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Optimizing Interference Management in Multi-Channel Multi-Radio Wireless Mesh Networks

Dr. Harsh Lohiya[1], Mulla Tahaseen Munaf[2]
[1]Research Guide, Dept. of Computer Science & Engineering
Sri Satya Sai University of Technology and Medical Sciences,
Sehore, Bhopal-Indore Road, Madhya Pradesh, India

[2]Research Scholar, Dept. of Computer Science & Engineering
Sri Satya Sai University of Technology and Medical Sciences,
Sehore, Bhopal-Indore Road, Madhya Pradesh, India.

ABSTRACT

Wireless Mesh Networks (WMNs) face challenges in load balancing due to high traffic volumes. Unequal load distribution stems from two main factors: the dispersed nature of clients and their varying demands. The primary goal is to develop multi-frequency hybrid radio network systems with dynamic frequency allocation and gateway selection. A framework termed "LACE - Load-Aware Frequency Estimation" is introduced to enhance network protection, lifespan, and quality while reducing packet loss, latency, energy consumption, and routing overhead. This approach facilitates the expansion of coverage without compromising frequency capacity by enabling dynamic frequency allocation and gateway selection in WMNs.

Keywords: Multi-frequency hybrid radio networks, Dynamic frequency project, Gateway selection, Load-Aware Frequency Estimation (LACE), Network performance optimization

INTRODUCTION

Wireless Mesh Networks (WMNs) are strategically positioned on the periphery of wired networks to extend Internet accessibility for mobile users. These networks, also known as multi-hop radio net systems, have been widely adopted, with implementations in various American communities like Oregon, Medford, and Minnesota's Chaska. Notably, Philadelphia, Pennsylvania, has the infrastructure to establish a comprehensive WMN covering the entire city, enabling local residents and businesses to access commercial Internet services. The access points (APs) in radio net routers are typically fixed and exhibit stable structures similar to wired counterparts, minimizing disruptions and node failures over time. While WMNs have self-organizing capabilities, node additions or alterations are infrequent. Each net router can efficiently manage data transfers from multiple mobile clients, ensuring a uniform distribution of traffic load across all net routers. Some WMNs feature a gateway functionality facilitating connections with wired networks. Most WMNs primarily utilize their radio backbone for communication, addressing challenges such as interference through multiple radios in net routers. Researchers have developed heuristic algorithms for frequency allocations and load-aware routing to enhance WMN performance and evenly distribute loads across gateways. Despite these methods, optimizing WMNs remains a challenge, requiring continuous monitoring and adaptation to changing traffic demands and network topologies. The study focuses on the complexities of allocating frequencies and managing traffic in multi-radio infrastructure WMNs. WMNs offer diverse applications, including local area network coverage, network connectivity, and broadband Internet access for both mobile and stationary users. The evolution of WMNs from single-radio to multi-radio systems has enhanced performance and reliability, making them increasingly popular across various industries. Efficient routing protocols are essential for WMN communication, allowing data exchange across radio hops and adapting to topology changes. With WMNs, controlling various systems like temperature and security becomes more accessible and cost-effective compared to traditional wired systems. Overall, WMNs provide a resilient and dependable networking solution with significant potential for expansion and innovation.

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LITERATURE REVIEW

Yuan et al. (2020) growth a technique they dubbed "delay and interference aware routing" (DIAR). We looked at the bandwidth, the likelihood of failure, and any interference to determine the delay. It was simple to determine the delay because both the amount of interfering nodes and the delay were considered. Every time DIAR discovers a route, it analyses the network and considers how things might change in the future. A more effective genetic algorithm for load balancing was growth to address the optimization issue. It was determined that DIAR was effective in enhancing network performance across many scenarios.

An approach to dynamically handle path failures in the local domain of the given network using a segmental routing mechanism was proposed by Manmeet et al. (2019). Another idea was to use node availability-aware neighbour creation and a status tracking technique to keep the network informed about the nodes that were working and to eliminate the ones that weren't. As a measure of success, we looked at the end-to-end delay, energy consumption, package-based analysis, and the quantity of anchor nodes. They came to the conclusion that this system handled the route between two nodes in separate parts of the network better and faster. A more flexible framework for spectrum distribution is being considered, however other proposals have been put forward. Improvements include a stronger spectrum market, shorter licensing terms (and more frequent transactions), and licenses that permit optional cognitive usage while preserving critical user rights and demands. Spectrum rights can be purchased, sold, traded, or rented; the latter is the most flexible option. Spectrum licensees have the option to share their capacity with other organizations if they do not anticipate using all of their data transmission capacity. Improvements include a stronger spectrum market, shorter licensing terms (and more frequent transactions), and licenses that permit optional cognitive usage while preserving critical user rights and demands. Spectrum rights can be purchased, sold, traded, or rented; the latter is the most flexible option. Spectrum licensees have the option to share their capacity with other organizations if they do not anticipate using all of their data transmission capacity.

METHODOLOGY

A system known as Load-aware Frequency Estimation (LACE) was suggested. The frequency project protocol collects data on the locations of the routers, their transmitting and receiving distances, the inter-frequency interference thresholds, the amount of frequency, and the amount of radios on each node. The frequency are thereafter sent to the radios of every router. The objective of this project is to accomplish frequency allocation using link-based traffic. This will be accomplished by reviewing the features of multifrequency WMN in light of previous studies.

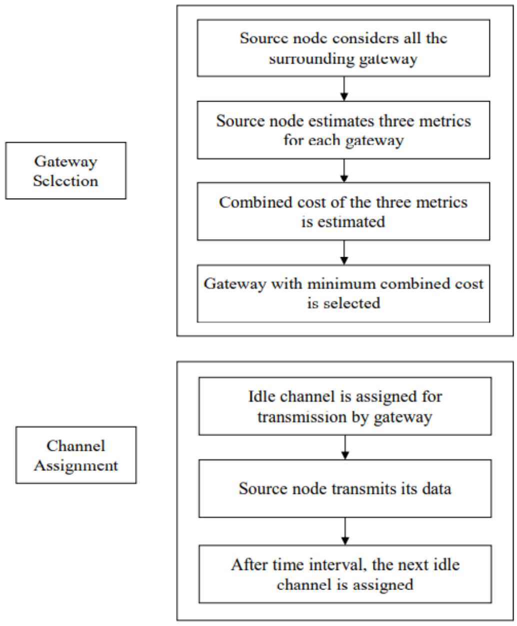

Figure 1: Architecture Framework

Using the information that there are numerous frequency in a network architecture and avoiding interference are the primary goals of capacity augmentation (CA). The distinction between the topology-building and project-frequency-building functions is made very evident by this frequency. The likelihood of the flow being halted is reduced as a result of this. To implement load-aware frequency project, one must follow these four stages. The initial stage involves assembling the network. The algorithm assigns frequency by default in the second stage. Step three is load balancing, and step four is load-based frequency project.

RESULT

An increase from 2 to 10 customers demanding CBR traffic is used to slow down the network. Here, we find the outcomes of increasing the node count from 4 to 10.

Presentation of E2D for Variable Nodes

The E2D varies for various node counts, as seen in Table 1 and Figure 1. An increase in the E2D of 37.18–42.7 Ms is seen for LACE, an increase of 42.05–45.8 Ms for WCP, an increase of 46.7–49.6 Ms for GLBM, and an increase of 48.2–52.9 Ms for GSCM. The E2D of LACE is thus 13% lower than that of GLBM and 15% lower than that of WCP.

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Table 1: Presentation of E2D for Variable Nodes

Nodes	E2D (Ms)			
	LACE	WCP	GLBM	GSCM
2	37.28	42.05	46.75	39.24
4	37.25	43.34	46.97	39.74
6	37.69	43.85	47.81	40.65
8	41.94	44.16	40.3	42.87
10	42.7	45.97	40.6	43.95

Presentation of Package Droplet let for Dissimilar Nodes

Table 2 and Figure 2 show the package droplet let for dissimilar amounts of nodes. It can be seen that the package droplet of LACE goes from 1289 to 3488 packages, the package droplet of WCP goes from 10072 to 11219 packages, the package droplet of GLBM goes from 10601 to 13850 packages, and the package droplet of GSCM goes from 11785 to 14121 packages. This means that the package droplet of LACE is 77% less than that of WCP, 80% fewer than that of GLBM, and 82% less than that of GSCM.

Table 2 Presentation of Pack Droplet for Variable Nodes

Nodes	Packages Droplet Ped			
	LACE	WCP	GLBM	GSCM
2	2289	10072	10601	11785
4	2568	10225	11048	12784
6	3220	10450	11628	12942
8	3321	10634	12465	13425
10	4488	11219	13850	14121

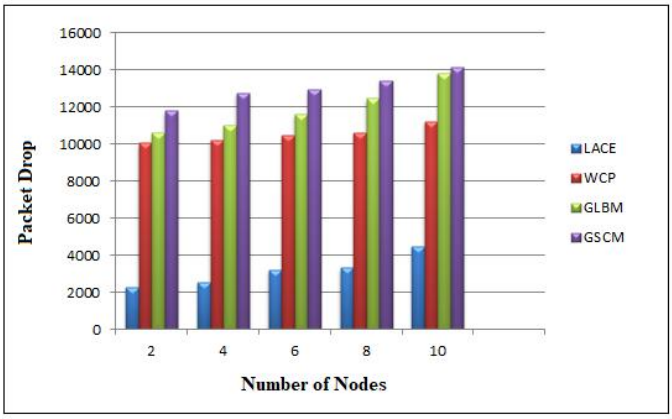

Figure 2: Outcomes of Package Droplet let for dissimilar amount of nodes

A dynamic frequency project and GW load-balanced routing protocol for multi-frequency WMN are proposed. In this protocol, the source node picks the GW with the lowest cost metric and then assigns a frequency to it. In GW load-balanced routing, IQL is used to choose a path with the least load of traffic. At intermediate routers, congestion is found by looking at the size of the queue. At a GW, congestion is found by using HMM to predict the traffic load of the next interval. NS2 is used to test the proposed LACE protocol.

CONCLUSION

The paper introduces a dynamic frequency project and gateway selection algorithm for multi-frequency hybrid WMNs. It calculates the total cost for data transmission through each potential gateway, considering factors like queue waiting time and frequency change expenses. Once the gateway with the lowest total cost is chosen, a transmission frequency is assigned. The gateway manages fair and efficient frequency allocation for all transmitting nodes, and a GW load-balanced routing technique is proposed. This technique selects the gateway with the lowest cost metric and delegates frequency control to it. The GW employs Intelligent Queue Length (IQL) to determine the least congested path. Congestion is detected at intermediate routers by monitoring waiting list length and using Hidden Markov Models (HMM) to predict traffic volume at gateways. Simulations in Network Simulator 2 validate that the GLBRCC protocol enhances data transmission, reduces packet loss, and minimizes waiting times.

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