IoT Static Wireless Mesh Network Routing

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***Abstract*— Due to the emerging popularity of IoT devices, mesh networks became an inevitable network topology to consider. However, many technical issues still exist in this field. Most of the Embedded devices categorised as IoT devices are inherently constrained by low memory, processing power and throughput. This paper attempts to introduce a new routing scheme for static wireless mesh networks for IoT devices.**

Introduction

Wireless Mesh Networks (WMNs) are dynamically self-organized and self-configured, with the nodes in the network automatically establishing an ad hoc network and maintaining the mesh connectivity[1]. Wireless mesh networks offer advantages over other wireless networks; these include easy deployment, greater reliability, self-configuration, self-healing and scalability[2].

Some of the optimal assumptions considered during its design cycle are- any failure in this network is infrequent, the amount of data exchanged is very much minimal (less than 10MB per hour per Node), timeliness of the packet is negotiable, the physical position of the IoT devices are static and any two nodes considered as connected should be able to do bidirectional data exchange.

Every Static WMN cluster must have at least one node that acts as the gateway node and all other nodes acting as a slave to the gateway.

I. Static Mesh Network Topology

S-WMN clusters can function without gateways however, they are very much critical for handling network failures and data exchange between other WMN clusters.

A. Addressing

By default, S-WMN cluster assigns distinct whole numbers as the logical address for every node in the network. No two nodes can have the same logical address but a single node can have multiple logical addresses which is very much relevant in cases of gateways. Gateways can use reserved address spaces mapped to global or local IPv4/IPv6 addresses that can be used to establish communication outside of its scope. For any node in the network with multiple addresses ranging from x to $x+n$ where n is the number of addresses allocated to that node, then x will act as its native address and all other addresses ranging from $x+1$ to $x+n$ will act as a foreign address. Any device that seeks access to the cluster through a node will be assigned the foreign address of that node which will act as a DHCP server. This, in turn, can be used to integrate dynamic nodes or gateways into the cluster on the fly without sacrificing the performance of the network. This also opens to the fact that insertion or deletion of new dynamic nodes to the network via a static node doesn't disrupt the routing tables of the mesh topology.

B. Gateways

Gateway nodes are special nodes in the network with a bit more of memory, processing power and throughput. They are very much critical in re-calculating routing tables when a new node joins or disconnect from the cluster. By default, any data exchange outside of the cluster happens through the gateway nodes. Gateways are categorised into two-

- Primary Gateway - A Single standalone node in the network that handles the routing tables. By default, the primary gateway will have the first starting address in the succession of logical addressing. Primary gateway will be in charge of network administration, control and configuration of the network. Primary gateways can route packets in and out of the cluster and also between other clusters.
- Secondary Gateways - Any node in the system that can act as a primary gateway by connecting to the cluster as a dynamic node.

II. Routing Table

Primary gateway is responsible for maintaining routing tables. Routing tables are updated whenever a new node is added or disconnected from the network. Routing table also assigns a logical address to the nodes that help in the routing. The logical address of the nodes will tend to change when there is a change in the network topology hence, insertion and deletion of new nodes to the network are handled in a sequential manner.

A. Graphing Network

Primary gateway will fetch all the information about the nodes and forms a weighted undirected graph of the network (G). G can be either acyclic or cyclic for a network but must be connected. Disconnected graph components tend to form different clusters and hence wireless proximity between the nodes are essential to form a connected graph. Vertex (V) in the graph will represent a node and the weighted edge (E) will provide a real value that resembles the Quality of Service that comprises of several related aspects of the network service often considered, such as packet loss, bit rate, throughput, transmission delay, availability, jitter, etc[3].

Fig. 1 shows an example of a static wireless mesh network cluster. The same depicts a cluster with 8 nodes with physical addresses A, B, C, D, E, F, G, and H. In this particular cluster, the Node A is assumed to be the primary gateway. Node A is connected to a router which is in turn connected to the internet. By this way, routers can effectively route packets in and out of the cluster using the port forwarding feature which is common in all of the routers available today.

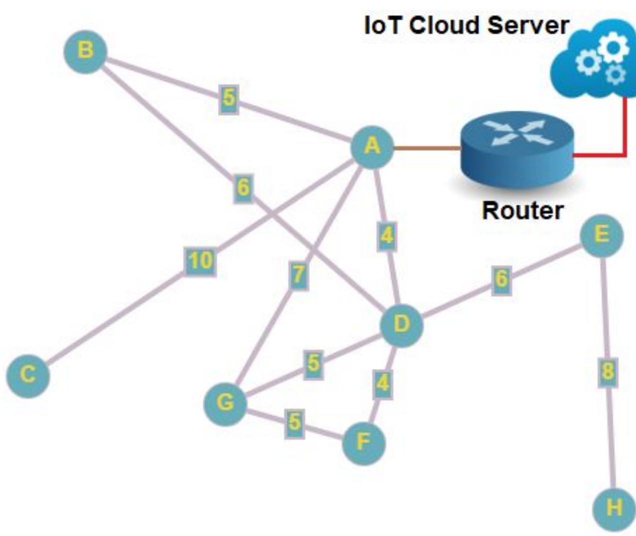

Fig. 1 An undirected weighted graph (G) of the cluster

B. Minimum Spanning Tree

Using optimal, parallel or distributed algorithms we can obtain MST for the graph G from Fig. 1. Research has also considered parallel algorithms for the minimum spanning tree problem. With a linear number of processors, it is possible to solve the problem in O(log n) time[4][5]. Bader & Cong (2006) demonstrated an algorithm that can compute MSTs 5 times faster on 8 processors than an optimized sequential algorithm[6].

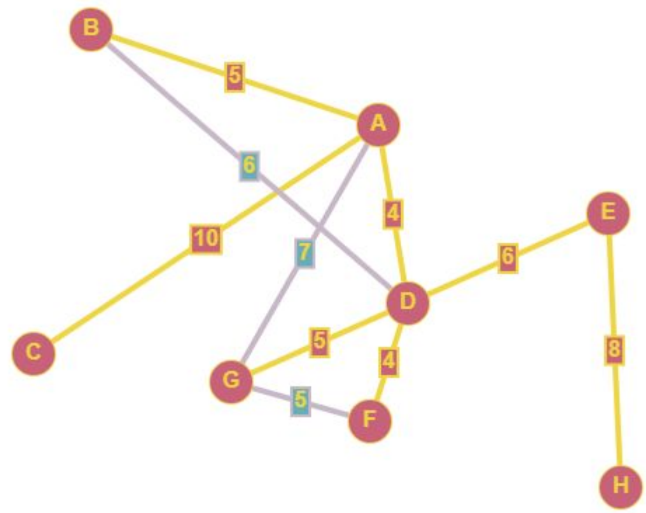

Fig. 2 MST of the graph G

Fig.2 shows the MST of graph G from Fig. 1. The weighted edges from B to D, A to G and G to F are eliminated to create a fully connected acyclic graph. Fig. 2 hence resembles a tree which is an undirected graph in which any two vertices are connected by exactly one path. Every acyclic connected graph is a tree and vice versa[7].

C. Assigning Logical Address to Nodes

Discretion is advised for nodes that need multiple logical addresses. Any node that is expected to connect with a dynamic node can allocate foreign addresses for later use.

MST gives a tree which is connected and is devoid of any loops, now a depth-first search is done on the tree starting from the primary gateway. All the nodes are appropriately numbered as like in Fig. 3 during the DFS.

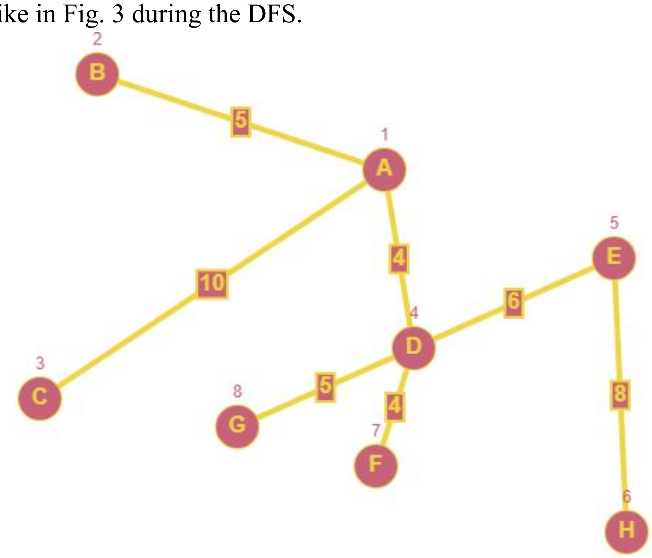

Fig. 3 DFS numbering on the MST

If you closely observe the numbering (logical address) on fig. 3 you can make some interesting observations which are the basis for this particular routing scheme.

1) *Observation 1:* Every subtree in the graph with more than one node has a subnode with a minimum value *Nmin* and maximum value *Nmax*. If any other node exists except the above mentioned two, then it must be within the range *Nmi*n and *Nmax*.
2) *Observation 2:* If a parent node exists for any child node then it must have a value less than that of the child node. This implies any data destined to a logical address which is lesser than its own logical address is to be routed to its parent node.

D. *Forming the Routing Table*

From fig.3 the routing table for a parent node can be inferred by observing the *Nmax* and *Nmin* for each of its individual subtrees.

TABLE I
Routing Table

	Next Node to Hop							
	A*	**B**	**C**	**D**	**E**	**F**	**G**	**H**
A*		2	3	4 - 8				
B								
C								
D					5 - 6	7	8	
E								6
F								
G								
H								

From TABLE I we can infer that nodes B, C, F, G and H don’t need a routing table as all traffic is routed to its parent node. For node E, any traffic to logical address 6 is routed to H and everything else is routed back to its parent node. This is the same in case of D, however node A is the primary gateway and hence it acts as the root node for all the communication. Primary gateways can be specifically programmed to route allocated foreign addresses to external IP’s which make them an ideal solution for IoT devices that needs cloud support to function properly. This also means that dynamic nodes can also do the same without any change in the network topology.

III. Conclusions

This work introduces a routing scheme that can be used to route data in static wireless mesh networks. Compared to the existing routing methodologies, while preserving the properties of the mesh network this routing scheme reduces the space complexity of the routing table which is a key factor for embedded devices with low memory, processing power and throughput. Hence this routing scheme can be effectively extrapolated to contain static mesh networks with thousands of nodes in a single cluster.

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Biographies

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