A Survey on Routing Protocol for Low-Power Lossy Network (RPL) in IoT

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Abstract

In this era, a new paradigm has emerged in the field of wireless communications called Internet of Things (IoT). IoT aims at the interconnection of various objects or things around human's living space. To introduce IoT, thousands of low-power and low cost embedded devices are required. The use of these devices in various applications established the network of intelligent objects. These networks are known as Low-Power Lossy Network (LLN). In addition, routing protocols play a crucial role. To enable IoT into reality, IETF has standardized the IPv6 Routing Protocols for Low-power and Lossy Networks (RPL).In this paper a survey on RPL is done.

Keyword- RPL, IoT, LLN, Contiki

I. INTRODUCTION

The digital revolution in the twenty-first century is more exciting than the past digital revolution. All the while in twentieth century, the world experienced two wonderful and important digital revolutions: first, computers come into existence into homes and offices, and then the Internet connected computers to each other.

Now in the current phase , the concept of the Internet has changed from set of connected computer devices to a set of connected surrounding things of human's living space, such as home appliances, machines, transportation, business storage, and goods etc. That is, Internet of Things links the digital world in to the physical world.

Internet has become more prevalent in our lives in a shorter time period than any other technology in the history. It recasted the way of communication. Currently, the Internet involves the process of connecting machines, equipment, software, and things in our surroundings. This connection will be through the use of the unique Internet protocol address that permits things for communicating to each other without human intervention. This new scenario is called IoT.

Fig. 1: IoT

With the increasing development of microcontrollers and microelectronic technologies, smart objects have been introduced. Smart objects can form sensor networks that probably consist of hundreds of thousands of nodes. A large number of smart objects used in various applications establish networks of intelligent objects. These kinds of networks are called Low-Power Lossy Network. LLN equipment has limited resources such as the processor, memory, battery, and unstable radio communications.

One of the challenging issues in LLNs is to find the best path for data delivery, so an efficient routing mechanism should be used to find and keep track of the changes in the network path. The routing mechanism should consider both natures of LLNs i.e. resource constraints and the lossy media.

IPv6 protocol supports a very large address space so that it is selected as the best option for Internet of Things. In recent years, several routing protocols have been suggested for low-power and lossy networks. Some efforts were done by IETF in order to define a standard for this, and finally in 2012 IETF standardized RPL as the best one.

The completeness of RPL makes it impressive among its competitors. Thus RPL becomes a promising protocol for LLN. In fact, one reason behind the success of RPL routing protocol in comparison with the other protocols is that it provides various types of traffic support likely, Multi-point-to-point (MP2P), Point-to-multi point (P2MP) and Point-to-point (P2P) and another is

its ability to directly connect to Internet nodes with global IPv6 addresses. This in turns makes RPL very flexible and can be easily tuned for different applications' requirements. In addition, it provides the benefits of both mesh and tree routing protocols as it supports both hierarchical and flat topologies. [1, 2, 3, 4, 5]

II. METHODOLOGY

A. RPL Routing Protocol

Routing over low-power lossy network (RoLL), a working group, was assigned by IETF to determine the appropriate routing protocol for low-power and lossy networks. Major mentioned requirements are as follows:

- Route tracking: Route discovery is facilitated with the availability of information such as path quality, the number of nodes, and the replaced active route with its associated costs.
- Route selection: Reliable route selection and high quality communication link determination is possible.
- Route cost: Routing protocols must support path quality criteria. The criteria include signal strength, available bandwidth, number of hops, amount of available energy and communication error rate.
- Path flexibility: At the time of convergence, paths needed to be flexible and selection criteria should be improved (e.g. signal quality and the number of visited hops)
- Alternate routes: The network layer should determine and establish second and third alternate routes to be used in failure time.
- Constraint based routing: There are some nodes that may lose their battery power faster than other nodes or with limited energy source. Some nodes have a larger memory space, so they are capable of saving more neighborhood information. Some others have a powerful processor and hence they can collect data in more sophisticated ways. In such situations, routing protocol must also support constraint based routing. Constraints such as the processor, memory size, battery level, etc. [5.9]

B. RPL Routing Protocol in LLN Networks

RPL routing protocol was designed based on large set of requirements. RPL has been designed for LLN networks. This includes resource-constrained equipment which communicates through lossy wired and wireless communication links. At the time of RPL design, decisions taken are based on the specific characteristics of LLN networks. [5, 9]

C. Routing Method

RPL is an Ipv6 based distance-vector routing protocol used in LLN networks. This routing protocol is based on Destination Oriented Directed Acyclic Graph (DODAG). Nodes organize vectors of DODAG and communication links among nodes organize DODAG edges. Nodes forward received and generated data traffic to their parents in order to reach data to DODAG root. LLN Border Router (LBR) acts as DODAG root and starts DODAG construction process by broadcasting DODAG Information Object (DIO) messages. When other nodes receive DIO messages for the first time, they join the DODAG by selecting the DIO sender as their parent and then broadcast DIO messages. This process continues and nodes join the DODAG. [5,9]

D. Destination Oriented Directed Acyclic Graph (DODAG)

In RPL, routing is based on a special kind of DAG. Special kind of DAG is known as DODAG. Before understanding RPL and how these DODAGs are formed, we need to understand some basic terminology, and key concepts, which are at the Heart of this Routing Protocol.

- Directed acyclic graph: It is a graph that contains no cycle, we see such kind of graphs in spanning trees.

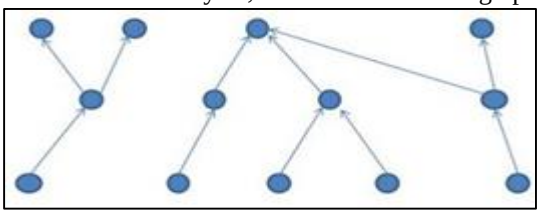

Fig. 2: Spanning Tree

- Root: It is the destination of the nodes in DAG, it has no outgoing edge
- Up: It is any edge that is directed towards the Root
- Down: It is any edge which is directed away from root.

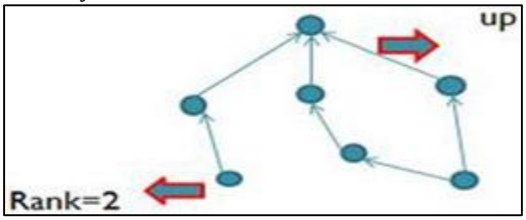

Fig. 3: DAG

- Destination Oriented DAG (DODAG): This special kind of DAG where each node wants to reach a single destination.
- Objective Function: It helps us to decide whether we are near to the root or away from it. Objective Function is decided by a programmer or designer. It is something which we want to minimize. It can be energy, it can be Latency. And once we decide what we want to minimize, we give it a Number.
- Rank: It is the distance from Root.
- RPL instance: When we have one or More DODAGs, then each DODAG is an instance.
- DODAG ID: Each DODAG has an IPv6 ID (128 bit). This ID is given to its root only. And as long as the root doesn't change ID also doesn't change.

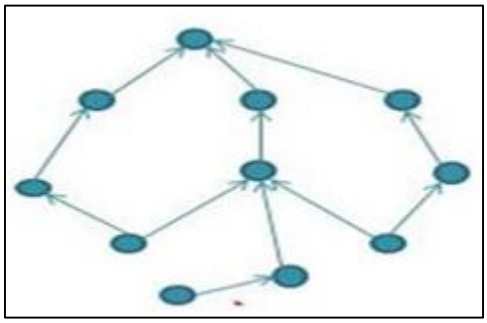

Fig. 4: DODAG

- DODAG Version: Each new shape of a DODAG means a new version.
- Goal: It is where a DODAG wants to reach, it can be a wired network. Goal is different that Objective function. In objective function our aim is to minimize. However Goal is where we want to go.

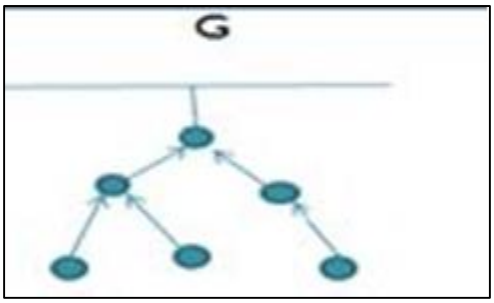

Fig. 5: Grounded RPL

- Grounded: When a DODAG reaches its goal it is known as Grounded. G in Figure 5 shows Grounded DODAG.
- Floating: When a DODAG isn't connected, or is yet to reach the Goal, it is called Floating. F in Figure 6 Shows Floating DODAG.

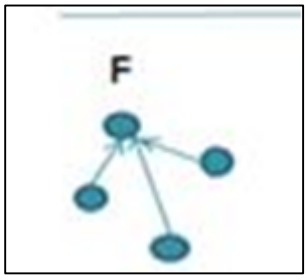

Fig. 6: Floating RPL

- Parent: Parent is where the Arrow is pointing towards. And a Child is where the arrow comes from. Parents can have multiple children; similarly a child can have multiple parents.
- Sub-DODAG: It is any sub tree of a given DODAG.
- Storing: Storing nodes keep the whole routing table. They know how to go from one node to another.
- Non-Storing: They are simple, they don't store an entire Routing Table, they only know about their Parents. The whole DODAG except from the root has to maintain uniformity, it has to be either Storing or Non-Storing. Root is always Storing.[7]

E. RPL Control Messages

1) DODAG information Object (DIO)
This message is Multicasted downwards. A given node In a DODAG may multicast this message , which lets other nodes know about it , Things like whether the node is grounded or not, whether it storing or non-storing, and it announces other nodes "if they are interested to join , Please Let Me know. "

2) DODAG Information Solicitation (DIS)
When no announcement is heard, and if a node wants to join a DODAG it sends a control message, for that it wants to know if any DODAG exists. So the message which it sends is Like "Is there any DODAG? "

3) DODAG advertisement Object (DAO)
It is a request send by a Child to parent or root. This message requests to allow the child to join to a DODAG.

4) DAO-ACK
It is a response Send by a root or parent to the child, this response can either be a Yes or No.[7,9]

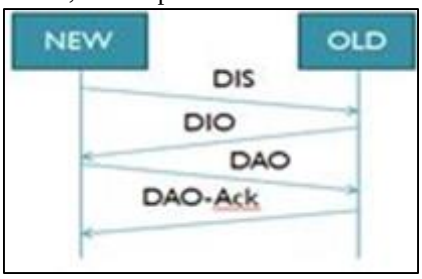

Fig. 7: Control messages

F. DODAG Formation
Root is a special node. All nodes don't have the capability to be roots. A root is programmed that way.
Suppose we have 5 nodes: A, B, C, D and E. And they to make a DODAG, then following steps are taken:
1) A multicast DIOs.
2) Rest of the nodes (B, C, D and E) upon receiving DIOs will try to join regardless of their distances. Upon receiving the DIOs they also come to know that their Distance from the A are 1,1,3,4 respectively.
3) Then B, C, D and E send DAOs to A.
4) A accepts them by replying with DAO -ACK.[7,9]

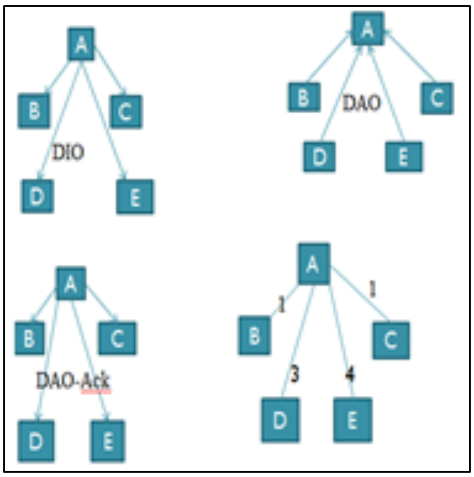

Fig. 8: DODAG Formation

III. SIMULATION

The performance evaluation of RPL was done using Contiki. Contiki is an open source operating system for the Internet of Things. Contiki connects tiny low-cost, low-power microcontrollers to the Internet. Contiki is a powerful toolbox for building complex wireless systems.

The simulation is done using Cooja simulator. We compile Contiki OS for Tmote Sky platform. We use Unit Disk graph medium (UDGM).Our aim is to examine how messages are transferred in DODAG. Fig.9. represents a screenshot of the simulation

environment. A total of 10 nodes are used for simulation. Among, one is a sender node and the rest is receiver node. This was simulated for 120 seconds. [6,8]

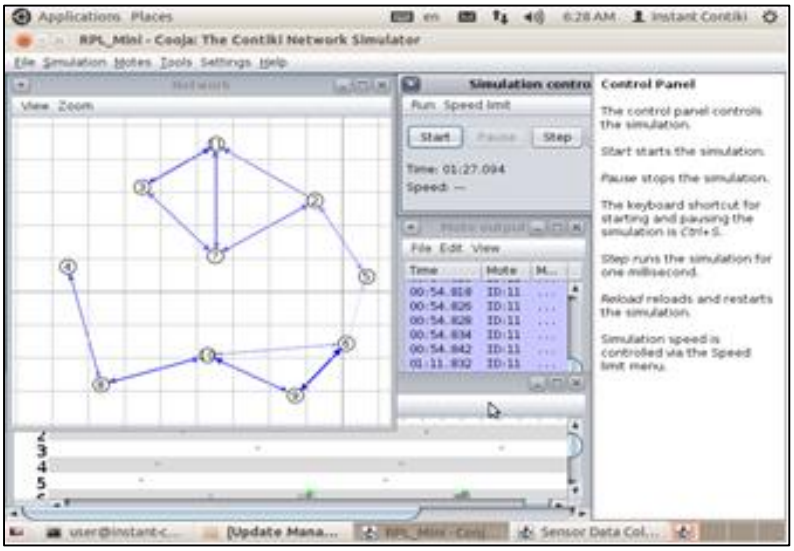

Fig. 9: Screenshot of RPL using Contiki

IV. CONCLUSION

RPL is the IPv6 based distance vector routing protocol for low power lossy network. It is a very promising routing protocol for LLNs as it provides a great level of flexibility to deal with different requirements of underlying applications. It is based on special kind of dag known as DODAG. In this work, implementation of RPL in IoT using the tool Contiki was successfully done.

Even though RPL is a promising protocol for LLN, it has many challenges. There are many ongoing discussions based on these challenges. One of the most heading challenges is Mobility. Many mechanisms are proposed for bettering mobility. Next generation communication networks with seamless connectivity is expected to achieve wireless sensor networks with improved mobility.

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