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Design of an Optimized Multicast Routing Algorithm for Internet of Things

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Abstract: Internet of Things (IoT) is a fast- growing technology in on-going research field that includes wireless sensor networks, cloud computing, big data analytics, ubiquitous computing, distributed decentralized systems, pervasive computing, embedded systems, mobile computing, machine learning etc. The above mentioned fields are mainly connected with IoT smart portable devices such as smartphones, home appliances, healthcare device, smart vehicle devices automation industry devices, etc. Though IoT enabled devices has been increased in many fields, the industries still faces many problem with connectivity issues because of several factors like mobility nature of devices; limited processing power and resource availability which includes energy, bandwidth constraints, routing cost and end to end delay; communication between node to node via intermediate mobile nodes towards destination may also fail links frequently, there by affecting the network performance. These limitations of existing topology based on reactive tree and mesh based routing protocols create challenging task while designing an optimized stable routing algorithm for IoT. In such a situation, resource optimization is an essential task to be performed by the IoT networks. In the proposed work resource optimization was done by Designed Optimized Multicast Routing Algorithm (DOMRA) for IoT. The DOMR algorithm implemented has route discovery process with nodes positions, directions of nodes, velocities of nodes, and then the path stability bases to overcome the connectivity issues. The proposed algorithm focusing to deploy various real time IoT enabled applications such as smart home automation, smart cites, smart agriculture, automation industry etc. To finalize the simulation results shows maximized system throughput, goodput, packet delivery ratio, network lifetime, network routing performance and reduced control overheads. The proposed algorithm hence produced better routing performance when compared with other existing algorithm in wireless networks.

Index Terms: Internet of things, stabile path, optimal route, improve network life time.

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I. INTRODUCTION

Internet of things is a wireless and wired network composed of mobile nodes or non-mobile nodes operated in absence of infrastructure or infrastructure based networks dependents on the environment [1].

There are no dedicated routers, servers, access points, and cables.

Because of its speedy and convenient deployment; robustness and low cost, an IoT can find its applications in the following areas [2].

- Smart agriculture
- Home automation
- Smart cities
- Military use (e.g. a network in the battlefield)
- Investigation and rescue.
- Vehicle-to-vehicle communication in intelligent transportation.
- Momentary networks in urgent business meeting, etc.
- Personal area networks connecting mobile phones, laptops, smart watches, and other portable computers etc.,

In the present Design of an Optimized Multicast Routing Algorithm (DOMRA) for the Internet of Things, routing algorithm focus only wireless mobile nodes. If two nodes are within in the transmission range, it can communicate with each other directly; otherwise, the nodes select the alternate path have to forward the packets. In such a case, every IoT enabled mobile node has to function as a router to forward the packets for others in the networks [18-19].

Traditional routing protocols used in hardwired or wireless networks, such as distance vector protocols (e.g. Routing Information Protocols) and link state protocols (e.g., Open Shortest Path First) etc., cannot be applied in the IoT directly for the following reasons:

- There may be uni-directional links between nodes.
- There is no more than one eligible path between two nodes.
- The consumption of bandwidth and energy incurred by periodic routing information updates.
- The routing topology change rapidly.

Most of the research effort has been put in the routing protocols for IoT [3]-[4]. Topology-based routing protocols can be divided into the following categories [5]:

1. Star based routing (Proactive routing)
2. Mesh based routing (Reactive routing)

In a review, each and every routing protocol has its strengths, weakness, and aims at a specific application.

As a result, the prospective standard for the design to optimize multicast routing algorithm in IoT is very likely to combine with some other techniques. Also it gives better routing performance when compared with the other routing algorithms [15].

II. RELATED WORKS

Existing various routing protocols in IoT, are compared as follows: 1. Depth-First Forwarding (DFF) protocols (Packet Delivery Ratio (PDR) is increased, End to End Delay (EED) is average and Energy Consumption (EC) is average), 2. Multipath Lossy and Low powered protocol (PDR is increased, EED is Less and EC is Average) [6], 3. Energy Efficient Probabilistic Routing Algorithm (EEPR) (PDR is average and EC is decreased), 4. Avoidance Multipath Routing Protocol (CA-RPL) (PDR is increased, EED is decreased and EC is average), 5. Movement-Aided Energy Balance (MAEB) (PDR is increased and EC is decreased), 6. Least Path Interference Beaconing (LIBP) (PDR is increased and EC is decreased), 6. Cognitive machine-to-Machine RPL Protocol (CoRPL) (PDR is increased, EED is Average and EC is average) [16-17], [20-21].

In existing multicast routing protocols, wireless networks concentrate for both independence and dependences applications. Whereas in the present algorithm, focus is only on the independence application based multicast routing algorithm [9]. Mesh based routing approach is used to modify the proposed algorithm and its main intention is to minimize the control overhead, increase network lifetime, especially battery enabled IoT mobile nodes [7]-[8].

An energy efficient routing protocol for wireless IoT sensor networks has been implemented by clustering mechanism which forms cluster head inside so that least energy expensive path and efficient computation in real-time routing has been created. Still path selection in IoT networks cannot assure adequate network of lifetimes and sustained sensing coverage [13], [16, 14].

Wireless routing protocols for IoT is a survey design intercommunication protocol for different devices and it dynamically support cloud computing environment for big data. Performance measures used are transparency, availability and privacy of big data [17]. Routing algorithm design for supporting IoT network architecture using fog computing is responsible for reducing the amount of data sent to the cloud. This algorithm yields lower installation cost and delays constraints unicast traffic under delay constraints which is a severe problem [18].

Multicast Ad-hoc On-demand Distance Vector (MAODV) protocols in each node maintains its routing table; tree structure can be constructed more quickly and efficiently, in the group leader then floods the hello, messages to intermediates nodes toward the destination [10].

Ad-hoc multicast routing algorithm are channels created continuously between pairs of group numbers then multicast distribution tree which is constructed periodically on the mesh links available, also it communicates using unicast routing protocol approach [11]-[12].

Differential Destination Multicast (DDM) is unicast routing protocol for forwarding the packets from source to destinations with reduced control overhead on the multicast routing structure which maintains the multicast routing information by the intermediate nodes [19].

Tree Based Multicast Ad-hoc On-demand Distance Vector (MAODV) routing protocols for working mechanisms such as single path between the source to destination and uses join tree messages to construct a tree and created by each source as many numbers of trees as a source [4].

Multicast Ad hoc On-Demand Distance Vector Routing Protocol (MAODV) discovers multicast route on demand based routing involves different stage such as Multicast Route Discovery (RREQ packets), Reverse Path Setup (RREQ packets), Forward Path Setup (RREP packets), Multicast Route Activation (MACT packets), Group Hello Messages (GRPH messages), and Mesh-Based Protocols (ODMRP)[4].

Mesh based On Demand Multicast Routing Protocol (ODMRP) floods join query packets once received destination node then it join reply packets establish multicast routes towards source node. Different stages for ODMRP working mesh creation, join query process, and join reply process [14].

While comparing MAODV with ODMRP: ODMRP has a better packet delivery ratio than MAODV, ODMRP is more robust than MAODV due to its minimal packet loss and availability of multiple routes, ODMRP is less scalable compared to MAODV as the number of senders or multicast group size is increased and finally MAODV has minimal control overhead as compared with ODMRP. In that both protocols advantage and disadvantages are discussed. To overcome the drawbacks in this case optimized multicast routing algorithm in IoT has been proposed here.

III. PROPOSED APPROACH

The proposed algorithm is to design an optimal multicast routing with stable path and shortest distance through destination node as well as increased goodput, throughput, reduced control overhead compared with other existing routing protocols in wireless ad-hoc networks and IoT as shown in fig. 1. In the proposed algorithm source node initiate the route discovery process with nodes positions, directions, and velocities of nodes, and then the path stability continuously maintains the route discovery up to reach the destination node. Otherwise, it is select to an alternate path to reach the destination node which is optimal with a stable path towards the destination node in the IoT networks.

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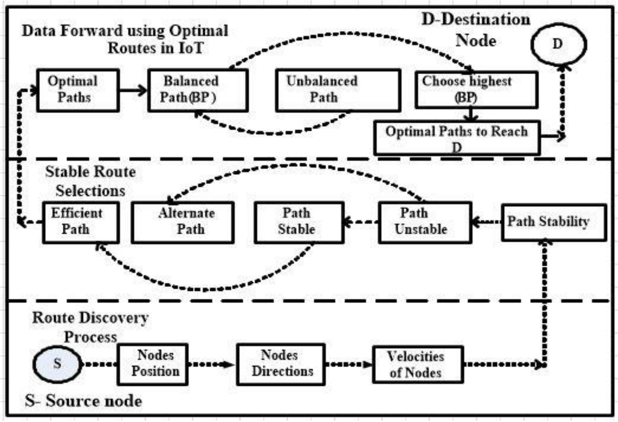

Figure 1: Block diagram of optimized route discovery process using IoT network

A. Algorithm for Optimal Route Selection in IoT

In the proposed DOMR algorithm is to detect the optimal stable path using origin and destination matrix techniques as shown in fig. 2.

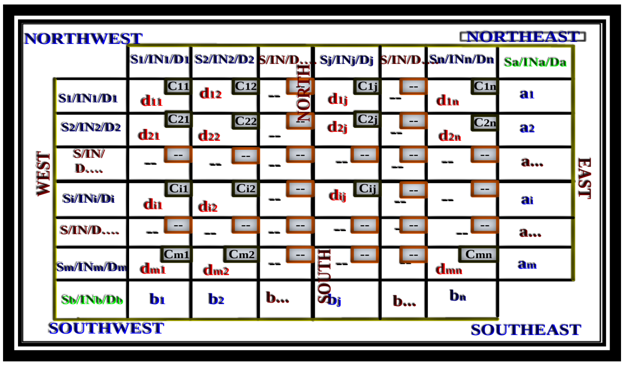

Figure 2: Origin and Destination (OD) matrix

Routing objective function is to minimize the routing cost Eq. (1):

$$Minimize \sum_{i=1}^{m} \sum_{j=1}^{n} d_{ij} c_{ij} \qquad (1)$$

Constraints for optimal stable routing in IoT, Eq. (2) is An i^{th} nodes, Eq. (3) is j^{th} nodes and in Eq. (4) d_{ij} is the shortest distance in terms of routing cost for M*N matrix format in the network:

$$\sum_{i=1}^{m} d_{ij} \leq S_i / IN_i / D_i, (i = 1, 2, ...m) \qquad (2)$$

$$\sum_{j=1}^{n} d_{ij} \leq S_j / IN_j / D_j, (j = 1, 2, ...n) \qquad (3)$$

$$d_{ij} \geq 0; (i = 1, 2, ...m); (j = 1, 2, ...n) \qquad (4)$$

Where:

d_{ij} → distance between i^{th} and j^{th} nodes

C_{ij} →Time taken between i^{th} and j^{th} nodes

$S_i / S_j = (i^{th}, j^{th})$ **or** $S_m / S_n = (m, n)$ = Source nodes

$IN_i / IN_j = (i^{th}, j^{th})$ **or** $IN_m / IN_n = (m, n)$ = Intermediate nodes

$D_i / D_j = (i^{th}, j^{th})$ **or** $D_m / D_n = (m, n)$= Destination nodes

B. Routing Formulation using OD Matrix

Step 1: $S_m/IN_m/D_m$ → m^{th} positions of the nodes

$S_1, S_2, …., S_m$, → Source nodes

$IN_1, IN_2, ..., IN_m$ → Intermediate nodes

$D_1, D_2, ..., D_m$ → Destinations nodes

Step 2: $S_n/IN_n/D_n$ → n^{th} position of the nodes

$S_1, S_2, ..., Sn$ → Source nodes

$IN_1, IN_2, ...INn$ → Intermediate nodes

$D_1, D_2, ….., D_n$ → Destinations nodes

Let be $a_i \geq 0$; i=1,2, ….m →Time available at the $S_1/IN_1/D_1, ..., i^{th}$ nodes.

Let be $b_j \geq 0$; j=1,2,….n →Time available at the $S_1/IN_1/D_1, ..., j^{th}$ nodes.

Step 3: Route Request transmitter nodes || Route Request receiver nodes and Route Reply transmitter nodes || Route Reply receiver nodes.

S_1 / S_2 **or** $S_i / S_j = (i^{th}, j^{th})$ **or** $S_m / S_n = (m, n)$ = Source nodes

IN_1 / IN_2 **or** $IN_i / IN_j = (i^{th}, j^{th})$ **or** $IN_m / IN_n = (m, n)$ = Intermediate Nodes

D_1 / D_2 **or** $D_i / D_j = (i^{th}, j^{th})$ **or** $D_m / D_n = (m, n)$ Destination nodes

Step 4: Distances b/w: Source node || Intermediate node || Destination node.

$d_{11}, d_{12}, d_{21}, d_{22}$ = Single Transmitter and receiver node

$d_{i1}, d_{i2} = i^{th}$, **or** $d_m = m$ =Transmitter node

$d_{1j}, d_{2j} = j^{th}$, **or** $d_n = n$ = Receiver node

$d_{ij} = i^{th}, j^{th}$ **or** $d_{mn} = m, n$ =Transmitter and receiver nodes

Step 5: Routing cost b/w: Total no. of Transmitter and Receiver in the network.

Cost has considered = Routing time taken between nodes

$C_{11}, C_{12}, C_{21}, d_{22}$ = Single Transmitter and receiver node

$C_{i1}, C_{i2} = i^{th}$ or $C_m = m$ = Transmitter node

$C_{1j}, C_{2j} = j^{th}$ or $C_n = n$= Receiver node

$C_{ij} = i^{th}, j^{th}$ or $C_{mn} = m, n$, =Transmitter and receiver nodes

Step 6: Δd_{ij} distance between node i and j, Δv_{ij} velocity of node i and j.

Where:

$$\Delta d_{ij} = d_i - d_j$$

$$\Delta v_{ij} = (V_i \cos\theta - V_j \cos\theta)$$

Assumptions:

All the vertices in the Graph (G) = [V, E] are labeled as [1, 2, …..,M] and [1,2,……,N] and the graph is represented by adjacency matrix of order M*N.

- Vertices[V] = Nodes in MxN routing environment
- Edges[E] = Paths in M*N nodes.

Time complexity T= O(d-1), d=No. of hops in between Source to Destination nodes.

Length [1,2,…….M, and1,2,……………N]=array of distances.

Path [1,2,………M, and 1,2,…………….N]=array of vertices.

Set [1,2,…………M, and1,2,…………N]=array of boolean tags.

R_{ij} = Route discovery between source to destination nodes.

In the R_{ij} '1' is path available from i^{th} nodes to j^{th} nodes the network, otherwise '0'.

C. Algorithm for Detecting Optimal Routes Between Sources to Destination

Nodes
Input:
Datasets→Adjacency_matrix.txt→m^{th} rows and n^{th} columns && Node_coordinator.txt →N is the No. of nodes in IoT networks.
Output:
Route stability level: VeryLow(L), Low(L), Medium(M), Average(A), High(H),Very High(VH).
Step 1: Route discovery process:
If ($S_1/IN_1/D_1$ ==1→ i^{th} nodes & m^{th} rows) && ($S_1/IN_1/D_1$ ==1 →j^{th} nodes &n^{th} columns)
{
Stable path b/w node i and j
if($S_1/IN_1/D_1$==0→i^{th} nodes & m^{th} rows)&&($S_1/IN_1/D_1$ ==0 →j^{th} nodes & n^{th} columns)
{
Route discovery process has fails, then to find the alternate path b/w node i and j.
}
}
Step 2: Route link stability selection:
if(Δd==low && ΔV==negative)||(Δd==low && ΔV==Zero)||(Δd==low&& ΔV==positive)||(Δd==medium&&Δv==zero)||(Δd==medium && Δv==positive) || (Δd==high&& Δv==zero)||(Δd==high && Δv==positive)
{
if(Link_stability==(medium)||(very high)||(low)||(high)||(average) ||(very low)
{
Link stable paths to forward the packets
}
}
Step 3: Packet forwarding:
/*Detect the optimal paths*/
/*Balanced Stable Path (BSP)*/
if **(**Sm/INm/Dm+Sn/INn/Dn-1**)**
{
Balanced_Route→(Sm/INm/Dm+Sn/INn/Dn-1= Cmn)
Choose the most positive value in BSP
}
else if
{
Unbalanced route, and then continue the process until when BSP occurred.
After found new BSP has obtained, then perform to find BSP, otherwise repeat the step: 3.
}
/*Unstable Path*/
elseif(Δd==medium&& v==negative)||(Δd==high&& Δv==negative)
{
if (Link_stability==(low)||(very low)
{
Unstable path to choose an alternate path
}
}
Step 4: Finally, calculating the path expiry time Eq (5).
Position of i^{th} node and j^{th} node at Time t →given by (x_i,y_i) and (x_j,y_j) [10].
Let v_i and v_j is the velocity of node→(θ_i ,θ_j) is the direction of i^{th} node and j^{th} node.
Transmission range of of i^{th} node and j^{th} node →r
Path Expiration Time →D_t

$$D_t = \frac{(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2} \quad (5)$$

Where:
a= $v_i \cos\theta_i$ - $v_j \cos\theta_j$
b= x_i-x_j
c=$v_i \sin\theta_i$ -$v_j \sin\theta_j$
d=y_i-y_j
/* Paths has valid only within the transmission range of nodes, otherwise go to Step 4*/

IV. RESULT AND ANALYSIS

The experimental work was carried out using the Network Simulator (NS3) which is a discrete event network simulator. Present algorithm has been evaluated and tested with random waypoint mobility models as shown in fig. 3 and following parameters are used to evaluate the algorithm in Table 1. So the proposed algorithm shows a better result when compared with existing protocols (MAODV and ODMRP).

A. Performance Metrics

(i) Packet Delivery Ratio (PDR)

PDR= $\frac{\sum[\text{No. of packet received at destination node}]}{\sum[\text{No. of packet send by source node}]}$

(ii) Throughput (T) and Goodput(G)

T= $\frac{\text{No. of received packets * packet size * 8}}{\text{Total simulation time}}$

G= $\frac{\text{Max No. of packets received by the Rx in sequence}}{\text{Total No. of packets sent sender Tx}}$

(iii)Control overheads (CO)
(i)Average queue length (E(N))=[Arrival rate(λ)*E(W)]
(ii)Average packet delay (E(W))

CO $=\frac{\sum[(\text{No. of slot time for each successful packet transmission})]}{\sum[\text{Total no. of slot time for each successful transmission packet})]}$

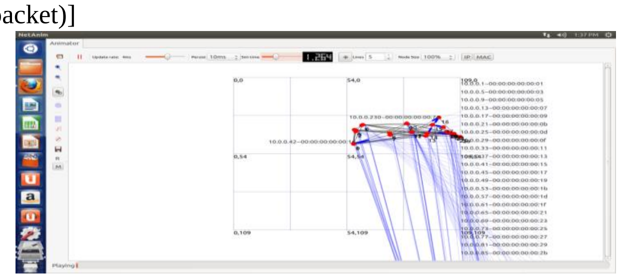

Figure 3: Implemented by DOMRA screen shot

B. Performance Comparison of DOMRA, ODMRP and MAODV

Fig. 4 shows the graphical representation of data between the varying constant velocity of nodes (m/s) and the packet delivery ratio in case of both the proposed DOMR algorithm which is represented in green color line, existing MAODV which is in black color line and ODMRP algorithm which is in red color. When the velocity increases from 2 to 10m/s, the PDR was observed to be 89% in the case of DOMR based algorithm, while the same was observed to be 77% in the case of ODMRP and 66% for MAODV algorithm.

Table 1: Simulation Parameters

Parameter	*Value*
Simulator	NS-3
Number of Nodes	100
Simulation Range	200x200m
Simulation Time	50ms
Transmission Range	255m
Bandwidth	10mbps
Traffic Type	CBR
Data payload	1000 bytes

Fig. 5 shows the graphical representation of data between the varying number of nodes and the throughput. In case of the proposed DOMR algorithm, it is represented in blue color line, existing MAODV is in black color line and ODMRP is with red color. When the number of nodes increases from 0 to 100, the throughput was observed to be 80% in the case of DOMR based algorithm, while the same was observed to be 68% and 55% in the case of ODMRP and MAODV respectively.

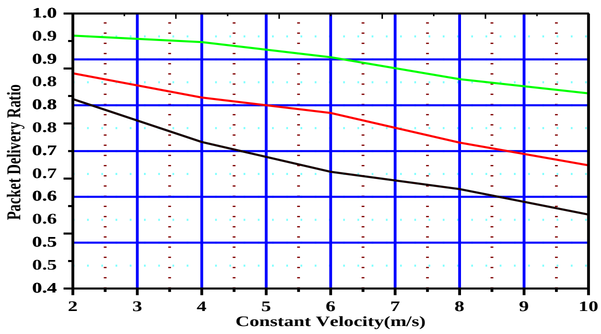

Figure 4: Number of Nodes Vs Packet Delivery Ratio

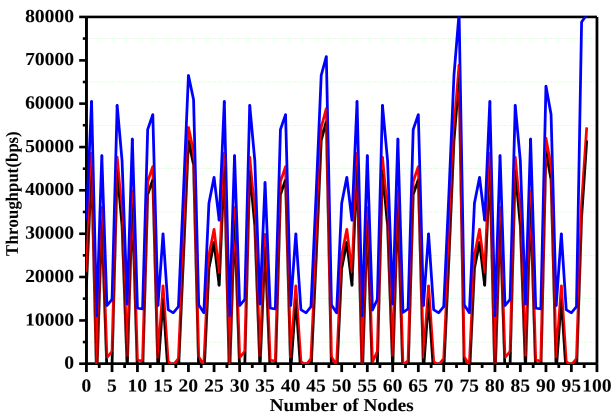

Figure 5: Number of Nodes Vs Throughput

Fig. 6 shows the graphical representation of data between the varying number of nodes and the goodput. In case of the proposed DOMR algorithm it is represented in blue color line, the existing MAODV is in black color line and ODMRP is with red color line. When the number of nodes increases from 0 to 100, the goodput was observed to be 85% in the case of DOMR based algorithm, while the same was observed to be 75% and 54% in the case of ODMRP and MAODV respectively.

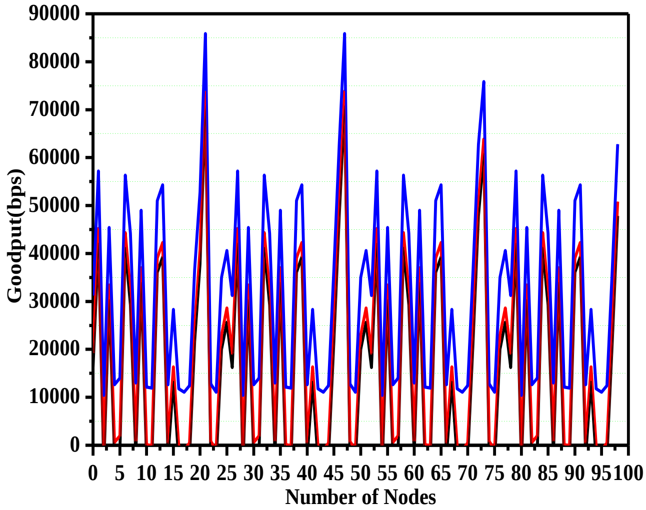

Figure 6: Number of Nodes Vs Goodput

Fig. 7 shows the graphical representation of data between the varying number of nodes and the control overhead. In case of proposed DOMR algorithm it is represented in green color line, the existing MAODV is in black color line and ODMRP is with the red color line mentioned in the graph. When the number of nodes increases from 0 to 100, the control overhead is reduced and was observed to be 65% in the case of DOMR algorithm, while the same was observed to be 80% and 85% in the case of ODMRP and MAODV respectively.

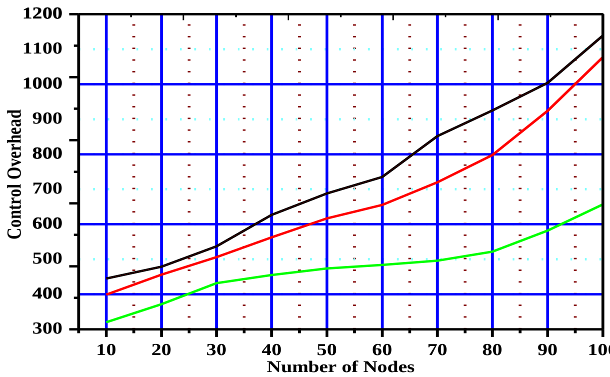

Figure 7: Number of Nodes Vs Control Overheads

V. CONCLUSIONS

Designed optimized multicast routing algorithm is used to improve the network lifetime, throughput, goodput, and to reduce the end to end delay along with control overhead. The present algorithm focused on mesh based multicasting routing techniques and are used to enhance the routing performances, lower energy consumption, efficient bandwidth utilization, minimize control overheads, and minimize routing cost with the help of DOMRA. The simulation result shows that the proposed DOMRA can considerably improve the performances over the existing MAODV and ODMRP.

The PDR was observed to be 89% for DOMR algorithm than compared with existing ODMRP which is 77% and for MAODV it is 66%. Throughput was observed to be 80% for DOMR algorithm when compared with existing ODMRP which is 68% and for MAODV it is 55%. Goodput was observed to be 85% for DOMR based algorithm, than compared with existing ODMRP which is 75% and for MAODV it is 54%. Control overhead is reduced and was observed to be 65% for DOMR algorithm compared with existing ODMRP which is to be 80% and for MAODV it is 85%.

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