FIT IoT-LAB tutorial: hands-on practice with a very large scale testbed tool for the Internet of Things

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Abstract

FIT IoT-LAB[1] provides a very large scale infrastructure facility suitable for testing small wireless sensor devices and heterogeneous communicating objects. The testbed offers web-based reservation and tooling for applications development, along with direct command-line access to the platform. Sensor nodes firmwares can be built from source and deployed on reserved nodes, application activity can be controlled and monitored, power consumption or radio interference can be measured using the provided tools.

The proposed tutorial is a hands-on training, with several practical exercises showing how to use the platform and demonstrating key features. We believe that researchers and engineers in fields different from the Wireless Sensor Network (WSN) community may as well benefit from using the tool, for instance parties interested in leveraging the facility for large scale ubiquitous application or large scale embedded software experimentations.

1 Introduction

Due to their massively distributed nature, the design, implementation, and evaluation of sensor network applications, middleware and communication protocols are difficult and time-consuming tasks. Addressing these issues, testbeds that feature a real physical WSN allowing researchers and programmers to validate the performance of algorithms and protocols "in real life" are just a handful ([4]).

Starting in 2007, the SensLAB project landed as a platform in 2010 ([1], [3], [2]) and offered an accurate, open access, multi-user scientific tool to support the design, development, tuning, and experimentation of distributed large-scale sensor network applications.

FIT IoT-LAB is the logical evolution of the SensLAB platform and goes far beyond the initial target of its predecessor. Building upon SensLAB and extending both capacity and ambitions, FIT IoT-LAB provides a very large scale testbed infrastructure designed to experiment with heterogeneous embedded communicating objects, in addition to small wireless sensor devices. This is a vast improvement, in terms of resources, in terms of experimental diversity, and in terms of extent. Moreover, the fundamental federative concept presiding over FIT[2] makes provision for linking IoT-LAB to other testbeds, present or future, into a single OneLab[3].

The paper presents the IoT-LAB platform, hardware and software side, outlines the exercises proposed in the tutorial, and concludes on future work.

2 FIT IoT-LAB presentation

IoT-LAB is part of the FIT experimental platform, a set of complementary components that enable experimentation on innovative services for academic and industrial users. The project gives French Internet stakeholders a way to experiment with mobile wireless communications, both on network and application layers, thereby accelerating the design of advanced networking technologies for the Future Internet.

IoT-LAB is a scientific testbed, providing full control of network nodes and direct access to the gateways to which nodes are connected. Using

[1]http://www.iot-lab.info

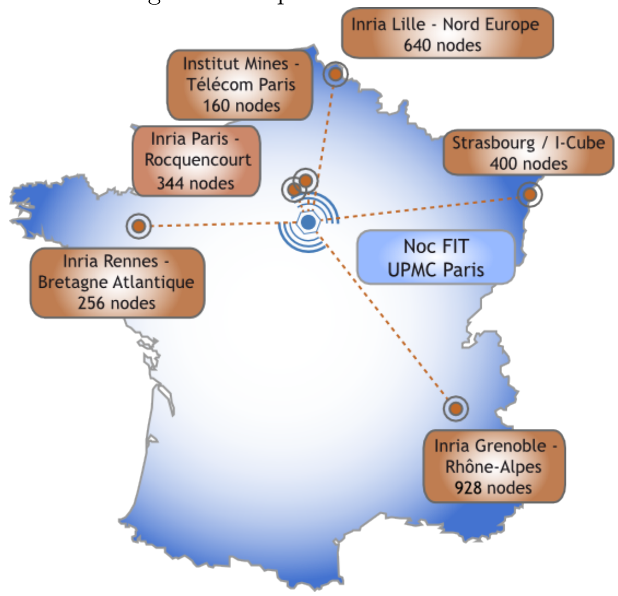
[2]http://fit-equipex.fr/

[3]http://www.onelab.eu/

web-based or command-line tools, users can allocate nodes for experiments, deploy firmware, monitor nodes energy consumption and network-related metrics, e.g. end-to-end delay, throughput or overhead. The facility offers quick experiments deployment, along with easy evaluation, results collection and analysis. Defining complementary testbeds with different node types, topologies and environments allows for coverage of a wide range of real-life use-cases.

With over 2700 wireless sensor nodes spread across six different sites in France, IoT-LAB is currently the biggest open WSN testbed in the world. Nodes are either fixed or mobile and can be allocated in various topologies throughout all sites. A variety of wireless sensors are available, with different processor architectures and different wireless chips. In addition, "open nodes" can receive custom wireless sensor for inclusion in IoT-LAB testbed.

Figure 1: Map of IoT-LAB sites



2.1 Deployement

IoT-LAB testbeds are located at six different sites across France. At full capacity, the platform will give forward access to 2728 wireless sensors nodes: Inria Grenoble (928), Inria Lille (640), ICube Strasbourg (400), Inria Rocquencourt (344), Inria Rennes (256) and Institut Mines-Télécom Paris (160). See the location illustration in figure 1.

Deployment of the platform is phased: overall infrastructure, tools, legacy WSN430 nodes and the first set of M3 nodes are already available for experiments. Other parts of the platform are still under construction and will gradually become available throughout 2014. Full capacity is planned for the end of the year.

2.2 Hardware components

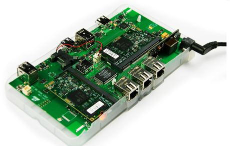
The IoT-LAB hardware infrastructure consists of a set of testbed nodes, tied within a global networking backbone that provides power, connectivity, in-band and out-of-band signal network capacity for command and monitoring, various servers, and disk space. IoT-LAB nodes themselves consist of three main components:

- **Open Node:** made available to the user during experiments. This device is totally open, user is granted full access to memory and hardware, any operating system or firmware designed for the hardware can be loaded, run, and debugged. IoT-LAB exposes the device's serial line and provides start, stop, reboot and (re)flash primitives on reserved nodes.
- **Gateway:** implements the connection to the global infrastructure, controls and monitors the Open Node. The gateway handles the open node's serial link and dumps monitoring data to disks.
- **Control Node:** used by the Gateway to interact, passively or actively, with the Open Node. This device monitors consumption and sensors values during experiments, selects power supply (battery or PoE).

Three main classes of nodes are available (see figure 2), each based on a different micro-controller (MCU) and radio communication chip:

- **WSN430 Node** MSP430F1611 MCU, 802.15.4 PHY Layer radio chip (800 MHz or 2.4 GHz), a set of sensors (ambiant sensor light, temperature). These are the SensLAB nodes, unmodified.
- **M3 Node** STM32F103REY MCU, 802.15.4 PHY Layer radio chip (2.4 GHz), a set of sensors (ambiant sensor light, pressure and temperature, tri-axis gyrometer, tri-axi accelerometer/magnetometer).

Figure 2: Different types of nodes

	
WSN 430 node	M3 node
	
A8 node	

- **A8 Node** TI SITARA AM3505 (Arm Cortex A8) mini-computer board. These can run Linux, and feature an embedded M3 Node with 802.15.4 radio.

Newer IoT-LAB nodes (M3 and A8) and legacy SensLAB nodes (WSN430) slightly differ in design and performance. WSN430 nodes are made of three separate boards, while M3 and A8 nodes are made of only two boards, with the gateway and the control node forming a single "host node".

2.3 Software

IoT-LAB offers full support for embedded software development, ranging from direct access to node hardware to operating system (OS) level features. Developers can leverage the different components, APIs and development environments to build a wide range of applications. Figure 3 illustrates the software components architecture.

Drivers expose the details of WSN430 and M3 open-nodes hardware as a thin layer of C. API entry-points provide full access to 802.15.4 PHY radio, physical sensors, serial buses, digital and analog input/output, and real-time clocks.

Wireless communications libraries offer various levels of API on top of raw 802.15.4 chips drivers. Libraries are provided as standalone building blocks or integrated on top of an OS, making development of connected applications quicker.

Various operating systems may be run on open nodes, depending on software maturity and node capacity, e.g. linux runs only on A8 nodes.

Featured OS-es are ports of leading open-source projects to the IoT-LAB hardware. All are well suited for the Internet Of Things, and come with different levels of support:

- **FreeRTOS**[4] is designed to be small and simple. The kernel itself consists of a few C files, and provides methods for multiple threads or tasks, mutexes, semaphores and software timers. Key features are very small memory footprint, low overhead, and very fast execution. IoT-LAB uses FreeRTOS by default for basic development for WSN430 and M3 nodes.

- **Contiki**[5] is an OS designed for networked, memory-constrained systems with a particular focus on low-power wireless Internet of Things devices. Contiki provides three network stacks: uIPv4, uIPv6, and Rime, and software components such as CoAP, REST and lightweight HTTP servers. The Contiki programming model is based on collaborative protothreads.

- **TinyOS**[6] is a component-based embedded OS targeting wireless sensor networks. Written in the nesC programming language, TinyOS provides interfaces and components for common abstractions such as packet communication, routing, sensing, actuation and storage.

- **Riot**[7] is a real-time multi-threading OS aiming to ease development across a wide range of IoT devices. Designed for energy-efficiency, reliability, real-time capabilities, small memory footprint, modularity, and uniform API access, RIOT provides several libraries such as Wiselib, as well as a full IPv6 stack for connecting constrained systems to the Internet.

- **OpenWSN**[8] is an open-source implementation of a standards-based protocol stack for capillary networks, rooted in the new IEEE 802.15.4e Timeslotter Channel Hopping standard. Coupled with IoT standards such as 6LoWPAN, RPL and CoAP, 802.15.4e enables ultra-low power, highly reliable mesh networks which are fully integrated into the Internet.

[4] http://www.freertos.org/
[5] http://www.contiki-os.org/
[6] http://www.tinyos.net/
[7] http://www.riot-os.org/
[8] http://www.openwsn.org/

Figure 3: Software Architecture

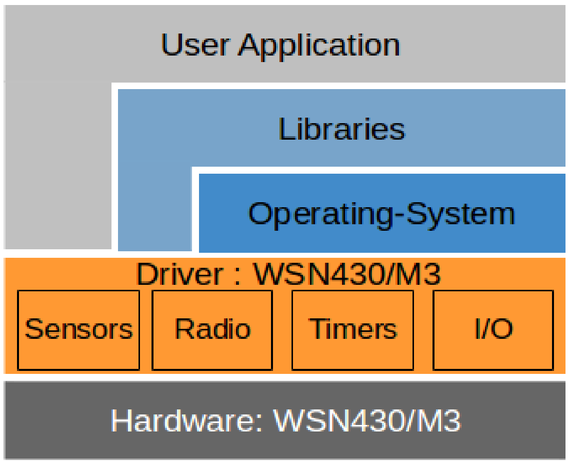
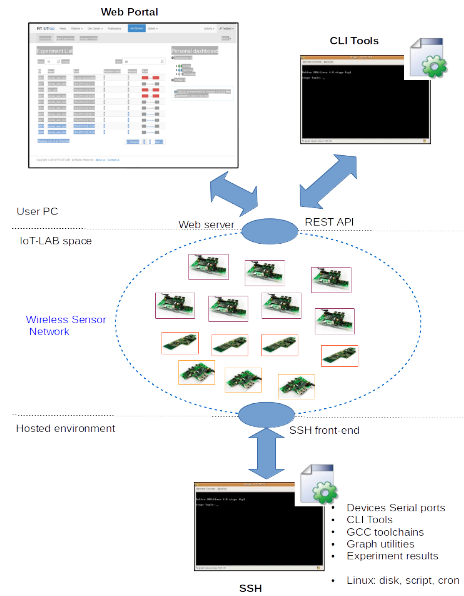


Figure 4: Platform Access



IoT-LAB software is licensed under a CeCILL License. IoT-LAB users are welcome to contribute code, papers, tutorials or experiments reports through IoT-LAB git-hub project[9].

2.4 How to use the platform ?

There are two main ways to interact with the platform: through the web portal or directly via command-line (CLI tools). The command-line tools can be used interactivly or by script, on the platform's ssh front-ends or on the user's computer. Target architectures cross-compiler toolchains are available on ssh front-ends or may be installed on the user's computer. Figure 4 illustrates these differents modes of use.

An experiment is divided in several steps: building nodes firmware, nodes reservation, monitoring tuning, launching the application and finally analyzing the data produced by the experiment.

3 The tutorial

This tutorial is a hands-on training. The goal is to learn by practice how to use the testbed platform and its key features. The tutorial demonstrates the testbed platform through five steps:

1. **first steps with IoT-LAB.** The aim of this first tutorial is to discover the IoT-LAB testbed tools by creating and submitting your first experiment, and then interact with running nodes.

2. **monitoring IoT-LAB devices** The aim of this tutorial is to monitor node consumption and radio signal power with an online measurement, and then graph collected results.

3. **basic Contiki ipv6.** The aim of this tutorial is to discover the basics of Contiki uIP stack and tools for IoT-LAB IPv6. You will access nodes directly with your browser over HTTP over IPv6 from your machine, using a local Contiki tunslip6 bridge.

4. **basic Contiki IoT.** The aim of this tutorial is to enhace the previous step by adding sensor information coming from the nodes.

5. **Big Red Button (demo):** integrate an external device into the IoT cloud (tm)

This tutorial does not require any particular skills or knowledge, except basics about using linux and terminal. All manipulations will be detailed in the instructions document delivered to attendees.

Attendees are invited to bring their own laptop under Linux.

[9] https://github.com/iot-lab/iot-lab/

4 Conclusion and Future Works

After the first installment of IoT-LAB in late March 2014, introducing the new web portal www.iot-lab.info and featuring all SensLAB WSN430 nodes, the extension of the platform carries-on in a progressive fashion.

Mid-May saw an additional 200 M3-based nodes delived on the Grenoble site. More nodes, on more sites, more material will be delivered throughout the year, eventually reaching full capacity at about 2700 nodes, including mobile nodes, additional functionalities e.g. linux support, and additional documentation e.g. use cases, linux support, and tutorials.

Providing several large scale sites, with different topologies and different node architectures allows to address the real-world scalability issues encountered in the Internet of Things case studies. IoT-LAB demonstrates how heterogeneous testbeds can be brought together to form well-organized, large-scale structures, allowing research at a much larger scale, and in different quality, with the ability to build dynamic scenarios involving complex and diverse setups.

With such a platform, we believe that potential use cases exceed Wireless Sensors Network applications and can be used for ambiant intelligence or embedded software applications. For example, the IoT-LAB architecture has inspired the Intelligent Tiles Infrastructure deployed in the LORIA smart-room [5], and we are planning a collaboration with Amiqual4Home project[10] for the use of our "instrumented corridors" in Grenoble.

Acknowledgements

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[10] https://amiqual4home.inria.fr/

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