Performance Comparison of CTP and RPL Implementations for TinyOS

Henrique Seiti Ogawa, Bruno de Carvalho Albertini and Cíntia Borges Margi

***Abstract*— Collection Tree Protocol (CTP) is a well-known and used routing protocol for wireless sensor networks, while IPv6 Routing Protocol for Low Power and Lossy Networks (RPL) is a standardized routing protocol. This work evaluates the performance of both protocols considering TinyOS implementation regarding energy consumption, metric that has not been explored in the literature so far. Experiments consider both routing protocols for selected applications running on a TelosB mote, both simulated (using Cooja) and on actual devices.**

***Keywords*— CTP, RPL, Routing Protocols, Wireless Sensor Networks, TinyOS.**

I. Introduction

The development of Wireless Sensor Networks (WSN) has been enabled by integrated silicon sensors, low power microcontrollers, RF integrated circuits, ad-hoc networking protocols, programming languages and operating systems for embedded systems [1]. TinyOS is a flexible and small footprint operating system that supports an event-driven concurrency model based on split-phase interfaces, asynchronous events and tasks [2] targeting low resource and energy constrained platforms. Collection Tree Protocol (CTP) [3] is one of the most used routing protocols for WSN and IPv6 Routing Protocol for Low Power and Lossy Networks (RPL) [4] is a standard for this restricted environment.

Performance evaluation is essential to assure protocol feasibility. Ko et al. argue that CTP and RPL perform very similarly, considering a 51-node network with regard to packet reception ratio, control packets transmission rate and path length [4]. In those experiments the traffic flows from any node to the root, since that is all CTP is able to perform.

This work evaluates the performance of TinyOS implementations of both CTP and RPL routing protocols on a TelosB mote, using simulated (Cooja simulator [5]) and physical environments, showing performance data in order to support WSN decisions.

II. Routing Protocols

CTP [6], the standard data collection protocol for TinyOS, starts with some number of nodes advertising themselves as (logical) tree roots, followed by other nodes that contributes forming a set of routing trees to the first ones. Route creation to root nodes uses Expected Transmissions (ETX) [3] as routing gradient, prioritizing routes with the lowest ETX values. Link estimation in CTP design is used to evaluate the communication link quality between the neighbors [3], [6]. By broadcasting beacon frames periodically, CTP has the ability to resolve routing inconsistences [6].

RPL is the IETF standard protocol (RFC6550) proposal for IPv6 routing over multihop wireless sensor networks. It is a protocol based on distance vector, using routing metrics to assemble a Destination-Oriented Acyclic Graph (DODAG) rooted at the border router. RPL is tree-oriented in a manner that one or more root nodes in a network may generate a topology that trickles downward to the leaf nodes [5], [7]. The RPL standards are based on a IPv6-based addressing layer (i.e. 6LoWPAN layer). 6LoWPAN (RFC4944) is considered to be a requirement for new wireless sensor networks systems because it provides an IPv6 stack that can fit in resource-constrained motes by using experimental IPv6 header compression [4].

III. Experimental Setup and Simulation

The experimental procedure started with design and development of a TinyOS application using CTP and RPL implementations. We used the standard implementations available as optional libraries to implement two versions of the same application, differing only by CTP or RPL. Leaf node sends two bytes of data every two seconds to the root node over a multihop network. The experimental multihop network consists of a four-node topology in which there is a leaf node, two routing nodes and a root node. Leaf node does not communicate directly with root node. Figure 1 illustrates the experimental network topology in Cooja simulator.

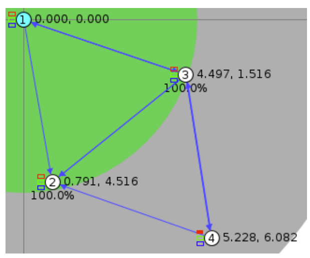

Fig. 1. Wireless network topology in Cooja simulator

Concerning RAM and ROM memory footprint for TelosB mote (which has 10 KB of RAM and 48 KB of ROM), the CTP application used 16502 bytes and 1556 bytes, respectively, while the RPL application allocates 37990 bytes of ROM and 7970 bytes of RAM. RPL has an increased memory usage due to its complexity and the use of BLIP, the 6LoWPAN implementation [4].

PCS-EPUSP, University of São Paulo, São Paulo-SP, Brazil. E-mails: {henrique.ogawa, balbertini, cintia}@usp.br. This work is funded by Fundação para o Desenvolvimento Tecnológico da Engenharia (FDTE).

Given the fact that the radio range of the TelosB motes is not accurately determined due to the environmental noise, the four-node multihop topology was defined to simplify the problem of network topology definition in physical nodes. Besides that, the CC2420 [8] radio output power of the TelosB mote was reduced to -15 dBm to limit the ranges of the motes. With these output level, the Cooja simulator presented a maximum range of 4.8 m for TelosB motes, while the range of the physical nodes during the tests were between 3 m and 4 m.

To gather the power consumption measurements, we used the measurement setup depicted in Figure 2. In order to obtain an accurate measurement of the current consumption, we used an Agilent E3631A power supply configured to provide stable fixed 3.00 V to power the TelosB and an Agilent 34401A digital multimeter to measure the current flow. A GPIB (General Purpose Interface Bus - IEEE 488 standard) cable was used to connect the Agilent 34401A multimeter to a computer running the software LabView, which collects and records the measurement samples. The digital multimeter was configured to provide a reading rate of 500 Hz.

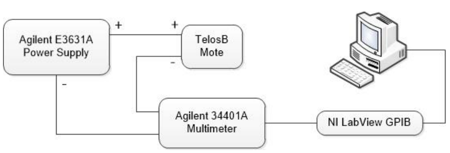

Fig. 2. Power consumption measurement setup.

IV. Results and Analysis

Using the electric current measurement setup, it was sampled 35000 values, which is equivalent to 70 seconds of current data collection. All the four nodes of the network were reseted at the same time and right after the current sampling startup. The obtained results are shown in Figures 3 and 4.

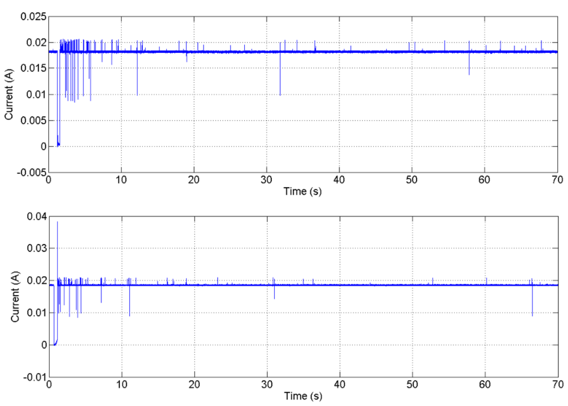

Fig. 3. CTP: current measurement on root (top) and leaf (bottom) nodes.

The CC2420 datasheet indicates a current consumption of 9.9 mA for RX mode when output power is configured to -15 dBm. On Figures 3 and 4 it is possible to identify this value, indicating the moments in which the mote is transmitting data.

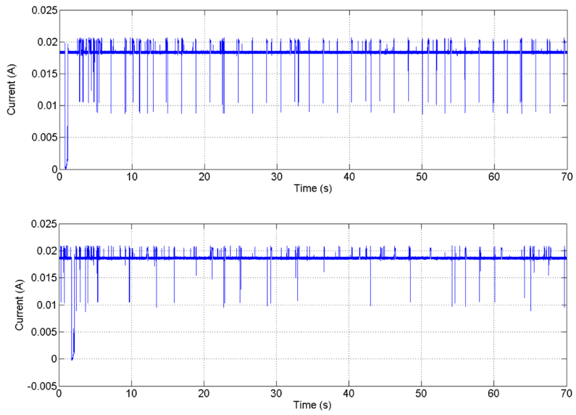

Fig. 4. RPL: current measurement on root (top) and leaf (bottom) nodes.

The current values close to 0 mA right after the initial instant indicates the reset and reboot. Given the restriction imposed by measuring setup sampling frequency, the current values verified in Figures 3 and 4 allowed the identification of CTP and RPL behavior in terms of control packets transmission rate. As illustrated in Figure 3, the interval between transmissions of control packets tends to increase in CTP, while RPL maintains a higher control packets transmission rate.

V. Conclusions

As expected, RPL has a higher control packet overhead since it maintains a graph for the network. We attribute this effect to DODAG maintenance overhead (DAO and DIO). We also present results measurement for energy consumption of both CTP and RPL running on TinyOS, which has not been presented in the literature so far. Due higher consumption generated by this overhead and greater footprint, CTP is more adequate for restricted environment with communication pattern from nodes to sink, unless 6LoWPAN is mandatory. For future work, we intend to increase the number of nodes and types of applications in our experiments, and evaluate routing protocols parameters.

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