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ROUTING IN WIRELESS MESH NETWORK USING RIVER FORMATION DYNAMICS

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ABSTRACT

Due to dynamic network behaviour, routing is a critically imperative part in Wireless Mesh Networks (WMNs). The routing approaches expanded for WMNs must be capable to make it an operationally self-configurable, self-organized system. We need to resort to nearby shortest path evaluation within a given time. Thus, require a few soft computing approaches which can place "best for sure" solutions with "good enough" solution. This work initially proposes formulation of a hybrid performance metric which contains per flow as well as per node parameters. This hybrid performance metric specifies the Integrated Link Cost (ILC). The paper further proposes River Formation Dynamics (RFD) algorithm based routing in hybrid WMNs. The proposed routing approach aims at finding the minimum ILC path. The result of the proposed approach has been matched with the three present techniques i.e. AODV, DSR and DSDV.

Keywords: Integrated link cost, Nature inspired computing, NS2 Simulator, River formation Dynamics, Wireless Mesh Network

I INTRODUCTION

Recently, Wireless Mesh Network technology (WMN) has become well-liked, particularly for its small cost consumption in the regions of bad network communications and terrain of tricky operation. WMN achieved a major consideration because of its several applications e.g., broadband home networking, neighbourhood networks, enterprise networking and building automation, etc. WMN architecture consists of wireless mesh routers and wireless mesh clients [1]. Mesh routers are fixed. On the other hand, mesh client can connect to network over both mesh routers and clients. WMN architecture can be categorized into three types: (1) Infrastructure/Backbone WMNs (2) Client WMNs (3) Hybrid WMNs. In infrastructure backbone WMNs: Wireless Routers together provide a wireless backbone infrastructure where wireless client node is passive device. In Client WMNs: client WMNs offers peer-to-peer networks and mesh clients perform routing and self-configuration functions. Hybrid WMNs: hybrid WMN is the mixture of infrastructure and client WMNs.

A detailed outline of WMNs is talking about the challenges and open research problems of each layer, security, mobility management [2]. WMNs are extremely dynamic networks. These irregular dynamic network situations critically affect the performance of WMNs. It is compulsory that routing strategy must effort in a self-organizing and self-configuring way, while optimizing network resource consumption and satisfying QoS conditions [3, 4]. The purpose of routing strategy is to maximize probability of data delivery, minimize delay, maximize throughput, and minimize energy consumption. It was shown by Decouto et al. [5]. In WMNs performance metrics and routing problems are examined in detail by Waharte et al. [6]. In WMN, performance parameters can be classified as per flow (packet loss ratio, throughput, delay, jitter, hop count and interference); per node (computation complication and power efficiency) and network broad parameters (QoS, total throughput etc.). The routing policies based on heuristics often converge to suboptimal routing solution in highly dynamic WMNs. various soft computing methods especially nature inspired swarm intelligence (SI) centred evolutionary algorithms are designed and implemented for various optimization problems.

A detailed explanation of a variety of nature inspired meta-heuristic techniques including Monkey search [7] flower pollination [8], firefly algorithm [9] black hole [10], big-bang big–crunch [11,12], dolphin echolocation [13], lion optimization algorithm [14], cuckoo search [15], river formation dynamics [16] and particle swarm optimization [17] are presented by research fraternity.

We consider River Formation Dynamics (RFD) optimization algorithm to calculate the optimal path under a specified time limitation. We initially form a mesh network of every node with a given radio range and generate routing metrics at each node for all the nodes within its radio range. We then at regular intervals renew and sustain this metric by comprising the new nodes incoming the radio range and removing those nodes which move away from the radio range of the node. After a network is recognized, all network nodes calculate the ILC for the adjacent nodes. This ILC decides the length of that path exists between a given source and destination node pair. On the given information by the ILC module for adjacent nodes, optimal paths/near shortest paths are specified [18]. The proposed technique is simulated in NS2 and its routing performance is compared with Adhoc On-demand Distance Vector (AODV) [19], Dynamic Source Routing (DSR) [20] and Destination Sequenced Distance Vector (DSDV) [21] routing algorithms.

This paper is organised into six sections. Section I represents the motivation for the present work as well as briefly describe of a few existing soft computing based nature inspired approaches is mentioned. Section II showcase the node architecture with cost evaluation module. Section III gives the description of the proposed RFD algorithm. Representation of system model with its parameters is incorporated in section IV. RFD is employed to evaluate the shortest path in the configured hybrid WMN in comparison with AODV, DSR and DSDV in section V. Section VI concludes the paper.

II NODE ARCHITECTURE

The proposed architecture of hybrid WMNs (where each node can also act as a router forwards the data packets to other nodes) is considered. The node architecture is shown in Fig. 1 where at each node there may be multiple inputs and multiple outputs. The Node Processing Unit (NPU) at a node makes the choice of selecting the most favourable link for corresponding communication within the restraints enforced by the network dynamics. NPU offers this link state information to Parameter Evaluation Module (PEM) to calculate various link parameters e.g. throughput, delay and residual energy of the node. Based upon this information Cost Evaluation Module (CEM) evaluates the ILC_i for the corresponding i^{th} link. The routing tables of all nodes are updated periodically.

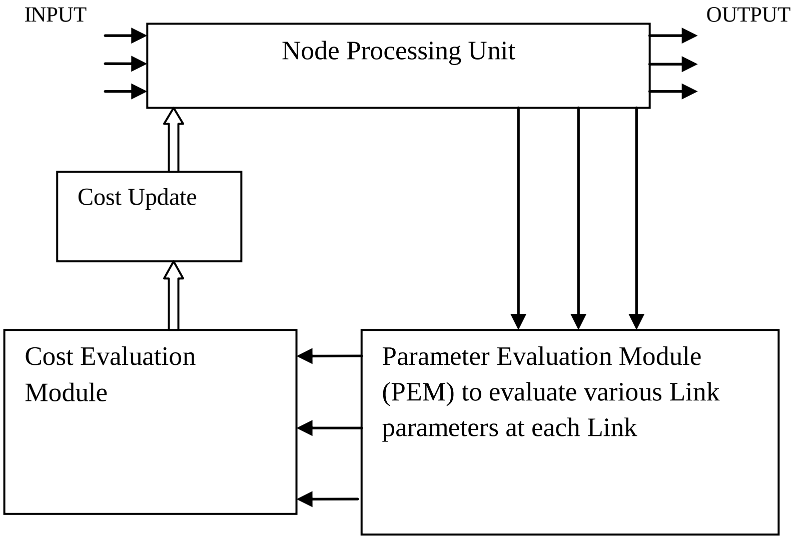

Fig. 1 Node Architecture

Figure 2 shows the integrated cost function measure. It consists of many parameters of the network like Throughput, end-to-end delay, number of hopes and residual energy. The cost evaluation module converge all the parameters in a single ILC.

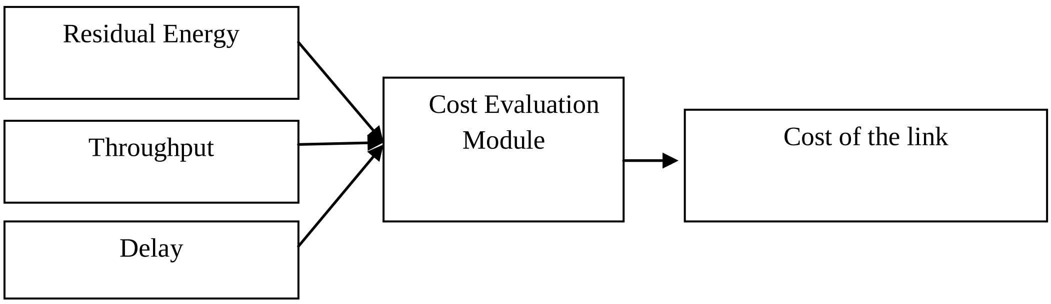

Fig.2. Cost function generated using Cost Evaluation Module

III RIVER FORMATION DYNAMICS (RFD) ALGORITHM

In the river formation dynamics (RFD), let us assume that mass of water is set free at top. When it showers in a peak, water makes an effort to discover its own way downwards to the ocean (sea) and water erodes the floor and converts the landscape, which finally creates a channel that occupied by a river called riverbed. When a powerful downwards slope is traversed by the water, it removes soil from the land in the manner. This mud is placed in a while when the slope is lesser. Rivers change the surroundings by decreasing or increasing the altitude of the land. If water is set free at every point of the location then the river optimize the mission of gathering water and take it to the sea [22]. Let us observe that there are a set of origin points. In fact, a type of joined grouped smallest and nearest path is generated. On the other hand, if water runs from a solo point and no other water source is measured, then the water path tends to offer the most capable way to decrease the altitude.

This phenomenon is known as RFD (River Formation Dynamics) [22]. The fundamental structure of this method works as follows. In the place of combined pheromone standards to edges, we combine altitude standards to nodes. Drops erode the floor or deposit the sediment and increase the altitude as they travel. The chances of the drop to obtain a specified edge in the position of others is proportional to the gradient of the downwards slope in the edge, which depends on the difference of altitudes between both nodes and the distance. At the starting, a plane and smooth atmosphere is provided i.e., every node has the similar altitude. The exemption is the destination called terminal node i.e. is a hole. Drops are set free at the source node, which spread in the region of the plane and smooth atmosphere until a amount of them fall in the destination node. This erodes neighbourhood nodes, which generates new downwards slopes, and in this way the erosion procedure is transmitted. New drops are placed in the source node to convert paths and strengthen the erosion of capable paths. After a few steps, good quality paths from the source to the destination are established.

River Formation Dynamics Pseudo Code:

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begin

/Initialization of WMN parameters/

Define Source Node, Destination node, Number of Nodes, location of nodes, Number of paths

while (true/ Termination criteria not met)

for *u* = 1 : *n* /for all n nodes/

for *v* = 1 : *n* /for all n nodes/

if *distance (i, j) < =Radio range of node*

connectivity matrix(i, j)=1

Integrated_link cost (i, j) =f (Throughput, Delay, Residual Energy)

end *if*

end for *j*

end for i

/Build path between source and destination/

move_Drops (i, j)

analyze_Paths (i, j)

erode_Path (i, j)

placed_Segments (i, j)

end while

Postprocess results and visualization

Fig.3. Pseudo Code of the RFD based routing algorithm

At the beginning, drops are initialized (initialize Drops (i, j)), that is, every drop is placed in the first node position. After that, every node of the graph are initialized (Initialize Nodes (i, j)) which basically consists of two functions. The altitude of the destination or terminal node is set to 0. In expressions of the RFD, this node is known as sea, i.e., the last ambition of every drop and the altitude of the remaining nodes is placed to several identical values. The while loop for this algorithm is carried out until either every drop find the similar respond (Every Drop Follows the Similar Path (i, j)), i.e., every drop passes through the identical series of nodes, or one more another optional ending condition is satisfied (other Ending Condition (i, j)) [22]. The initial action of the loop body consists in travelling the drops across the nodes (move Drops (i, j)) in a random mode. The following transition law describes the probability that a drop k at a node i choose the node j to move after that:

$$P_k(i,j) = \begin{cases} \dfrac{gradient\ (i,j)}{sum.(d_j)^{\alpha}} & for\ j \in V_k(i) \\ \dfrac{\omega}{/gradient(i,j)/ \, sum.(d_j)^{\alpha}} & for\ j \in U_k(i) \\ \dfrac{\delta}{sum\ (d_j)^{\alpha}} & for\ j \in F_k(i) \end{cases} \quad (1)$$

Here $V_k(i)$ is the group of neighbours with a positive gradient (node i has a superior altitude than j), $U_k(i)$ is the group of neighbours with a negative gradient (j has superior altitude than i) and $F_k(i)$ represents neighbours of smooth gradient (has same altitude as i). Gradient is defined as the difference of altitudes between successive nodes, and the coefficients ω and δ are particular fixed tiny standards. In this case the sum of the weights of every neighbour from dissimilar sets. Coefficient dj shows the length from node j to the goal and α represents a convergence tuning coefficient. [23]:

$$decreasing\ Gradient(i,j) = \frac{altitude(i) - altitude(j)}{distance(i,j)} \quad (2)$$

We judge that the possibility that a drop moves through an edge and with zero gradients is set to some standard. This permits drops to spread around a smooth atmosphere that is compulsory at the beginning of the algorithm. After that (erode Paths (i, j)) paths are eroded according to the actions of drops in the earlier phase.

$$Erosion\ (i,j) = \begin{cases} \dfrac{\varepsilon_V \ .gradient(i,j)}{(N-1).M.pathLength_k} & for\ j \in V_k \\ \dfrac{\varepsilon_U}{/gradient\ (i,j).(N-1).M.PathLength_k}, & for\ j \in U_k \\ \dfrac{\varepsilon_F}{(N-1).M.PathLength} & for\ j \in F_k \end{cases} \quad (3)$$

Where ε_V , ε_U and ε_F are factors associated to the particular class of neighbours: with positive, negative and plane gradient. Path $Length_k$ stands for the length of the path crossed by the drop. N and M specifies number of nodes and number of drops. When erosion procedure stops, the altitude of every node is little bit increased (deposit Sediments (i, j)). Finally, the last step (analyze Paths (i, j)) discovers all solutions (paths) set up by drops and stores the best distance (path) originate so far [23].

IV SYSTEM MODEL

In order to examine and optimize the performance of routing algorithm of hybrid WMNs, simulations were performed for various scenarios in NS2 v 2.35. 10, 20, 50, 100 and 200 node hybrid WMNs are considered. These networks are placed within a 500m x 500m, 1000m x1000m and 2000m x 2000m area. We varied transmission range of the nodes from 200 meters to 500 meters. The RFD algorithm was implemented in

Network Simulator (NS2). Numerical results were computed and compared with existing techniques i.e. AODV, DSR and DSDV. Fig.4. shows the graphical representation through the Network Animator Module (NAM). During the animation created by NAM we can observe the layout of the network.

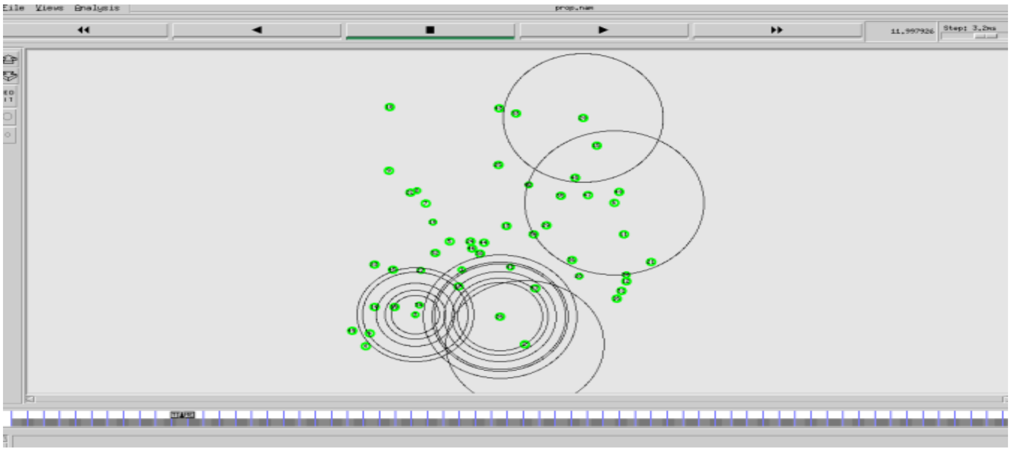

Fig.4 Graphical representation of Network Topology for 50 nodes

The simulation parameters used to configure the system according to WMN are listed in Table 1:

TABLE.1 System Properties

PARAMETERS	VALUES
Channel Type	Wireless Channel
phyType	Phy/WirelessPhy
Interface queue type	Queue/Drop Tail/PriQueue
Mac Type	Mac/802_11
Link Layer type	LL
Antenna Model	Omni directional
Time of simulation	70 s
Routing Protocol	Dynamic Routing
MIMO	5 I/P & 5 O/P
Radio Propagation	200m - 500m

Here we considered 10, 20, 50, 100 and 200 nodes for hybrid WMNs. We varied transmission range of nodes from 200 meters - 500 meters. In all the network models node number 0 act as source and terminal node is 1. The node density (no. of nodes) was varied in the range of [10,200]. Speed was also varied in the range of [20,100]. The architecture details of hybrid WMNs are tabulated in Table 2. 2, 4, 8, 16 and 32 fixed wireless mesh routers are placed to maximize the optimal network connectivity for 10, 20, 50, 100 and 200 nodes WMN respectively.

TABLE.2. Architecture details of WMNs

No. of Nodes	Area (m X m)	No. of Routers
10	500 x 500	2
20	500 x 500	4
50	1000 x 1000	8
100	2000 x 2000	16
200	2000 x 2000	32

Based on parameters like throughput, delay and energy, the RFD algorithm is applied and compared with the results of AODV, DSR and DSDV.

V RESULTS AND DISCUSSION

Table 3 and 4 shows the analysis of results of RFD algorithm for varying number of nodes. It is evident from the results that as more time is permitted by network, the optimal paths with less link costs are selected. The corresponding values of throughput, delay and energy with varying speed is tabulated in Table 5.

TABLE.3. Results of RFD algorithm

No. of nodes	Time(S)	Cost of path	Shortest path
10	0.1	11.4588	0-5-8-4-1
10	0.5	11.2614	0-8-5-3-1
20	0.1	12.8634	0-16-10-1

20	0.5	12.9331	0-3-5-1
50	0.1	14.4118	0-32-13-1
50	0.5	15.3379	0-27-44-1
100	0.1	10.6762	0-40-77-1
100	0.5	10.7514	0-81-35-37-1
200	0.1	19.9183	0-124-174-1
200	0.5	20.7388	0-147-88-178-1

TABLE.4 Throughput, delay, and Energy Analysis for varying nodes

Nodes	Throughput	Delay	Residual Energy
	RFD		
10	0.89	5.78	75.9228
20	0.93	5.87	68.7553
50	1.03	27.82	46.2218
100	0.96	40.12	32.2242
200	1.03	46.12	28.0978
	AODV		
10	0.83	5.90	62.5520
20	0.91	12.11	55.5148
50	0.97	23.26	46.1759
100	0.82	32.49	32.3112
200	0.97	78.55	22.1781
	DSR		
10	0.82	13.66	48.1117
20	0.86	10.91	48.7267
50	0.93	33.47	37.3112
100	0.67	48.45	28.6769
200	0.89	66.33	16.5508
	DSDV		
10	0.84	5.75	52.5632
20	0.79	5.72	48.1538
50	0.62	29.20	34.2218

100	0.75	40.00	28.2242
200	0.81	59.03	14.0978

TABLE.5 Throughput, delay, and Energy Analysis for varying speed

Speed	Throughput	Delay	Residual Energy
	RFD		
20	1.9	5.40	81.9535
30	1.1	5.68	72.1278
40	0.7	27.15	44.2068
50	0.5	41.15	38.8695
60	0.2	48.10	35.1961
	AODV		
20	1.6	5.30	72.0216
30	1.4	13.00	68.7110
40	0.9	24.23	52.1089
50	0.7	35.17	41.9403
60	0.5	78.10	32.0678
	DSR		
20	1.7	13.42	70.6515
30	1.3	22.15	57.2189
40	0.8	33.20	47.3027
50	0.7	48.07	43.8496
60	0.6	68.07	30.479
	DSDV		
20	1.8	5.76	65.5329
30	1.0	6.67	54.6221
40	0.8	30.00	47.6268
50	0.7	43.45	38.6127
60	0.4	59.00	25.6790

The analysis between Throughput and number of nodes is shown in Fig.4. As the number of nodes increases from 10 to 200 the throughput increases, delay and residual energy decreases as nodes has to maintain its routing table with increasing number of neighbourhood nodes. Fig. 5 shows the analysis between Throughput and speed of nodes. As the speed increases the throughput decreases. Fig.6 shows the variation of Delay with Number of nodes. With 10, 20, 50, 100 and 200 nodes the delay increases as the number of nodes increases. Delay v/s speed of nodes and energy v/s number of nodes are shown in Fig.7 and Fig.8 respectively. As the speed increases the delay also increases accordingly. Figure9. depicts the change in Energy with speed of nodes. As the speed increases the nodes have to utilize more energy for addition and deletion of new nodes in their neighbourhood matrix.

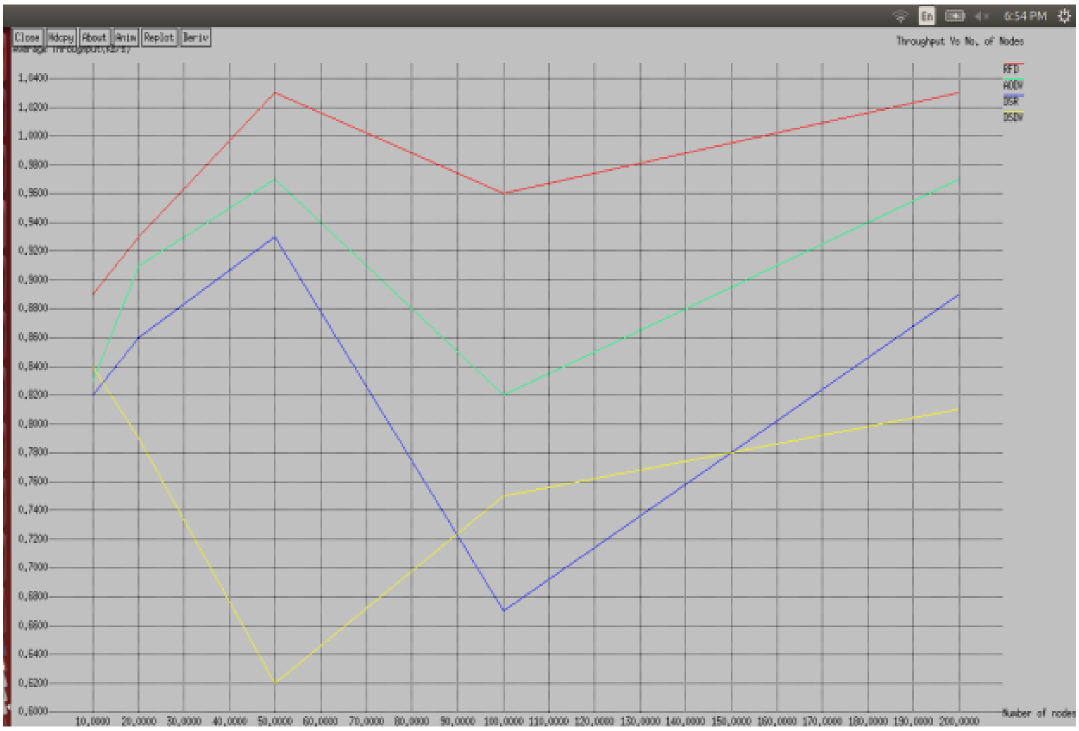

Fig 4. Throughput vs. Number of nodes

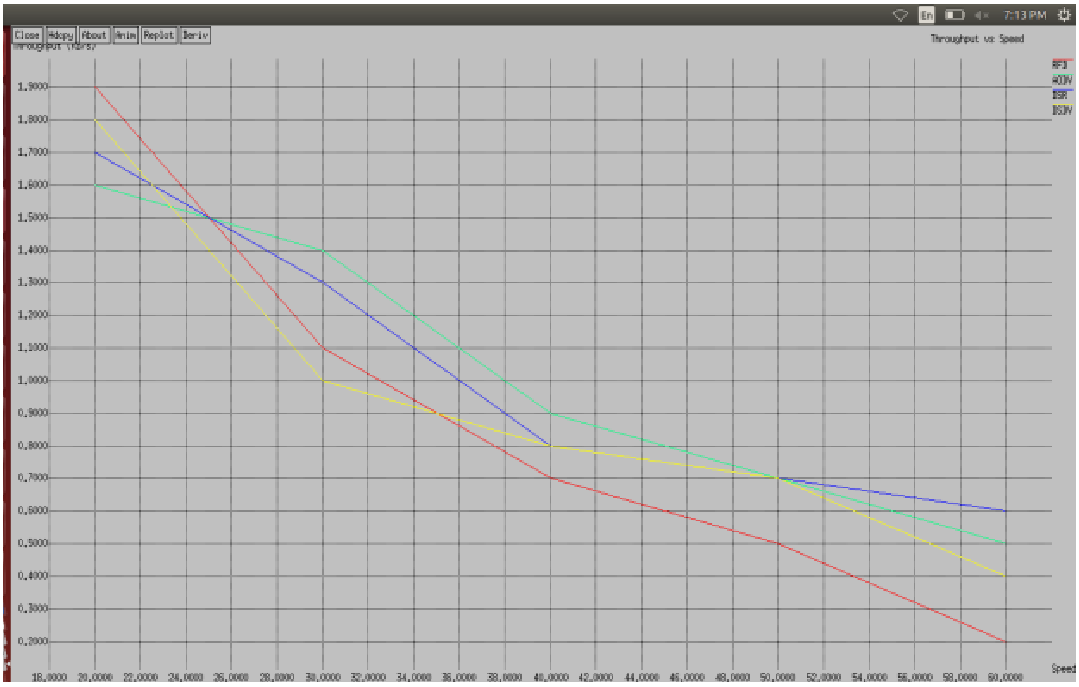

Fig.5. Throughput vs. Speed

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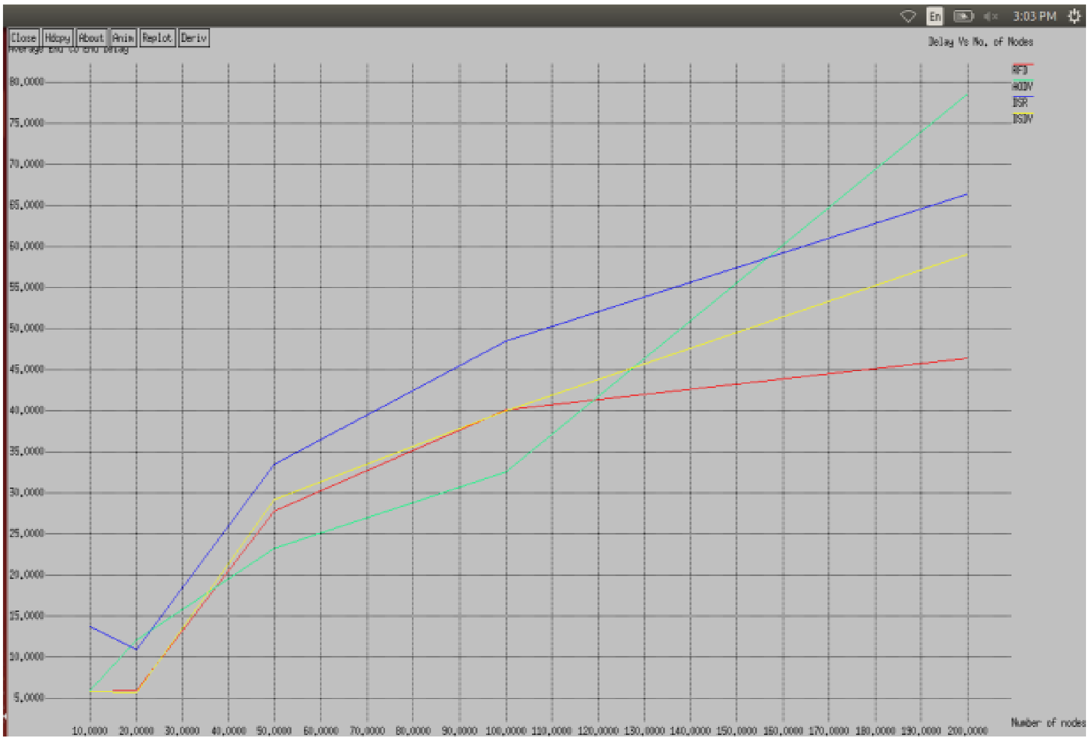

Fig 6. End to End Delay vs. Number of nodes

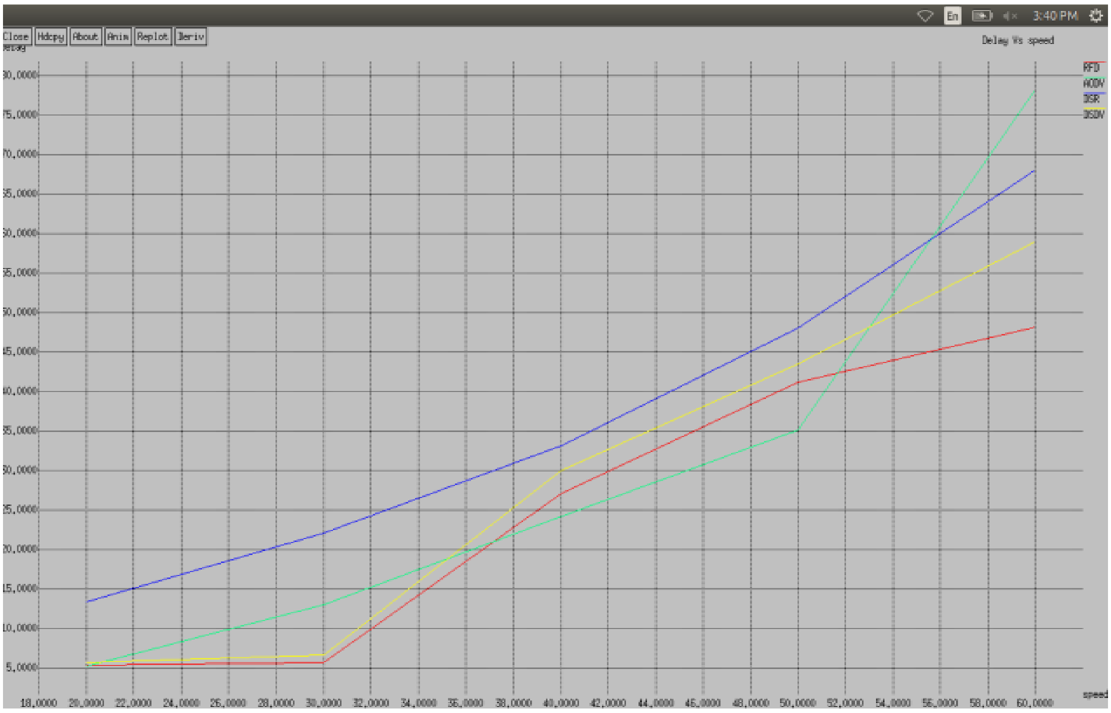

Fig.7. Delay vs. Speed

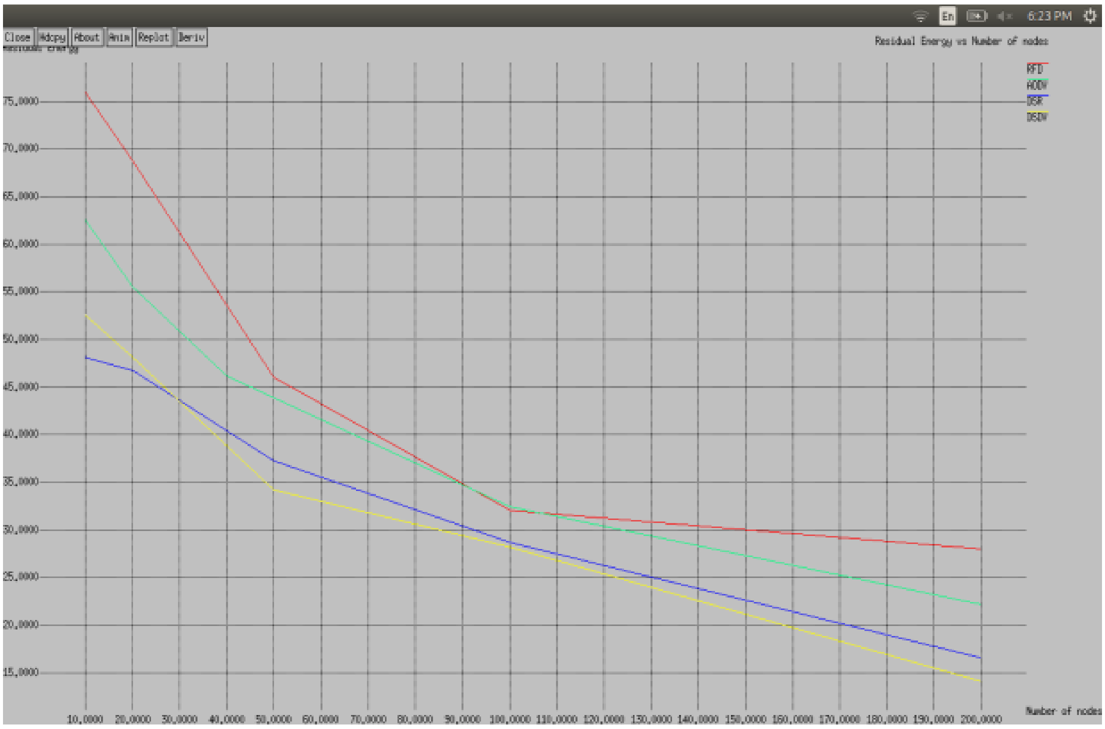

Fig.8 Energy vs. Number of nodes

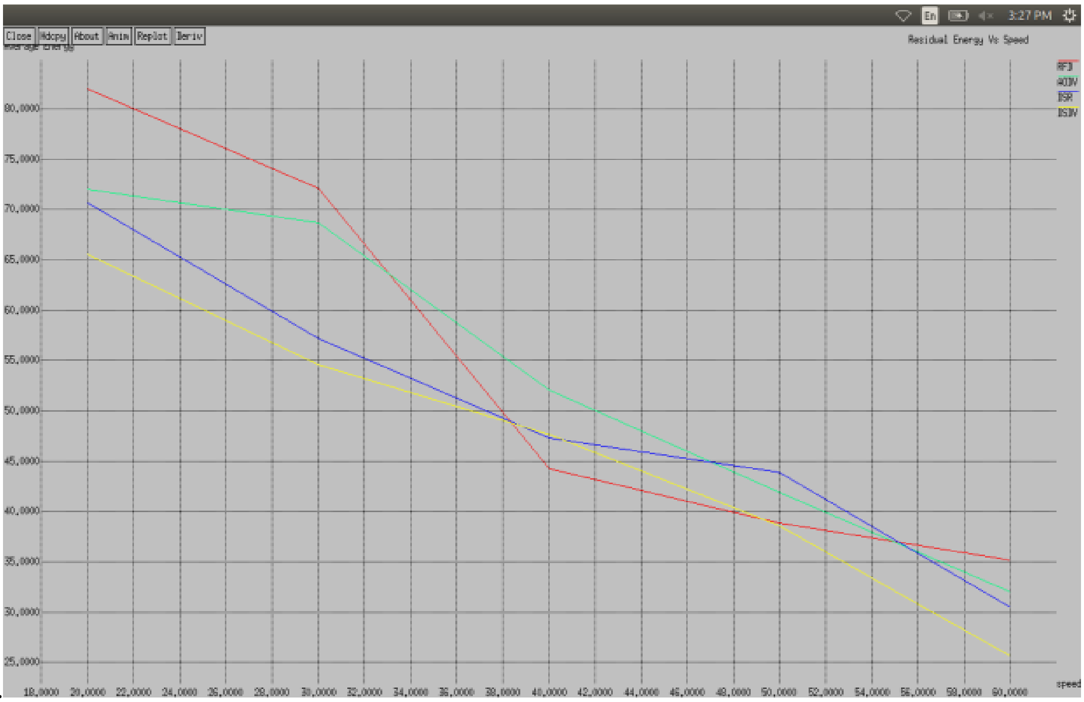

Fig 9. Energy vs. Speed

VI CONCLUSION

This paper simulates and analyses dissimilar topological WMN node structures on NS2 atmosphere, comparing the performance of RFD, AODV, DSR and DSDV. The judgment is made based on the performance metrics – average energy, average end to end delay, and throughput. It is observed that RFD performed better than AODV, DSR and DSDV in most of the test cases as depicted by results. Further, result showed that the metric like end-to-end delay and throughput showed better performance in RFD than the others. Scalability of RFD in comparison with traditional routing algorithm AODV, DSDV and DSR is verified by simulation results. RFD performs better in terms of throughput/packet delivery ratio at high rates, at huge number of nodes and with high mobility. The results indicated that RFD can be a potential candidate for large number of nodes, high data rate WMNs with high mobility.

Future improvements with respect to RFD can be done to improve the protocol by well tuning the control packet overhead to make it suitable for IoT (Internet of Things). The other developments that can be made are with respect to execute a priority concept at the node where priority data packets could be sent initially followed by the rest of the packets. Moreover RFD algorithm can be further enlarged by comparing the other bio-inspired algorithm where learning approaches have been performed.

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