Demo: A Realistic Use-case for Wireless Industrial Automation and Control

Junaid Ansari[1], Ismet Aktas[1], Christian Brecher[2], Christoph Pallasch[2],
Nicolai Hoffmann[2], Markus Obdenbusch[2], Martin Serror[3], Klaus Wehrle[3], and James Gross[4]

[1]Ericsson Research, Aachen Germany; junaid.ansari|ismet.aktas@ericsson.com,
[2]WZL, RWTH Aachen University, Germany; c.brecher|c.pallasch|n.hoffmann|m.obdenbusch@wzl.rwth-aachen.de,
[3]COMSYS, RWTH Aachen University, Germany; serror|wehrle@comsys.rwth-aachen.de,
[4]School of Electrical Engineering, KTH Royal Institute of Technology, Sweden; james.gross@ee.kth.se

***Abstract*—This demo showcases a typical industrial automation scenario of a robot picking and placing work pieces from a moving conveyor belt. It involves sensory data inputs to a Programmable Logic Controller (PLC), and instructions from the PLC to a robot for the pick and place operation. The scenario requires communication from sensors to the PLC and from the PLC to a robot with ultra-low latency and extremely high reliability. While none of today's wireless standards is capable of satisfying these stringent communication demands, our early prototype implementation of some of the design features of the future 5G standard enables industrial control using wireless communication. Our demo will show the live performance characteristics of the 5G design features for low latency and high reliability.**

I. Introduction

Industrial automation and control typically involves sensors that report data to a Programmable Logic Controller (PLC). Based on the sensory data, the PLC instructs an actuator, e.g., a robot, to perform a certain action. This forms a control loop as depicted in Figure 1. In industrial automation applications, these control scenarios are regarded as highly stringent with robust and real-time data communication demands. For instance, in discrete manufacturing processes involving packaging machines, printing presses, and palletizing stations, the maximum communication latency requirement can be lower than 1 ms and the reliability demand can be as high as affording only one transmitted message to be lost out of a billion transmissions [1].

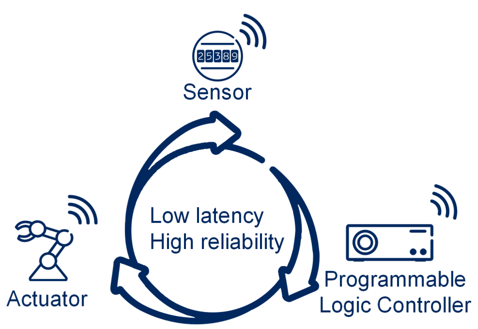

Fig. 1. An illustration of a control loop automation scenario involving communication from a sensor to a PLC and from the PLC to an actuator. This automation scenario typically has extremely high reliability and ultra-low latency communication requirements.

Today's industrial automation applications mainly rely on fieldbus standards [2]. Compared to wired communication, wireless communication can offer several advantages for industrial automation applications, such as faster installation, ease of maintenance, flexibility and extensibility, substantially lower cable damages resulting from moving machine parts, and effectively overall reduced operational costs. While wireless communication may bring several benefits to automation applications, none of the existing wireless technologies is capable of satisfying the ultra-low latency and very high reliability communication demands [3]. Enabling communication requirements of mission critical industrial applications is an important aspect of the future 5G cellular communication system [4]. In this demo, we showcase some of the design features that enable low latency and high reliability wireless communication for industrial automation. We have carried out the prototype implementation of our wireless communication solution on an Software Defined Radio (SDR) platform, and integrated it with a realistic time-critical automation and control use-case.

II. Wireless Industrial Automation Use-case

The use-case represents a typical setup in the domain of industrial automation consisting of a conveyor belt, a robot arm, sensors and a PLC contained in an autonomous automation cell as shown in Figure 2. The robot arm picks work pieces and places them on a conveyor belt, which moves them between two process stations. Light reflux sensors attached to the conveyor belt measure the discrete position of a work piece on the conveyor belt and send the positioning information signals periodically to the PLC. As the main logical and coordinating entity, the PLC processes all the incoming signals and sends out command signals accordingly to the actuators in order to achieve the desired automation task. When approaching a certain specified position, the PLC notifies the conveyor belt to reduce its speed and the robot arm to pick up the work piece. The work piece is then placed at another specified position on the conveyor belt representing the second process station. Afterwards, the conveyor belt is instructed to increase its speed. After each cycle, the conveyor belt toggles its direction of motion. This scenario realizes an industrial automation control loop by sending sensor data to a PLC, and commands to a robot and a conveyor belt periodically at an update interval of 5 ms. The communication from sensors to the PLC and from the PLC to the robot as well as from the PLC to the conveyor belt takes place wirelessly.

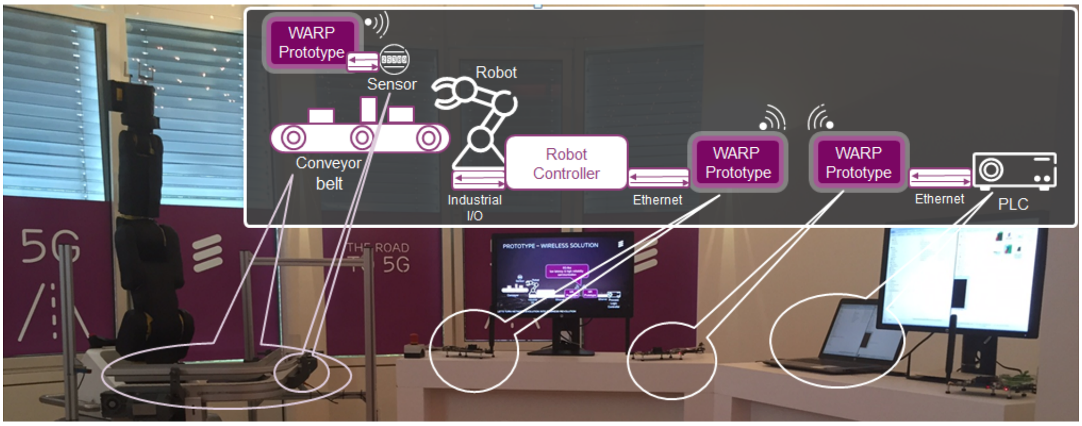

Fig. 2. Schematics of the wireless industrial automation use-case and a snapshot of the demonstration setup.

III. Demonstration Description

A. Automation Entities

Our demonstrator supports the widely used and open source industry standard Modbus-TCP [5] on top of our wireless communication solution. We used Bosch‘s Automatic Production Assistant (APAS) robot to perform the pick and place operation of work pieces on a moving conveyor belt. The robot arm has six degrees of freedom, which allows it easy maneuverability. The centric movements of the attached 3-finger universal gripper on the robot arm allows picking up a broad range of objects. Light reflux sensors mounted on the conveyor belt acquire the discrete position of the work piece by indicating the presence or absence whilst using a digital output signal between +0 V and +24 V. The PLC is realized as a custom implementation of a soft PLC on a PC to (a) gather real-time positioning information of the work pieces on conveyor belt and (ii) send series of instructions to the robot for the pick and place operation, and to the conveyor belt for the speed and direction control.

B. Wireless Communication

The wireless communication is realized using the WARP SDR platforms [6]. Our wireless communication solution uses Medium Access Control (MAC) layer concepts that allow resource management and scheduling in time and frequency so that the stringent traffic Quality of Service (QoS) requirements are satisfied. The QoS parameters include traffic priority, data size, real-time constraints, and reliability demands. The wireless communication uses the network assisted device-to-device (D2D) paradigm, where the base station assigns time and frequency resources to nodes in a dynamic fashion based on the indicated QoS requirements. The resource assignment takes into account both periodic and aperiodic traffic patterns. Over provisioning of time and frequency resources appropriately ensures a high degree of reliability while satisfying the traffic timeliness constraints. Besides the MAC layer aspects, 5G physical layer concepts such as Orthogonal Frequency-Division Multiplexing (OFDM) waveform with a wide sub-carrier spacing, short Transmission Time Intervals (TTIs), self-contained transmissions, early decoding and convolutional codes are part of our prototype implementation.

C. Visualization and Configuration Interface

A Graphical User Interface (GUI) based application is developed for the demo to visualize the live over-the-air performance characteristics in terms of latency and throughput, and to configure the soft PLC parameters.

The demonstration and the related visualizations will be accomplished in a table-top manner as shown in Figure 2. The required time to setup the demo is approximately 45 mins.

IV. Conclusion

This demo will showcase a realistic industrial automation use-case, where stringent latency and reliability requirements are achieved through wireless communication. While offering a high degree of flexibility, our wireless communication solution is able to provide wire-like seamless behavior for the realistic industrial use-case. Moreover, the demo will present new possibilities for human robot interaction, which are not feasible when using the traditional fieldbus communication.

Acknowledgement

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