Demo: Physical and Network Layer Interconnection Module for Realistic Planning of IoT Sensor Networks

Akis Kokkinis
Eindhoven University of Technology, The Netherlands
a.kokkinis@tue.nl

Aristodemos Paphitis
Cyprus University of Technology
am.paphitis@cut.ac.cy

Loizos Kanaris
Eindhoven University of Technology, The Netherlands
l.kanaris@tue.nl

Charalampos Sergiou
University of Cyprus
sergiou@cs.ucy.ac.cy

Stavros Stavrou
Open University of Cyprus
stavros.stavrou@ouc.ac.cy

Abstract

Deploying a functional large scale Wireless Sensor Networks (WSNs) or Network of Internet of Things (IoTs), remains a big challenge, mainly due the difficulties in introducing realistic physical layer conditions in network layer simulators. In this demo we demonstrate the interconnection of a commercial physical layer simulator, *TruNET wireless*, with *Cooja*, an open source network simulator, in such a way that the resulting simulator platform, can provide accurate and realistic results.

1 Motivation

One of the biggest challenges in designing and developing smart Cities is the efficient operation of large scale, heterogeneous sensor networks. Significant differences exist between simplified theoretical performance and real deployments of such networks. This gap occurs due to the complexity of the urban environment and the presence of multiple other devices in ISM frequency bands that can act as interferers. In other words, existing open source wireless network design tools, fail to provide functional solutions, due to their inability to simulate realistically at the physical layer, the performance (real coverage) of complex network setups, as well as influence of interferers, such as the 802.11 devices which exist in the environment. A more detailed analysis of the problem indicates that existing network layer simulators implement and use simple propagation models such as free space loss, plane earth loss, or utilize statistical or semi-empirical models, which are inadequate to extract realistic coverage results in complex urban environments. This leads to miscalculation of radio coverage parameters and erroneously predictions propagate at the network layer resulting in erroneously network performance predictions.

In this work we demonstrate the use of a new, effective simulation tool that resulted from the combination of two established simulators. The first simulator is the TruNET Wireless[5], a powerful physical layer simulator capable to accurate simulate the physical layer effects, along with Cooja simulator, a network layer simulator that provides the unique feature of direct downloading to the real nodes, a binary file extracted from the simulations. The proposed tool is designed to meet the challenges of functional smart cities wireless sensor networks design and deployment, by providing innovative solutions. These solutions are (a) the creation of real city environment in a few simple steps, based on either importing the 3D building data, image processing or manually designing the environment in TruNET environment, (b) the deployment of a large number of sensors or interfering devices in the generated city environment, based on a set of dynamic rules in a few simple steps (c) the realistic large scale simulation capability, based on deterministic EM techniques of TruNET for calculating coverage, interference effects from interfering 802.11 or other in band devices and calculation of network performance characteristics through the tight integration with the well accepted open source Cooja network simulator.

This overall simulation platform provides the unique feature of creating a completely realistic snapshot of the Received Signal Strength (RSS) coverage and the Ray Paths through TruNET and then through Cooja, the resulting binary file could be exported and downloaded in real nodes for immediate implementation. The fact that through TruNET the exact physical layer network parameters are calculated and then imported to Cooja Network simulator, gives to the academia and industry, the ability to adjust the placement of the nodes, to modify the topology or even to tailor existing protocols and algorithms with the requirements of the specific project. This platform attempts to solve a timely problem since current deployments of IoT networks either indoor or outdoor in complicated environments like contemporary cities, fail to perform. This happens because network simulators like NS-3 [3], OMNET++ [4], Cooja [1] etc are unable to handle radio propagation conditions.

As a result, although network deployments in such sim-

International Conference on Embedded Wireless Systems and Networks (EWSN) 2018
14–16 February, Madrid, Spain

ISBN: 978-0-9949886-2-1

Table 1. RSS (dBm)

	TX1			RX1			RX2			RX3			RX4		
	Real	TruNET	MRM	Real	TruNET	MRM	Real	TruNET	MRM	Real	TruNET	MRM	Real	TruNET	MRM
TX1	-	-	-	<-100	-92		<-100	-92		-78	-79	-54			x
RX1	-94		x	-	-	-	-84	-80	-53	-93	-94	-55	-95	-100	x
RX2	<-100		x	-79	-83	-53	-	-	-	<-100	-91	x	-89	-86	x
RX3	-80		-54	<-100	-90	-55	<-100	-91	x	-	-	-	<-100		x
RX4	<-100		x	<-100	-94	x	-89	-86	x	<-100		x	-	-	-

ulators seem to be effective, when real deployment takes place, the results tend to be disappointing. Nodes cannot communicate between them, many packets are lost and the whole situation becomes problematic. The importance of accurately predicting the RSS coverage at the physical layer and combining it with the network layer, can be extracted by analysis of Fig. 1. In this figure, the Packet Reception Rate (PRR) is presented vs the RSS based on a measurement campaign performed in [2], for the same radio chip CC2420 that we use in this demo. It is clear that correlation between PRR and RSS varies with an obvious transition. When the RSS is better than 87 dBm, the PRR is always beyond 90%, indicating a desirable link; when the RSS is less than 92 dBm, the PRR is close to zero.

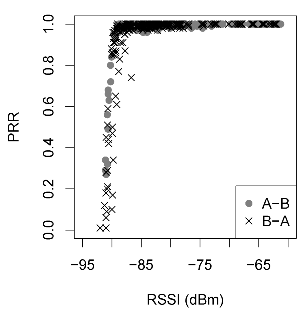

Figure 1. Packets Reception Rate vs RSS [2]

This *bimotal behaviour* of Wireless Sensor Nodes highlights that, if the RSS coverage estimation is not accurate enough, **the simulation will most probably indicate a perfect network performance, while when deployed in a real environment the network will either completely fail or perform poorly.**

2 Prototype System

The prototype system consists of a PC platform hosting the simulation tool that interconnects the physical layer, through *TruNET wireless*, with the network layer, through *Cooja*. The simulation tool initially simulates the real 3D environment and deterministically estimates the physical layer parameters with high accuracy. At a second phase, it encapsulates these data in a file which acts as an input to the network layer simulator for realistic simulations. Additionally, as a proof of concept during the demo procedure, a number of Wireless Sensors will be deployed in the conference area. The sensor locations will be selected in such a way, in order to represent a realistic network deployment with both Line of Sight (LOS) and Non-LOS conditions. Initially, we will demonstrate how the nodes are interconnected in Cooja simulator using the existing physical layer algorithms and then we will demonstrate the results when the new simulation platform is applied. Both results are compared with the real results derived from the wireless sensor nodes.

Below we present an example of a similar scenario developed in our labs. Four nodes have been developed in different places in the laboratory floor. The simulated results have been compared with the real results, derived from the nodes. In Fig. 2 we present a 3D snapshot from TruNET simulator.

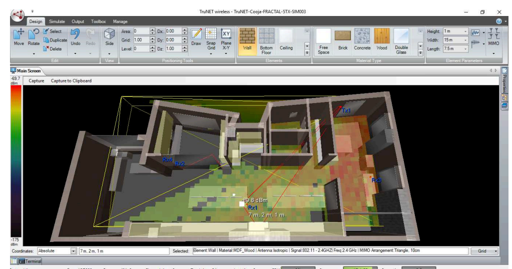

Figure 2. 3D Snapshot from TruNET Simulator

In Table 1 we present the results of RSS values in the deployed environment, when TruNET feeds Cooja and when Cooja utilizes the built-in MRM model. The results clearly indicate that MRM in unable to capture the real conditions. The results also indicate that the TruNET deterministic results are almost in absolute match with the actual measurements and can capture the critical and sensitive bimotal behaviour of the sensor nodes as analysed previously. In Fig. 3 we present a graph with the comparison between the real and simulated results.

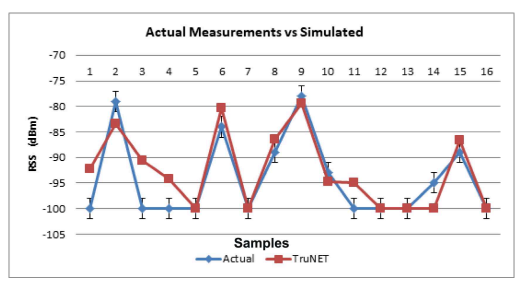

Figure 3. Real vs Simulated Results

3 References

[1] COOJA. www.contiki-os.org/start.html, Date Accessed: 28 October 2017.

[2] X. Ding, G. Sun, G. Yang, and X. Shang. Link investigation of ieee 802.15.4 wireless sensor networks in forests. *Sensors*, 16(7), 2016.

[3] NS-3. https://www.nsnam.org/, Date Accessed: 28 October 2017.

[4] OMNET++. https://omnetpp.org, Date Accessed: 28 October 2017.

[5] TruNET. http://www.fractalnetworx.com/, Date Accessed: 28 October 2017.