergence Protocol (PDCP) which is used to process header compression/decompression, ciphering/deciphering, and integrity protection. The Intel® QuickAssist Technology (Intel® QAT) card is installed on the O-CU sled to provide hardware-based acceleration for ciphering/deciphering and integrity. Please note that O-CU can be further disaggregated into two parts and run on different sleds if needed.

EP100 System



EP100 Sled

Figure 2. EP100 chassis/sled.

The midhaul network connects the O-DU and O-CU using a 10GbE SFP+ DAC cable. For the backhaul connection, we used another server set to install the enterprise 5G core network provided by our software partner Affirmed Network* (a Microsoft company). The O-CU and the Affirmed 5G Core network are connected via redundant switches with 10GbE SFP+ DAC cable for test and evaluation purposes (see Figures 3 and 4).

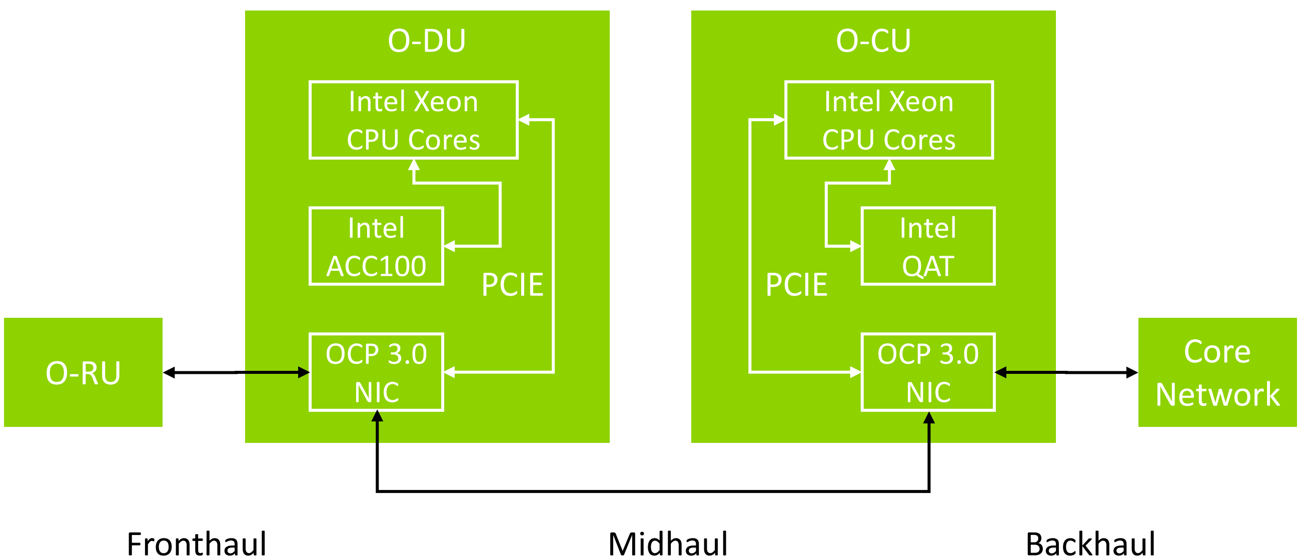


Figure 3. Hardware setup of Wiwynn 5g SA sub-6 GHz O-DU and O-CU.

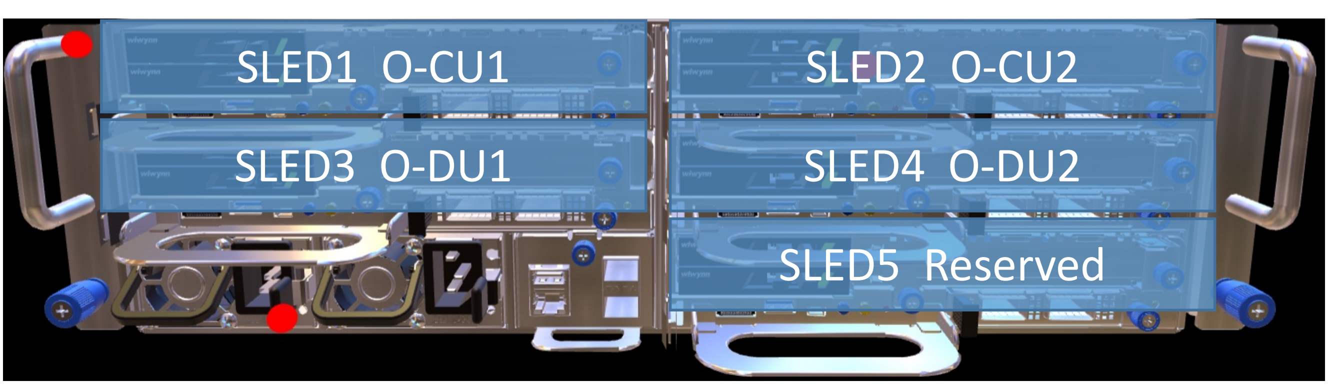


Figure 4. EP100 sled allocation.

To conclude, each sled is equipped with one Intel network adapter X710-DA4 and one PCIe card for special hardware functions. Refer to figures 3 and 4 for the hardware setup. In this smart factory usage scenario, only four sleds are used for CU/DU. The reserved sled will be for lightweight 5G Core network software package. The detailed hardware spec of EP100 sleds for O-DU and O-CU are listed in the Table 1.

	EP100 SLED CAPABILITY	TEST CONFIGURATION
PROCESSOR	1S 2nd Gen Intel® Xeon® Scalable processors	Intel® Xeon® 6209U CPU
DIMM	DDR4; up to 2933 MT/s; 8 x DIMM slots, supporting 2 x Intel® Optane™ Technology	CU: 128 GB DU: 256 GB
STORAGE	2 x U.2 hot plug SSDs 2 x onboard NVMe M.2 modules	7.68TB Not used
EXPANSION SLOT	1 x PCIe 3.0 FHHL x16 AIC	O-DU: Intel ACC100 accelerator O-CU: Intel® QAT card
	1 x OCP 3.0 Mezz (x16)	Intel® Ethernet Converged Network Adapter X710-DA4 (4-port 10Gbps SFP+)
SYSTEM DIMENSIONS	3U; 448 x 430 x 130.6 (mm) (W x D x H), 19" rack compatible	

Table 1. Hardware configuration of Wiwynn® EP100.

2.1.4 5G DU/CU Software Configuration

Table 2 lists the critical software stack of O-DU and O-CU.

As O-DU performs real-time L1 high PHY and L2 functions, the Linux kernel is updated with a real-time kernel patch. Intel FlexRAN is used for L1 high PHY function on the O-DU, which leverages DPDK for fronthaul transportation. To offload FEC from Intel FlexRAN to Intel ACC100 accelerator card, DPDK has to be patched to be utilized by Intel FlexRAN.

For time synchronization, PTP for Linux was installed on O-DU, which is a set of tools to provide necessary PTP functionality. The O-DU L2 function is provided by the Radisys Trillium* 5G NR solution 2.5.1. Radisys has adopted NETCONF/YANG to programmatically configure and manage its DU and CU solutions (implemented and provided by ConfD).

For the O-CU, the software configuration is less complicated. The Intel® QAT driver is installed for the use of Intel® QAT card. DPDK is also installed to bind the Intel QAT virtual function for O-CU usage. CU solution of Radisys Trillium 5G NR solution 2.5.1 and ConfD are installed to provide the O-CU function.

	O-DU	O-CU
OS	▪ CentOS 7.8.2003 Kernel 3.10.0 with real-time kernel patch	▪ CentOS 7.8.2003 Kernel 3.10.0
DPDK	▪ DPDK v20.11.1 with FlexRAN patch	▪ DPDK v20.11.1
DRIVERS		▪ QAT.L.4.15.0-00011
SOFTWARE	▪ Intel® FlexRAN™ 21.03 ▪ PTP for Linux ▪ Radisys Trillium 5G NR Solution 2.5.1 (DU) ▪ ConfD	▪ Radisys Trillium 5G NR Solution 2.5.1 (CU) ▪ ConfD

Table 2. Critical software stack of O-DU and O-CU.

ITEM	CONFIGURATION
FREQUENCY BAND	N78 (3.7GHz – 3.8GHz)
CELL BANDWIDTH	100 MHz
SUB-CARRIER SPACING	30 kHz
SLOT CONFIGURATION	DDDDDDDSUU
QAM (DL/UL)	256/256
ACTIVE UES	5
THROUGHPUT (DL/UL)	500 Mbps/20 Mbps

Table 3. Configuration Settings and Throughput

O-DU and O-CU functions operate through the cooperation of multiple software applications. Multiple processes and threads share the server's hardware accelerators and network adapters. Configurations of the hardware and software resources are critical to making the entire system work. The single CPU design of EP100 can simplify the configuration and reduce set-up efforts. For example, smart factories can run the DU with optimized kernel/driver configuration on one sled and specific optimized configuration for the CU on another sled, instead of running one single configuration for both CU and DU on a dual-CPU server system.

The used PCIe-based hardware accelerators and network adapters support Single Root I/O Virtualization (SR-IOV) to improve both performance and scalability. Multiple virtual functions (VFs) were created on those hardware devices and with the correct CPU cores and memory configurations to serve the required resources for O-DU and O-CU software/ applications.

For performance requirements, Linux Grand Unified Bootloader (GRUB) settings can be adjusted by software and applications. CPU cores must be isolated from the operating system for O-DU and O-CU software / applications usage. Huge pages support in the CPU is also enabled to improve performance. The CU/DU global specification is listed in Table 3.

2.2 Usage scenarios

Since the scope of the smart factory is broad, we selected two scenarios that can benefit from the advantage of 5G using scenarios from Wiwynn's factory. The first usage scenario is for automated optical inspection (AOI), and the second usage scenario is AMR. This section describes the architecture for AOI and AMR usage scenarios. The chapter also briefly reviews an overview of the platforms sed in the Wiwynn factory.

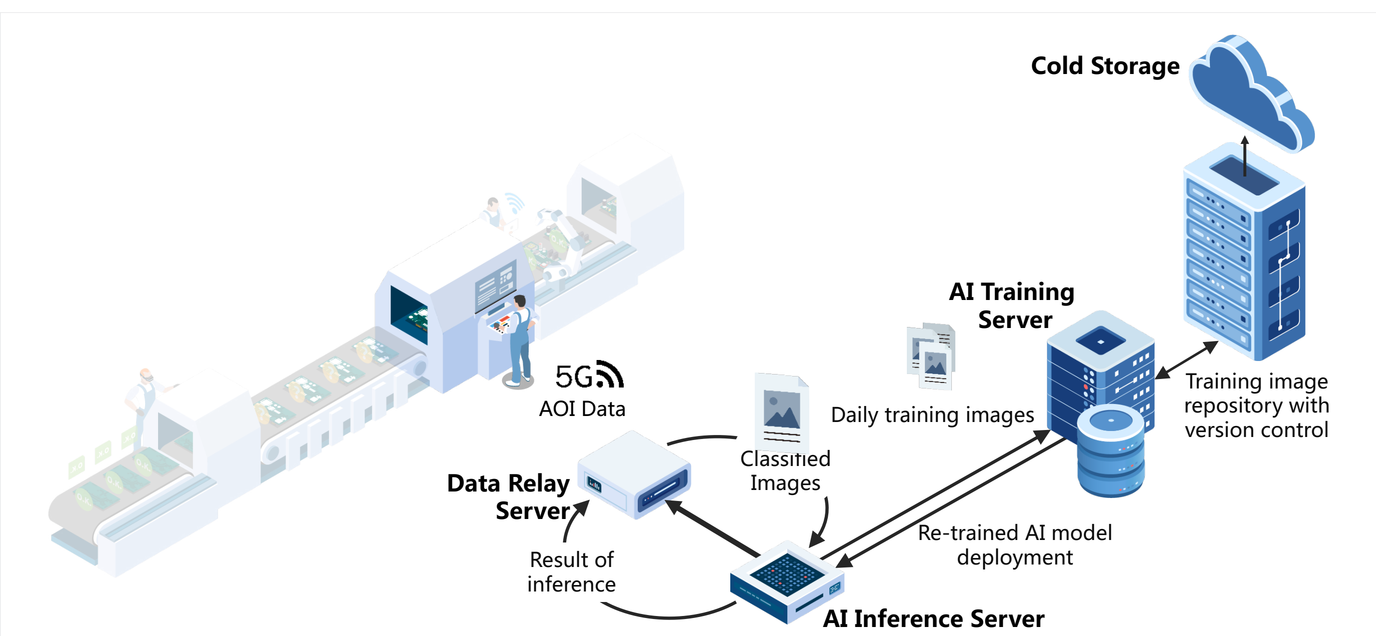


Figure 5. Architecture of Wiwynn AOI / AI on 5G platform.

2.2.1 AOI usage scenario architecture

AOI is a high-speed, high-precision optical image inspection system that uses "mechanical vision." The AOI system in this scenario does not provide 5G connection ability. However, a 5G uCPE device will be used as the repair station client to connect to the 5G platform. The relay server will synchronize the image files to the inference server as well as to the AI training server and image repository server (see Figures 5 and 6).

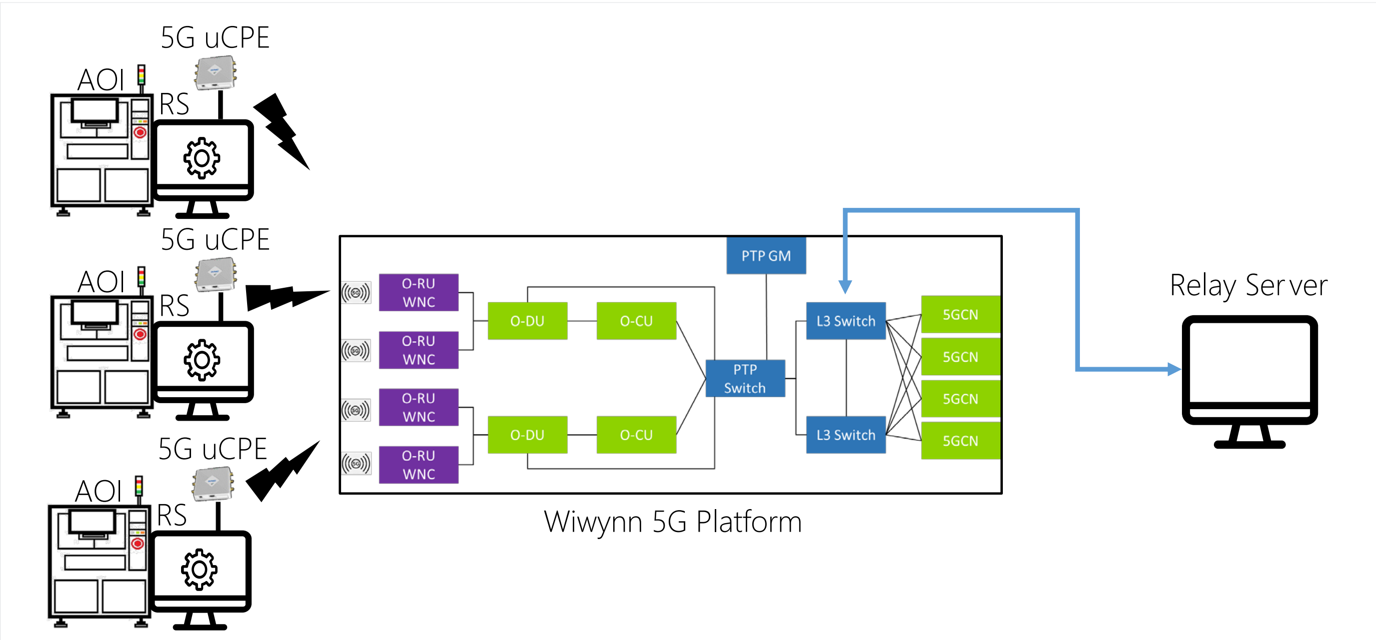


Figure 6. Topology for AOI on 5G platform.

2.2.2 AMR usage scenario architecture

AMR automatically carries material from a material preparation area (MPA) to the surface mounted technology (SMT) production line. With optimized planning in the fleet management system, AMR has multiple navigation paths to meet the requirements of different SMT lines. One 5G uCPE is used connect to the AMR to provide the connection to the 5G platform. Behind the 5G core network, the fleet management system will manage and plan the navigation path (see Figures 7 and 8).

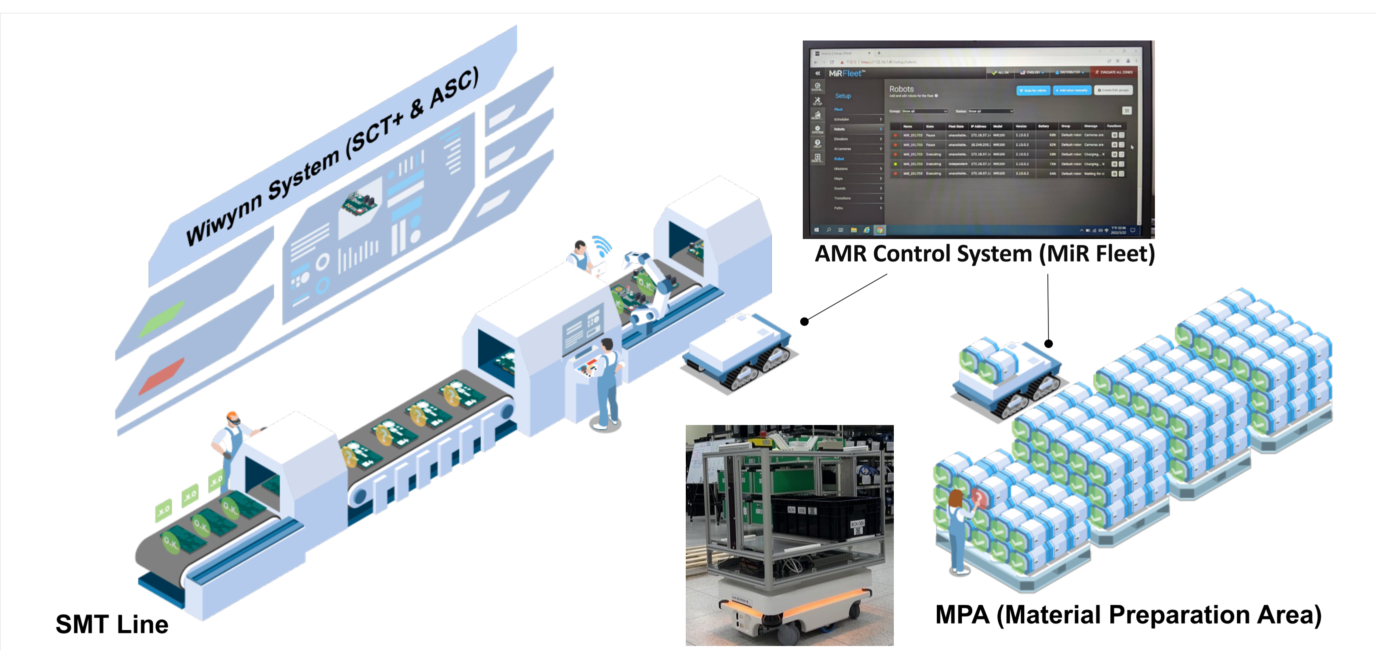


Figure 7. Architecture of Wiwynn AMR in in the Wiwynn smart factory.

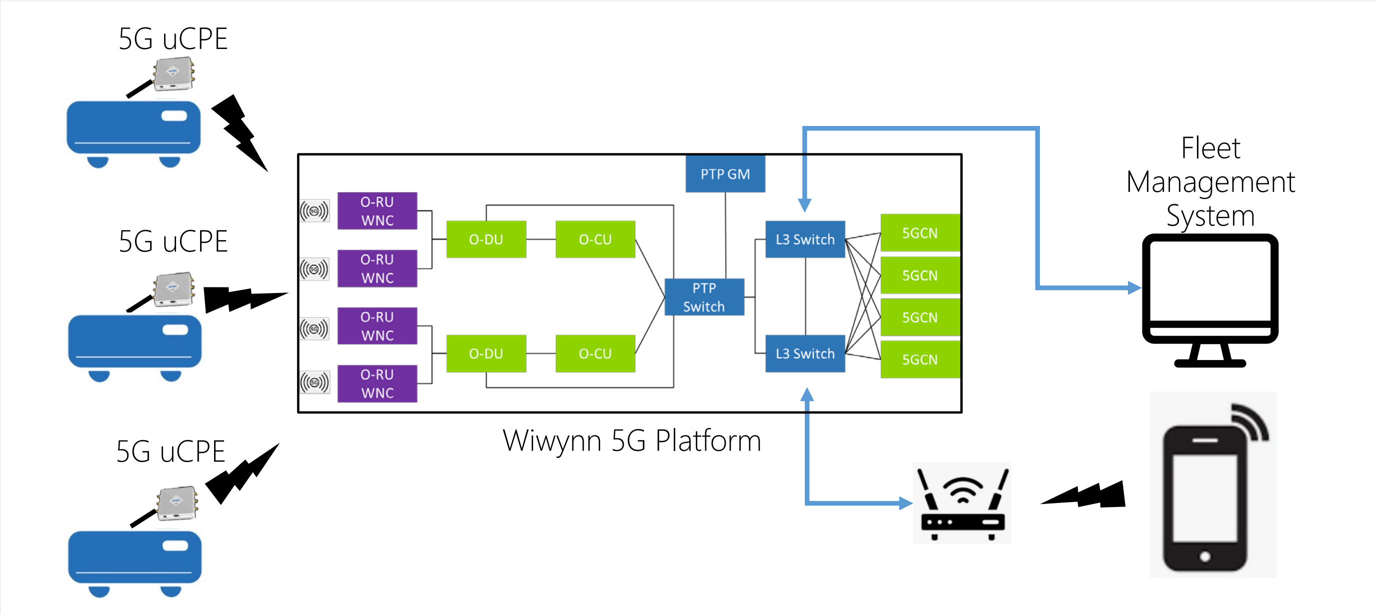


Figure 8. AMR topology on a 5G platform.

2.3 Field Site Deployment

2.3.1 Hardware list

The table below is the major equipment list that includes server, switch, RU and uCPE.

TYPE	DEVICE	QTY	REMARK
RACK	42U standard 19" rack	1	Install all equipment in this rack
SERVER	Wiwynn F5I	4	Affirmed 5G core network
	Wiwynn EP100 (5 sleds)	1	DU/CU server
	Wiwynn ES200	2	AOI AI training
	Wiwynn ES200	1	AMR fleet management system
	Wiwynn ES210	2	AOI relay & inference
SWITCH	Edgecore AS5812-54X-EC	2	Affirmed 5G core network HA
	Precision time protocol enabled switch	1	Fronthaul switch
	Juniper EX4300-48T-AFO	1	Management switch
5G DEVICE	WNC iRouter	16	5G uCPE
	WNC RU	6	Ceiling mount
	PTP grandmaster	1	

Table 4. Major equipment list of smart factory usage scenario.

2.3.2 Site survey

Before the actual deployment, Wiwynn 5G service teams will go through the site survey standard operating procedure (SOP) to plan the hardware, software, and the location for the RU deployment. Figure 9 shows the RU location based on the Wiwynn service team's field site simulation. Based on the simulation, the RUs should be ceiling-mounted.

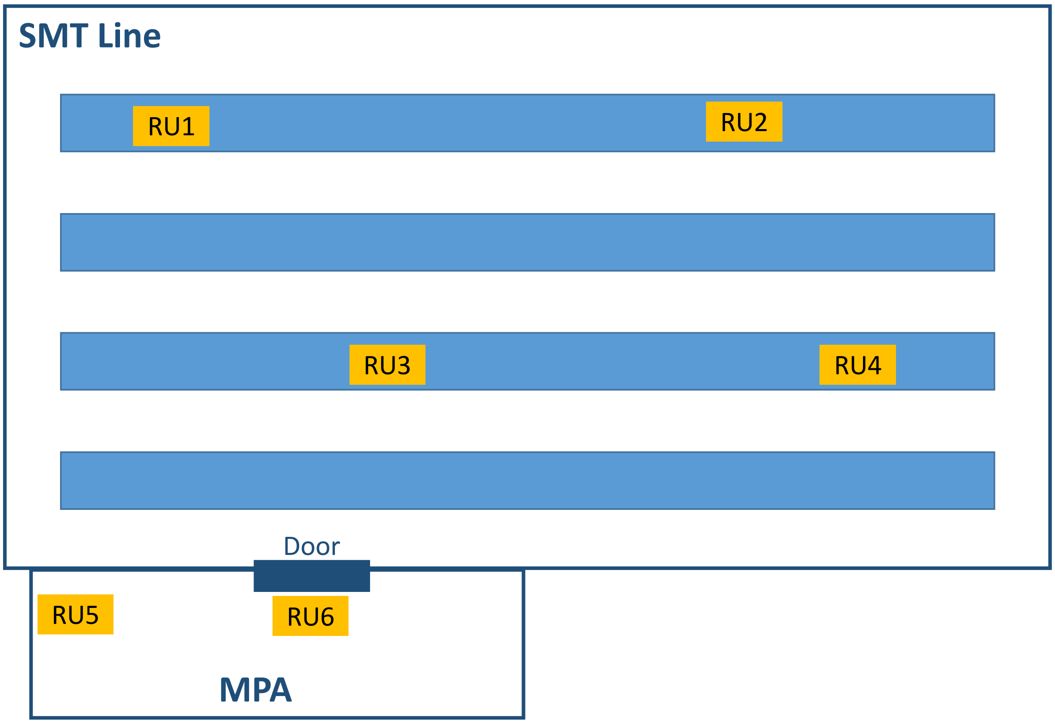


Figure 9. RU location via field site simulation.

Once the RU location simulation is completed and reviewed, the Wiwynn service team will move the 5G platform to the factory. Real UEs were used to evaluate the signal strength for each planned RU location. Figure 10 shows the most critical paths that are measured. From the figure, each rectangle is 10m x 10m, the floor height is about 3m. The brown area is the area with high signal strength, and the yellow is the area with low signal strength.

After the signal strength measurement, the Wiwynn service team will confirm that the measurement result is almost identical to the simulation. After that, we connect the 5G uCPE devices with AOI and AMR on the UE side and connect the AOI relay server and AMR fleet management system with Wiwynn 5G platform.

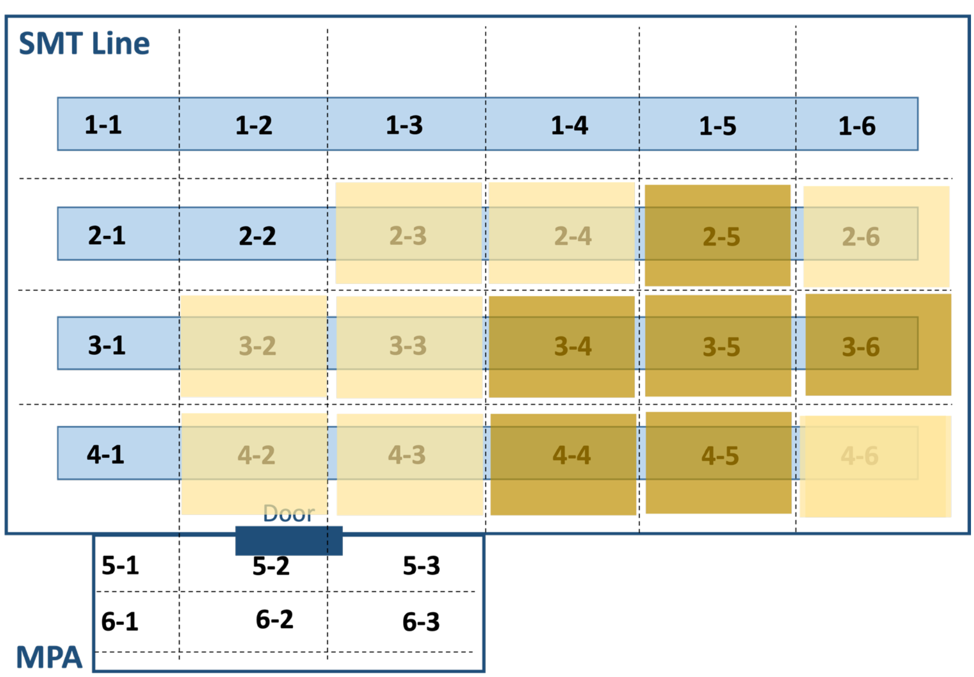


Figure 10. RU4 signal strength.

2.3.3 The challenge

From the successful deployment of the AOI and AMR scenarios, the Wiwynn service team overcame several difficulties:

- Field site simulation: Before running the simulation, a survey is made of the field site's space, the objects in the space, the object location in the space, the object material and its size must be listed in detail to improve the accuracy of the simulation.
- Field site signal measurement: The measurement of signal strength for each RU is a time-consuming job and needs to be repetitively executed. Location and direction of the antenna, and angle from uCPE to RU are all major factors that can affect the signal strength.
- UE handover: In this AMR scenario, Wiwynn successfully demonstrated the handover ability between different CUs and between different RUs (in the same DU). The algorithm to trigger the hand over process should be carefully evaluated based on the reality of the field site.

3. Acceleration of Wiwynn CU/DU platform

This chapter introduces the technologies used to achieve CU/DU performance requirements.

COMPONENT		DEPLOYED AT	ACCELERATION
INTEL® QAT CARD		CU server	Leverage the Intel ® QAT card to accelerate the encryption / decryption of the packet between CU and Core network servers
INTEL® ACC100 ACCELERATOR CARD		DU server	Accelerate the Forward Error Correction (FEC) in L1 high PHY
INTEL X710 NIC		CU server	Leverage the Dynamic Device Personalization (DDP) feature to accelerate the packet forwarding performance
INTEL ENHANCED PLATFORM AWARENESS (EPA)	CPU pinning	CU/DU	Pin the CPU cores to allocate the dedicated CPU resource to avoid the context switch and cache swapping
	Huge pages	CU/DU	Allocate the continuous and fixed memory space to accelerate packet processing performance
	DPDK	CU/DU	DPDK provides the drivers for Intel QAT card, Intel ACC100 dedicated vRAN accelerator card, and Intel X710 NIC

Table 5. Hardware accelerators used in Wiwynn smart factory 5G application.

4. Conclusion

Driven by the huge demand from digital transformation, 5G technology is in a good position to accelerate different deployment scenarios. With 5G's high throughput, high mobility, low latency and easy-to-deploy characteristics, it is becoming easier to develop and deploy in many smart factory use cases. This white paper explored two usage scenarios, AOI and AMR, which were deployed in the Wiwynn factory. 5G -powered AOI provides high throughput image file transformation. 5G also avoids the construction of a wired network in an existing environment. For 5G-based AMR, this solution successfully demonstrates 5G mobility and low latency requirements. The field site experience described in this paper can be carried over to serve as a reference that can accelerated the development of other usage scenarios.

5G networks use disaggregated architectures to achieve capital and operating cost savings as well as greater deployment flexibility. The O-RAN Alliance has standards that enable the disaggregation of RAN networks and a more competitive and vibrant RAN supplier ecosystem. This open ecosystem is accelerating innovations to improve user experience and the efficiency of RAN deployments for mobile operators. Wiwynn 5G SA sub-6 DU and CU solution applies O-RAN Alliance standards and are deployed on its OCP openEDGE-based EP100 platform.

The solutions adopt Intel Xeon Scalable processors, hardware accelerators, Intel FlexRAN reference architecture, and Radisys Trillium 5G NR solution, which is capable of running 5G RAN functions and supporting O-RAN standards.

The Wiwynn EP100 platform is well designed for communication service providers to deploy open, disaggregated, and scalable radio access networks. The single CPU design of the EP100 sled simplifies software deployment and saves set-up efforts. The flexibility that enables the configuration of different sleds in the same EP100 chassis helps mobile operators deploy RANs at different scales and with different time synchronization configurations. They can scale out by adding more EP100 systems. On the other hand, they can use one fully equipped EP100 chassis for 5G-in-a-box to provide holistic private 5G network functions including RAN, Multi-access Edge Computing (MEC), and 5G Core Network.

About Wiwynn

Wiwynn® is an innovative cloud IT infrastructure provider of high-quality computing and storage products, plus rack solutions for leading data centers. We aggressively invest in next generation technologies for workload optimization and best total cost of ownership (TCO). As an Open Compute Project (OCP) solution provider and platinum member, Wiwynn actively participates in advanced computing and storage system designs while constantly implementing the benefits of OCP into traditional data centers.

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Intel® Network Builders is an ecosystem of infrastructure, software, and technology vendors coming together with communications service providers and end users to accelerate the adoption of solutions based on network functions virtualization (NFV) and software defined networking (SDN) in telecommunications and data center networks. The program offers technical support, matchmaking, and co-marketing opportunities to help facilitate joint collaboration through to the trial and deployment of NFV and SDN solutions. Learn more at http://networkbuilders.intel.com.