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Interference Conscious Joint Channel Allocation Method in Multi-Channel Wireless Mesh Networks

Md. Shahnawaz[1]*, Mr. Manoj Yadav[2], Mr. Ankit Joshi[3]

[1] Research Scholar, Dept. of Computer Engineering, SOE, SSSUTMS, Sehore, India
[2] Assistant Professor, Dept. of Computer Engineering, SOE, SSSUTMS, Sehore, India
[3] Assistant Professor, Dept. of Computer Engineering, SOE, SSSUTMS, Sehore, India

ABSTRACT

Wireless mesh networks have become a common method of communication because they are cheap and easy to install. Video conferencing, internet radio, and television are examples of interactive applications that require high bandwidth and low transmission latency. It is important to have good control to improve the quality of interactive applications. In WMN, nodes are mostly mobile, but in many applications they can be in one location. Thus, nodes can switch between being mobile and fixed. In this case, performance can be greatly increased by using a hybrid motion control system that can plan the route in advance and change the route. If we can predict how people will move based on how they have moved in the past, we can reduce the time it takes to scan and switch between devices. Movement predictions are almost always accurate based on four factors: location, group, time of day, and duration.

By using location in the routing, you avoid the additional work of sending information indicating the new location of the metric routing. Location-based routing uses a location-based routing method to find a user's location by looking at the location of their uploads and downloads on the network. The proposed framework is called Load-Aware Channel Estimation (LACE). The channel allocation process stores information such as where the routers are located, how far they can transmit, how many radios there are, and how many radios are connected to each one. It then sends the channel to each router's radio. Channel distribution based on network connectivity is the goal of this work. This will be done by determining the properties of multichannel WMNs based on completed research.

Keywords: Multichannel, Online radio, Wireless mesh networks, Bandwidth, Handoff.

1. Introduction

Wireless Mesh Network (WMN) is a multihop wireless network made up of mesh routers and Internet gateways that can be set up for a low cost. It is a special kind of ad hoc network with static topologies. Unlike most ad hoc networks, mesh routers do not have energy limits. WMN is used in building automation for surveillance, remote health care delivery, and smart grids. Mesh routers are the most important part of a wireless mesh network. They help mesh clients route their network traffic. Mesh routers can also have more than one radio to increase the network's capacity and decrease the amount of interference. IEEE 802.11 is a good choice for wireless mesh deployment because its parts are easy to find and can be used in different ways. 802.11-based networks make wireless access cheap, flexible, and easy to set up in places like campuses, airports, and hospitals. In an 802.11-based WMN, backhaul links can be run on any of the channels that don't overlap. Also, because network interface cards were cheap, they made it possible to use multiple radios and channels to increase the throughput.

Wireless mesh architecture is the foundation for lowering the cost and simplifying the process of mobility in a certain region. The term "wireless mesh infrastructure" refers to a network of wireless routers that eliminates the need for physical cables. It differs from conventional WLANs in that it doesn't rely on access points (APs) that must be physically connected to a wired network port. With a mesh network, data can be transmitted across great distances by dividing the journey into smaller segments, called "hops." The signal is strengthened by the intermediary nodes, and the entire network collaborates to transmit the data from A to B. In order to accomplish this, they employ a process known as routing, in which they determine which packets to forward depending on their knowledge of the network. When nodes in a wireless mesh network fail or new ones are added, the network's "stable-topology" remains relatively unchanged. Since traffic originates from so many different consumers, its path rarely changes. Almost all data in a mesh network's infrastructure passes via or out of a gateway. Alternatively, in wireless ad hoc networks, also known as client mesh networks, communication can occur between any two nodes. Wireless mesh networks degrade and experience poor communication when nodes move around frequently or when there are frequent link breakdowns. The control of such an infrastructure can be centralized or distributed. Since each node simply needs to send to the next node, they are both low-cost and can be exceedingly dependable and durable. Through the use of routing protocols, intermediate nodes relay information from closer nodes to more distant peers. The result is an expanded network's ability to serve more people. A mesh network can't have too many moving pieces, as its topology can't change too frequently. If a node in a network suddenly stops functioning, whether due to hardware failure or some other issue, its neighbors can immediately discover an alternative path using the protocol.

Multiple radios and channels in wireless local area networks are investigated. In this research, we evaluate the efficacy of various approaches to channel allocation in a multichannel setting. Which nodes have variable data transmission and reception rates? For this reason, most network channel assignment algorithms rely on heuristics to determine which nodes should be allocated which channels. It is possible to construct a functional network using any number of different channel assignment algorithms. Every bit of data sent between nodes in a wireless mesh network creates interference in the surrounding region. In a nutshell, this is a major issue that hinders the performance of WMNs. Sending a signal with an adequate level of high power is necessary for it to be received successfully at the receiver.

In a mesh network, nodes can be physically located anywhere and can be either stationary or movable. Emergency circumstances, tunnels, oil rigs, military surveillance, high-speed mobile-video applications on public transit, real-time racing-car telemetry, and communities that set up their own Internet connectivity all call for distinctly diverse approaches. Voice over Internet Protocol (VoIP) is a potential breakthrough for wireless mesh networks. If the wireless mesh implements a quality of service strategy, local phone calls could be routed over it. Wi-Fi mesh networks serve the same purposes as ad hoc networks do.

Smart electric meters, which are already being installed in houses, broadcast their readings to each other and subsequently to the central office for billing, to name only two examples of contemporary applications of wireless mesh networking. This eliminates the requirement for a meter reader and the cords used to connect them.

With wireless mesh networking, the laptops distributed via the One Laptop per Child program allow students to access the Internet and work on projects independent of the availability of fixed or mobile network infrastructure. Wi-Fi ad hoc networking, sometimes called Wi-Fi mesh, is supported by a number of popular smart home products. The Google Wi-Fi, Nest Wi-Fi, and OnHub are all examples of this.

Midway through the 2010s, a number of companies that made Wi-Fi routers started selling home mesh networks. Satellites in close proximity to one another can wirelessly interact with one another thanks to a mesh network set. Calls made using a satellite phone may now be routed directly between satellites in the same constellation, without going via a ground station, thanks to the mesh. Due to the shorter distance the signal must travel, the latency is reduced. Further, the constellation may operate with a far smaller network of ground stations than would be needed to support the same number of conventional communications satellites. The Iridium constellation is a network of 66 active satellites in polar orbit that together create a worldwide mesh system for establishing and maintaining connections.

Operation

Data travels from one device to another in a manner analogous to that of packets in the wired Internet. Every gadget's in-built dynamic routing algorithms make this possible. Each node in the network must exchange routing data with every other node for these dynamic routing protocols to function properly. Then, the information is processed differently by each device. The information may be forwarded to the subsequent device or stored locally, depending on the protocol. Data transmission should always be prioritized over other considerations by the routing algorithm.

Combinatorial radio-frequency mesh

If a mesh's nodes are connected by radios of varying frequencies, we say that the mesh is multi-radio. To put it another way, each wireless hop has its own unique frequency and CSMA collision domain. More radio bands means more communication channels, which means more ways to communicate. Offering several channels for data transmission and reception is analogous to this.

Optimizing for many levels at once

Research that cuts across multiple layers is currently quite fashionable. In this kind of research, information is transmitted between multiple communication levels to learn more about the network and its current status. As a result, perhaps more efficient new procedures will be developed. The performance of a network can be enhanced by using a protocol that simultaneously handles multiple design difficulties, such as routing, scheduling, channel assignment, and others. Note that cross-layer design done without attention might lead to code that is hard to maintain and add to.

Software-defined wireless networks

It might be a hybrid approach, where certain functions are centralized while others are decentralized. Thanks to an improved SDN layout for WANs, route information is no longer flooded between hops in a multi-hop way. Therefore, progress toward WDNs is aided. The key idea is to use two different frequency bands to separate network administration from data transmission. Within one of the frequency ranges, the forwarding nodes and the SDN controller communicate via control signals and share data on the network's links. During data transmission, the other frequency is used.

Security

An example of a node in a WMN could be a client computer or a router, both of which contribute to the network's ability to bring people together. Due to the open nature of the design, attacks that use clients as routers and flood the network with data packets (such as denial of service or distributed denial of service) are possible (DDoS).

2. Literature Survey

Yuan et al. (2020) came up with a method called "delay and interference aware routing" (DIAR) that uses optimization to find the best routes in WMNs. The delay was figured out by looking at the chance of failure, the bandwidth, and any interference. Since the number of interfering nodes and the delay were both taken into account, it was easy to figure out the delay. DIAR also thinks about how things change over time and analyzes the network each time it finds a route. To solve the optimization problem, a better genetic algorithm for load balancing was made. It was decided that DIAR worked well to improve network performance in different situations.

Manmeet et al. (2019) have come up with a way to handle path failures in a dynamic way using a segmental routing mechanism in the local domain of the given network. Also, a status tracking scheme and node availability-aware neighbor formation were thought of to keep the network up-to-date on which nodes were working and to get rid of the ones that weren't. The number of anchor nodes, the end-to-end delay, packet-based analysis, and the amount of energy used were used to judge the results. It was decided that this mechanism managed the path between two nodes in different segments of the network more quickly and efficiently. There are different ideas about how a more dynamic spectrum distribution framework could be set up. Shorter licensing terms (and more frequent trades), licenses that allow for optional cognitive usage while maintaining important user rights and demands, and a robust spectrum market are all positive developments. You can buy, sell, trade, or rent spectrum rights, making the latter option the most adaptable. If a spectrum licensee anticipates that it will not need all of its data transmission capacity, it may choose to share it with another organization. Shorter licensing terms (and more frequent trades), licenses that allow for optional cognitive usage while maintaining important user rights and demands, and a robust spectrum market are all positive developments. You can buy, sell, trade, or rent spectrum rights, making the latter option the most adaptable. If a spectrum licensee anticipates that it will not need all of its data transmission capacity, it may choose to share it with another organization.

Sathyasri et al. (2019) have come up with a protocol called Enhanced Traffic Aware Channel Assignment protocol (ETCA) for assigning channels to mesh nodes in a large-scale network. Based on the multipath routing assignment protocol, the following parameters are looked at to improve the rate of data transmission: I the transmission process, (ii) channel assignment, (iii) traffic realization, and (iv) routing formation. When there is congestion in the network, resources are wasted. This is why it is important to prevent congestion, which is what ETCA does. ETCA also reduces overall network intrusion and improves network performance. The existing system of static spectrum distribution and spectrum bartering is straightforward, but it does have a few flaws. Most importantly, as the number and types of wireless devices keep growing, there is less and less room for new spectrum. Transfer speeds are getting more and more expensive and hard to get. On the other hand, research into how the spectrum is used now has led to an interesting result.

Lu et al. (2019) made a load-balance and interference-avoid partially overlapped channels assignment algorithm for WMNs with hybrid traffic that uses both multi-radio multi-channel (MRMC) and partially overlapped channels (POC). The interfaces of neighboring nodes were given out using a centralized allocation algorithm that was based on a Huffman tree. Based on the interference model, the links were broken up into M sets of links that would not interfere with each other. Last but not least, by increasing the number of links scheduled per time slot, more time slots were made available for links without causing any problems. It was decided that this mechanism worked well in WMN with hybrid traffic in terms of the number of packets that were lost and the amount of data that could be sent.

Junhua et al. (2019) wrote about the maritime communication environment, with the static channel assignment as the main topic. Here, a heuristic algorithm called the modified particle swarm optimization (PSO) algorithm was used to solve the optimization problem. A new merging solution was used to change the channels for nodes without breaking the radio rules. This algorithm made the network work better and caused less interference than the previous algorithm. It also assigned channels in the best way possible.

Keerthi et al. (2019) have come up with an improved AODV protocol called Buffer Based Routing Mechanism Ad hoc On-Demand Distance Vector (BBL-AODV). In this protocol, both the amount of data in a node's buffer and the average amount of data in the buffers of nodes next to it are used to find the best route. In terms of total packets received, jitter, throughput, and delay, the BBL-AODV protocol did better than the standard protocol. This improved the performance of WMNs' networks. The average of the six areas found that only 5.2% of spectrum 25 was being used. Even though some groups were heavily used in some areas, even the area with the most people still only used 13.1% of spectrum 25 as a whole. In other words, despite the incredible value of wireless resources, they are being wasted to a significant extent. A certain degree of trust can be placed in this; application is conditional on necessity. Nonetheless, despite the fact that some organizations made heavy use of the spectrum, overall use was occasionally low. An obvious interest in wireless networks existed in many cases, but only in a specific frequency range.

Yuan et al. (2019) have designed a Load and Interference Balance Hybrid Routing Protocol (LIB-HRP), which detects and eliminates nodes with heavy load and interference. It also considers the node status at interfering nodes, neighboring nodes and current node, and the energy consumption of mesh clients. The results have shown that this protocol enhanced network performance and also enhanced energy consumption of mesh client effectively.

Sowmiya et al. (2019) have come up with a water flow algorithm (WFA)-based link optimization that improves traffic flow and reduces congestion in WMNs. It also solves the problems of flooding, jamming, and traffic jams that can happen when packets arrive at different times. The simulation results showed that WFA outperformed the other algorithms in terms of throughput, routing overhead, packet loss, and round-trip time. The resources are rigorously guided to ensure that wireless spectrum is used and communicated effectively. The uses, locations, procedures, and audiences for spectrum are all governed by regulations developed by administrative agencies. The framework was built around the principle of frequency division. Different users and uses are allotted certain portions of the spectrum. Political borders and the unique requirements of each province contribute to further separation along geographical lines.

Yuvaraj et al. (2019) have created a new algorithm called Cross-layer Handling Link Asymmetry QoS-based Congestion Avoidance using Congestion Aware Routing (CHLA-QSCACAR) extended with machine learning algorithm (CHLA-MQSCACAR) based on Support Vector Machine to reduce congestion effectively. Here, the output parameter was the congestion window size, and the input parameters were the packet loss rate, the data rate, the congestion balance factor, the aggressive factor, the window decrease factor, and so on. It was decided that this approach was better than the existing one in terms of the following metrics: prediction accuracy, network lifetime, throughput, energy consumption, routing overhead, bit error rate, delay, and latency.

Jihong et al. (2015) came up with a traffic-independent channel assignment algorithm that reduces network intrusions overall and gives channels to all links in the network by making good use of Partially Overlapping Channels (POCs). This algorithm used a theoretical calculation method to minimize interference ranges, which stopped them from being too weak to transport. When POCs are used, the overall network delay, throughput, and parallel transmission are all improved.

Yong et al. (2011) gave examples of different intrusion methods and How they play a role in determining channel assignment. Additionally, they discussed the distinction between directional and omni-directional antenna networks and the networks used by each. The data shows that the channel allocation strategy is founded entirely on the assumption of an incursion model and network traffic. Moreover, they emphasized the fact that both static and dynamic approaches have their advantages and disadvantages.

3. Proposed work

The proposed framework called Load-aware Channel Estimation (LACE). The channel assignment protocol takes information about where the routers are, how far they can transmit, how far they can interfere with each other, how many channels there are, and how many radios are on each node. It then sends the channels to the radios of each router. Link-based traffic to achieve channel allocation is the goal of this project. This will be done by analyzing the characteristics of multichannel WMN based on research that has already been done.

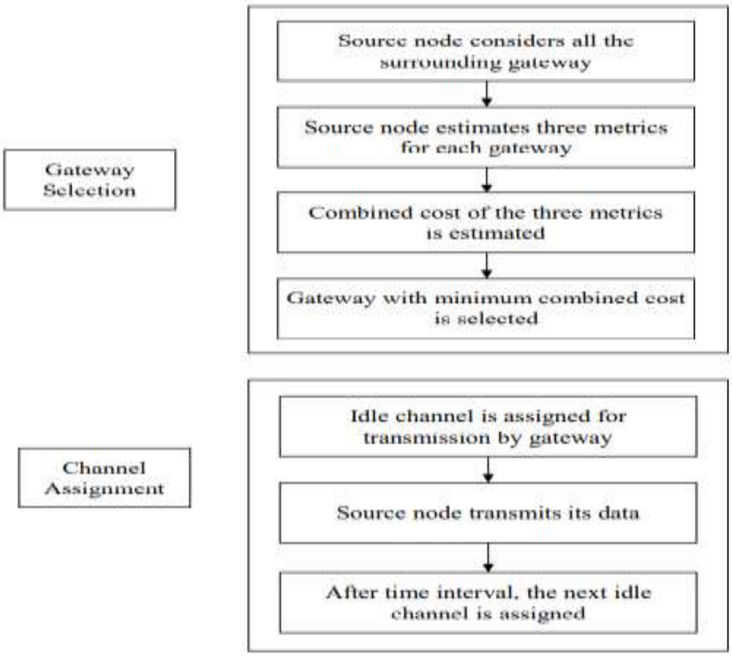

Figure 1 Architecture Framework

The main goal of CA is to maximize network capacity while minimizing interference and making use of the fact that there are multiple paths in the network topology. This channel makes it clear that the functions of building the topology and assignment channels are different. This makes it less likely that the flow will be interrupted. There are four steps to how load-aware channel assignment works. In the first step, the network is put together. In the second step of the algorithm, default Channel assignment is done. Load balancing is the third step, and the last step is channel assignment based on Load.

3.1 Link Formation of Mesh Network

An individual node verifies the availability of a communication channel before transmitting data. If it receives a signal that is stronger than its carrier sense threshold, it will pause transmission for an unpredictable amount of time. The Distributed Inter Frame Space (DIFS) is the amount of time during which a node will wait to send before sending data. Each network node has three major ranges it can deliver packets from:

• A node's Transmission Range (TR) is the region in which it can reliably receive and decode packets.

Any additional broadcast will cause interference with packet receipt inside the Interference Range (IR).

The range across which a node may detect a signal and cease transmission is known as the Carrier Sensing Range (CS).

Most of the time, we assume that carrier sensing range and interference range are the same (CS=IR), and we also know that the transmission range cannot be greater than the sensing range plus the interference range (TR CS). Increased collisions will occur if the CS range is too small, and the node will stop transmitting if the threshold is too large. Throughput in the network will decrease in either circumstance. Setting the correct number for the carrier sensing range is crucial since it determines whether or not a node will transmit. The suggested idea creates a network with a hop count of 2.

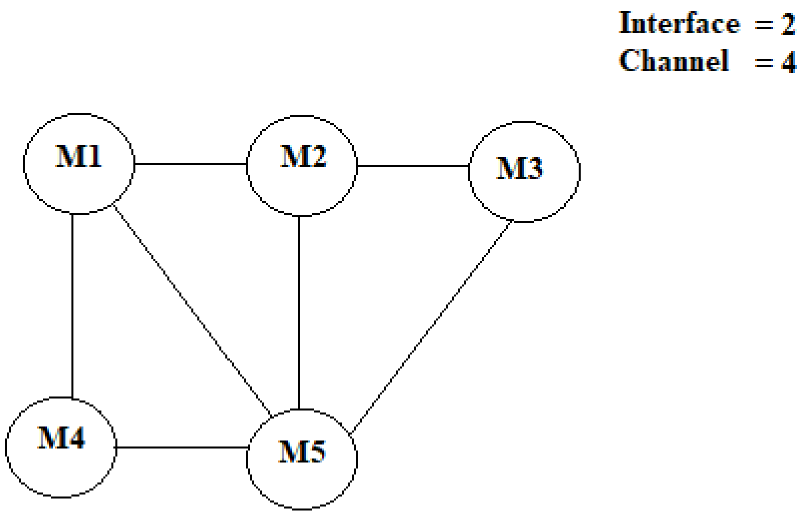

Figure 2 Hop count = 2 Mesh Network

3.2 Channel Assignment

The default channel assignment is done in the second part of the framework. It measures the packet loss rate by looking at both packets sent and packets received.

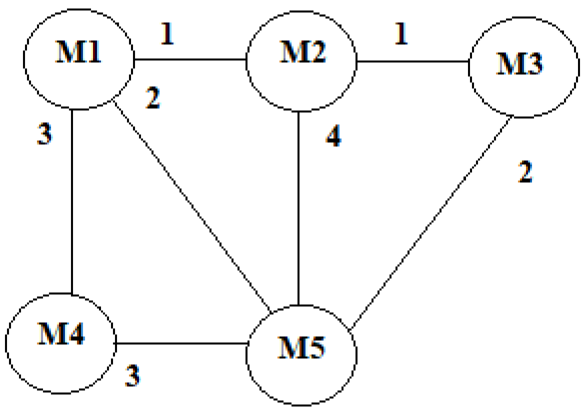

Figure 3 Channel Assignment

3.3 Interface Checking

When interface checking is done, an interface on the incident node is bound to a link. It checks to see how many network interfaces a certain node has and how many channels are available. If the network is in a balanced state, the data is sent over the channel that was assigned. If not, load balancing is done. NIC should not be more than the number of channels (Network Card Interface).

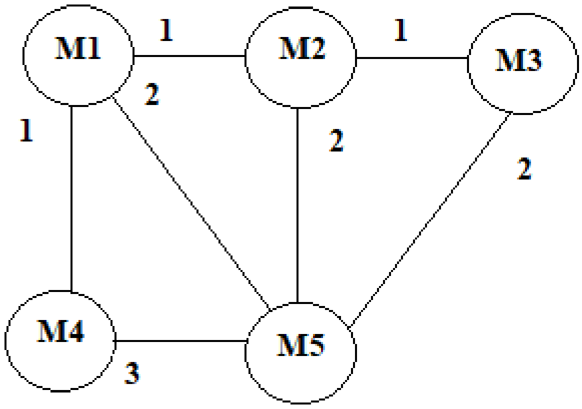

Figure 4 Interface Checking

3.4 Load Balancing

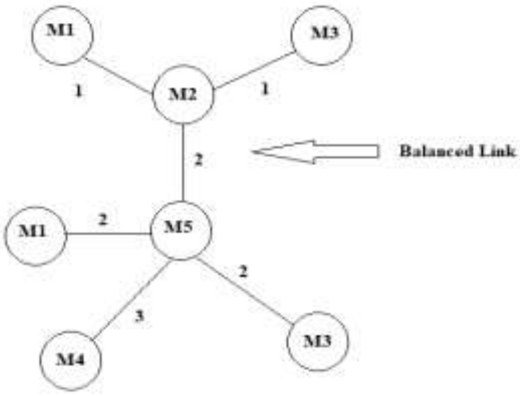

Figure 5 Balanced Link

4. Results and Experimental Settings

NS2 was used to implement LACE, and WCP (Sumit et al. 2011), GLBM (Liang et al. 2010), and Gateway Selection and Clustering in Multi-interface (GSCM) (Arash et al. 2017) were used to compare its performance. End-to-end delay (E2D), throughput, packet drop, and average Packet Delivery Ratio are some of the ways to measure performance (PDR). Table 5.1 shows how the experiments were set up.

Table 1 Experimental Settings

No. of mesh clients	4, 6, 8, 10 and 12
Size of Area	1300 × 1300m
MAC protocol	802.11
Simulation time in seconds	100s
Traffic source	Constant Bit Rate (CBR)
Data sending rate in kbps	250
No. of channels per node	1 to 5
Propagation	Two ray ground
Antenna	Omni Directional antenna

4.1 Analysis of varying the mesh clients

To make the network slow down, the number of clients asking for CBR traffic is raised from 2 to 10. In this section, the results are obtained by changing the number of nodes from 4 to 10.

4.1.1 Performance of E2D for Varying Nodes

Table 5.2 and Figure 5.1 show how the E2D changes for different numbers of nodes. It can be seen that the E2D of LACE goes up from 37.18 to 42.7 ms, the E2D of WCP goes up from 42.05 to 45.8 ms, the E2D of GLBM goes up from 46.7 to 49.6 ms, and the E2D of GSCM goes up from 48.2 to 52.9 ms. This means that the E2D of LACE is 15% less than WCP, 23% less than GLBM.

Table 2 Performance of E2D for Varying 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

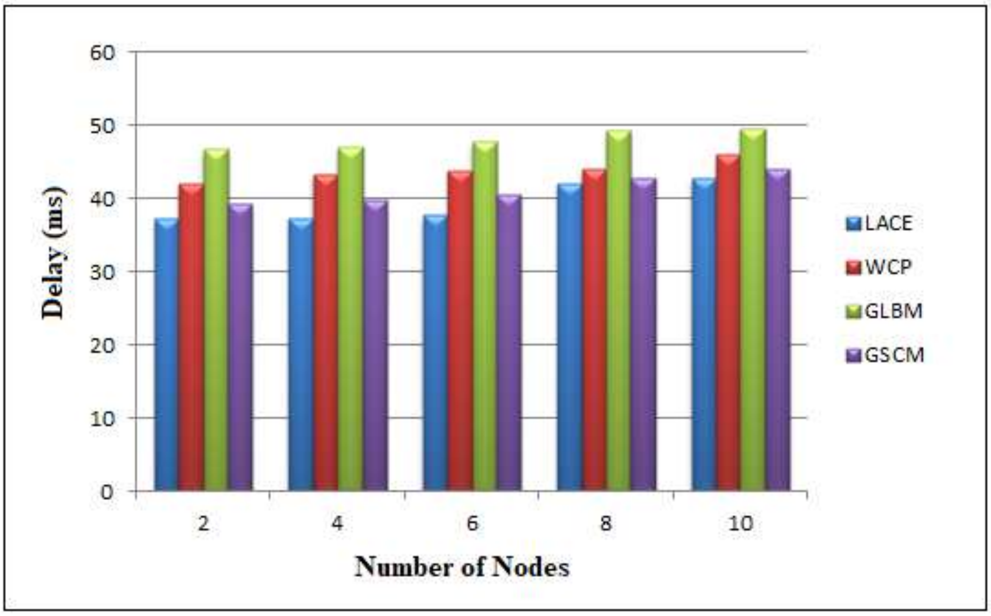

Figure 5.1 Results of E2D for different number of nodes

4.1.2 Performance of PDR for Varying Nodes

Table 5.3 Performance of PDR for Varying Nodes

Nodes	**PDR**			
	LACE	**WCP**	**GLBM**	**GSCM**
2	0.852128	0.710864	0.693312	0.1017
4	0.809801	0.707776	0.643494	0.1548
6	0.80834	0.678859	0.597122	0.1475
8	0.730866	0.62772	0.559928	0.1574
10	0.696364	0.621914	0.5476	0.1147

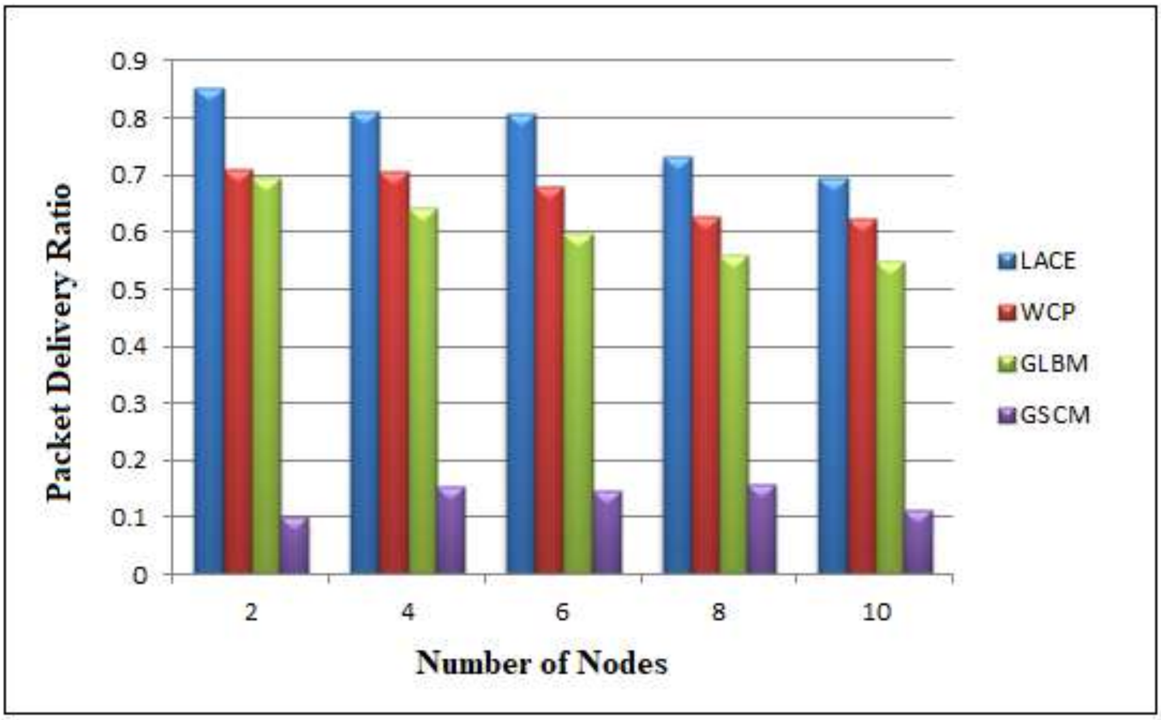

Figure 5.2 Results of PDR for different number of nodes

Table 5.3 and Figure 5.2 show the PDR for different numbers of nodes. The PDR of LACE goes from 0.85 to 0.69, the PDR of WCP goes from 0.71 to 0.62, the PDR of GLBM goes from 0.69 to 0.54, and the PDR of GSCM goes from 0.10 to 0.11. This means that the PDR of LACE is 12% higher than that of WCP, 19% higher than that of GLBM, and 73% higher than that of GSCM.

4.1.3 Performance of Packet Drop for Different Nodes

Table 5.4 and Figure 5.3 show the packet drop for different numbers of nodes. It can be seen that the packet drop of LACE goes from 1289 to 3488 packets, the packet drop of WCP goes from 10072 to 11219 packets, the packet drop of GLBM goes from 10601 to 13850 packets, and the packet drop of GSCM goes from 11785 to 14121 packets. This means that the packet drop of LACE is 77% less than that of WCP, 80% less than that of GLBM, and 82% less than that of GSCM.

Table 5.4 Performance of Packet Drop for Varying Nodes

Nodes	**Packets Dropped**			
	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

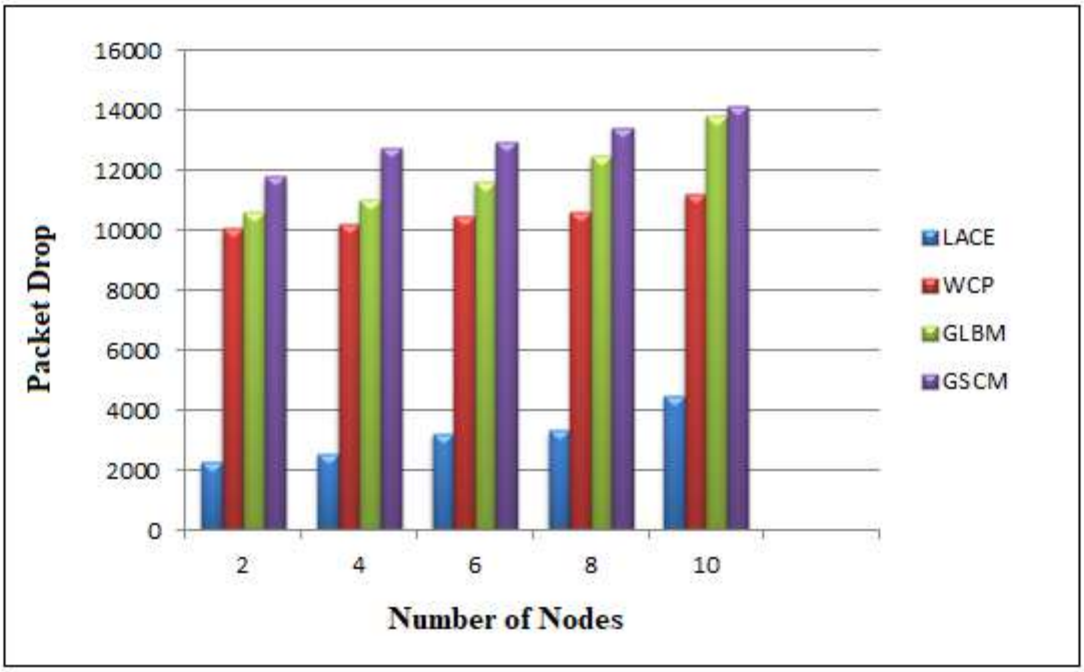

Figure 5.3 Results of Packet Drop for different number of nodes

5. Conclusion

In this thesis, a dynamic channel assignment and gateway selection algorithm for multi-channel hybrid WMNs is proposed. To transfer data, the source node in this method calculates the total cost of sending data through each possible gateway and then selects the gateway with the lowest total cost. The waiting time in the queue, the expense of changing channels, and the anticipated transmission time are only some of the network elements that go into calculating the total cost. Once a reliable data communication gateway has been selected, a transmission channel is assigned to move the data at a predetermined rate throughout the network. Fair and efficient channel assignment for all transmitting nodes is handled by the gateway. A GW load-balanced routing technique for multi-channel WMN is then proposed. The source node selects the GW with the lowest cost metric and gives it control of the channel using this protocol. The GW uses the IQL to determine which path has the lightest traffic load and takes it in load-balanced routing. Congestion is detected at intermediate routers by measuring the length of the waiting list. Congestion at a GW is identified using HMM to foresee the upcoming interval's traffic volume. The proposed GLBRCC protocol is simulated in Network Simulator 2. Number simulations confirm that the GLBRCC protocol improves throughput while decreasing the number with which packets are lost in transit and waiting times.

6. Future work

WiMesh is a mesh network for deploying multihop, high-speed wide-area networks according to the IEEE 802.16 WiMax standard. The 802.16 standard offers a superior QoS structure and uses better use of radio resources than previous 802.11 standards. This is due to its adaptable scheduling and connection-focused media access control (MAC). WiMax base stations, which may provide speeds of up to 70 Mbps, allow for expanded wireless coverage. The fundamental signaling flows and message formats for joining a mesh network have been specified in the IEEE 802.16a standard. However, QoS is challenging to achieve in a multi-hop WiMax mesh. In order to provide users with assured quality of service, WiMesh networks must employ a method known as load balancing. The load metric in an 802.16 WiMesh network depends on factors such as the number of users connected at the maximum achievable throughput (MAP) and the mean received signal strength indicator (RSSI) value of these users, in comparison to 802.11-based mesh networks. WiMesh system performance is highly dependent on the channel assignment strategy because to the scarcity of the frequency spectrum in wireless communication systems. WiMAX has two methods for assigning channels: the Non Prioritized Scheme (NPS) and the Reserved Channel Scheme (RCS). Because this thesis focuses on improving IEEE 802.16 mesh networks as a whole, there is still opportunity for more work in this area.

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