Experimental Analysis Of RPL Routing Protocol In IOT

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Abstract: IOT is one of the ever-widening networks which are used to connect devices, tools, machines, things, people and applications as well as other areas of physical world to the internet that has the ability to transmit data over network without any human and machine communication. The Routing Protocol for low power Lossy network (RPL) is a routing protocol developed by Internet Engineering Task Force (IETF) that is designed for constrained devices. This research work focused on the major routing protocol RPL in the Unit Disc Graph Radio Model implemented in contiki3.0 and Cooja simulator using sky mote. This paper examined the performance of RPL routing protocol in terms of power consumption, radio duty cycle, etc., in 6LoWPAN network.

Keyword: RPL, IETF, 6LoWPAN, IOT.

I. Introduction:
IOT has the ability to connect the physical devices or things to the internet that allows the communication through the network. IOT has various set of applications such as home automation, industrial monitoring, smart cities, health monitoring, fitness tracking, environment protection, precision agriculture, waste management, energy conservation, etc. [1]. Currently the LR-WPAN is become very big issue and use IPv6 to address such issue, the IEEE 802.15.4 standard are described with short range, low bit rate, low power and low cost. These standard devices are used to connect the physical things to real-world applications. The IEEE802.15.4 defined a sort of low cost, portable Wireless Network devices or mobile devices in December 2000. This standard that specifies the PHY layer and MAC layer of Wireless Network by having 1% of 802.11 powers, as easy to embed and use. The architecture for IEEE802.15.4 is shown in Fig.1. [3]

![Fig.1. Architecture of IEEE802.15.4](image)

IOT consists of numerous sensor nodes for data transmission. Every sensor node consists of a processor and a RF module that is known as mote which is used to accumulate and process the data and communicate with other sensor nodes in the network. Now the 6LoWPAN (Low power Wireless Personal Area Network that uses IPv6 for data communication from one sensor node to another sensor node in the network. The 6LoWPAN has packet that contains data with IPv6 over IEEE 802.15.4 frame. It also affords less power consumption [4]. In the modern world, everybody uses low power devices that are connected with internet which leads to increases the growth of such device in the day to day life. The Low Power and Lossy Networks (LLNs) contain various gadgets with low power, memory and assets. These systems administration gadgets are interconnected by means of different connections and utilized in a few applications like industrial monitoring, wireless sensor networks and mesh network, etc [12]. IOT (Internet of Things) offers networking devices in LLNs with Internet access. In the existing routing protocol, there are lots of routing issues which are faced to address the communication patterns. To overwhelm such issues, the ROLL group designed Routing Protocol for low power Lossy network (RPL) that use IPv6 Address. Nevertheless the RPL protocol is susceptible to many attacks such as hello-flooding attack, version number attack, blackhole attack etc., [5]. The ROLL working group conducted study and affords a broad vision into the RPL security issues. The CIAA model (confidentiality, integrity, authentication and availability) classifies these attacks [6]. The research study in [7, 8, 9, and 10] also shows some attacks directing RPL protocol to identify these attacks using intrusion detection system (IDS). The Cryptography algorithm plays an important role to encrypt and decrypts the data on sender as well as receiver sides. The existing cryptography algorithms are used to encrypt and decrypt the data during the data transmissions in last two decades. However, the cryptography is developed for giving strong security in data communication phase [13]. Distributed computing is the great conveyance model of cloud administration over the web. In this worldwide world everybody utilized cloud processing. The innovation was financially acknowledged as a result of more affordable. Web is spine for distributed computing innovation. The distributed computing connected in Business, IT part, informal community destinations, web mail and so on[14]. The power the executives is one of the principle moving
issues in 3G cell phones. The 3G innovation was utilized in cell phones and tablets for high speed information correspondence. The 3G versatile spends major measures of vitality during correspondence [15]. Many steering conventions of MANET utilize the topology data to find the course in the dynamic condition. The geographic or position based routing beats a portion of the hindrances of topology based directing utilizing a few extra data [16]. IoT gadgets are likely going to be sent in wide numbers in remarkably connected with business sectors. Advancement updates taking after Moore's law will probably be utilized to make installed contraptions progressively reasonable, humbler, and more prominent criticalness proficient yet less progressively genuine. Normal implanted IOT gadgets are equipped with 8-or 16-piece microcontrollers that have no RAM and point of confinement limits [17]. The paper is organized as follows: Section 2 discusses the overview of the RPL routing protocol. Section 3 shows the simulation setup and Results are discussed in detail. Finally, conclusion and future work is presented.

II. RPL ROUTING PROTOCOL:
The RPL routing protocol is a distance vector routing protocol which works on IEEE802.15.4 for Low power and Lossy network [11]. This RPL network can have many RPL Instances in which it may have multiple DODAG (Destination Oriented Directed Acyclic graph). A DODAG is created like a tree structure that has path from leaf node to root node and the structure of DODAG is shown in Fig.2.

![Fig.2. Structure of DODAG](image)

This protocol has the following RPL Messages such as: DIO (Destination information Object), DAO (Destination Advertisement Object), DIS (Destination Information Solicitation), and DAO-ACK (DAO-Acknowledgement). The DODAG is formed by upward direction as well as downward direction. In upward direction, the path construction starts from root node to leaf node. The root node(R) sends DIO message to its neighbor node (A, B). The node A accepts DIO message and it chooses the R as a parent. Then calculate the rank based on objective function and included in the DIO message & forward the DIO to its neighbor node (C). After getting the DIO message, the node (C) chooses A as its parent. The node B accepts DIO message and it chooses the R as a parent. After successful formation of DODAG, the node (D) sends DIS message to its neighbor node (C) and attempt to join in the DODAG. The node C sends DIO message while getting the node D’s DIS message [2]. Now Node D chooses C as a parent and the DODAG tree structure is formed successfully with upward direction is shown in Fig.3.

![Fig.3. Formation of DODAG with upward direction](image)

In downward direction, the root node receives DAO message from node B after processing the DIO message from root. The root node adds node B’s information in its routing table and send back DAO – ACK to the particular node. In such a way, the other node’s send DAO message to its parent node and send back DAO – ACK to its children node which is the confirmation from the parent node that has received DAO message through its children and the DODAG tree structure is formed successfully with downward direction is shown in Fig.4.

![Fig.4. Formation of DODAG with downward direction](image)

III. SIMULATION SETUP
The simulation of RPL Protocol is implemented by using one of the open source operating system Contiki. The Contiki is especially designed for low-power and lossy network devices which contains the following models such as Unit Disc Graph Model - Distance Loss, Unit Disc Graph Model - Constant Loss, Multi-Path Ray-Tracer Medium. In
In this study, the routing protocol is tested using Cooja simulator with unit Disc Graph Model – Distance Loss and evaluated the performance metrics. The parameters used for the simulation is presented in the table below:

**Table I. EXPERIMENTAL PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPL Operating System</td>
<td>Contiki-OS</td>
</tr>
<tr>
<td>Simulation Environment</td>
<td>Cooja</td>
</tr>
<tr>
<td>Radio environment in simulation</td>
<td>UDGM</td>
</tr>
<tr>
<td>Mote Type</td>
<td>Sky Mote</td>
</tr>
<tr>
<td>Physical Layer</td>
<td>IEEE802.15.4</td>
</tr>
<tr>
<td>Network Layer</td>
<td>RPL with 6LOWPAN</td>
</tr>
<tr>
<td>Startup delay</td>
<td>1000 ms</td>
</tr>
</tbody>
</table>

This simulation use Sky mote to emulate motes that contains MSP430 microcontroller with 10 KB RAM and IEEE 802.15.4 standard. In Cooja simulator, the chosen model for simulating the network is Unit Disk Graph medium that shows the transmission range of the mote which is used to find position of any motes in environment. It takes 10 6lowpan with RPL sender nodes and one sink node depicted in the network as they transmit the resources as temperature and humidity values to sink node from LBR (6LOWPAN Border Router) is shown in Fig. 5.

**Fig.5. Topology of 11 Nodes in RPL with 6LOWPAN**

In Fig.5. Node 1 is the sink or border router node which has the following nodes such as 2, 3, 4, 5, 6, 7,8,9 and 11 with its transmission range while node11 is in interference range as they are not participating in the packet transmission within the network. The mote output is shown in the blue color with mote id and time and message. We have used collect view during simulation to observe the details such as node transmission time, power consumption, average power consumption of the node, average radio duty cycle. The network graph for the given topology is created during simulation is shown in Fig.6.

**Fig.6. Network Graph – Collect View**

The performance metrics are evaluated in terms of power consumption, average radio duty cycle, Received packets per node are shown in below.

**Fig.7. Received Packets per node**

**Power Consumption**

The Power consumption calculated as transmission as well as reception of packet successfully delivered per node in the network. The RPL protocol used to analyze power consumption of nodes using power tracer tool in Cooja. Figure 8 and 9 shows radio duty cycle and average power consumption graph of nodes. In figure 9, node 2 and 8 has maximum duty cycle than the other node in the network as it is very close to the sink node. Consequently it generates more traffic than the other nodes. In figure 10, the power is consumed by these node is also high.
CONCLUSION

One of the promising features in IOT is enlightening our day to day activity with embedded or smart devices, technologies, and applications. The paper has illuminated about RPL routing protocols and its DODAG formation with both upward and downward direction. The performance analysis of RPL routing protocol in terms of parameter metrics such as Average power consumption, average radio duty cycle, packets received per node using Contiki and Cooja simulator. The result indicates that maximum numbers of packets are received per node with high throughput and average latency. Once the intermediate node increase then the power consumption also increases and if the node has less power consumption then the radio duty cycle decreases. In future, the performance of RPL routing protocol will be analyzed with the presence of malicious node based on metrics such as packet delivery ratio, network ETX, etc.

References:
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