January-February 2020
ISSN: 0193-4120 Page No. 8673 - 8683

Performance Analysis and Comparisons of AODV-RPL Routing Protocol in Low Power and Lossy Networks (LLN)

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Article Info
Volume 82
Page Number: 8673 - 8683
Publication Issue:
January-February 2020

Article History
Article Received: *5 April 2019*
Revised: *18 Jun 2019*
Accepted: *24 October 2019*
Publication: *08 February 2020*

Abstract:

Recently, Low Power and Lossy Network (LLN) has turned into indivisible part for the wireless communication. These networksare versatile without the utilization of a current infrastructure of network or centralized monitor. However, routing in LLN are having restrictions on energy, memory, power and processing. The connection between the devices in such network are characterized by unstability, low data rates and high packet loss. In this paper, we proposed a AODV based RPL routing protocol that makes use of RPL protocol and AODV routing protocol that exhibits the functionality, characteristics and different parameters of both routing protocol, i.e. AODV and RPL routing protocol. In LLN networks, route discovery is a desirable feature and need to handle point to point asymmetric and symmetric traffic flows. This proposed work uses point to point reactive route discovery operation between asymmetric links of the origin node and the target node.

Keywords: *LLN, AODV, RPL routing Protocol.*

I. INTRODUCTION

The Low power and Lossy network, i.e. LLN, is a collection of embedded devices which are interconnected with each other, for example sensor nodes, are characterized by resource constraints node and constraints on communication technologies. Constraints on node may include power restriction, storage and processing, while there is high loss, limitation on size of frame, low data rates, short range for nodes to communicate and change in topology effectively in the communication system in LLN. Generally, IPv6 infrastructure is connected with LLN network with utilization of edge routers. It has a vital role for in and out traffic in the LLN and are able to manage following activities: interchange of information between different nodes in the network, exchange of data between internet or IPv6 network and nodes in LLN, maintenance and generation of subnet. LLN might connected to IPv6 infrastructure via multiple edge router which transmit IP packet between various media. The nodes in the LLN may play role of either router or host. There can be multiple edge routers possible at a time in LLN. Limitation in resources for devices in LLN includes low power, low processing and low storing capabilities, the communication technologies subject to highly asymmetric characteristics of the link, high loss of data, low data rates, variable data loss on lossy links and communication in short range. The nodes in LLN usually has similar type of characteristics, although there may be differences in node storing and computing capabilities. The protocol used in LLN for routing specifies RPL (IPv6 routing protocol for low power and lossy network) and it supports various traffic flow like multipoint-to-point (MP2P), point-to-point (P2P) and point-to-multipoint (P2MP). In MP2P, traffic flows from any node in the network towards the sink node which is the central point (border router) and P2MP includes traffic flow from the border router to some node present in LLN. In this paper, we proposed a AODV based RPL routing protocol that makes use of RPL protocol and AODV routing protocol that exhibits the functionality, characteristics and different parameters of both routing protocol, i.e. AODV and RPL routing protocol. In LLN networks, route discovery is a desirable feature and need to handle point to point asymmetric and symmetric traffic flows. This proposed work uses point to point reactive route discovery operation between asymmetric links of the origin node and the target node.

II. Related Work

This section presents the literature review of ad-hoc routing protocols which includes reactive and proactive routing. Reactive routing protocol works on-demand and proactive routing are table driven in which every router maintains a routing table for communication with the other devices in the network. In addition. This section also reviews the routing protocol used in low power networks, i.e. RPL and its working principle.

Routing in Ad Hoc Mobile Network: Routing protocols in Ad Hoc Mobile Network is divided in two major categories: Pro-active routing protocol and Re-active routing protocol. In Proactive Routing Protocols: These protocols are table driven. Each node in the network shares their topological related information with the other node continuously to learn about the topology used in the network. To have the latest information related to the network, nodes keeps on updating the routing table. The protocols of proactive routing are Destination Sequenced Distance Vector Routing Protocol (DSDV) and Wireless Routing Protocol (WRP).

Reactive Routing Protocol: Routes established are on demand to the final destination. These protocols depend upon query-reply dialog. The benefit of these routing protocol is that there is no need for unnecessary control messages. The protocols of reactive routing are DSR (Dynamic Source Routing) and AODV (Ad-hoc On-Demand Distance Vector Routing)

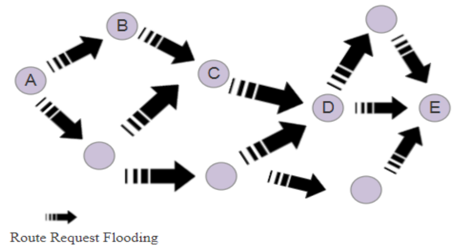
a. Overview of Ad-Hoc On-Demand Distance Vector (AODV):

In this routing protocol, every node knows the distance to reach other nodes which are their neighbors. AODV supports both multicast and single cast. AODV forms a path from source to the destination with the use of RREQ-RREP cycle. Whenever any source node wants a route to send a packet to its destination, it floods RREQ in the network. For the starting node and nodes which receive the packet, the routing table contains the backward pointer for those nodes and thus update the route information. For the destination, in addition to IP address of source, the current sequence number, a broadcast id, RREQ contains the updated sequence number. A node which is either the destination node (D) or an intermediate which knows the path to the D with higher sequence number which received the route request message will transmit the route reply message. Nodes can maintain both RREQ's broadcast id and IP address of source.

AODV performs three mechanisms which are the process of route discovery, generation of route messages and route maintenance. When there is an on-demand route request from a node then route discovery operation is performed by AODV. Following are the four various AODV messages:

- RREQ (Route Request Message): When a new route is needed from source to destination, RREQ was used.
-
- RREP (Route Reply Message): It is an acknowledgment to the RREQ.
- RERR (Route Error Message): It is a message for route error.
- For checking the presence of active neighbors, broadcasting of Hello messages is done periodically.

January-February 2020
ISSN: 0193-4120 Page No. 8673 - 8683



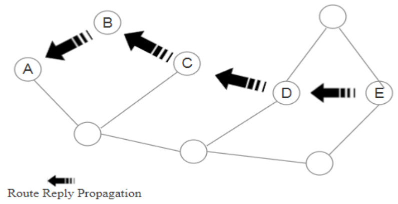


Figure-1: RREQ floodingFigure-2: RREP propagation

Limitations and Advantages of AODV:

The advantages of AODV are as follows:

- Quick response to the change made by the topology in the network which affect current active routes.
- Use of destination sequence no. to discover the updated path to destination and it follows the on-demand route discovery mechanism.
- As there is no concept of source routing in this protocol, there is no extra overhead on the packets.
- Both multicast and unicast data transmission are supported by AODV.

The limitations of AODV are as follows:

- AODV is vulnerable to different attacks because of all the nodes contribute to the route establishment.
- High bandwidth overhead.
- High latency for route discovery: It is a reactive routing protocol, as network size increases there is a decrease in performance.

b. Overview of Routing Protocol In LLN Network:

The routing protocol for low power and lossy network in IPv6 infrastructure, i.e. RPL is suitable for devices which are resource constrained. The main focus of RPL is to give IPv6 infrastructure to the wireless embedded devices which are battery operated that communicate using low power radios and those devices can deliver the data over number of hops. This routing protocol was useful in different applications in the wireless sensor network and IoT domain. It is treated as critical component that connects IETF protocol application layer for LLN to the low power network. The devices which are resource constrained includes power restriction, restriction on storage and processing and the communication between different nodes subjects to low data rate, high packet loss, small communication range, limitation on frame size and change in network topology dynamically. The RPL Protocol is a type of DVR (distance vector routing protocol) that fabricate DAG (directed acyclic graph) which is based on selected constraints and metrics of routing. The DAG is built in support of efficient upstream traffic pattern support with nodes which are resource constrained. RPL basis is to construct Destination Oriented Directed Acyclic Graph, i.e. DODAG which is rooted at atleast single DODAG root and it supports IPv6 bidirectional communication between the nodes in the network.

RPL’s start the process with parent selection and control message with the simple structure of network in which there is only one DODAG. Every single node in the graph advertise its routing constraints and metric via DIO (DODAG Information Object). When a node receives DIO from its neighbour, it chooses its preferred parent for routing based on the objective function (OF) and it collects path information (e.g. DODAG ID, RANK) from DIO and creates a route topology (DODAG). In RPL, there can be several parent nodes for a single node to accomplish reliable delivery of packets via path diversity. Based on the Trickle Timer, DIO messages

January-February 2020
ISSN: 0193-4120 Page No. 8673 - 8683

are sent to accomplish a balance between fast recovery/convergence and control overhead (consumption of energy). As a request, upon receiving DIS, i.e. DODAG Information Solicitation, DIO are sent to the node from which DIS was received. Rank can be defined by objective function to show route distance from a particular device to LLN Border Router. Once each node in the network chooses routes towards LBR, for the construction of reverse route, RPL make use of Destination Advertisement Object (DAO). How a DAO is handeled by the LBR and every node is depend on the mode of operation (MoP) utilized for downstream route: non-storing mode or storing-mode. In storing-mode (table driven routing), every node stores downstream routing data for all of its descendant nodes while in case of non-storing mode, information of all the nodes was stored by LBR, i.e. the root node in the network. In each case, idea is to process ancestor nodes and information storage in DAO to construct entries for routing for all the nodes in its subtree. If a new node is not having a route then that it may use DIS (DODAG Information Solicitation) from an RPL node to request a DIO. A node in the RPL may use DIS message to check its neighbour for adjacent DODAG.

RPL Operation and Topology: Physical network is formed by RPL in the form of DAG (directed acyclic graph) where a single destination is associated with each DAG and in terms of RPL it is called as DODAG. For the traffic, DODAG represents final destination in the network where it can bridge the topology with IPv6 infrastructure. It is termed as LBR (LLN border router) in LLN network. The term upward routing in RPL represents the route from a node in the network to LBR, i.e. MP2P while routes from LBR to any some node, i.e. P2MP are referred as downstream routing. In case of upward route, every node in the network must choose its neighbour node towards the root as parent node (next hop) based on the objective function or metrics. Similarly, every node who is willing to be a part of downward routing must report itself to its parent (preferable is preferred parent). The term instance used in RPL refers to various DODAGs which shares same routing mechanism and policies. There may be more than one instance of RPL coexist at a time within a particular topology and at a time a RPL nodes may connect with various instances. However, a node is permitted to associated with a single DODAG root within each RPL instance.

RPL initiates four control messages to exchange route information which is required to create routing paths and network topology. They are as follows:

- **DODAG Information Object (DIO):** The DIO are utilized to contain significant data and parameters arrangements that enables a device to find instance of RPL, connect with a particular DODAG, choose candidate parent set and keep up the DODAG.

- **Destination Advertisement Object (DAO):** DAO enables a node to spread its data for destination to the LBR (DODAG root) along the DODAG in upward direction with the goal of constructing route from LBR to its corresponding node in downward direction.

- **DODAG Information Solicitation (DIS):** RPL node uses this control message to request/solicit from neighbouring node a DIO message so as to connect with the DODAG.

- **Destination Advertisement Object Acknowledgement (DAOACK):** Recipient of DAO message sent DAOACK to the sender of the DAO message as an acknowledgment of DAO reception.

Building DODAG Topology (RPL Upward Route): DIOs controlled the process of upward routing and building the DODAG. In addition to the information of routing, DIOs carry the relative location of a node w.r.t DODAG root, the rank and objective function (OF) which shows how rank is computed by an RPL node and chooses its preferred

January-February 2020
ISSN: 0193-4120 Page No. 8673 - 8683

parent. In particular, the development of the DODAG is started by a DODAG root multicast DIOs to its neighbour node declaring its rank and objective function that ought to be utilized. This showed in figure 2.18.

Upon getting a DIO message, node in RPL do the following: (a) it adds the identity of sender to its parent candidate set, (b) computes own rank, (c) from the parent applicant it chooses its preferred parent and at last (d) it updates the DIO received with rank of its own and after this to all the neighbouring nodes it multicast the computed rank. Based on RPL specification, received DIO may be discarded by the node.

RPL Downward Routes:

In RPL, for the communication patterns, there must be establishment of downward routes and it must be maintained. For this reason, RPL make use of DAO messages. If a node in RPL wants to report itself as an approachable node from the perspective of root, then to the preferred parent it sends a DAO message in which it publicizing its own prefix of destination. Depending on the MoP mentioned in the DIO message, the parent node will process the DAO received.

RPL defined two modes for constructing and maintaining downstream routes, i.e. storing (based on routing table) and non-storing mode (source routing). Whenever a parent node encounters a DAO message from any of its child, then in the case of storing mode it does following: (a) it stores the prefix of destination in route table and along with this it stores address of DAO transmitter as the next immediate hop to go to that target, (b) it transmits the DAO encountered to its preferred parent to guarantee the spread of the promoted target upward to LBR. However, whenever a parent node encounters a DAO from its children, then it only send to its preferred parent without keeping any route state, until DODAG root receives it. When the LBR gets the DAO, then it keeps up the received data in its route table as a parent-child relationship.RPL likewise allows point-to-point communication between two nodes in the network. Thus whenever a node wants to transmit a packet to some other node in the DODAG, it sends out the packet upward in the DODAG till that packet reaches an ancestor (a node which is having known route for the destination). After this the ancestor transmits the packet downward toward the destination through intermediate nodes and the packet at last reaches the destination node. This is shown in figure 2.18c and the final DODAG was shown in figure 2.18d.

RPL Limitations and Drawbacks:

Single Path Routing: In RPL, all the traffic flow will be transmitted via preferred parent once it is selected and there is no attempt to implement load balancing among various accessible parent candidates.

Implicit Hop Count Impact: In objective function of RPL, the cost of routing for a particular path is computed by submission of all the cost of links coming on that path. This may be misleads when the routing decision are taken as there is higher chance for smaller path to be selected despite that path may have low quality links.

Memory Constraint in Storing Mode: In RPL, every storing node should maintain the information of all the nodes present in its sub DODAG in its routing table. Therefore, the node which is overloaded will be unfit to oblige all the route entries which is needed to be kept up in the routing table.

Non-Storing Mode contains Long Source Header: In case of non-storing mode, the root of the DODAG is needed to append the header of source root for each forwarded packet in the downstream direction.

III. Proposed RPL-AODV Routing Protocol:

This section presents the proposed work of RPL-AODV routing protocol and its working principle which is based on a graph structure. The Routing

January-February 2020
ISSN: 0193-4120 Page No. 8673 - 8683

protocol for LLN (RPL) is IPv6 DVR (distance vector routing protocol) for LLNs i.e. low power and lossy network which supports various traffic flows in a DODAG (destination-oriented DAG) through root. Typically, router do not contains the information regarding other router. So, for the flow of traffic between different routers within the DODAG, in case of non-storing mode, data packet have to visit the root while in the case of storing mode, packets have to visit common ancestor. Such type of packet flows are more likely to follow longer paths and it may results in congestion in the DODAG near to the root. To discover the better path for traffic flow in RPL, it specifies a temporary destination oriented DAG in which the source node behaves as local root. The source node introduces DODAG Information Object (DIO) which encapsulates point to point route discovery (P2P-RDO) option with the identity of both source routing (H=0) mode and hop-by-hop (H=1) mode. Intermediate routers add their IP address and then multicast the DIO till the packet reaches the TargNode, which send the Discovery reply. Point to point-RPL is suitable for source routing but due to extra overhead of address vector it is less suitable for hop by hop routing.RPL and Point to point-RPL both specifies the utilization of DODAG of symmetric links in the network where both the direction of the link must satisfy the objective function constraint. This doesn't allow the use of unidirectional asymmetric links. Networks which composed of asymmetric bidirectional links, RPL-AODV provides point to point route discovery, using RPL with new mode of operation (MoP). RPL-AODV make use of two different multicast message to find the possible asymmetric routes which achieves high route diversity. The need of address overhead is eliminated by RPL-AODV in case of hop-by-hop mode. Significant reduction in control packet size is useful for restricted low power networks. RPL-AODV messages make use of AODV terminology, namely RREP (route reply) and RREQ (route request). RPL-AODV eliminates some feature as compared to AODV which are omitting single directional links, route error flagging etc.

In RPL-AODV, paths from origin node to target node are established on demand within the low power and lossy network (LLN). In other words, mechanism of route discovery in RPL-AODV act reactively when origin node wants to transmit data packet to the target node but the existing route doesn't satisfy the requirement. There is no such constrained of traversing a common ancestor for the route discovered by RPL-AODV. RPL-AODV enables asymmetric bidirectional links with asymmetric communication. For this reason, RPL-AODV enables finding of route from origin node to target node and from target node to origin node. When required, RPL-AODV enables route discovery for symmetric communication along paired DODAG.

In RPL-AODV, discovery of routes is done by forming temporary DAG which is rooted at the origin node. During the formation of routes between the origin node and the target node, Instances (paired DODAG) are constructed based on RPL-AODV mode of operation. RREQ instance is established from the origin node to the target node by the control messages and the RREP instance is established from the target node to the origin node by the control messages. The rank which is calculated from DODAG Information Object (DIO) helps intermediate routers to join the DODAG. The transmission of data from target node to the origin node is based on the route which is found in the RREQ Instance and the transmission of data from origin node to the target node is based on the route which is found in the RREP Instance.

Asymmetric and Symmetric Routes of RPL-AODV Routing Protocol:

As depicted in figure-3 and 4, O is the origin node, LLN border router is represented by BR, T is target node and R be the intermediate router. If bit S is set to one and the interface is symmetric, on which RREQ-DIO arrives, then S bit remains one as shown in figure4. If any intermediate router forwards RREQ-DIO having bit S value as one, then for every

1-hop link from origin node to this router satisfies the need of route discovery and the route can be utilized symmetrically.

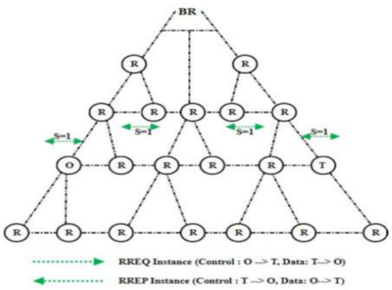


Figure 3: Symmetric Paired Instances in RPL-AODV

When a node receives RREQ-DIO with bit S set to one, it checks for this 1 hop link to be symmetric, i.e. data transmission requirements is satisfied in both the directions. If the interface is asymmetric, on which RREQ-DIO arrives, then S bit set to zero. If bit S is already set to zero when arrived at a node then on retransmission bit S is set to zero again (shown in figure 4). Therefore, for route which is asymmetric, there must be atleast 1 hop which do not satisfy the constraint in both the directions. Depending upon bit S received in RREQ-DIO, Target node T checks for the symmetric route before transmission of the RREQ-DIO upstream towards origin node O.

Whether the link is asymmetric or symmetric, determining this is out of scope of this document and it may be specific to implementation. For an instance, the intermediate nodes might utilize information (e.g. bandwidth, bit rate), quality of link based on previous communication, etc.

RPL-AODV OPERATION:

Route Request Generation: With RPL-AODV, routes from origin node to target node are established on demand within the low power and lossy network (LLN). In other words, mechanism of route discovery in RPL-AODV act reactively when origin node wants to transmit data packet to the target node but the existing route doesn't satisfy the requirement. In such case, origin node frames a local RPL instance and a destination oriented DAG rooted at itself. After this, origin node forwards a DIO message which contains only one RREQ option (refer section 3.6.1) through link local multicast. Atleast one RPL-AODV target option must contained in DIO message. The origin node transmits RREQ-DIO message with bit S=1.Sequence number is maintained by origin node. Whenever origin node transmits new RREQ for the route discovery operation, it increments the sequence number. Similarly, in reply to new RREQ, whenever target node transmits new RREP, it increments the sequence number. Origin node can simultaneously initiates route discovery for different targets by adding different RPL-AODV target option and the route requirements to various target nodes within RREQ-DIO must be same. The origin node can manage various RPL instance to find routes for same target with different requirements. With the help of instance-id pairing operation, RREP-DIOs for several RPL instance can be differentiated. Forwarding of RREQ-DIO follows Trickle Timer. When the time stamp showed by L bit has over, the origin node has to leave DODAG and it has to stop transmitting RREQ-DIOs in related RPL instance.

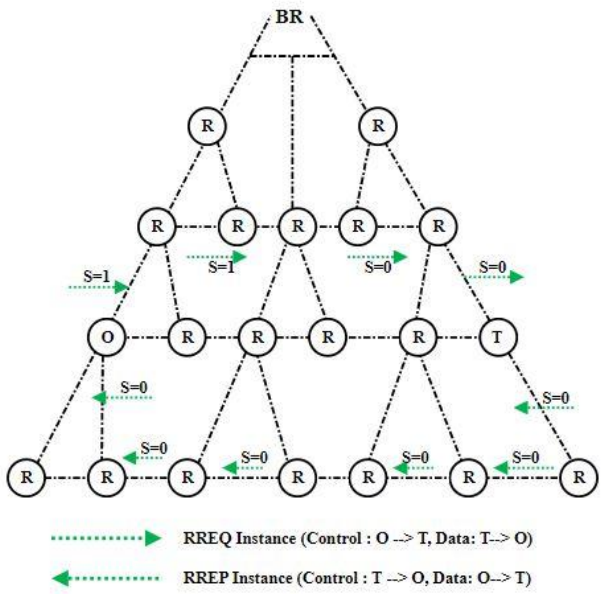


Figure 4: Asymmetric Paired Instances in RPL-AODV

Forwarding and Receiving RREQ message
A router which do not belongs to the instance of RREQ, when it receives RREQ-DIO, it follows the following steps:

Step1: If bit S is set to one then both the direction of the link is checked by the router for the link from which it receives RREQ-DIO. The case in which the link downward stream (towards the target node) cannot satisfy the requirements, the link cannot be used symmetrically and hence RREQ-DIO which is to be transmit, its S bit is set to zero. In the received RREQ-DIO, if bit S is set to zero then only upward direction of the link is checked by the router (towards the origin node).

The case in which the link upstream link (towards the origin node) satisfies the requirement which was mentioned in constraint option and the rank of the router cannot cross the maximum rank limit, the router can join the RREQ instance DODAG. Preferred parent is the router which sent the received RREQ-DIO. The case in which the maximum rank limit or constraint is not satisfied, the router should abandon the RREQ-DIO received and DODAG must not be joined.

Step2: Router then checks for one of its address in one of RPL-AODV target option. If found then it is the target node otherwise an intermediate node.

Step3: If bit H is one, then the intermediate node or the target node must build entry for upward route accordingly. The entry for route must contains the following: Instance id, address of source, address of destination, lifetime and next hop. The instance id can be learned from RREQ-DIO RPL instance-id and DODAG ID helps to return destination address and RPL-AODV target option can return the source address. The next-hop is preferred parent.
If bit H is zero, then the interface address which receives the RREQ-DIO of the intermediate router, stores in the address vector.

Step4: The intermediate router forwards RREQ-DIO through local multicast. RREP-DIO is prepared by the target node.

Route Reply (RREP) Generation at Target node-RREQ-DIO for Symmetric Route:
If the RREQ-DIO message encounter at the target node with bit S=1, there is a route which is symmetric along which both the two directions of the link can satisfy the requirements. It may possible that other RREQ-DIO later provide upward asymmetric route (S=0). Whether the route is asymmetric or symmetric with better performance, determining this is out of scope of this document and may be specific to implementation.

In case of symmetric route, according to the route entry, i.e. H=1 and accumulated address vector, i.e. H=0, unicast RREQ-DIO is sent to next hop. Thus there is no need to build DODAG in the RREP instance. In case when H=0, RREP-DIO must contains the address vector which was received in RREQ-DIO. The origin node address must encapsulate in RPL-AODV target option and encapsulates in RREP-DIO and the destination seq no. is incremented.

RREP-DIO for the Asymmetric Route:
With bit S=0, when RREQ-DIO message arrives at target node, so to find the path from origin node to the target, the target node must create destination oriented DAG in the instance of RREP rooted at itself. The RREP-DIO must be retransmitted through link local multicast till it exceeds maximum rank or the origin node is reached.

Forwarding and Receiving Route Reply:
A router which do not belongs to the instance of RREQ, when it receives RREP-DIO, it follows the following steps:

Step1: If bit S is set to one then router goes to step 2. If bit S of RREP-DIO is zero over the link on which router received RREP-DIO then only downward direction of the link is checked by the router (towards the target node). The case in which the downstream link (towards the target node) satisfies the requirement which was mentioned in constraint option and the rank of the router cannot cross the maximum rank limit, the router can join the RREP instance DODAG. Preferred parent is the router which sent the received RREP-DIO. Afterwards some other RREP-DIO can be received.

The case in which the maximum rank limit or constraint is not satisfied, the router should discard joining of DODAG and the router should abandon the RREQ-DIO and do not proceed for the further steps.

Step2: Router then checks for one of its address in one of RPL-AODV target option. If found, then it is the origin node otherwise an intermediate node.

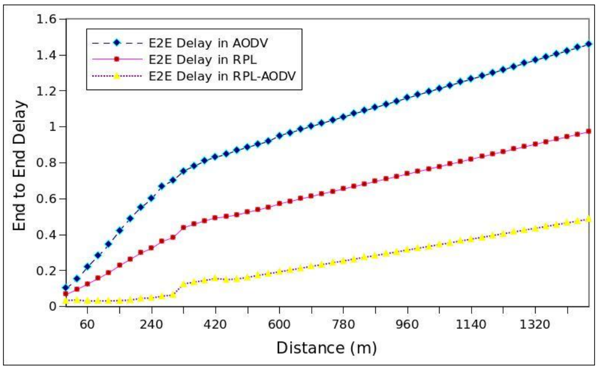
Step3: If bit H is one, then the intermediate node or the origin node must build entry for downward route accordingly. The entry for route must contains the following: Instance id, address of source, address of destination, lifetime and next hop. For symmetric route, router which is at one hop distance in the entry of route, is the router from where RREP-DIO was received. For asymmetric route, RREQ instance contains the DODAG in which next hop router is preferred parent. Route entry which contains instance-id, it must be original RPL Instance id. DODAG ID helps to return destination address and RPL-AODV target option helps to return the source address.

For asymmetric route if bit H is zero, then the interface address which receives the RREP-DIO of the intermediate router, stores in the address vector while for symmetric route, nothing to do.

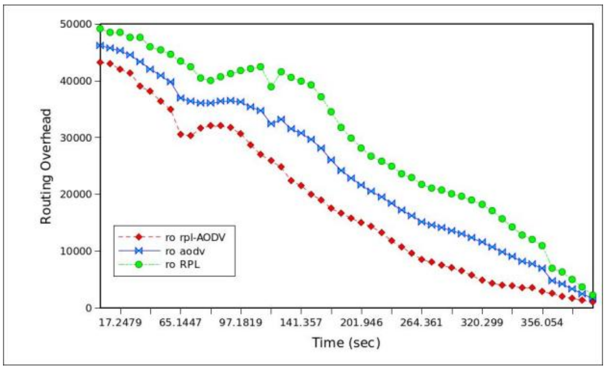
Step4: For asymmetric route, an intermediate router sends out RREP DIO through link local multicast while for symmetric, according to the local entry of route (H=1) or the address vector (H=0) in RREP-DIO, message RREP-DIO was sent unicastly to next hop.

IV. Result and Performance Analysis

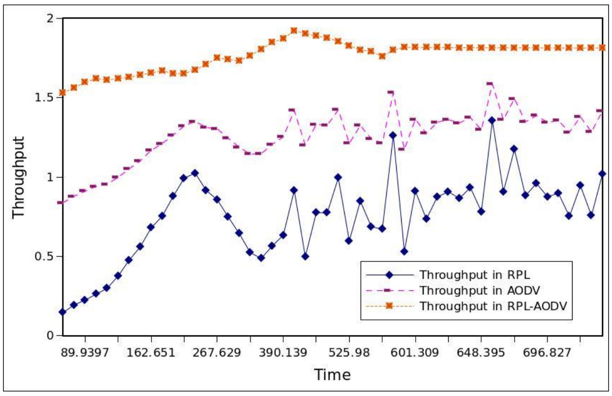
This section presents the results of proposed work, which is implemented using Network simulator (NS-3). The NS-3 is a tool used for simulating the real-world network on one computer by writing scripts in C++ or Python. We analysed the proposed work with various performance metrics- Average end-to-end-delay, Throughput, Packet Delivery Ratio and Routing Overhead.



Fgiure-5 :End-to-End Delay Vs Pause Time

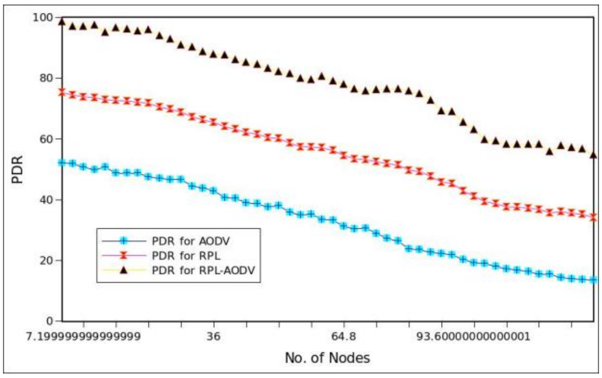


Fgiure-6 : Routing Overhead Vs Pause Time



Fgiure-7 :Throughput Vs Pause Time

January-February 2020
ISSN: 0193-4120 Page No. 8673 - 8683



Fgiure-8 : Packet Delivery Ratio Vs Pause Time

The figure-5 shows the end-to-end delay of AODV, RPL and proposed AODV-RPL routing protocol with various pause time. It is observed that the proposed AODV-RPL protocol provides less end-to-end delay compared to RPL and AODV protocol, because AODV-RPL provides optimal path between source node and the destination node.

The figure-6 shows the end-to-end delay of AODV, RPL and proposed AODV-RPL routing protocol with various pause time. It is observed that the proposed AODV-RPL protocol provides reduces routing overhead compared to RPL and AODV protocol, because AODV-RPL protocol only uses storing node should maintain the information of all the nodes in its routing table.

The figure-7 shows the Throughput of AODV, RPL and proposed AODV-RPL routing protocol with various pause time. It is observed that the proposed AODV-RPL protocol provides better throughput compared to RPL and AODV protocol, because AODV-RPL shortest path and optimal path between source node and the destination node.

The figure-8 shows the Packet Delivery Ratio of AODV, RPL and proposed AODV-RPL routing protocol with various pause time. It is observed that the proposed AODV-RPL protocol provides better Packet Delivery Ratio compared to RPL and AODV protocol, because AODV-RPL protocol not only uses the optimal path but also upward and downward forwarding the information.

V. Conclusion

This paper presents AODV based RPL routing protocol that makes use of RPL protocol and AODV routing protocol that exhibits the functionality, characteristics and different parameters of both routing protocol, i.e. AODV and RPL routing protocol. In LLN networks, route discovery is a desirable feature and need to handle point to point asymmetric and symmetric traffic flows. This proposed work uses point to point reactive route discovery operation between asymmetric links of the origin node and the target node. We analysed the proposed work with various performance metrics- Average end-to-end-delay, Throughput, Packet Delivery Ratio and Routing Overhead. The results shows that proposed method performs betters with various metrics compared to other routing protocol.

VI. References

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