Advantages Of Multiple Gateway Association Over Single Gateway Association In Wireless Mesh Networks

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Abstract

The Wireless Mesh Network (WMN) is emerging as one of the IEEE 802.11 networks family's key technology for next generation networks. The reason is its features, like providing broadband access with low cost and applicability to versatile areas with reduced dependency on wired communication. WMN's use gateways for transferring data to and from the client nodes to the backbone for Internet access in multiple hops. The client nodes may be wired or wireless, mobile or stationary. In any case, Gateway has fixed bandwidth to be shared by all the clients for communication. With increased number of clients there is a considerable reduction in the efficiency of the per client communication. Associating clients to gateway is a crucial decision for performance improvement as is gateway placement, routing and scheduling. The default way of associating nodes to a single nearest gateway causes non-reliability in communication and also unfairness amongst the nodes. Clients can be associated to multiple gateways. Having choice of using multiple gateways for communication in WMN can improve performance.

1. Introduction

All Wireless mesh network (WMN) has gained a distinctive attention in the recent years both by industries and researchers. An IEEE 802.11s Wireless mesh networks connects several Mesh Access Points (MAPs) and Mesh Points (MPs) directly through radio. The IEEE802.11s terminology for Access Points in wireless mesh networks is as follows:

1. Mesh Portal Point (MPP): the Internet Gateway that connects the wireless subnet to through a wired or wireless connection.

2. Stations (STA): mobile clients and end users in WMN.

3. Mesh Access Points (MAPs): the routers that connect the mobile STAs to the wireless subnet.

4. Mesh Points (MP): are the intermediate nodes that let the STA get connected to MAP through multiple hops. MPs cannot provide services to STA. These are the nodes that act as both host and router for forwarding packets to the nodes in the range. They are just the intermediate nodes for STAs to get connected to the MAP and finally to the MPP for getting the services.

The mesh routers or gateways are those nodes which only perform the routing task and provide application support through backbone. There are three types of wireless mesh network architecture [5]:

Infrastructure or backbone network-

Infrastructure networks are the most basic class of WMN where the MAPs connect the clients to the backbone to provide the access to internet applications.

Client WMN-

In this type of architecture, there are no mesh routers. The clients provide all the facilities of applications required for each other.

Hybrid WMN-

The advantages of both the infrastructure and client network are in hybrid and therefore hybrid networks can be considered as the true WMN. The clients may also interact amongst themselves as in case of the client mesh networks.

Consider infrastructure or hybrid multi-hop network. The clients may not be uniformly distributed. For communication, a client node will always try to connect to the nearest gateway. The performance of the network may degrade in such case. There are two reasons for this. First, the congestion in the path as number of clients accessing a particular path increases. Second, on the gateway side there may be bottleneck. All the clients have to share the fixed bandwidth of the gateway and therefore it forms an upper limit on the number of clients accessing a particular gateway. There are even chances of unfairness among the clients. Remote clients may face starvation or may feel lost, whereas the clients nearer to the gateway will always enjoy the access with minimum delay.

The organization of the paper is as follows. In Section II the motivation for impact of gateway association on WMN is discussed. Challenges in gateway association are discussed in Section III. Section IV briefs how gateway affects the performance of WMN. Section V gives summary and the paper ends with section VI, the references.

2. Motivation

There are a variety of applications where WMNs are used and therefore there is some lower

bound on expected performance of WMN. There are several factors which may affect the performance of WMN on different layers as given in [3]. Gateway placement and gateway association is emerging area of research in the wireless mesh networking for performance consideration, though there are researches going on in improving routing and scheduling as well as channel allocation. The goal of all is the same: improving throughput of WMN and thereby improving the overall performance.

WMN are used widely because of low cost installations, use of un-licensed spectrum, no wired setup and therefore suitable for rural and the areas where wired setup is very difficult. The scalability both in size and density and flexibility are few more advantages of WMN. The ease of expansion and maintenance is added one.

Among wireless networks, WMN has enjoyed a great share of popularity. There are a number of successful deployments reported in [1][2][5]. But the related issues and drawbacks in WMN cannot be neglected. The issues related to the multi-hop wireless networks as discussed in [6], are inherent in WMN. Apart from these, WMN have their own pros and cons [3][4].

3. Challenges Related To Gateway

The In WMN, a gateway may play dual role- that of a client and as a router. The issues in gateways are of both hardware as well as software [13]. Gateways have their prominent role in network layer. The challenges in the network layer of WMN are therefore mostly gateway related. Following are few important ones –

Gateway placement-

Clients in WMN are not always uniformly distributed. For example, there is less density in parking area for communication as compared to that in an office. To improve the performance of WMN, placing the gateway at the right place in the network is essential [8][11]. Moreover, the WMN are dynamically self-organizing and self-healing and this imposes even more responsibility on gateway placement.

Mobile gateways-

The clients in the vicinity of gateway have access to it. As the basic requirement of WMN is support for wireless networking, the clients may be mobile. With the introduction of Wi-Fi and Wi-Max in the client network, the need for mobile gateways is felt even more. Implementing and installing mobile gateways without degradation of performance is another challenge related to the gateways in WMN[4]. It can be considered as one of the major reasons behind the need for modifications in the hardware of gateways.

Routing Protocols-

Many of the routing protocols of multi-hop wireless network and ad-hoc wireless network support for packet forwarding in WMN. Some specific routing protocols are needed for the WMN to improve the performance [13]. One of the characteristics of wireless architecture is that the connectivity is highly dependent on the routing protocols. It becomes even more important when the individual client networks are of different types and using different technologies. The routing protocol affects the performance of entire WMN as it has to provide support for the mobile user connectivity as well as the wired user connectivity.

Scheduling Algorithms-

Yet another challenge the researchers trying to cope is the scheduling. Gateway forms the hotspot where all the traffic for a client network is concentrated. Apart from this, the gateways have to communicate with each other. Scheduling algorithms, therefore, are crucial in deciding the performance of a WMN. A number of researchers have introduced a variety of scheduling algorithms[14]. The scheduling algorithm in the client level may be different than the scheduling at the inter-gateway level.

Gateway access-

In hybrid WMN, clients are having access to each other and can access to any gateway in the network. The limited bandwidth has to be shared by the associated clients. Moreover, a variety of topologies can be used simultaneously in a WMN. In such cases, compatibility should be provided. The issue is discussed in more detail in the next section.

4. Gateway Association In WMN

Gateways are the hotspots where all the traffic of network is accumulated. There is no direct connectivity from client to the Internet. This makes it crucial on part of gateway to consider fairly all the clients and providing flexibility. Some applications involve audio and video data communication. For these, the speed also matters a lot. Gateways being the most costly device in network cannot be left over the performance issue of the network. Following are few of the impacts of gateway association:

Congestion in the network -

All the clients try to access the nearest gateway for getting connectivity to the backbone. This leads

to the congestion on the path having higher density of clients. When each client has a single gateway association, the gateway has fixed bandwidth which shared by all the clients associated to it, there are chances of data loss. The nearer clients may even get the chances but the clients located remotely may completely feel lost in the network. The congestion may lead to bottleneck at the gateway side also.

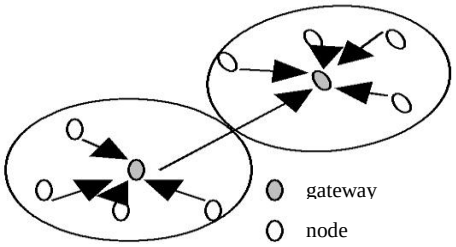

Figure 1: Congestion at the Gateway

Throughput Reduction-
The capacity of WMN is the capacity of gateway to communicate data in the network from source to destination not only in a secured way but even faster [7]. The throughput in WMN is given by

$$NT = \sum_{i=1}^{g} \min(GL_i, C_i)$$

Where,

NT is the network throughput for a network with g gateways, and ,GLi is the aggregate load on the ith gateway, Ci is the capacity of the ith gateway,

The gateway has fixed bandwidth to be shared by all the clients by directing all the communication towards the gateway. It causes reduction in per client throughput as the number of clients is increasing.

Unfairness-

As in case of other networks, in WMN, each client connects to the nearest gateway for accessing the services. It is a multi-hop network and there are chances of treating nearer clients in a fairer way as compared to the farther ones. If clients have access to multiple gateways, on average every client will get same chances for communication [9].

Insecurity-

If the client network has only one gateway, through which the clients can access the Internet, then its very convenient for the eavesdropper and intruder to concentrate on that gateway and try to collapse the client network [10]. Client network associated to more than one gateway is comparatively better choice in such situation.

Performance degradation-

The performance degradation may be due to the hardware limitations of gateways, like limitations on range, the processing power, environmental issues (line of site). Instead of associating to a single gateway, for better results multiple gateway association may be a better choice [9]. Client associated to more than one gateway also increases the reliability by providing a redundant path for communication.

Complexity-

Though multiple gateway association appears to be a better choice it may have its own drawbacks. Maintenance of the routing information at the gateways may not be as simple as in single gateway association. Moreover, packet scheduling and sequencing may be another issue as all the clients may not be working in same topology. The architecture will become more complex with the added links for getting connectivity to more than one gateway.

5. Routing in clustered WMN

The For a clustered wireless mesh network, the clients communicate through the cluster head within the cluster. These cluster heads in turn facilitates the communication with the neighboring clusters through a node common to both the clusters.

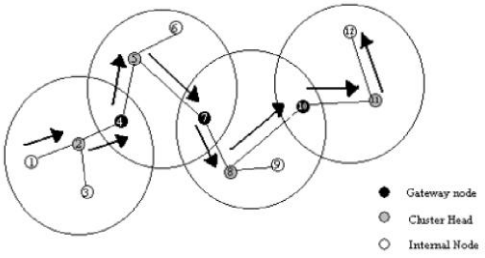

Figure 2: CGSR

Normally used routing protocol in such case is CGSR (Cluster head Gateway Switch Routing) that uses LCC (Least Cluster Change) algorithm to choose a cluster head. If a node has to route a packet, it finds the nearest cluster head along the route to the destination according to the cluster member table and the routing table. Then it will consult its routing table to find the next hop in order to reach the cluster head selected above and transmits the packet to that node. The routing principle in short is:

- Lookup of the cluster head of the destination node

- Lookup of next hop
- Packet send to destination
- Destination cluster head delivers packet

The advantage of CGSR is that there is only one entry for all the clusters in the routing table of a node and that is of the cluster head. But the disadvantage is that the cluster head failure may cut off the complete cluster from communication network. Also it is also very difficult to avoid congestion and unfairness with single cluster head.

Layered Structure is another option for wireless networks which is equally applicable to WMN. Each layer can have its own gateway and the routing can be done through either nearest gateway, through least loaded gateway or in a hybrid way.

Yet another combination may be the clustering and layering applied in the same WMN. Consider a hybrid WMN, as shown in figure 4, in which the cluster as well as layered concept is implemented. In the center is the cluster head selected by using the LCC algorithm. All the nodes in the single hop distance of the cluster head form the Layer 1 (L1), nodes at hop2 are the part of Layer2 (L2). The cluster head will periodically broadcast the routing table information along with list of nodes in single hop, two hops, and so on.

The node which was comparatively more static in a particular layer can be selected as the Layer-Head (LH) of that layer. All the nodes in a layer will communicate only through the Layer Head (LH). The nodes have to keep track of its LH only, whereas the LH will maintain information about the nodes in its layer and LH of neighbouring layers only. The cluster head will actively require the information about layer head of the single hop layer.

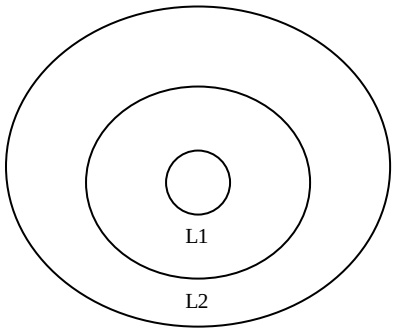

Figure 3: Layered WMN

These layer-heads along with the cluster head act as gateways and improve the performance of the WMN as-

The traffic is divided in inter-cluster and intra-cluster type.

The cluster head is concentrating on inter-cluster traffic.

Layer heads are responsible for intra-cluster communication.

It will reduce the congestion at cluster head.

Layer-to-layer communication can be done through layer-heads.

6. Summary

Wireless Mesh Networks can be utilized to their full potential provided that the issues are fixed to an acceptable level. The prominent issues related to gateway association which affect the performance of WMN are congestion, reduction in throughput, fairness problem, insecurity and reliability. The performance of WMN can be improved by associating the clients to multi gateways with added complexity, which is much lower compared to the performance gain. In clustered WMN, there can be multiple cluster heads which may work as backup or may take charge when the major cluster head fails. The secondary cluster head may assist the main cluster head for managing the routing or may in parallel work for sub-cluster within the cluster. The layered clustering is another option for improving the performance. Gateways form the foundation of WMN on which the entire network is built. Gateway association therefore cannot be placed in the second row when it comes to performance improvement of the network.

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