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A Novel Broadcast Network Design for Routing in Mobile Ad-Hoc Network

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ABSTRACT MANET is an infrastructure-less, fixed topology less, multi-hop and bandwidth constraint wireless network. In MANET optimized control message broadcasting through an efficient routing can results in bandwidth utilization and efficient data transmission with minimum numbers of hops. An efficient routing technique using a broadcast network, designed by existing minimum cost spanning tree (MCST) is also unable to provide all-nodes-to-all shortest route and also have issues about data transmission efficiency. In this article, our broadcast network design approaches can provide a solution for optimized control message broadcast and data transmission efficiency by considering Kruskalś MCST based broadcast network as a base network. Initially, we consider high-frequency links (HF-Link) to be added in the base network by considering the Dijkstra algorithm. Secondly, the broadcast network is designed by including those links with the neighbors who have at least a fixed number of neighbors (CF-Link) and finally, only those links are added with the base network which gives a shorter path to all other nodes (ST-Link) in the network. Using Omnet++ we have compared individual broadcast network design with the base network and observe that a slight increment in control overhead in existing based techniques could increase data efficiency significantly through a given suboptimal path.

INDEX TERMS Broadcast network, control overhead, MANET, routing, MCST.

I. INTRODUCTION

A Mobile ad hoc network (MANET) is an autonomous collection of mobile nodes and communicates among them in their radio range. Each node in MANET can identify the nodes that are in their transmission range by means of control message transmission, known as a neighbor node but have no idea about the nodes that are beyond its transmission range. MANET is an autonomous, multi-hop wireless network that needs an efficient routing protocol to transmit data packets from source to intended destinations. The routing techniques of MANET are normally classified as proactive and reactive. There exist several different types of proactive/reactive routing protocols for MANET. These protocols are mainly designed based on the information collected from the prior transmission of control messages to identify the neighbor or out of range node via intermediate neighbors. In converse, due to the mobility of the nodes, it is also hard to define any dedicated path among the nodes with a fixed topology for MANET. In the case of a proactive routing protocol for a particular instance of time, the individual node initially discovers their neighbors using a beacon message collected information about neighbors and are stored in a table. Later on, these individual tables share among them and update the individual table to identify the out of range nodes. There exist several different types of proactive routing protocol for MANET but due to mobility periodically these individual tables need to be updated and again utilized bandwidth. To avoid this periodic updating of the tables in reactive routing protocol before data transmission takes place source node uses a route discovery mechanism to identify a destination. In reactive routing initially sources broadcast route request (RREQ) control messages, and establishes a path between sources to a destination after receiving route reply (RREP) control messages. In our work, we consider here DSR (dynamic source routing) one of the reactive routing protocol for MANET. In DSR the RREQ recipient neighbors initially check their route cache so that, due to any previous data communication there may have

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requested a destination node's path information that has been kept into their cache table or not. For positive findings, recipient nodes send a reply (RREP control message) with full path information to the source, otherwise, the control message is being re-broadcasted again by the recipient. According to the stated mechanism, the multiple copies of the same requested control message are gradually filling the network, as in the MANET there may exist of multiple numbers of paths between sources to destinations and one's neighbor can also be the neighbor of other nodes. Considering all the nodes of MANET for a particular instance of time with paths/links attached with corresponding neighbor nodes, one can graphically represent the MANET topology. Although individual nodes have no idea about this topology during neighbor identification or route discovery but requested RREQ control messages flow through exactly all these paths that are reflecting into the network graph. The broadcasted control message passes through all the paths/links attached to a node is basically generating control overhead into the network as routing overhead is directly proportional to the path distance and the control message transmitted through all these connected paths/links also have the redundant control message transmission for the same request. The control message is passed through all these multiple numbers of paths although finally, a single route is being established with multiple numbers of hops in between source to destination to transmit the data packet. The control messages flow through all these possible paths creates wastage of wireless bandwidth that increases control overhead and depending on the cost matrices of the paths data transmitted through more numbers of hops is also decreases data efficiency. In the graphical representation an individual mobile node is denoted by the vertices of the graph and the links between nodes indicate their corresponding neighbors in their transmission range. The cost of the links is considered by various parameters and here, we have considered Euclidean distance between the end nodes as the cost of the links. The transmitted control messages pass through all these possible paths during neighbor discovery is need to keep as minimum as possible for future communication, otherwise, network overhead is also increasing and deteriorates performances. Our aim is to reduce the numbers of redundant control message broadcasting into the network before data transmission takes place, using a reactive routing protocol like Dynamic Source Routing (DSR). Optimized control message passes through lesser numbers of paths (links reflected into our designed broadcast network) among all possible links that are reflecting into the original network graph could utilize wireless bandwidth for those paths through which control messages are not transmitting. With the reduction of control message overhead, our aim is also to increase data transmission efficiency into the network by transmitting data as to a destination as possible as a lesser number of hops with minimum path cost. Through our proposed broadcast network designed from the original network topology any node to any node all the paths are shortest, and transmitted data would reach a destination with the possible minimum number of hops.

Some existing research [1] applied Kruskal's algorithm over graphically represented MANET topology to design a broadcast network, but it does not imply that any node to any node all the paths is shortest. Multicast routing is considered as a serious component for the real-time application. The major design issues of MANET routing protocol [8] is to achieve the optimum values of various performance parameters by considering individual nodes mobility, that may lead to an unpredictable and frequently [5] dynamic change of the network topology. In order to ensure better packet delivery ratio, lower delays and overhead reduction recently the group-oriented services supported mesh-based multicast routing [23] is used to finds the stable multicast path from source to destinations. Whereas in [6] the mobility-based multicast routing protocol is being used in terms of the packet delivery ratio, multicast route lifetime, control message overhead, and end-to-end delay. In [3] authors express that, to transmit a data packet efficiently from a node to all other nodes it's required a standardized single methodology for MANET. In [5] authors propose various schemes to improve routing performances based on the mobility prediction of the individual node. According to [6] MANET requires a standardized single methodology that effectively delivers data packet from one node to all another node. To broadcast a packet to the neighbor nodes in a wireless network [7] it is quite different as it needs an efficient routing technique for multicast and broadcast in an Ad-hoc network. In [5] author define multi-constrained QoS multicast routing using Genetic Algorithm and also had to define flooding with limited available resources and minimum computation time in a dynamic environment by considering a crossover, mutation and population size. In [6] authors proposed an algorithm for MANET by taking mobility as constant and will be a random variable with unknown distribution in the network. The routing problem is transformed into an equivalent stochastic Steiner tree problem and shows that their method is best among other existing mobility-based multicast routing protocols with respect to multicast route lifetime, packet delivery ratio, end-to-end delay as well as control message overhead. From [8] authors proposed a fast multi-objective evolutionary algorithm (MOEAQ) for solving multicast routing problem (MRP) in MANET. The two different approaches "Greedy" and "family competition" are combined into MOEAQ to speed up the convergence and to maintain the diversity of the population. Whereas in [9] they proposed frequent group communication by the group members that can facilitate the distributed autonomous network system for MANET. A group-oriented application like a conference, e-commerce can be done easily. So, for the demand of group communication, a reliable multicast route has to be established having a dynamic topology with ups and downs of channel condition. Through this proposal author mainly concentrate on reliable QoS based multicast routing mechanism which helps for multimedia communication over MANET. A mechanism can be applied under different topologies such as mesh, zone tree, and hybrid. For route establishment broadcasting in MANET is an information distribution from the source node to all other nodes within the network as well as outside the network [10]. Here authors make a comparative analysis for Probability Based and Area Based schemes in terms of a number of rebroadcasting nodes SBA (Scalable Broadcast Algorithm) and AHBP (Ad-hoc Broadcast Protocol). Due to node mobility routes are subject to frequent disconnections [11]. In such an environment effective delivery of data packets while minimizing connection disruption is crucial in Ad-hoc networks. Examination clarifies the use of mobility prediction to anticipate topology changes and perform rerouting prior to route breaks. Mobility prediction mechanism was applied to some of the most popular representatives of the wireless Ad-hoc routing family, namely an on-demand unicast routing protocol, a distance vector routing protocol and for a multicast routing protocol. Random waypoint model [14] is considered for network communication. Fundamental stochastic properties with respect to the transition length and time of a mobile node between two endpoints, the spatial distribution of nodes, the direction angle at the beginning of a movement transition and the cell change rate model is used in a cellular-structured system area. Whereas the table driven optimized link state routing protocol (OLSR) is based on the link state algorithm [17]. OLSR compress the size of information sent by the node as well as reduce of retransmission of a message within the entire network. OLSR applied multipoint relaying technique as well as an optimal path in terms of a number of host for delivering the message to the entire dense wireless network. Flooding [18] is a crucial operation for delivering a control message in MANET. Normal Flooding algorithm causes unnecessary packets rebroadcast, packet loss, wastage of bandwidth as well as create contention within the network. To overcome this problem probabilistic flooding algorithm based on phase transition phenomenon observed in percolation theory and random graphs. This algorithm will benefit from delivering information in the present wireless network system. In MANET among the different routing schemes, the proper use of the probabilistic scheme can reduce the chance of information loss, a number of rebroadcasting, a chance of contention and also reduce the chance of collision among the adjacent nodes within the network [19]. A well-known probabilistic broadcast protocol can achieve higher throughput and lower energy consumption. Here authors define an efficient probabilistic approach scheme for dynamically accustom rebroadcasting with the mobility of the node in the entire network which based on locally available information without assisting the position of the nodes. Some discovery protocols for MANET have been proposed [20] over the last couple of years but they induce significant traffic overhead and are thus primarily suited for small-scale MANET with few nodes. Building upon the evaluation of existing protocols, authors here introduce a scalable service discovery protocol for MANET, which is based on the homogeneous and dynamic deployment of cooperating directories within the network. They express scalability of protocol comes from the minimization of the generated traffic, and the use of compact directory summaries that enable to efficiently locate the directory that most likely caches the description of a given service. In [16] authors already define the Broadcast Storm Problem define as broadcasting by flooding cause contention in the network, redundancy as well as a collision between the intermediate nodes. Apart from flooding, there are some threshold schemes applicable on node density for performing the same could work much better. Likewise in [21] authors discuss various adaptive threshold schemes which can frequently adjust the threshold value based on local information in the network which has proved better efficiency and reachability compare to the tradition one. In [23] authors express that protocol can safeguard lower delay, packet delivery ratio and reduce control overhead. A mesh based routing scheme which finds a reliable path from a sender to the receiver is proposed here. The scheme established from route request and route reply control packet with the help of link-based stability database and route cache information. Through assumed parameters such as received power, a distance between neighboring nodes and the link quality link stability has been computed. To get the better result in terms of Performance of the proposed scheme is compared with two well known mesh-based multicast routing protocols, i.e., on-demand multicast routing protocol (ODMRP) and enhanced on-demand multicast routing protocol (EODMRP).

In mobile Ad-hoc network, there does not exist any fixed infrastructure or topology as the nodes are movable and they work on limited power with limited resources. The nodes in MANET work as a router or intermediate node in between a source to a destination operating by their existing limited resources. In our proposal, we show the way to design an efficient broadcast network for MANET by applying classical Kruskalś and Dijkstra algorithm over a graphically represented MANET topology as a base network. In our consideration, any source transmit control message through a broadcast network for routing and make route discovery with reduces bandwidth loss than ever existing one using lesser number of control message broadcasting through a lesser number of paths and data efficiency would also increase by transmitting data from a source to a destination with possible minimum number of hops represented by total path cost. The simulation using omnet++ is being carried out over our proposed broadcast networks with the different sample MANET networks, and it is shown that our proposed broadcast based approach reduces control messages overhead significantly than from the ever existing one. Above all a network need to deal with duplicate control message transmitted through multiple numbers of nodes connected by the multiple routed paths, that has to deal unnecessarily, resulting in effective decreases of network performance as it may need to establish a specific path between sources to a destination during data transmission for a reactive routing protocol. Our simulation result shows control message transmitted through the original network have a huge control overhead but data efficiency is higher. Existing [1] Kruskal's based broadcast network have minimum control overhead and data transmission efficiency is also minimum. Whereas and our designing broadcast network increases huge data efficiency with a small increase of control overhead than from existing [1] Kruskalś based broadcast network.

The balance of this article is organized as follows. In Section 1, we described the basics of a broadcast network. In the section 2 we describes how to design a broadcast network using classical Kruskalś algorithm followed by Dijkstra algorithm. In section 3 our proposal of designing the different broadcast networks is being presented by applying classical Dijkstra and Kruskalś Algorithm with simulation results followed by the analysis. Finally, section 4 is a conclusion followed by the references.

II. WHY BROADCAST NETWORK FOR MANET

To establish a path in between a source to a destination using a broadcast network, a mobile node can broadcast optimized control messages to all other nodes simultaneously with minimum control overhead and transmission delay through a minimum possible hop. The control messages broadcast through a lesser number of paths among all the existing paths of a network can reduce control overhead, as control messages pass through more number of paths means more control overhead generation and bandwidth utilization. A network that contains as minimum as possible numbers of the path to connect all the mobile nodes in such a way that control message broadcast should be optimized, is known as an efficient broadcast network. According to our proposal in order to reduce control overhead, control messages will only flow through those links that are only used to form a broadcast network. In graphical representation of MANET topology Path or link is considered when nodes are in their radio range and are known as neighbor nodes.

In this article, we have considered DSR (dynamic source routing) routing protocol for MANET routing. In our approaches to establish a path in between a source to a destination using DSR routing techniques initially source node will broadcast route request (RREQ) control message to its neighbors, through paths that are only reflecting into a broadcast network. As an example, consider Fig. 1 is an initial graphical representation of a network that has a connection among 6 nodes using 10 links or paths. Whereas in Fig.2 one of the spanning trees based broadcast network [1] formed by applying Kruskalś algorithm over Fig. 1 also have a connection among these 6 nodes with only 5 links or paths. Although Kruskalś based broadcast network could not provide an all-nodes-to-all shortest path. As an example here, we have considered 1 as a base network and applied our different approaches to design an efficient broadcast network. In case of path establishment using DSR routing technique through a spanning tree broadcast network by Fig. 2 only the reflected bold 5 links could be utilized to broadcast RREQ control messages. A path is being established after source node receive RREP (route reply) control message replied by the destination in reverse path and finally data transmission takes place through this established path. For instance, consider node 'A' of Fig. 1 is a source, to locate any destination within the network. Initially a node 'A' has no idea about the position of a destination hence to identify initially node 'A' broadcast control message to its neighbors AB, AC, and AD. But according to Fig. 2 RREQ only flows through AB. Hence, control overhead could be reduced if a broadcast network corresponding to MANET is used for path establishment and data transmission.

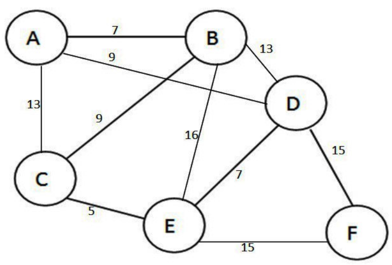

FIGURE 1. Graphical representation of a network topology.

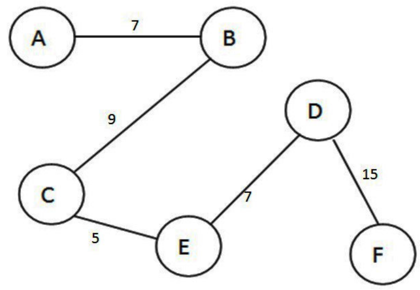

FIGURE 2. Kruskal's Based Broadcast Network Topology.

From Figure 1 as an example, let consider if node 'A' is a source and node 'F' is a destination data can transmit through a path AD → DF having path cost 24 unit (9+15) with only two hops whereas, from Fig. 2 path is AB→ BC→ CE→ ED→ DF having path cost 43 unit (7 + 9 + 5 + 7 + 15) with five hops to transmit the data. From this example, it is clear to say that, without broadcast network control overhead is generated due to control messages transmission through multiple numbers of paths but may also reduce data transmission efficiency due to increasing numbers of hops. Hence, to save wireless bandwidth by control overhead reduction as well as to increase data transmission efficiency it is required to design a best possible broadcast network and the same has been presented into this article by applying classical Kruskal's and Dijkstra algorithm.

A. KRUSKAL'S ALGORITHM BASED BROADCAST NETWORK

In an ad-hoc network, the mobile nodes communicate with other nodes that are in their transmission range and are known

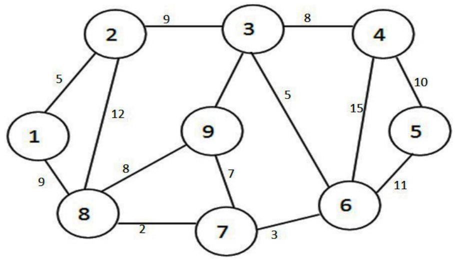

FIGURE 3. An Example of MANET.

as neighbors. The links denote the respectively connected neighbors of the nodes of that network. To interconnect 'n' number of mobile nodes it's required (n-1) number of links or paths. We can represent this network with a connected, undirected graph $G = (N, E)$, where N is the set of nodes, E is the set of possible links or paths between pairs of nodes and for each link or path $(u, v) \in E$,

Here, weight w (u,v) specifying the cost to connect 'u' and 'v' and here we consider the Euclidian distance in between u and v as a cost matrix of the network. We wish to find a subset $T \subseteq E$ that connects all the nodes and whose total weight is minimized [24] by applying Kruskal's algorithm is given below

$$W(T) = \sum_{(u,v)\in E} W(u, v) \tag{1}$$

T is an acyclic graph that connects all the nodes of the network and forms a tree, which we can call a spanning tree and we determining the tree T the minimum cost spanning tree (MCST) by applying Kruskal's algorithm. It finds a subset of the edges that forms a tree that includes every vertex, where the total weight of all the edges in the tree is minimized. A spanning tree based broadcast network below describes the steps to form a spanning tree based broadcast network [1].

STEP 1: create a set of trees T, where each vertex in the graph is a separate tree

STEP 2: create a set S containing all the edges in the graph

STEP 3: While not S is empty and T is not yet spanning

a) Remove an edge with minimum weight from S

b) If that edge connects two different trees, add it and combine two trees into a single tree, otherwise discard that edge.

At the termination of the algorithm, there exists only one component and forms a minimum cost spanning tree of the graph. This spanning three can use as a broadcast network for control message transmission during route discovery and data transmission to a destination after establishing the path in between source to a destination. As an example consider Fig. 3 is a graphical representation of a network. Each vertex of a graph is considered as a mobile node and the connected links or paths are representing their respective neighbor and each having their weight matrices. Fig. 4 shows the formation of a minimum cost spanning tree (MCST) based broadcast network (bold lines) that are formed after applying Kruskal's algorithm over Fig. 3. The individual iterations are shown in Fig. 4(a) to Fig. 4 (h). According to Fig. 4 (h) all the nodes of an initial network graph are present and are connected using bold lines having lesser numbers of paths or links representing a Kruskal's based broadcast network [1]. Hence during route discovery control messages will flow through these bold lines reflecting into Fig 4(h) formed by applying Kruskal's algorithm. For example, for a particular instance considers node '1' is a source and node '4' is a destination according to Fig. 4 (h) the path cost is 27 and the respective path is 1→ 8→7→6→ 3→ 4. Although, according to Fig. 3 from node '1' to node '4' there was already a path 1→2→ 3→ 4 with cost 22. Hence, data transmission efficiency may decrease whether a broadcast network is designed by applying Kruskal's algorithm.

B. DIJKSTRA ALGORITHM BASED BROADCAST NETWORK

Dijkstra's algorithm solves the single-source all destination shortest paths problem on a weighted, directed graph G = (V, E) for the case in which all edge weights are non-negative. Therefore, we assume that $w(u, v) \geq 0$ for each edge $(u, v) \in E$. Dijkstra's algorithm maintains a set S of vertices whose final shortest path weights from the source 's' have already been determined. The algorithm repeatedly selects the vertex $u \in (V - S)$ with the minimum shortest path estimate, adds u to S, and relaxes all edges leaving u. The following step shows the formation of a broadcast network using the Dijkstra Algorithm.

Step 1: It maintains a list of unvisited nodes. Consider node 1 of 3 is a source and assigns maximum possible cost (i.e. infinity) to reach to every other neighbours.

Step 2: The cost of the source remains zero as it actually takes nothing to reach from the source node to itself.

Step 3: In every subsequent step of the algorithm it tries to improve by minimizing the cost for each node. The cost here be the distance taken to reach that node from the source node. The minimization of cost is a multi-step process. For each unvisited neighbour (node 2 and node 8) current source (node 2) calculate the new cost from the source node. The new cost would be the sum of cost of the source + cost of the current source. Here sum of cost of node 1 + the cost of edge from node 1 to node 2.

Step 4: When all the neighbors of the current node are considered, it marks the current node as visited and is removed from the unvisited list.

Step 5: Select a node from the list of unvisited nodes which has the smallest cost and repeat step 4.

Step 6: At the end there will be no possibilities to improve it further and the algorithm ends.

For illustration, as an example formation of a broadcast network is shown in Fig. 5 after applying Dijkstra shortest path algorithm over a MANET topology are shown in Fig. 3. Similarly, formation of a broadcast network after applying Dijkstra algorithm for node 2 to node 9 over the network graph Fig.3 are also shown in Fig.6(a) to Fig.6(h).

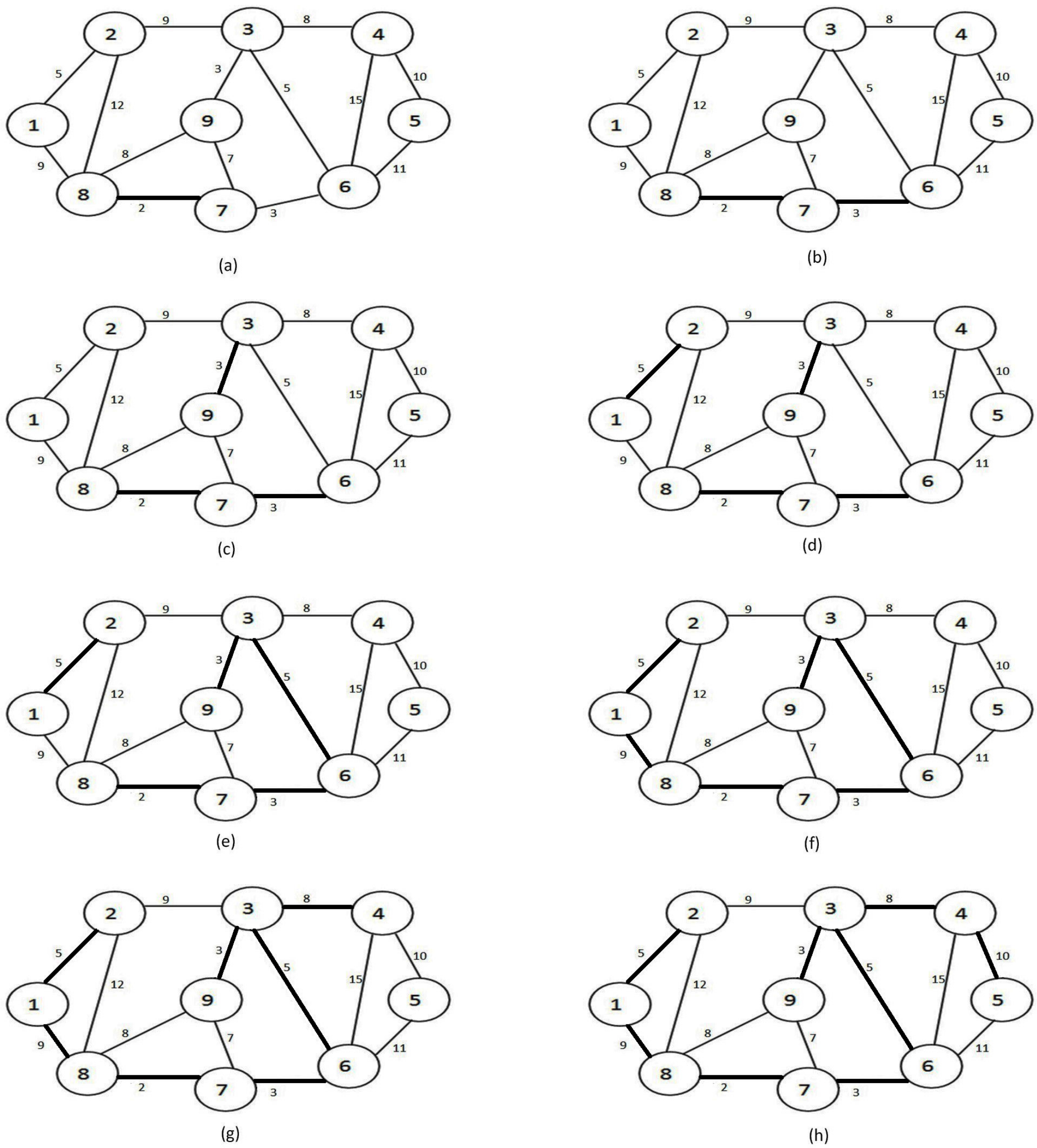

FIGURE 4. Kruskal Based Broadcast Network.

III. PROPOSAL OF TO DESIGN DIFFERENT BROADCAST NETWORK

A. HF LINKED BASED BROADCAST NETWORK

In this section, we have proposed to design HF (highest frequency) -Link based broadcast network. Here, we apply classical single-source all destinations Dijkstra algorithm and minimum cost spanning tree based Kruskalś algorithm. Initially, we consider every node of a network as a source and apply Dijkstra shortest-path algorithm to design an individual topology. After that, considering individual link we create a table in descending order about how many times they are reflecting into those topologies. The link that is reflecting into different topologies means whoever be the source most of the cases control message must flow through these link. So finally, we examined from top of the table, whether a higher repetitive link is being present into Kruskalś based broadcast network or not.

In order to design HF-link based a broadcast network the link that is not present into Kruskalś based broadcast network, we gradually added those links and simulate the result. After adding a single link into Kruskalś based broadcast network we observed the change in control overhead and data transmission over the network and gradually so on how long the change is not so much in control overhead and data transmission occur and hence designed our broadcast network. Links repetition is higher, specifies the maximal uses of links/paths by the nodes in a network during their control message or data message transmission in most of the time. The steps to design our proposed broadcast network are given below.

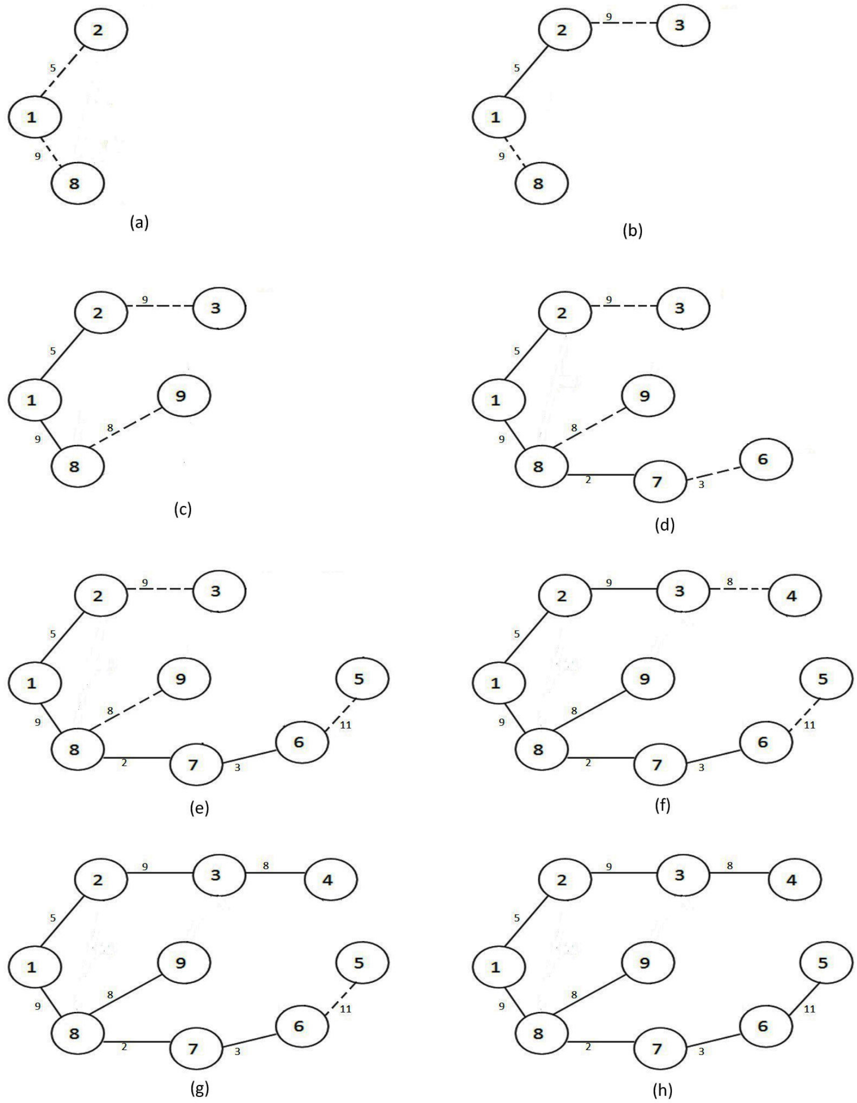

FIGURE 5. Iteration shows Formation of broadcast network when source node is '1' and applies Dijkstra Algorithm on the network graph.

We gradually incorporate higher counted link(s) formed from STEP 4 into MCST based broadcast network, how long the changes have no effect in terms of cost. As we added a number of links into MCST based broadcast network, it must increase some control overhead than MCST based broadcast network, as we know control messages transmitted through more number of paths will increase control overhead respectively. Although in spanning tree based [1] broadcast network all-to-all nodes paths are not shortest hence any source to any destination data transmission efficiency is less as in some cases it may have more numbers of hops exists in between sources and destination. In our Broadcast network, data transmission efficiency will increase by transmitting data with fewer numbers of hops. Using our broadcast network each node's transmitted data can reach to any other destination using the shortest route or minimum-possible hops so, data transmission efficiency will increase, and control message is per-transmitted over such broadcast networks for establishing a route flows through lesser numbers of paths will significantly reduce control overhead from the original network topology. As an example, consider Fig. 3 is a graphical representation of MANET topology for a particular instance of time, where each vertex(V) is considered as a mobile node and the links represent its respective neighbor nodes into their transmission range. Here, Euclidian distance between the nodes is measured the weight matrices of the individual link. We apply Kruskal's algorithm over the graphically represented MANET topology to form an MCST based broadcast network, the steps are shown in Fig.4(a) to Fig.4(h), illustrate the final formation of MCST based broadcast network using Kruskalś algorithm applied over Fig.3. Again on this initial graph Fig.3 we applied the Dijkstra algorithm by

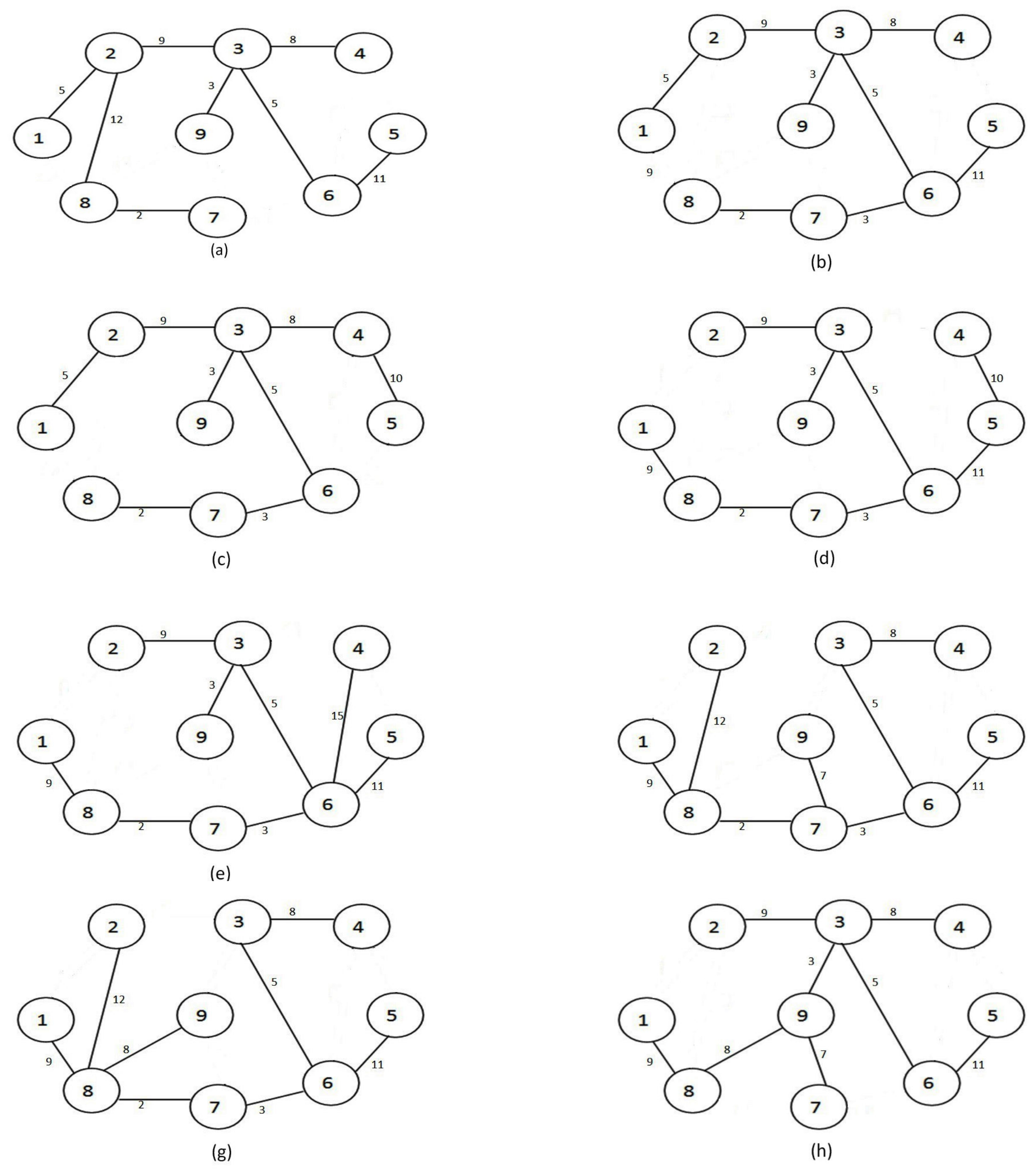

FIGURE 6. Broadcast Networks by considering source as '2' to '9' and applies Dijkstra Algorithm at Fig.3.

considering each node as a source to design an individual topology. From these topologies, we counted the number of occurrences of the individual links/edges and create a table according to their number of occurrences and are shown in Table 1. We investigate MCST based broadcast network shown in Fig.4(h) so that, higher occurrences link reflecting from Table 1 is being present into MCST based broadcast network or not. If not found we include those edges to form our modified broadcast network (MBN). The number of occurrences is higher means during communication among the nodes these links are being used most of the time.

According to our algorithm here, for a particular instance of time we applied Kruskalś Algorithm over the graphically represented ad-hoc network. The time complexity to design this broadcast network by applying Kruskalś algorithm is O (E log V) or O (V log V), where E is the number of edges and V is the number of vertices. Again we applied the Dijkstra algorithm over the initial graph for each vertex. The time complexity to form an individual topology for each vertex is O (V log V + E log V). Hence for V number of nodes/vertices it will take O(V(V log V + E log V)) or O(V^2log V) + V.E log V).

Algorithm 1 HFBN Algorithm

1: Apply Dijkstra shortest-path algorithm for each node over the network graph and formed individual topology by considering individual node as a source.
2: Apply Kruskal's algorithm over the same network and formed MCST based broadcast network.
3: Consider individual link and count the number of occurrences into different topologies of that link formed by STEP 1.
4: Arrange the number of occurrences of those links into descending order and forms a table.
5: Collect one link at a time from top of the table and observe whether that link is present into MSCT based broadcast network or not. If not, add it into MCST based broadcast network.Repeat the steps until the change of control overhead and data transmission are inefficient.

TABLE 1. The number of occurrences of the individual link.

source	destination	link	Number of Occurrence of Link
3	6	(3,6)	8
5	6	(5,6)	8
7	8	(7,8)	8
3	4	(3,4)	7
2	3	(2,3)	7
6	7	(6,7)	7
1	8	(1,8)	6
3	9	(3,9)	6
1	2	(1,2)	4
2	8	(2,8)	3
8	9	(8,9)	3
4	5	(4,5)	2
7	9	(7,9)	2
4	6	(4,6)	1

Total time complexity of our algorithm is

$$T(n) = O(n \log n) + O(n^{2\log n} + n(E \log n)) = O(n^2 logn) \quad (2)$$

n is the number of network nodes or vertices and E are the links or edges.

As an example, consider MANET topology that are shown in Fig.3 having nine (9) nodes/vertices (V) and a set of fourteen(14) links/edges (E)

$$V = 1, 2, 3, 4, 5, 6, 7, 8, 9 \quad (3)$$

$$E = (1, 2), (1, 8), (2, 3), (2, 8), (3, 9), (3, 4), (3, 6), (4, 6), (4, 5), (5, 6), (6, 7), (7, 9), (7, 8), (8, 9) \quad (4)$$

In MCST based BN shown in Fig.4(h) that are formed by applying Kruskalś algorithm over Fig.3 have nine nodes/vertices(V) and among fourteen links/edges(E) only eight links/paths is reflecting that would be utilized to transmit control message and data.

$$V = 1, 2, 3, 4, 5, 6, 7, 8, 9 \quad (5)$$

$$E = (1, 2), (1, 8), (7, 8), (3, 9), (6, 7), (3, 6), (3, 4), (4, 5) \quad (6)$$

In MCST based broadcast network, all the nodes of an initial MANET network are connected but only reflected edges would be used to transmit control messages for route discovery. As an example, when node '1' is a source and node '9' is destination the control message will only flows through (1,2), (1,8,7,6,3,9) and (1,8,7,6,3,4,5) using MCST based broadcast network as shown in Fig.4(h) but according to MANET's base topology Fig.3 the control messages will flows through all the paths (1,2,3,9), (1,8,9), (1,8,7,9), (1,2,8,9) etc. In contrary, let source node is '1' and the destination node is '5', the path cost to travel the control message from a node (1, 5) is 37 according to Fig.4(h). Whereas, without a broadcast network, according to the original MANET topology the cost from node '1' to node '5' there exist a path having cost is equal to 25 according to Fig.3. Therefore, we can say that all-to-all other nodes the paths are not shortest. In one sense designing minimum cost spanning tree based broadcast topology are not efficient to transmit a data into the network in all cases.

Hence an efficient broadcast network design is required that can reduces the number of control message transmission to locate the destination or reduces control overhead of the network as well as increases data transmission efficiency over MCST based broadcast network

In Table 1 their exist all the connected links and if all the nodes that are involved in transmitting control messages the paths or links may use how many numbers of times, is reflecting. From the top of Table 1 the higher occurrences link gradually compared with MCST based broadcast network whether the link exists into the broadcast network or not. If not present they are added to design our proposed broadcast network. Here Fig.4(h) is an MCST based broadcast network and from Table 1 it has seen the link (2,3) and (5,6) is not being present into Fig.4(h). According to our proposal by adding these two links will generate final HF Linked based broadcast network and are shown in Fig.7

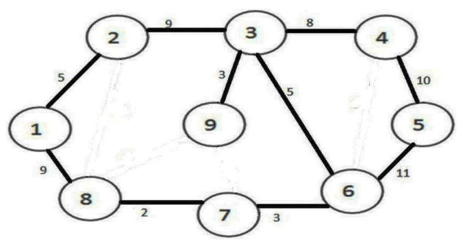

FIGURE 7. HF Link based broadcast network after adding high frequency link into MCST based network.

B. SHORTER PATH BASED BROADCAST NETWORK(SPBN)

Let C_{ij} be the path cost from node i to node j. Here we have proposed another algorithm for forming a broadcast network. Like the earlier algorithm, initially a base broadcast network is formed with the help of the Kruskal algorithm and each node uses Dijkstra's algorithm to find the shortest path to all other nodes.

Algorithm 2 SPBN Algorithm

```
for each node i in parallel do
    Find broadcast network(MCST) using kruskal's algorithm and Cost_difference=0
end for
for each node j do
    calculate shortest path from i using dijkstra's algorithm,considering the broadcast links only.
end for
for each neighbor k of node i do
    for each node j ≠ i do
        if ( then C_ij > (C_ik + C_kj ))
            Cost_difference += (C_ik + C_kj) − C_ij
        end if
        if Cost_difference ≥ cut_off then
            Add link to the broadcast network.
        end if
    end for
end for
```

Each node adds its neighbor in the broadcast network if it finds a better cost path to all other nodes. If the sum of the cost of all better paths is greater than a cutoff value, link to that neighbor is added to the broadcast network. Proposed algorithm(SPBN) is given next.

Time Complexity of the algorithm is O(cV2)+O(E lg V), where E is the number of links, V is the number of nodes and c is constant.

C. MAXIMUM NEIGHBOR BASED BROADCAST NETWORK(MNBN)

The proposed algorithm is based on the degree of the neighbors. Like earlier two algorithms, the Kruskal algorithm is used to form the base broadcast network. Thereafter each node checks the degree of its neighbors and if it is more than a specific number δ, the link to that neighbor is added to the broadcast network. The value of δ is close to the value of the maximum degree of the nodes in the network. The main aim of adding links to higher degree nodes is to reach the nodes in the network with lower cost. The algorithm is given next.

Algorithm 3 MNBN Algorithm

```
for each node i do
    Apply kruskal's algorithm to find MCST.
end for
for each neighbor k do
    if node k has neighbors > δ then
        the the link to k with MCST.
    end if
end for
```

Time Complexity of the algorithm is O(E lg V)+O(1).

D. MATHEMATICAL MODEL

Let consider the number of link for Network is N and cost per link is C_i. Total cost T for a network for a particular instance of time is calculated as follows.

$$T = \sum_{i=1}^{n} C_i \tag{7}$$

Average cost per link for a network on that instance of time is A_c where

$$A_c = \frac{T}{N} \tag{8}$$

For a network, T is minimum, if N is minimum and T is maximum if N is maximum. Hence, A_c increases if T increases for N decreases. On the other hand A_c decreases, if T decreases for N increases. But A_c remain unchanged, if both T and N decrease or increase proportionally.

For a network control overhead should be minimized and data efficiency increases when cost per link decrease should be maximized, A_c decreases maximum, if decrease of T is maximum with minimum number of link(N_i) increases. A_c decreases minimum, if decrease of T is maximum with maximum number of link(N_i) increases.

Hence, being a minimum numbers of link in Kruskal's based broadcast network control overhead is lower but data efficiency is lower and being a maximum numbers of link is normal network the control overhead is higher but data efficiency is higher. In our three different proposed algorithms we have designed an novel broadcast network by adding as minimum as possible link added with Kruskal's based broadcast network so that, for minimum increases in control overhead can give maximum data efficiency.

IV. SIMULATION RESULTS

Simulation is done using simulator software Omnet++ 4.3. We have considered MANET network where nodes are placed in an area of size 1000 x 1000 square units. The number of nodes has been chosen to as 20, 30, 40 and 50 for different simulation runs. We have considered the random way point mobility patterns for implementing our routing algorithms. For these models, the maximum velocity of nodes is chosen as 30 units/sec and transmission range of each node chosen as 150, 200 and 250 units for a different simulation run. We have considered a wireless channel with a data rate of 1 Mbps. Data packet size has been chosen 1024 bytes and overhead packets(RREQ and RREP) size are chosen 32 bytes. We have considered IEEE 802.11 as MAC protocol and all simulations are continued for 100 seconds. Data packets, that are generated from nodes follow a Poisson distribution with an average data packet rate is considered 5 packets/sec in most of the simulation runs.

We have studied the performance of the routing algorithms based on different broadcast networks proposed in this work. In the first set of simulation, the number of nodes is considered as 20. From table 2, it is found that based Broadcast network formed by using Kruskalś algorithm only have

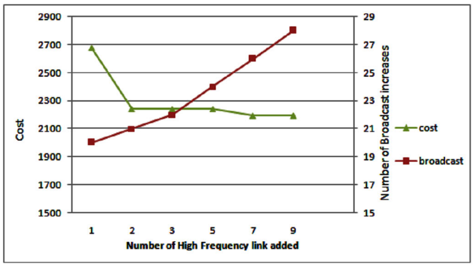

FIGURE 8. High frequency link with 20 nodes.

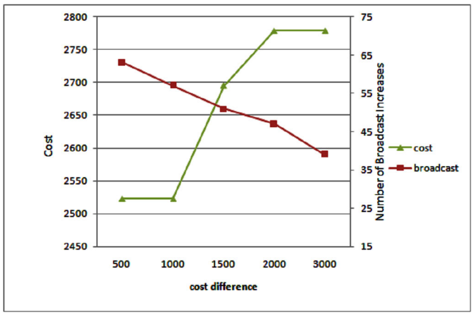

FIGURE 9. SPBN with 20 nodes.

19 broadcast link for control message transmission and an average path cost for message transmission is 2779. By using HFBN algorithm or HF-link based broadcast network, broadcast increase and average message cost per link decrease are shown in Fig.8, where both these parameters are measured by adding the high-frequency link gradually with base network. Performances of SPBN algorithm is shown in Fig.9 where the same parameters are measured with cost differences (δ). Using MNBN algorithm broadcast and message cost is measured by considering neighbor degree as 3 and 2, where the number of the broadcast are gradually 35 and 39, and message costs are 2572 and 2192 shown in table 2 with average cost per link is 12.93 and 29.35 eventually.

For 20 nodes in table 3 it is clearly shows the changes of link cost decreases with broadcast increases for HFBN model. It is also shown that with the increases of just 2 broadcast links, cost per broadcast decreases is maximum by 269. Comparing HFBN model from table 3 with MNBN model from table 2 and SPBN from table 4 in terms of link cost per broadcast it's found that the decreases of link cost with increasing broadcast occur due to adding more broadcast links with the base model (Kruskal's based broadcast network). From these broadcast networks using HFBN can give better result among the other two designing methods in terms of data efficiency and control messages utilization as cost per broadcast decreases is maximum for adding minimum numbers of link high frequency link and here for twenty nodes just two link addition gives highest cost decrease per link. Hence from table 3 and table 4 it is clear to say that according to HF-Link based method the cost decreases by 269 with only adding just 2 high frequency link with Kruskal's based broadcast network. Whereas, the cost decreases by 256 required 44 numbers of link addition with Kruskal's based broadcast network and as we know increases of link means more control overhead generation without any confirmation that source to destination all to all path are shortest. In the first second set of simulation, the number of nodes is considered as 30. From table 5, it is found that based Broadcast network formed by using Kruskal's algorithm only have 29 broadcast link for control message transmission and an average path cost for message transmission is 5783. By using HFBN algorithm HF-link based broadcast network, broadcast increase and average message cost per link decrease are shown in Fig.10, where both these parameters are measured by adding the high-frequency link gradually with base network. Performances of SPBN algorithm is shown in Fig.11 where the same parameters are measured with cost differences (δ). Using MNBN algorithm broadcast and message cost is measured by considering neighbor degree as 3 and 2, where the number of the broadcast are gradually 58 and 72, and message costs are 4197.29 and 3026.43 shown in table 5 with average cost per link is 54.68 and 64.11 eventually.

For 30 nodes from table 6 it is clearly shows the changes of link cost decreases with broadcast increases for HFBN model.

TABLE 2. Number of broadcast, link cost and average cost per link for 20 nodes w.r.t base network (Kruskal), Original network and MNBN for greater then or equal 2 or 3 neighbour.

Model	No of broad-cast	Link cost	Broadcast increase	Average cost per Link
Kruskal	19	2779	0	146.26
Original Broadcast	47	2075	28	25.14
Krusmod($neighbor \geq 3$)	35	2572	16	12.93
Krusmod($neighbor \geq 2$)	39	2192	20	29.35

TABLE 3. Change in cost with change in broadcast(cost_per_broadcast) for HF-Link for node 20.

broadcast increase	cost decrease	cost_per_broadcast decrease
1	100	100
2	538	269
3	538	179
5	538	108
7	587	84
9	587	65

TABLE 4. Change in cost with change in broadcast(cost_per_broadcast decrease) for ST-Link for 20 nodes.

broadcast increase	cost decrease	cost_per_broadcast decrease
44	256	6
38	256	7
32	84	3
28	0	0
20	0	0

TABLE 5. Number of broadcast, link cost and average cost per link for 30 nodes w.r.t base network (Kruskal), Original network and MNBN for greater then or equal 2 or 3 neighbour.

Model	No of broad-cast	link cost	Broadcast increase	Average cost per Link
Kruskal	29	5783	0	199.41
Original Broadcast	74	2498	45	73
Krusmod($neighbor \geq 3$)	58	4197	29	54.68
Krusmod($neighbor \geq 2$)	72	3026	43	64.11

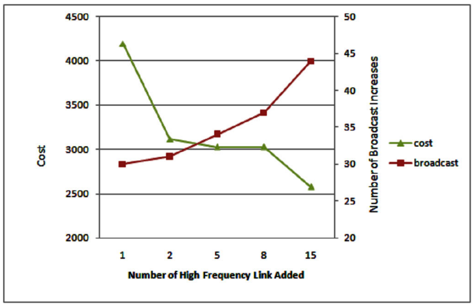

FIGURE 10. High frequency link with 30 nodes.

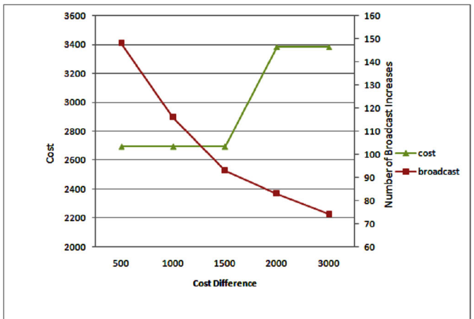

FIGURE 11. SPBN with 30 nodes.

It is also shown that with the increases of just 4 broadcast links, cost per broadcast decreases is maximum by 292.75. Comparing HFBN model from table 6 with MNBN model from table 5 and SPBN from table 7 in terms of link cost per broadcast it's found that the decreases of link cost with increasing broadcast occur due to adding more broadcast links with the base model (Kruskal's based broadcast network). From these broadcast networks using HFBN can give better result among the other two designing methods in terms of data efficiency and control messages utilization as cost per broadcast decreases is maximum for adding minimum numbers of high frequency links and here for thirty nodes just four link addition gives highest cost decrease per link.

Hence from table 6 and table 7 it is clear to say that according to HF-Link based method the cost decreases by 292.75 with only adding just 4 high frequency link with Kruskal's based broadcast network as we know increases of link means more control overhead generation. In the third set

TABLE 6. Change in cost with change in broadcast(cost_per_broadcast) for HF-Link for 30 nodes.

broadcast increase	cost decrease	cost_per_broadcast decrease
1	1080	1080
4	1171	292.75
7	1171	167.2857143
14	1623	115.9285714

TABLE 7. Change in cost with change in broadcast(cost_per_broadcast) for ST-Link for node 30.

broadcast increase	cost decrease	cost_per_broadcast decrease
119	1503	12.6302
87	1503	17.2758
64	1503	23.4843
54	813	15.0555
45	813	18.0666

of simulation, the number of nodes is considered as 40. From table 8, it is found that based Broadcast network formed by using Kruskal's algorithm only have 39 broadcast link for control message transmission and an average path cost for message transmission is 5086. By using HFBN algorithm HF-link based broadcast network, broadcast increase and average message cost per link decrease are shown in Fig.12, where both these parameters are measured by adding the high-frequency link gradually with base network. Performances of SPBN algorithm is shown in Fig.13 where the same parameters are measured with cost differences (δ). Using MNBN algorithm broadcast and message cost is measured by considering neighbor degree as 3 and 2, where the number of the broadcast are gradually 76 and 128, and message costs are 4247 and 2834 shown in table 8 with average cost per link is 22.67 and 22.74 eventually.

For 40 nodes table 9 it is clearly shows the changes of link cost decreases with broadcast increases for HFBN model. It is also shown that with the increases of just 2 broadcast links, cost per broadcast decreases is maximum by 180. Comparing HFBN model from table 9 with MNBN model from table 8 and SPBN from table 10 in terms of link cost per broadcast it's found that the decreases of link cost with increasing broadcast occur due to adding more broadcast links with the base model (Kruskal's based broadcast network). From these broadcast networks using HFBN can give better result among the other two designing methods in terms of data efficiency and control messages utilization as cost per broadcast decreases is maximum for adding minimum numbers of link high frequency link and here for forty nodes just two link addition gives highest cost decrease per link.

Hence from table 9 and table 10 it is clear to say that according to HF-Link based method the cost decreases by 360 with only adding just 2 high frequency link with Kruskal's based broadcast network i.e cost per broadcast decreases maximum by 180, as we know increases of link

TABLE 8. Number of broadcast, link cost and average cost per link for 40 nodes w.r.t base network (Kruskal), Original network and MNBN for greater then or equal 2 or 3 neighbour.

Model	No of broad-cast	link cost	Broadcast increase	Average cost per Link
Kruskal	39	5086	0	130.41
Original Broadcast	136	2664	97	24.96
Krusmod($neighbor \geq 3$)	76	4247	37	22.67
Krusmod($neighbor \geq 2$)	128	2834	91	24.74

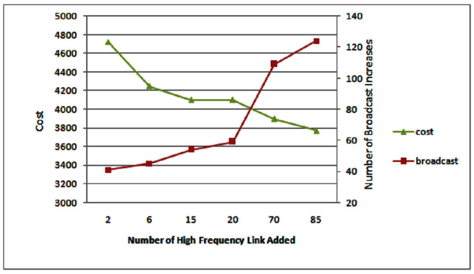

FIGURE 12. High frequency link with 40 nodes.

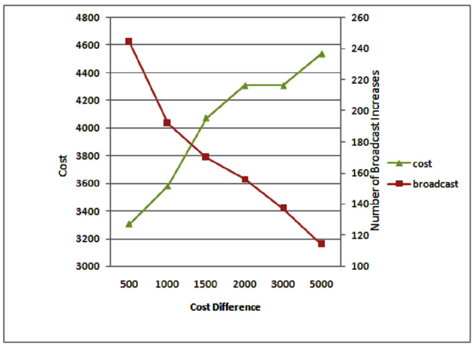

FIGURE 13. SPBN with 40 nodes.

TABLE 9. Change in cost with change in broadcast (cost_per_broadcast) for HF-Link for 40 nodes.

broadcast increase	cost decrease	cost_per_broadcast decrease
2	360	180
4	479	119.75
13	627	48.2307
18	627	34.8333
68	828	12.1764
83	953	11.4819

means more control overhead generation without any confirmation that source to destination all to all path are shortest. In the fourth set of simulation, the number of nodes is considered as 50. From table 11, it is found that based Broadcast network formed by using Kruskal's algorithm only have 49 broadcast link for control message transmission and an average path cost for message transmission is 4768. By using HFBN algorithm HF-link based broadcast network, broadcast

TABLE 10. Change in cost with change in broadcast (cost_per_broadcast) for ST-Link for 40 nodes.

broadcast increase	cost increase	cost_per_broadcast
205	1782	8.6927
153	1506	9.8431
131	1014	7.7405
117	778	6.6496
98	778	7.9388
75	549	7.3200

TABLE 11. Number of broadcast, link cost and average cost per link for 50 nodes w.r.t base network (Kruskal), Original network and MNBN for greater then or equal 2 or 3 neighbour.

Model	No. of broad-cast	link cost	Broadcast increase	Average cost per Link
Kruskal	49	4768	0	97.30
Original Broadcast	210	1767	161	18.63
Krusmod($neighbor \geq 3$)	162	4374	113	3.48
Krusmod($neighbor \geq 2$)	195	3162	116	13.84

TABLE 12. Change in cost with change in broadcast(cost_per_broadcast) for HF-Link for 50 nodes.

broadcast increase	cost increase	cost_per_broadcast
1	0	0
5	0	0
10	978	97.8
25	1403	56.12
205	2959	14.4341

increase and average message cost per link decrease are shown in Fig. 14, where both these parameters are measured by adding the high-frequency link gradually with base network. Performances of SPBN algorithm is shown in Fig. 15

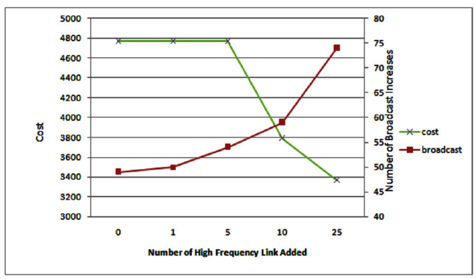

FIGURE 14. High frequency link with 50 nodes.

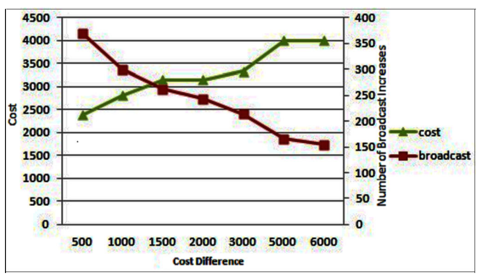

FIGURE 15. SPBN with 50 nodes.

TABLE 13. Change in cost with change in broadcast(cost_per_broadcast) for ST-Link for node 50.

broadcast increase	cost increase	cost_per_broadcast
321	2380	7.41
251	1957	7.80
213	1623	7.62
194	1623	8.37
165	1439	8.72
117	768	6.56

where the same parameters are measured with cost differences (δ). Using MNBN algorithm broadcast and message cost is measured by considering neighbor degree as 3 and 2, where the number of the broadcast are gradually 162 and 195, and message costs are 4374 and 3162 shown in table 11 with average cost per link is 3.48 and 13.84 eventually.

For 50 nodes table 12 it is clearly shows the changes of link cost decreases with broadcast increases for HFBN model. It is also shown that with the increases of just 10 broadcast links, cost per broadcast decreases is maximum by 97.8. Comparing HFBN model from table 12 with MNBN model from table 11 and SPBN from table 13 in terms of link cost per broadcast it's found that the decreases of link cost with increasing broadcast occur due to adding more broadcast links with the base model (Kruskal's based broadcast network). From these broadcast networks using HFBN can give better result among the other two designing methods in terms of data efficiency and control messages utilization as cost per broadcast decreases is maximum for adding minimum numbers of link high frequency link and here for fifty nodes just ten link addition gives highest cost decrease per link.

Hence from table 12 and table 13 it is clear to say that according to HF-Link based method the cost decreases by 978 with only adding just 10 high frequency link with Kruskal's based broadcast network i.e cost per broadcast decreases maximum by 97.8, as we know increases of link means more control overhead generation without any confirmation that source to destination all to all path are shortest.

V. CONCLUSION

The novelty of our work is the design of an efficient broadcast network for MANET where control overhead is reduced and data transmission efficiency is increased. Here, we have proposed three algorithms named HFBN, SPBN and MNBN to design an efficient broadcast network. We have compared our proposed HFBN, SPBN, and MNBN algorithms to search to provide solution among these algorithms by which as minimum as the possible link would be utilized for control message optimization. As well as we have designed an efficient broadcast network for promising solutions in such a way that low path cost can have in between source to destination for the improvement of data efficiencies. Our comparison studies in terms of control overhead and data efficiency we have proposed the better algorithm for an efficient broadcast network that can be designed for the improvement of network performance. From our study and experiment, we came to know that more number of connected links among the nodes in a network means more bandwidth utilization and increases control overhead due to flows of control message transmission through all the paths. After comparing among these models, we tried to give the optimal solution about the optimized designing method with respect to control overhead and data transmission efficiency and find out that the HFBN algorithm is the best designing methodology of a broadcast network. Finally, our proposed HFBN algorithm design model is the better solution in terms of control overhead reduction and data transmission efficiency because as minimum as possible high-frequency link addition with classical Kruskalś base model can give the best results in terms of data efficiency.

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