White Paper

Private 5G for Industrial Applications
Use cases, Applications and Network Deployment

2024-11-19

Introduction

This white paper gives an overview on the joint research project 5Gearing funded by the FFG Breitband Austria 2030 GigaApp program (see Förderdatenbank). The project ended in October 2024 after 1½ years of work on the requirements and the deployment of a test setup in the LIT Factory at the JKU Campus in Linz.

Participants of this project were

- **Silicon Austria Labs** GmbH (SAL) as a research institute
- **Arico Technologies**, a consulting company in the area of Mission Critical Communications
- **LIWEST** Kabelmedien GmbH as 5G network operator and licensee of 5G spectrum in Austria
- **Magna International Europe** GmbH as potential user of 5G technology in its factories worldwide
- **CANCOM** Converged Services GmbH (formerly Kapsch BusinessCom) as System Integrator.

Motivation

Industry 4.0 digital transformation is led by the automation of manufacturing processes. Industrial applications are quite heterogeneous and pose diverse requirements to the communication system. The transformation towards industry 5.0 has also been initiated recently which emphasizes on the inclusion of humans into the increasingly automated physical processes.

At the same time, the 5G cellular technology is evolving to support highly diverse and heterogeneous environments for various applications in different business sectors. Private 5G wireless technology promises to provide connectivity for the industrial internet of things scenarios because of its support for deterministic and ultra-reliable low latency communication.

Industrial application requirements can be particularly demanding and the setup of Private 5G technology for a certain application must be carefully analyzed and tested before deployment.

Objectives of the project

The project had several work items to address different questions related to the deployment of Private 5G in an industrial environment. Following main objectives were addressed:

- Analysis of requirements and typical use cases based on a reference manufacturing plant
- Derivation of technical requirements for a the Private 5G system like availability, throughput, latency and user density
- Establishment of planning guidelines for a Private 5G network
- Set up of a test environment, where selected use cases could be tested

Requirement analysis

First step was to analyze the different mobile applications which are typically used in a car manufacturer's shopfloor. A reference production plant with 40.000 m2 with a ceiling height of 6m was defined for the further analysis.

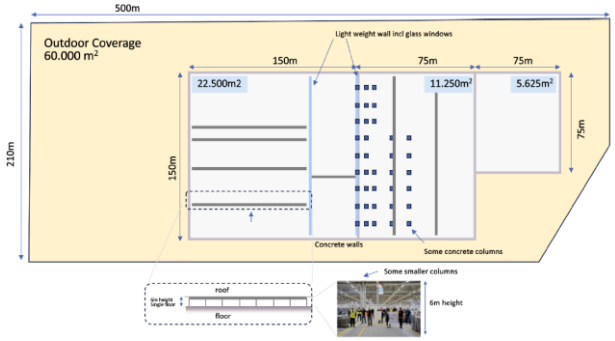

Figure 1 Reference Factory

Within the plant, 165 semi-automated production / assembly lines with about 170m2 each are assumed. Between the warehouse and the production line, modern mobile robots transport goods and assembled products. Mobile data terminals like tablets are used to access production data. Video streaming is used for product inspection and personal safety.

Some of the applications like the pick and place robot requires low latency in the area of 20ms. Other applications like video require high data throughput of 8Mbps.

Some of the technical requirements like indoor positioning with an accuracy of a few cm is hard to achieve with Private 5G only, but can be implemented by combining Private 5G with other technologies like UWB.

Mobile robots are already used in industrial environments, but it was found that currently available products normally act more or less autonomous and do not benefit form a possible exchange of data between the robots. This could significantly improve the performance of a fleet of mobile robots. In addition, these robots typically use Lidar and mechanical sensors to detect the environment and generate a map. This could also be improved by more sophisticated camera systems and central data processing.

Figure 2 Reference Mobile Robot from Omron

Planning Guidelines

Private 5G uses licensed spectrum. This is a significant difference to WiFi, which uses an unlicensed band and therefore is not immune to interference from other systems using the same channel in a close vicinity. Therefore the first consideration is on the spectrum used for the Private 5G system. In Austria all available spectrum below 6 GHz is licensed to country-wide or regional operators. mmWave Spectrum will likely be made available for local campus-applications. In Germany the band 3.700-3.800 MHz is licensed for local campus-applications.

Different architecture options were discussed in the project team. From all options as described in the literature [1], two options seem to be most useful for the industry application.

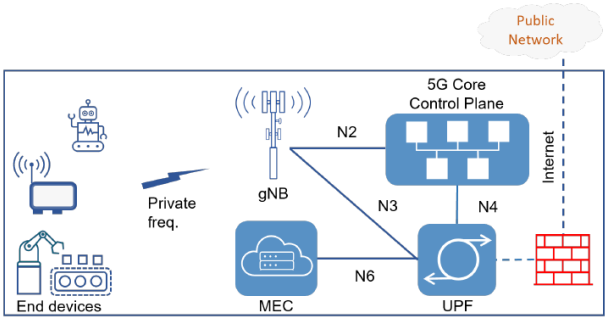

Figure 3 Isolated deployment [1]

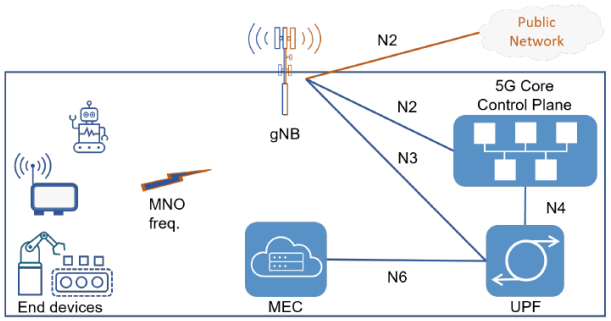

Figure 4 Shared access network [1]

An isolated deployment may be feasible in countries like Germany, where spectrum for Private 5G Networks is available. As an alternative, a network operator may sub-license spectrum in case 5G spectrum is not directly available for Private networks. In this case the 5G network can be set completely autonomously without any dependency. To avoid interference with radio systems with adjacent frequency bands, a synchronization is required.

A shared access network makes sense, if all the 5G spectrum is held by mobile operators like in Austria. In this case the Radio Access Network (5G Base Stations, gNB) is set up by the operator with a dual-core configuration. One connection goes to the operators core, the other to the local core on customer premise.

Testing Environment

Setting up the test environment was a joint effort of the project team, where SAL provided the Radio Access Network (5G Pico Cells), Liwest the Radio Spectrum and CANCOM the 5G Core. Test applications were developed by SAL. The system was set up at the JKU LIT Factory in Linz and served as basis for further tests.

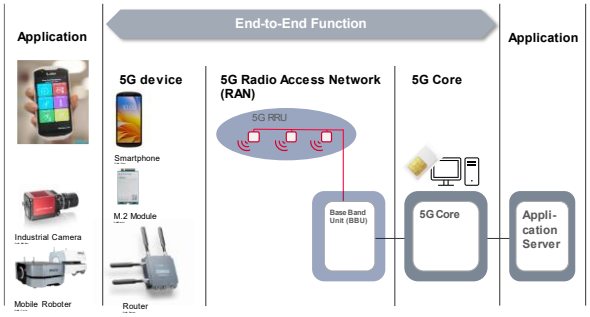

Figure 5 Private 5G system

Indoor coverage simulations

A reliable 5G radio coverage is fundamental for industrial applications. To get a better understanding of the equipment needed and the achievable throughput, a radio planning was done based on the coverage requirements in the reference manufacturing plant, throughput and spectrum.

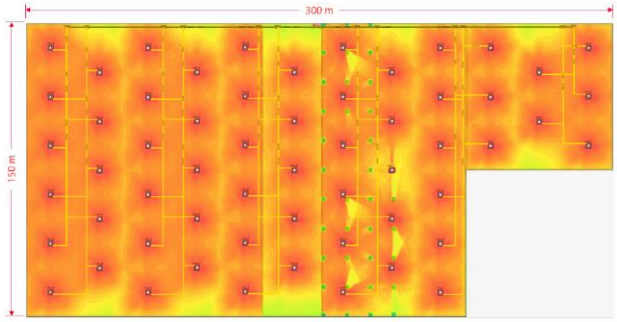

Figure 6 Simulated signal level in the Reference Factory

Indoor coverage measurements

Later on the coverage and network performance was evaluated in the testing environment. Details on the measurements can be found in [2].

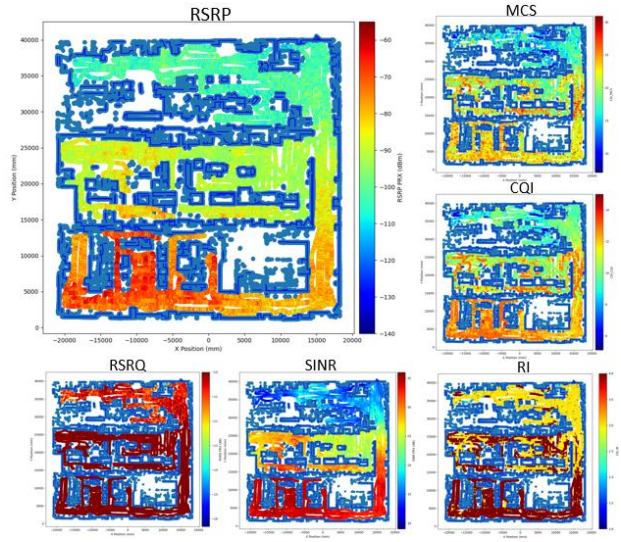

Figure 7 Signal quality measurement in the Testing Environment

Implementation of use cases

One of the main reference use cases was a pick and place scenario with a collaborative handover of goods between a mobile robot and a robotic arm. Both, mobile robot and robotic arm are equipped with a 5G router, which makes the solution very flexible.

Figure 8 Private 5G pick and place showcase

Another use case implemented is video streaming over 5G. Video is required for end of line inspection and also for mobile robots.

Status and outlook

Based on the results from the project, similar scenarios and real-life use cases can be implemented. 5G is well suited for real-life industrial applications and the necessary tools and techniques for deploying a Private 5G network have been discussed in the project.

The project members will continue their work in the area of Private 5G and have applied for a new FFG funded project. Interesting areas for testing is the mmWave band, Time Sensitive Networking and Indoor Positioning.

Results of the 5Gearing project can be found on the 5Gearing project webpage.

Publications

[1] R. Muzaffar, M. Ahmed, E. Sisinni, T. Sauter and H. -P. Bernhard, "5G Deployment Models and Configuration Choices for Industrial Cyber-Physical Systems – A State of Art Overview" in IEEE Transactions on Industrial Cyber-Physical Systems, vol. 1, pp. 236-256, 2023, doi: 10.1109/TICPS.2023.3311394.

[2] D. Hamidovic, A. Hadziaganovic, R. Muzaffar and H. -P. Bernhard, "5G Campus Network Factory Floor Measurements with Varying Channel and QoS Flow Priorities" IECON 2023-49th Annual Conference of the IEEE Industrial Electronics Society, Singapore, Singapore, 2023, pp. 1-6, doi: 10.1109/IECON51785.2023.10311715.