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Mobility Support for the Routing Protocol in Low Power and Lossy Networks

Hanane Lamaazi[1], Nabil Benamar[1], Muhammad I. Imaduddin[2]
1Laboratory of Modeling Analysis and Control System
University Moulay Ismail, Faculty of Science, Meknes
Meknes, Morocco
{Lamaazi.hanane; benamar73}@gmail.com
2University TelkomSierre, Faculty of Electrical Engineering, Bandung, Indonesia
m.iqbal.imaduddin@gmail.com

Adib Habbal[3], Antonio J. Jara[4]
3InterNetWorks Research Lab, School of Computing, Universiti Utara Malaysia, Malaysia
adib@uum.edu.my
4University of Applied Sciences Western Switzerland (HES-SO)
Sierre, Vallais, Switzerland
jara@ieee.org

***Abstract*—Mobility is the most issues for the majority of protocols including the RPL (IPv6 Routing Protocol for Low Power and Lossy Networks). RPL a routing protocol standardized by IETF is usually used in Internet of Things Technology. It is proposed to support communications in Low power and Lossy Networks (LLNs). However, mobility limits the use of RPL protocol in realistic study. In this paper we have classify the mobility models in two entities in order to evaluate the performances of RPL in each entity separately. So we have defines two different scenarios. We first, evaluate characteristics of RPL with a group mobility models which contain Reference Point Mobility Model (RPGM) and Nomadic Mobility Model (Nomadic) Mobility Models. Then we give another evaluation of features of RPL with the Entity mobility models which contain Random Walk Mobility Model (RWK), Random Waypoint Mobility Models (RWP) and self-similar least action walk (SLAW) Mobility models. The results show that the type of mobility models has a direct influence on the protocol performances. In addition, increasing of number of nodes causes an increasing of all parameters, especially in delivered and received data. Furthermore, the group mobility models give better metrics than entity mobility models in terms of lost packets, Packet Delivery Ratio (PDR) and Throughput. Also, in each type of mobility models each model provides better metrics than others. RPG offers best number of lost packets and PDR than Nomadic model and lowest in terms of Throughput while SLAW models gives the best value in all metrics than RWK and RWP. Our simulation shows clearly that lost packets, PDR and Throughput are directly related to the type of mobility models.**

Keywords*— *ETX; Mobility Models; Power Consumption; RPL routing protocol; RWK; RWP; Wireless Sensor Networks;

I. Introduction

The need to have ubiquitous connectivity [1]increase the need to have reliable mobility support especially in low-power wireless networks (LPWNs). Internet of Things (IoT) and some application domains as health-care monitoring, smart cities and industrial automation are based on Low Power wireless technologies; and because of their environmental context, scalability features and wireless nature these applications use low-power and low-cost devices. These devices are characterized by simple single radio transceivers. It uses a basic antennas and electronics and employs a very low TX/RX power to communicate. To extend Low Power wireless to be connected to the Internet, Internet Engineering Task Force (IETF) [2] through to standardized protocols based on this kind of network and which facilitate their access to internet. The first one and which play a big role for LoWPAN networks is the 6LoWPAN protocol. Thanks to its adaptation layer, 6LoWPAN allows IPv6 to run over IEEE 802.15.4 link [3][4] [5]. The second one is RPL (Routing Protocol for Low Power and Lossy Network) [6] [7]. Unlike to traditional routing protocols like OSPF (Open Shortest Path First) [8], AODV (Ad hoc On-Demand Distance Vector) [9] and OLSR (Optimized Link State Routing Protocol) [10] which are not very suited for routing of IP packets for constrained devices, seen their limitations in power consumption, RPL is designed for networks with lossy links. It is developed to select different metrics to calculate the optimal path by considering number of objects connected to the network. It uses by default the ETX (Expected Transmission) [11] as a routing metric which influence directly quality of packets, delay and transfer of data. However, Mobility support [12]becomes an important part of IoT development. Most of IoT applications are based on mobility like industrial automation, health care monitoring, and smart grid. Previous research has considered cooperation between mobile and fixed sensor. For instance, in hospitals [13] [14], oil refineries [15] and warehouse [16] [17] devices are used to collect data and return it in real time. Consequently, applications require guaranteeing reliability to transmit in mobility condition the critical messages.

The aim of this paper is to analyze RPL behavior in different scenarios and to analyze its features performances. It makes comparison between different mobility models using sink and senders nodes. Each simulation is studied independently and combined afterwards to give critical view. Network Topology is also considered. The remaining of the paper is structured as follow: in section 2, we present RPL protocol to give a general idea about it. Related works are discussed in section 3. Section 4 gives a classification of different existing mobility models and explains the choice of mobility models used for simulation. Section 5 shows implementation of RPL in Cooja simulator. Analysis and

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evaluations are discussed in section 6 and we conclude this paper by a conclusion in section 7.

II. RELATED WORKS

In [18], the Authors investigate RPL behavior in mobile environment. They compare between fixed and mobile sink node using different network metrics such as packet delivery ratio (PDR), latency and the energy consumption. The results show that fixed sink nodes provide better RPL performances in all metrics than mobile sink nodes. Accordingly, results show that RPL has some complexity and high sensitivity when it is used in mobile environment with regards to the number of isolated nodes that it provides.

In [19], authors study the impact of the objective function on RPL environment. They consider two objective functions: the objective function zero (OF0) and Minimum Rank with Hysteresis Objective Function (MRHOF). Additionally, authors propose to make their evaluation based on different parameters as Packet Reception Ratio (RX) and Random and Grid topologies. The chosen parameters have a direct impact on PDR and energy consumption. Also, the results indicate that RPL behave similarly for OF0 and MRHOF but the later gives better performances within light density networks especially in terms of power consumption, which means that MRHOF is less consumed than OF0**.**

In [20], authors propose an enhanced version of Trickle Algorithm named E-Trickle. This new proposition allows resolving short-listen problem instead of the use of listen-only period. Consequently, the results show that the E-Trickle conserve same efficiency of scalability, reliability and power consumption as Trickle while provide an augmentation of the convergence time up to 43%.

III. RPL PROTOCOL OVERVIEW

The RPL (IPv6 Routing Protocol for Low power and Lossy Networks) was proposed by IETF ROLL working group [21]. It is designed to run in large-scale networks composed of tiny devices which communicate over low-power and low- cost communication technologies. It allows to minimize memory requirements, reduce routing signaling overheads, Adopt low-complexity routing and data forwarding mechanisms, efficiently discover links and peers and Distribute compact routing information [22].

RPL is a Distance Vector routing protocol that builds a DODAG (Destination Oriented Directed Acyclic Graph) rooted toward a data collector or sink node. It is based on rank parameter which represents individual position of nodes relative to the DODAG root [23]. The rank is calculated by considering DODAG's Objective Function (OF): hop counts, link metrics or other constraints. Link metrics are expected transmission count (ETX) which is the expected number of transmissions required to successfully transmit and acknowledge a packet on link [24]. Thus, forwarding a packet to the DODAG root consists to choose neighbor node with lowest rank. A routing objective function (OF) defines how nodes calculate their rank values and how it select their parents [23]. All nodes broadcast DODAG Information Object (DIO) messages periodically which ensure maintenance and construction of DODAG. It contains a variety of information such as DODAG identifier, Objective Function, node rank, or the metrics used to calculate the path. All nodes create a list of possible successors. When node receive a DIO (DODAG Information Object) message it added the transmitter to its list, then it choose its preferred parent and send all its traffic. After that, the node uses the Objective Function to calculate its own rank and start in its turn to broadcast DIO messages [25].

To exchange information associated to a DODAG, RPL defines a set of ICMPv6 control messages [24]:

• DIO: DODAG Information Object (multicast) allows a node to discover a RPL instance,

• DIS: DODAG Information Solicitation (multicast) used when a node joins the network

• DAO: Destination Advertisement Object (unicast) used to propagate destination information upwards along the DODAG. The node updates its routing table when it receives a DAO.

IV. MOBILITY MODELS

In this paper we focus on the analysis and modeling of mobility models. We are also interested in studying the impact of mobility on the performance of RPL routing protocols. The mobility of users is designed via model of mobility. This model describes movement, location change, velocity and acceleration over time. It allows to determinate protocol performance [26].

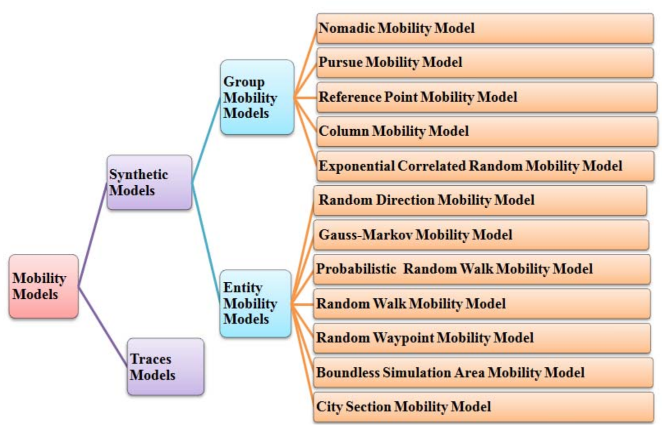

Fig 1: Classification of Mobility Models

There are two principal classifications of mobility models considering specific mobility characteristics of each model. The first one classifies mobility models based on their temporal, spatial dependency and geographic restriction or a random model. The second consider two repartitions: Trace model and synthetic model which contain also two reparations a group mobility model and an entity mobility model as shown in figure 1.

A. Group Mobility Models

1) Reference Point Group Mobility Model (RPG)

The use of reference point approach allows achieving special dependence. Reference Point Group Mobility Model (RPGM) is proposed to emulate movement of a set of nodes dependently as a group. Each node use a reference point to realize movement of nodes situated inside a group and the group move according to a mobility model chosen arbitrary. A random movement vector in addition to reference point position defines current position of a node. In a group, relative position of reference point doesn't change in contrast with absolute position which changes according to mobility model chosen arbitrary [27].

2) Nomadic Mobility Model

Nomadic Mobility Model is proposed to define movement of nodes traveling together. This models usually used in military application or in a conference through a mobile communication. The full group of mobile nodes changes location to reach another by using random movement. The movement of group determinate reference point of each node. Each node inside the group can make up for arbitrary vector to its predefined reference point [26].

B. Entity Mobility Models

1) Random Walk Mobility Model (RWK)

Random Walk Model acts similarly to Random Waypoint Mobility Model. In both model, movement of node has strong randomness. In addition, Nodes move in unpredictable way for this RWK is suggested to imitate their movement attitude. Moreover, nodes don't conserve their speed and direction but it changes these two parameters in each time interval. It is considered as a memory less mobility process because each step is calculated independently with the previous one [26] [28].

2) Random Waypoint Mobility Models (RWP)

Random Waypoint Mobility Model (RWP) is the popular model used by research community because of its wide availability and its simplicity to use. In simulation fields, mobile node selects a position (x,y) randomly as a destination and choose randomly and uniformly the velocity from a range (V_{min}, V_{max}) to travels towards this destination. When it reaches destination, the node stops for little time called 'pause time' parameter T_{pause}. After this period of time, node choose one more another destination randomly toward it, and continuous the same process until simulation end [26] [29].

3) self-similar least action walk (SLAW)

SLAW present a mobility model that can generate synthetic walk traces of human movement. The new studies are interested to human mobility seen it most important in mobile networks. In this kind of network, control of mobile devices is related to the human users. However, the last studies of human walk traces exposed a variety of statistical patterns of human mobility. There are four statistical patterns: inter-contact and pause-times, flights truncated power-law distributions, heterogeneously defined areas of individual mobility and fractal way-points. In contrast to others mobility models, SLAW are interested to all these features [30].

V. RPL SIMULATION ENVIRONMENT

C. Cooja Simulator:

Cooja is a simulator based on Contiki OS using sensor nodes and allowing the use of hardware or software. Cooja can operate on network level, operating system level, and the machine code instruction level. It can run over different platforms as Sky, TelosB, native… [31]. Cooja is an open source which responds to our need for this study. All parameters used in this study are described in section VI. Cooja simulator does not adopt any mobility model. For this, we use Bonnmotion simulator [32] to generate the mobility pattern traces.

D. Scenarios and Objectives:

Two scenarios are considered: Firstly nodes move under a Group Mobility Models which are RPGM and Nomadic Mobility Models, in the second, they move according to an Entity Mobility Model containing RWK, RWP and SLAW Mobility models. The aims objectives of this simulation are:

- Investigate RPL behavior in mobile environment
- Propose the use of different mobility models classified into two entity: group and entity models
- Demonstrate the factor that impact RPL performances
- Show which mobility models are suited for LLNs networks

E. Metrics:

TABLE I. METRICS DESCRIPTION

Metrics	Description
Sent Packets	The total number of packets delivered to the destination
Received Packets	The total number of packets arrived until destination
Lost Packets	The total number of packets dropped during the simulation
PDR	Packet Delivery Ratio (%)= (total packet received/total packet sent)*100
Throughput	Throughput (Kbit/s)= total received packets/total simulation time

VI. SIMULATION AND EVALUATION:

a. Simulation

We compile contiki OS for Tmote Sky platform. We use Unit Disk Graph Medium (UDGM) with Distance Loss as a propagation model [33]. This model defines two parameters including success rate of transmission and reception and Interference. During communication, the packets which are interfered are lost. All parameters used for simulation are described in Table 2 and Table 3[34]. Figure 2 shows the mobility models in Cooja simulator.

TABLE II. COOJA PARAMETER SETUP

Settings	Table Value
Propagation Model	UDG Model with Distance Loss
Mote Type	Tmote Sky
TX Range	50m
Simulation Time	360s
Number of Nodes	10, 20, 30
Topology	Point-to-multipoint
Nodes Position	Random
Speed	No limit speed
Mobility Model	RPGM, Nomadic, RWK, RWP, SLAW

TABLE III. BONNMOTION PARAMETER SETUP

Settings	Table Value
Number of nodes	10, 20, 30
X; Y area	100m for all value of nodes
Minimum speed	0
Maximum speed	5m/s
Simulation Duration	3600s
Minimum pause time	0
Maximum pause time	20s

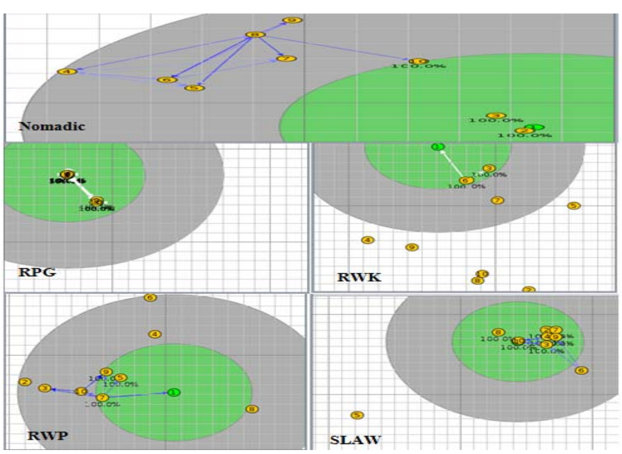

Fig 2: Mobility Models in Cooja simulator

b. Results

In this work, we have considered two important parameters to study the behavior of RPL: number of nodes and mobility models. This variety especially of mobility models helps us to reveal what is the model that can give us the best metrics in our study. Accordingly, it is important to take into account all metrics already described to show difference between these mobility models. In all figures, simulations are focusing on analyzing RPL performance considering number of sent, received and lost packets, PDR and Throughput. The results are compared between five mobility models divided on two entity, Group mobility models and Entity mobility models. For group mobility models we have choose RPG and Nomadic model and for Entity model we have choose RWK, RWP and SLAW models. The topology used in all simulation is one-to many which contain one sink node and the rest are sender nodes. For all figures, we considered five mobility models to give best comparison. In Figure 1, in group model Nomadic sent more packets than RPG while RWP sent a less number of packets than SLAW and RWK. These entity mobility models offer the greater value compared to the group mobility models. Figure 2 shows the received packet, generally when number of sent packets is too much means that number of received packets are also too much. The only condition that gives contradiction with this means is loss of packets. In Figure 2, RPG has a minimum of received accordingly to send packets which means it has a minimum of lost packets which is confirmed in Figure 3. The Nomadic model has more received packets than RPG which means it has more lost packets. For the entity mobility models and already explained RWK has the most packets sent compared to RWP and SLAW models but they don't have the same classification in received packets in Figure 2 due to number of lost packets; on which we remarks in Figure 3 that RWK model has a most of lost packets. Figure 4 shows the PDR value. We notice that PDR value describe the quality of protocol performances. It allows illustrating level of delivered data to the destination. For group mobility models, RPG model provide best performances of RPL than Nomadic with greater value of PDR. In the other side, SLAW offers greater PDR than RWK and RWP which substantiate that RPL has the best performance in this entity model. In contrast with Figure 4, entity models offer the best Throughput as showing in Figure 5 compared to Group model which increase gradually with number of nodes. SLAW model is better than RWK and RWP in entity models and RPG is lower than Nomadic model in group models.

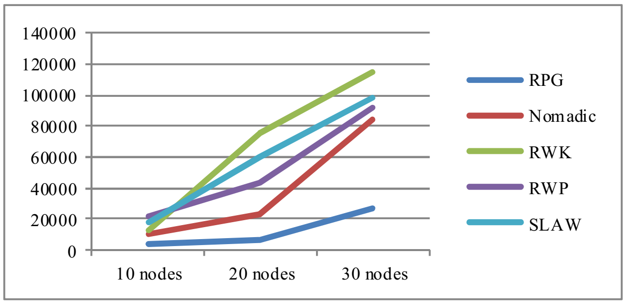

Fig 1: Number of sent packets vs. the number of nodes

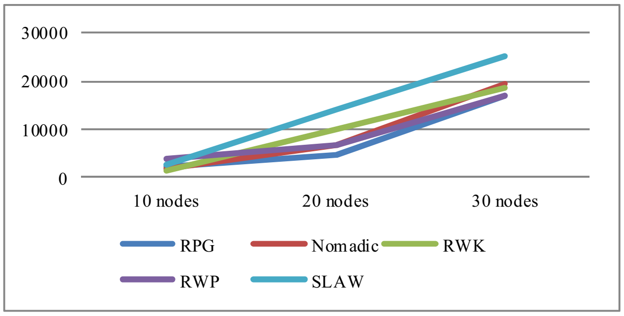

Fig 2: Number of received packets vs. number of nodes

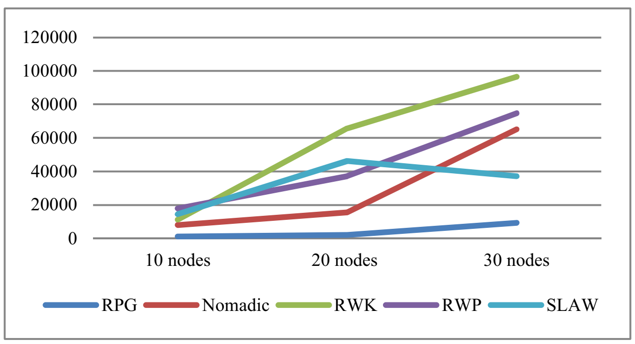

Fig 3: Number of Lost packets vs. number of nodes

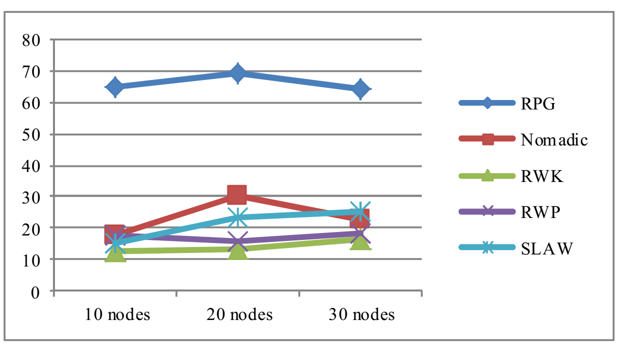

Fig 4: PDR value vs. number of nodes

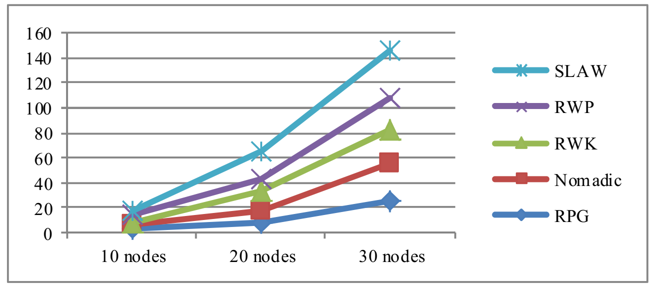

Fig 5: Throughput value vs. number of nodes

The table 4 summarizes all the results obtained in the experimental study:

TABLE IV. RESULTS SUMMARY

	Group Mobility Model		**Entity Mobility Model**		
	RPGM	**Nomadic**	**RWK**	**RWP**	**SLAW**
Sent packets	Low	High	High	Medium	low
Received packets	Low	High	Medium	low	High
Lost packets	low	High	High	low	Medium
PDR	High	Low	low	Medium	High
Throughput	Low	High	Low	Medium	High

VII. CONCLUSION

In this work, we have studied RPL performances related to different mobility models and for different metrics. Besides, the protocol performance is obviously influenced by the density of network and which is proved by experimental result. In this paper, comparison has been made using five metrics: sent, received and lost packets, RDP and Throughput. The results show that these metrics increase according to number of nodes. Furthermore, the type of mobility models has a straight impact on data transmission. Group mobility models prove best metrics compared to Entity mobility models in terms of lost packets and PDR while they gives lowest value in Throughput.

As a future work, it would be interesting to investigate RPL behavior in terms of energy. Future work will also address experimentation and testing of this implementation in real deployment and adapted the best mobility models in some metrics to be best in all metrics that we need.

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