Multipath Routing Protocol for Internet of Things

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Abstract- **Internet of Things (IoT) enables the interaction of objects or things with each other or with the surrounding environment. "Smart" objects, embedded with RFID are the key element for IoT. These objects are provided with the unique identities which addresses each device uniquely in the network. Routing plays a major role in adapting the IoT vision as nodes must communicate and exchange information efficiently with each other. A major challenge for IoT is the design and implementation of routing algorithms that adapt to the frequent and randomly changing network topology. In this paper a multipath routing protocol for IoT that is MRPIoT has been proposed which adapts to the basic requirements of IoT network. In the proposed work an Internet Connecting Routing Table (ICRT) is used which consists of routing information as well as internet connecting nodes information thereby eliminating need to maintain separate table for internet connecting nodes information. We have analyzed and evaluated the performance of proposed protocol on the basis of parameters such as packet delivery ratio, energy consumption and throughput.**

Keywords: **IoT, Routing, MRPIoT**

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I. INTRODUCTION

The Internet of Things (IoT) is considered to be the interconnection of internet with the real world objects and people which extends the concept conventional Human to Machine interconnection to the Machine to Machine interconnection, wherein the things [1] are uniquely identified by providing them unique addresses. The sensing ability is not generally supported by conventional internet, and it only interconnects the devices. But the IoT does provide sensing ability as the sensors [2] are embedded in the IoT devices along with Radio Frequency Identification (RFID) tags [3] and actuators, which enables the communication between the devices [4].There is no usually consented meaning concerning the Internet of Things. IoT term was first used by Kevin Ashton [5] in a presentation in 1998, described a growing globe, Internet-based information service architecture. There are numerous areas where the IoT can be applied or implemented such as smart homes, industries, healthcare, military, traffic management and many more. The real world things and objects whether it is human, animal, cars, refrigerator, ATM or any other real world thing are embedded with sensors, actuators and RFID tags [6]. The sensors sense the environment and collect the data, and actuators perform actions specified for a particular event. The collected data is send to the Gateways and then to the Internet [7]. When a user requests for a particular service be it industries or healthcare, their relevant data is provides to the user in real time as shown in figure 1.

The IoT is considered as smart network that links all things to the Internet for the intention of exchange of data and communication between the devices with some agreed protocols. Routing is main requirement for IoT due to the dynamic nature of the Internet connected objects. The network layer is mostly used to implement the routing in IoT. The IoT consists of very large number of objects or devices, the intermediate nodes have to relay their packets towards next node in multi-hop networks.

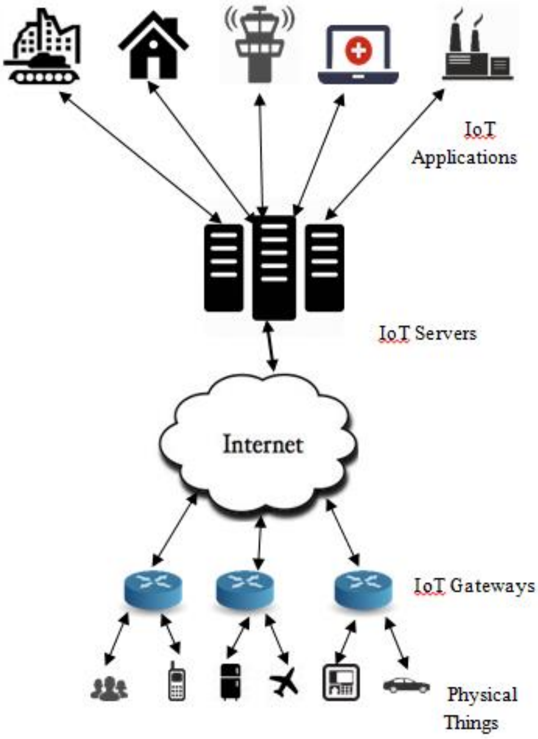

Fig. 1: A Typical IoT Architecture

The routing protocol must be designed in a way to reliably transmit the data over the network with minimum energy consumption as the battery power is limited for IoT nodes [8].

Routing is main requirement for IoT due to the dynamic nature of the Internet connected objects. The network layer is mostly used to implement the routing in IoT. The IoT consists of very large number of objects or devices, the intermediate nodes have to relay their packets towards next node in multi-hop networks. The routing protocol must be designed in a way to reliably transmit the data over the network with minimum energy consumption as the battery power is limited for IoT nodes [9] and also need to maintain multiple paths from one node to another to reduce the delay when there is route or node failure. In this paper, we propose a multipath routing protocol, MRPIoT, which maintains multiple paths from one node to another and also provides internet connectivity to the nodes in the network and thus maximize the life time of the network.

The rest of this paper is organized as follows: In section 2, we discuss the related works relevant to our proposed work. Section 3 provides our proposed protocol and a detail operation. In section 4, we evaluate the performance of the proposed system through simulation experiment. Finally, we conclude to our work in section 5.

II. RELATED WORK

Routing algorithms are used to find the routes the data will take and should fulfill some of the properties such as the routes between nodes should be chosen in a way that the data reaches its destination in the best way possible. Best way can be defined depending on some metrics according to application requirements. For instance, one very important metric is finding and using the route with the lowest end-to-end delay, or the highest throughput, while some other could be to use the route with minimum hop distance or the best link quality. So, to enable the nodes in the network to transmit the data to each other, the routing protocol is needed to provide the route it computed between them. As the IoT network is very large which means massive number of things, extreme heterogeneity in the network and devices are resource constrained, the routing may affected by the frequent topology changes and irregular connectivity which impose severe challenges to the routing [8]. Internet of Things (IoT) is a wireless network, and nodes are free to move. With limited battery power the node and route failures affects the performance of the network [10]. So multipath routing approach have to be considered while creating the routes which will provide alternate route to the nodes if there is any failure and hence reduce the overall delay.

Various routing protocols regarding multipath approach have been designed. To provide a multipath routing solution for the network Le, Q. et al. [11] provided modified techniques for RPL (IPV6 Routing Protocol for Low Power and Lossy Network) protocol which is an extension of basic RPL protocol. The authors outlined major limitation of routing protocol RPL, regarding lack of multi path routing which is based on construction and maintenance of DODAGs (Destination Oriented Directed Acyclic Graph) to send the data from sensor nodes to root over a single path. To overcome this limitation the authors proposed three multipath schemes based on classical RPL which are Energy Load Balancing-ELB, Fast Local Repair-FLR and the combination of these two ELB-FLR, then the schemes are integrated in a modified IPv6 communication stack for IoT. First scheme, ELB resolve unbalanced load in RPL, a new set of objective functions are proposed to calculate rank based on both hop-count and residual energy. Second scheme, FLR is proposed to reduce number of local repairs, by providing more path redundancy to use in urgent situation, to achieve this FLR uses a new term sibling. Third scheme ELB-FLR, a combination of two former methods integrates objective function and load balancing of ELB, faster local repair and loop detection/avoidance of FLR into RPL.

Tian, Y. et al**.** [12] proposed an improved AOMDV (Ad hoc On Demand Multipath Distance Vector) routing protocol for IoT for route designing. This modified of ad-hoc on-demand multipath distance vector aims to find node-disjoint and link-disjoint route and also to create the connection between nodes and internet efficiently. The protocol can select the stable internet transmission path dynamically through regular updating the Internet Connecting Table. The routing overhead is more in this protocol due to requirement of additional Internet Connecting Table with routing table. Qiu, T. et al [13] proposed a An Efficient Multi-Path Self-Organizing Strategy in Internet of Things, to improve the fault tolerance and organizing performance of the wireless network protocol GEAR which is based on the geographical location information in the IoT network and attain better energy conservation and distribution effects. So the authors proposed SMG, Self-organized Multipath GEAR, a new multipath routing organizing protocol which is based on the conventional geographic routing protocol GEAR of sensor networks. By the two-step organizing, the communication empty nodes along with the communication hole can then join the network respectively and energy spreading out and the mechanism of dormancy of the multi-path are used to spread out and save energy. Dhumane, A. et al [9] proposed a Context Aware and Multipath Routing Algorithm CAMRA. The protocol focuses on two main things that is load balancing mechanism and try to minimize the average energy consumption for that delay is somewhat compromised. The proposed It is a reactive protocol which is efficient for energy deficient, static and delay tolerant IoT networks. The devices used in the CAMRA will timely sense the information. As CAMRA is a context aware routing protocol, the remaining energy of the nodes is considered to be the prime context.

III. MRPIoT PROTOCOL

In this paper, we propose a Multi-path Routing Protocol for Internet of Things (MRPIoT), an on-demand multipath protocol used for ad hoc networks. The proposed MRPIoT is a reactive routing protocol that is the route is created only when it is required. Data transmission in the MRPIoT can be multi hop that is using other nodes known as intermediate nodes that act as relay points. It is based on the distance vector routing concept and uses hop-by-hop routing approach. The proposed MRPIoT protocol aims to find node-disjoint and link-disjoint route and it is done by finding more than one paths from a source node to destination in every single path discovery. Multiple paths so computed are guaranteed to be loop-free and disjoint. The proposed MRPIoT meets the requirement of internet connectivity in the nodes of IoT network with improving the overall throughput of the network. Proposed MRPIoT protocol adapt to the requirements of the internet of things that is to make the efficient internet connection between the nodes and also to maintain an ICRT (Internet Connecting Routing Table) for the nodes.

ICRT: The proposed MRPIoT protocol consists of the addresses of all of the nodes in the network along with that it consists of information about the nodes that are connected to the internet. It also contains the next hop address for a packet to take to reach the node. ICRT is updated everytime there is some change in topology of the network.

The proposed MRPIoT protocol works in following two stages.

i. Route Discovery
ii. Route Maintenance.

i. Route Discovery

The need for route discovery arises when a source node wants to establish a communication with a particular destination node in the network to forward the data packet. Route discovery procedure in on demand routing protocols is then initiated by broadcasting the RREQ to all of its neighboring nodes. Whenever a source node in a network needs a path to any particular destination, it initiates a path discovery by flooding a Route Request (RREQ) message for the destination in the network and then waits for a route reply (RREP) message.

If a source node wants to connect and communicate or send data packet to the internet connected node, it will broadcast the RREQ message. For example in the figure 3.1 suppose that node C be the source node and node K, E and I are connecting to the internet. Through the RREQ, it will found: C-A-K, C-D-B-K, C-A-B-E, C-D-H-E and C-F-G-I. The required node that is node K then receives the RREQ message, it will then send back a RREP message to its upper nodes that is from the nodes it had received RREQ message, nodes A and B. A and B then receive the RREP message and then, they will update their ICRT table. Node C will receive the RREP message from node K through A or B, and update its ICRT. Simultaneously, the other internet connecting nodes E and I will send back RREP message through their possible routes that is C-A-B-E, C-D-H-E and C-F-G-I. The source node then compares these links and chooses the optimal route with less hop count. No separate table is maintained for internet connecting nodes the routing table itself contains the information about the wireless nodes in the network as well as the nodes which are connected to the internet.

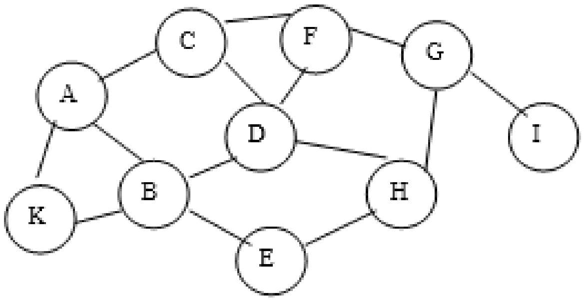

Fig. 2: Network Structure

ii. Route Maintenance

Route maintenance procedure in the I-AOMDV is similar to the traditional AOMDV and AODV protocols. If a node is unreachable due to route breakage or the internet link is failed, then their neighboring nodes send the RERR message and update their sequence number until every node in the network receive the message. Additionally, they set the unreachable node's hop count to infinity. If a node still needs to connect to the destination node, or if all of its internet connecting nodes is unreachable, then the node rebroadcast a RREQ, and try to find appropriate route again. The operation of the proposed MRPIoT protocol is described in flow Chart as shown in figure 3.2.

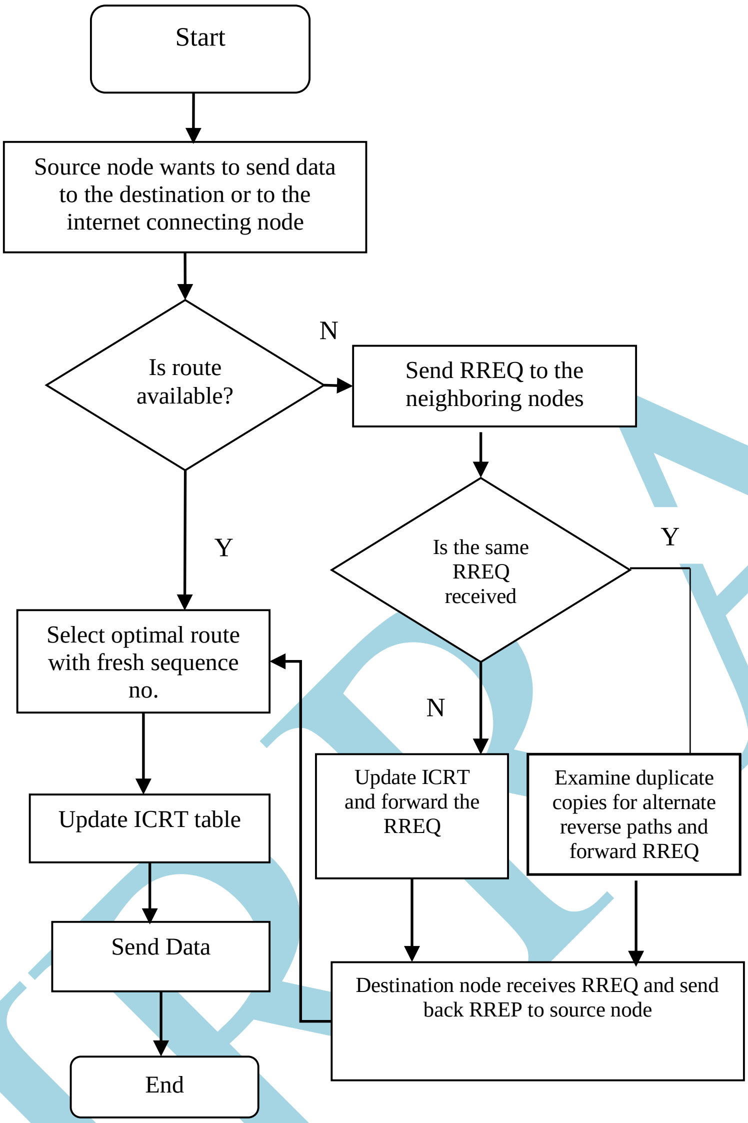

Fig. 3 Flow chart of MRPIoT Protocol

IV. SIMULATION AND RESULTS

The proposed scheme has been implemented in NS2. The simulation environment consists of different number of nodes. Simulation of the proposed system has been carried out by varying number of nodes. The scenario is designed for an area of 1000*1000m and IEEE 802.11 as the MAC layer. The simulation is run for 1000 sec by varying number of nodes from 25 to 45 with 30, 35 and 40 number of nodes in between. Table 1 summarizes various simulation parameters.

Table 1: Scenario I Simulation Parameters

Parameter	Values
Channel Type	Wireless Channel
Radio Propagation Model	Two Ray Ground
Simulation Time (sec)	1035
Simulation Area	1000*1000
MAC Type	MAC/802_11
Number of Nodes	25, 30, 35, 40, 45
Internet Connecting Nodes	2
Transmission Range	250m
Initial Energy	100J
Data Rate	50kb

The following metrics are used to analyze the performance of the proposed system.

Packet delivery Ratio

Packets delivery ratio is the ratio of successfully delivered or received data packets to the packets send by the source. Packets delivery Ratio describes how successfully protocol delivers the packet from source to destination.

PDR = (Packet received/ Packet send)*100

Energy Consumed

It is the average energy consumed by the nodes in the network. The total energy consumed of the nodes is calculated and from that the total energy consumed of the network is calculated.

Throughput

Throughput of the routing protocol is the measure of the number of packets that are successfully transmitted to their final destination nodes per unit time.

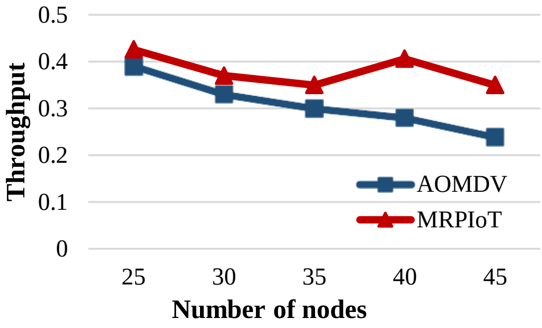

Fig. 4: Throughput vs. No. of nodes

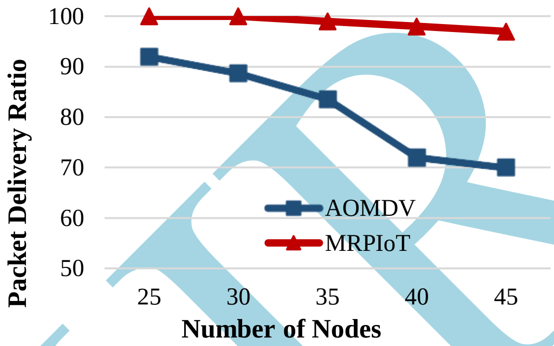

Fig. 5: Packet Delivery Ratio vs. No. of nodes

Figure 4 shows the comparison of throughput between AOMDV and proposed MRPIoT with varying number of nodes. According to the following graph we can see that throughput of MRPIoT is better in comparison to the AOMDV protocol with increasing number of nodes because the data packet loss in MRPIoT is less as compared to AOMDV and more number of data packets are send per unit time.

Figure 5 shows the comparison of packet delivery ratio between MRPIoT and AOMDV protocol by varying number of nodes. The packet delivery ratio of MRPIoT is high as compared to AOMDV i.e., it sends more packet to the destination as compared to AOMDV. The overall number of packets drop in MRPIoT is less as compared to AOMDV.

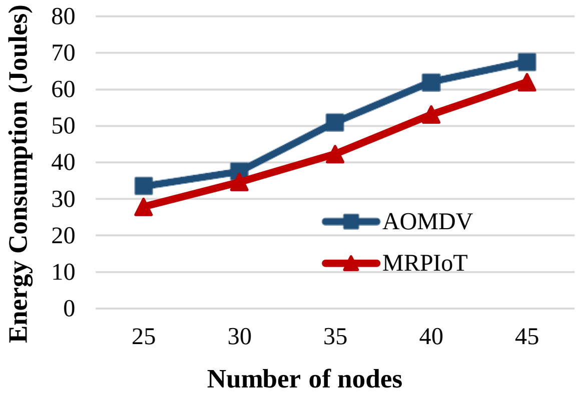

Fig. 6: Energy Consumption vs. No. of nodes

Figure 6 shows that the proposed MRPIoT consumes less energy as compared to AOMDV protocol when the number of nodes is varied because maintenance and regular updation of single routing table consumes less energy than two tables. With increasing the number of nodes, energy consumption of AOMDV also increases, while in MRPIoT the energy consumption increases but it is low as compared to AOMDV.

V. CONCLUSION AND FUTURE SCOPE

We have proposed MRPIoT which is based on multipath routing approach. The traditional AOMDV is compared with the proposed MRPIoT for IoT against different parameters throughput, energy consumption and packet delivery ratio by varying the number of nodes. Simulation results shows that MRPIoT performs better in IoT environment as compared to AOMDV protocol with better packet delivery ratio and throughput and less energy consumption as compared to AOMDV protocol.

Analysis of the proposed MRPIoT protocol for relatively more number of internet connecting nodes and with a runtime mobility of the nodes can be considered for the future enhancement of the proposed protocol. As we have used two internet connecting nodes in our proposed protocol, so with more number of internet connected nodes and by providing runtime mobility to the nodes, the proposed work can be implemented in more realistic environment and its performance can be verified.

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