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Q-Learning and MADMM Optimization Algorithm Based Interference Aware Channel Assignment Strategy for Load Balancing in WMNS

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Abstract: Wireless Mesh Networks (WMNs) have been considered one of the main technologies for configuring wireless machines since they appeared. In a WMN, wireless routers provide multi-hop wireless connectivity between hosts on the network and allow access to the internet through the gateway routers. These wireless routers are normally equipped with the multiple radios in the wireless mesh network that operate on multiple channels with the multiple interference, which is caused to reduce the network performance and end-to-end delay. In this paper, we proposed an efficient optimization algorithm to solve the channel assignment problem which cause due to the multichannel multi-radios in WMN's. The main objective of our paper is to minimize the channel interference among networked devices. So, initially we construct a multicast tree with minimum interference by using Q-Learning algorithm, which is helps to minimize the end-to-end delay of packet delivery. From the constructed multicast tree, we intend to develop a channel assignment strategy with the minimum interference by using Modified version of Alternative Direction Method of Multipliers (MADMM) optimization algorithm, which is helps to increase the network throughput and packet delivery ratio. The proposed strategy was implemented by using NS-2 (Network Simulator-2) and the experimental result show that the performance of the proposed method is very high compared to the other method and the performance was calculated by using the feature metrics such as average throughput, packet delivery ratio, end-to-end delay and total cost, which is compared with the other existing channel assignment strategies such as Learning Automata and Genetic Algorithm (LA-GA), GA-based approach, link-channel selection and rate-allocation (LCR) and learning automata based multicast routing (LAMR) channel assignment methods.

Keywords: Wireless mesh network (WMN), Multi-radio multichannel, Channel assignment, Minimum interference, Multicast tree, Q-learning algorithm, MADMM optimization algorithm.

1. Introduction

Wireless Mesh Network (WMN) is made up of multiple radio nodes that are organized within the mesh topology [1]. In a WMN, wireless routers provide multi-hop wireless connectivity between hosts on the network and allow access to the Internet through gateway routers [2]. These wireless routers are normally equipped with the multiple radios in the wireless mesh network that operate on multiple channels with the multiple interference, which is caused to reduce the network performance and end-to-end delay [3]. Several authors have addressed the problem of channel assignment and multicast routing in wireless mesh networks [4]. In [5], a Learning Automata and Genetic Algorithm (LA-GA) is proposed the strategy in two phases; at the initial stage, it construct a multicast tree based on the learning automata (LA) algorithm to minimize the tree cast among the two neighboring tree nodes in the multi-radio wireless mesh network. Consequently, it employs a genetic algorithm (GA) for reduce the channel interference among the radio nodes, which is based on the machine learning algorithm. This method can be used to efficiently minimize the channel interference among the multicast tree nodes and also reduces the network throughput. In this method, the some of the specific multicast tree function does not perform well in the multichannel wireless mesh networks.

The joint link-channel selection and rate-allocation (LCR) is introduced for channel allocation in the overall mesh networks, which helps to mitigate the channel interference problem with the minimum rate or minimum power consumption rate [6]. Moreover, a direct graphical model based Radio aware - Channel Allocation (Ra-CA) algorithm is proposed [7]. This method can be used to mitigate the channel interference in Multi - radio Multichannel (MR-MC) wireless mesh network. Likewise, the channel assignment and multicast routing problems are addressed by the proposed genetic algorithm based channel assignment strategy is employed for the construction of multicast tree, which is described in [8]; and an efficient channel assignment strategy was proposed in [9]. The Q-learning algorithm was proposed in [10, 11]. This method was accomplished the channel assignment overall on the multichannel multi-radio wireless mesh networks (MCMR-WMNs). The investigation of this channel assignment method is to increase the network throughput efficiently and also optimize the performance of the average end-to-end delay of packet delivery and average packet delivery ratio [12]. But it takes more time to consume energy in the network [13]. The interference aware of channel assignment strategy was described in [14] and the load-aware of channel assignment in multichannel multi-radio WMNs multicast routing approaches are illustrated in [15]. In [16], a Quality of Service Channel Assignment and multicast Routing (Q-CAR) algorithm is proposed to implement the performance of an efficient channel assignment in the wireless mesh network. This algorithm was used as an intelligent solving method for both channel assignment problem and multicast routing problem in a multichannel multi-radio WMNs. This proposed method uses a genetic algorithm for construct a multicast tree [8]. This method is also used to optimize the tree cost as well as increases the network throughput and the disadvantage of this paper is that the packet delivery ratio is low compared with the Quality of service multicast routing and channel assignment (QoS-MRCA) method.

To overcome the problems of existing channel assignment problem, our proposed framework implements a hybrid approach for channel assignment and multicast routing in the multicast multi-radio multichannel WMNs. We introduce a Q-learning algorithm for construct the multicast tree for reducing the channel interference among the neighbouring tree nodes in the mesh network and we employ the modified version of alternative direction method of multipliers for channel assignment with the maximum number of radio nodes in the multichannel multi-radios wireless mesh networks (MCMR-WMNs) [17]. This paper is organized as follows: Section 2 describes the related works; Section 3 includes the proposed methodologies of multicast tree construction and channel assignment; Section 4 illustrates the simulation result and analysis; finally, the Section 5 concludes the paper.

2. Related works: a brief review

In this section, different methods of channel allocation strategies are analysed in WMNs, some of which are audited here,

Balusu, et al. [5] in 2019, they have been proposed an intelligent channel assignment method for load balancing of WMNs by using a hybrid method of Learning Automata and Genetic algorithm (LA-GA). This method can be used to efficiently minimize the channel interference among the multicast tree nodes and also reduces the network throughput. The main disadvantage of this paper is that the some of the specific multicast tree function does not perform well in WMN.

Islam, Maheen, et al. [6] in 2016, they have proposed ajoint link-channel selection and rate-allocation algorithm (LCR) is proposed to reduce the congestion over the network and also diminish the channel interference. The LCR method can be used to allocate the channel among the multi-radio nodes, which can be helps to minimize the channel interference problem with the minimum rate (or minimum power consumption) by using spectrum-learning method. The main advantage of this paper is to mitigate the channel interference to raise the network throughput and the disadvantage of this paper is that it allows more transmission channels among the neighboring nodes, which is leads to decreases the performance of network.

Jayaraman, Ramkumar, et al. [7] in 2018, has proposed a Radio aware - Channel Allocation (Ra-CA) is proposed in this paper, which is based on the direct graphical model. This method can be used to mitigate the channel interference in Multi - radio Multichannel (MR-MC) wireless mesh network. This channel allocation method which is helps to allocate the channel with the minimum number of interferences in the overall network. The performance efficiency of this proposed method is very high when compared to the other existing channel allocation method such as, Breadth First Search-Channel Assignment (BFS-CA) and Maximal Independent Set Channel Assignment (MaIS-CA), methods in the multi-radio networks and the energy efficiency of the network is very low when compared to the other existing systems.

Oda, Tetsuya, et al. [8] in 2016, have been evaluated the performance of the Genetic algorithm (GA) based channel assignment in the wireless mesh network. The WMN-GA based algorithm was used to find the optimal allocation among the mesh routers. This method can be used to diminish the channel interference problem efficiently to raise the network throughput. The main disadvantage of this paper is that it takes more time to optimize the performance of end-to-end delay of packet delivery.

Araqi, Amin Erfanian, et al. [10] in 2019, has proposed a Q-Learning algorithm for increasing the performances of a joint channel assignment and multicast routing problem. This method was accomplished the channel assignment overall on the multichannel multi-radio wireless mesh networks (MCMR-WMNs). It provides efficient data distribution than the other unicast routing methods. The investigation of this channel assignment method is to increase the network throughput efficiently and also optimize the performance of the average end-to-end delay of packet delivery and average packet delivery ratio. But it takes more time to consume energy in the network.

Ramezani, et al. [15] in 2018, have introduced a neural network model of a Fuzzy Credit Assigned Cerebellum Model Architecture Controller (FCA-CMAC) for construct a multicast routing tree in the WMN networks this method can be used to reduce the multicast routing problem and channel assignment problem in the network efficiently. This algorithm produced an efficient multicast tree with the minimum interference. The main advantage of this paper is to increase the network throughput and reduce the time of energy-consumption of the network. The packet delivery ratio of this algorithm is high compared to the other existing ones.

Chakraborty, Dibakar, et al. [16] in 2017, has proposed a Quality of Service Channel Assignment and multicast Routing (Q-CAR) algorithm for implement the performance of an efficient channel assignment in the wireless mesh network. This algorithm was used as intelligent solving method for both channel assignment problem and multicast routing problem in a multichannel multi-radio WMNs. This method uses a genetic algorithm for construct a multicast tree. The main advantage of this method is to optimize the tree cost as well as increases the network throughput and the disadvantage of this paper is that low packet delivery ratio when compared to the QoS-MRCA method.

Parvanak, A. R., et al. [18] in 2019, have been proposed a distributed gateway selection algorithm with cross-layer algorithm for channel assignment in the multichannel multi-radio WMNs (MCMR-WMNs). The performance efficiency of the proposed algorithm is increased in various feature metrics such as average packet delivery ratio, average end-to-end delay and average throughput of the network than the existing algorithm of Reinforcement Learning algorithm based Best Path Routing Algorithm (RL-BPR). The main disadvantage of this paper is the cost calculation of the network is very high and it requires more energy (transmission power rate).

3. Proposed methodology

In our proposed framework, we intend to develop a channel assignment strategy with minimum interference for avoiding the problems of channel assignment problem in multi-radio multichannel WMNs. When two nearby nodes of multi radio WMNs interference with each other, the throughput will be decreased [1]. So for, we introduce a channel assignment strategy, which helps to avoid the interference problem of channel assignment that is to reduce the interference among the network devices or nodes (radio nodes in WMN).

In this paper, we propose to improve a channel assignment strategy with minimum interference by using the Alternating Direction Method of Multipliers (ADMM) optimization algorithm for multicast multi-radio channel among the network devices or nodes, that accurately models the interference relationship among the pairs of multicast tree nodes by using the interference concept of the interference factor and assign channels to the tree nodes to minimize the nodes of interference within the multicast tree. The multicast tree is built by considering the available multi-radio multichannel by using Q-learning algorithm. From the constructed multicast tree, the channel assignment strategy is achieved with the minimum interference using Modified version of Alternative Direction Method of Multipliers (MADMM) optimization algorithm. In our proposed system, we were using two approaches for address the problems; first we using Q-Learning algorithm [10] for constructing the multicast tree and second we using MADMM optimization algorithm for achieving the strategy of channel assignment with minimum interference. The block diagram representation of proposed methodology is shown in Fig. 1.

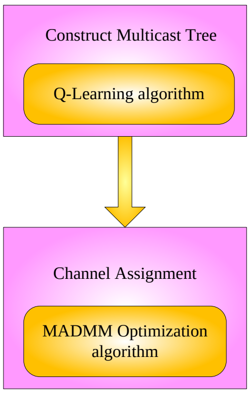

Figure. 1 Representation of proposed methodology

3.1 Constructing multicast tree using Q-learning algorithm

Based on the Q-learning algorithm, we built a multicast tree, which is considering all available nodes in the multi-radio multichannel WMNs. Q-learning algorithm is one of the reinforcement algorithm; it is more useful algorithm for network management, process control and they can be used in multi-agent environments. Currently, Q-learning algorithm is applied in the fields of network management, i.e. which helps in the routing optimization of network communication among all connected devices or nodes. In our proposed system, we construct a multicast tree based on the Q-learning algorithm with available radio nodes. The WMN's multicast tree is built in a way of $G = (V, E)$; where, 'V' represented as the set of nodes are devices of multi-radio multichannel WMN and 'E' represented as the set of edges or communication links between the radio nodes in WMNs. We propose a Q-learning algorithm for building multicast tree in multi-radio multichannel WMNs. Q-learning algorithm uses an off-policy approach for separating the actions from the learning policy and which is also used to solve the dilemma in routing problems. The main advantage of Q-learning algorithm is that even when the selected action doesn't know the previous information about its action, because that information is not added in the updating state of the Q-function of the current state. In Q-learning algorithm, the Q-value is mapping the action/state pairs to the values, which can be denoted as Q (S, A). The Q-value Q (S, A) pair is related to each node in the action/state pairs. The value 'S' means the state and 'A' means action. The total value is received from the starting state and performing action based on the Q-learning; the Q-value equation is expressed in equation 1:

$$Q(S, A) \leftarrow Q(S, A) + \alpha[R + \gamma max Q(S', A') - Q(S, A)] \quad (1)$$

Algorithm 1: Pseudo-code for Q-learning algorithm
Initialization
Consider $Q(S, A) = \forall S, A$
Initialize the starting state S
Repeat for each step
Choose action A from starting state S using policy derived from Q
Perform action A, observe R and achieve new state S'
$Q(S, A) \leftarrow Q(S, A) + \alpha\, [R+\gamma.\max Q(S', A')- Q(S, A)]$
Update a new state as S
$S \leftarrow S'$
Until S is terminal

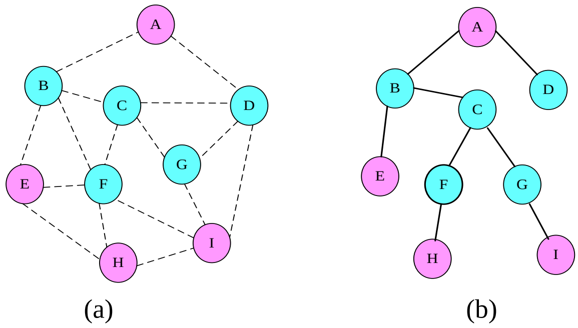

Figure. 2: (a) Example of WMN topology and (b) multicast tree construction

Where, α is represented as the learning rate; it decides the learning speed and it has a value between 0 and 1. If the value is larger, the learning speed will be increases. R is the reduction rate of reward and γ is a discount factor and its number between 0 and 1, which avoids the variance of quality function during the learning. A Q_{max} [S', A'] represents the quality of the most optimum action at new position state and its update the new position state S' as S. The Q-learning algorithm is continued by updating the Q-value for each state using the Eq. (1). This process is repeated until S is terminal. The pseudo-code for Q-learning algorithm is described in Algorithm 1:

Based on the Q-learning algorithm we construct multicast tree with the available nodes or devices in multi-radio multi-channel WMNs. The total value is received from the Q-table and constructs the multicast tree with the minimum interference. Consider a wireless mesh network topology with several nodes and construct a multicast tree by using the Q-learning algorithm. Fig. 2 (a) is shows that the example representation of WMN topology and its multicast tree construction is shown in Fig. 2 (b). In this below diagram, the circles represent the nodes or devices, links represent the communication between the nodes and the solid arrow shows that the path between source and destination in the multicast tree of multichannel multi-radio WMNs.

3.2 Channel assignment using MADMM optimization algorithm

After constructing multicast tree, the channel assignment strategy is achieved with the minimum interference. So for, we were using a modified version of alternative direction method of multipliers (MADMM) in our proposed work, which is adapted with the multichannel multi-radios WMNs. This optimization algorithm is simple and more powerful to the distributed node convex optimization problem in wireless cellular network, which had been more applicable in many aspects successfully; that is used in features of large-scale problems in diverse applications, high-dimensional data processing, time-series analysis and scheduling and so on; this method is effectively reduce the average network delay and enhance the network reliability. The MADMM optimization algorithm was proposed to solve the channel distribution optimization problem in multichannel multi-radios WMNs, which is possible to enhancing the network throughput and reducing the delay in wireless mesh networks. This optimization algorithm was beneficial to found the optimal solution for channel distribution optimization problem with low complexity. The basic procedure of modified version of alternative direction method of multipliers is to separating the channel distribution problem into two sub problems and assign different channel to two neighbouring nodes or devices.

In traditional wireless communication of mesh network topology, the channel assignment strategy is could not assign the link between the data communication nodes. In this proposed work, we assist a channel number to this communication channel on the multicast routing tree, which is suitable for the every connection of nodes in the tree in order to its achieve the minimal interference in the multichannel multi-radios in WMNs. In this paper, we using the ADMM method [19-21] for obtain the minimum interference in the channel assignment in WMNs. First, we propose this algorithm for channel separation among the multicast tree in the multichannel multi-radio WMNs and solve the some convex optimization problem with low computational complexity. In multicast tree, the channel distribution optimization problem is solved by using MADMM based minimum interference channel assignment strategy, which decomposes the multichannel interference problem into sub problems and assign channel number to each sub problem independently and coordinate the solution of sub problem to the original multicast tree. The ADMM's first step is to perform the channel separation, which computes the channel separation among all pairs of nodes in the multicast tree. This method considers (*U*, *V*) as all pairs of nodes in the multicast tree and obtains the channel separation between U and V's children and V and U's children. Here, we use interference factor for calculate the computational complexity of the channel separation of these two nodes. The interference factor means the ratio of an interference range and its transmission range.

$$IF(Interference\ Factor) = \frac{I_{range}}{T_{range}} \qquad (2)$$

From this Eq. (2), the interference range is obtained by multiplying the interference factor with the transmission range of wireless nodes in the multicast tree. In our proposed multicast tree have the transmission range of 300 m and the transmission range is shown in Table 1. According to the Table.1, if the two associated nodes have the same distance in the interference range, that mean they may be interfere with each other; even though, we can eliminate the interference among the two nodes by using the strategy of increasing the channel separation. The value of channel separation is increases when the interference factor decreases. For example, if the value of channel separation is greater than or equal to 5, that means no interference between the associated nodes in the WMN. At the same time, this is possible to get the channel separation without interference between those two nodes. At last, we can get the final channel separation among the *U* and *V*'s children and V and *U*'s children. This procedure of channel separation in multicast tree was shown in Fig. 3.

Using this channel separation procedure, we only calculate the channel separation among *A* and *B*. The ADMM based minimum interference channel assignment is to totally eliminate the interference between the two nodes. In this situation we consider the pair of *A* and *B* associated nodes, the *A*'s children are *B* and *D* and *B*'s child is *E*. End of the result, (*A*,*E*) and (*B*, *D*) pairs are considered as a channel separation of *A* and *B*.

Table 1. Interference range of WMNs

Channel Separation	2 Mb/s	5.5 Mb/s	11 Mb/s
CS 0	2.5 R	2.2 R	2 R
CS 1	1.62 R	1.5 R	1 R
CS 2	1.1 R	1 R	1 R
CS 3	0.96 R	0.81 R	0.62 R
CS 4	0.4 R	0.37 R	0.21 R
CS 5 (or) >5	0	0	0

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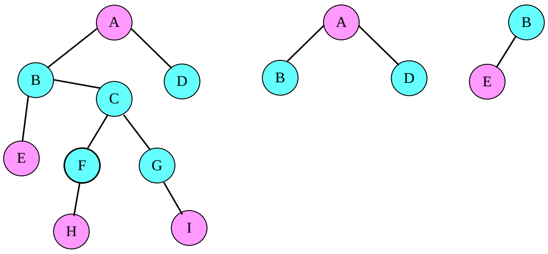

Figure. 3 Channel separation in multicast tree

Algorithm 1: Channel Assignment to all nodes
1. Initialization
2. Input: A multicast Tree, *T*
3. Set of nodes with Channel Number CN_Y
4. Set of node without Channel Number CN_N
5. The channel separation of all pairs of nodes in the multicast tree T**,** CS<U,V>
6. A channel number for each node i, CN_i
7. Output: Channel assignment for all nodes with no interference
8. PROCEDURE:***CHANNEL ASSIGNMENT***
9. **while** $CN_N \neq 0$ **do**
10. **find** maximum CS<X,Y>
11. **for** each node i∊ CN_Y**do**
12. *R=R+1*
13. **end**
14. X←U
15. Y←V
16. allocate CN_Y to all node i
17. End

Finally, ADMM based minimum interference channel allocation method wants to assign a channel number to all nodes in the multicast tree. This final channel assignment process is described in Algorithm. 2.

Based on the algorithm the channel is allocated to all pairs of node in the multicast tree, which is possible to reduce the interference and increase the network throughput in multichannel multi-radios WMNs. The channel assignment in multicast tree is shown in Fig. 4.

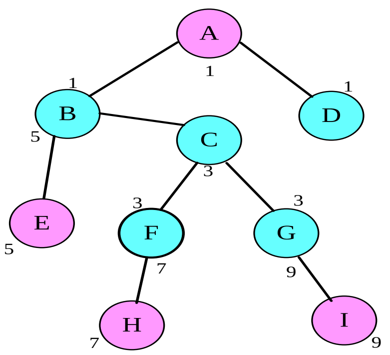

Figure. 4 Channel Assignment in Multicast tree

4. Simulation result and analysis

The experimental result for the suggested methodologies of channel assignment in Wireless Mesh Network is implemented by using NS-2 (Network Simulator-2). The simulations conditions and parameters values are given in Table 2.

The performance efficiency of the proposed method is compared with the existing method of multicast channel assignment approaches. Our proposed framework implements a hybrid approach for channel assignment and multicast routing in the multicast multi-radio multichannel WMNs. We introduce a Q-learning algorithm for construct the multicast tree for reducing the channel interference among the neighbouring tree nodes in the mesh network and we employ the modified version of alternative direction method of multipliers for channel assignment with the maximum number of radio nodes in the multichannel multi-radios wireless mesh networks.

The performance efficiency of proposed methodologies of channel assignment with minimal interference for load balancing of WMN's using Q-Learning and MADMM are compared with the other existing approaches such as Learning Automata and Genetic Algorithm (LA-GA) [5], LCR, learning automata based multicast routing (LAMR) [18] and Genetic Algorithm (GA)-based approach [8].

The performance was evaluated by using the metrics such as average throughput, packet delivery ratio, end-to-end delay and total cost with the given explanations.

Average throughput is defined by the number of packets received by the receiver at the time required to deliver the average number of packets that the entire multicast receiver receives.

Table 2. Simulation conditions

Parameter	**Value**
Area size	1500 m ×1500 m
Number of smart meters	100, 200, 300, 500
Number of gateways	4
Propagation model	Free space path loss model
Routing protocol	LA-HWMP
Packet size	512 bytes
Transmission energy	17.4 mA
Receiving energy	19.7 mA
Simulation time	3600 s
Packet generation interval	900 s
Traffic type	CBR
Transmission range	300 m

$$throughput = \frac{output\ data(bit)}{60s} \quad (3)$$

Average End-to-End delay is defined as the average time is taken by the packet which is to be transfer across the multicast network from a source to the entire multicast receiver.

$$delay = \frac{average\ time}{data\ packet} \quad (4)$$

Average packet delivery ratio is defined as the number of packets received by all multicast receivers above the packets sent by the average source on the entire multicast receiver. This criterion specifies the number of packets delivered to multicast recipients over the number of packets expected to be established by the multicast receiver.

$$packet\ delivery = \frac{number\ of\ packets\ received}{number\ of\ packets\ send} \quad (5)$$

Total cost is defined as the number of connections or links that make up the multicast routing tree.

Packet loss: The packet loss ratio represents the ratio of number of packets not received divided by the total number of packets. Each packet has a deadline before execution, and if this is not possible, the scheduler tries to minimize the number of lost packets due to deadline expiry. It is not a measured value but is obtained by subtracting the delays of two successive requests. The packet loss rate is expressed to find the reliability of a communication network path.

$$Packet\ Loss = \frac{No\ of\ packets\ not\ received}{Total\ no\ of\ packets} \quad (6)$$

Energy consumption: The energy consumption depends on average rate of the power consumption of node times the time of operation. These powers can easily determine experimentally as the nodes are available.

$$Enerfy\ consumption = \frac{Avg.\ power\ consumption\ rate\ in\ each\ node}{Time} \quad (7)$$

Energy efficiency: Energy efficiency can be described as the ratio between the total number of packets received at the destination node and the total energy spent by the network to deliver these packets.

$$Energy\ effciency = \frac{Total\ energy\ spent}{time} \quad (8)$$

Network costs: Network costs are calculated by cost per Rack Unit. They start by calculating costs for network hardware, network infrastructure maintenance, and labor. These expenses are added together and then divided by the number of rack units.

$$\text{Network costs} = \frac{Total\ cost}{Rack\ unit} \quad (9)$$

The graphical representation of the Figs. 5, 6, 7, 8, 9, 10, and 11 are represents the experimental comparison of proposed method with the existing approach of WMN's network average end-to-end delay, average packet delivery ratio, data loss, energy consumption of the network, energy efficiency, network throughput and the cost calculation of the network respectively.

From Fig. 5, it can be seen that our proposed system takes less time for the end-to-end delay as compared to other existing approaches. In fact, our proposed algorithm's end-to-end delay is an average of 2.1%, 11.5%, 16.3% and 22.5% lower than LA-GA, LCR, GA and LAMR respectively. Thus the reason of proposed optimal channel assignment approach used the end-to-end delay packets for the minimum result because the time taken to select the optimal path is shorter compared to other existing

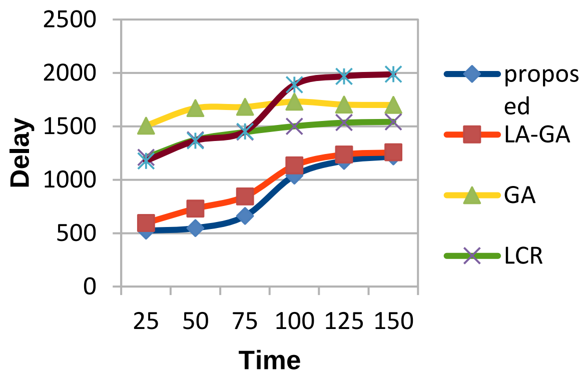

Figure. 5 Comparison of average end-to-end delay

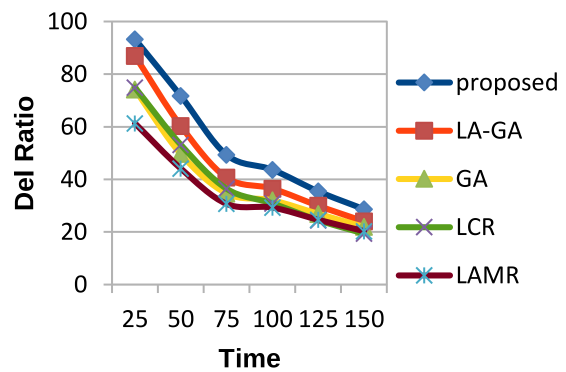

Figure. 6 Comparison of average packet delivery ratio

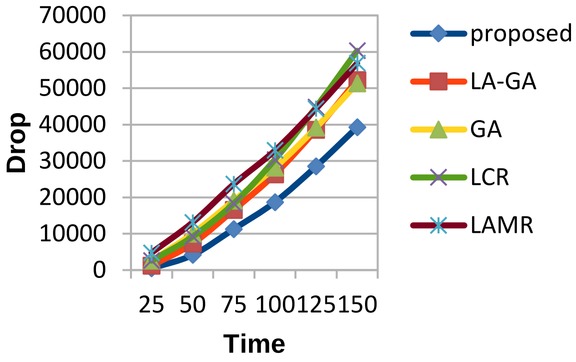

Figure. 7 Comparison of packet loss

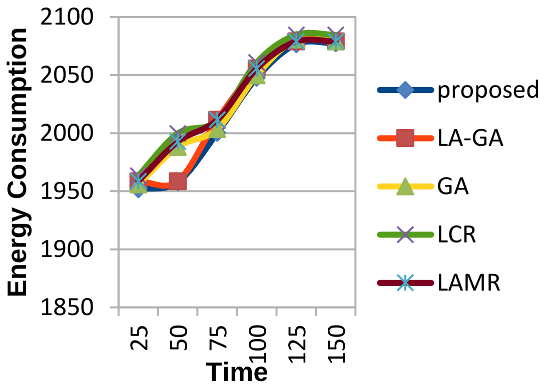

Figure. 8 Comparison of energy consumption of the network

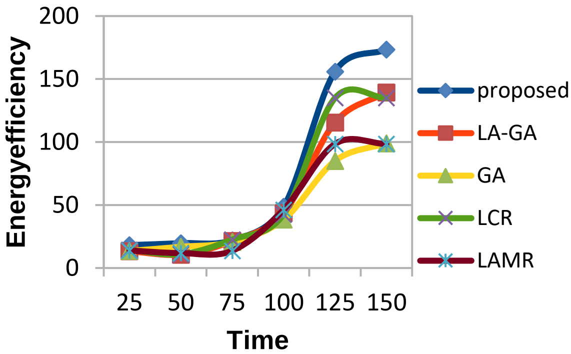

Figure. 9 Comparison of energy efficiency of the network

approaches. Compared to the other channel assignment approach, our proposed approach uses the minimum end-to-end delay packets built on the multicast tree because the time and interrupts it takes to select the optimal path.

From the Fig. 6, our proposed algorithm's average packet delivery ratio is higher than those of LA-GA, GA, LCR and LAMR by an average of 3.2%, 18.5%, 18.3% and 29.2% respectively. So the average packet delivery rate is rises by increasing the number of available channels.

From the Fig. 7, the loss of data in the wireless mesh network caused due to the multi-radio multichannel WMN's is very less in our proposed strategy with compared to the other existing channel assignment approaches. In fact, our proposed algorithm's packet loss is an average of 26.5%, 26.2%, 30.5% and 32.3% lower than the LA-GA, GA, LAMR and LCR respectively. When compared to the other existing channel assignment approach, our proposed system takes less time for energy consumption in the channel assignment strategy.

In the Fig. 8, our proposed algorithm's residual energy consumption of the network is an average of 1.1%, 1.2%, 1.4% and 2.1% lower than LAMR, LAGA, GA and LCR respectively. The LCR based channel assignment approach takes more time compared to the all.

From the Fig. 9, the energy efficiency of the GA based MADMM channel assignment approach is very high compared to the other channel assignment strategies. In this above figure, the energy efficiency of the proposed algorithm is higher than the LA-GA, LCR, GA and LAMR by an average of 25.2%, 24%, 39.5% and 39.6% respectively. The average efficiency of the proposed approach is high when attempting to create a multicast tree with minimal interference in each iteration of the Q-learning algorithm.

Fig. 10 shows the variation in average network throughput in relation to the time. It is clear that our proposed algorithm has a higher throughput than the than the other existing methods. When compares with the GA, LA-GA, LAMR and LCR, our proposed algorithm's throughput increases by an average of 20.5%, 32.2%, 36.7% and 39.4% respectively. Fig. 11 shows the variation of cost calculation of the network in relation to the time. It is clear that our proposed algorithm has a lower cost than the other existing methods. When compares with the GA, LCR, LA-GA and LAMR, our proposed algorithm's cost calculation increases by an average of 20.5%, 22.2%, 26.7% and 49.4% respectively.

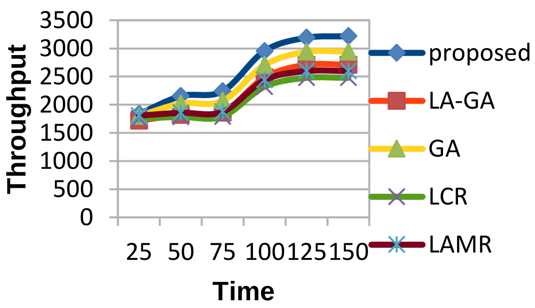

Figure. 10 Comparison of network throughput

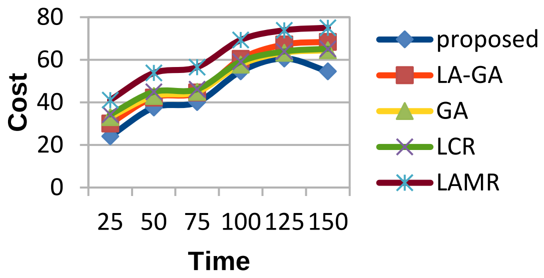

Figure. 11 Comparison of cost calculation of the network

From the Fig. 6, 9 and 10 the network average packet delivery ratio, energy efficiency and the network throughput estimation of the proposed channel assignment approach is very high when compared to the other existing channel assignment approaches. According to the Fig. 5, 7, 8 and 11, the network average End-to-End delay, data loss, energy consumption of the network and the cost calculation of the network of the proposed channel assignment with minimum interference of Q-Learning algorithm based MADMM strategy is very less when compared to the other existing channel assignment strategies such as LA-GA, GA-based approach, LCR and LAMR channel assignment methods.

5. Conclusion

In this paper, an effective channel assignment method of Q-Learning and MADMM based channel assignment algorithm is proposed to minimize the interferences of the network produced due to the multi cast multi-radios wireless mesh network and enhance the network throughput significantly. One of the best ways to reduce interference is to allocate a different channel to each wireless machine instead of using the same channel, by creating the optimal multicast tree using the Q-learning algorithm. Our proposed framework implements a hybrid approach for channel assignment and multicast routing in the multicast multi-radio multichannel WMNs. The Q-learning algorithm used for the multicast tree for reducing the channel interference among the neighbouring tree nodes in the mesh network and we employ the modified version of alternative direction method of multipliers for channel assignment with the maximum number of radio nodes in the multichannel multi-radios wireless mesh networks. The experimental result for the suggested methodologies of channel assignment in Wireless Mesh Network is implemented by using NS-2 and the performance was evaluated by using the metrics such as average throughput, packet delivery ratio, end-to-end delay and total cost, which is compared with the other existing channel assignment strategies such as LA-GA, GA-based approach, LCR and LAMR channel assignment methods. The simulation results show that the proposed method is 14.1% better than LA-GA, 19.42% better than LCR, 24.2% better than GA, 30.64% better than LAMR.

Conflicts of Interest

The authors declare no conflict of interest

Author Contributions

Karunya Rathan: Conceptualization, Methodology, Writing—Original Draft Preparation,
Susai Michael Emalda Roslin: Reviewing & Supervision

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