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Ripple Routing Protocol (RPL) for routing in Internet of Things

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ABSTRACT

The objective of this paper is to analyze the routing protocols for the Internet of Things (IoT) with a focus on simulating the RPL protocol, which is in the process of being standardized as a routing protocol for IoT. There is a critical need for an optimal routing protocol. This paper addresses the key routing challenges in IoT design, with particular emphasis on RPL. Additionally, the issues associated with RPL are examined to enhance IoT's performance in various applications, from healthcare to entertainment. The potential of InformationCentric Networking (ICN) as a complementary technique to address RPL-related challenges is explored, highlighting both its advantages and areas for further research before RPL can be fully standardized for IoT.

Keywords—Internet of Things, Routing, Error control, Flow control, RPL, ICN

INTRODUCTION

The IETF formed a group called ROLL to find a routing protocol standard for Internet of Things (further referred as IoT) in 2008. The ROLL group came up with an algorithm called Ripple routing protocol (further referred as RPL) based on various analysis made on low power lossy networks [4]. This proposed protocol was employed on IP layer instead of link layers like other routing protocols.

RPL is basically a routing protocol that makes a destinationoriented directed acyclic graph (DODAG) to find paths to the destination in this case root node. It makes use of two things, one is objective function and another is a set of metrics or constraints.The objective function can be made on various constraints like ETX(expected transmissions) or hop count.

RPL basically creates graphs and follows it to route packets across and within networks. The main notion is multiple graphs can be deployed on the same network topology i.e same physical topology with various logical topologies on top of it [5]. The nodes within the network can join one or more graphs but at a given instance they can be part of only a single graph.

A. Working of RPL

RPL builds graph and this process begins from the border router and segregates to other nodes. RPL makes use of three messages such as DAO (DODAG Destination Advertisement Object), DIS (DODAG Information Solicitation) and DIO (DODAG Information Object).

The root hub begins promoting the data about the graph by making use of the DIO message.The hubs which are present in the neighbourhood of the root would receive the DIO message and would now process the DIO message and think over whether to join the graph based on certain constraints and metrics. If the hub joins the graph than it has a path directly connecting to the root The parent node or the node generating the DIO message is called the "root" of the graph. The node counts the ran of itself with respect to the root of the graph and thereby makes use of constraints and metrics. If the node is selected as the forwarding node than it further forwards the DIO packet to those nodes which are in its vicinity but not in the vicinity of the root. If the node is not the forwarding node and just the"leaf node" than it would just calculate the rank and doesn't forwards the DIO message

The nodes thereby receiving the DIO messages would compute their rank and the DODAG graph would be constructed gradually. In this manner a graph is constructed and there exists a path from the node to the root such that every node in the graph can reach the root node in the graph. Here it can be seen that all nodes have a path towards the root hence it can be said that a multipoint-topoint model is formed and it is termed as UPWARD routing. All nodes in the graph has rank associated with them and are closely linked in the graph with the root of the graph. The rank is computed based on the constraints and metrics such as ETX or Hop count. The steps of creation of DODAG building process is modelled in the figure 1. Same as UPWARD routing

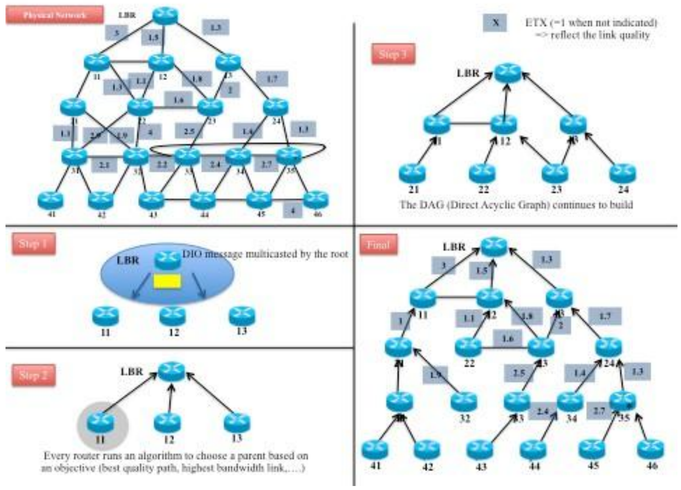

Figure 1DODAG building

where the message packets originates from leaf node to root node there can be a condition when message generates from root or another network to the leaf node, this requires a path from root to leaf node.This kind of routing is termed as DOWNWARD routing.It is obtained by making use of DAO messages. DAO messages are used by the nodes to send routing information to the neighbouring nodes or root to store the routing path or not store the path but to keep track from where the messages has arise. The DAO message is an advertisement message which advertises the various DODAG information to all the nodes in the topology. The prefix reachability matrix is constructed through this process. The nodes receiving the DAO messages stores the routing information in their respective routing tables. This way of storing information is making use of what is termed as ”storing” nodes. The RPL also supports ”non-storing” mode. The prefix reachability matrix creates a downward routing path from the leaf nodes to the root node.

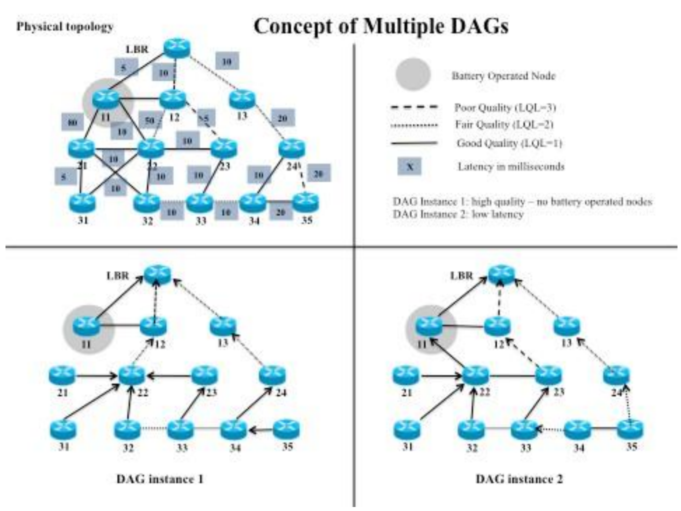

Figure 2 Multiple DAGs

B. Metrics and Constraints

Metrics and Constraints is used in RPL to generate the objective function thereby resulting in formation of DODAG. The metrics is a scalar quantity which measures the quality of the graph formed or the topology created. Constraints are the limitations that are imposed on the objective function to create the DODAG graph and thereby optimizing the graph building process.These metrics and constraints are something which are not fixed or compulsory but are liable to context and conditions.An example of some metrics is ETX or Hop count and the constraints imposed on them can be that ETX should not be over 55.

C. Storing and Non-Storing nodes

Storing nodes are the one that would store the routing information in their routing tables implied that they have been provided that routing information is provided to them via the DAO messages. The prefix reachability matrix provides this information. Another mode is "non-storing" where the nodes do not store the routing information but the root node does. Thus the root node has all the routing information. All packets are sent via the root node of the graph [2]

The important aspect here is that there is tradeoff between both the nodes available in RPL. In storing mode a lot of memory space is to be required with all the nodes which might increase the size of the node. In case of non-storing mode there is performance lacking as all packets pass through the root. It should be noted that hybrid mode is not possible.

D. Loop Avoidance and Detection

RPL provides basically two mechanisms for loop avoidance and detection. Firstly discussing the loop avoidance mechanisms, the RPL provides maximum depth rule in which the rank of parent cannot be more than the children node and an node cannot go deep in the graph to increase their rank and become greedy to save their power. But it is not always possible to avoid the loops so a loop detection mechanism is required.

The loop detection mechanism is such that when a packet arises from the root node and is travelling towards the leaf nodes and when any node checks its routing table and finds that the packet needs to go upwards then it is detected that there is some discrepancies involved in the routing of the packet. So the intermediate node doesn't forward the packet further but discards the entire packet without making any amendments in its routing information. Then a local repair is emerged to solve this problem and get correct routing information.

E. Global and Local repair

Repair is a key element for any steering convention and alludes to the capacity to repair the steering topology when disappointments happen. When a packet arises from the root node and is travelling towards the leaf nodes and when any node checks its routing table and finds that the packet needs to go upwards then it is detected that there is some discrepancies involved in the routing of the packet. So the intermediate node doesn't forward the packet further but discards the entire packet without making any amendments in its routing information. Then a local repair is emerged to solve this problem and get correct routing information. As local repairs happen the diagram may begin to separate from its ideal shape, and soon thereafter it may be important to reconstructing the chart (DODAG) thanks to a corresponding instrument called the "Global Repair".

Issues in Rpl

A. Throughput

Like the IEEE 802.15.4 MAC in layer, RPL in the system layer additionally meets the throughput challenges as a result of different existing together applications in one physical system and the potential extensive system size. Unique in relation to the DAG steering topology utilized by RPL, the line mindful back pressure directing calculation sends parcels to the gateway(s) by misusing all conceivable end-to-end ways, which has been ended up being throughput ideal in principle and effectively executed in genuine sensor systems. To move forward the potential throughput, RPL could characterize the line accumulation as a hub metric and join this with connection quality measurements (e.g., information rate) for information sending. Other than the back-weight approach, incorporating the thoughts of deft directing and arrange coding are additionally encouraging what's more, reasonable arrangements.

B. Packet numbering

Unique in relation to customary tree-based WSN directing, RPL gives multipath steering arrangements (i.e., the DAG steering topology; a hub can have different parents).The multiway steering structure would bring about bundle reordering; that is, prior created parcels might be gotten by the portal later.Therefore, this key issue of multi-way steering ought to be tended to when RPL is utilized to give organizing administrations to jitter-delicate applications, for example, target following.

C. Duty Cycle

Other than the MAC layer, dynamic obligation cycling additionally has a non-insignificant effect on the end-to-end execution of the system layer, including end-to-end inactivity, throughput, conveyance radio, and different variables. In vitality gathering systems, for occurrence, each sensor hub ought to adjust to the time-shifting environment vitality by modifying its obligation cycle (i.e., vitality consumption)dynamically,in request to accomplish economical operation (i.e.,no hub ought to come up short on battery). Be that as it may, the current RPL plan has given careful consideration to obligation cycling. In this manner, the most effective method to flawlessly incorporate obligation cycle mindfulness into the multi-way directing RPL remains an open inquiry.

Simulation

To observe the behavior of RPL as routing protocol the simulation is performed on COOJA simulator in Contiki OS [3]. The application collect view is used to collect the various readings. Many topologies ranging from 10 nodes to 100 nodes have been studied and with different random positioning of nodes. Figure 3, 4 and 5 are the basic three topology of 10 nodes which shows that what kind of arrangements of nodes of nodes is made in the different topologies of 10 , 25 and 100 nodes.

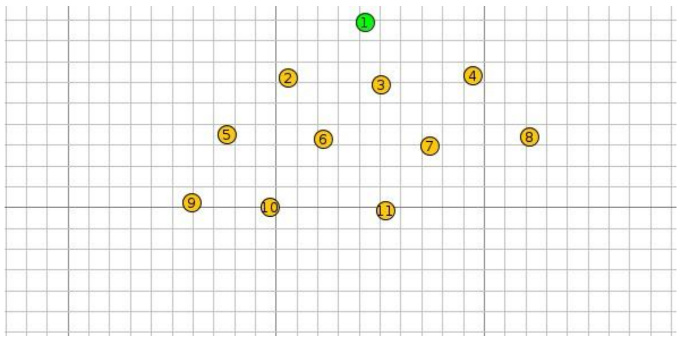

Figure 3Topology 1

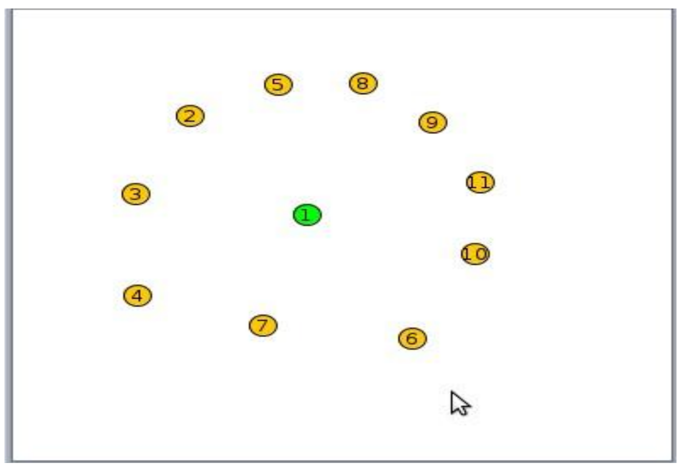

Figure 4 Topology 2

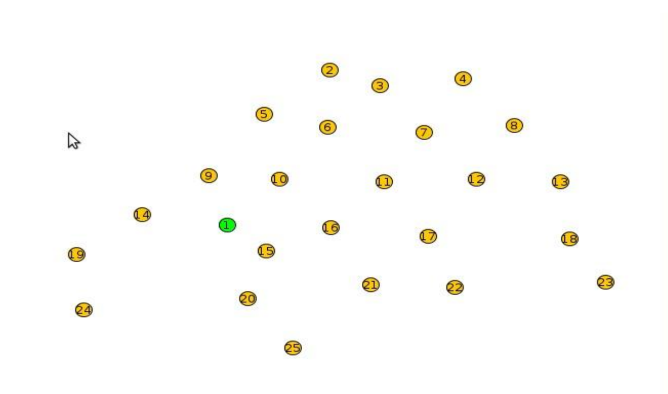

Figure 5 Topology 3

A. RPL overhead

As mentioned above on performing simulations on various topologies following observations have been made:

On initial phase of network setup most of the traffic is due to RPL control messages.

The average time required for all topologies simulated here to move from 100% control messages to 25% is 10 minutes.

The above two observations can be demonstrated in the figure 6. The observation has been make that RPL control messages increases with increasing number of nodes. This means that if a low-power small WSN application with 100 nodes is deployed it would consume much more power in signaling. Hence from the Figure 7 and 8 it can be observed that listening phase also incurs more power.

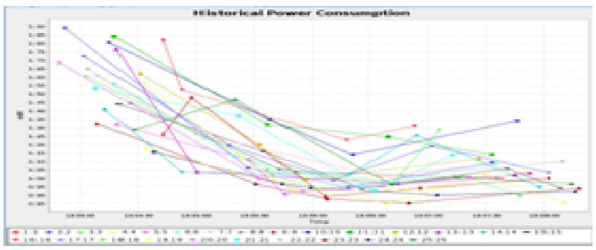

Figure 6.

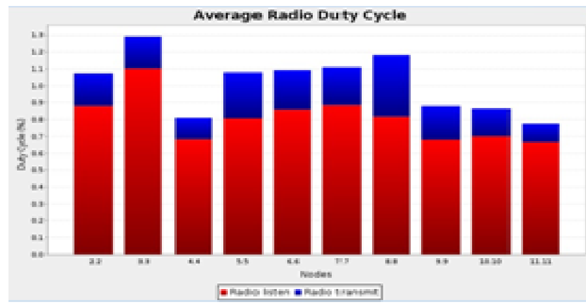

Figure 8.Average radio duty cycle

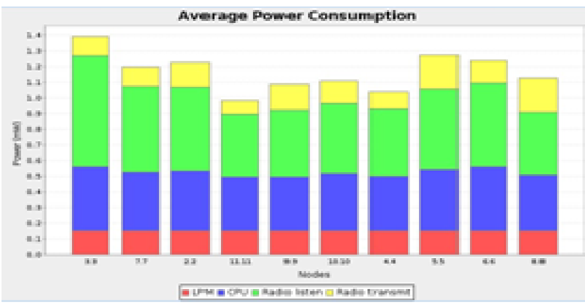

Figure 7.Average power consumption

B. Packet Delays

Related to the delays in Packet reception it is observed that The more far the node from the sink the delay is involved. Here the parameter used for finding the packet delay involved is ETX (expected transmissions).

The figures 9, 10 and 11 shows the values of ETX of a father node and of a nearby node The results show that the packet delays for 10 nodes and 20 nodes topology is ranging from about 2s to 5s whereas of 100 modes topology goes about 8 S as mentioned in [1]

Hence our observation for RPL overhead can be concluded to basically two observations:

The network set-up time for RPL is quite fast which is most suitable for military applications.

Protocol optimizations are required in order to reduce the control messages thereby decreasing the signaling overhead to create the DODAG graph.

Figure 9.10 nodes ETX to next hop

Figure 10. 20 nodes ETX to next hop

Future Scope

The ICN technique studied here can be employed on top of the routing layer to deal with issues pertaining to RPL before standardizing it as a routing protocol for IoT. The pros and cons of the ICN is also an issue which need to be addressed in future work. Employing this technique would definitely solve some issues in RPL. ICN deployed over RPL is something which can be studied and analyzed further resulting into better RPL performance.

CONCLUSION

The study shows that RPL is undoubtedly apt routing protocol for IoT. Though certain changes are required such as it is necessary that the signaling overhead of the RPL is reduced as it incurs the most of power consumption and thereby reducing the performance. Moreover, RPL also needs to provide better scalability compared to other protocols available.

It is noteworthy that RPL provides very fast network-set up and that is useful in case of critical applications deployment. RPL needs to be more context – dependent and need for providing a way for auto – configuration. The deployment of

Information-Centric networking (ICN) over RPL would result into providing better connectivity and routing performance. Some limitations of RPL like duty cycling can be improved using ICN over RPL.

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