Externalization of Smart Factory Solution using Local 5G

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The 5th generation mobile communication system (5G) features “ultra-high speed / large capacity,” “ultra-low delay / high reliability,” and “multiple simultaneous connections,” and verification tests of “local 5G” that utilizes this 5G in local private networks are being conducted in various fields.

OKI has conducted a PoC (Proof of Concept) of the “Local 5G + Visual Abnormality Detection System” from FY2020, and started operation at a section of its Honjo Plant. This article introduces the externalization efforts of the system based on the operation results at the plant.

Application of Local 5G Solutions to Manufacturing Industry

Labor reduction, automation, and robotization in manufacturing are being considered at many factories, and are being adopted mainly for line work. However, looking at each process, the reality is that automation has not progressed in the “assembly” and “inspection” processes. Automation of these processes are said to be difficult since they often rely on the knowledge (know-how) and techniques of skilled workers.

There is an urgent need to pass on these knowledge and techniques, including those of experienced technicians, through digitization, and it has become an inevitable initiative for manufacturing sites to promote digital transformation (DX) in assembly and inspection processes where manual work remains. In the automation of manual work, importance lies in how to digitize the techniques possessed by skilled workers. Currently, there are high expectations that the use of images corresponding to the “eyes” of skilled workers, and the use of data and AI corresponding to the “knowledge” will serve as the means. AI solutions that utilize images aim to digitize the “eyes” and “intelligence” of skilled workers to save manpower, and OKI’s Visual Abnormality Detection System is precisely the system that utilizes images and AI to automate the inspection process.

Moreover, production factories need to be wireless for layout flexibility, and reliability and confidentiality must also be ensured for operation continuity and prevention of information leakage. Local 5G, which requires a license for usage, has been cited as the solution to ensuring the reliability and confidentiality required with wireless communication. Local 5G with its ultra-high speed and large capacity features is also suitable for transmitting image data from high-definition cameras. Therefore, it is considered an ideal wireless communication system for the manufacturing industry.

Overview and Status of Local 5G Solutions

(1) Overview of Visual Abnormality Detection System

The Visual Abnormality Detection System automates the visual detection of product abnormalities in real-time using AI image analysis at the edge domain[1]. The detection results are immediately notified to the worker, and the inspection images, product information, and other trace data including the detection results are stored in the upper level management server for use in analysis and quality control (**Figure 1**).

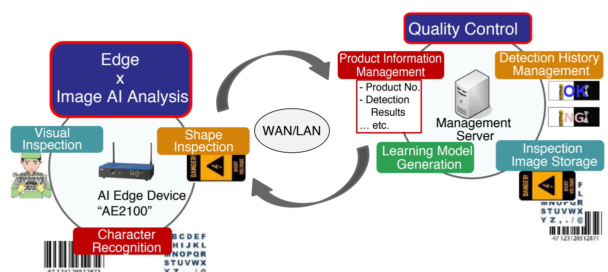

Figure 1. Configuration of Visual Abnormality Detection System

Three application examples of the Visual Abnormality Detection System are presented below.

1) Board Mounting Inspection

Confirmation of screw attachment during board mounting is performed when the assembly work support system receives a completion notification from the electric screwdriver.

The presence or absence of screws is checked by visually detecting abnormalities according to predefined rules (**Figure 2**). Since the inspection characteristics for the presence or absence of screws are specifically defined, a “rule-based” method was adopted as the image analysis method. This makes it possible to detect not only the presence or absence of screws, but also whether screws of the correct color, size, and shape have been attached. If an abnormality is detected, the worker is immediately notified and early countermeasures can be taken.

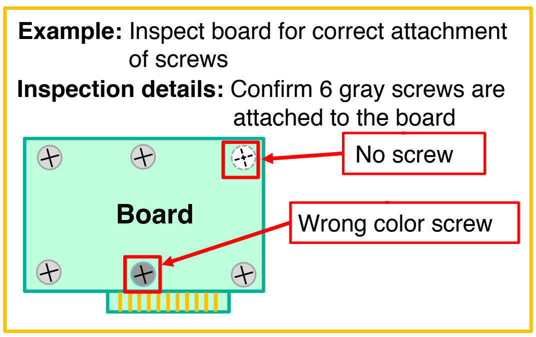

Figure 2. Screw Attachment Inspection

2) Casing Inspection

During casing inspection, the top cover is checked for scratches and stains (**Figure 3**). Since it is necessary to capture indistinct and varying conditions such as straight scratches, curved scratches, stains, etc., “deep learning” was adopted as the image analysis method. By learning both normal and abnormal images, and formulating rules for decision making in advance, detection results can be obtained immediately after image acquisition.

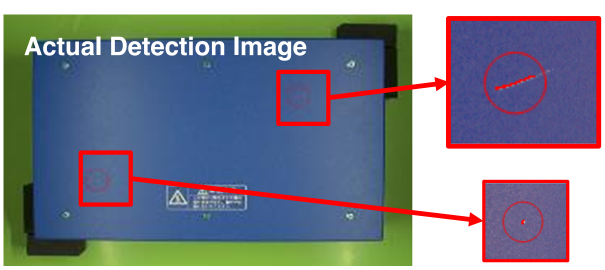

Figure 3. Scratch Detection of Top Cover

3) Nameplate Character Inspection

In the character inspection of a nameplate, standard characters in a specified section are checked for chipping using “rule-based” image analysis (**Figure 4**). In a given detection, if the luminance value is determined to be black, there is no character chipping. However, if there is a break in the black color, character chipping is determined to exist. At the same time, OCR is used to check whether the correct characters are printed.

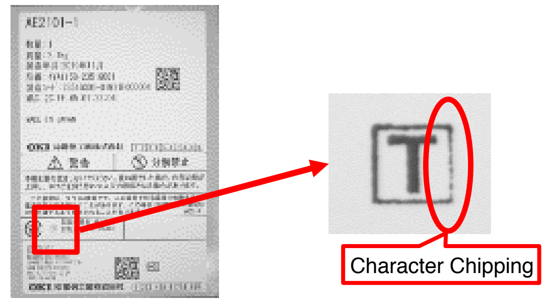

Figure 4. Nameplate Character Inspection

(2) Status of Local 5G Initiative

Prior to implementing local 5G at the Honjo Plant, the wireless communication characteristics of Sub6 band local 5G was measured in the production area[2]. The target area covered approximately 4800m^2 (about 80m x 60m). Measurements were taken with the base station placed at a height of 3m in the center and near a wall of the target area. The terminals were placed at 25 locations, including line-of-sight and out-of-sight, at a height of 1m. **Figure 5** shows the floor plan and measurement points.

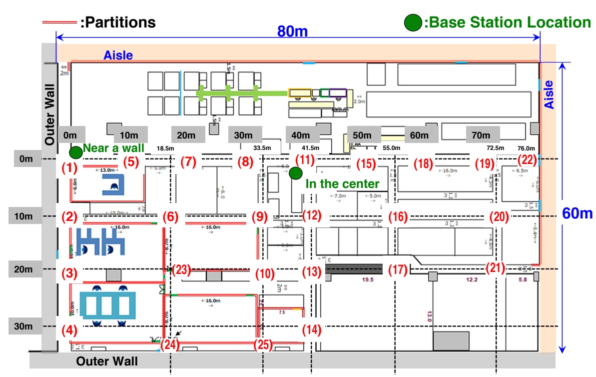

Figure 5. Floor Plan and Measurement Points

Figure 6 shows the measurement results of the uplink TCP throughput at each measurement point when the base station was placed in the center of the target area, and **Figure 7** shows the same measurement results when the base station was placed near a wall. The throughputs were measured for one minute, and the measurement results of the average throughputs (Mbps) were as follows.

Good throughput characteristics can be obtained at locations within a certain distance and in line-of-sight of the base station. It was also confirmed that even out-of-sight areas can obtain suitable throughput characteristics if power reception is high due to reflected waves from production equipment, etc.

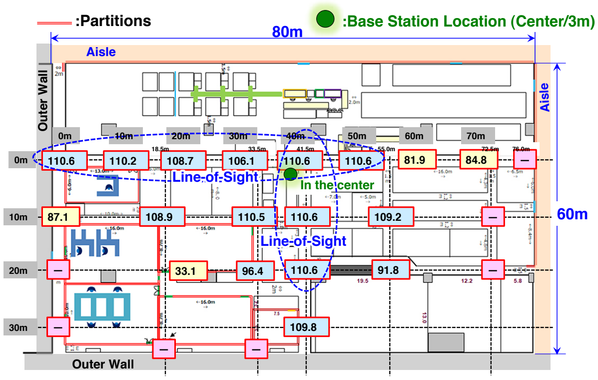

Figure 6. Uplink TCP Throughputs (Center/3m)

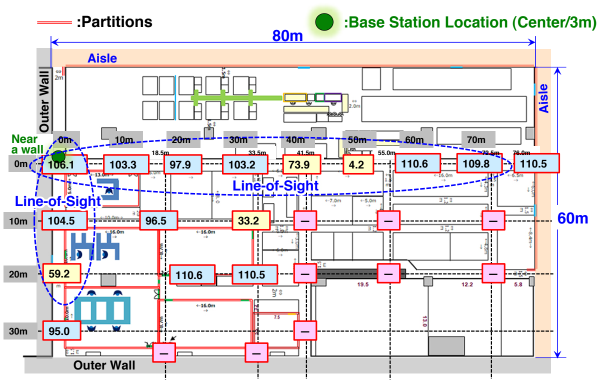

Figure 7. Uplink TCP Throughputs (Near Wall/3m)

In a factory, it is presumed that various reflected waves from production equipment, partitions, walls, workers, etc. exist in a complex manner, and even if the communication distance is the same, differences in received power will occur. Therefore, it is important to check the characteristics (radio wave propagation environment) of each factory where the local 5G will be implemented and to consider in advance where the base station should be installed.

Sub6 band local 5G is approved for outdoor use on certain specified frequencies (4.8 - 4.9GHz). Using the same local 5G equipment, wireless communication characteristics were measured while moving the terminal at 10km/h on the outdoor test course of the Honjo Plant. **Figure 8** shows the measurement results of TCP throughput and received power with respect to the distance from the base station.

At an outdoor environment where there are only a few reflecting objects such as buildings nearby, the reflected waves are predominantly from the ground, and in many cases the wireless communication characteristics follow a two-wave model with the direct waves. Downlink communication is possible up to about 140m, but it was confirmed that communication may be difficult in places where the received power drops in the two-wave model.

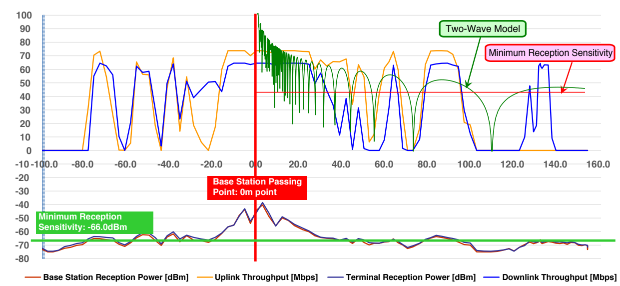

Figure 8. Results of Outdoor Wireless Communication Characteristics

Although local 5G features “ultra-high speed / large capacity,” “ultra-low delay / high reliability,” and “multiple simultaneous connections,” it is not possible to simultaneously achieve all of these features. Therefore, the feature prioritized for implementation differs depending on the device vendor (device model). OKI currently possesses several local 5G devices, and is verifying their wireless communication characteristics and connectivity to different base station models.

Issues and Resolutions for Externalization

(1) Externalization of Visual Abnormality Detection System

In preparation for externalization, the system was re-evaluated based on each verification result. Specifically, since there is a trade-off between image resolution (analysis accuracy / system response time) and network bandwidth, an acceptable configuration needed to be devised. High-precision analysis of high-definition images requires large-capacity data transmission, which extremely pressures network bandwidth. Therefore, the analysis process was re-evaluated and system configuration was changed so that image analysis is performed at the edge domain close to the device (camera) and transmitting only the analysis results to the network. This enables high-precision analysis of high-definition images without overloading the network.

Next, the operational aspect was addressed. Accuracy of image analysis is greatly affected by the imaging environment. In order to maintain high-precision image analysis, an operation manual was prepared for customers so that periodic system maintenance can be performed only by adjusting parameters.

As described, from the perspective of implementation and operation, necessary functions and operational procedures were prepared enabling the externalization of the Visual Abnormality Detection System.

(2) Externalization of Local 5G

From measurements of wireless communication characteristics taken in an actual factory, it was confirmed that even if the distance from the base station is the same, the characteristics differ depending on obstructions such as production equipment. Since the usage environment and usage requirements differ for each site, local 5G has been externalized by establishing the following procedure.

Step1. Investigate usage environment -> Base station placement design

Step2. Clarify usage requirements -> Device model selection

Step3. Construct system -> Measurement and analysis of wireless communication characteristics

Step4. Feedback the above measurement and analysis results to base station placement design

First, local survey of the usage environment at the externalization site is conducted to confirm the size of the local 5G communication area, height of the ceiling, layout of production equipment, etc. The usage environment is modeled as a radio propagation environment, and using simulation tools, the location to install the local 5G base station is evaluated (**Step1**). Specifically, in the modeled radio propagation environment, the position and height of the base station are used as parameters to estimate the reach of the radio waves.

Next, the customer at the externalization site is interviewed regarding the number of terminals that require local 5G communication and applications to be used. Based on this information, requirements such as throughput, permissible communication delay, and number of connections are clarified, and a local 5G device model capable of meeting the requirements is selected (**Step2**).

After procuring the selected device, the local 5G system is built according to the usage environment and network configuration of the externalization site, and the wireless communication characteristics are measured (**Step3**). The received power is then measured to confirm where and to what extent the radio waves are reaching. Additionally, throughputs and communication delays are measured using tools such as iPerf and ping at locations where the local 5G devices are assumed to be installed. In order to perform these measurements quickly and accurately, OKI is working to improve the operability of measuring instruments and tools, establish measurement methods, and standardize analysis of measured data.

The measurement/analysis results of **Step3** are fed back and compared/verified with the estimated values from the radio propagation simulation performed during the base station placement design of **Step1** to improve the accuracy of the simulation (**Step4**). By accumulating various radio propagation models, it will become possible to bring the estimated values obtained from the base station placement design of **Step1** closer to the measured values of an actual usage environment.

Furthermore, during the course of the factory's daily cycle (manufacturing, shipping schedule), fluctuations in the radio waves' blockage and reflection patterns are likely to occur due to environmental changes around the local 5G devices such as movement of workers/carts, and increase/decrease of components and finished products. Based on previous verifications, it is expected that such changes in the radio propagation environment can be compensated by allowing a margin of about 6 to 8dB when designing the circuit for base station placement.

Conclusion

The manufacturing industry is facing a major crisis in its sales and production plans from the disruption in the supply chain caused by the pandemic and geopolitical risks, such as the US-China conflict and Russia's invasion of Ukraine. In order to respond flexibly to environmental changes in this highly uncertain world, dynamic capability (corporate transformation power)[3] is necessary. It will be important than ever before to accelerate DX including succession of knowledge and technology through digitalization, and production reform / labor saving / automation through IoT and AI.

Beginning with the "Local 5G + Visual Abnormality Detection System," OKI will promote the externalization of solutions based on the results of its in-house operating experiences to support DX in the manufacturing industry.

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References

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TIPS 【Glossary】

externalization
To provide in-house DX-proven technologies, processes, and know-how to external users as solutions, products, and services.

Sub6 band
Refers to frequencies below 6GHz. As local 5G frequency bands, Sub6 band from 4.6 to 4.9 GHz and millimeter wave band from 28.2 to 29.1 GHz are specified. Since the millimeter wave band has a strong linearity, it is assumed that the Sub6 band is more suitable for places such as factories where there are many interfering objects.