User Case

Comba 5G containerization 5G Components
Intel® Smart Edge
Intel® Xeon® Scalable Processor / Intel® Xeon® D Processor

5G Private Network for Smart Factory

Private 5G in a Smart Factory Enabled by Intel® Smart Edge and Comba's 5G RAN and 5G Core.

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Preface

By embracing digital transformation, factories are moving to automation leveraging AI to reduce monotonous work and dangerous heavy lifting tasks for human workers and to enable efficient and safer factory management. 5G plays a key role for remote management in factory automation. In this transformation to smart and connected factories, automated guided vehicles (AGVs) deserve significant attention. In this solution brief, we present a smart factory solution using Intel® Smart Edge, Intel architecture CPUs, and Comba's 5G network functions. The solution uses private 5G and AGVs to enable connected and smart factories. We tested the solution in Comba's factory, showing how automation through AI and remote management resolved several daily pain points for workers and increased efficiency and accuracy of tasks.

1. Pain Points in Factories

1.1. Material Movement

Handling materials, such as stock, work in process and other parts, and moving them from location to location is a manual process that is not time or cost efficient. AGVs are now being used to automate this process. However, AGVs need computer vision and connectivity capabilities to be fully functional and autonomous.

AGV laser navigation is one solution, but the cost is high, and setting up the system in a typical warehouse environment is relatively complex. Any mistakes can impact AGV positioning due to instability of Wi-Fi connectivity in an electrically noisy factory environment. Signal disruptions can mean insufficient AGV references for large changes in environmental factors. The Comba solution discussed in this paper provides 5G and AI capabilities to AGVs to ensure full automation, resolve the limitations in current AGV deployment, and provide high efficiency and accuracy equal to, or better than a manual process.

1.2. Asset Tracking

High value tools and equipment in a factory are frequently used and it is important to track them to ensure they are replaced and ready for the next use. Today's Bluetooth-based indoor high-accuracy positioning systems can be used to quickly track the real-time location and usage status of tools and equipment. However, Bluetooth beacons that are used in the solution have between 3-5 meter of precision, which, in many cases still leaves a lot of manual searching to find the missing tool.

For some dangerous or high-risk jobs, precise location is needed but it's also to identify whether the personnel using the tool is in a safe state, and if the personnel skill and training is appropriate for the high-risk job. This will improve safety by not allowing employees who don't have relevant skills to have access to high-risk areas. Our solution helps resolve these limitations providing accuracy in real-time asset tracking and helping workers safety in high-risk areas.

2. Overall Solution

2.1. Objective

The objective is to build an edge solution that provides intelligent and efficient management of Comba's factory leveraging a private 5G network with computer vision and Ultra-Wideband (UWB) to improve autonomous guided vehicles (AGV) operation.

2.2. Architecture

The Comba factory includes five floors, and the 5G signal needs to cover the entire factory area. The overall architecture is shown in Figure 1:

- UWB base stations and pRRUs are deployed in different areas to provide connection for user equipment
- The rHUB provides electric power for all pRRUs
- The 5G base station, 5G core and edge applications are all running on an Intel Smart Edge cluster
- The Intel Smart Edge cluster provide services and exposes servers to factory managers

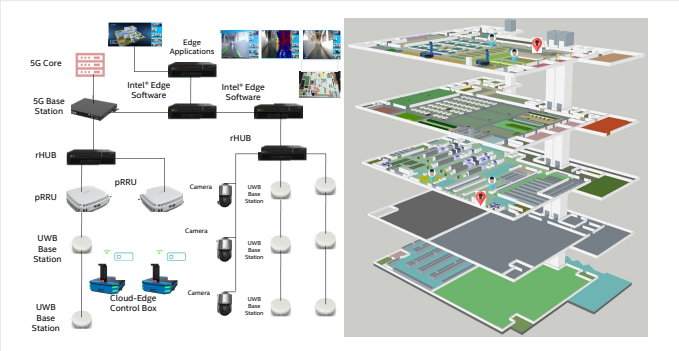

Figure 1. Solution overview.

2.3. Hardware for the Edge Deployment

Comba's private remote radio unit (pRRU) is used to provide 5G new radio (5GNR) signals. Comba rHUB is used to provide power for pRRU and support multiple pRRU access. Both vRAN and 5G core are deployed on Intel® Xeon® Scalable processor-powered servers using cloud native containerization.

For different numbers of cells, two sets of basic hardware references are provided:

1. Based on the Dell EMC PowerEdge R750 Server, 3rd Gen Intel® Xeon® Scalable processor-based server, the multi-cell reference design supports up to four cells and reserves 38 cores to provide computing resources for complex edge applications.

HARDWARE	NOTES
Dell EMC PowerEdge R750 Server	Single Server 3rd Gen Intel® Xeon® Scalable CPU 100GbE Intel® Ethernet Network Adapter E810-CQDA2 Intel® vRAN Accelerator ACC100 Adapter Intel® QuickAssist Technology
Comba rHUB	5G indoor mini base station expansion unit
Comba pRRU	Remote radio unit
Comba GPS	Time service antenna

Table 1. Multi-cell reference design using 3rd Gen Intel® Xeon® Scalable CPU.

2. A single cell reference design, based on Intel® Xeon® D CPU, supports one cell and reserves 10 cores to provide computing resources for edge applications.

HARDWARE	NOTES
Moro City Customer Reference Board Server	Single Server Intel® Xeon® D CPU 25GbE Intel® Ethernet Network Adapter E810-XXVDA4 Intel® vRAN Accelerator ACC100 Adapter
Comba rHUB	5G indoor mini base station expansion unit
Comba pRRU	Remote radio unit
Comba GPS	Time service antenna

Table 2. Single cell reference design on Intel® Xeon® D CPU.

The hardware deployment topology is illustrated in Figure 2.

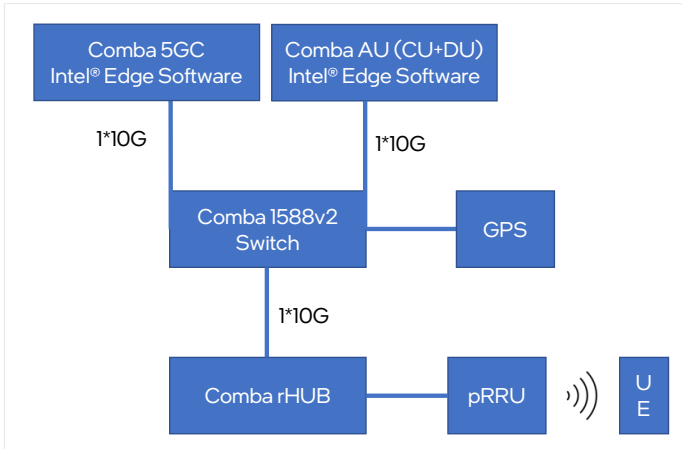

Figure 2. Hardware deployment topology.

2.4. Software Stack

Intel Smart Edge provides cloud native workload orchestration for network functions and for edge applications with abstraction of the underlying hardware complexity, ease of use for accelerators, and optimization on IA for network and applications workload. Comba's vRAN, 5G core and industrial intelligent edge applications are on-boarded on an Intel Smart Edge cluster to provide intelligent industrial services for smart factories.

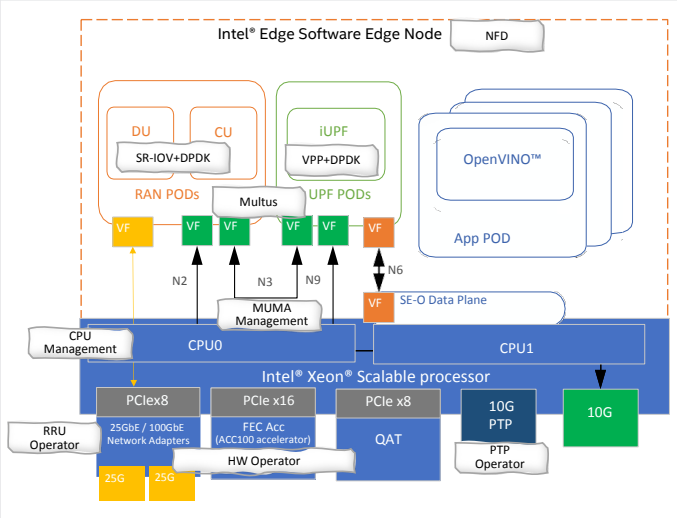

Figure 3. Network software stack.

Intel Smart Edge also provides several cloud native capabilities for ease of use of hardware capabilities and resources management for 5G and edge applications workload. These include:

- **NFD:** Node feature discovery adjusts the scheduling strategy for container workloads through the detection of hardware features.
- **Multus CNI:** Multiple network interfaces are provided for 5G network components. Calico is used for the control plane and single root I/O virtualization (SR-IOV) is used for the data plane.
- **SR-IOV:** Provides a high-performance data plane for 5G network functions.
- **CPU Management:** Provides CPU isolation, CPU allocation and CPU scheduling to support 5G network functions and edge applications.
- **Non-uniform memory access (NUMA) Management:** Provides information to schedule 5G network functions on nodes having memory and I/O co-location.
- **Hardware operators:** Provides the cloud native management capability for different hardware. In this case, it involves the management of Intel® QuickAssist Technology (Intel® QAT) and forward error correction (FEC) accelerator cards.

2.5. Opportunities for Cloud-Native Edge Applications with 5G

Several cloud-native applications are provided to help multiple deployment scenarios with private 5G for factory automation. All the edge applications are running as services on the Intel Smart Edge platform.

2.5.1 360° Panorama Monitoring

360° cameras stream video to the edge platform over 5G, where video analytics take place. The video analytics application allows monitoring of the environment for safety, and timely alarm information in the event of emergencies.

2.5.2 Automatic Identification

Workers have headsets connected to the 5G network and are streaming data that allows inspection of employees' temperature and facial recognition. For factories that have different production areas, employees in each section are assigned corresponding permission rights only to their production area. This application helps to decentralize and automate the access control and enhances plant security.

2.5.3 Manipulator Control

With 5G, robotic arms can respond in real-time to remote control. This helps automate and remotely manage complex tasks and improves flexibility and efficiency of the production line, while greatly reducing the cost and lifecycle of production line transformation.

Figure 4. Cloud native manipulator control.

2.5.4 Augmented Reality (AR) Glasses/ Remote Workstation Guidance

With high-throughput and low latency 5G coverage, employees at different debugging stations can use augmented reality (AR) glasses to share what they are seeing and collaborate. Both parties of the collaboration wear AR glasses and launch real-time remote guidance for specific problems. Engineers that are subject matter experts examine problems through the video provided by the AR glasses, provide real-time guidance and collaboration that can solve the problem and ensure production efficiency.

Figure 5. Collaboration across remote workers.

3. Usage Scenarios in Factories

3.1. AGV with 5G and Computer Vision

3.1.1 Solution

AGVs transmit their environmental information over 5G, which is collected by multiple cameras connected to an edge node. Running on the edge node is a navigation application that provides scene and environment analysis through computer vision and sends path planning information to the AGV for both safe navigation and movement and also helping them to carry out their assigned tasks.

Figure 6. Solution overview.

AGVs can be used to transfer products and materials across various production lines, buffer zones, and test zones thereby improving efficiency and reducing the need for manual labor to undertake such tedious tasks.

3.1.2 Key Technologies

1) **Computer Vision for navigation, positioning, and obstacle avoidance**

Thanks to 5G, the cameras on AGVs can transmit video streams to edge servers that host computer vision applications for AGV navigation based on a global view of the warehouse environment. With 5G and computer vision applications at the edge, Comba's factory automation solution can avoid the use of expensive 3D laser radar reducing the AGV's cost and ensuring safe navigation with accurate obstacle detection based on a global view of the environment.

2) **High Definition (HD) monitoring for the environment**

5G offers high uplink bandwidth which enables the Comba 5G Smart Factory solution to support better physical security and environment control through 360° monitoring using security cameras with multiple zoom capabilities and visual inspection techniques.

3) **Unified task management**

With 5G-connected AGVs and computer-vision based navigation, assisted by edge applications, assigning and managing tasks for AGVs can take place in the edge server. This will reduce AGV's cost because that will require less onboard compute capabilities and, at the same time, will provide better collaboration for tasks among AGVs.

3.1.3 Value Added in Factories

1) **Lower cost**

Because it replaces the high-beam laser radar navigation with 5G sensing, the Comba 5G Smart Factory system can drive down the cost of AGV systems and hence ushering in scalability for larger deployments.

2) **Accurate tracking**

High-definition video monitoring helps the Comba system to identify which reference objects are fixed and which reference objects are temporarily added. This provides real-time monitoring and accurate tracking.

3) **Significantly reduce the blind spots for AGV**

Currently, obstacle avoidance is mainly achieved through ultrasonic radar and laser. Laser is responsible for only one plane. If objects appear above or below the laser scanning plane, the laser system cannot perceive them. Ultrasonic radar has been used to overcome this scanning plane challenge, but it has a large blind spot in that it too has a fixed scope of view and cannot see around corners or through obstacles. Even the smallest protrusion on the ground can cause an ultrasonic malfunction requiring human intervention. Using these systems, obstacle avoidance is a big problem in practical application. The Comba factory automation solution offers visual recognition through cameras mounted on the AGV which provides the ability to see obstacles in all directions, which results in a very high recognition accuracy.

4) **Cross floors and buildings transportation**

With navigation and task management deployed in the edge server, the AGV can automatically move from building to building providing transportation for boxes and cases, for example, from production to shipping.

3.2. UWB System with 5G

3.2.1 Solution

The Comba 5G small base station platform is composed of a three-tier architecture that includes an access unit (AU), a remote radio unit hub (rHUB) and a pico remote radio unit (pRRU).

The baseband AU is hosted on a server that is powered by a range of Intel® architecture CPUs including Intel® Xeon® Scalable processors and Intel® Xeon® D processors. These are COTS servers that support Comba's hardware and software disaggregation architecture. The AU is deployed in a cloud native cluster using Intel Smart Edge and can be scaled with new pRRUs and other base stations making the 5G network flexible and upgradable.

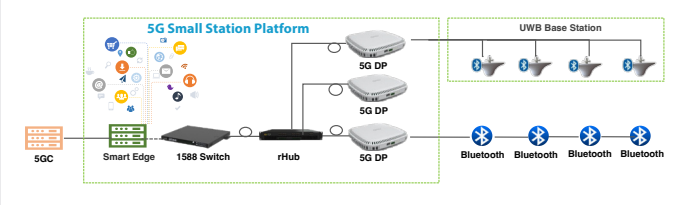

Figure 7. Solution overview.

Comba's base station supports UWB positioning through standard radio interfaces, which expands the high precision indoor positioning capability for 5G networks. For indoor positioning applications, the Comba solution combines 5G for low latency, high bandwidth, and high reliability characteristics; with UWB which brings high-precision location reporting to within centimeters. This UWB high-precision positioning application is deployed on the edge cluster to provide a more economical and flexible deployment solution for enterprise indoor positioning applications. In addition, a geographic information system (GIS) is deployed in the edge server cluster, that displays all information from these sensors including material location, status, movements, etc. The GIS system helps managers to get an overview on the material flow of the whole factory.

3.2.2 Key Technologies

1) **Ultra-wideband**

Ultra-wideband communication technology brings several advantages such as low system complexity, low density of transmitted signal power spectrum, insensitivity to channel fading, low signal interception ability, and high positioning accuracy. It is especially suitable for high-speed wireless access in dense multi-path scenarios. It can effectively remedy the indoor signal blind areas defects of satellite positioning technology and solve the poor accuracy and weak reliability problem of traditional positioning technology. 5G combined with UWB allows for the management of UWB positioning through the 5G base station. UWB is very useful in smart factories enabling real-time positioning.

2) **Geographic information system**

Through the combination of 3D GIS technology and the Comba factory management application, all kinds of information, including positioning information and robot real-time status, and 3D geographic information can be displayed intuitively for the factory managers. It solves the problem of miscellaneous and disordered information in traditional information systems and helps the decision-making analysis and management.

3) **Video monitoring**

Combining high precision positioning systems and video monitoring system at the edge server cluster enables real-time best-camera selection for tracking based on the location provided by high-precision positioning system and the algorithm model. Objects can always be in the best video shooting state using the camera's pan/tilt/zoom (PTZ) capabilities to control angle and focus. The integration of these two systems and 5G communication brings real-time video information to the positioning system and makes it possible for video to monitor and follow specific objects. This technology can also be applied to workers to monitor for safety and AGV control.

3.2.3 Value Added in Factories

1) **Object high precision positioning**

5G with UWB offers low latency and highly reliable connectivity combined with UWB's high precision location service capability. This brings benefits to factories where workers and objects could be located precisely down to the centimeter range.

2) **Material tracking**

The Comba 5G Smart Factory solution enables tracking and monitoring for key materials and assets and provides a reliable capability for internal logistics scheduling.

3) **AGV on-demand Call**

The Comba 5G Smart Factory system with 5G with UWB enables AGV task management and scheduling within designated locations. Combining high precision positioning technology with robot technology, and using location awareness and mobile interconnection technology, factory operators can call the AGV to a specific position anytime and anywhere through a 5G-connected mobile terminal and change the original fixed driving line mode of AGV into an on-demand call mode, expanding the use of the AGV and improving the production efficiency.

4) **Factory safety and security**

Combining high precision positioning technology with video monitoring enables real-time video tracking of objects and workers located in unsafe areas using a 360-degree spherical camera. This system intelligently selects the camera, sets the focus, and controls the PTZ, providing a reliable system for enterprise security, worker safety, and resource scheduling.

4. Summary

Comba's factory automation system provides a solution for factory automation leveraging Intel architecture CPUs, Intel Smart Edge and Comba's 5G CNFs, Comba tested the solution in Comba's Guangdong intelligent manufacturing factory, where the results was that the solution helped Comba to improve factory efficiency and improve production.

5. Abbreviations

5G	5th Generation Mobile Communication Technology
PWEK	Private Wireless Experience Kit
AU	Access Unit
CU	Centralized Unit
DU	Distributed Unit
AGV	Automated Guided Vehicle
PCB	Printed Circuit Board
UWB	Ultra-Wideband
RRUH	Remote Radio Unit Hub
PRRU	Pico Remote Radio Unit
GPS	Global Positioning System
vRAN	Virtual RAN
AOI	Automated Optical Inspection
CPE	Customer Premises Equipment
AR	Augmented Reality
GIS	Geographic Information System

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