Long Distance Wireless Sensor Networks: simulation vs reality

Marco Zennaro
The Abdus Salam International Centre for Theoretical Physics
Trieste, Italy, and KTH
Stockholm, Sweden
mzennaro@ictp.it

Antoine Bagula
University of Cape Town
Cape Town, South Africa
bagula@cs.uct.ac.za

David Gascon, Alberto Bielsa Noveleta
Libelium
Zaragoza, Spain
d.gascon@libelium.com, a.bielsa@libelium.com

ABSTRACT

Wireless sensor networks allow unprecedented abilities to observe and understand large-scale, real-world phenomena at a fine spatial-temporal resolution. Their application in Developing Countries is even more interesting: they can help solve problems that affect communities. One of the limitations of current wireless sensors is the communication range, with most devices having 100 meters as maximum limit. In contrast, many applications require long-range wireless sensor network where nodes are separated by large distances, giving the advantage of being able to monitor a vast geographic area. In this paper we will present the results of simulations and of experiments carried out using off-the-shelf equipment over distances ranging from 300m to 12km. The results show that long distance wireless sensor networks (LDWSN) are possible and that the quality of these links is high.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous; D.2.8 [**Software Engineering**]: Metrics—*complexity measures, performance measures*

General Terms

Wireless sensor networks, long distance wireless, ICT4D

Keywords

Wireless sensor networks, long distance wireless, ICT4D, simulation

1. INTRODUCTION

In practical applications that require sensor monitoring over long distances such as farming or water quality monitoring in developing regions, the short wireless range provided by WSNs may become a limiting factor in terms of both cost (multi-hop routing over long distances may require many sensors) and coverage (the short range sensors can cover only a few hundred of meters). This paper revisits the problem of long distance wireless sensor network deployment by (1) assessing the relevance of using simulation in planning long distance links and (2) proposing a long distance wireless sensor deployment as case study. The main contributions of our paper are twofold. First, using the Radio Mobile simulation software, we evaluate the accuracy of using a simulation package that builds around real maps to preplan long distance wireless sensor links. Secondly, we present a case study of a long distance wireless sensor network deployment using the Waspmote [1] technology with experiments conducted in harsh conditions.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, to republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
NSDR '10 San Francisco, California USA
Copyright 2010 ACM 978-1-4503-0193-0 ...$10.00.

2. SIMULATION OF THE LINKS

To check if radio links were feasible, we decided to use Radio Mobile [2], a free tool for the design and simulation of wireless systems. It predicts the performance of a radio link by using information about the equipment and a digital map of the area. Radio Mobile uses a digital terrain elevation model for the calculation of coverage, indicating received signal strength at various points along the path. It automatically builds a profile between two points in the digital map showing the coverage area and first Fresnel zone. During the simulation, it checks for line of sight and calculates the Path Loss, including losses due to obstacles. It is based on the ITS (Longley-Rice) propagation model. Digital elevation maps (DEM) are available for free from several sources, and are available for most of the world [3].

2.1 Candidate locations

To test the feasibility of long wireless sensor links, it is necessary to find a location with an unobstructed line-of-sight between two sites. For our experiments we selected the Los Monegros Desert near Huesca, Spain. Los Monegros is located within the provinces of Zaragoza and Huesca. The lack of human activity ensured an interference-free environment. We did not carry out a site survey when selecting the candidate locations.

We selected ten spots in the area, which allowed us to establish six links with distances ranging from 300m to 12km. We considered both links with line of sight (LOS) and those with non line of sight (NLOS) as sensor networks are meant to be deployed in different scenarios.

2.2 Simulation data

In addition to the locations, more data is required to run a simulation in Radio Mobile. The characteristics of the equipment, type of antennas and elevation above the ground need to be given as inputs to the software. For the experiments, we used Waspmote devices produced by Libelium, equipped with seven different 802.15.4/ZigBee transceivers. The XBee transceivers are equipped with SMA antenna connectors so an external antenna can be used. For the simulation we considered omnidirectional antennas, with a gain of 2dBi and 5dBi in 2.4GHz and in 868/900MHz. Antennas with such gain can be commonly found on the market and do not require special alignments. The links used vertically polarized antennas. The height from ground is assumed to be 2m, as this is the maximum height of a tripod.

2.3 Simulation results

The equipment we wanted to use for the experiment consisted of seven different XBee cards, each one with two possible antennas. We thus had fourteen different hardware solutions for each of the six links. As can be seen in Figure 1, Radio Mobile provides a graphical view of the Fresnel zone and of the Path Loss. We calculated the feasibility of all the links, and the simulator confirmed that links behave differently according to the frequency used and to the output power. Longer links are only possible using lower frequencies (868 and 900 MHz), while 2.4 GHz is only usable for shorter links.

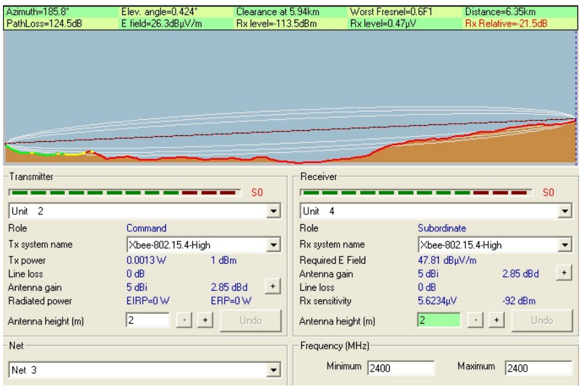

Figure 1: ***Radio Mobile simulation of a 6.3 km link at 2.4 GHz.***

3. EXPERIMENTS

In October 2009 we performed the experiments in the Los Monegros Desert over a period of 3 days. We wanted to check if the experimental results were consistent with the simulation ones in a real-world environment. To test the link quality, we sent 100 packets of 90 Bytes each and counted how many packets were received to measure throughput. We also measured the RSSI level.

3.1 Experimental results

To check if the simulations give similar results compared to the experiments, we graphed the simulated link margins and the measured throughput for all the links. The results for one specific link (1239m long) are shown in Figure 2.

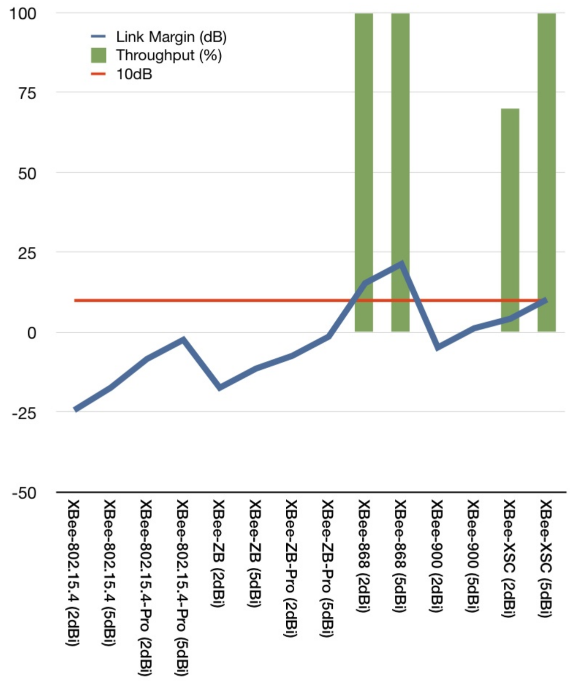

Figure 2: ***Comparison between the simulated link margin and the measured throughput for the 1239m link. Highlighted is the threshold value of 10 dB.***

When the link margin is above 10 dB, then the link is possible and the throughput is high (70% up to 100%). When it is lower than 10 dB, then the link is not possible. From the experimental results, only links that use 868 or 900 MHz were possible at 1239 m. This is in agreement with the simulation results which predicted that longer distance links were feasible in only the lower frequency bands of 868 MHz and 900 MHz.

4. CONCLUSION

Building upon the Radio Mobile and Waspmote family of WSNs, this paper has assessed the relevance of using simulation in wireless sensor network preplanning and presented a long distance WSN deployment scenario in harsh conditions. The results presented reveal that simulation may be in agreement with the reality obtained through experimentation when planning long distance links. These results also reveal that by offering a diversity of transceivers running in different frequency bands, the Waspmote family of WSNs present a good platform for the deployment of long distance WSNs.

5. REFERENCES

[1] Waspmote: http://www.libelium.com

[2] Radio Mobile: http://www.cplus.org/rmw/english1.html

[3] Obtaining ASTER GDEM Data: http://www.ictworks.org/obtaining-and-converting-aster-gdem-data-srtm-radio-mobile