Demo Abstract: A TestBed for the evaluation of Link Quality Estimators in WSNs

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***Abstract*—Link quality estimation is a basic component for routing and topology control protocols in Wireless Sensor Networks (WSNs). Several Link Quality Estimators (LQEs) have been proposed, but none of them has been the subject of a thorough experimental evaluation. Evaluating LQEs is of paramount importance to the design and operation of WSNs.**
In this demo, we present LQE-TB, a Testbed for the evaluation of link quality estimators. Our TestBed (TB) includes (*i.*) hardware components that are based on Universal Serial Bus (USB) technology and (*ii.*) a software tool to control and analyze the experiments. Our TB is useful to understand the characteristics of low-power links in WSNs and to help higher layer protocols designers choose the most suitable LQE.

I. Introduction

WSNs are energy constrained networks. Thus, there is a need to optimize the communication process by understanding wireless links characteristics and integrating link quality estimation techniques at higher layer protocols, namely MAC, routing and topology control protocols. Particularly, efficient routing protocols should integrate a link quality estimation technique to forward data over links having good quality to improve network throughput and lifetime. More importantly, the accuracy of the LQE impacts greatly the efficiency of communication protocols in maintaining acceptable network performance. Therefore the experimental evaluation of link quality estimation solutions is a requisite step, before being integrated at higher layer communication protocols. Such experimentation requires performing data measurement through packet statistics collection.

Several TBs have been designed for WSNs experimentation [1]–[5]. However, only [1] and [5] have been devoted to link quality measurements. [1] is a program running under Emstar system [6] gathering statistics on packet delivery by using Mica2 motes. Being featured by CC1000 ChipCon, Mica2 makes [1] unsuitable for the evaluation of all LQEs as it doesn't allow the computation of LQE based Link Quality Indicator (LQI) metric. [5] is a promising recent TB analyzing single-hop 802.11 or 802.15.4 networks links properties. However it does not offer modules for LQE evaluation. In addition, some tasks in SWAT are performed manually, especially the designation of the experimental nodes.

Being inspired by SWAT TB, we have designed and implemented LQE-TB, a TestBed for the evaluation of Link Quality Estimators. Our TB offers several facilities allowing for extensive experimentations enabling a thorough evaluation of LQEs.

II. LQE-TB overview

LQE-TB allows researchers to analyze and understand the statistical properties of LQEs, independently of collisions and routing. These statistical properties allow for the performance analysis of these LQEs. The different hardware and software components of LQE-TB are shown in Fig. 1 and Fig. 2 and described in the rest of this section.

A. Hardware components

The hardware components of LQE-TB include the motes, the USB backbone and the laptop PC (Fig. 1).

Motes: Our TB supports platforms integrating an Universal Serial Bus (USB) such as TelosB or Tmote sky. The motes are programmed in nesC over TinyOS 2.x environment.

USB backbone: All the motes are connected to a standard laptop PC using a combination of USB cables and active USB hubs constituting an USB backbone. This backbone is used as a logging/control channel between the motes and the PC.

B. Software components

LQE-TB includes a software tool composed of two independent applications, as shown in Fig. 2: The first, developed in java, is the *Experiment Control* Application (ExpCtrApp). It provides a graphical interface enabling (*i.*) motes programming and control, (*ii.*) network configuration, and (*iii.*) data logging into a MySQL database. The second application, developed

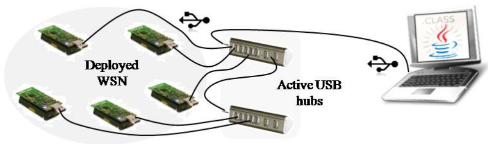

Fig. 1. LQE-TB hardware components

in Matlab, is for an off-line *data analysis* (DataAnlApp). It provides a second graphical interface allowing for LQEs, computation, tuning, and performance analysis (including graph generation). Next, the above facilities are described.

Motes programming: The set of bidirectional communication rules between motes/motes or motes/ExpCtrApp are defined in a NesC application. The compilation of this application using TinyOS environment returns the *binary code* that will be installed on the motes. The ExpCtrApp detects the motes connected to the PC and offers the facility to program them by installing automatically the binary code.

Network configuration: Using ExpCtrApp, the user can specify a set of parameters, including the traffic pattern, number of packets, inter-packet interval, packet size, radio channel, transmission power, link layer retransmissions on/off and maximum retransmission count. Once these settings are communicated to the motes, they start performing their tasks.

Data logging: The main task of the motes is to exchange data traffic in order to collect packet statistics such as sequence number, received signal strength, background noise, etc. Packet statistics are sent though serial channel to the ExpCtrApp, which in turn stores them into a MySQL database.

Motes control: The ExpCtrApp controls the data transmission according to the traffic pattern set at network configuration phase. In fact, we considered two traffic patterns: *Bursty* and *synchronized* traffics: Given a link $N_i \leftrightarrow N_j$; for the Bursty traffic, N_i sends a first burst of packets to N_j. When it finishes, it notifies the PC, to allow N_j sending its first burst of packets to N_i. This operation is repeated for a pre-fixed number of bursts. As for the synchronized traffic, N_i and N_j are synchronized to exchange packets (one packet a time). The PC sends a command to each mote indicating the beginning of transmission time so that the mote sends its data in an exclusive time slot (to avoid collisions).

Data analysis: The collected statistics of the various experiments are stored in a database. The DataAnlApp connects to the database and processes the stored data to derive link quality estimates, at each *estimation window*. To analyze the statistical properties of LQEs, the DataAnlApp proposes (*i.*) a set of statistical metrics, such as the CV (Coefficient of Variation), the CDF (Cumulative Distribution Function) and the CC (Correlation Coefficient), and (*ii.*) pertinent figures, such as the temporal evolution of link quality estimates.

III. Evaluation of link quality estimators

A pre-simulation studied LQEs [7] have been implemented under LQE-TB. To assess their performance, we have deployed 49 TelosB motes positioned in circular topology. Then,

Fig. 2. LQE-TB software components

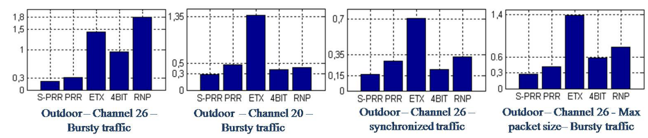

Fig. 3. CV of LQEs under different settings

we have conducted extensive experiments by varying different settings impacting the link quality. We compared the stability property of these LQEs for the different settings as showed in Fig. 3 by computing the CV of their estimates. Such information helps higher layers protocols designers knowing the most resistive LQE to transient fluctuations in the link quality.

IV. Conclusion

In this demo, we have presented LQE-TB a testbed to automate the process of experimentally evaluating the performance of LQEs. This TB is useful for the optimized design and operation of WSNs.

The current version of LQE-TB studies only statistical properties of LQEs. We are currently extending LQE-TB capabilities to be able to assess the impact of LQEs integration in routing.

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