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How to choose an experimentation platform for wireless sensor networks? A survey on static and mobile wireless sensor network experimentation facilities

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ABSTRACT

With the development of new technologies, these last years have witnessed the emergence of a new paradigm: the Internet of Things (IoT) and of the physical world. We are now able to communicate and interact with our surrounding environment through the use of multiple tiny sensors, RFID technologies or small wireless robots. This allows a set of new applications and usages to be envisioned ranging from logistic and traceability purposes to emergency and rescue operations going through the monitoring of volcanos or forest fires. However, all this comes with several technical and scientific issues like how to ensure the reliability of wireless communications in disturbed environments, how to manage efficiently the low resources (energy, memory, etc.) or how to set a safe and sustainable (both hardware and software) platform maintenance. All these issues are addressed by researchers all around the world but solutions designed for IoT need to face real experimentations to be validated. To ease such experimentations for IoT, several experimental testbeds have been deployed offering diverse and heterogeneous services and tools. In this article, we study the different requirements and features such facilities should offer. We survey the different experimental facilities currently available for the community, describe their characteristics. In particular, we detail the different hardware used for sensor networks and robot platforms and the scope of services the different facilities offer with a specific focus on testbeds which enable experimentations with mobility. We expect this survey assist a potential user to easily choose the one to use regarding his own needs. Finally, we identify existing gaps and difficulties and investigate new directions for such facilities.

1. Introduction

The Internet of Things (IoT) results from the combination of technological progresses and the new habits humans have developed facing it. By means of recent technological advances in the wireless, Internet and micro-electromechanical fields, we are now able to communicate and interact with our surrounding environment through the use of multiple tiny sensors, RFID technologies or small wireless robots. This allows a set of new applications and usages to be envisioned ranging from logistic and traceability purposes to emergency and rescue operations going through the monitoring of volcanos or forest fires. The communication establishment between (wireless) heterogeneous objects, without requiring any human-to-human nor human-to-device interaction, is a key aspect of the Internet of Things concept.

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Nowadays, technologies have improved, becoming more complex and more efficient, and new technological challenges have emerged. The applications developed on top of these technologies need to be tested and improved before being exposed to the reality. Efficient simulation tools are useful to help in the design of IoT applications, since they offer a quick and flexible way to experiment the behaviour of an application, a protocol, and in a repeatable manner. But simulation leads to assumptions on several parameters of the environment, that is a cause of uncertainty. IoT applications and wireless propagation are seriously influenced by unpredictable events and physical characteristics that are very difficult to simulate.

There is a strong need to deploy applications in a real-life like context, therefore conducting experiments on real hardware, at large-scale, and to benefit from appropriate tools for experimentation management. Indeed, the recent technological advances have driven to cost reduction and increased availability of the hardware needed for such experimentation, thus allowing the deployment of large-scale testbeds. But experimenting on large scale requires a lot of hardware and is a fastidious and time-consuming task. Therefore, several testbed platforms have been deployed all around the world to allow faster experimentations, with various sizes, hardware, topologies, and degrees of flexibility. Some facilities focus on large-scale deployment, others on mobility. Some are quite specialised, others more flexible, allowing experimentation of purely technical issues as well as higher level applications.

This paper first defines the basic requirements a facility should address and the challenges faced up for such deployments. Then, it browses the existing available wireless sensor network testbeds, describing them with regards to those requirements. Of course, we do not pretend to be exhaustive since the number of testbed initiatives in the world is huge. We choose to focus on the currently most meaningful and active testbeds. Likewise, some additional functionalities of the mentioned testbeds may have been omitted for the sake of clarity and coherency. The interested reader is invited to refer to the cited papers for further information. This paper especially highlights wireless sensor network testbeds, with a focus on the mobility in those testbeds, and brings an up-to-date overview of the state-of-the-art. We expect this survey constitute a tool to assist an experimenter to find the adequate facility that better matches its specific needs.

The remainder of the paper is organised as follows. Section 2 defines the different requirements for an IoT experimental testbed and sets the terminology used later on in the paper. Section 3 describes the existing facilities and discusses their main purposes and functionalities. Some comparisons and highlights on strengths and weaknesses of each platform are provided, highlighting what they enable or not. Finally, Section 4 broaches the expectations from a user point of view of the next generation of testbeds and the attempts performed to fulfill the future requirements.

2. Functionalities and related challenges

Because of the diversity of wireless networking issues and applications, there exists a large variety of wireless sensor network (WSN) testbeds, that can be either specialised, or more flexible, supporting various network topologies and network layer protocol options. In any case, facilities must enable the design of as much realistic IoT experimentations as possible, in terms of scale, behaviour, functionalities, environment and constraints and offer a set of specific tools.

We have identified several services and functionalities a testbed platform is likely to offer depending on the targeted applications and protocols. They are gathered into five main categories summed up in Fig. 1: (1) Experimentation tools, (2) hardware features, (3) maintenance, (4) mobility enabling and (5) extra features, and described in more details in the following.

2.1. Experimentation

From the testbed user perspective, it is essential to benefit from assisting tools all along the lifetime of an experimentation, before, during and after running it, from the design to the result analysis. The services and tools offered to design and interact with the experiment should be easy and intuitive to take in hand.

2.1.1. Before an experimentation

Simulation: When designing a wireless sensor network application, emulation and simulation are essential steps ahead of experimentation to eliminate design issues. Some efficient simulation and emulation tools exist and are widely used, like WSNet,[1] NS-2/3,[2] and Wsim.[3]

However, simulation tools suffer from a lack of accuracy in capturing realistic environmental conditions, like radio propagation. Some wireless characteristics cannot be modelled with precision. Therefore, most of the wireless sensor network testbeds focus on real-world experimentation, since there is a vital need of facing up to the reality in that field. Some testbeds include simulation tools to alleviate the design of experiments, and to verify the consistency of a protocol or algorithm, before putting it into practice by using the testbed hardware. However, an interesting approach, detailed later in Section 3.1.3, is to combine simulation, emulation and physical elements together into a single testbed, in order to gain flexibility on the scale and the offered configurations and to lower the trade-off between repeatability, reliability and scalability.

Experimentation specification: Specification is the first step for conducting an experiment, *e.g.* the selection of the adequate resources in terms of number, type or other properties, but also the specification of the programs to upload, and the data to be collected. The way to set up an experimentation and validate the configuration is an important feature of an IoT testbed.

[1] http://wsnet.gforge.inria.fr.
[2] http://www.nsnam.org.
[3] http://wsim.gforge.inria.fr.