A testbed for teaching and experimenting with WSNs

Adriano Branco[1], Bruno Silvestre[3], Noemi Rodriguez[1] and Silvana Rossetto[2]

[1]abranco,noemi@inf.puc-rio,br Departamento de Informática, PUC-Rio, Brazil
[2]silvana@dcc.ufrj.br Departamento de Ciência da Comuputação, UFRJ, Brazil
[3]brunoos@inf.ufg.br Instituto de Informática, UFG, Brazil

In this paper, we describe the construction of a platform for research and education on distributed applications spanning hybrid networks, that is, networks combining conventional computers with embeddable and monitoring devices such as wireless sensor nodes.

Wireless sensor networks have been growing in importance during the last decade due to their use in a wide range of application areas [RM04]. Many of these applications rely on nodes with very limited processing and memory resources, often called *motes*.

In spite of this growth in usage, learning to write applications for WSNs is hard, and the development of new techniques and protocols needs extensive testing. Students and researchers do not usually have access to large numbers of motes, and even if they do, it is hard to set up experiments and load the desired code in a large number of devices. Experiments are typically carried out through simulation, but this strategy has some limitations which have spurred the construction of WSN testbeds for remote experimentation. Most of these testbeds, however, provide support for applications which are completely defined in the wireless sensor network (possibly relying on a well-equipped computer to collect and process data from the network). With the growth of interest in the Internet of Things and with the realisation that arbitrary applications may profit from access to microcontrollers for sensing as well as for control, it becomes important that students and researchers experiment with hybrid environments. Testbeds should be able to support applications that combine the use of WSNs with the use of the conventional Internet as well as of other wireless networks.

Computers on the Internet have, in a number of projects, been connected to motes and other restricted devices through drivers. In such platforms, a gateway is typically used to translate HTTP (or other protocol) requests to a less demanding protocol that transmits the request to the devices with restricted resources. What we are proposing is not this. Instead, we believe it would be interesting to have all devices talking directly to the Internet, so as to make it possible to experiment with arbitrary peer-to-peer patterns of communication.

Over the last two years, we have been working on an experimental testbed with funding from the CTIC/RNP (Brazilian Research and Education Network) program. In this project, we devoted attention to existing solutions for installing the IPv6 stack on motes with limited resources. We also developed part of the infrastructure that is necessary in any testbed setting: a portal through which the user can upload his/her program to motes and control its execution. We are now, also with support from RNP, redesigning this infrastructure so that it can support hybrid experiments, that is, experiments with parts running on the conventional Internet and parts running on wireless sensor nodes. We are also extending our testbed, which originally contained only Telosb and Micaz motes, to encompass other architectures, such as a few Arduinos. Some of the new nodes will rely on

Raspberry Pi systems for their connection to the local network (the wired local network which is used for loading code on the testbed devices). Reseachers will also be able to upload arbitrary code directly on these Raspberry Pis, allowing for one more type of embedded device in their experimentation with hybrid networks. The testbed portal is being extended so as to authenticate users through the CAFe (shibboleth-based) federation.

Writing applications involving restricted devices like Micaz or Arduino is not easy, and becomes even harder in the context of a complex hybrid network. The programmer must deal with a number of concurrent and asynchronous events while managing the restrictions of memory that are typical of these platforms. Over the last years, we have been working on platforms that facilitate this task. We are working on Terra [Bra13], a platform that combines a virtual machine providing a number of ready-built facilities with a scripting language called Céu [SRI+13] which statically verifies that there are no infinite loops or inconsistent accesses to shared variables in the application program. Although our portal allows any arbitrary program to be uploaded to nodes, we believe the use of Terra will be a facilitator for students and experimenters.

Our goal is to allow researchers and students to experiment with hybrid networks at different levels of abstraction. Terra's VM can be tailored to provide higher or lower levels of abstraction for communication, allowing the researcher or teacher to configure the abstraction level at which he desires to work. For teaching or experimenting with lower level protocolos, a bare-bones version of Terra can be used, while the full Terra VM provides ready-made components for automatic collection and aggregation of data.

We have also started work on developing materials supporting the use of this testbed for teaching. Part of our group was involved in a new syllabus for Ditributed Algorithms and Distributed System courses which exploits WSN platforms for hands-on experience with peer-to-peers algorithms and interaction patterns, as well as for the more general issue of fault tolerance [RR12, BMRR13]. This syllabus contains a set of labs which start from a code basis and ask students to code adaptations and extensions. These materials will also be made available at the testbed portal.

Teaching materials, as well as the Terra programming system, are available but not yet organized for use through the portal. We intend to have the portal organized with these materials by May 2014, and would like to submit a full paper about the resulting environment.

References

[BMRR13] A. Branco, A. L. Moura, N. Rodriguez, and S. Rossetto. Teaching concurrent and distributed computing – initiatives in Rio de Janeiro. In *Proc. IEEE 27th International Symposium on Parallel and Distributed Processing Workshops and PhD Forum*, IPDPSW '13, pages 1318–1323, 2013.

[Bra13] A. Branco. Terra: Flexibility and safety in wsns. In *Sensys 2013 Doctoral Symposium*. ACM, 2013.

[RM04] K. Romer and F. Mattern. The design space of wireless sensor networks. *Wireless Communications, IEEE*, 11(6):54–61, 2004.

[RR12] N. Rodriguez and S. Rossetto. Distributed systems with wireless sensor networks. In *Proc. IEEE 26th International Symposium on Parallel and Distributed Processing Workshops and PhD Forum*, IPDPSW '12, pages 1299–1302, 2012.

[SRI+13] F. Sant'Anna, N. Rodriguez, R. Ierusalimschy, O. Landsiedel, and P. Tsigas. Safe system-level concurrency for resource-constrained nodes. In *Proceedings of the 11th International Conference on Embedded Networked Sensor Systems*, SenSys '13. ACM, 2013.

0.0.1 Author Biographies

Adriano Branco is working for his PhD at the Catholic University of Rio de Janeiro (PUC-Rio). He has a MSc in Computer Science also from PUC-Rio.

Bruno Silvestre is Adjunct Professor at the Federal University of Goiás. He holds a PhD and MSc in Computer Science from the Catholic University of Rio de Janeiro (PUC-Rio).

Noemi Rodriguez is Associate Professor at the Catholic University of Rio de Janeiro (PUC-Rio). She holds a PhD and MSc in Computer Science from the Catholic University of Rio de Janeiro (PUC-Rio).

Silvana Rossetto is Adjunct Professor at the Federal University of Rio de Janeiro. She holds a PhD in Computer Science from the Catholic University of Rio de Janeiro (PUC-Rio) and an MSc in Computer Science from UFES.