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Gateway Load Balancing in Wireless Mesh Networks

Monalisa Jena[1], Bhupendra Ku. Gupta[2]
Institute of Technical Education and Research,
Siksha O Anusandhan University, Bhubaneswar, Odisha, India

Abstract: Gateway nodes are most important in Wireless Mesh Networks (WMNs) as most of the traffic is forwarded through them. As a result of this imbalance in the network condition may occur if one gateway becomes overloaded (through which maximum flow is forwarded) and some become underutilized. We propose one Gateway Load Balancing Algorithm (GWLBA) which is a distributed load-balancing protocol where gateways co-ordinate and exchange information about network condition and reroute traffic from congested gateways to underutilized ones. Our approach takes interference into consideration along with load balancing. We have simulated our approach using ns-2 .We have compared our scheme with some other schemes and shown that our scheme is better than them.

Keywords: Gateway nodes, wireless mesh networks (WMNs), load balancing, traffic, flow, GWLBA

I. INTRODUCTION AND MOTIVATION

Wireless Mesh Network (WMN) is a multi-hop wireless network with partial mesh topology, which can replace wired infrastructure backbone in a traditional wireless network, to wireless. It is a network in which each node does not operate as a host only but also acts as a router, which forwards the packets on behalf of other nodes which may not be within the direct transmission range of their destinations [1]. It is an exciting new technology that has applications in defense, metro-area internet access, and disaster management. It consists of mesh routers and mesh clients, where mesh routers have minimal mobility. The backbone of the wireless mesh network consists of mesh routers, which connect each other in an ad hoc manner via wireless links. The presence of backbone mesh routers and utilization of multiple channels and interfaces allow the wireless mesh networks to have better capacity than that of the infrastructure-free ad-hoc networks formed by mesh clients directly. Some of these mesh routers are directly connected to a fixed infrastructure network and function as gateways for other routers [2].

Gateway nodes are Key components in WMNs. Most of the traffic is forwarded to or from gateways. They act as communication bridges between the wireless backbone and the internet. All information is pass through the IGWs. Thus, traffic aggregation occurs in the paths leading to a gateway. Some of the IGWs are heavily loaded while others are lightly loaded. Congestion occurs around a heavily loaded IGW. It leads to decrease in the network performance in terms of increased packet delay and higher packet loss probability. Load balancing routing is essential to accommodate more user traffic by properly distributing load among sink routers and choosing an optimal route(s) between each user and the corresponding sink router.

II. RELATED WORKS

There are a number of works concerning the problem of load-balancing in WMNs. Various solutions are proposed in [3], which focus on evening the load of all gateways. Most of these don't take into account the effects of contention and interference of flows and perform poorly in practice, as we will show in this paper. In WCETT-LB [4] and AODVST [5], extensions are made to existing solutions to allow nodes to switch to alternate gateways when their default gateway is congested. In [6] and [7], authors propose load-balancing schemes with similar objectives. Most of these can suffer from route flapping or poor performance for not taking contention into account. Hsiao and others in [8] propose a distributed algorithm to find a fully top load-balanced tree, using a interference-free model. Authors in [9] study the problem of load-balancing in mesh networks. The load-balancing algorithm is executed in a centralized point outside the mesh network, using a interference-free graph-theoretic model. Several studies use balanced trees rooted at the gateways and route traffic along the tree paths. Raniwala et al. propose the Hyacinth architecture for multi-radio multichannel WMNs in [10]. Routing and channel assignment is done distributively and dynamically. The performance results are mainly concerned with the increase in throughput due to the use of multiple channels and the different channel assignment strategies. Authors in [11] seek a delay-optimal routing forest, where a tree is rooted at each gateway. The cost function is not load-dependent; therefore their scheme won't achieve appreciable gains over shortest path routing in balanced topologies. In [12], authors proposed one Gateway Load Balancing (GWLB) Algorithm which is build upon nearest gateway (NGW) solution. It outperforms many schemes. Our paper is an extension of [12].

III. NETWORK MODEL

We consider WMNs which comprise of wireless static or quasi-static mesh routers, also called nodes. These nodes form a wireless multi-hop network. Mesh clients, also called users, connect to the mesh routers. A subset of nodes, referred to as gateways, is directly connected to a fixed infrastructure, which we say Internet.

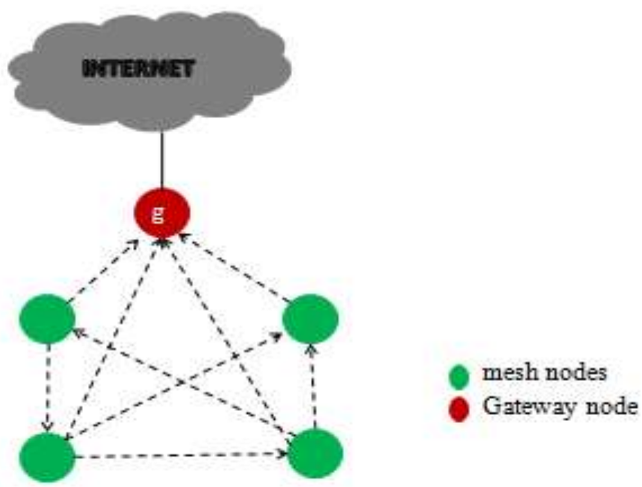

Fig.1: Graphical presentation of Network model

Each router has one radio interface (e.g. 802.11b or g) for communication with other routers, using a single common channel. Communication between nodes and users is done via a separate interface (wired or wireless). Although intra-WMN communication is possible, we assume that most of the traffic will be directed to the Internet. A user can access the Internet through one or more links leading from its router to a gateway.

A. Problem Statement:

Let G be the set of gateways in the WMN. A sink is a router that receives Internet traffic. Traffic directed to a sink must be served by a gateway node. The choice of serving gateway for each particular sink must be made by the load-balancing protocol. A domain di is the set of sinks served by gateway GW_i where i=1, 2, 3 in case of our example. Fig. 2 shows an example of WMNs. A set D of domains constitutes a solution to the problem. Let us call nearest gateway (NGW) the solution adopted by shortest path routing using a particular metric (e.g. hop-count).With NGW all sinks are associated with their nearest gateway in terms of the routing metric. Fig. 1 shows a possible NGW solution using hop-count. NGW can result in domains which are congested while others are not. In the example of Fig.2, if we assume that the capacity of the domains is 25, d3 will be overloaded (its load is the sum of demands of its sinks, i.e.30). While the load of d1 is 15 and d2 is 20. If the traffic ofR14 is rerouted to d1or d2, all domains would be uncongested.

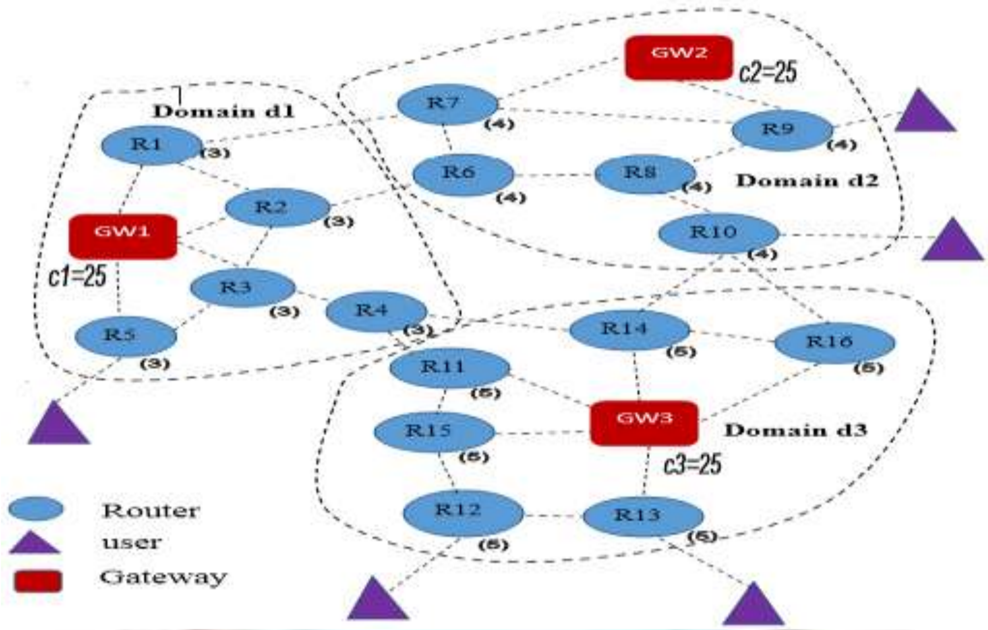

Fig 2: WMNs divided into 3 domains each having capacity 25

Now question arises to which domain should we move the traffic of R14 so that d3 becomes uncongested? The extra amount of load on d3 is 5(30-25). If we move this amount to d3 then load of d2 will become 25 which is equal to its capacity. So here a bottleneck condition arises. We can easily move the traffic to d1 as after moving the traffic its new load becomes 20 which is still less than its capacity so nothing to worry. So after load balancing the load of d1=20, d2=20 and d3=25. Now the network is in a balanced-condition.

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IV. EVALUATION

We analyzed the performance of our approach using network simulator ns-2[13]. Our goal is to compare the performance of GWLBA with some of the load-balancing algorithms in [3]. Simulations run for 500 seconds. The MAC layer employs 802.11b with a data rate of 11Mbps. We have generated one random topology which consists of 100 static nodes placed in a 1000×1000 square meter area. Of these, five act as gateways and the rest as mesh routers. Mesh clients are also present at the border regions of the square area. Gateway placement is fixed for all topologies: there is one gateway in the center and one in each corner of the square area hence resulting in four domains. Mesh routers are placed randomly, but with
Some restrictions: there is a minimum distance of150 meters between every pair of nodes, and the generated topology must be connected.

Gateways are connected to the wired network (Internet) by100Mbpslinks. A subset of routers act as sinks. Traffic is generated at an Internet server and sent to a varying number of randomly chosen sinks in the WMN, between 5 and 20. Traffic is CBR/UDP type. For each user, the time between start of connections follows an exponential distribution with λ = 1/10,000 ms, and the size of the download traffic of a flow follows an exponential distribution with λ = 1/65,000 byte. Simulations last until all flows finish, with users starting connections during the first100s.The switching threshold of GWLBA is Δ_s = 1.6. For the other protocols, we have used the same parameters as in [3].

We compare the network throughput and packet delivery ratio of all schemes. In the Fig 3 each point represents an average of ten runs (corresponding to the ten different topologies). Traffic pattern and sinks are the same across all protocols tested. We have tested and compared GWLBA with two protocols of [3]: Minimum load-index (MLI) and Centralized assignment (CA). We can see from the figures3 and 4 that GWLBA outperforms the two schemes.CA performs poorly because contention is not taken into account. It doesn't take into account their distance to gateways or interference with other flows. GWLBA outperforms MLI because it only switches to minimize overload, i.e. when a domain is congested and others are not. GWLBA provides better throughput than them with respect to increase in number of nodes; also it provides better packet delivery ratio than them.

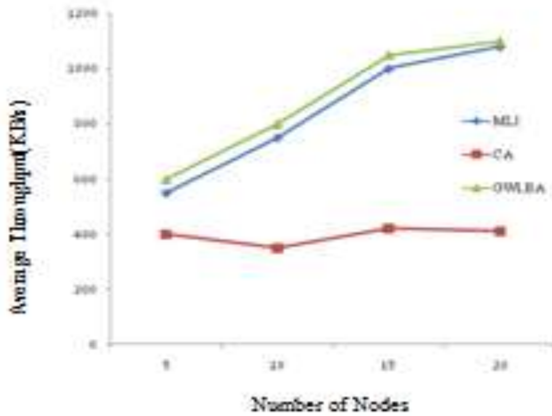

Fig.3: Average Throughput vs. Number of nodes

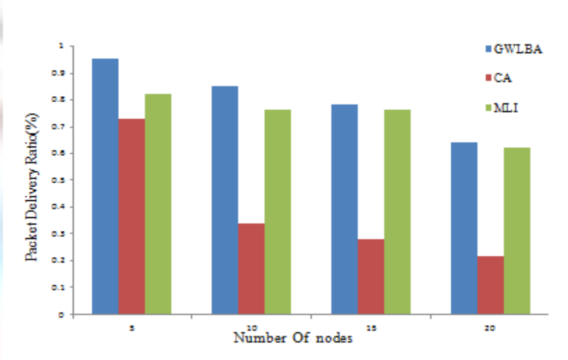

Fig.4: Packet Delivery Ratio vs. Number of nodes

In addition, we have taken another parameter, i.e. average delay into account for performance evaluation of GWLBA with respect to increase in number of nodes. Result is shown in Fig 5. Average delay decreases with respect to increase in number nodes. Where deviations occur that may be possibly due to the reason of any simulation error.

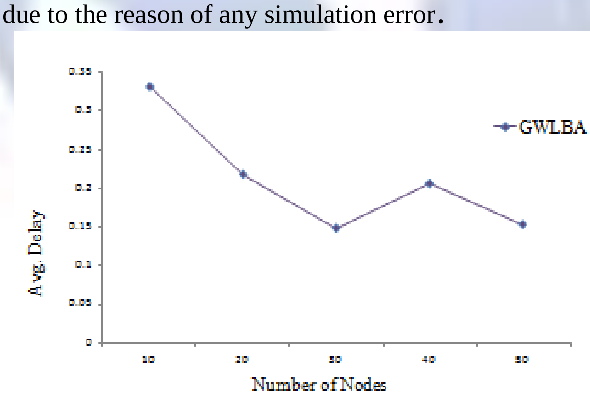

Fig.5: Average delay vs. Number of nodes

V. CONCLUSIONS AND FUTURE WORKS

We proposed GWLBA, a distributed protocol where gateways exchange information about their associated nodes and their demands, and co-ordinate to balance the load among them. Along with load balancing we have also taken the effect of interference and congestion into account. We have compared our approach with 2 other schemes such as Minimum load index (MLI) scheme and Centralized Assignment (CA) scheme and shown that our approach is better in terms of performance.

We have evaluated our approach using 3 parameters. In future we aim to extend our approach by evaluating the performance of the approach using other parameters such as bandwidth, packet loss ratio, etc. For further extension, GWLB can be applied to other networks such as multi-radio wireless mesh networks.

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