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Editorial

Welcome to the second 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 the thesis awards for the best master and PhD theses in the area of cooperating objects. The winners received their awards at EWSN 2009 in Cork, Ireland. Furthermore, this issue also contains an article on environmental noise monitoring with cooperating objects.

This issue's "member profile" presents the Networked Embedded Systems group at SICS, Swedish Institute of Computer Science. We also take the opportunity to present some of the work being done within the CONET consortium in the "Cooperating Objects Roadmap". This issue presents a summary preview on "Quality of Service in Cooperating Object Systems". ■

CONET Master and PhD Thesis Awards

The CONET Master and PhD Thesis Awards were handed over at EWSN 2009. Theses in the area of Cooperating Objects that were completed during the year 2008 were assessed by a jury of CONET members with respect to scientific

originality, scientific significance for the field of Cooperating Objects, quality of the presentation and potential for practical application. Below are the abstracts of the theses that won the awards.

Academic MSc Award: Ricardo Severino

Ricardo Severino received the academic MSc award for his Master Thesis "On the use of IEEE 802.15.4/ZigBee for Time-Sensitive Wireless Sensor Network Applications". The thesis was performed at ISEP-IPP under the supervision of Prof. Mário Alves and Dr. Anis Koubâa.

Thesis abstract: This Thesis focuses on the use of standard protocols, particularly IEEE 802.15.4 and ZigBee, combined with commercial technologies as a baseline to enable WSN infrastructures capable of supporting some of the QoS requirements that future large-scale networked embedded systems may impose.

We aim at closing the gap between theoretical/simulation work and the real world by performing a series of comparisons between simulation and experimental results on topics like: (1) evaluation of the network performance of the IEEE 802.15.4 Slotted CSMA/CA mechanism; (2) validation of a mechanism to mitigate the hidden-terminal problem and its demonstration in a real application scenario, featuring a target tracking application; (3) experimental validation of a methodology for modelling cluster-tree WSNs and computing the worst-case end-to-end delays, buffering and bandwidth requirements. This work also identifies a number of technological constraints, namely related to hardware/software and to the Open-ZB protocol stack implementation in TinyOS, which triggered a new implementation effort to port the Open-ZB IEEE 802.15.4/ZigBee protocol stack to the ERIKA real-time operating system.

Industry PhD Award: Oliver Amft

Oliver Amft received the industry PhD award for his PhD Thesis "Automatic dietary monitoring using on-body sensors". The thesis was performed at ETH Zurich. Oliver is now at TU Eindhoven.

Thesis abstract: Oliver's thesis focuses on activity and behaviour recognition in body-worn sensors. While the fundamental concepts and methods developed in the thesis are relevant for

recognising human activities and context in countless applications of Ambient Intelligence and personal healthcare, the work addresses specifically the challenging topic of diet monitoring based on information derived from sensor networks. Oliver's thesis is structured in eight scientific publications that are introduced and discussed in the first part. Moreover, in this first part, the novel concept of automatic dietary monitoring (ADM) is introduced and an overview on intelligent sensing techniques for ADM is provided. Subsequently, intelligent sensing approaches are presented, including a chewing sensor as well as a sensing collar to monitor swallowing.

The potential of these sensing techniques for recognising activities and inferring behaviour was analysed. Novel algorithms for spotting activity events in the presence of signal noise and temporal signal pattern variability have been introduced and evaluated. The algorithm concept was demonstrated to scale to various event spotting tasks and sensor modalities. By structuring temporal events using a language modelling approach, complex activities have been successfully traced and inferred. Oliver's thesis demonstrates the excellent prospect of sensor networks as information source in intelligent ambient and personal assistants. Solutions presented in the thesis can enable rapid realisation of novel context-aware sensor networks. Moreover, the thesis makes fundamental contributions to diet monitoring, which is the basis for diet coaching and considered as a vital approach to fight the overweight and obesity pandemics.

Academic PhD Award: Luca Mottola

Luca received the academic PhD award for his PhD thesis "Programming Wireless Sensor Networks: From Physical to Logical Neighborhoods". The thesis was carried out at Politecnico Di Milano (Italy) under the supervision of Prof. G. P. Picco. After a period at the University of Trento (Italy) where he was involved in several real sensor network deployments, Luca is now with SICS.

Thesis abstract: Luca's PhD thesis focuses on programming abstractions for WSNs. The thesis starts with an extensive classification of the current literature, which has also posed the basis for a successful tutorial on the topic. Next, Luca's thesis tackles the challenge of programming WSNs at different levels. Starting from programming solutions revolving around a node's physical neighborhood (e.g., the TeenyLIME

middleware), the thesis presents novel addressing mechanisms to program application-defined group of nodes (the Logical Neighborhood abstraction), and ways to empower existing macro-programming frameworks with notions of scoping. A characteristic common to all solutions presented is that of co-designing the programming abstractions with the underlying system support to enable optimal performance. The solutions described in Luca's thesis hold the potential to greatly simplify programming WSNs, which is commonly agreed as one of the major obstacle to a widespread adoption of this technology.

PhD Honourable Mention: Andreas Lachenmann

Andreas Lachenmann received a honourable mention for his PhD Thesis "A Cross-Layer Framework for Sensor Networks". Andreas performed his thesis work at the University of Stuttgart.

Member Profile: SICS

The Swedish Institute of Computer Science (SICS) is an independent non-profit research organization that conducts advanced research in strategic areas of computer science. SICS actively promotes the use of new research ideas and results in industry and in society at large. SICS collaborates with both large and small companies, both in Sweden and internationally.

<http://www.sics.se/>

The Networked Embedded Systems group (NES) is one of the most successful European research groups in the area of cooperating objects with three full papers at ACM SenSys in 2006 and 2007 as well as two IPSN papers in 2009. Furthermore, NES has developed software that is widely used in both academia and industry such as the Contiki operating system.

NES was created in 2006 and does research in system software for sensor networks and embedded systems, applying AI methods to sensor networking, protocol implementations for memory-constrained systems, simulation of wireless sensor networks, and application of wireless sensor networks to water monitoring, climate protection and energy management.

Besides participating in CONET, NES is active in the FP7 project GINSENG on performance-controlled sensor networks. NES also leads an

ITEA2 project “European Sensor Network Architecture” and has a leading role in the SICS Center for Networked Systems and the Uppsala VINN Excellence Center for Wireless Sensor Networks (WISENET).

① <http://www.sics.se/nes/>

The Contiki Operating System

Contiki is an open source, highly portable, multi-tasking operating system for memory-efficient networked embedded systems and wireless sensor networks. The Contiki project was started in 2002 at SICS and has subsequently grown to include both research institutions and major industry players.

Many advances in wireless sensor networks come from Contiki, such as power profiling, hybrid multi-threaded programming, cross-layer simulation, and IP-based sensor networking.

Several Contiki mechanisms have been released as separate open-source packages and have seen significant industrial uptake. The uIP embedded IP stack, originally released in 2001, is today used by hundreds of companies in systems such as freighter ships, satellites and oil drilling equipment. Contiki's protothread programming abstraction, first released in 2005, has been used in digital TV decoders and wireless vibration sensors.

For sensor network communication, Contiki provides a low-power radio networking stack called Rime. The Rime stack implements sensor network protocols ranging from reliable data collection and best-effort network flooding to multi-hop bulk data transfer and data dissemination. IP routing is implemented within the Rime framework.

Interaction with a network of Contiki sensors is done with a web browser, a text-based shell interface, or dedicated software that stores and displays collected sensor data. The text-based shell interface is inspired by the Unix command shell but provides special commands for sensor network interaction and sensing.

Contiki provides a flash-based file system, called Coffee, for storing data inside the sensor network. The file system allows multiple files to coexist on the same physical on-board flash memory and has a performance that is close to the raw data throughput of the flash chip.

To ease software development and debugging, Contiki provides three simulation environments: the MSPsim emulator, the Cooja cross-layer network simulator, and the Netsim process-level simulator. The development process for software for Contiki typically goes through all three

simulation stages before the software runs on the target hardware.

In October 2008, major industry players Cisco and Atmel joined Contiki. Cisco, Atmel and SICS jointly announced uIPv6, the world's smallest fully compliant IPv6 stack. uIPv6 builds on the uIP stack and is integrated in Contiki and the SICS Slowpan IPv6 header compression layer.

The Contiki team currently consists of seventeen members from SICS, SAP AG, Cisco, Atmel, NewAE and TU Munich.

① <http://www.sics.se/contiki/>

Cooperating Objects for Environmental Noise Monitoring

By *ETH Zurich*

Monitoring remote or hazardous terrains at a fine-grained spatial and temporal resolution and without the need for human intervention had long been an unspoken dream of many natural scientists. With the progress of wireless sensor networks technology, systems materializing these dreams are becoming a reality. Indeed, wireless sensor networks already helped monitoring bird habitats and habits¹, investigating the interplay of climate change and rock fails in permafrost areas², or studying the influence of environmental parameters on the quality of agricultural products³.

Systems of heterogeneous, static and mobile sensors aiming at monitoring environmental pollution parameters in urban areas also started to appear in recent years. For instance, the CitySense⁴ deployment provides a fixed network of line-powered wireless sensors to capture data on air pollution and to deliver it in real-time to the

¹ Robert Szewczyk and Alan Mainwaring and Joseph Polastre and John Anderson and David Culler. *An Analysis of a Large Scale Habitat Monitoring Application*. Proceedings of the Second ACM Conference on Embedded Networked Sensor Systems (SenSys 2004), Baltimore, Maryland, USA, November 3-5, 2004.

² Igor Talzi, Andreas Hasler, Stephan Gruber and Christian Tschudin. *PermaSense: Investigating Permafrost with a WSN in the Swiss Alps*. Proceedings of the Fourth ACM Workshop on Embedded Networked Sensors (EmNets 2007), Cork, Ireland, June 25-26, 2007. (See also: www.permasense.ch.)

³ Aline Baggio. *Wireless sensor networks in precision agriculture*. Proceedings of the First Workshop on Real-World Wireless Sensor Networks (REALWSN 2005), Stockholm, Sweden, June 20-21, 2005.

⁴ www.citysense.net

users. The interplay with mobile (sensing-enabled) devices like mobile phones or vehicles will allow to capture pollutants' distributions with an accuracy that was unimaginable, though desirable, even a few years ago. Fine-grained data collection is essential to foster scientific research and increase the understanding about actual pollutants spreading mechanisms and their influence on human health. Furthermore, any action plan aiming at the reduction of environmental pollutants may be ineffective if no adequate actual data is available for planning and successive validation.

An interesting example in this context concerns the problem of noise pollution in urban areas. The World Health Organization estimates that about half of the European citizens live in noisy spaces, and that about a third experience noise levels so high that these can cause sleep disruption. Recent studies on this matter clearly linked exposure to environmental noise to health risks (e.g., hypertension), productivity losses, and negative social behavior⁵. Recognizing in noise pollution a serious hazard to health and productivity as well as a source of increasing complaints from the public, the European Commission reacted with the enactment of Directive 2002/49/EC, which requires administrations of all agglomerations with more than 250'000 inhabitants to regularly provide accurate mappings of noise levels throughout their jurisdiction and to make this information publicly available. Creating a comprehensive set of initial noise measurements is indeed the first building block towards the definition of an adequate action plan to address this problem and work towards lowering noise levels.

But today's processes for generating these data sets are fraught with inaccuracy, as current noise maps are mainly based on extrapolating a few noise measurements using inevitably limited computational models. This is because gathering such data is costly and time consuming. It involves staff to drive around town, setting up expensive equipment in carefully chosen key locations, and storing the data for later offline analysis⁶. While fixed installations exist, their need for frequent recalibrations hampers long-time unattended operations. Instead, adequately

equipped sensor nodes could be deployed over an area of interest and collect noise pollution readings over longer periods of time, operating unattended and requiring human intervention only for network installation and removal. While the low-power design and small form factor of such sensor nodes prevents the use of high-fidelity microphones and circuitry, this also eliminates the previous need for frequent recalibrations, and thus human intervention.

Mobile phones may also provide an interesting alternative to obtain comprehensive data sets for noise mapping. Both Google's GPhone and Apple's iPhone already offer a number of applications that leverage the built-in microphone to estimate current noise levels in the user's surroundings. Location information from the on-board GPS and the phone's wireless communication make "noise reporting" to a central mapping service a snap.

Noise data collected using mobile phones or sensor nodes may however still be too inaccurate for being used as direct input to noise maps. Researchers at the Institute of Pervasive Computing of the ETH Zurich have shown that noise levels data measured by currently available platforms may indeed enable gross classifications of "noisiness", but can hardly reach the accuracy required for noise mapping⁷. At the same time, the much larger amount of available data may actually compensate for the reduced sensor accuracy.

The first report on the implementation of Directive 2002/49/EC, due next July, will "assess the need for further Community actions on environmental noise and, if appropriate, propose implementing strategies"⁸. In particular, the report will analyze how scientific and technical progress may support the European noise policy and thus also define the role pervasive sensing technologies may play in supporting the preparation of noise maps. The main question that remains, of course, is whether cheap sensor nodes and mobile phones data will indeed allow one to create quality from quantity.

■

⁵ Hildegard Niemann and Christian Maschke. *Final Report on Noise Effects and Morbidity*. WHO Large Analysis and Review of European Housing and Health Status (LARES), Interdisciplinary research Network "Noise and Health", 2004.

⁶ Silvia Santini, Benedikt Ostermaier, Andrea Vitaletti. *First Experiences Using Wireless Sensor Networks for Noise Pollution Monitoring*. Proceedings of the Third ACM Workshop on Real-World Wireless Sensor Networks (REALWSN 2008), Glasgow, United Kingdom, April 1, 2008.

⁷ Silvia Santini, Benedikt Ostermaier, Robert Adelman. *On the Use of Sensor Nodes and Mobile Phones for the Assessment of Noise Pollution Levels in Urban Environments*. Submitted for publication to the Sixth International Conference on Networked Sensing Systems (INSS 2009), Pittsburgh, PA, USA, June 17 - 19, 2009.

⁸ Directive 2002/49/EC, article 11.

On the Quality of Service in Cooperating Object Systems

By School of Engineering (ISEP) of the Polytechnic Institute of Porto (IPP)

Introduction

Over 99% of all microprocessors produced today are used in embedded computing systems⁹. These are usually “hidden” from their users (e.g. cars, lifts or home appliances) but interacting with them and with the physical environment at unprecedented levels.

However, an even more dramatic change is yet to come when these (mostly) isolated islands of computing intelligence will be seamlessly interoperating and cooperating for achieving common goals. Road vehicles will interact between them and with fixed infrastructures; humans and machines will coexist in smart computing environments; the Internet will penetrate the physical world via wireless sensor/actuator networks; every single “object” on earth will be electronically and remotely identifiable, monitorable and controllable.

We refer to this new paradigm as “Cooperating Objects” (CO) systems¹⁰. CO systems must be conceived in a way that the quality of the service provided to their users (e.g. humans, animals, robots, plants, environment) is above an acceptable threshold. It is also of huge importance that realistic (real-world) requirements and system models are identified¹¹.

The remainder of this short article (based on an EWSN Tutorial¹² and Section 3.3 of the CONET roadmap¹⁰) outlines some relevant properties of a CO system that, although not affecting its functionality, affect its behavior or performance, i.e. the Quality of Service (QoS) properties.

QoS – a New Perspective

Traditionally, “QoS is the ability to provide different priority to different applications, users, or data flows, or to guarantee a certain level of performance to a data flow...”¹³. QoS is thus usually associated with bit/data rate, throughput, delay and bit/packet error rate. We believe that this concept is too strict, i.e. these properties alone do not reflect the overall quality of the service provided to the user/application.

Therefore, QoS should be addressed in a wider and holistic perspective, instantiated in a diverse range of properties such as heterogeneity, timeliness, scalability, reliability, mobility and security (Figure 1).



Figure 1: QoS properties in CO systems

Balancing QoS Properties

The quality attributes previously referred are not new concepts and have already been addressed separately (or in subsets). Nevertheless, addressing and satisfying all of them have not been done yet.

According to each CO application/task requirements, computations and communications must be correct, secure, produced “on time” and with the smallest energy consumption possible. Cooperating objects (CO) systems are highly heterogeneous and must be cost-effective, maintainable and scalable. They must also be as much “invisible” to their users/environment as possible, to be widely and calmly accepted and used¹⁴.

⁹ J. Turley, “Embedded Processors by the Numbers”, on-line article at <http://www.embedded.com/1999/9905/9905turley.htm>

¹⁰ CONET Consortium, “Research Roadmap on Cooperating Objects”, Draft, FEB/2009. To appear by JUN/2009, <http://www.cooperating-objects.eu>

¹¹ B. Raman and K. Chebrolu, “Censor networks: a critique of “sensor networks” from a systems perspective”, ACM SIGCOMM Computer Communication Review, v. 38, n°3, pp. 75–78, July 2008.

¹² M. Alves, “The wireless sensor networks standards and COTS landscape: can we get QoS and “calm technology”?”, Tutorial at EWSN’09. Slides available at <http://www.hurray.isep.ipp.pt/ART-WiSe>

¹³ Wikipedia page for Quality-of-Service, www.wikipedia.org. Consulted on JAN/2009

¹⁴ Mark Weiser, “The computer of the 21st Century”, Scientific American, 1991. Available at: <http://nano.xerox.com/hypertext/weiser/SciAmDraft3.html>

All this intends to stress the fact that all QoS properties are strongly interdependent, in a way that changing one may impact other. Just two examples: (1) to increase network throughput (one of the characteristics of Timeliness), it might be necessary to increase the "hardware" bit rate or nodes duty cycle, leading to more energy consumption (thus impacting Energy-Efficiency); (2) implementing more reliable CO systems may increase cost (structural redundancy, e.g. hardware replicas), reduce energy-efficiency/system-lifetime (e.g. information redundancy, e.g. adding parity or CRC/FCS bits to messages) or reduce throughput (time redundancy, e.g. repeating a computation or resending a message).

Final Remarks

As people increasingly depend on embedded computing systems, the quality of their service is also of growing importance, particular for Cooperating Object (CO) applications where humans, fauna, flora, the environment or any valuable good may be severely affected. Moreover, QoS can no longer be seen in the too restrictive "classical" perspective of "throughput, delay and error rate". A wider and holistic approach to QoS encompassing many different yet complementary properties is precluded as mandatory for CO systems' design.

For further reading, please refer to the upcoming (first) edition of the CONET Roadmap¹⁰, which will feature a survey on the current state and future directions of research, practice and technology in CO systems. ■

Announcements

EWSN 2009 CONET Best Paper Award.

CONET donated a prize for the best paper of EWSN. It was awarded to Konrad Iwanicki and Maarten van Steen for their paper "Multi-Hop Cluster Hierarchy Maintenance in Wireless Sensor Networks: A Case for Gossip-Based Protocol".

Special Interest Groups. The CONET project is hosting several mailing lists instantiated during the Concertation Meeting in October 2008 in Brussels. Although the lists cover topics related to CONET they are no internal CONET mailing lists. Everyone who is interested in these topics is invited to join!

① <http://www.cooperating-objects.eu/sigs/>

IPSN 2009 tutorial. The Contiki team will arrange a tutorial on IP-based sensor networks at IPSN 2009, April 16 2009, San Francisco.

① <http://ipsn.acm.org/2009/>

CONET Sponsored Events

ETTX'09. The First European TinyOS Technology Exchange took place in Cork, Ireland, on February 10th, collocated with EWSN'09.

① <http://sites.google.com/site/ettx2009>

Workshop on Wireless Sensor Networks and Cooperating Objects.

This workshop is organized by WASP and CONET and takes place on March 25th, 2009 at Fraunhofer Institute for Computer Graphics Research IGD, Darmstadt, Germany.

① <http://www.cooperating-objects.eu/events/>

RWI 2009. The International Workshop on Integration of the Real World and the Future Internet will be held at Marina del Rey, California, June 10, 2009. The workshop is co-located with the IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS '09).

SemSensWeb 2009. The first International Workshop on the Semantic Sensor Web will take place in Heraklion, Crete, June 1st, 2009. It is co-located with the 6th European Semantic Web Conference (ESWC 2009).

EWSN 2010. EWSN 2010 will be held in Coimbra Portugal early 2010. A first call for papers will be available soon.

Register @ <http://www.cooperating-objects.eu/> to receive future issues of the CONET Newsletter