Networked control systems with PROFINET and IWLAN

MICHAL BLAHO, LEO MRAFKO, MARTIN URBAN, JÁN MURGAŠ
Institute of control and industrial informatics
Faculty of Electrical Engineering and Information Technology
Slovak University of Technology
Ilkovičova 3, 812 19 Bratislava
SLOVAK REPUBLIC
michal.blaho@stuba.sk, martin.urban@stuba.sk

Abstract: Distributed control systems have been one of the most studied and challenging areas in control. Networked control systems (NCS) have become interesting research subject in field of distributed control systems over last decade. Many papers focused mainly on theoretical part of NCS and lots of algorithms have been designed. There is lack of practical applications, which deals with concrete implementation of NCS. In this paper we present NCS that was designed using PROFINET and IWLAN technologies. We connected two PLC modules through PROFINET as well as IWLAN and realized simple identification and control of simple DC motor.

Key-Words: Networked control systems, PROFINET, IWLAN, DC motor, Programmable logic controller, Identification, Process control

1 Introduction

In distributed control systems elements of the control system are distributed throughout the system with each component sub-system controlled by one or more controllers. Each of the system elements is connected by communication network. Many papers come with studies on design, implementation or performance of distributed control systems [1,2].

Networked Control Systems (NCSs) are one type of distributed control systems where sensors, actuators, and controllers are interconnected by communication networks. Many authors interested in topics of NCS studied problems of NCS like control of the variable transport delay and packet dropouts [3,4,5].

Despite the fact that traditional networks like CAN are still used new possibilities of modern data networks (cable or wireless) occurred in control area. As we mentioned many authors deal with NCS problems. However not many papers are focused on practical implementation with available modern network solutions (like PROFINET or IWLAN) for industry applications [6,7].

This paper is mainly focused on the practical usage of the mentioned technologies. Network control system as laboratory model of DC motor control system with communication over PROFINET and IWLAN technologies was designed. For this system we realized simple identification and control.

2 Networked control systems

Computer data networks have a long history. Lots of new communications media and protocols have been developed and improved for many years. This led to many benefits as remote data transfers and data exchanges, reduce wiring, costs of medias and easier maintenance. Considering this benefits data networks became popular in control systems [8].

Multiple sensors and actuators are connected to a centralized controller via shared communication medium in a NCS. Controller, sensors and actuators transmit information and control signal via network as you can see on figure 1 [3].

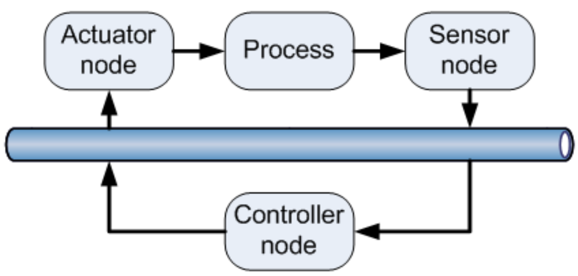

Fig. 1 NCS block diagram

Since an NCS operates over a network, data transfers between the controller and the remote system will induce network delays in addition to the controller processing delay. Another problem in NCS is packet dropout [8]. These issues have been discussed in many papers but they are not subjects of this paper.

There are different networks suitable for NCS in industrial applications. Data can be transferred through cable network (e.g. CAN, EtherCAT, PROFINET) or wireless network (e.g. ZigBee, IWLAN). Next subsections describe these communications technologies.

2.1 CAN

The most used industrial cable network is CAN bus. CAN was originally developed for car industry. Because of its effectiveness CAN bus has also spread into others fields of industry. The biggest manufacturers of industry devices has implemented connection to the CAN bus.

CAN bus is reliable, fast and cost effective for multi master and real time applications. It is ideally suites applications requiring high number of short messages for multi recipients and system-wide data consistency is mandatory in a short period of time with high reliability in rugged operating environments [9].

CAN standard do not include application layer protocol. Users can design their own protocol. There are several protocols, but in industrial applications are especially used CANopen and DeviceNet.

2.2 EtherCAT

EtherCAT is the open real-time Ethernet network originally developed by Beckhoff. The EtherCAT technology overcomes the system limitations of other Ethernet solutions. The Ethernet packet is no longer received, then interpreted and copied as process data at every connection. Instead, the Ethernet frame is processed on the fly - each slave node reads the data addressed to it, while the telegram is forwarded to the next device. The telegrams are only delayed by a few nanoseconds.

The update time for 1000 distributed I/Os are only 30 μs. EtherCAT supports almost any topology. The bus or line structure known from the fieldbusses thus also becomes available for Ethernet. With EtherCAT, the data exchange is completely hardware based on "mother" and "daughter" clocks. Each clock can simply and accurately determines the other clocks run-time offset. [10]

2.3 PROFINET

PROFINET is the innovative open standard for Industrial Ethernet. PROFINET satisfies all requirements of automation technology. PROFINET enables solutions to be developed for factory automation, process automation, safety applications, and the entire range of drive technology up to and including isochronous motion control applications.

PROFINET family comprises two different protocols designed to be employed at different levels of factory communication systems: PROFINET CBA for the high levels and PROFINET IO for the device level [11].

2.4 ZigBee

ZigBee is the only standards-based wireless 802.15.4 technology designed to address the unique needs of low-cost, low-power wireless sensor and control networks. ZigBee protocol features include: support for multiple network topologies such as point-to-point, point-to-multipoint and mesh networks, low duty cycle – provides long battery life, low latency, up to 65,000 nodes per network, encryption for secure data connections. ZigBee found usage in many applications like building automation, remote control, health care, home automation and many others [12, 13].

2.5 IWLAN

IWLAN is a technology that means WLAN is applied to industrial environment. It is used in these situations, where difficult to realize wired connection between devices in some environment, as well as not allow or expect wired connection in the view of technology. [14]

IWLAN wireless interface modules enable distributed I/O system to communicate wirelessly. The technology could find applications in driverless transport systems, warehouse logistics, electrical trolley conveyors and remote service applications. To sum up the main advantage of wireless solutions is easy and flexible access to mobile stations.

3 Control over PROFINET and IWLAN

The biggest supplier of PROFINET and IWLAN devices in the world is Siemens [15]. Siemens offers a comprehensive range of products for PROFINET as well as IWLAN. An overview of all product families, all variants follow:

- Automation systems
- Drive systems
- Network components

- Identification systems
- Sensor systems
- Software & Tools
- Technology components

As we have already mentioned PROFINET and IWLAN can be used in many applications like factory automation, process automation, safety applications and many others. Here we mention few concrete application areas where this communication technology can be used in:

- Manufacture materials handing storage
- Motion Control
- Process Control

3.1 System configuration

The whole system was designed as laboratory model, operated by a stored program in the PLC. It is formed of four main parts: the PC, PLC controller, distributed I/O device and DC motor. DC motor is designed as simple process where input is voltage from range of 0-10V and output is revolution speed converted to voltage of 0-10V via tachogenerator. Figure 2 shows system configuration for PROFINET communication.

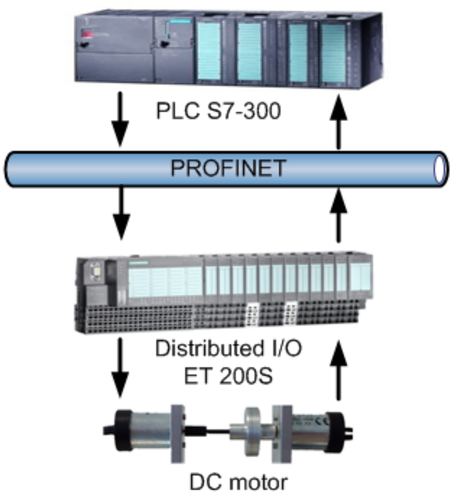

Fig. 2. PROFINET system configuration

Data transmission to control the DC motor was provided by the PLC and the Distributed I/O via PROFINET.

IWLAN system configuration was designed as previous PROFINET configuration in addition to wireless access point and client modules. Access point is directly connected to PLC controller and exchanges data via wireless network with client module that is connected to distributed IO module.

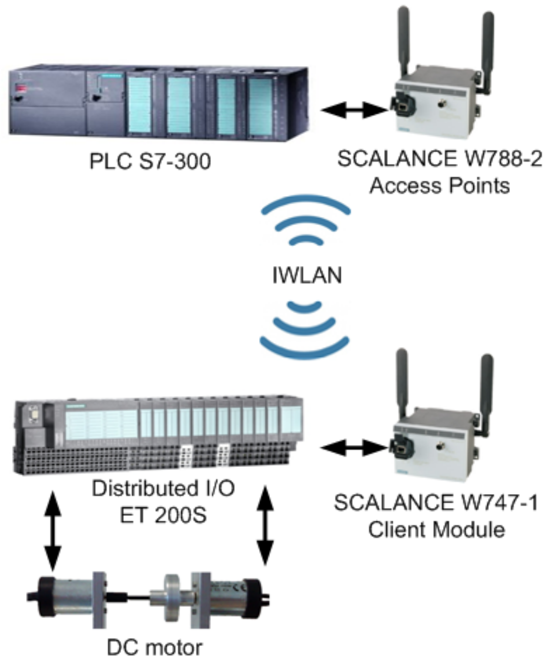

Fig. 3. IWLAN system configuration

3.2 Identification and control

As we mentioned before we wanted to control simple laboratory DC motor through PROFINET. First we had to perform motor identification. Setpoint of the input for identification was set to 5V and few steps within +-0.5V were made with sample time of 0.1s. Program saved data to array and OPC server and client was necessary to obtain this data. We used OPC Server for Siemens S7 PLCs from Matrikon [16]. Data were transferred to standard PC through Matlab OPC client tool (*opctool*) in which we could read all items from out PLC. Measured data are depicted on figure 3.

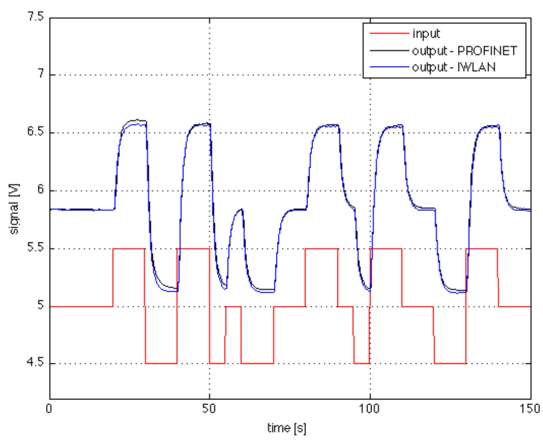

Fig. 4 Data for system identification

The system identification was performed with another Matlab GUI tool called *ident*. We simple read data from workspace and identify system as second order ARX model with our sample time 0.1s. The discrete transfer functions has following form

$$G_{PROFI}(z^{-1}) = \frac{0.001824z^{-1}+0.05674z^{-2}}{1-1.312z^{-1}+0.3512z^{-2}} \quad (1)$$

$$G_{IWLAN}(z^{-1}) = \frac{0.001222z^{-1}+0.06101z^{-2}}{1-1.292z^{-1}+0.3343z^{-2}} \quad (2)$$

Acording to transfer functions the identified systems were almost identical. Next we modeled closed loop system in Simulink environment to tune controller parameters. We also used Matlab feature of tuning parameters within PID controller block. Our controller type was PI, but we had to convert from Matlab form to PLC form which is in next equation

$$G_R(s) = P\left(1 + \frac{1}{T_i s}\right) \quad (3)$$

The best parameters in simulation caused that system oscillates. We slow response time in tuning and achieved better results. The final parameters for controller were P=0.7313 and Ti=0.7946. On the figure 4 you can see desired values and closed loop system with our PI controller.

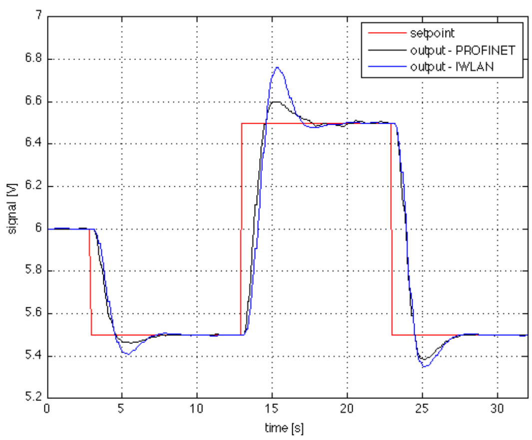

Fig. 5 Closed loop system response

As we can see on the figure 5 output for PROFINET and IWLAN communication networks are not identical. We can observe worse output control for IWLAN what is caused by higher latency of IWLAN network compared to PROFINET.

6 Conclusion

Networked control systems are one of the most popular area in control for past decade. Although many authors studies properties of NCS only few papers deals with practical implementation. For this purpose many communication technologies are suitable like CAN, EtherCAT, PROFINET, ZigBee, IWLAN.

We used PROFINET and IWLAN for identification and control of small DC motor in laboratory environment. We were able to control process with small overshoots. Communication was realized on small distances therefore no packet dropout was noticeable.

Acknowledgement

This work was supported by VEGA agency under contract number 1/0592/10.

References:

[1] Q. A. Memon, H.-UR Rehman, *Customized Design and Development of Distributed Control System for Process Control*, Proceedings of the 4th WSEAS Int. Conf. on Information Security, Communications and Computers, Tenerife, Spain, December 16-18, 2005, pp. 33-39

[2] E. Diaconesu, *A Model of Distributed Control for the Hybrid Transmission System using Multi-Agents*, Proceedings of the Applied Computing Conference 2009 (ACC '09) and the 11th International Conference on Mathematical Methods and Computational Techniques in Electrical Engineering (MMACTEE '09), Vouliagmeni, Athens, Greece, September 28-30, 2009, pp. 379-383, ISBN: 978-960-474-124-3

[3] Z. Xiang, X. Jian, *Communication and Control Co-Design for Networked Control System in Optimal Control*, 12th WSEAS International Conference on SYSTEMS, Heraklion, Greece, July 22-24, 2008, pp. 698 – 703, ISBN: 978-960-6766-83-1

[4] L. Eriksson, A PID Tuning Tool for Networked Control Systems, WSEAS Multiconference, Signal Processing, Robotics and Automation (ISPRA 2005), Salzburg, Austria, February 13-15, 2005

[5] L. Chunmao, X. Jian, Z. Yue, *Stochastic Delay Estimation and Adaptive Control of Networked Control Systems*, Proceedings of the 6th WSEAS International Conference on Simulation, Modelling and Optimization, Lisbon, Portugal, September 22-24, 2006, pp. 72 – 76

[6] P. Ferrari, A. Flammini, D. Marioli, A.Taroni, *An experimental approach to estimate real-time*

characteristic of PROFINET IO versus PROFIBUS DP V2, Proceedings of the 5th WSEAS Int. Conf. on Instrumentation, Measurement, Circuits and Systems, Hangzhou, China, April 16-18, 2006 pp. 104-111

[7] P. Neumann, A. Pöschmann, *Ethernet-based Real-Time Communications with PROFINET IO*, Proceedings of the WSEAS Conference: Automatic Control, Modelling and Simulation (ACMOS '05), Prague, Czech Republic, March 13-15, 2005

[8] Y. Tipsuwan, M.-Y. Chow, *Control methodologies in networked control systems*, Control Engineering Practice 11 (2003) pp. 1099–1111

[9] M. K. Al-Mekkawy, A. M. Mahmoud, A. Zavochikove, A. E. Salama, *Reliable design of the CAN bit synchronization block*, Proceedings of the WSEAS Conference: Information Science, Communications and Applications (ISCA 2005), Cancun, Mexico, May 11-14, 2005

[10] EtherCAT Technology group, *EtherCAT – Ethernet for Control Automation Technology* [online], EtherCAT Technology group cit:28.06.2011 available at <http://www.ethercat.org>

[11] PROFIBUS Nutzerorganisation e.V., *PROFINET System Description* [online] PROFIBUS & PROFINET International Support Center, cit:28.06.2011 available at < http://www.iteclb.com/industrialnetworking/PROFINET/PROFINET_system_en.pdf>

[12] Z. Bradáč, P. Fiedler, O. Hynčica, F. Bradáč, *Design of ZigBee Device*, Proceedings of the WSEAS Conference: Automatic Control, Modelling and Simulation (ACMOS '05), Prague, Czech Republic, March 13-15, 2005

[13] ZigBee Alliance, *ZigBee Technology* [online] ZigBee Alliance, cit:28.06.2011, available at < http://www.zigbee.org >

[14] Y. Zheng, A. Xu, Y. Song, W. Zhao, M. Liu, *Industrial wireless deterministic communication based on WLAN: design, implementation and analysis*, Communications Technology and Applications, 2009. ICCTA '09, pp. 274 – 278, ISBN: 978-1-4244-4816-6

[15] Siemens, *Automation Technology*, [online] Siemns AG cit: 28.06.2011 available at < http://www.automation.siemens.com>

[16] Matrikon, *Siemens S7 PLC OPC Server - MatrikonOPC OPC Servers*, [online] Matrikon Inc. 2011, cit: 28.06.2011 available at <http://www.matrikonopc.com/opc-drivers/opc-siemens-s7-plc/base-driver-details.aspx>