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Mobile Laboratory for Training in Network Technologies

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Introduction

The evolution of industrial communication has brought the use of networks in control to the mainstream. Monitoring and control systems wherein data are transferred through a network are already used in most industrial control and monitoring applications. Using a distributed architecture has many advantages over a point-to-point design such as low cost of installation, easy of maintenance and flexibility. Today, leading manufacturers of control and monitoring technology offer network interfaces for their devices. Decreasing costs and increasing demand for a single, standard network type, from boardroom to plant-floor, have led to the development of Industrial Ethernet.

In the response to the demands the concept of mobile laboratory was proposed and has been implemented by the consortium of university and industrial partners from six European countries and two partners from Turkey. Karel de Grote-University College and Limburgs Technologie-Centrum from Belgium, University of Rousse from Bulgaria, Fachhochschule Düsseldorf and Germany-Phoenix Contact from Germany, Technological Educational Institute of Crete from Greece, AGH University of Science and Technology from Poland, TelePedagogic Knowledge Center from Sweden, Yildiz Technical University and Enosad Industrial Automation from Turkey – all these partner institution have recognized the demand for efficient development of quality industrial Ethernet systems and need for development of international learning environment.

CoNeT, the EU-funded project, stands for Cooperative Network Training. The project aims at training of automation engineers, maintenance engineers, process workers and students both graduate and undergraduate in modern wired and wireless industrial network technology applied to control operations and automated solutions. The current trend in engineering curricula applies the concept of “learning by experiments” or “learning by projects” [1]. Such “learning by doing” concept was also proposed for the collaborative project as a part of the pilot CoNeT implementation phase.

The overall objective of the CoNeT project is to contribute to the qualification of future Ethernet-based network-specialists. The specific objective of the project is to develop training modules in the field of Industrial Ethernet for students, technicians and engineers in industry. It is anticipated that trainees who are already employed will need to fit their learning around existing family or work commitments, therefore the laboratory will be broken up into ‘bite-sized’ discrete modules and flexible modes of delivery will be used including the use of both distance and face-to-face teaching. These mobile labs can be transported between companies and universities and used to complement the training courses.

Industrial Ethernet

There are three major trends observed in contemporary industrial control systems:

- distributing and decentralizing structures of automation, as the “intelligence” is shifted towards field components,
- increasing integration of vertical communication through all the levels of the control systems,
- growing demand for application of IT standards.

Most of the contemporary industrial automation systems adopts multilevel, vertical control architecture.

Logically, the system is structured into three levels (Fig. 1), which are: the direct (device) control level, supervisory level and management level. Basic task of the direct (device) control level is to maintain the process states at the prescribed set values. Device controller level provides interface to the hardware, either as separate modules or as microprocessors incorporated in the equipment to be controlled. A number of embedded control nodes and Programmable Logical Controllers (PLC) are used as the front-ends to take the control tasks. High speed networks and fieldbuses are implemented at the direct control level to exchange in real time the information between front-ends and the device controllers and, vertically, with the supervisory control level. This architecture has the advantage of locating the hard real-time activities as near as possible to the equipment. The supervisory level comprises workstations and industrial PCs providing, the high-level program support, database support, graphic man-machine interface, network management and general computing resources.

Current communication systems for automation include different protocols. This is a substantial disadvantage, leading to necessity of using vendor-specific hardware and software components, which increase installation and maintenance costs. Moreover, presently used fieldbus technologies make vertical communication across all levels of the automation systems difficult. Gateways need to be used to establish connections between different kinds of fieldbus systems used in the lower level, and Ethernet used in the upper levels. Differences in data format also obstruct communication.

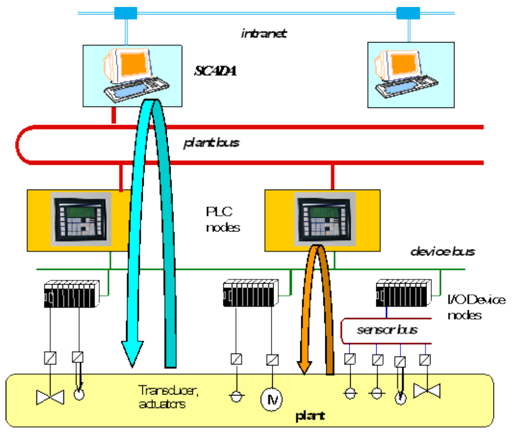

Fig.1. Multilevel structure of the industrial automation system

Ethernet comes as a solution to the problems mentioned above, at last to some extent. It provides unified data formats and reduces the complexity of installation and maintenance, which, together with the substantial increase of the transmission rates and communication reliability over the last years, results in its popularity in the area of industrial communications. It is a result of Ethernet's desirable properties, namely:

- comparatively high transmission rates,
- possibility of connecting large number of nodes in a single network,
- relatively low cost of components and wiring,
- interoperability, ease of integrating multi-vendor products into a single application (Ethernet is an open standard),
- transparency, which allows different protocols to be utilized concurrently in one network,
- scalability and reconfigurability,
- portability of applications,
- compatibility of networks applied on process level with higher level company networks, which facilitates data acquisition, production supervision and management.

Ethernet, as defined in IEEE 802.3, is non-deterministic and thus, is unsuitable for hard real-time applications. The media access control protocol, CSMA/CD with its backoff algorithm, prevents the network from supporting hard real-time communication due to its random delays and potential transmission failures. In real-time systems, delays and irregularities in data transmission can very severely affect the system operation. Therefore, various techniques and communication protocol modifications are employed, in order to eliminate or minimise the undesired effects.

To employ Ethernet in industrial environment, its deterministic operation must first be assured, which can be accomplished in several ways. Coexistence of real-time and non-real time traffic on the same network infrastructure remains the main problem. This conflict can be resolved in several ways, by [2]:

- embedding fieldbus or application protocol on TCP/IP – the fieldbus protocol is tunneled over Ethernet, and full openness for "office" traffic is maintained,
- using special Data Link layer for real-time devices – special protocol is used on the second OSI layer, implemented in every device. The real-time cycle is divided into slots, one of which is opened for regular TCP/IP traffic, but the bandwidth available is heavily limited down,
- using application protocol on TCP/IP, direct MAC addressing with prioritization for real-time, and hardware switching for fast real-time,
- maintaining real-time on TCP/IP is achieved by prioritized messaging and time synchronization – the synchronized devices assign higher priority and timestamp real-time messages,
- using Ethernet physical layer with built-in application-specific integrated circuits and special protocols – Ethernet is used only as underlying technology.

All the specific techniques allow considerable improvement in terms of determinism. The desire to incorporate a real-time element into this popular single-network solution has led to the development of different real-time Industrial Ethernet solutions called "Real-time Ethernet", as PROFINET, EtherCAT, Ethernet/IP [3,4] and many more. The conditions for the industrial use of Ethernet are described by international standard IEC (*International Electrotechnical Commission*) IEC 61 784-2 *Real Time Ethernet* (Fig. 2).

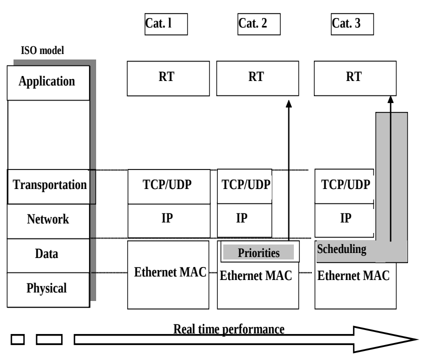

Fig. 2. Classification of industrial Ethernet (IEC 61 784-2)

Mobile laboratory

The overall objective of this project is to contribute to the qualification of future Ethernet-based-network-specialists. The proposed laboratory supports a number of experiments, each of them based on Industrial Ethernet communication solution. The laboratory will be divided into portable modules to enable future mobility between partner universities.

The following experiments will be implemented.

- Module 1: *Ethernet based IO systems.* Objective: a) to train on basis principles of Ethernet based IO systems in a practical context, b) to demonstrate difference between an “Office LAN” and an “Industrial LAN” – for example, to demonstrate how network-induced delays may vary depending on the network load and medium access protocol. The module will include: a) Configuration of the network, b) Monitoring the traffic via an Ethernet diagnostic tools, c) Implementation of devices from different automation device suppliers, d) Combinations of different communication protocols, e) Device to Device Communication and Device to I/O Communication Applications. As project work the data exchange experiments between PC and PLC via different communication protocols will be implemented.
- Module 2: *Siemens Profinet.* Objective: Practical implementation of a Profinet IO systems (Phoenix Contact, Wago, Beckhoff) on a Siemens PLC, such as Simatic S7 (Simatic S7 Manager), Profinet CBA, and study of different gateways: Profinet/Profibus, Profinet/Interbus.
- Module 3: *Phoenix Contact Profinet.* Objective: Development of a mobile laboratory to learn Profinet systems (multi-vendor) on a Phoenix Contact platform and study of different gateways.
- Module 4: *EtherCat.* Objective: Implementation of EtherCat protocol on a Beckhoff PLC platform (TWINCAT) and study of different gateways such as EtherCat/Profibus, Ethercat/Modbus TCP/IP.
- Module 5: *Allen Bradley Ethernet/IP.* Objective: Practical implementation of Ethernet/IP protocol on a Allen-Bradley PLC and study of laboratory distributed control example (How changing of the EthernetIP meesage type influences the Quality of Control?).
- Module 6: *Wireless communication.* Objective: Implementation of wireless communication concepts in an industrial environment (Wireless Ethernet, Access Point, Access Client, Bluetooth based wireless, GPRS. Studding the security aspects: WEP, WAP, MAC filters etc.
- Module 7: *Real-time processes.* Objective: Presentation and practical exercises on laboratory real-time processes in which several Ethernet IO and fieldbusses can be integrated. Processes will be connected to the PLC modules by using fieldbusses and Ethernet-based IO by simple replacement of the fieldbus module. Examples of controlled processes are: level control, temperature control, magnetic levitation, some mechatronics laboratory models, pneumatic manipulators etc.

Each module will be supported by a number of documents available on-line. Between them are: technical documents (handbooks, technical manuals) and didactic materials: module descriptions, laboratory instructions, tests.

Main Project activities are planned as follows:

- developing of the training modules (hardware and software),
- developing the curriculum for the modules,
- elaborating the lecture and training material,
- providing the lecture and training material on-line for the lifelong learning process,
- documenting the implementation of the Project, including monitoring and evaluation reports of the Project progress,
- conducting the lectures and trainings (next phase of the project).

The Project considers students in their final year undergraduates, in their first year postgraduate students and graduates who need additional qualification in the subject Ethernet-based-systems. The target groups at the second rank are people (graduates and non-graduates) in the working process and have to specialize in the field of Ethernet-based-networks. The didactical approach in the modules implementation goes for blended learning by applying classroom lectures, expert presentations, self- and team study sessions as well as team work. It is envisioned that the training load for each Module will be 12 hours for 2-day course, consisting of 4 hours theory and 8 hours of practice.

Conclusions

Technology progress has significant impact on engineering curricula which require continuous modification designed to prepare students for technological challenges of the modern workplace. The curriculum must be sensitive to the changes of technology and incorporate recent technological advances. Rapid progress of computing and communication technologies is the major reason that the programs like electronics, computer and software engineering, robotics and control engineering need continuous updates.

Constantly increasing number of Ethernet's industrial applications shows, that its benefits still overweight the disadvantages. In the response to the demands the concept of mobile laboratory was proposed.

The following goals are expected as long-term results of the CoNeT project:

- upgrading knowledge of employees and students in the field of Industrial Ethernet,
- exchange of knowledge in the field of Industrial Ethernet between Higher Education and Enterprises,
- improvement of soft skills such as self-learning, flexibility and use of English language,
- gaining experience related to cultural immersion and international aspects of the project.

The teaching material will be developed through close collaboration between academic staff, company representatives familiar with the needs of their employees and the training organizations. Students will have the opportunity for training and project work in the partner companies as well as study abroad with partner universities. Academic staff will participate in teaching and research related activities with both academic and non-academic partners.

Acknowledgment

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Technological development has brought the use of networks in control to the mainstream. Ethernet-based systems are becoming an increasingly attractive technology as they combine large capacity and high speed with flexibility. New trends in control technology must be reflected in the respective teaching activity. In the response to the demands the concept of mobile laboratory was proposed and has been implemented by the consortium of university and industrial partners from six European countries and two partners from Turkey. The CoNeT (Cooperative Network Training) project described in this paper aims at training of automation engineers, maintenance engineers, process workers and students both graduate and undergraduate in modern industrial Ethernet technologies. Ill. 2, bibl. 4 (in English; abstracts in English, Russian and Lithuanian).

В. Грега, Г. Пападоуракис. Применение технологических сетей в учебном процессе // Электроника и электротехника. – Каунас: Технология, 2010. – № 6(102). – С. 139–142.

Предлагается новая концепция проведения лабораторных занятий. Разработаны мобильные принципы учебного процесса осуществлена с участием шести стран Европы и двух предприятийми Турции. Описан проект C_ON_e T предназначен для обучения инженеров автоматики и магистров инженерного технологического профиля. Ил. 2, библ. 4 (на английском языке; рефераты на английском, русском и литовском яз.).

W. Grega, G. Papadourakis. Mobiliosios laboratorijos taikymas tinklų technologijų mokymo procese // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 6(102). – P. 139–142.

Sparčiai tobulėjant technologijoms daugiau dėmesio skiriama tinklams ir jų taikymui. Internetu paremtos sistemos tampa vis patrauklesnės, todėl mokymuose tikslinga tai įvertinti. Pasiūlyta mobiliosios laboratorijos koncepcija, kuri buvo įdiegta universitetų konsorciumo kartu su šešiais Europos šalių ir dviem Turkijos pramonės partneriais. Aprašytas CoNeT projektas, skirtas automatikos, inžinieriams, ir modernių pramonės interneto technologijų bakalauro ir magistro studijų studentams. Il. 2, bibl. 4 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).