RPL Modeling in J-Sim Platform

P. Karkazis[1], P. Trakadas[2], Th. Zahariadis[3], A. Hatziefremidis[3], H. C. Leligou[3]
[1]*Technical University of Crete, Greece, pkarkazis@isc.tuc.gr*
[2]*Hellenic Authority for Communications Security and Privacy (ADAE), trakadasp@adae.gr*
[3] *Technological Educational Institute of Halkida, zahariad@teihal.gr, ahatzi@teihal.gr, leligou@teihal.gr*

***Abstract*—Recently, Routing Protocol for Low Power and Lossy Networks (RPL) has been proposed by IETF ROLL WG in order to cope with Low Power and Lossy Networks (LLN) requirements implied by different application domains. In this paper, we present RPL modeling in J-Sim simulation environment, providing a complete simulation framework for performance evaluation as well as experimentation on open issues, such as the support of multiple instances and the definition of routing strategies based on the composition of several metrics.**

***Index Terms*—wireless sensor networks, simulation, RPL**

I. Introduction

Recently, the IETF Routing Over Low Power and Lossy Networks (ROLL) Working Group has developed an IPv6-based Routing Protocol for Low Power and Lossy Networks (RPL) [1]. RPL is a distance-vector, hop-by-hop routing protocol, based on the construction of a Destination-Oriented Directed Acyclic Graph (DODAG).

RPL supports Multipoint-to-Point (MP2P), Point-to-Multipoint (P2MP) as well as Point-to-Point (P2P) traffic patterns through respective ICMPv6 control messages (DIO, DAO, DIS). Since MP2P is the dominant traffic flow in RPL, the root node transmits DIO messages, containing (among other parameters) the supported Objective Function (OF) and the Rank value of the node. Then nodes receiving this DIO message recalculate Rank, based on specific link or node parameters (defined in the respective OF) in order to select their parent node.

Given that RPL has gained considerable attention and that some issues still remain under discussion, our simulation model, based on J-Sim platform [2], provides a complete RPL simulation environment that allows the developer to accurately model a platform-independent, real-world scenario and directly compare RPL to other routing protocol implementations.

II. RPL Modeling Description

In this section we describe the modifications and enhancements that took place in J-Sim environment to model RPL functionality.

A. *Support of multiple instances*

Being an open issue in IETF ROLL Community, our simulation platform supports the existence of multiple instances, each one defining its own OF and thus constructing a separate, application-specific DODAG tree.

B. *Routing metrics modeling*

Taking into consideration the definitions presented in [3], we implemented a variety of metrics in order to capture different LLN topology characteristics.

1) *Hop-Count*

Hop-Count (HC) is the most widely used metric in Mobile Ad Hoc Networks (MANET), mainly due to its incomparable conceptual and implementation simplicity. Following RPL specifications, HC has been included as a metric in our simulation model.

2) *Expected Transmission Count*

ETX captures bidirectional link reliability, providing optimized performance in terms of throughput and energy-efficiency. Apart from the noise model, already present in J-Sim, that may result in failed MAC acknowledgements reception, we further modified the respective component, providing a tool for affecting reliability of a particular link in the simulated network topology. This can be defined either in the Tcl or dynamically during simulation run-time.

3) *Remaining Energy*

Since sensor node energy expenditure is the most critical factor in LLN deployments, we modeled Remaining Energy (RE), so that it can be included as a routing metric in RPL simulation model.

4) *Received Signal Strength Indication*

Utilizing RSSI, one is able to route traffic through reliable links and thus minimize packet loss ratio. We modified the respective J-Sim component in order to be able to dynamically reduce the transmission power of a specific node in the simulation network topology.

5) *Packet Forwarding Indication*

Packet Forwarding Indication (PFI) is a trust-aware metric capturing parent node trustworthiness. This is achieved by counting (through channel overhearing) the number of data packets sent from child to parent node over the number of data packets further forwarded by the parent node towards the root node. This metric follows the concept of ETX but captures node trustworthiness instead of link reliability. Using PFI, a node can identify and exclude from future interactions nodes acting maliciously (black- and grey-hole attackers) [4].

C. *Security constraints modeling*

In conformance to RPL specifications [5], our simulation model supports constraints related to security characteristics. Thus, the exclusion of a node that does not support encryption or/and authentication capabilities can be achieved, given that these constraints are used in the respective OF.

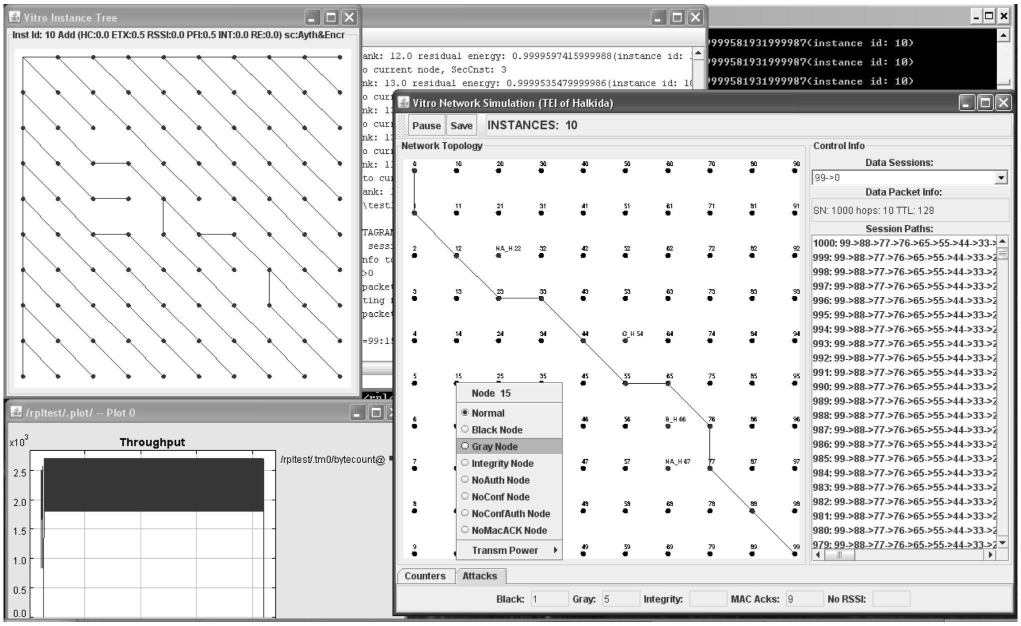

Figure 1. Snapshot of the J-Sim based RPL simulation platform. Node 0 is considered as the root node (destination) and node 99 the source node.

D. Metric composition approaches

The diversity of LLN's and the Quality-of-Service (QoS) requirements dictated by modern and demanding applications motivate the design of composite routing metrics. Adopting and extending routing algebra formalism framework [6], our simulation model offers the capability of evaluating the performance of composite routing metrics.

E. Performance metrics

Apart from latency and throughput, already supported by J-Sim, we developed the following performance metrics: packet loss ratio, number of attacks, control message overhead, energy expenditure. Utilizing these performance metrics, one is able to check the responsiveness, robustness and flexibility of RPL routing protocol under several conditions.

F. Graphical User Interface

We developed a user-friendly GUI that provides a graphical representation of the network topology that can be used for evaluation, debugging and presentation purposes. Moreover, GUI supports the dynamic modification of a link or node characteristics during simulation run-time, offering a powerful tool for evaluating the routing protocol responsiveness.

III. Preliminary Evaluation Results

The upper-left window of Figure 1 depicts the DODAG tree constructed under the OF presented in the parenthesis. In this example, OF is based on the additive metric composition approach where ETX and PFI metrics are equally (0.5) weighted, supporting authentication and encryption constraints. Furthermore, on the right side of Figure 1, the traversed path (per source-destination pair) can be observed. In this example, node 99 sends 1000 packets to root node (denoted by 0), traversing a stretched path in order to avoid unreliable links (nodes 22 and 67) and nodes acting maliciously (node 54 is a grey-hole and node 66 a black-hole attacker). Also, in the tab presented in the lower part of this window, the number of events/attacks is depicted. In this example, the path traverses once through node 66 (black-hole attacker), it tries five times to forward traffic through node 54 (grey-hole attacker) and passes 9 times through unreliable links (no LL acknowledgements received from nodes 22 and 67) before selecting the "clear" path shown in the Figure. Moreover, one is able to modify, during run-time, the behavior of a node. As an example, in this Figure, node 15 can be transformed into a black- or grey-hole attacker, provide (or not) encryption and authentication capability, reduce its transmission power and send (or not) LL acknowledgements upon data packet reception.

IV. Conclusion

In this paper, we presented a complete RPL simulation model, based on J-Sim environment, which enables routing protocol performance evaluation and responsiveness under several metrics and constraints, supporting multiple RPL instances.

Acknowledgment

The work presented in this paper was partially supported by the EU-funded FP7 ICT-257245 VITRO project.

References

[1] T. Winter, P. Thubert, A. Brandt, T. Clausen, J. Hui, R. Kelsey, P. Levis, K. Pister, R. Struik, and JP. Vasseur, "RPL: IPv6 Routing Protocol for Low Power and Lossy Networks", draft-ietf-rfc-rpl-19, March 2011, work in progress.

[2] A. Sobeih, J.C. Hou, L-C Kung, N. Li, H. Zhang, W-P Chen, H-Y Tyan, H. Lim, "J-Sim: A Simulation and Emulation Environment for Wireless Sensor Networks", IEEE Wireless Communications, vol. 13, no. 4, August 2006, pp. 104-119.

[3] JP Vasseur, M. Kim, K. Pister, N. Dejean, D. Barthel, "Routing Metrics used for Path Calculation in Low Power and Lossy Networks", draft-ietf-roll-routing-metrics-19, March 2011, work in progress.

[4] H.C. Leligou, P. Trakadas, S. Maniatis, P. Karkazis, T. Zahariadis, "Combining Trust with Location Information for Routing in Wireless Sensor Networks", Wireless Communications and Mobile Computing, DOI:10.1002/wcm.1038, 2010.

[5] T. Tsao, R. Alexander, M. Dohler, V. Daza, A. Lozano, "A Security Framework for Routing over Low Power and Lossy Networks", draft-ietf-roll-security-framework-06, June 2011, work in progress.

[6] T. Zahariadis, P. Trakadas, "Design Guidelines for Routing Metrics Composition in LLN", draft-zahariadis-roll-metrics-composition-02, November 2011, work in progress.