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# Dynamic Channel Assignment and Gateway Selection for Multi-Channel Hybrid Wireless Mesh Networks

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**Abstract:** Due to the growing demand and wide usage of Wireless Mesh Network (WMN), the situation wherein two or more links using the same channel is increasing. This causes interference and other related issues which degrades the network performance. Also, choosing an appropriate gateway among the available multiple gateways is a critical concern. In order to address these issues in this study, a dynamic channel assignment and gateway selection protocol for multi-channel hybrid wireless mesh network is proposed. In this protocol, a suitable gateway is chosen which fulfils the criteria of the source node. Then channels are assigned in the network by the gateway between itself and the mobile nodes in a fair manner. Simulation results show that the proposed technique attains maximum throughput and minimized delay when compared to the existing cross-layer control dynamic gateway selection approach.

## INTRODUCTION

A Wireless Mesh Network (WMN) consists of numerous fixed access routers which are linked to one another to connect the mobile nodes similar to conventional Wireless Local Area Networks (WLAN). These access routers are capable of communicating with one another through multiple hops. Some of them are connected to the internet through wired links to act as internet gateways for the network. IEEE 802.11 based mesh network with self organizing ad hoc networking ability provides greater network coverage at lesser costs and with simple deploying requirements[1].

In WMN, the static routers function as Access Points (APs) to the mobile nodes in the network. The mobile nodes send their data to the corresponding AP. The data is transmitted across the network through several hops in the internet[2]. In the traditional single channel networks, if a node senses the channel to be busy then it will wait until the channel becomes idle to start its data transmission. Later when the node finds the channel to be idle, it performs data communication[3]. In WMN, to enhance the network capacity, every mobile node has many radio interfaces to allot many channels[4].

In reality, when the WMN is used for data communication, the overall number of network interfaces present is more than the total channels accessible. Also, every mobile node may have minimum of two interfaces because of which several links that interfere with each other are allotted to the same channel set. Due to the interference between coinciding transmissions, the throughput and the overall network performance gets degraded. Hence, it is necessary to reuse the radio frequency in order to reduce the interference effect. Thus, the channel assignment is the main problem in WMN while handling multiple radios and channels[5, 6].

In WMN, due to interference of the wireless communication, the backbone network capacity decreases. Hence appropriate channel assignment becomes critical in multi-channel multi-radio WMN. To improve the network performance, every radio of every node should be allotted to suitable channel[7]. Hence, a good channel allotment algorithm is critical to decrease the interference which is a result of nearby transmissions utilizing a single channel[8].

In WMN, the overall network performance degrades as the number of mobile nodes increases. As a result, it is not suitable for applications with larger traffic and delay sensitive. This limitation can be clearly observed when a common link is used by various live streams. Also, on the receiver end, the received video quality reduces as a result of the dynamic characteristics of traffic as well as interflow interference which causes local congestion[9].

In WMN, routing is carried out at the data link layer in IEEE 802.11s standard and is referred as path selection process. In IEEE 802.11s, the Hybrid Wireless Mesh Protocol (HWMP) is the default routing protocol which functions in reactive as well as proactive mode. The Radio-Aware Optimized Link State Routing Protocol (RA-OLSR protocol) which functions in proactive mode, is also supported by the 802.11s standard[10].

In multichannel WMN, channel assignment and gateway selection are crucial issues. Apart from interference, delay and channel quality metrics should be considered while selecting the gateway.

In CLC_DGS[11], dynamic gateway selection strategy is proposed in which the gateways are selected based on the queue length. Then the traffic is distributed among the selected gateways. Though this approach considers the capacity and delay constraints among the links, it does not consider the quality of the channels at the selected gateways. While assigning the channels to a node, the channel switching cost should be minimized. More discussions on other existing works are presented in the next section. Hence, our objective is to design a Dynamic Channel Assignment and Gateway Selection (DCAGS) algorithms for hybrid WMN to minimize the delay, interference and packet losses.

**Literature review:** Marina *et al*.[1] have presented a graph-theoretic formulation of the channel assignment guided by a novel topology control perspective. They have then developed a new greedy centralized channel assignment algorithm (CLICA) to determine connected interference less topologies by using multiple channels. But this approach is not distributed and scalable. Moreover, it does not depend on the traffic load and hence not suitable for high loads.

Jin *et al*.[3] have proposed a synchronization-free, hybrid temporal-spatial multi-channel assignment scheme. The gateway is allowed to switch its radios to all the available channels sequentially in a round-robin fashion. This temporal channel assignment approach ensures that all the neighboring nodes that communicate with the gateway directly shall have a fair access to the gateway. The channel assignment for the remaining wireless nodes is based on the geographical location and channel/radio availability (a spatial approach) to avoid the interface during the transmission period. But it does not involve techniques for gateway selection.

Pinheiro *et al*.[12] have proposed path selection and message forwarding mechanism in IEEE 802.11s networks. This mechanism is appropriate for industrial environment. DHT-based Cluster Routing Protocol (DCRP) is proposed which is basically a DHT based routing protocol and creates node clusters along with proxy usage. In networks with greater size, DCRP minimizes path selection time as well as number of hops involved in data transmission. But it involves huge storage and communication overhead when the size of DHT increases.

Laven *et al*.[13] have proposed latency aware anypath routing and channel scheduling for multi-radio WMN. In this technique, any path routing scheme is utilized to handle the delay sensitive traffic and single path routing is used to handle the normal traffic. The delay sensitive traffic is prioritized by a new queuing technique. The queuing strategy works together with the channel switching component to further reduce latency. But this mechanism does not include techniques to reduce the interference and improve the channel quality.

## MATERIALS AND METHODS

### Dynamic channel assignment and gateway selection

**Overview:** In this study, we propose a dynamic channel allocation and gateway selection algorithm for multi-channel hybrid wireless mesh networks. In this algorithm, the dynamic gateway selection method of[10] is extended by incorporating channel quality and switching cost along with queue length. Based on the values of each of the metrics, the gateway selection is dependent. A combined cost metric is determined comprising queue length[11], CSC and ETT of the source node for each gateway. Then the gateway having minimum cost metric

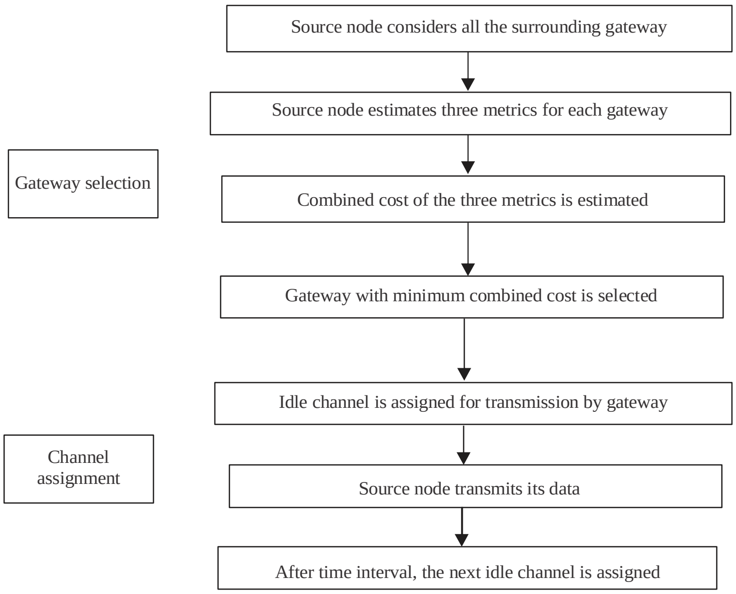


Fig. 1: Block diagram of the proposed algorithms

is selected by the source node. Then temporal channel assignment scheme[3] is used for assigning the channels to the selected gateway (Fig. 1).

**Gateway selection algorithm:** Before selecting the gateway to which a flow is to be forwarded, the source node selects the best gateway for its data transmission based on three metrics. They are queue length, Channel Switching Cost (CSC) and Expected Transmission Time (ETT) which are measured for each channel along the gateway. The ETT metric is based on Expected Transmission Count (ETX) and the link capacity metrics. Then a combined cost metric is determined comprising queue length[11], CSC and ETT of the source node for each gateway. Then the gateway having minimum cost metric is selected by the source node. This process is described in Algorithm 1:

**Notations:**

| | | |
|---|---|---|
| I | : | Source node |
| t | : | Time |
| GW | : | Gateway |
| $QGW_i$ | : | For node i que.ue length at GW |
| a, b | : | Nodes |
| f | : | Traffic flow |
| $\mu^{GWib}$ | : | Number of packets with forwarding destination GW transmitted over link between node i and b |
| $\mu^{GWia}$ | : | Number of packets with forwarding destination GW transmitted over link between node i and a |
| $y^{fGW}$ | : | Fraction of flow f's traffic that has forwarding destination as GW |
| $r^{fi}$ (t) | : | Amount of traffic flow admitted into network at t |
| | : | Set of mesh nodes |
| CSC | : | Channel switching cost |
| P | : | Probability that a channel switching is required |
| k | : | Channel into which traffic flow has to be switched |
| d | : | Delay involved in switching between channels |
| ETX | : | Expected transmission count |
| LC | : | Link capacity |
| ETT | : | Expected transmission time |
| $d_r$ | : | Reverse delivery ratio |
| $d_f$ | : | Forward delivery ratio |
| $S_{LP}$ | : | Size of large packet |
| $D_j$ | : | Delay sample |
| S | : | Packet size in general |
| CC | : | Combined Cost |

**Algorithm:** The i initially considers all the available GW in its surrounding to select the best GW for its data transmission. The i estimates the next possible $Q^{GWi}$ at each GW at the next time slot, (t+1) according to Eq. 1:

$$Q^{GW}{}_{i}(t+1) \leq \max\,[Q^{GW}{}_{i}(t) - \sum_{b\varepsilon\tau} \mu^{GW}{}_{ib}(t), 0] + \Sigma\, y^{f}{}_{GW}.r^{f}{}_{i}(t) + \sum_{b\varepsilon\tau} \mu^{GW}{}_{ia}(t) \quad (1)$$

Next, the i will estimate the CSC for each channel along the GW according to Eq. 2:

$$CSC = P(k).\, d \quad (2)$$

Then the i estimates the ETX for each link towards GW according to Eq. 3:

$$ETX = 1 / d_r.d_f \quad (3)$$

The LC is estimated by i for each link according to Eq .4:

$$LC = S_{LP}. / d_i \quad (4)$$

Based on the ETX and LC values estimated, i estimates ETT value according to Eq. 5:

$$ETT = ETX.\, S / LC \quad (5)$$

After the estimation of these parameters, i generates a combined CC by including $Q^{GWi}$, CSC and ETT for each GW according to Eq. 6:

$$CC = Q_i^{GW} + CSC + ETT \quad (6)$$

The GW with minimum CC is selected by i for handling its data transmission. Thus, the appropriate gateway with minimum combined cost is selected by the source node for transmission of its data.

**Channel assignment algorithm:** After the selection of the gateway, the source node sends it data through channels assigned by the gateway. The channel assignment process is performed in a timely manner, where each channel is assigned for data transmission by the gateway[3]. This process is described in Algorithm 2.

**Algorithm 2:**
**Notations:**

| | | |
|---|---|---|
| GW | : | Gateway |
| i | : | Source node |
| x | : | Channel |
| RTR | : | Request To Receive message |
| $T_{RTR}$ | : | RTR Timer |
| $T_{BUSY}$ | : | Busy Timer |
| $T_{back\_off}$ | : | Back off time |

**Algorithm:** The GWs in the network broadcasts RTR message to all the nodes along a channel x and initiates $T_{RTR}$. When i receives the RTR message, it checks if the broadcasting GW is same as the selected GW. If the broadcasting GW is not the selected GW, then i ignores the broadcast message. If the broadcasting GW is the selected GW, then i responds to the RTR message by sending a RESPOND message to GW after $T_{back\_off}$.

When GW receives the RESPOND message, it will check if the $T_{RTR}$ has expired. If $T_{RTR}$ has expired, then GW ignores the message. If $T_{RTR}$ has not yet expired, then it will broadcast a BUSY message to prevent other 1 hop nodes on x from transmitting. When GW broadcasts the BUSY message, it simultaneously initiates $T_{BUSY}$ to check the utilization of x.

When the i receives the BUSY message, it starts transmitting its data packets through x. If i completes transmitting its data packets before the expiration of $T_{BUSY}$ then it sends a COMPLETED message to GW and stops its data communication. When GW receives the COMPLETED message, it assigns the next idle channel for data communication. If i does not complete its data transmission even after $T_{BUSY}$ expires, then it will send an EXPIRED message to i and terminates the data communication by disconnecting the channel. When i receives the EXPIRED message, it will stop the data transmission. Then the GW will assign another channel for transmission.

In this way, the channels are assigned to perform data communication between the nodes through the gateway such that each channel is allotted a specific time interval to perform data transmission to the available nodes. The channel assignment function is managed solely by the gateway and the source nodes transmit its data through the channel during its turn. Thus, the channels are effectively assigned to perform data communication.

## RESULTS AND DISCUSSION

### Simulation results

**Simulation parameters:** We use NS2 to simulate our proposed Dynamic Channel Assignment and Gateway Selection (DCAGS) protocol. We use the IEEE 802.16 for wireless Mesh networks as the MAC layer protocol. It has the functionality to notify the network layer about link breakage.

In our simulation, the number of mobile node s is varied as 4, 6, 8, 10 and 12. The area size is 1300×1300 m square region for 50 sec simulation time. The simulated traffic is Constant Bit Rate (CBR). Our simulation settings and parameters are summarized in Table 1.

**Performance metrics:** We evaluate performance of the new protocol mainly according to the following parameters. We compare the Cross-layer Control

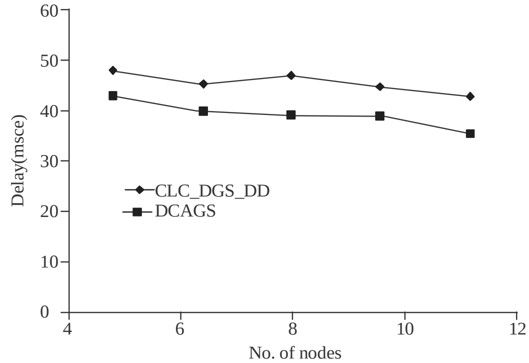


Fig. 2: Nodes vs. delay

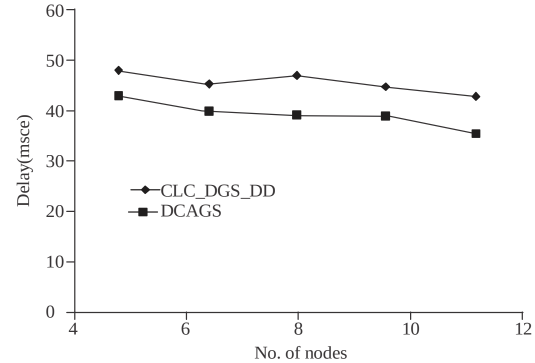


Fig. 5: Channels vs. delay

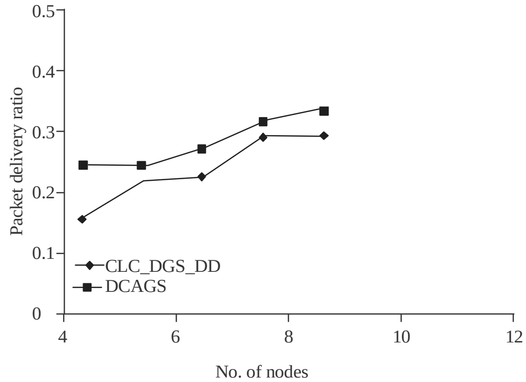


Fig. 3: Nodes vs. delivery ratio

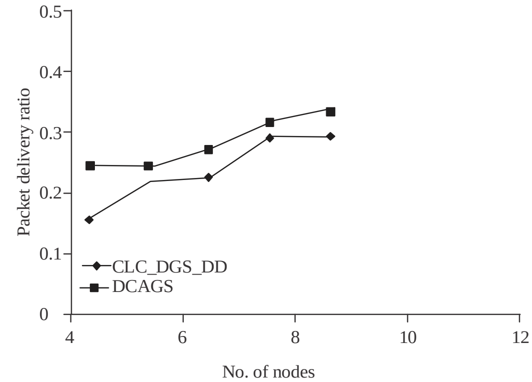


Fig. 6: Channels vs. delivery ratio

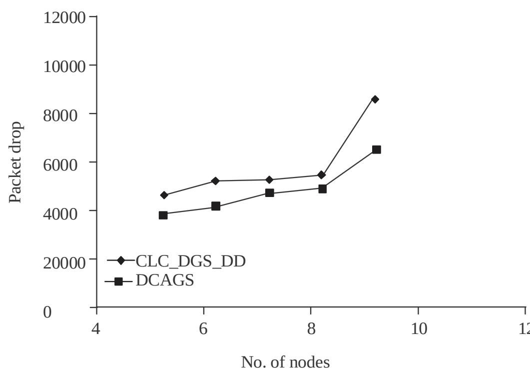


Fig. 4: Nodes vs. packet drop

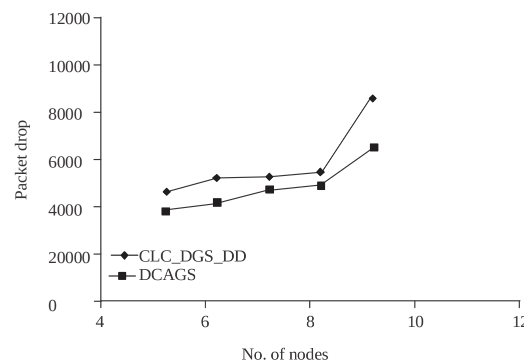


Fig. 7: Channels vs. packet drop

Dynamic Gateway Selection with Different Delay requirements (CLC_DGS_DD)[11] algorithm with our proposed DCAGS protocol.

**Average packet delivery ratio:** It is the ratio of the number of packets received successfully and the total number of packets transmitted.

Table 1: Simulation parameters

| Number of nodes per domains | 4, 6, 8, 10 and 12 |
|---|---|
| Area | 1300×1300 m |
| MAC | 802.16 |
| Simulation time | 50 sec |
| Traffic source | CBR |
| Number of channels | 1-5 |
| Rate | 50 Kb |

**Delay:** It is time taken by the data packets to reach the destination.

**Packet drop:** It is the number of packets dropped during the data transmission.

**Results and analysis:** The simulation results are presented in the next section. Varying the nodes in first experiment, number of mesh nodes per domain is varied as 4, 6, 8, 10 and 12.

Figure 2-7 show the results of delay, delivery ratio and packet drop by varying the number of mobile nodes from 4-12 for the CBR traffic in CLC_DGS_DD and DCAGS protocols. When comparing the performance of the two protocols, we infer that DCAGS outperforms CLC_DGS_DD by 13% in terms of delay, 23% in terms of delivery ratio, 25% in terms of packet drop.

**Varying the channels:** In second experiment, number of channels per node is varied as 1, 2, 3, 4 and 5. Figure 5-7 show the results of delay, delivery ratio and packet drop by varying the number of Channels from 1-5 for the CBR traffic in CLC_DGS_DD and DCAGS protocols.

When comparing the performance of the two protocols, we infer that DCAGS outperforms CLC_DGS_DD by 29% in terms of delay, 19% in terms of delivery ratio, 56% in terms of packet drop.

## CONCLUSION

In this study, we have proposed a dynamic channel assignment and gateway selection for multi-channel hybrid wireless mesh networks. In this process, the source node which intends to transmit its data selects a gateway appropriate for its data transmission based on the combined cost.

The combined cost is dependent on the network parameters like queue length, channel switching cost and expected transmission time. After the selection of an efficient gateway for data communication, channel is assigned for carrying the data across the network in a time regulated manner.

The channel assignment process is controlled by the gateway and serves every transmitting node in a fair and proficient manner.

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