Global Journal of Computer Science and Technology: E
Network, Web & Security
Volume 16 Issue 6 Version 1.0 Year 2016
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Gateway Placement in Mesh Network Using Traffic off Loading Through 2g/3g Networks

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Abstract- Wireless mesh network is a new network paradigm to provide seamless internet services. In this network, users interact with access points also called router are placed at various points in cities and user can access the internet by connecting to these access points. Access points in turn connect via multi hop to internet gateway. Internet gateway provides internet services. Wireless Mesh network suffers from congestion problems with increasing user base. Many solutions have been examined previously like increasing the gateways, optimum location of gateways, etc., but all these still solutions have a constraint on maximum scalability and many times traffic load is maximum only at a certain period of time and later load is less, so scaling is not a profitable solution in this case as the access point is not loaded to capacity most of time and cost spent on it is not fruitful.

GJCST-E Classification : C.2.6, C.2.1

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Strictly as per the compliance and regulations of:

Gateway Placement in Mesh Network Using Traffic off Loading Through 2g/3g Networks

Nanda P [α] & Dr. Josephine Prem Kumar[σ]

Abstract- Wireless mesh network is a new network paradigm to provide seamless internet services. In this network, users interact with access points also called router are placed at various points in cities and user can access the internet by connecting to these access points. Access points in turn connect via multi hop to internet gateway. Internet gateway provides internet services. Wireless Mesh network suffers from congestion problems with increasing user base. Many solutions have been examined previously like increasing the gateways, optimum location of gateways, etc., but all these still solutions have a constraint on maximum scalability and many times traffic load is maximum only at a certain period of time and later load is less, so scaling is not a profitable solution in this case as the access point is not loaded to capacity most of time and cost spent on it is not fruitful. Considering this problem, we have proposed a hybrid mesh network solution integrating 2G/3G network into mesh network [1] to handle the load on a mesh network. But the location of the gateway is fixed in this approach, based on the traffic offloading pattern, if the gateway can be moved, we can still achieve some more QOS. In this paper, we explore this idea and propose a solution for effective placement of gateway for the offloaded mesh network.

I. Introduction

Wireless Mesh Network (WMN) is emerging as a promising technology for providing internet services in cities and urban area with minimal infrastructure cost and fast deployment.

WMNs are multi-hop infrastructure based wireless networks that are interconnected by a set of relatively stationary wired gateways connected to the Internet. The routers that relay traffic and the client may or may not be mobile. Most of the traffic in a WMN flows from the client to the gateways.

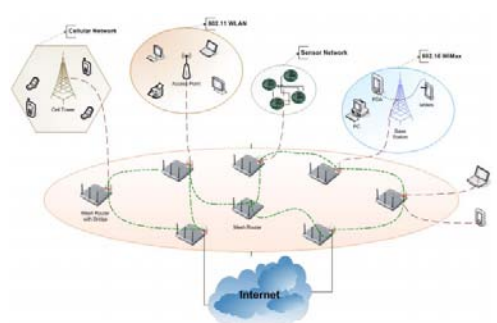

Figure 1: Wireless Mesh Network

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a) WMN consists of following types of nodes

WMN Clients: These are the end-user devices like PDAs, laptops, smart phones, etc., that can access the network for using applications like email, web surfing, VoIP, and alike. These devices are assumed to have limited power, having none or limited routing capabilities, and may or may not be always connected to the network. Mobile Ad-hoc Networks (MANETs) can be assumed to be a special case of WMNs that are formed purely by WMN clients.

WMN Routers: These network elements are primarily responsible for routing traffic in the network. Traffic does not originate or terminate at a router. The routers are characterized by limited mobility and relatively high reliability. Compared with conventional wireless routers a wireless mesh router can achieve the same coverage with much lower transmission power consumption through multi-hop communications. Additionally, the Medium Access Control (MAC) protocol in a mesh router supports multiple-channels and multiple interfaces to enable scalability in a multi-hop mesh environment..

With increasing user base, congestion happens in routers or gateways and due to this quality of service degrades in the Wireless Mesh Network. Many solutions have been proposed to increase the quality of service in wireless mesh network and this is surveyed in the section 2 of this paper. We have proposed a concept of hybrid mesh network with some of the mesh clients doing 2G/3G offloading of internet services. When offloading clusters are created in the network, we can still increase the QOS if the Gateway can be repositioned according to the location of offloading clusters. In this work, we evaluate this concept and measure the QOS due to Gateway repositioning according to offload clusters.

II. Related Work

We categorize the existing works on QOS improvement as below

1. MAC Layer optimization
2. Optimized Routing Protocols
3. Optimized Gateway Placement
4. Optimized Router Placement
5. Cross Layer Protocols

a) MAC Layer Optimization

In [1], S-TDMA based MAC was proposed for wireless mesh network in which continuous power control is done to reduce the noise interference and rate allocation is done to increase the capacity.This solution relies on conflict free scheduling, to increase the throughput by avoiding collisions, but the solution does not address delay due to conflict free scheduling, Mesh Routers and Mesh client have to wait in turn for time schedule and as delay increases buffer overflow occurs in routers and QOS is affected. So it is not a scalable solution.

In [2], solution based on increasing the contention window size to lower the collision is proposed. By reducing the collision throughput can be increased. A spatial extension of the TXOP concept called 'express forwarding' to clear multi-hop flows sooner, and a new mechanism called 'express re-transmission' to reduce collisions on retransmission were also proposed.

In [3], use of smart antenna to do directional transmission and link scheduling algorithm to activate the links in such a way to increase the network capacity was proposed. But this is not a scalable approach as new routers are deployed to existing network; placement becomes a difficult operation and has to place without interfering with the path of another router. Also the use of smart antenna will increase cost of Routers.

In [4], STDMA based scheduling was done at MAC layer with admission control. Admission control ensures clients have a minimum guarantee of bandwidth and maximum delay. It works for VOIP services, but it is not profitable to apply this solution as clients will switch to a different operator if strict admission control is enforced.

b) Optimized Routing Protocol

In [5], the routing protocol in WMN is adapted to choose the relay nodes in the path on estimation of wireless link quality and bandwidth. But without any control on the rate of transfer, this approach is not useful as a path found efficient based on link quality and bandwidth can later be congested due to a variable rate of usage from clients.

In [6], Weighted Contention and Interference routing Metric (WCIM) is proposed. Based on interference, bandwidth available, quality of link, etc., a metric is calculated for each node. Routing is done in such a way next node with the highest value of the metric is choosen as relay node in the route. The problem with these approaches is that it requires frequent exchange of information between nodes to calculate the metric and also it is not end to end decision. When end to end is considered there may be a better path with more WCIM value than the current chosen path and the solution converges in local minima.

In [7], routing based on opportunistic method is proposed. Every node overhearing other nodes in wireless medium can assist in routing in case of failure. But this method has many practical difficulties in deciding the cooperation and also increases the network communication overhead.

c) Optimized Gateway Placement

In [8], the controllers are placed optimally in the network using Particle Swarm optimization technique for maximizing the flaws in network found out by using a Ford Fulkerson algorithm. But this method requires frequent movement of controller based on traffic observation over a period of time.

In [9] wireless mesh network is clustered based on the degree/number of Wireless mesh routers connections, while ensuring Delay, Relay load and Cluster size constraints.

In [10], is proposed a genetic algorithm based solution for gateway placement. This solution optimized variation of MR-IG-hop counts (VAR-MRIG-Hop) among MRs to ensure that the Gateways are placed in the appropriate positions. But during loading, the solution cannot maintain QOS.

d) Optimized Router Placement

In [11], a heuristic solution, called PRACA (Placement, Routing And Channel Assignment) has been proposed to find the optimal position for the router in the Mesh Network. The solution jointly considers routing channel assignment and placement to get the optimal solution for placement. In this way it tries to eliminate interference and improve QOS.

In [12], solution for placement of multi rate routers in mesh network was considered. It presented a heuristic placement algorithm called ILSearch which takes into account both multiple transmission rates and co-channel interference. The ILSearch consists of two components: (1) Coverage MR determination which greedily exploits the capability of each selected MR to cover mesh clients (MCs); and (2) Relay MR determination that incrementally chooses the additional MRs for traffic relaying through the local search.

In [13], the nearest cell association algorithm was proposed to reassign users to routers in different times and a greedy search to find optimal positions for the router. They have proved that QOS is improved due to switching users between routers in this way.

e) Cross Layer Protocols

In [14], cross layer mixed bias algorithm was proposed. The cross-layering will provide information on the link-quality and distance between nodes. Link quality will be provided from the physical layer while distance can be provided in many ways. The Distance could be computed by the number of hops between two points, by measuring the delay or by using real life coordinates if the nodes are equipped with Global Positioning

Systems (GPS). In this paper the author used the number of hops. A portion of the scheduling resources will be biased according to a set of heuristics that penalize nodes for various “bad behaviors” such as distance from the gateway, overuse of traffic, poor link quality and so on. Each heuristic will be assigned a different proportion of the network resources which will be determined experimentally. Another portion of the resources will be left for absolute fairness in order to ensure that none of the links are starving and that some minimum level of service is maintained. Then the collective system will be optimized to produce high throughput fair scheduling for wireless mesh networks.

In [15], two cross layer routing was proposed a loosely coupled cross-layer scheme and a tightly coupled cross-layer scheme. In the loosely coupled cross-layer scheme, routing is computed first and then the information of routing is used for link layer scheduling; in the tightly coupled scheme, routing and link scheduling are solved in one optimization model. The two cross-layer scheme involves interference modeling in multi-hop wireless networks with omni directional antenna. A sufficient condition of conflict-free transmission is established, which can be transformed to polynomial-sized linear constraints, and a linear program based on the sufficient condition is developed.

In [16], the authors proposed a new routing metric for wireless mesh network—CAETT (Congestion Avoidance Expected Transmission Time). With the queue's utilization rate and the transmit situation of control frames in 802.11 protocol's MAC layer, a reasonable path is chosen in terms of the channel competition status, link data frame delivery rate and the node's queue utilization rate.

From the survey we notice that each solution tries to achieve maximum QOS by reducing interference, parallel data rate, smart antenna, network component placements, etc.

One of the most important points noticed in all the solutions suffer from scalability issues and gateway can get overloaded soon with internet service requests. To reduce the overload on the gateway, multi gateway is suggested, but still there is a scalability problem.

III. Problem Definition

Given a wireless mesh network with mesh nodes, access points and gateways and some of the mesh nodes have internet connectivity through their 2G/3G and when the load on mesh network is high and some of access points in the network are, offloading network load through some of mesh nodes using their 2G/3G interfaces. By this way offload clusters are created in the network, the gateways has to be repositioned according to the location of offload clusters. The objective of this work is to find the best location for gateway, so that QoS is improved by the network due to the new location of gateways.

IV. Hybrid Mesh Network With 2G/3G

The architecture of the hybrid offloading scheme is given below in figure 2.

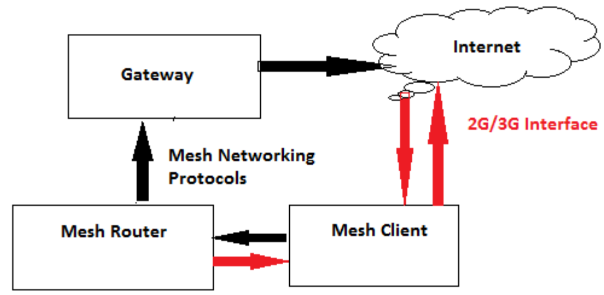

Figure 2 : Hybrid Mesh network with 2G/3G Interface.

From the traditional architecture, we introduce a offloading facility at Mesh Client for sharing its unused 2G/3G interface to wireless mesh network.

The mesh router's routing protocol is modified to enable the 2G/3G offloading capability.

Mesh clients who are interested in offloading their traffic must register their interest to the mesh router. Also Mesh client at any point of time when it needs the additional bandwidth can unregister its interest for offloading to mesh router.

By this way offload clusters are created in certain spots in the network. Offload clusters provide internet services. The gateway positioning according to load of network is an existing solution for improving quality of service.

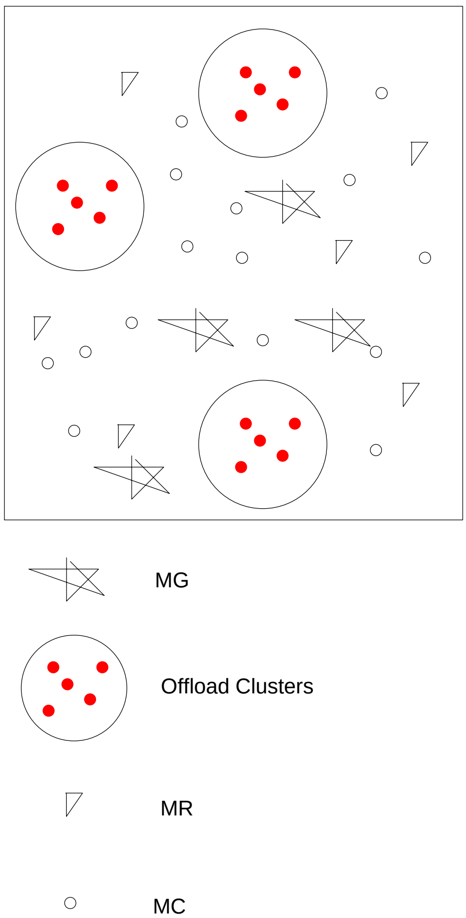

Figure 3 : Offload clusters and other hybrid mesh network elements

In this work, we use three important information to position the gateway, the prediction of load at different spots, current load at spots and the location of offload clusters.

The wireless mesh network is split to lots of grids. The historic traffic generated at each of these grids are collected and we train a AIRMA model to predict the load on the grid in the next interval of time called epoch. As a result of this, we know the current load at grid and predicted load at next interval of time.

Suppose that there are Ng mesh gateways located on the network and Nc offload clusters created in the network with current load and the predicted load known at each of the grid, the Ng mesh gateway has to reposition to provide a better QOS.

QOS we model as dependent parameter on distance and load at the gateway. QOS is better if the node finds a gateway at the nearest distance with less load.

$Q \propto 1 / (Dg * Dg)$

$Q \propto 1 / (Lg)$

$Q = k / Dg^2 * Lg$

Where

Q is the Qos

Dg is the distance to gateway

Lg is the load at gateway.

For each Grid, the current QoS and predicted QoS for each of the N gateway and the offload clusters is calculated. From the current QOS values we find the average QOS values and find the number of gateways with QOS less than average and number of gateway above the average.

A fitness function is modeled for the entire network as

F = w1 * Ngabove - w2 * Ngbelow

The w1, w2 value can be set to any value from 0 to 1 such a way that w1 + w2 = 1.

The best position of Gateway is found using GSO(glowworm swarm optimization) with the maximization of the fitness function (F) defined above.

In GSO, glowworm swarm S, which consists of m glowworms, is distributed in the objective function search space. Each glowworm gj (j =1...m) is assigned a random position pj inside the given search space. Glowworm gj carries its own Lucifer in level Lj, and has a vision range called local-decision range rdj. The Lucifer in level depends on the objective function value and the glowworm position. The glowworm with a better position is brighter than others, and therefore, has a higher Lucifer in level value and is therefore closer to the optimal solution. All glowworms seek the neighborhood set within their local decision range, and then move towards the brighter ones within the neighborhood set. Finally, most of the glowworms gather in compact groups in the function search space at multiple optimal locations. GSO works in an iterative process that consists of several Lucifer in updates and glowworm movements, which are executed to find optimal solutions. The Lucifer in level Lj is updated using the following equation:

$$L_j(t) = (1-\rho)L_j(t-1) + \gamma F(p_j(t))$$

After that, each glowworm j explores its own neighborhood region to extract the neighbors that have the highest luciferin level by applying the following rule:

$$z \in N_j(t) \;\; \textit{iff} \;\; Distance_{jz} < rd_j(t) \;\; and \;\; L_z(t) > L_j(t)$$

where z is one of the neighboring glowworms close to glowworm j, Nj (t) is the neighborhood set, Distance jz is the Euclidean distance between glowworm j and glowworm z, rdj (t) is the local decision range for glowworm j, and Lz (t) and Lj (t) are the Lucifer in levels for glowworm z and j, respectively. After that, each glowworm selects the movement direction using the roulette wheel method. Therefore, the glowworm position (pj) is adjusted based on the selected neighbor position (pz) using the following equation:

$$p_j(t) = p_j(t-1) + s\,\frac{p_z(t) - p_j(t)}{Distance_{jz}}$$

pj(t−1) is glowworm j's previous position, s is a step size constant, and Distancejz is the Euclidean distance between glowworms j and z.

The glowworm runs in iteration to the find best position for the gateway based on the maximization of the Fitness function. Once the iteration is completed, the best position for the gateways are known and the gateway is moved to that point if the predicted load is less than the current load in the current position of the gateway.

V. Results

We simulated the proposed solution on the wireless mesh network simulator Jprowler where some of the nodes are randomly chosen for offloading. Service requests are generated from the node with Poisson distribution over the simulation duration configurable by user.

We compared our solution without movement of gateway with just offload alone.

By varying the number of offload clusters, we measured the effective QOS in the network in terms of packet delay and the result is figure 5.1.

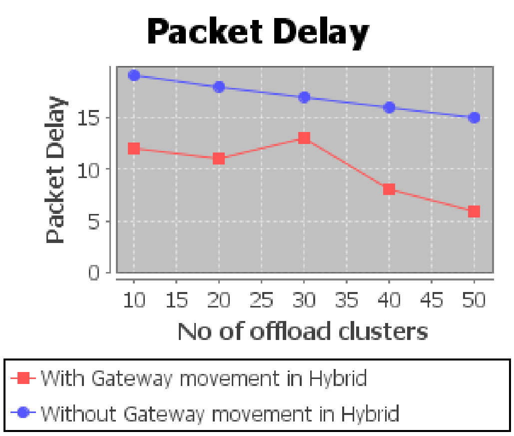

Figure 5.1 : Packet delay vs No of offload clusters

By varying the number of gateways in the network, we measured the effective QOS in the network in terms of packet delay and the result is Figure 5.2.

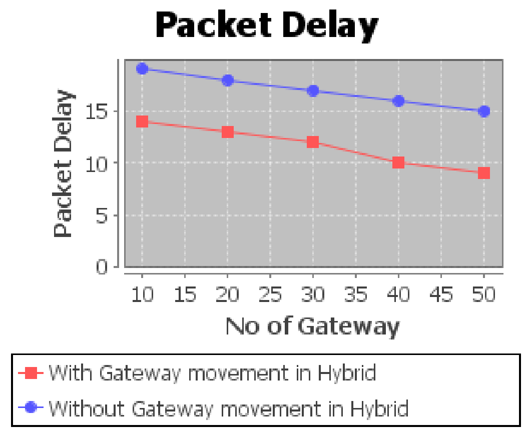

Figure 5.2 : Packet delay vs No of Gateway

By varying the number of offload clusters, we measured session drop ratio and the result is figure 5.3.

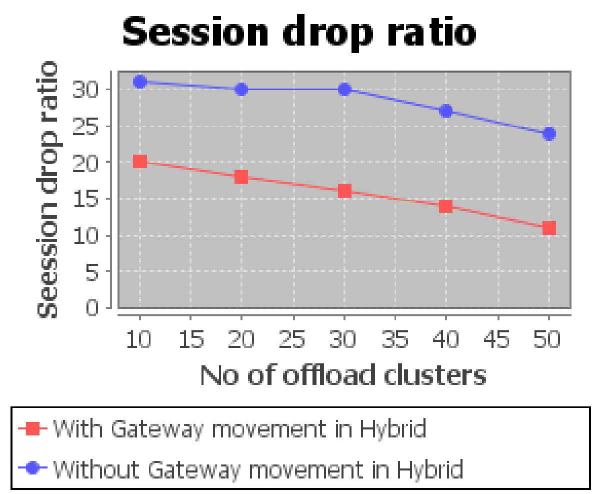

Figure 5.3 : Session Drop ratio vs No of offload clusters

By varying the number of gateways in the network, we measured the session drop ratio and the result is figure 5.4.

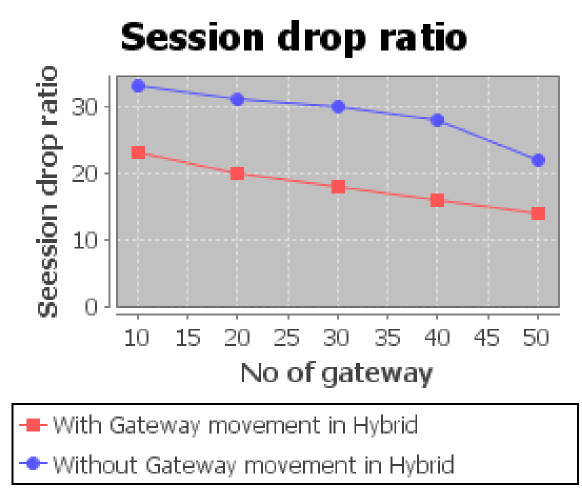

Figure 5.4 : Session Drop ratio vs No of Gateway

VI. Conclusion

The proposed offload solution with gateway movement is implemented through simulation, and we have proved that the QOS is improved in the network in terms of session drop ratio reduced and the average packet delay is reduced in the network.

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