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Research Article

An Efficient Multi-path Routing Algorithm Based on Hybrid Firefly Algorithm for Wireless Mesh Networks

K. Kumaravel and A. Marimuthu
Department of CSE, Government Arts College (Autonomous), Coimbatore, India

Abstract: Wireless Mesh Network (WMN) uses the latest technology which helps in providing end users a high quality service referred to as the Internet's "last mile". Also considering WMN one of the most important technologies that are employed is multicast communication. Among the several issues routing which is significantly an important issue is addressed by every WMN technologies and this is done during the process of data transmission. The IEEE 802.11s Standard entails and sets procedures which need to be followed to facilitate interconnection and thus be able to devise an appropriate WMN. There has been introduction of several protocols by many authors which are mainly devised on the basis of machine learning and artificial intelligence. Multi-path routing may be considered as one such routing method which facilitates transmission of data over several paths, proving its capabilities as a useful strategy for achieving reliability in WMN. Though, multi-path routing in any manner cannot really guarantee deterministic transmission. As here there are multiple paths available for enabling data transmission from source to destination node. The algorithm that had been employed before in the studies conducted did not take in to consideration routing metrics which include energy aware metrics that are used for path selection during transferring of data. The following study proposes use of the hybrid multipath routing algorithm while taking in to consideration routing metrics which include energy, minimal loss for efficient path selection and transferring of data. Proposed algorithm here has two phases. In the first phase prim's algorithm has been proposed so that in networks route discovery may be possible. For the second one the Hybrid firefly algorithm which is based on harmony search has been employed for selection of the most suitable and best through proper analysis of metrics which include energy awareness and minimal loss for every path that has been discovered. Simulation results clearly shows that proposed algorithm performance is far better than other traditional algorithms in metrics such as packet delivery ratio, average end-to-end delay as well as routing overhead; additionally, it possesses high resilience in terms of capacity to cope with topological changes, which makes it absolutely appropriate and suitable for deployment in to industrial wireless mesh networks.

Keywords: Hybrid Firefly (HFA), industrial wireless mesh networks, multi-path routing, prims algorithm

INTRODUCTION

A Wireless Mesh Network formulation has been done by employing gateways, mesh routers and clients. Gateways and mesh routers may be considered as the ones that form the basic foundation of the network, wherein there is a reduced mobility (Geeta and Krishna, 2012). Mesh clients may be in the form of cell phones, laptops or various wireless devices. There is communication that takes place between Routers and the external network like in the case of internet; which is done by forwarding each one's traffic, this includes client traffic as well; in the direction of gateway nodes, that are directly connected and integrated with the wired infrastructure. A WMN in one wherein all the routers forward packets for other nodes (these include those that necessarily may not be within direct wireless transmission range of their destinations). Furthermore gateway functionalities facilitate integrating WMNs with other prevalent wireless networks like Wi-Fi, cellular networks, WiMax and host of other ones.

However in various other networks, WMN employed for certain routes makes it more prone to greater usage in comparison with others. But, as opposed to wired networks, there is limited spectrum in wireless networks, which makes it almost impossible and tough to exceed link dimension. Hence, techniques enabling complete advantage from possible routes are significantly important with respect to such scenarios. Another promising approach that has been relatively popular in such scenarios is Multipath routing which helps achieve such results. Determining several paths between any given source and respective destination, enables load balancing between several routes and additionally also increases available bandwidth for applications.

Primary aim in wireless mesh network is use of multipath routing while determining various reliable

Corresponding Author: K. Kumaravel, Department of CSE, Government Arts College (Autonomous), Coimbatore, India

paths in order to reach specific destinations and simply not confining to determine one best path (Yigal *et al*., 2007), without having to impose additional control overhead whilst still maintaining such reliable paths.

Multipath routing algorithms as such have enabled to enhance WMN reliability by ensuring fault-tolerance caused on account of node failure. This has proven to be relatively useful for extending battery-constraint WSN lifetime which further increases data flow which is possible through load balancing of the utilized energy for each path's data flow (Zhiyuan and Ruchuan, 2009). Increasing WMN Flow transmission confidentiality may be statistically carried out through the process of splitting original encrypted information and thereafter transmitting the same along several paths determined between source and respective destination. Through this, supposedly if on any of path flows a malicious user possesses access to information, original message's probability of getting reconstituted is in general low.

Yet, over the last decade or so in spite of the popular usage of WMN as well the importance of the role multipath routing plays, results obtained on throughput bounds that are achieved by employing a wireless multipath routing algorithm still remains an area that required in depth study and evaluation (Qureshi *et al*., 2014). Primary aim and objective of this study is to find means to address the above mentioned area. There is an inherent issue raised on account of maximizing routing throughput in the following research work which exists in the arbitrary WMN taken in to consideration between the pair of nodes. The issue is resolved by first setting up a transmission constraints set that will assuredly generate collision-free reception. Then set up search pruning axioms that will be useful in considerably reducing computation cost of finding paths. Following that the greedy algorithm is employed for spatial reuse of the 'existing' time slots. This particularly chooses only other routing paths that increase total routing throughput. Experimental results generated indicate that given the pre-set routing path flows constraints finding throughput is possible that will improvise routing path provided if a path like that is present.

The algorithms for majority multipath routing that are part of wireless mesh network took the shortest path algorithms for example the dijkstra, kruskal and others. Shortest path algorithm is basically employed here to determine several paths for transmitting data.

The aforementioned issues have been resolved by employing the multipath route routing algorithm. Previous studies and researches conducted have used several multi-path routing algorithms that were suggested to resolve issues created on account of multipath route selection. A few of the multipath routing algorithms that had been developed before include split multi-path routing (Lee and Gerla, 2001), multi-path dynamic source routing (Nasipuri *et al*., 2001) and ad hoc on-demand multi-path distance vector (AOMDV) (Marina and Das, 2001) which are referred to as the shortest path algorithms. Resolving multipath route selection issues and other related concerns regarding WMN QoS or quality of service still pose certain challenges.

Primary objective of the routing algorithm that has been proposed here is mainly aimed at decreasing communication delay, energy consumption reduction and attaining very reliable communication with no elevated flooding whatsoever.

LITERATURE REVIEW

Le (2011) in his study for WMNs has proposed a multi-path routing design where in the main idea was to deploy the QoS-aware algorithm for computing multi-path which were responsible for taking in to consideration channel load as well as interference on wireless links. In their study both Bedi and Gupta (Bedi *et al*., 2011) has presented using a geographic multi-path routing protocol employing virtual coordinates enabling packet transmission. In the protocol, hop-count metric can determine the location as well as the congestion its immediate neighbors. Qu *et al*. (2010) in their study had proposed using a node-disjoint multi-path routing protocol. This was based AOMDV and additionally contributed by adding routing sequence number, which is quite similar to DSR source routing sequence. This particular innovative multi-path routing algorithm possesses less computational intricacy and routing overhead in comparison with AOMDV. Li (2011) in his study of multi-path routing has researched about cooperation problem prevalent mesh routers and hence proposed reputation-based system wherein multi-path routing can actually provide stimulation for each node which will impact the different paths and thus packet forwarding will be possible from others. Hu along with a couple of associates (Hu *et al*., 2010) who were studying routing and sustenance of forwarding paths suggested using a multi-path routing protocol MGMP which has multiple gateways supported. Results from simulation clearly outlined performance of MGMP being far better than HWMP, AODV and OLSR.

With respect WMNs (Rong *et al*., 2010), supporting video communications efficiently of prime importance. Hence in order to address this problem the following study evaluates and proposes various techniques and several descriptions for multipath routing for MD video delivery over IEEE 802.11 based WMN. Particularly, first designing of a framework that will enable transmitting MD video over WMNs through different is done; thereafter which the associated technical complexities and challenges that are encountered are evaluated. What has been discussed by the author here is that multipath routing depends on maximally disjoint paths to deliver a good traffic engineering performance. Generally video applications possess stringent delay requirements, make it tough to determine different qualified paths that have least joints. Addressing the issue, an improvised version of Guaranteed-Rate or GR packet scheduling algorithm has been developed, that is virtual reserved rate GR or VRR-GR, which in multiservice network environment shortens packet delay of video communications.

WMNs or wireless mesh networks (Zheng *et al*., 2012) have static and traffic is transferred using backup paths can likely be adverse as it impacts other flows as well as the multicast group, as back up paths raise transmissions and subsequently network interference and congestion. Evaluation of this impact though has not been done with respect to multicast routing. Author here presents simulation results actually quantifying impact when comparing data overhead between multicast multipath and single-path routing.

Author in this research has primarily focused on wireless mesh networks issues and utilizes inherent broadcast nature of wireless by employing of multipath routing (Radunovic *et al*., 2008). Also an optimization framework enabling scheduling, optimal flow control, rate adaptation schemes and routing has been proposed along with network coding that will address routing issues. Author here also achieves optimality and is able to formulate primal-dual algorithm which becomes the foundation of practical protocol. Author also used simulation to present realistic topologies achieving throughput improvement in comparison with single path routing and recent related opportunistic protocol (MORE).

Author for WMNs proposes quality based routing protocol which attempts maximizing probability of successful transmissions simultaneously it also minimizes the end-to-end delay (Amitangshu and Asis, 2011). Routing protocol employed in reactive route discoveries for collecting parameters from each candidate route estimates probability of both success and delay of transmitted data packets. For attaining accurate route quality assessments, what has been utilized is a new route quality metric which delivers a better data packet transmissions performance models in comparison with estimating route quality from control packets transmission which possess varying transmission characteristics. It is only after accurate and cautious evaluations that multi-hop wireless transmissions have been developed and further been validated by computer simulations.

Uncomplicated and efficient management WMN structure has been proposed by the author that may be referred to as configurable access network or CAN. As per the architecture the control and switching functions have been separated, such that control functions are executed by network operation center or NOC positioned in the wired infrastructure. NOC examines requirements of both network topology as well as user performance on the basis of which it determines the path between all wireless routers and gateways and further distributes fair bandwidth transferring associated traffic in the predefined route. Execution of functions like NOC helps in offloading network management overhead from wireless routers, further it helps in deploying simple/low-cost wireless routers. The main aim here has been to maximize network use through the process of balancing traffic load, at the same time generating fair service and quality of service or QoS thus guaranteeing users. As the issued here is NP-hard, what has proposed is approximation algorithms that assure quality of the estimated solutions as opposed to optimal solutions.

PROPOSED METHODOLOGY

Neighbor table here collects as well as stores neighboring node information through the early period of a network.

Neighbor table: This table is one which consists of a list of nodes wherein each node is capable to communicate with the other directly. Once the network's initial phase if over neighbor table of all the nodes are populated.

Graph table: Network graphs are deployed to route messages usually from source to destination nodes. However every node is not really aware of the entire route and knows only about the next hop destination legal for circulating the packet. Route with graph ID is on the basis of data transmission, along with graph ID as shown in the graph table. Routes fitness levels in any graph table are usually used to index for route selection (Fig. 1).

Minimum spanning tree formation using prim algorithm: An industrial wireless mesh network can be represented as a simple connected graph, $G = (V_G, E_G)$, where V_G and E_G denote the set vertices and the set of edges, respectively. In the previous work, the weight is considered as distance between the nodes. The distance between the nodes can be measured using the signal strength and it is mainly relies on Time-of-Arrival (TOA) measurement. The most basic localization system to use TOA techniques is GPS (Essays, 2013). If the speed of the signal and time between signals sent and received are known then distance can be calculated by formula:

$$distance = speed * time \tag{1}$$

The signal strength can be viewed as a good indicator for measuring link quality since a packet can be transferred successfully. Therefore the weight of the edge is referred as strength of the signal used between the nodes.

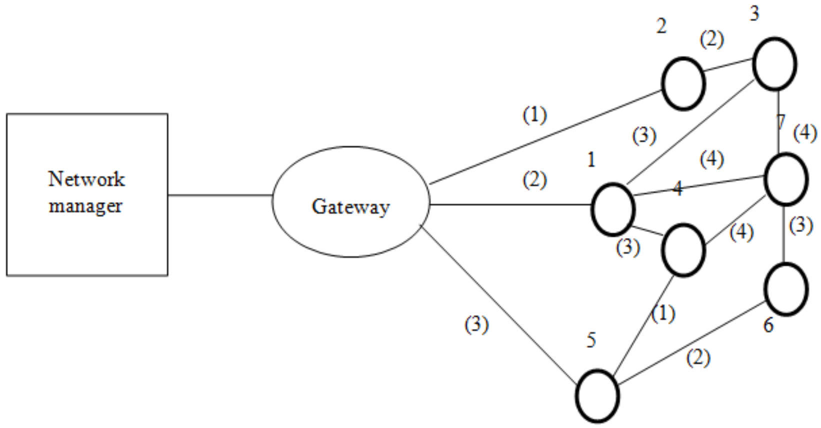

Fig. 1: Sample wireless mesh network

Though path selection is done on the basis of arrival time and signal strength, its efficiency is still a cause of concern. At time delay generally arises in the path on account of bandwidth as well as the intermediate node capacity. In order to address these inherent issues in previous work, the following research executes path selection on the basis of estimation of end to end bandwidth and then further it reflects as weight in the graph.

Bandwidth estimation: The gateway sends series of the packet with size S and length L to travel into each and every node present in the network. Once the neighboring node receives the series packets the time spacing between the arrival of first and last packet is calculated. The bandwidth between the two nodes is estimated as a:

$$b(L) = (L-1) \times \frac{S}{\Delta(L)} \qquad (2)$$

where, $b(L)$ is the bandwidth estimate, L is the length of the packet train, S is the size of each packet and $\Delta(L)$ is the difference in time between the first packet and the final packet of the train. The bandwidth is estimated for links between the nodes present in the network. In this research, the prim's algorithm is proposed to find the path between the nodes and gateway.

Prim is a greedy algorithm that solves the MST problem for a connected and weighted undirected graph. A minimum spanning tree is a set of edges that connect every vertex presented in the original graph, such that the total weight of the edges in the tree is minimized. The algorithm initiates at a random node of the graph and for each iteration evaluates all available edges from visited to non-visited nodes in order to choose the one with the lowest cost. The destination of the selected edge is then sum up to the visited nodes set and the edge added to the MST. The pseudo-code of the algorithm 1 is presented below:

Algorithm 1: Standard Prim's algorithm

Input: A non-empty related weighted graph G is a collection of vertexes V_G and edges E_G, possibly with null weights

Result: the minimal spanning tree in the *finalpath* array

Initialization: $V_T = \{r\}$, where r is a random starting node from V

```
while V_T ≠ V_G do
  minimum ← ∞
  For Visited nodes s ∈ V_T do
    For all edges E(s, v) and v ∉ V_T do
      If Weight(E) ≤ minimum then
        minimum ← Weight(E)
        edge ← E
        newVisited ← v
      End if
    End for
  End for
  finalPath ← finalPath ∪ {edge}
V_T ← V_T ∪ {newVisited}
```

Let G be a connected, weighted graph. In each iteration of Prim's algorithm, an edge is identified that links a vertex in a sub graph to a vertex outside the sub graph. Since G is connected, there will always be a path to every vertex. The series of packet is send to the neighboring nodes. First the distances between the nodes are calculated by Eq. (1) then the bandwidth is calculated using the Eq. (2). If both bandwidth and distance are satisfied means then the node is included in the path. The output G of Prim's algorithm is a tree, since the edge and vertex added to G are connected (Fig. 2). Let Y be a minimum spanning tree of G. V be the set of vertices associated by the edges added before e.

Similarly the maximum routes for each node are discovered using the prim's algorithm and from the discovered routes best routes are chosen for the data transmission. As the search process is accomplished,

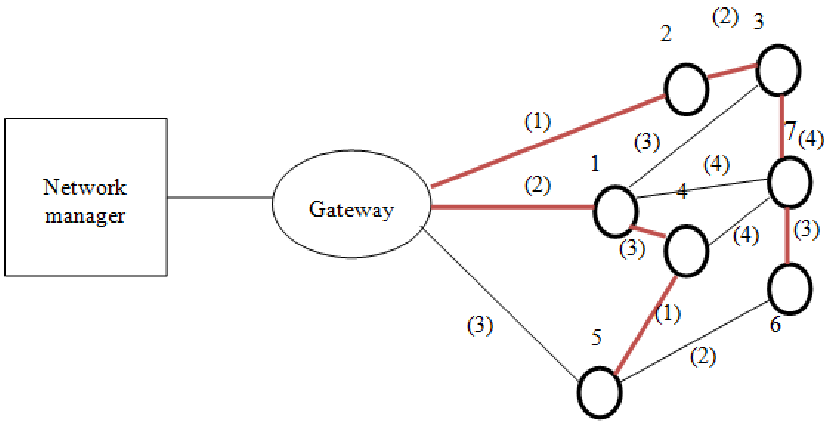

Fig. 2: Shortest path using Prim's algorithm in wireless mesh network

the network manager keeps the information data of the shortest routes for each node. Then, the network manager transfers the related routing information to the nodes to populate their relevant graph tables. From the information in the graph tables, the nodes can recognize the graph ID, the destination node and the next-hop node. This method is called target direction query. At this point, if a person asks for directions to a exacting place, then other person will provide him some directions; after that, at the next crossing, this person will ask another person for help. This process decreases the memory space of each node; therefore omit redundant multi-hop search process. Each node has one shortest route to the gateway for sending data packets. Once the routes are discovered the nodes.

Route exploration using hybrid firefly algorithm:
Proposed algorithm: In this research hybrid firefly algorithm using harmony search is proposed for selecting the best path for data transmission (Guo *et al*., 2013), initial populations are considered as a route discovered by prim's algorithm and named as a KEEP. The distance between the nodes is considered as r in the algorithm. The paths found in the first phase are considered as a firefly algorithm. The parameters such as energy, bandwidths are considered as parameters of the algorithm. The fitness value of the algorithm is considered as a residual energy. The light intensity is considered as a total energy cost for particular path or route from source to destination. The light intensity of the proposed system is directly proportional to the fitness of the algorithm $I(x) \propto f(x)$.based on the light intensity the path's are selected and given as input to the attractiveness.

Fitness value: The residual energy of a node by calculating the total energy consumed by a node whenever it is in one of the following states (Zogkou *et al*., 2013; Guo *et al*., 2013):

- **IDLE:** During this state the node is idle
- **CCA_BUSY:** During this state the node is busy
- **TX:** During this state the node only transmits packets
- **RX:** During this state the node only receives packets
- **SWITCHING:** During this state the nodes switches from one channel to another

For each node n_i the residual energy $R(n_i)$ is computed as:

$$R(n_i) = E_{current}(n_i) - E_{con}(n_i) \quad (3)$$

where, $E_{current}(n_i)$ and $E_{con}(n_i)$ denote the current energy of the node n_i and the energy consumed by the node n_i, respectively. On the verge, the current energy is set to the initial energy of the node. $R(n_i)$ is considered as a attractiveness of the path.

Since the consumed energy of each node n_i is influenced by the node is (i.e., IDLE, TX, RX, CCA BUSY, SWITCHING), the following equation is used to determine its consumed energy as:

$$E_{con}(n_i) = Current(n_i) * Voltage(n_i) * Duration \quad (4)$$

where, $Current(n_i)$ is the current in Ampere and it depends on the state in which the node n_i is, $Voltage(n_i)$ voltage is the supply voltage in Volts and $Duration$ is the interval that passed since the last energy update.

Light intensity calculation: For each node $n_i$an energy cost function $C(n_i)$ is assigned that is given by:

$$C(n_i) = \frac{E_{init}(n_i)}{R(n_i)} \quad (5)$$

Therefore, the total energy cost for a route p commencing source node n_S to destination node n_D, is given by:

$$E_p = \sum_{n_i \in p, n_i \neq n_D} C(n_i) \quad (6)$$

The selected route l will be the one that satisfies the following property:

$$E_l = min\{E_p : p \in V\} \quad (7)$$

where, V is the set of all the possible routes.

Attractiveness: The end-to-end Minimum Loss with Additive Cost (MLAC) metric from a path p:

$$MLAC = \prod_{uv \in p} \left(\frac{1}{ETX_{uv} + \lambda}\right) \quad (8)$$

where, the adjustable parameter λ is a non-negative constant. The unitary link weight is omitted as long as $\lambda > 0$. The constant λ is added to ETX symbolize a constant employed to avoid paths with a higher number of hops. ETX is defined as the expected number of transmissions/retransmissions in the network layer that is essential for packets to be effectively transmitted by a wireless link. The ETX metric is considered in a row in each intermediate node separately for each link that belongs to the path.

Harmony search parameters like HMCR for the path's total energy become its threshold value. Parameter rand is employed for best path selections provided there is inefficient light intensity. Rand parameter is taken as the random number generator from uniform distribution. This is then compared with HMCR in order to calculate distance; harmony search algorithm's pitch adjustment rate is employed for best output selection on the basis of path's bandwidth calculated by Eq. (1).

While considering discovered routes, selection of the best route is done on the basis of parameters which are calculated in the algorithm that has been proposed. Assuming that routes possess a fitness value, the algorithm then depending on attractive on the basis of energy and light intensity value from source to the respective destination determines best path. The network manager in the following study has for each node allocated top five routes on the basis of routes metrics values. Considering node for i five routes are absent, in that case for all discovered routes are selected. Every top five route is denoted by a graph ID, metric value and information regarding the next-hop node along this route. Data transmission route information storage takes place in graph tables of nodes along these routes.

In graph table, the route for each node present in the network is stored and unique graph ID is k assigned to each path. The path is selected for data transmission by calculating the probability of the path from gateway to each node present in the network. It is denoted as P_{ki} and the probability is calculated through the light intensity parameter and bandwidth of the related path. N_i^{ld} is the number of the graph IDs stored in the graph table of node i. The parameter β_2 controls the forwarding of data packet and is set at 5. Setting a high β_2 represents that the data are spread over the routes if several routes have similar behavior. On the other hand, if one path is obviously better than other paths, then the better path will always be preferred, while the data are spread out over multiple paths when β_2 is low:

$$P_i^k = \frac{(E_p)^{\beta_2}}{\sum_{k=1}^{N_i^{ld}} (E_p)^{\beta_2}} \quad (9)$$

The number of routes used for data transmission is defined earlier due to the fact that the quality of the routes varies with each node. Like this, data transmission can be dispersive for load balance. Then, selecting the five best routes and setting β_2 as five guarantees deterministic transmission and balances the link load in networks, thus transmitting the data through relatively better routes. As a result, these five routes can take on data transmission uniformly. The threshold values of cost function for energy and end to end minimum loss is considered here:

Begin
Step 1: Initialization. Set $t = 1$; define γ; set α, β_0 at $r = 0$; set HMCR; set the number of top fireflies KEEP.
Step 2: Evaluate the fitness value of the path
Step 3: Evaluate the light intensity I
Step 4: While $t < MaxGeneration$ do
Sort the fireflies by light intensity I
For $i = 1: KEEP\ (all\ Top\ fireflies)\ do$
For $j = 1: NP\ (all\ fireflies)\ do$
$If(I_j < I_i)$ then
Move firefly i towards j;
Calculate the probability of route;
else
For $E = 1: D\ (all\ elements) do$
If $(rand < HMCR)$ then
If $I < thr_l\ and\ P_i^E < thr_d$
$r_1 = \lceil NP * rand \rceil$
$x_\gamma(E) = x_{r1}(E)$
If $(rand > PAR)$
$x_i(E) = x_j(E) + bw(2 \times rand - 1)$
else
$x_\gamma(E) = x_{min,E} + rand \times (x_{max,E} - x_{min,E})$
End if
End for E
End if
Update attractiveness
Update light intensity
End for j
End for i

Evaluate the light intensity I
Sort the population by light intensity I
$t = t + 1$
Step 4: end while
End

Route maintenance for topological changes: There may be inherent changes in topology of the industrial fields which may be on account of either faulty nodes or imminent external environmental factors. Topological changes like those occurring in network topology like the node movement, joining of new nodes, or failure in nodes, can activate route maintenance. Hence in order to adjust to these networks the manager can generate matching processes on the basis of these varying topological changes.

Joining of new nodes: In case there is a node that intends to join the network, it needs to apply in order to do so as per the information from "Advertise" messages that other nodes to the network. Once that is a successful new nodes that have joined establish connections with others nodes provide distance between the nodes lies within range of communication. Several routes selection is done by the network manager for data transmission for node as per sampled routes attractiveness.

Nodes moving: With the existing nodes movement, notifications as "keep-alive" messages are relayed across to the neighbors of the node that is in movement. In the paper here network manger takes a decision regarding starting route exploration on the basis of certain definite conditions. Considering the node movement covers a short distance no change takes place in the hops between various nodes. Hence, route exploration commencement becomes redundant; as an alternative, routes fitness values are updated by the network manager depending on the moving node. This is because there is a change in the distance between node and its respective neighbors.

Node failure: When a neighboring node sends an "unconnected message" to the node, on receipt of the same or when there is no exchange from the neighbor node does regarding exceeding the "Time keep-alive interval," in that situation the node needs to inform the network manager by sending the command "Alarm graph route failed". Once received, the network manager passes on this information to other nodes regarding failure node route. This is done to facilitate other nodes to track this particular topological change. Link failure's route maintenance is relatively similar to the other two maintenance mechanisms that facilitate node movement. The paper here presents a scenario wherein only one route is available that enables transmitting of data transmission from an end node, for the node the network manager here has to restart route exploration.

EXPERIMENTAL RESULTS AND DISCUSSION

Proposed algorithm's performance is ascertained by carrying out model experimentation by employing the Ns2 simulator. Simulation is carried out selecting experimentation nodes in a random manner and those that are within the range 100, 200, 300 and 400 nodes in a square area with area distance end to end of 10 units. Data transmission communication is performed among two nodes based on their distance values which may be less than or equal to $\sqrt{2}$ units. Parameters below have been generally utilized for analyzing algorithm results in WMN:

- Here the End-to-end delay function is to measure delay time that is the time taken to send packets from source to destination in data transmission communication path.
- Packet delivery ratio refers to the packets that are received resultantly at the point of destination with no packet or failure loss, considering system packet delivered ratio is high then both security as well as efficiency are high.
- Overhead in number of packets refers to the association between number of packets which is monitored and checked throughout the process of data transmission communication as well total number of delivered packets at receiver side.

Three metrics that have been stated as above have been utilized for analyze method results so facilitate comparison.

The performances comparison results of the end to end delay between the methods such as PAWMNet, FKAWMNet and DAWMnet is illustrated in Fig. 3a, it shows that the proposed PAWMNet has less end-to-end delay than the other approaches FKAWMNet and DAWMnet

The packet delivery ratio of the proposed PAWMNet and existing FKAWMNet and DAWMnet results are illustrated in Fig. 3b. It shows that the proposed PAWMNet has high packet delivery ratio when compare to existing approaches FKAWMNet and DAWMnet.

The Overhead in number of packets of the proposed PAWMNet and existing FKAWMNet and DAWMnet rresults are illustrated in Fig. 3c. It shows that the proposed PAWMNet has less Overhead in number of packets when compare to existing approaches FKAWMNet and DAWMnet.

The graphical representation throughtput comparison of PAWMNet and existing FKAWMNet and DAWMnet results are illustrated in Fig. 3d. It shows that the proposed PAWMNet has maximum

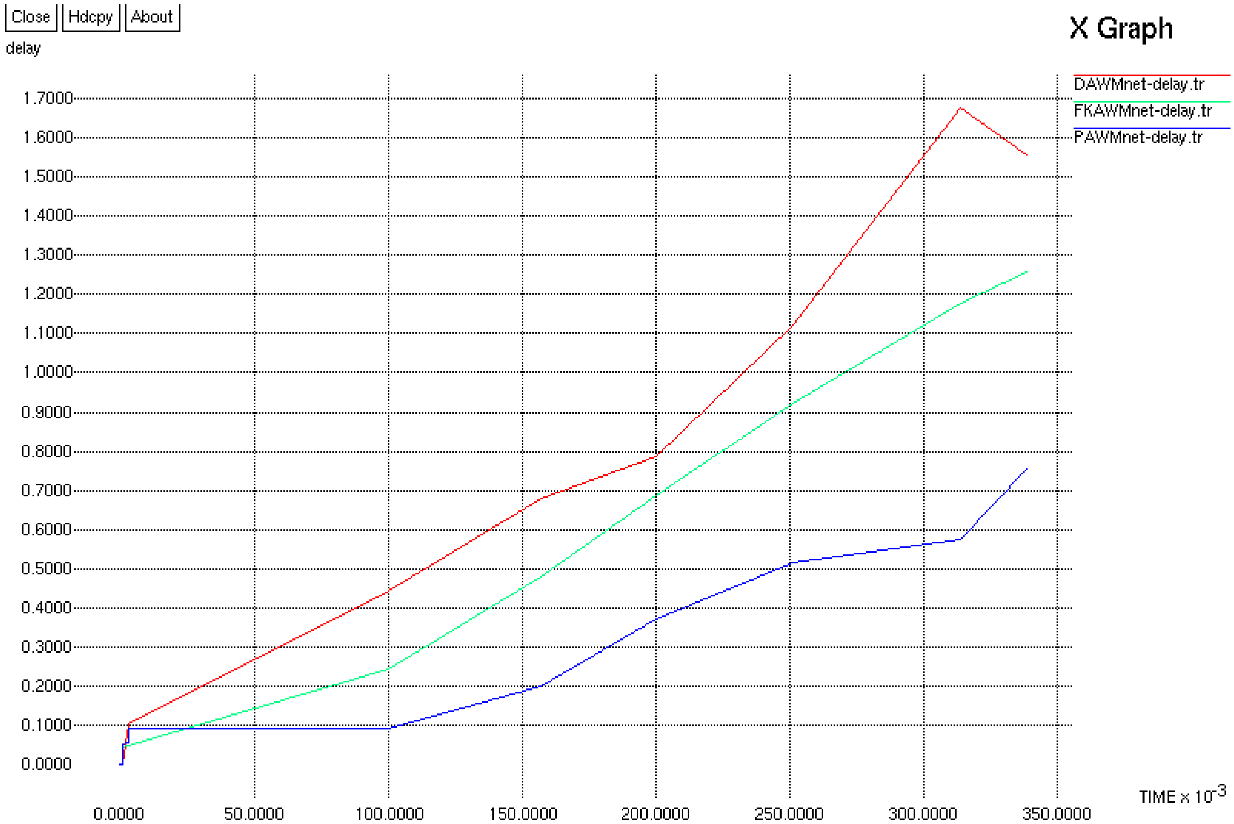

Fig. 3a: Average end to end delay

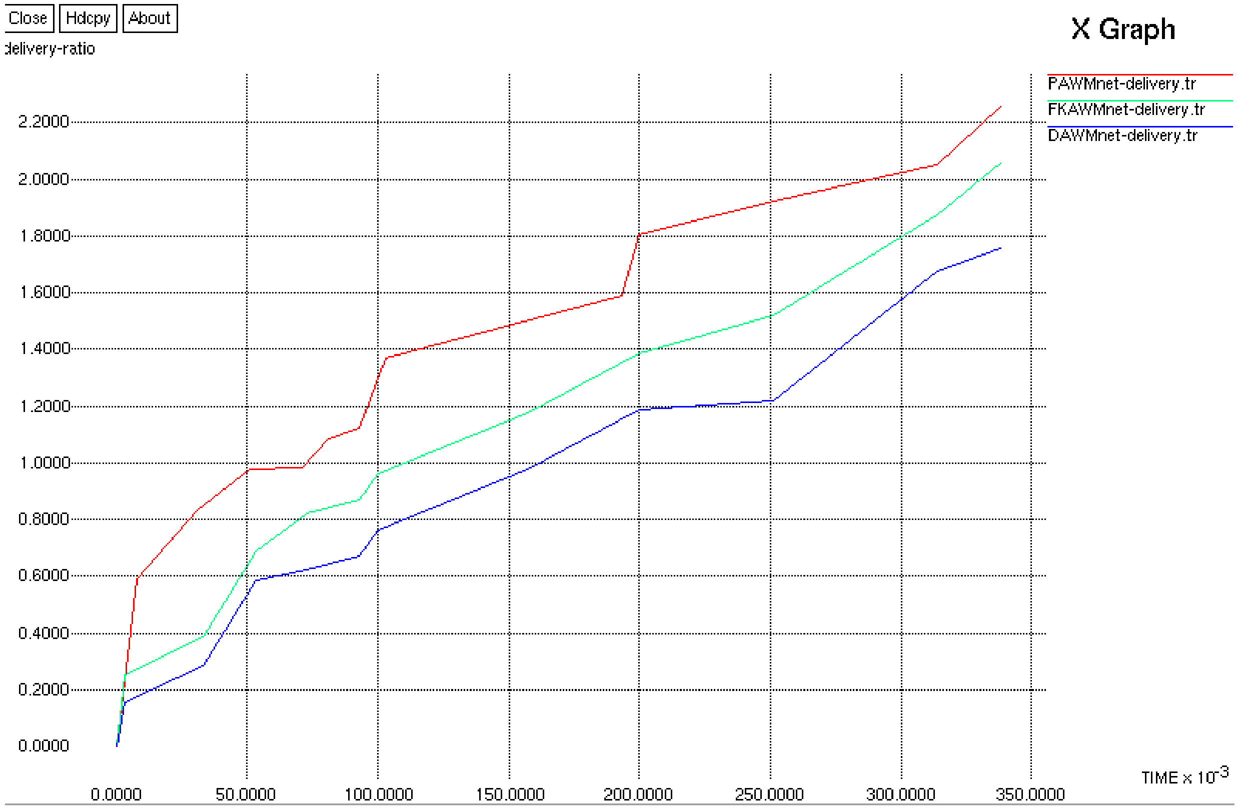

Fig. 3b: Packet delivery ratio

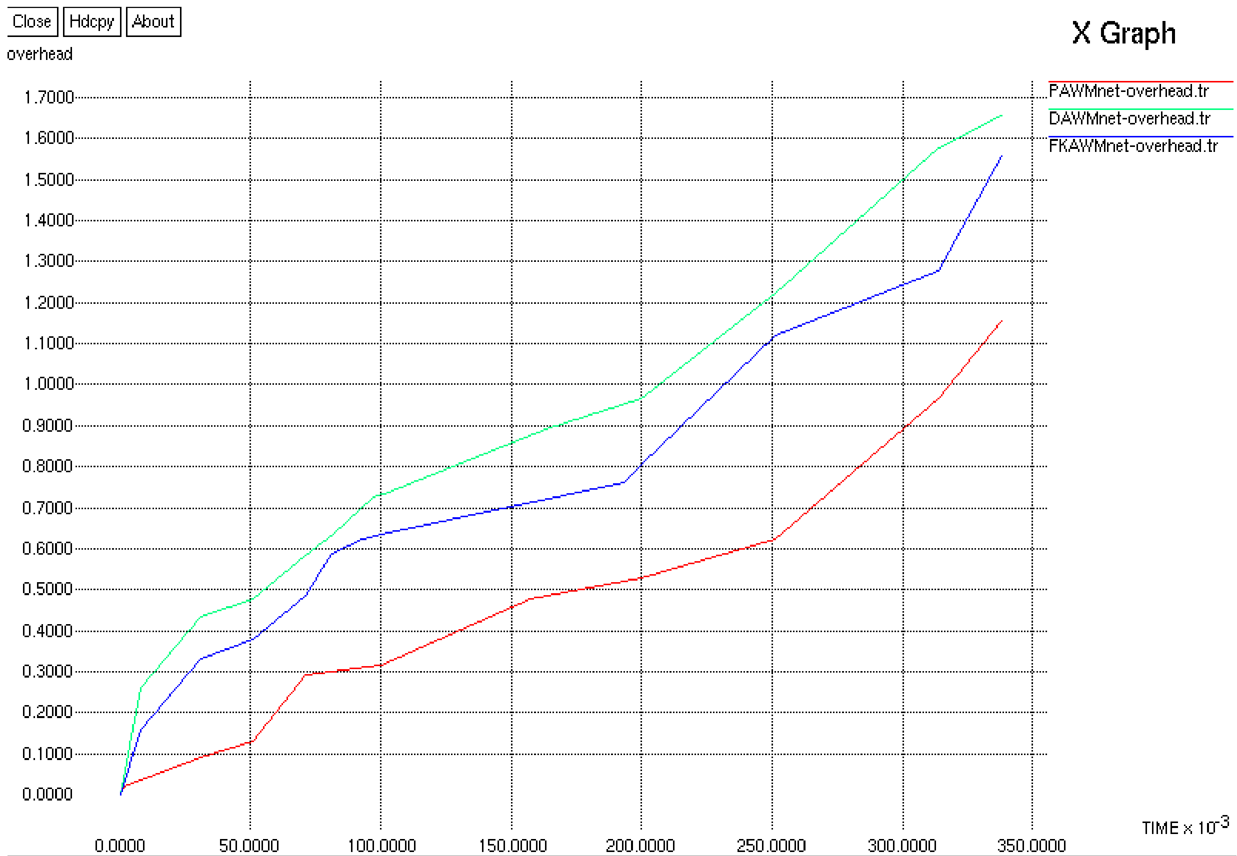

Fig. 3c: Overhead in number of packets

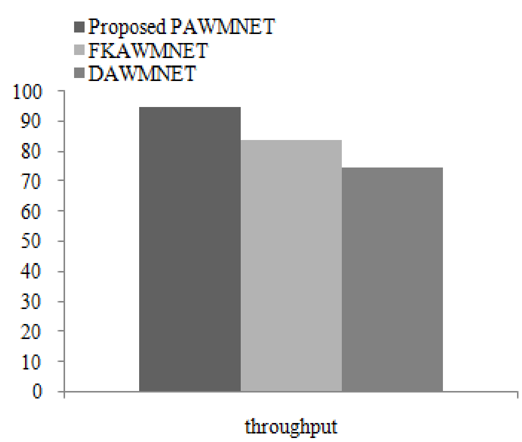

Fig. 3d: Comparison of throughput

throughput when compare to existing approaches FKAWMNet and DAWMnet.

CONCLUSION

The research paper here proposes hybrid multipath routing algorithm in lieu of WMN. WMN achieves a fair level of consistency through deployment of mesh connections existing between various nodes. Here WMN for the on-demand path discovery results less cost estimation is achieved over several WMN links through the evaluation process of energy aware metrics for ever single path. The proposed study executes two primary functions for multipath route routing on the basis of Prims algorithm and the second one is route exploration which is based on the Hybrid firefly algorithm is apt in maintaining the best maintenance which additionally is also developed. Enhanced

PAWMnet and HFA here attain a higher route setup results and further boost route examination results which is done by removal of those routes that are redundant. Here proposed algorithm additionally takes in to consideration minimum loss metric which enables efficient path selection from several paths and is also able to attain a higher rate of data transmission. Proposed PAWMNet simulation results clearly indicate that the performance executes and provides a lesser end to end delay and routing overhead and a higher packet delivery ratio in comparison with existing routing protocols like FKAWMNet and DAWMNet. Hence the PAWMNet proposed here attains immensely reliable communication, guarantees load balancing and application to topological changes with zero node failure is possible.

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