Energy Efficient Routing for SDN based Internet of Things (IoT) Applications

[1]Kavyashree K, [2]Dr.Shreenath K N

[1]Student, [2]Associate Professor
Department of Computer Science and Engineering
Siddaganga Institute of Technology

***Abstract*—Internet of Things (IoT) can possibly make advances the way we interact with things. IoT imagines the possibility of widespread connectivity of everything which is characterized as the worldwide system of uniquely identifiable and addressable smart things representing the capacity to communicate and interact with other smart things. Each of these systems comprises of a microchip, handset module, sensors and power source. The greater part of the circumstances these frameworks need to manage low power and lossy networks (LLNs), where each nodes have restricted memory, processing capability, and power.. A steering convention is required as these gadgets can be scattered in an unpredictable way. Considering unexpected attributes of LLNs, Internet Engineering Task Force (IETF) developed, and institutionalized the Routing Protocol for LLNs (RPL). This paper presents SDN based IOT in which the control plane implements RPL which is an IPv6 system and creates a tree-like topology which depends on few system metric enhancement process utilizing distinctive Objective Functions (OF) to satisfy wanted routing procedure. This paper presents a routing and a transmission control calculation to plan a solid vitality effective and low cost RPL based framework for IoT applications.**

***Keywords*—Internet of Things; Low Power and Lossy Network; Software Defined Network; Routing Protocol for Low Power and Lossy Network.**

I. INTRODUCTION

The idea of IoT was first detailed in 2005, by the International Telecommunication Union (ITU) expressing the future society will be an "omnipresent system society" where bunches of smart articles can be associated with the web [1].
Since the start of the idea IoT, the plan of a directing convention to meet its prerequisite ended up noticeably essential. There are couple of conventions which are characterized utilizing the IEEE 802.15.4 Physical and MAC layers. The 6LowPAN system layer adjustment convention likewise can be utilized as an extension between low power gadget and the IP world. Notwithstanding, the execution of these conventions weakens under LLN.

Software Defined Network (SDN) is a new networking system that changes the impediments of present network infrastructure. SDN decouples the forwarding plane (data plane) from the systems control rationale (control plane) which is generally combined with each other. SDN is another approach for organize programmability where the system administrator programs the controller to consequently oversee data plane gadgets and optimize the resource use.

In SDN based IOT, the control plane computes the routing protocol proactively which is known as RPL(Routing protocol for low power and lossy networks). RPL is a directing convention which begins finding the courses when the RPL organize is instated. [2]. RPL makes a tree-like topology with leaves at the edges and a root at the best. Dissimilar to the tree topology, RPL offers additional connections which is an imperative necessity in LLN [3].

By overcoming heterogeneity of gadgets the interoperability of IoT gadgets can be resolved utilizing SDN. . This will have the capacity to deal with concurrent associations of different communication technologies. System administration choices, for example, routing, planning can be done at the SDN controller.
The entire network is managed and supervised by SDN controller. The central position of the SDN controller makes it appropriate to have a global vision of the network topology and conditions, performing system control, for example, directing and QoS control. The controller can decide the best directing choices and entering these into forwarding table.

For executing RPL by and by, it is expected to indicate the objective application. To finish that objective application, prerequisites must be characterized. At long last, the goal capacity ought to be outlined in light of the application particular necessities. The target work is a component of connection metrics/node metrics which allots a cost to every way. Connection metric contains the data about the connection associating two hubs while hub metric speaks to the trait of a hub. Since we will probably actualize the proposed framework in IoT based applications, the principle concern is control utilization.

II. RELATED WORK

As indicated by RFC6551, RPL steering just considers either unwavering quality or vitality utilization [4]. Generally existing executions of RPL utilize jump tally and Expected Transmission Based (ETX) based OF. The issue with hop count
based OF is it doesn't consider low power and lossy properties of the system while for ETX metric based OF, hubs are positioned in view of their connection quality towards the root [5]. ETX considers just connection misfortune paying little mind to considering the transmission control expected to diminish misfortune level [5].

In standard executions of RPL, the ETX esteem for a interface is refreshed by a transmitter subsequent to sending an information bundle. Such usage at first expect that a connection has the most exceedingly terrible quality and this gauge is amended after some time. This refresh system has an inalienable issue, in that the ETX
Metric is just refreshed on ways where information movement is as of now being sent, i.e., to the favored parent. In this way, if some other neighbor hubs were to improve as a parent due to a change in connect quality, this hub would not be found.

Alvi et al. proposed an upgraded form of RPL where guardians picked by hubs depend on an arrangement of system measurements which are the postpone imperative, battery utilization of potential parent hubs, sorts of vitality source along the course towards the root hub. The proposed directing convention is named Green- RPL and here principle need was to limit carbon impression emanation and vitality utilization while keeping up required QoS [6].

Marques et al. proposed an application-driven expansion to RPL in [7]. At the outset, a few suspicions are made for example, each hub will choose its parent from an arrangement of hubs where a similar application is running. Every hub's application layer imparts data to different layers of the correspondence stack. The principle commitment here is cross layer arrangement considered as an augmentation of RPL which utilized shared data to frame the Directed Acyclic Graph (DAG). This enables the hubs to choose guardians with deference to the applications which lessens the system vitality utilization as it confines radio correspondence exercises.

In [5], Elnaz Rezaei proposed a versatile transmission control that limits the normal vitality cost of transmitting bundles. An OF was proposed which chooses ways with least expected transmission vitality. The primary thought of this approach is, a hub tests its potential parent set of three to decide best transmission control. Toward the finish of examining the hub refresh its favored guardians. Here Received Signal Strength Indication (RSSI) is utilized to get the potential parent set of three. The testing is done at the season of instatement and condition evolving cases. In this calculation, examining is improved the situation every one of the three individuals from potential parent set which can cause bigger system joining time.

In [8], Zhao et al. proposed a vitality productive locale based steering convention called ER- RPL. Not at all like ordinary RPL, has this system guaranteed both vitality productive parcel conveyance and unwavering quality. In this approach, they gave area mindfulness capacity to an arrangement of hubs which are name Reference Nodes (RNs). With the assistance of RN, arrange range is fragmented into couple of locales. Alternate hubs need to make sense of at which locales they live in. Every hub gauges the separations to every rn in view of RN's organizes and their jump check to comparing RN. The specific area where a hub dwells in the system is spoken to by an area code (RC) which is processed utilizing the Self-rejoining calculation. The course revelation between a source and a goal hub is performed just among a subset of hubs in the system as per the RC with area based course disclosure. Their work is reproduction based, what's more, the nature of hubs with respect to battery life isn't considered.

The architecture of an IoT framework with the adoption of a Software Defined Networking. SDN permits network administrators to manage network services through abstraction of higher level functionality. The system layer as appeared in is presently separated into two layers: the information layer and the control layer while different layers stay unaltered. The information layer involving SDN switches and switches don't make the basic leadership of the data being gotten/transmitted by/to the detecting layer. Rather they leave the basic leadership to the control layer by permitting programmable control of the switches and switches through a southbound APIs.

III. SDN based ROUTING PROTOCOL FOR LOW POWER AND LOSSY NETWORK (RPL)

The SDN based IoT control plane computes forwarding rules i.e, RPL acquires multi-hop ways to a root from a set of sensor nodes. Here, to handle multi point to point traffic a destination oriented Directed Acyclic Graph (DAG) known as DODAG is formed . For the DODAG formation a set of parents for every node which can be potential next hop on a path to the root is selected. The root, which is also called an LLN border router (LBR), may be connected to a non-LLN network, such as a private network . Favorable circumstances of DAG over the tree is a DAG structure enables a node to have more than one parents, which is forbearing of connection failure.

Rank: It is a scalar number which speaks to a connection/hub's cost. The Rank figuring relies upon the OF which is reliant on application. The rank is utilized to decide the relative position of a hub in the DODAG which aids for avoiding loop formations. The rank is a 16bit monotonic scalar which is registered by the OF and dependably higher than any parent's rank.
Host: Here a host is one which can generate traffic and process it but couldn't forward it.

Router : Router can forward ,generate and advertise the information. The reach ability of router must be verified before it can be used as a parent. RPL requires an external mechanism to be triggered for the parent selection to determine link properties and reach ability of neighbor.
Objective function : OF dictates the formation of DAG by giving rules to the section of parents. By defining how node translates the metrics and constraints into a value called rank. The OF of network might include throughput, Latency .link reliability or expected transmission count.

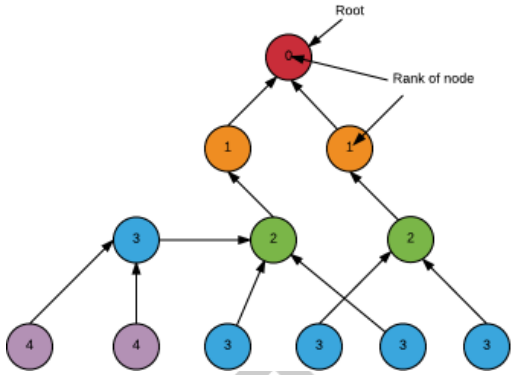

Fig: DAG with one root (DODAG)

DODAG has the information that is required by RPL to route the traffic upward, The DODAG tells who the chosen parent of the node is. In this way, if a node needs to send a packet to the root, it basically sends the packet to its favored parent in the tree, and the favored parent at that point sends the packet to his favored parent etcetera until the packet reach the root.
The RPL convention populates DODAG with the parent data. The DODAG utilizes control parcels called DODAG Information Object (DIO) which is sent from controller plane to the nodes.
The development of the DODAG is administered by various directing measurements (node and path) and OF.

Routing Metrics: A directing metric is a quantitative incentive to decide the path costs. In this way, the best path is the one which has the least cost regarding some predefined measurements.
Measurements and limitations are promoted in the DIO packet, and the set of routing parameters utilized by the RPL example is signaled along the DAG worked by a particular OF. Measurements are for the most part of two sorts: node metric, Link-metric.

Node-metric: Node energy, Hop-count, Node State Attribute (NSA) etc.

Link-metric: RSSI , Latency, Throughput, ETX, Link Quality ,etc.

Most regularly utilized measurements are hop count and Expected Transmission Count (ETX).

ETX: It speaks to the quantity of transmissions a node hopes to make to convey a packet to its destination effectively.

Ps: The probability of successful delivery of a packet to the receiver.

Pr: The probability of successfully receiving the acknowledgement packet.

Hop-count: It signifies the number of hops required to reach the destination.

IV. SYSTEM DESIGN

The combination of ETX and RSSI values are used in this algorithm to form the DAG and selecting parent to send data. After selecting parent a node would find optimal transmission power to guarantee energy efficient data transmission.

The entire procedure is divided into three algorithms or steps which are preferred parents set formation, finding preferred parent for routing and transmission power control.

Algorithm 1: Preferred parents set
In algorithm 1 a parent set for a node is formed avoiding its neighbors which is ranked infinite. After getting the parent set, the controller will sort this set based on the ETX value (ascending). The preferred parent set would be the initial three elements of the sorted parent set. In the event that the parents set's size is below three, the parent set will be the preferred parent set. This calculation is done during the state Initialization or if the current chose parent's connection's RSSI falls below the threshold.

Input: Node x and its neighbor
Output: Preferred parent set
If (neighbor's rank! = infinite rank)
parent set, Pt;
End
Current preferred parent p;
If (RSSI (p) < threshold) or state initialization
new_Pt = sort Pt, based on ETX (ascending);
IF size of(Pt)> 3
Preferred parent set= First three element of new_Pt;
End
End

Algorithm 2: Preferred parent;
Algorithm 2 uses the preferred parent set which is the output of the algorithm 1 as input. In this algorithm the parent set is sorted ascending based on RSSI. The parent with the highest RSSI would be the preferred parent which is the last parent of this sorted set.
Input: Preferred parent set;
Output: Preferred parent, p;
RSSI_PT= Sort the parent set based on RSSI (ascending);
p= RSSI_PT(Last); // Higher the RSSI better the link.
Do transmission power control for p;

Algorithm 3: Transmission Power Control
The control plane selects the preferred parent, after that transmission power control algorithm is done. The RSSI values above -85 dB for RF transceiver CC2420 represents the good quality of a link. At whatever point this esteem dips under the farthest point, the packer-drop increases through that connection. Be that as it may, for the RSSI above - 85dB, a node execution is about the same with respect to packet drop [10].Since the higher transmission power, the higher RSSI, for an energy efficient routing, it's been projected to keep system the RSSI between ((-85) dB - (-84) dB).

Input: RSSI info for Tx
Output: Optimal Tx
From the preferred parent the RSSI of the signal is checked
If (for a RSSI range)
Set corresponding Tx level End

CONCLUSION :This paper presents routing for SDN based IoT application in which the objective of the routing protocol was to obtain a energy efficient framework for IoT applications where nodes would consume lesser power. Further, this algorithm would make use higher throughput of the network. By use of SDN which splits the network layer into data and control plane reduces the burden of route computing tasks from the power constrained IoT nodes .

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