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Performance analysis of IoT protocol under different mobility models☆

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ABSTRACT

Internet of Things [IoT] is a network that encompasses sensors, actuators and networking devices for the purpose of communication and control. The IoT devices are resource-constrained which require a specialized routing protocol in order to transmit the sensed data from source to destination efficiently. The IPv6 Routing Protocol for Low power and Lossy network (RPL) is one of the widely used routing protocols in IoT networks. The performance of RPL protocol is evaluated on the three different mobility models; Manhattan Grid (MG), Gaussian Markov (GM) and Random Waypoint (RW) at different scalability levels in Contiki based Cooja simulator. The standard Quality of Service (QoS) parameters; Packet Delivery Ration (PDR), Average Power (Pavg) and Hop Count (HC) are considered for analysis. The extensive experimental analysis of RPL when exposed to different mobility model and scalability reveals that, the Manhattan Grid model provides better QoS performance by preserving the working nature of RPL optimally.

1. Introduction

Data transmission from source to destination in IoT network requires efficient routing protocol. Unlike protocols like DSR [1], AODV [2] which are originally designed for adhoc networks, the protocol for IoT network must have greater focus on energy and resource constraints. Besides, the routing protocol needs to extend the network's life time and deliver better packet ratio. The application of IoT network is expanding and can be witnessed in several domains today. For example, Vehicular Adhoc Network (VANET) [3,4] is IoT enabled wireless sensor networks that are built for cars and buses in urban areas for traffic control, navigation and automation of vehicles. Additionally the IoT network can also be used for conditional monitoring [5] of large scale farms by Drones. Further the IoT networks can be formed on adhoc basis in urban areas for data exchange The IoT devices in present trend exhibit high level of scalability and mobility due to fall in price and increase in mobile users. For example smart watches that can measure the physiological information such as body temperature, pulse, step counts and BMI data can be transmitted to cloud on the go [6]. Growing commercialization of IoT devices among the normal users increases the need to study scalability. In order to measure the performance of these networks, it is essential to analyze the power usage and packet delivery rate. RPL protocol (RFC 6550) [7] is one of the standardized protocols that supports the routing protocol in IoT networks. So it is essential to understand, how RPL routing protocol reacts with different mobility patterns. Further it is most essential to study the performance of RPL over average power consumption (Pavg), average packet delivery ratio (PDR) and hop count (HC) of the network on a par with scalability of the network

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[8]. It also motivates us to identify a linear model for measuring the performance of the network on varying scalability and mobility. This model enables us to study the correlation between the observed QoS metrics, mobility and scalability of nodes [9]. By using these linear relationships, it is feasible to customize the RPL protocol for specialized application area that can yield better quality of experience (QoE) from it.

This article is organized as follows; Section 2 presents the working nature of RPL protocol. Section 3 elaborates the current state of art in RPL analysis. Section 4 explains the experimental setup and metrics of interest. Section 5 discusses the results of the simulation, and provides a linear model to predict the behavior of the network. The conclusions are provided in Section 6.

2. Routing protocol for low power and lossy network

The RPL (Routing Protocol for Low Power and Lossy network) is one of the well known protocols that support routing process in low power, lossy and highly scalable network. This protocol is driven by Directed A-cyclic Graph (DAG). The routing mechanism by RPL is based on the formation of Destination Oriented Directed A-cyclic Graph (DODAG) for each cluster with a sink and source nodes. Every sink with its associated nodes will have separate DODAG for routing and uniquely identified by the DODAD_ID and RPLInstance_ID. Whenever nodes are added or removed from the cluster, the DODAG associated with that cluster is modified and its newer version is reflected in the DODAG Version number for indicating the updated one. The root node of the DODAG will be the sink node that collects the sensed information from the sources at next level of the DODAG. The best route is selected by the Objective Function (OF) associated with the RPL_Instance. By default the OF will consider hop count (HC) and Estimated Transmission Count (ETX) for identifying and selecting the optimal route form source to sink [10]. Addressing in RPL is based on IP version 6 (IPv6) which has more addressing space for encompassing rigorous scalability of IoT nodes. During the process of routing in RPL, the root that is often viewed as sink will send the DAG information Option messages (DIO) to the child node in the DODAG. These DIO messages contain the rank information about the broadcasting nodes in the network. For an instance the rank can be computed as the proximity of node form the back bone network and DODAG_ID and OF etc. Further if a node connects to non RPL implementing node can be considered as a link level border router (LBR), and has the rank equal to 1. Upon receiving the DIO message by a node, it calculates the rank based on the rank received from the DIO message and cost of reaching the destination node form itself. The parent node in the RPL DODAG is selected based on the certain criteria such as link quality, OF, cost of the route, rank etc. The node with the highest rank will be the parent node in the DODAG formation. Finally the generation of DIO message for the construction of DODAG is governed by the Trickle_Timer associated with the RPL. This Trickle_Timer will trigger the generation of periodic DIO message for construction and maintenance of DODAG. Every node in the network updates the routing table based on the information in DIO messages.

3. Related works

In this section, the performance of RPL is studied and evaluated at different scenarios. RPL protocol is investigated in its different applications, for measuring its performance based on several configurations. The following works discuss the different approaches made for evaluating the performance of RPL.

For the energy constraint IoT networks, the model of multi-parent concept was proposed [10] for enabling the equal spread of load among the network to increase the network life time. Using multi hop routing process and expected life time metric the traffic load was uniformly distributed among the nodes in the network. The result of this approach ends up with increased network life time by reducing the number of DODAG reconfiguration.

In another scenario, the performance of RPL was simulated in a real outdoor environment with specific topology and link quality [11]. The inference is that the trickle timer used in the RPL protocol helps in controlling the control and data packet generation. By controlling the trickle timer activity, the generation of excess control packet is reduced to keep the DODAG stable. This simulation failed to address the mobility issue that directly affects the function of trickle timer in generation of control packets.

Further the protocol was analyzed in larger scale network consisting of thousands of nodes in operation [12]. They incorporated different network settings to analyze the impact of RPL on behavior of network, convergence time of network, average power consumed by the network, packet loss and delay. The inference here is that the objective function of the RPL protocol does not have any open impact on foresaid parameters in ranking. So this leaves open ground for further research in defining an optimal objective function for better performance of RPL protocol.

In addition to the above works, the RPL was implemented in a network with two configuration modes such as static and mobile sink for performance analysis [13]. The performance of both the configurations was analyzed with regard to average power consumption, latency and packet delivery ratio. The result of this simulation reveals that when compared to mobile sink, network with static sink delivers better performance. This may be due to isolation of nodes from sink due to mobility factor.

In a hybrid network, both static and mobile nodes were deployed for performance analysis. It used different frequency for radio communication and ContikiMac for data transfer [14]. For routing mechanism, the standard RPL was used in this network. The inference is that change in frequency of duty cycle directly modifies the RPL performance. Furthermore the