CONET Newsletter

INFSO-ICT-224053 www.cooperating-objects.eu Issue nr.11, February 2011

Contents

Editorial

Welcome to the 11th issue of the CONET newsletter. CONET is the EU FP7 network of excellence on Cooperating Objects, merging the fields of embedded systems for robotics and control, pervasive computing and wireless sensor networks. CONET focuses on establishing the field of Cooperating Objects within the research and industrial community, thus strengthening the position of Europe in the research landscape.

This issue presents a guest column from Karl H. Johansson, Royal Institute of Technology, Stockholm (Sweden) about wireless process control. Wireless networking is becoming more and more important in control. In the guest column, Prof. Johansson discusses challenges and some promising recent approaches in this research field.

The issue's "member profile" presents the Telecommunication Networks Group (TKN) of Technische Universität Berlin (TUB) together with an overview of the laboratory facilities, with particular reference to the TWIST testbed, and several projects related to CONET in which they are involved.

We also take the opportunity to announce a few events related to the area of Cooperating Objects.

If you are interested in obtaining up-to-date information about the CONET project please visit our website at: http://www.cooperating-objects.eu

We hope you will enjoy this issue ■

Towards Wireless Process Control

By Karl H. Johansson, Royal Institute of Technology, Stockholm (Sweden)

Wireless networking is becoming an important technology in process and automation industry. In this short note we discuss some of the challenges in wireless networked control and some promising recent approaches. The note is based on a keynote talk given at the IFAC Workshop on Distributed Estimation and Control in Networked Systems, Annecy, France, 2010.

1. Introduction

There is a growing deployment of wireless networks for industrial control systems. Lower installation costs and easier system reconfigurations for wireless devices can have a major influence on future distributed control and monitoring systems. For robust and efficient use of this new technology, there is a need for better understanding of how the allocation of the network resources through the communication stack should be integrated with the application layers. As the wireless medium may create interference and conflicts between control loops, it is essential to have rigorous techniques for how to perform the overall system design. A separation of concern has been the dominating approach up till now, where some dedicated wired communication protocols, such as Fieldbus and Controller Area Network, suitable for a wide class of local control applications have been used. However, as new open network protocols and wireless communications are presenting cost benefits, it becomes import to create mechanisms that are able to handle the limited resources and the application demands in a more agile and adaptive way.

The outline of the note is as follows. Section 2 describes control network architectures and the current trends. Wireless network protocols applicable for control and monitoring applications are discussed in Section 3. One feature of these protocols is that they are able to serve both event- and time-triggered traffic. Control methods that support these communication paradigms are presented in Section 4. The note is concluded in Section 5.

2. Network Architectures

Communication networks influence every aspect of our lives. Traditionally these networks were developed mainly to serve personal communication and information exchange between computers, but they are now starting to integrate sensors and actuators creating large geographically distributed infrastructures with a potential to react to changes in the environment and control physical processes. The networks are often integrated with the Internet and the cellular network infrastructure, but they can locally be tied to wireless sensor and actuator networks.

Device communication in process control has followed the general trends but on a slower pace due to the longer time frame for plant investments. Today's industrial communication architecture is organized in a hierarchy, where on the lowest layer there are sensors and actuators connected through a network, e.g., Fieldbus, supporting real-time control. On a middle layer there are non-time-critical communication networks, e.g., Ethernet, connecting programmable logic controllers and supervisory control units. The top layer often consists of a regular office network supporting process operators and maintenance support. Currently most of the major vendors in process automation are introducing radio interfaces for some of their devices on the lowest layer and several deployments are already in place. A process plant might have thousands of control loops, but so far the number of wireless devices is small.

A future scenario with many wireless sensors and actuators will have major consequences for the control system architecture. From today's centralized control systems with low-level loops closed over wired networks and control algorithms being executed in few computers centrally located, we could move into an architecture where sensors and actuators communicate directly to each other over a multi-hop wireless network. Control commands can be derived locally in microcomputers in network devices, e.g., by so called smart sensors and smart actuators. In this way, a dramatic architectural change can take place in which a fixed hierarchical and centralized system transitions into a flexible and distributed one, in which the intelligence is moved from dedicated computers to sensors and actuators. The benefit of this change would be an increased process performance and flexibility, with a lower cost for cabling and maintenance.

3. Wireless Networking for Control Applications

Industrial automation and control applications set drastically different requirements than multimedia and other common applications supported by wireless systems. This has recently been recognized by several standardization bodies, which are active in developing a suitable communication stack for wireless control systems. Major initiatives include WirelessHART, ISA 100, and IEEE 802.15.4.

An overarching design question is how to share the common wireless network resources while maintaining a guaranteed performance for a multitude of individual control loops and other applications. Many wireless protocols support a periodic allocation of communication slots, which can either be part of a contention free period suitable for TDMA scheduled devices or part of a contention access period suitable for CSMA/CA communication. One interesting challenge is to design a suitable access scheme for the wireless devices, so that the network does not degrade the closed-loop control performance during instances of traffic congestion and interference. In order to study this problem, appropriate models for medium access control (MAC) and routing protocols need to be introduced. These models should be detailed enough to capture the network dynamics on a time scale of the closed-loop control application, but of low complexity so that they can be incorporated in a system-level design framework.

To model end-to-end reliability and delay for wireless protocols, it has been shown recently in the literature that Markov models provide a useful tool. The models include mechanisms like the exponential back-off process with retry limits and acknowledgements, which might have a considerable influence on the real-time traffic. Based on these models, the MAC protocol can be optimized to support the application demands, or even adapt online to changes in the network state. A control-communication co-design framework has been developed based on the network constraints and the control objectives.

4. Time- and Event-Triggered Control

The control application layer needs to handle communication imperfections, such as loss, conflicts, delays, outages, and rate limitations. There are many recent proposals on how to deal with these issues. Here we will discuss two recent approaches based on time- and event-triggered communication and control.

Time-triggered communication supports traditional periodic sampled-data control system design and might therefore be desirable in many applications as existing control synthesis methods can be used. Through various levels of abstraction, the wireless communication standards allow the designer to distribute synchronous communication schedules to all network nodes. In that way, one can separate control, routing, and medium access and introduce a formal framework for the dynamics of the composed system. The framework allows separate analysis of control loops and enables a compositional design of schedules that cope with competing needs of communication and computation resources. In this way, one can synthesize systems that take into account delays, and robustness, as well as MAC layer scheduling and network routing. A limitation of such a time-triggered approach is scalability and flexibility, as large networks with many devices require a complex schedule to be pre-allocated and distributed throughout the network. Such a schedule might be hard to adapt online.

For many control applications, the time constants are much larger than the underlying time frame of the wireless communication. Still, when disturbances and other unpredictable events affecting the plant happen, a guaranteed control action needs to take place. Such reactive, or event-triggered, control is an interesting new paradigm for large-scale wireless control systems. Event-triggered transmissions can be generated based on decisions taken locally at the sensor node. In this way, it is possible to reduce the network utilization but still keep a guaranteed control performance, as the system reacts only when it is needed. A variety of such proposals are currently studied in the literature, where the sensor transmission decision can also be supported by information in the controller or in other sensor devices. For instance, if the state observer in the controller notices that the quality of its information about a certain plant state is poor, it can request data from sensors related to that state.

5. Conclusions

The realization of the completely wireless industrial plant might be far into the future. In this note we have discussed a number of interesting developments in using wireless devices for process control and we have illustrated that local wireless sensor networks are already being deployed in some industrial settings. The widespread use of wireless control relies however on further research and developments. Some promising advances related to wireless networking protocols suitable for control applications were discussed together with new time- and event-triggered control paradigms

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Member Profile: TKN/TUB

The internationally renowned Technische Universität Berlin (TUB) is located in Germany's capital city at the heart of Europe, and is one of the major German Universities of Technology.

The seven faculties have some 27,000 students enrolled in more than 90 curricula (July 2010). The University employs over 7,000 people including 320 tenured professors, 2,364 researchers, and 2,038 staff members. In addition there are 2,303 student assistants and 145 trainees (September 2010)[1].

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TUB activities focus on achieving four sharply-defined core goals: building a distinctive profile for our university, ensuring exceptional performance in research and teaching, providing our graduates with excellent qualifications, in addition to a forward-looking approach to efficient university governance. Strong regional, national and international networking partnerships with science and industry are an important aspect in this regard.

The TUB research and teaching endeavors can be characterized by a broad spectrum of academic disciplines, ranging from engineering science to natural science, planning science and economics, as well as the humanities and social sciences.

TUB is a research university with telecommunications (inc. TKN) being one of the key areas of its competence. The School of Electrical Engineering and Computer Science (EECS), in cooperation with a group of affiliated research institutes and the on-campus industrial research (e.g. the Deutsche Telekom Laboratories; Fraunhofer Institutes, Leibniz Institutes), creates a unique ecosystem in telecommunications oriented basic and applied research. The recently established Innovation Centre of Human-Centric Communication bundles research effort of numerous faculties and leading researchers within this ecosystem.

ⓘ [1]http://www.tu-berlin.de

TKN Telecommunication Networks Group

The Telecommunication Networks Group (TKN) at TUB, founded by Prof. Adam Wolisz in 1993, focuses on design and evaluation of architectures and protocols for communication networks in mobile and wireless communication systems. TKN research addresses three major areas:

- **Networked Embedded Systems**, following the path from Sensor Networks towards Cooperating Objects and Cyber-Physical Systems.
- **Wireless Access Systems**, addressing specifically system heterogeneity and cognitive, cooperative usage of the available capacities.
- **Solutions for the Future Internet** – with special attention to efficient green solutions.

The TKN research methodology relies both on performance modelling as well as on early prototyping in hardware and software. The research results are disseminated by publications (see http://www.tkn.tu-berlin.de/publications) and contributions to open source communities.

With around 30 researchers and PhD students TKN belongs to the strongest research groups of the EECS School. The group actively participates in several international projects like:

- **COAST – Content Aware Searching retrieval and sTreaming**, EU FP7, Specific Targeted Research Project:

  http://www.coast-fp7.eu/

  The project aims to build a content-centric network overlay architecture able to intelligently and efficiently link billions of content sources to billions of content consumers, and offer fast content-aware retrieval, delivery and streaming, while meeting network-wide service level agreements in content and services consumption.
- **CREW – Cognitive Radio Experimentation World**, EU FP7, Integrated Project:

  http://www.crew-project.eu/

  The main target is to establish an open federated test platform, which facilitates experimentally-driven research on advanced spectrum sensing, cognitive radio and cognitive networking strategies in view of horizontal and vertical spectrum sharing in licensed and unlicensed bands.
- **TREND – Towards Real Energy-efficient Network Design**, EU FP7, Network of Excellence:

  http://www.fp7-trend.eu/

  TREND will integrate and drive towards commonly agreed technical goals, the many recent research efforts in energy-efficient networking, laying down the bases for a new holistic approach to energy-efficient networking, investigating effective strategies and mechanisms to reduce energy consumption in current and future networks in general, and the future Internet in particular.
- **MEVICO – Mobile Networks Evolution for Individual Communications Experience**, EUREKA Cluster Celtic “Cooperation for a sustained European Leadership in Telecommunications”, call 7:

  http://www.celtic-initiative.org/

  The project is on research of the network aspects of the 3GPP LTE-mobile broadband network for its evolution in the mid-term in 2011-2014. The goal is to contribute to the technical drive and leadership of the EPC network (3GPP), and thus support the European industry to maintain and extend its strong technical and market position in the mobile networks market.

Furthermore, TKN's researchers are involved in technology oriented activities like the TinyOS working groups.

Within CONET, TKN is leading the efforts towards establishing a platform for federating the testbed resources of multiple CO testbeds, through a set of common testbed management and experiment-control APIs.

TKN researchers are also active in the CONET research clusters, in particular:

- **Resource Management and Adaptation** (RMA, cluster leader), addressing the development of mechanisms for reliable assessment of the current RF interference situation as a basis for dynamic resource adaptation that will provide better end-to-end system performance and quality of service (e.g. for mobile body area networks).

- **Recognizing Emotions using Wireless Sensor Networks** (REWSN), investigating the application of cooperative techniques between body area networks and wireless sensor networks to recognize human interactions, emotions and other metal conditions.

TKN Lab Facilities

TKN has well equipped laboratories, including a unique sensor networks testbed facility, environments for prototyping of WLAN systems and LTE-type systems, has access to an emerging open mesh network testbed and is participant of the world largest Internet testbed – **PlanetLab**.

The TKN Wireless Indoor Sensor network Testbed (**TWIST**), with over 200 nodes and more than 1500 m^2 of instrumented space, is one of the largest testbeds for controlled experimentation with WSNs under realistic conditions of an indoor office space. The TWIST architecture has been used as the blueprint for development of several additional commercial and academic testbeds.

It is characterized by unique power supply control capability and hierarchical architecture support. Built on open standards, open architectures, and open source it can be readily replicated by other institutions.

TWIST is scalable and flexible testbed architecture for indoor wireless sensor network deployments, in particular:

- network-wide programming and node configuration,
- out-of-band extraction of debug data,
- application data forwarding and storage.

The TWIST architecture provides support for:

- heterogeneous sensor node platforms,
- active power-supply control of the nodes,
- evaluation of flat and hierarchical deployments.

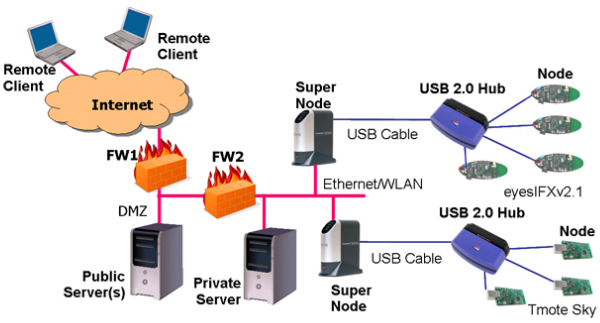

Figure 1: TWIST hardware instantiation

The self-configuration capability, the use of standardized hardware and open-source software make TWIST scalable, affordable, and easily replicable!

TWIST – Quick Facts

One of the largest indoor WSN testbeds in Europe:

- 3D deployment, spanning 3 floors of the TKN office building
- 1500 m^2 instrumented space

204 installed sensor nodes:

- 102 Tmote Sky
- 102 eyesIFXv2.1
- 46 super nodes
- 50 USB 2.0 hubs and 1335 m USB cabling

TWIST - dynamic experiments

The powerful power-supply control capabilities enable:

- easy transition between USB and battery powered experiments,
- dynamic selection of topologies,
- controlled injection of node-failures in the system.

The TKN group is also operating an **OFDMA testbed** consisting of 8 OpenAirInterface nodes. OpenAirInterface is an open-source hardware/ software development platform that provides all means to evaluate, modify and extend emerging industrial OFDM air interface standards such as 802.16m and 3GPP LTE in terms of spectral, algorithmic and protocol efficiency. In the context of cognitive radios, the testbed can be used for the development of innovative techniques that will support the coexistence of licensed and unlicensed wireless users in a same area.

ⓘ http://www.tkn.tu-berlin.de
http://www.twist.tu-berlin.de/wiki ■

Announcements

The Second International Workshop on Networks of Cooperating Objects CONET 2011

April 11, 2011, Chicago, USA

ⓘ http://www.cooperating-objects.eu/events/conet-2011/

Important dates:
Submission deadline: Monday, February 28, 2011
Acceptance Notification: Monday, March 21, 2011
Camera Ready: Monday, March 28, 2011
Workshop: Monday, April 11, 2011

CPSWeek 2011

April 11 -14, 2011, Chicago, USA

ⓘ http://cpsweek2011.cs.illinois.edu/

The CPSWeek brings together five leading conferences – HSCC, ICCPS, IPSN, LCTES, and RTAS – as well as several workshops and tutorials on various aspects on the research and development of cyber-physical systems: Embedded Systems, Hybrid Systems, Real-Time and Sensor Networks.

IEEE International Conference on Robotics and Automation ICRA 2011

May 9-13, 2011, Shanghai China

ⓘ http://www.icra2011.org/

The 2011 IEEE International Conference on Robotics and Automation (ICRA 2011) will take place from May 9 to 13, 2011 at the Shanghai International Conference Center and the Shangri-La Hotel Shanghai Pudong in Shanghai, China.

2011 EECI Graduate School on Control

January 17-May 13, 2011, Supelec – Paris, France

ⓘ http://www.eeci-institute.eu/GSC2011

Intensive teaching: 15 independent modules, one module per week (21 hours).

EECI, the European Embedded Control Institute has been created on 16 May 2006 in the framework of the HYCON Network of Excellence (FP6-IST-511368). EECI promote the education of students and researchers.

Latest News

8th European Conference on Wireless Sensor Networks (EWSN 2011)

February 23-25, 2011, Bonn, Germany

ⓘ http://www.nes.uni-due.de/ewsn2011

EWSN 2011, the European Conference on Wireless Sensor Networks, is the eighth of a series of annual meetings focusing on the latest research in the area of wireless sensor networks. The exciting program includes the presentation of 14 technical papers, 13 posters, 8 demos, several project posters and industrial demos, a conference reception with guided tours at the DHL Innovation Center, and two tutorials on the first day.

Register now!

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