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Wireless Mesh Network Routing around Connectivity Holes with Triangulation based Path Planning

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Abstract

Objectives: Wireless Mesh Network is a promising technology in delivering the last mile broadband access. The smart routing technique has been defined during this paper for mesh networks with path selection along the connectivity hole avoidance using pushback mechanism. This paper also deploys a load balancing algorithm among the best paths available. The new design also incorporates the multi-channel triangulation method for the purpose of the optimal path selection among the multiple options. Energy aware routing mechanism is also deployed for evaluating the energy consumed during this network. **Methods:** The mesh network topology with 120 mesh network nodes deployed randomly over the given area of 100 x 100 meters in order to simulate the multiple networks zones. The network has been majorly divided into the three major zones in order to depict the mesh network zones, which are signified with the different colors in the given topology. The initial connectivity is entirely based upon the transmission radius of the nodes, which keeps the initial connectivity module in to the one-hop connections formation. **Findings:** The planned methodology compares with the existing routing scheme of Delaunay Triangulation. The performance parameters which compared with existing technique are average distance stretch and packet drop ratio. In this paper, other evaluation metrics are determined which are throughput, latency, number of aggregators and energy consumption. **Novelty of the Study:** The experimental observations have shown that planned routing mechanism outperforms to other existing scheme in terms of average distance stretch and packet drop ratio.

Keywords: Connectivity Hole Avoidance, Distance Stretch, Load Balanced Routing, Multipath Routing

1. Introduction

Wireless Mesh Network (WMN) is considered as self organizing as well as self configuring type of network. This network mainly consists of mesh routers, clients as well as gateways. WMN became as one of the main hot spots in the recent research due to its broad applications, low cost, network flexibility, easy to expand etc. Wireless Mesh Network routing algorithms should be based on the features of multi hop wireless networks to meet requirements[1]. Self configuring and self healing feature of WMNs reduce maintenance cost as well as setup time. It is also a multiple hop wireless network which have partial mesh architecture that could displace wired infrastructure in traditional wireless network, into wireless network. In WMN, every node do not only operate as host but conjointly operate as router as well. Wireless Mesh Network is suitable for impassable areas where building wired network offices or commercial areas are not possible, disaster recovery is also difficult etc. Specifically in the terms of cost, for setting up the network with cable and currently IEEE 802.11 WLAN routers, cost would be more than WMNs[2].

The main problem exists in the networking domain is the routing process of the data that travels from one vertex to another in the graph. The routing process becomes tougher as it must be local in a network. The routing process is called as local when routing procedure should select the further node (or called as vertex) for passing the message. This further node is chosen on the information regarding the sender vertex and receiving vertex, present vertex at which message stores and all nodes that are directly connected with the present node. A graph G is known as k-spanner when for any combination of vertices

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u and v in G, there exists a route in G from u to v with length not more thank|[uv]|. In various cases, the proof of existence of these routes basically contains the complete information about the graph. Hence a question is raised whether the routes are built using local knowledge of the graph. There is basically no answer to the above question. By not knowing the full information of graph, online routing algorithm cannot find a shortest path in general so the goal is to follow a route whose length is as minimum as possible. Online routing algorithm is called as c-competitive only if the cost evaluated by using the technique or any formula from the vertex s to vertex t is not more than c times the cost evaluated from shortest path which exists in the graph from vertex s to t. In case the total cost of path is at the most c|[st]|, wherever |[st]| is Euclidean length of the line segment [st]. Even so, there exist c-competitive online routing techniques for many of these categories of geometric graphs. The most important geometric graph is Delaunay triangulation (DT)[3]. DT is a geometric graph which contains an edge among the two vertices a and b only if a circle exists by considering a and b on its circumference which encompasses no other vertex of the graph. DTs are employed in scientific computing in several manifold applications. It is also a type of triangulation graph which does not contain any another node in the interior of the circum-circle associated with any of its triangular faces. These triangulations have been widely used as network topologies. If the circle made in Delaunay Triangulation is substituted with the equilateral triangle over the definition of Delaunay triangulation, then it is called as TD-Delaunay triangulation. If the circle is substituted with square then, it is called as L1-Delaunay triangulation. No Delaunay Triangulation exists between the group of points which draw on the same or concurrent line. In[3] presented an online routing algorithm over the Delaunay triangulation with competitive and routing ratios of 5.90. This algorithm improves upon the most effective algorithm which has competitive and routing ratio 15.48. The proposed algorithm is a generalization of deterministic 1 local routing algorithm on the *L*1-Delaunay triangulation. Once a message follows the routing path developed by proposed algorithm, its header wants only the coordinates of sender and transmitter. This is an improvement over the presently notable competitive routing algorithms over the Delaunay triangulation, to which the header of a message should in addition contain partial sums of distances along the routing path.

Load balancing is required to effectively use offered sources and maintain the energy consuming power of the node balanced by disseminating the load equally in the network. The main problem occurs when data is forwarded on the path which is congestion free, and also balances the total load exists on the network and reducing the end to end latency. Dividing or Stabilizing the load inside the network mainly possess two benefits: foremost, by dividing the network load, the resources in the network are completely exploited. An economical load balancing routing protocol is able to increase packet delivery rate and network throughput. Secondly, energy consumption balanced by distributed load equally, in order that the network lifetime might be prolonged[4].

In[5] reported a variety of new Memory less Online Routing algorithms that work for Delaunay triangulations, hence greatly enhancing the family of such algorithms. This paper also evaluated and compared these new MOR algorithms with three existing Memory less Online Routing algorithms. The experimental results have shown the performance with respect to both Euclidean and link metrics and additionally reveal certain properties of Delaunay triangulations. Also, this paper discussed three main problems with their significance explained in the paper. Memory less online routing algorithms are best suitable for the applications which uses only local information to discover paths in the network. In[6] presented an Adaptive load balancing algorithm with Rainbow mechanism over wireless sensor networks. This new protocol adds the cross layer integration of geographic routing to the contention based Medium Access Control to balance the load and selection of best route. And Rainbow mechanism is helpful in finding the route by avoiding connectivity holes. The both algorithms are helping to resolve the problem of routing among dead ends by not using the overhead intensive strategies like planarization and face routing. This paper proved that ALBA-R considerably perform better than the other existing converge casting procedures and solution for handling the problem of connectivity holes particularly in vital traffic condition as well as less density network. Results shown that ALBA-R procedure is an energy effective protocol which attains the remarkable performance with respect to packet delivery rate as well as end to end delay in various scenarios. In[7] proposed the combination of geometric deployment with the routing technique for mesh networks. The geometric deployment of the topology is done by using the geometric graphs called Delaunay triangulation and the routing is performed by using the technique of greedy forwarding. In[8] compared three different techniques for routing packets into a wireless mesh network. These techniques considers reactive hop by hop protocol, wireless mesh gateway protocol and proactive field based routing protocol. Results have proved that the proactive field routing protocol outperforms all other routing protocols in terms of packet delivery ratio whereas mesh gateway procedure of routing is the most scalable to the network size and also has a very high packet delivery ratio. In[9] studied various techniques related to contention reduced channel allocation with minimum energy utilization and collision control mechanisms. The deprivation with respect to existing methods is analyzed. This paper enhanced the WMNs existing channel allocation techniques with significant enhancements to improve the QoS metrics.

2. Proposed Work

The pushback procedure is deployed in the super active mode to detect the perfect paths across the Wireless Mesh Networks (WMN) for the data propagation. The smart path planning and selection is realized by using the multi-factor routing procedure. The shortest route selection is evaluated by using pushback mechanism as well as the load balancing procedure in the proposed scheme. The path exists between two network nodes is made on the basis of Connected Dominating Sets (CDS) for the vital primary path selection across the multivariate path enabled WMN. Wireless Mesh Networks are usually divided into the network zones, which are further inter-connected in order to promote the maximum connectivity for the network users. The inter-zonal connectivity requires the selection of the stronger nodes across the mesh network to transmit the data between the nodes from the multiple zones.

The primary step towards the path selection begins with the path lookup by sending the route request to the one-hop neighbor nodes. The connectivity holes across the paths are verified by the pushback algorithm, which works on the basis of connection cross verification. The pushback algorithm verifies the connection health by receiving the data acknowledgements to examine the packet delivery rate. For analyzing the real connectivity holes in the network, the probability of nodes suspected as connectivity holes has to be evaluated. As of the occurrence of the connectivity loophole, the probability of the link failure has been given as following and depicted by the symbol P.

$$P = (\text{Total Availability} - \text{Connection Failure})^2$$

The total availability is given by I and connection failure rate is denoted by a. The following equation denotes the availability of the given nodes (node A in this example):

$$A = I - P$$

or

$$A = I - (1 - a)^2$$

Algorithm 1: Optimal Path Selection Algorithm-

The wireless mesh network (WMN) algorithm boots up the routing operations after the network nodes boots up.

- Smart path selection module starts up the incessant path look up procedure.
- The local pushback agent is sourced and verified and the path discovery begins the path selection procedure.
    - If the sourcing and verification stages passes, the agent is registered and initiated.
    - Otherwise the pushback module produces the error and path lookup is terminated

- If 2(a) returns true, perform the following:
    - Verify the connectivity holes in the given path using the pushback algorithm
    - If negative response is received the sourced node is skipped
    - If ping is received back, then the hurdle recognition method boots up.
    - Otherwise switch to 2(a)

- If 3(c) is true
    - Pushback algorithm based link health evaluation is initiated with every N-hop node over the defined route.
    - Node with connectivity hole is marked using the equation
    - [cH timeTot] = f(x) {n (x), X, Y };
    - Where cH is the connectivity hole index, timeTot is amount of delay, n(x) is node id, X and Y are the coordinates of the node.

- Another node lookup is initiated instead of the connectivity hole node.
- If another node is found over the route
  - The routing procedure is continued

- Otherwise
  - Return the message no path available between source and destination
  - Close the node lookup procedure

Energy awareness requires the number of energy constraint factors to be evaluated across the nodes in the path, which must be analyzed and studied in detail in order to deeply investigate the energy consumption through given route or network. The following mechanism shows how the tracking of energy consumption among the network is determined.

Algorithm 2: Energy Aware Routing in WMN

Assume EW(T) denotes the total amount of energy consumed by WMN route.

- $EW(T) = \mathbf{WN_s}\ (tx) + \{ \sum_{t=0-N} \mathbf{WN}\ (t)(tx) + \mathbf{WP}\ (t)(rx) \} + \mathbf{WN_d}\ (rx)$

  where EW denotes the total energy consumed over the route;
  WNs is the transmitting (or source) node;
  WNd is the receiving (or sink) node;
  WN is the intermediate (or relay) nodes over the path;
  t is the packet counter;
  tx is the transmission energy;
  rx is the receive energy;
  N denotes the number of packets transmitted.

- In case the total energy utilized by any node is less than the threshold value, then the node selection is eliminated.
- Determine the total energy among all routes in the given mesh network.
-

$EW(\mathbf{H_D}) = n)$
$\Sigma_{(i = 0, \ldots, j)} (WN_0\ (tx) * n + WN_0\ (rx) * n), (WN_{(1)}\ (tx) * n + WN_1\ (r) * n), \ldots \ldots \ldots \ldots, (WN_j\ (tx) * n) + WN_j\ (rx) *$

where EW denotes total energy consumption;
WN denotes the nodes in the network;
i is the packet counter;
j is the total number of packets;
rx gives energy for receiving packets;
tx gives energy for transmission of packets;
n defines the no. of nodes in the given path.

3. Results

With the given routing algorithm, the distance stretch for a source/destination pair (*s*, *t*) or for a graph is defined with respect to Euclidean distance among nodes. The average distance stretch of a graph is described as the average distance stretch for all source/destination pairs in the graph. The distance stretches increase with the growth of network size, means that the routes found by the geometric routing protocols are more likely to deviate from optimal when the network size is increased. The proposed algorithm achieves low distance stretches which indicates that it performs well in finding paths with shorter lengths and it also performs better than existing algorithm.

The figure 1 gives the average distance stretch across the selected paths in the proposed routing mechanism. The average distance stretch evaluates the ratio of nodes that are selected in route to the no. of nodes existing in the network. This ratio in the proposed technique has been discovered extremely low in comparison to the existing model, which can be considered as the big improvement than the existing routing model for the mesh networks. Packet drop ratio is evaluated as number of packets which are dropped by nodes to total number of packets generated by all nodes throughout the experiment. Figure 2 shows that the drop ratio of proposed algorithm decreases in comparison with the existing model with the growth in network size.

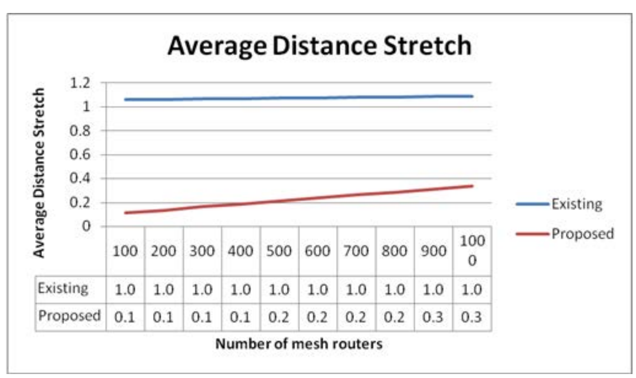

Figure 1. Average distance stretch.

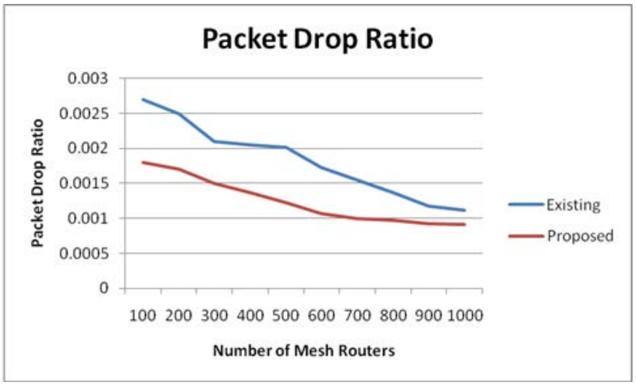

Figure 2. Packet drop ratio.

4. Conclusion

With the increase of user expectation of anyplace connectivity as well as quality of service guarantees, new wireless techniques are sought after for their skillfulness, ease of deployment as well as low cost. WMNs have come forward to support these features and also provide additional coverage in multi-hop communication. These networks recently received plenty of attention from researchers everywhere in the world for its potential application in wireless communications. In this paper, the smart routing solution is proposed for avoiding the connectivity holes using pushback mechanism and manages the load among the best paths available in the network. This paper also proposed the energy efficient routing scheme in WMNs for tracking the energy consumption throughout the network. The performance of the proposed technique is compared with existing with respect to packet drop ratio and average distance stretch. Both of the parameters have shown better results when compared to existing mechanism.

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