Topology Virtualization for Wireless Sensor Network Testbeds

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Abstract. In recent years Wireless Sensor Networks (WSNs) have enjoyed a growing amount of attention. One particularly promising prospect is to employ WSNs as an extension of the future internet into the real world; this motivates experimentally driven research to evaluate and benchmark new concepts on WSNs. With our poster we will show our approach to virtualizing Wireless Sensor Network testbeds. With this technique we are able to reconfigure the topology of a WSN testbed without changing the physical location of nodes; it even allows building virtual topologies on top of federated testbeds.

1 Introduction

Testbeds are the natural way for evaluating new algorithms, approaches, or applications after simulations. On the one hand, a testbed with real hardware allows evaluating a system with the hardware restrictions of a WSN, like limited buffer size and battery capacity, variable transmission characteristics, environmental interference, variable time drift, and real-world sensor data. On the other hand, a testbed is expensive to set up and to maintain, hard to reconfigure for a different experiment, and usually features a fixed number of nodes. A possible approach to deal with these disadvantages is to virtualize parts of the testbed. First steps towards virtualization are introduced in [4], where the radio communication in a WSN is virtualized, and in [1], which describes how to run concurrent experiments in one testbed.

In this paper, we present the approach taken by WISEBED, an FP7 EU project, which comprises 9 partners from 6 different countries. Each partner provides a local testbed (i.e., the one presented in [3]) consisting of heterogeneous sensor nodes (such as TelosB, Mica2, iSense or Sun Spot equipped with different sensors) arranged in different topologies with a total of up to 2000 nodes. A user may use the complete WISEBED testbed or only use a subset and can control the experiment via a web-based interface or a piece of software. In the following, we introduce our technique for virtualization (so-called *virtual links*) and their application to create (virtualized) federated testbeds.

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2 Virtual Links

Virtual links allow sensor nodes—located in the same or in different testbeds—to communicate with each other even if they are not in communication range or have incompatible radio interfaces. Virtual links are created using a piece of software on each sensor node (a so-called virtual radio), which contains a routing table of the form (SensorNodeID, interface). Upon sending a message to a specific node, the radio knows via which *interface* a message has to be sent. This interface could be the node's hardware radio or the virtual interface, which forwards the message to a testbed server (as shown in Figure 1(b)), which in turn delivers it to the destination node. In addition to adding links to a node, it is also possible to drop messages from certain senders to prohibit communication between neighboring nodes.

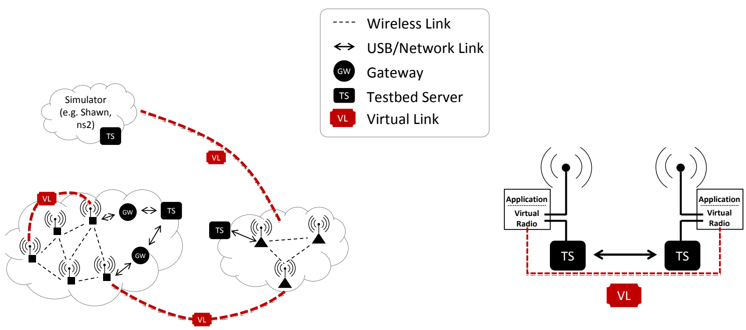

Fig. 1. Architecture of a virtualized testbed (a) and a virtual link (b)

Nodes that are arranged in a grid can be rearranged using this technique, e.g., in a line or using a random topology. This feature allows the specific definition of the desired testbed topology needed for an experiment, similar to simulations, but the experiment is run on real hardware. Furthermore, one can add simulated nodes to a physical testbed and define communication parameters like RSSI, LQI, and message loss. These functions pave the way for building any virtual topology, as it is needed for an experiment. For more details on virtual links, we refer the reader to [2].

3 Federating Testbeds

As shown in Figure 1(a), a physical or simulated testbed is exposed to the internet by a testbed server. Each testbed server provides the functionality to allocate parts of a testbed for a specific period and to manage and control experiments, e.g., flashing and resetting sensor nodes, monitoring the experiment, managing virtual links, etc. The testbed server exposes this functionality through a set of Web Service APIs. In addition to physical and simulated testbeds, we developed a federating testbed server that is able to control different testbeds.

The federator implements the same set of Web Service APIs mentioned above, thereby providing transparent access to the underlying testbeds. Furthermore, the server can control both physical and simulated testbeds, as well as other federated testbeds, allowing for arbitrary hierarchical composition of testbeds.

This means that a user can reserve a local testbed, configure an experiment, log the runtime, and compare the results with experiments on other local testbeds or even federated testbeds, just by changing the connection to the specific testbed server. In a federated testbed, virtual links are used to tunnel messages from one node to nodes in a different testbed, making them virtual neighbors. This allows defining virtual topologies in a federated testbed and hiding boundaries between different testbeds from the application.

4 Poster

We ran a number of experiments, comparing non-virtualized with virtualized testbeds (including flooding of sensor data or time synchronization) to evaluate the impact of virtualization. First results show that our approach is realistic and provides a good performance for experiments. Furthermore, applications cannot distinguish between a real testbed and a partially virtualized one. On our poster we introduce the architecture of virtualized testbeds and the API used to define and establish the virtual topologies, present first results, and give an outlook on future work within WISEBED.

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