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Wireless Mesh Network Deployment through Gateway Selection in Disaster Area

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Abstract: ***As communication services turns very important in disaster affected areas, the recovery of the remaining infrastructure becomes essential. Wireless Mesh network (WMN) proves to be a cost effective technology that provides backbone infrastructure to yield city-wide network access. Due to the self-recovery characteristics of Wireless Mesh Network (WMN), it has been used as an appropriate solution for network access in disaster areas. Throughput is used for evaluating the performance of the WMN. In this paper, we propose a gateway selection method to connect the destroyed network to an external network. Selection of different wireless mesh routers as gateway results in different system performance. The gateway is selected in a manner to maximize the system throughput. The simulation results show that effect of gateway selection of nodes on the system performance. The simulation is done using network simulator (NS2).***

Keywords: Wireless Mesh Networks (WMN), Mesh Gateway (MG), Access points (AP), Movable and Deployable Resource Unit (MDRU).

1. Introduction

The recent advancements in mobile units such as web-browsing, powerful processing and large storage capacity have changed their use from simple communicating units into powerful hand held computers. This requires a universal broadband Internet connectivity. Wireless Mesh Networks (WMN) is a next generation of wireless network which provides better services. In WMN, nodes are present as mesh router and mesh clients.

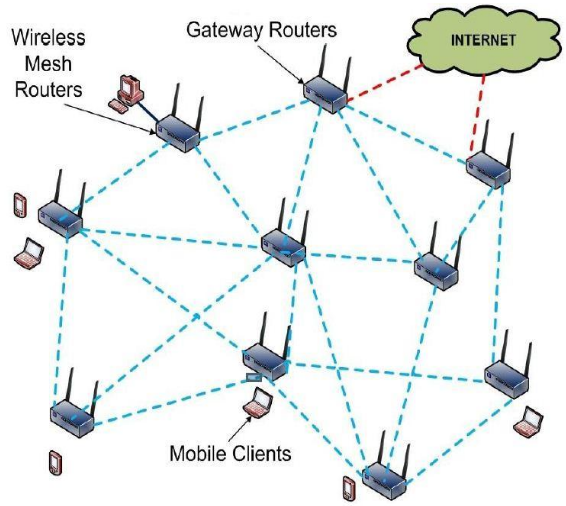

Figure 1: Basic Wireless Mesh Network infrastructure

Every node works as a host as well as a router as shown in Fig 1. It executes the process of forwarding packets on the side of other nodes which may or may not be within transmission range of their destination. For rescue operations, safety information such as number of victims, location and safety status are essential.

A number of still-active access points (AP) are always present even after the disaster, which can be used for network recovery. The APs must be able to quickly connect to nearby Internet access services. This network establishment should be quick and transparent to the victims. This is because the victims cannot be presumed to execute setup operations [4].

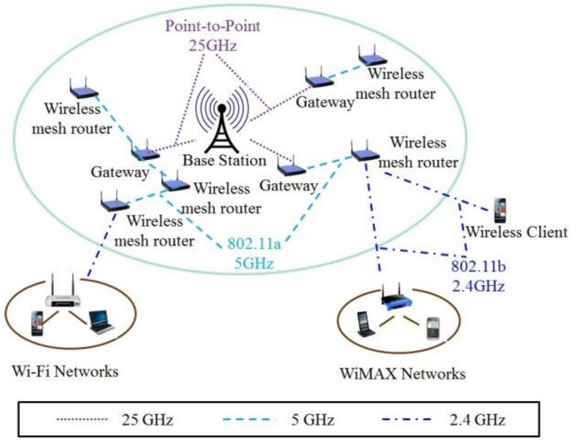

Figure 2: Internetworking Wireless Mesh Network

In a certain area, method to choose a mesh router as the gateway to provide maximum available system throughput has been a key issue in recent years. The goal is to easily and quickly find the candidate gateways that maximize the system throughput. WMN have gathered more attention because of its attractive advantages [2], [3].In[2], author has explained the details about Wireless mesh networks (WMNs).In [3], author has given an overview of WMN design considerations. The study identifies the fundamental WMN design problems such as interference modeling, power control, topology control, link scheduling and routing.

J. Jun et al. [6], considered throughput as one of the major criteria to evaluate network performance. There are many techniques to analyze the capacity of wireless mesh networks [6], [7], [8], [9], [10].P. Gupta et al. [10], present a solution to estimate the lower and upper bounds of network capacity under a protocol model of non-interference. The result showed that splitting the channel into several sub channels does not affect the results of bounds of network capacity. It also provided an important result that the throughput capacity decreases sharply with the increase in node density.

Panu Avakul et al. [4], presents a recovery technique for destroyed WMN. In this technique a Movable and Deployable Resource Unit (MDRU) is transported to the affected area. The MDRUs are huge communication device composed of various communication equipments. After MDRU arrives at the affected area, it will commence an initialization signal which can propagate through a large distance. Any still-working AP which receives this initialization signal and it will switch its working mode from normal AP to Mesh Router. These MRs will then construct a backbone network with a Mesh Gateway in that area.The overall capacity is given by Eq. 1.

$$C_{n\,f\,t} = C_{channel} \times num(MDRUs) \ (1)$$

where num(MDRUs) stands for the total number of MDRUs used [8].

Quang Tran Minh et al. [5], explains another approach which is to on-the-fly establishment of multihop wireless access networks (OEMAN). OEMAN expands Internet connectivity using remaining APs to the victims with the use of their own devices. After the distruction of all main components, the Internet access for any user in the affected area has been disconnected. The closest mobile node to the still-alive AP will attempt to associate with this AP. This would result in initialization of OEMAN.

2. WMN Deployment

A wireless mesh network (WMN) is a mesh topology of radio nodes organized to form a communication network. WMN is a type of ad hoc network. The mesh clients can be wireless devices such as cell phones, laptops, etc. The mesh routers are used to forward traffic which passes from the gateways. The nodes not only act as an end user but also perform function of a router.

WMNs have various attractive advantages [2], like low up-front cost, easy network deployment, stable topology, robustness, reliable coverage, and so forth. Since WMNs can be easily deployed without wire lines among wireless mesh routers, they allow fast recovery for network access services in disaster areas even if the existing network infrastructures have been enormously destroyed.

As shown in Fig. 2 an example of WMN infrastructure designed for an actual disaster area is considered. Here, the network is divided into three hierarchies. The top hierarchy is deploying a base station located at the center of the wireless mesh network to take charge of the whole area, choosing a certain number of wireless mesh routersas gateways, and establishing a connection with each of them by point-to-point with 25GHz band. The middle hierarchy consists of wireless mesh routers that make up the network backbone with one or more of these nodes directly connected to the base station as the gateway, with high frequency band (5 GHz), is used in the network backbone. The bottom hierarchy consists of mesh clients that are deployed at the edge to communicate with the mesh routers by using 802.11b with 2.4 GHz.

2.1 Gateway Selection Method

The method of selecting gateways which has a connection to external networks, significantly impacts on the network performance when the topology and routing have been fixed in the wireless mesh network. Here, we suppose a wireless mesh network which consists of wireless mesh routers and a base station directly connected to external networks. The base station of the wireless mesh network chooses a certain number of wireless mesh routers as gateways, and establishes a connection with each of them. The goal is to easily and quickly find the candidate gateways that maximize the system throughput without solving a complex optimization problem which includes a large number of parameters and involves heavy computation load.

The base station canselect a number of wireless mesh routers as gateways, and establish a connection with each of them. Only one gateway is considered ina certain area. If there are multi-gateways, the problem can be solved by separating the nodes related to one gateway from nodes associated to other gateways.A network topology has been designed to analyse the system throughput. Thewireless mesh router nodes are randomly deployed within a certain area, and they contact with adjacent nodes when the distance between two of them is less than the transmission range. The Minimum Spanning Tree (MST) algorithm has been utilizedto delete the redundant paths and maintain the uniquerouting path for our network topology.

2.2 System Parameters

1) Theoretical Maximum Throughput

To track the issue of calculating available system throughput, there are two key factors to affect the result. One is the theoretical maximum throughput T_{max} in MAC layer [11]. We can get the value of T_{max} by utilizing Eq. 2.

$$T_{max} = \frac{MSDU\ size}{T_{delay}} \ (2)$$

where MAC Service Data Unit (MSDU) is defined as a packet pushed from the higher layer down to the MAC layer, and T_{delay} is the consumed time for transmitting per MSDU packet, including the components like Short Inter Frame Spacing (SIFS), Acknowledgment (ACK), Distributed Inter Frame Spacing (DIFS), Request To Send (RTS), Clear To Send (CTS), Back Off (BO), and payload size [1]. As a consequence, we can calculate the exact result of theoretical maximum throughput in MAC layer.

2) Bottleneck Collision Domain

After obtaining the theoretical maximum throughput T_{max}, another key factor to determine is the bottleneck collision domain, which is the collision domain that has to forward the most traffic in the network, to analyze the throughput of the network. Here, the collision domain is determined as a set of wireless links with the shared nature that connects mesh router nodes. The available throughput can be reached the upper bound G_{max}, when it is equal to the theoretical maximum throughput in MAC layer T_{max} divided by the Bottleneck Collision Domain (BCD) [6] as shown in Eq. 3.

$$G_{max} = \frac{T_{max}}{BCD} \quad (3)$$

3) Selecting a wireless mesh router as the gateway

We need to select an optimal node as the gateway to ensure the maximum throughput in the network. The throughput depends on the theoretical maximum throughput T_{max} and the bottleneck collision domain. T_{max} can be exactly calculated as a constant value by the given 802.11 protocol [12]. In other words, the bottleneck collision domain is the key factor to affect the optimal throughput in the network. As a consequence, the mesh router node that has the smallest bottleneck collision domain should be chosen as gateway.

3. Algorithm

The selection of gateway follows the following steps:

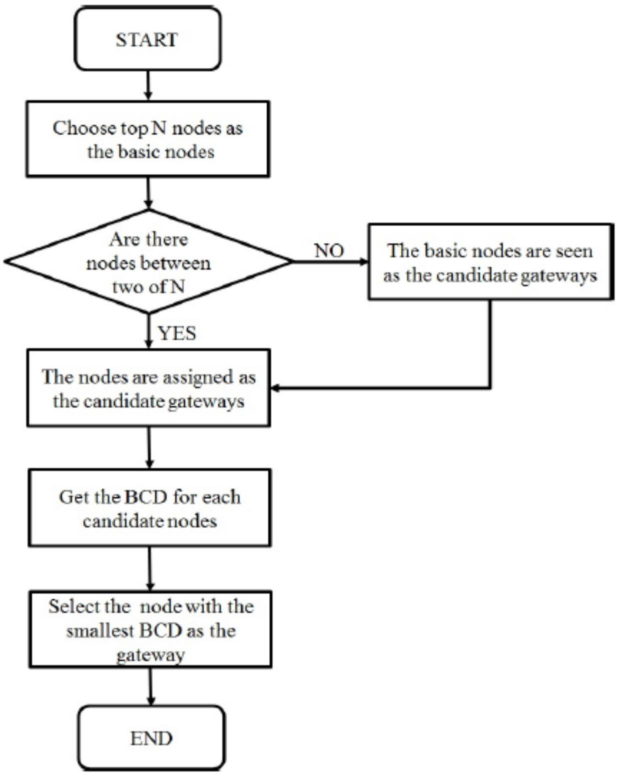

Figure 3: Gateway selection algorithm

- Step 1: First focus is on the nodes that have the heavy loads. These nodes are vital to influence on the bottleneck collision domain. Therefore, from all of the mesh routers, we choose the number of top N nodes with heavy traffics asthe basic nodes, which account for the vast majority of traffic loads in the network.
- Step 2: Then, concentrate on narrowing down the range of the candidate nodes by utilizing the selected top N nodes. Assign the nodes that are on the routing path between two of N as the candidate gateways.
- Step 3: Furthermore, according to the analytical calculation method given in the system parameters, estimate the system throughput on basis of each candidatenodes regarded as the gateway.
- Step 4: Finally, through comparing the results of each candidate nodes, select the node with least distance as the gateway.

4. Simulation

The performance evaluation is achieved through network simulator (NS-2). The default simulation parameters are presented in Table 1.

Table 1: Simulation Parameters

Parameters	Value
Number of nodes	50
Network size	1000
Radio range	250
Traffic source	CBR
Sensor field(m^2)	1000 x 1000
Packet size	512
Packet interval (ms)	2

The simulation results show that the throughput varies considerably with the selection of gateways. The variation of throughput after selection of different number of gateways is shown in fig 5. The distance of gateway selected affects the energy consumed by the node for transmission. Fig 6 shows a difference in the energy required due to selection of gateway with least distance. As for disaster area energy efficient method is more profitable.

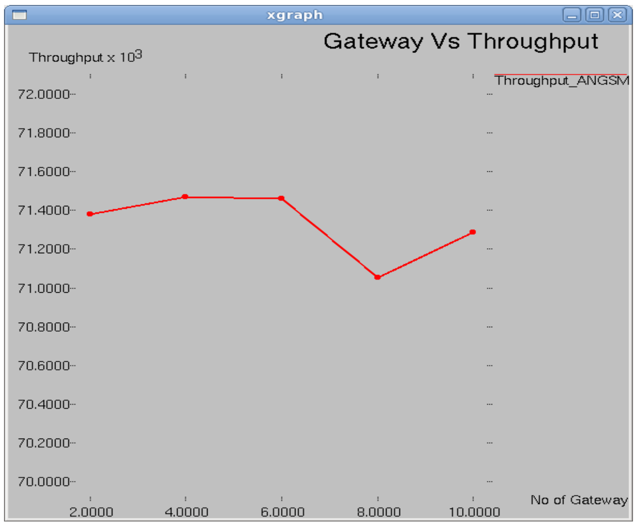

Figure 4: Simulation result for gateway vs throughput.

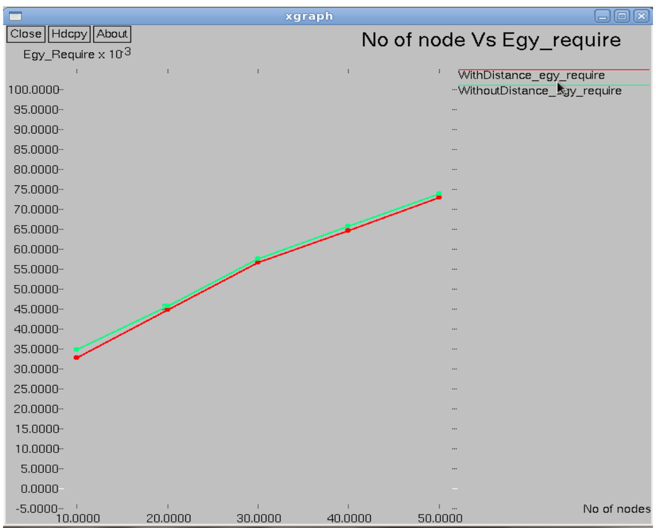

Figure 5: Simulation result for effect of distance on energy required

5. Conclusion

A method that easily assigns a few nodes as candidate gateways that are on the routing path between the selected basic nodes can be implemented. Evaluation of throughput for each candidate node can be done and then the node with maximizing the system throughput is selected as the gateway. This reduces the need for solving a complex optimization problem which includes a large number of parameters and involves heavy computation load.

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