# Distributed Efficient Channel Allocation technique for Multi radio Multi Channel Interference aware Multi path routing protocol in Wireless mesh Networks

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*Abstract : In this work, we present a distributed channel assignment technique for wireless mesh networks. According to this work, first of all we utilized graph coloring theory for mesh network modeling. With the help of this, interference range and communication range are established for wireless mesh network. Further, we use conflict graph and connectivity graphs for network modeling. Later, we have developed a distributed channel assignment technique using link capacity and load criticality estimation. Link capacity and load criticality estimation models have been discussed in literature and have been considered as promising technique but due to huge amount of data traffic, these techniques are unable to provide the significant performance. In order to address this issue, here we present a greedy approach for channel selection. This approach results in significant channel selection resulting in interference reduction.*

## 1.1 Introduction

Recently, communication demand has increased drastically due to improved communication technology and increased number of devices. The growth of multimedia communication over wireless network demand for better quality of service (QoS) for end user. In order to satisfy this communication criteria, wireless mesh network have been considered as a promising technique. In previous sections we have discussed about the mesh network architecture. Generally, based on the radio configuration mesh network are categorized into two main categories as: single- radio mesh network and multi-radio mesh network. According to existing multi-radio wireless mesh network studies, it is concluded that multi-radio mesh network performs better when compared to single-radio mesh network. According to the working process of single-radio mesh network, each node is operated in the same channel configuration. In this configuration, the forwarding node causes interference with two continuous nodes resulting in the end-to-end throughput performance degradation [1, 2] whereas multi-radio mesh networks are capable to eliminate the intra-path interference if the interference links are present in the non-overlapping channels. Another key advantage of multi-radio networks is defined as its ability to use non-overlapping channels in the same physical region i.e. it can used multiple non-overlapping channels in the same communication environment. This process helps to reduce the inter-path interference by considering multiple flows in multi-radio mesh network resulting in the performance improvement in terms of end to end throughput. However, various researches have been carried out in the field of mesh network describing the issue of multi-radio mesh network in the real-world communication system [3,4]. Real world communication such as deployment of mesh network in urban environment is a challenging task because this scenario poses design and performance challenges. In order to address this issue, in [5,6] developed a new protocol and tested it for real time environment.

## 1.2 Related Work

This section provides the description about the most recent studies in the field of channel assignment. In the field of communication, mobile ad-hoc networks are also considered as a promising technique which has attracted lot of attention of researchers. In [7], authors considered MANET based communication and presented a new approach to improve the MANET performance by considering multi-channel and multi-hop behavior. In this work, authors have presented various issues present in the multiple channel utilization. In order to overcome these issues, a new multi-channel MAC protocol is proposed. This approach consists of below mentioned features:

- According to this approach, channels are assigned based on the "on-demand" style to mobile hosts.
- Channels pose independency from network topology and degree.
- It is capable to adapt mobility and exchange some control message to obtain the channel assignment
- In this approach, there is no need to perform clock synchronization.

Similarly, in [8] authors have presented a study for channel assignment in wireless mesh networks. According to this research, it is concluded that multi-channel communication can improve the performance of wireless mesh networks when compared with single-channel communication schemes. Multi-channel communication schemes are capable to reduce the interference; this interference reduction improves the overall performance of the network. to address this issue, in this work interference-aware topology control scheme and QoS routing (based on IEEE 802.11) is presented by considering dynamic traffic in the network. In these kinds of networks, channel assignment and routing are well-known issues which are causing the performance degradation in the network. In this work, authors have presented a new concept about co-channel interference and by considering this assumption; a heuristic approach for network topology is developed as Interference Survivable Topology Control (INSTC). This topology considers channel assignment problem for k-connected network topologies. Later, bandwidth aware routing problem is formulated for the given network topology.

## 1.3 Existing Model

In this section we present the existing approach for channel assignment in wireless mesh network. In order to do this,

routing-based dynamic channel assignment protocol[9,10,11] is discussed here

### 1.3.1 Problem Description

First of all we discuss the problem formulation stage based on these conditions:

- Let consider a problem of channel assignment in static wireless mesh network. The network is equipped with N communicating nodes which are having $K$ number of interfaces. Relationship between channels and interfaces is given as $C > 1$ and $C >= K$.

- Communication between two nodes $i$ and $j$ takes place if these nodes are in the same range and of communication and sharing a common channel. During this stage, a link is generated which is responsible for communication. This link ensures communication and network connectivity by providing channel assignment.

- Interfere avoidance which is ensuring the communication quality.

In this work, we have considered an existing approach for dynamic channel assignment which is known as routing based channel assignment algorithm. In this process, assigned channels are varying dynamically based on the direction of next-hop.

### 1.4 Proposed model

In this section we discuss about the proposed approach for distributed channel assignment problem. In order to carry out this study, first of all we present a theoretical study of wireless mesh network architecture. As we have discussed in previous section that channel assignment problem is known as NP-hard problem. This approach is similar to the graph coloring problem. Hence, we present a mathematical modeling of graph coloring approach.

### 1.4.1 Graph Coloring Problem

For channel assignment problem formulation, graph coloring model is used here. This approach is based on the communication range and interference range. Communication range denotes the possible reliable communication between two nodes whereas interference range in which the transmitting node can affect the communication of other node which is operating in same channel or partially overlapped channel. In this approach, communication range is always smaller than the interference range.
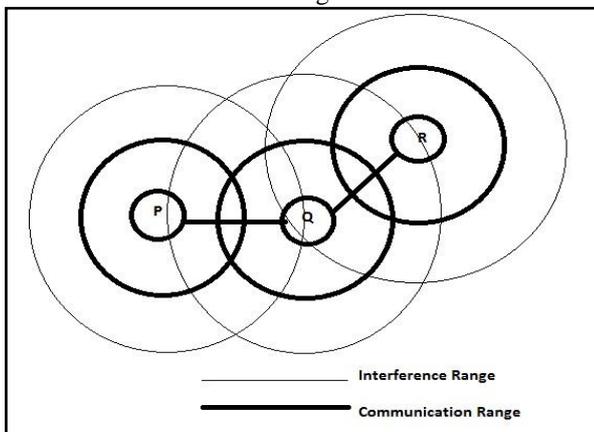


**Figure 1.1 Graphical representation interference and communication range**

Let us consider an undirected graph denoted as $G(V, E)$ where $V$ denotes vertices and $E$ denotes network edges and $G$ is defined as the set of vertices and edges. Since, the network is considered as mesh network so vertex denotes the mesh

router and wireless link between two mesh routers is denoted by edge. According to the coloring approach, our main aim is to cover all vertices such as that the adjacent vertices should not use the same channel.

Next we discuss about connectivity graph model to analyze the network connectivity during communication.

### 1.4.2 Connectivity Graph

This type of network architecture, where set of vertices $V$ contains network nodes which may be equipped with multiple radio interfaces and set of edges $E$ denotes all communication links in the mesh network. Let $(v_i, v_j)$ be a pair of communication nodes and the link between these two nodes is denoted as $e$ where $v_i, v_j \in V$. Graph $G$ denotes the connectivity graph as depicted in Fig 5.5
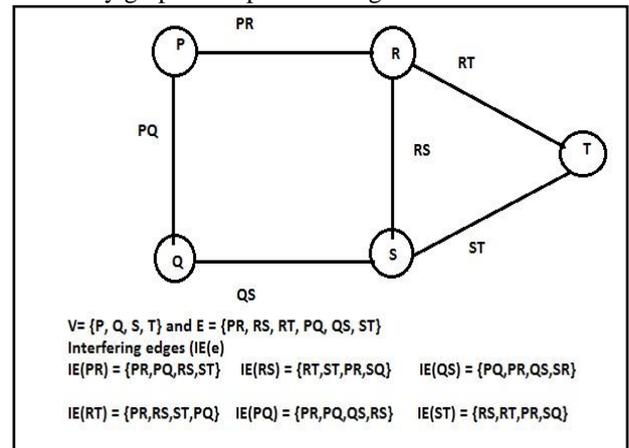


**Figure 1.2 Connectivity Graph and Interference edges**

### 1.4.3. Interfering edges

During communication, mesh nodes face the interference issue, in order to consider this issue in our simulation study, we introduce the concept of *interfering edges*. In this assumption, interfering edges are defined as the set of all edges which are using same channel but can $e$ but cannot use it simultaneously in active state together with edge $e$. according to this study, all edges are competing for same channel to communicate, hence our main aim is to minimize the number of all edges to improve the capacity with the help of channel assignment technique.

### 1.4.4 Conflict Graph

Here we discuss about the conflict graph technique for wireless mesh networks. Let us consider a conflict graph which is denoted as $G_c(V_c, E_c)$, set of edges $E_c$ and vertices $V_c$. Vertices and connectivity graphs have a relationship as $e \in E_c$ and $v_c \in V$.

During communication, if interference is caused in the connectivity graph then there exists a conflict graph between conflict graph edges. This conflict graph is used for representing the interference model. If any interference occurs between two edges then it can be said that the nodes are present in the same wireless range and interference range.
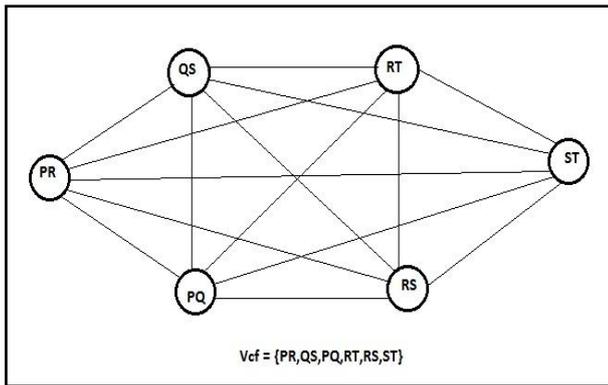
**Figure 1.3 Conflict Graph**

*1.4.5 Load estimation and channel assignment*

This approach denotes a dynamic approach for channel assignment and routing approach where data traffic is routed towards gateway node in the network. It is assumed here that offered traffic load is known to each virtual link. The main aim of this algorithm is to assign channel such a way that network connectivity should not affect by taking into account bandwidth limitation issues. Initially, this approach estimates the total expected load on each link caused by traffic flow. In next stage, channel assignment approach is imposed by visiting each virtual link and channels are assigned greedily by arranging links in decreasing order. This algorithm is initialized by an initial load estimation and iterated by considering bandwidth allocation until network load criteria is matched. This iterative process is depicted in figure
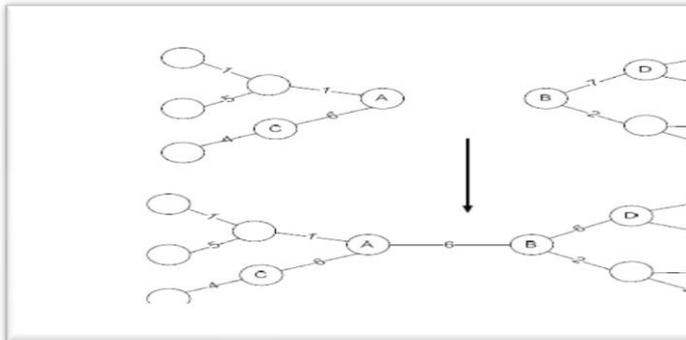


**Figure 1.4 Channel Revisiting Process**

*1.4.6 Link Load Estimation*
In this section we estimate the load on each link caused due to the traffic flow in the mesh network. This technique is based on the estimation of load criticality by assuming perfect load balancing method throughout the entire network.
For link load estimation, we require total number of acceptable path for communication which is expressed as $P(x, y)$. This path is estimated between tow pair of nodes, this pair is denoted as $(x, y)$, $P_l(x, y)$ and connected through a communication link denoted by $l$. Let us consider that $B(x, y)$ is the estimated load by considering $x$ as source node and $d$ as destination node.
With the help of this expected traffic load can be computed:

$$\phi_l = \sum_{x,y} \frac{P_l(x, y)}{P(x, y)} . B(x, y) \qquad (5.1)$$

From this expression, it can be concluded that initial expected traffic is equal to the sum of loads of all acceptable paths considering each link.

*1.4.7 Link Capacity Estimation*

Here we present the concept of communication link capacity estimation. It is the measurement of available channel bandwidth to a virtual link. It can be determined by knowing the number of all virtual links in its interference range that are assigned to same radio channel. During measuring the capacity of each virtual link, it is important to consider all traffic loads in the range of its interference. According the concept of channel assignment process, higher load link should get more bandwidth compare to other links. However, higher loads links which are having more interference should carry less bandwidth. Hence the link capacity is invers proportional to the interfering load and direct proportional to the traffic load. Thus, the capacity $bw_{(i)}$ assigned to link $i$ can be obtained using the following equation:

$$bw_{(i)} = \frac{\phi_i}{\sum_{j \in intf \ (i)} \Phi_j} * C_{ch} \qquad (5.2)$$

$\phi_i$ = expected load on link $i$
$C_{ch}$ = sustained radio channel capacity
$intf \ (i)$ = virtual links

**1.5 Distributed Channel Assignment**

In this section we present the proposed distributed channel assignment technique used for wireless mesh network. First of all, channel selection algorithm is applied, later this approach is adopted into practical scenario of communication where nodes are equipped with single radio card and can transmit and receive single channel at a time.
*1.5.1 Channel Selection*

Here we make an assumption that each node can transmit data over a single channel which can be selected from any $K$ available channels but can interact with all $K$ channels. This assumption simplifies the problem by allowing to transmit a message for channel selection and interference reduction.
Intuitively, a node would like to choose a channel upon which its transmissions are least likely to suffer interference from other senders' transmissions (on interfering channels). To do this, each node continually seeks to greedily improve its current choice of channel via the following algorithm:

**Algorithm 1: Channel Selection Process (node n)**
**Input :**
Nodes which are present in the range of interference
Channel of each node present in the network
Current channel
$(S_i, c_j, c_i)$ denoted respectively
**Initialize process**
For all $k = 1, ..., K$

$$F(k) \leftarrow \sum_{j \in S_n} f(k, c_j)$$

If $F(c_n) > F(k)$ for any $k = 1, ..., K$ then
$c_i \leftarrow k_{min}$ where $k_{min} = k: F(k) \leq F(k') \forall k' = 1, ..., K$
**End if**
**End procedure**

If the prior choice minimizes the sum of interference costs, then the node makes no change. The mesh node i's select channel only on the information available in its local proximity. This makes algorithm fully distributed which uses the information available within its local region.

We make two important observations:

• Each node i's choice of channel depends only on information that is available within its local domain, i.e., how many nodes will experience collisions when node i attempts to transmit to them. Hence, the algorithm is truly distributed, using only information available within its local region.

• The efficacy of the node's choice depends on how well this sum of interference costs actually maps to the interference levels the node experiences. A more ideal solution would be to test every channel and see which one interferes the least with neighboring transmissions. However, it would be unrealistic in a distributed setting to assume that every node could simultaneously perform such checks, varying its own channel selection across the spectrum while its neighbors stay fixed. It is not intuitively obvious that this distributed channel selection process is self-stabilizing, i.e., that nodes continually looking to improve on their local interference cost will eventually converge to a stable channel allocation; one node's channel change can increase some other node's interference level, and cause the other node to change its channel, and so forth. However, we will next show that indeed this process does stabilize. To prove stabilization, we make some simplifying assumptions about the network environment. Namely:

• Every node $i$ has the correct channel information of all other nodes in its interference range, $S_i$.

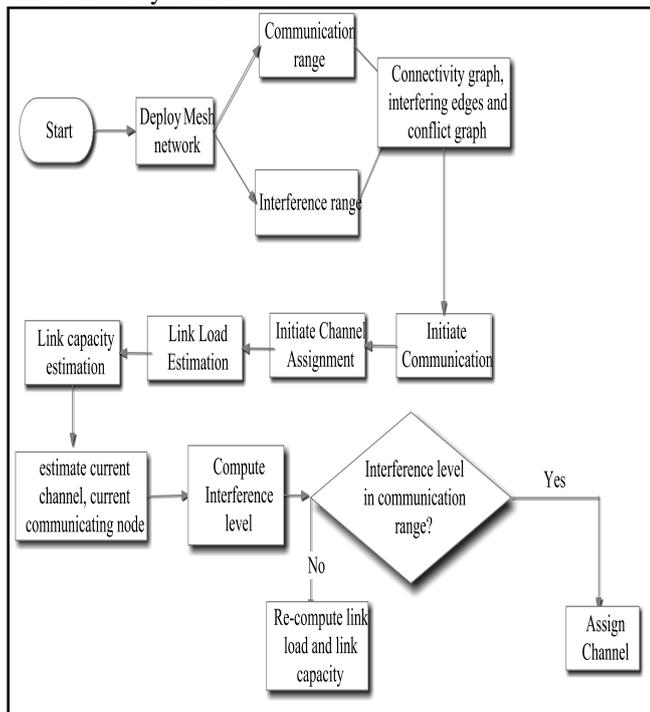• No other node in Si changes its channel simultaneously with node $i$



**Figure 1.5 Channel Selection Process**

## 1.6  Experimental study

This section deals with experimental study of proposed approach for distributed channel assignment protocol for wireless mesh network. This study is carried out using MATLAB simulation tool. In order to analyze the performance of proposed approach, 50 mesh nodes are deployed in the area of 1000 m x 1000 m. each node is kept apart from each other by distance of 250 m.  Each link capacity is fixed to 10Mbps. This model is simulated for 900 seconds. For radio type, 802.11 a/g is used and for MAC protocol 802.11a is used where TRS/CTS not applied. For simulation study, broadcast data rate is considered upto 10 Mbps by considering constant bit rate traffic scenario. Here, 1 packet is transmitted per second with the packet size of 512 bytes size. The default simulation parameters used are shown in Table 1.1

**Table 1.1 Simulation parameters**

| Parameter | Value |
|---|---|
| Simulation area | 1000 x 1000 meter |
| Total number of nodes | 50 |
| Communication Radio Type | 802.11 a/g |
| Routing Protocol | Multipath |
| Transmission range | 250 meters |
| Slot size $K$ | 25 ms |
| Number of Slots in a quarter of linkframe | 4 |
| Size of data packet | 512 bytes |
| Weight between perfect and avg traffic δ | 0.3 |
| Higher Threshold Value | 3 |
| Lower  Threshold Value | 0.6 |
| Considered model for path loss | Two-ray propagation |
| Channel Frequency | 2.4 GHz |

We chose three performance metrics for simulation evaluation:

*Average End-to-end Delay*: This is the average measurement of time taken to deliver a packet from source node to destination node where successfully delivered packets only considered for performance evaluation.

*Average Throughput*: This is the measurement of total number of packets delivered during complete communication

*Packet Loss*: this is the measurement of number of drop packets during communication.

## 1.7  Results and Discussions

The comparison of Distributed Channel Allocation Multipath Routing Protocol carried out with varying traffic load and number of available channels.

Here we present a comparative study of proposed distributed channel assignment approach and existing Routing-based Dynamic Channel Assignment approach [9].

### 1.7.1 Performance evaluation against varying traffic loads

This performance analysis is presented in figure 5.10. In order to carry out this analysis traffic load is varied and numbers of nodes are varied as 25 nodes and50 nodes. First of all, we evaluate the throughput performance in terms of kbps, later the similar study is performed for 25 mesh nodes. According to this study better throughput performance is reported for 25 mesh node because distributed channel allocation allows nodes to share the channel efficiently with less interference. All nodes in the network will be able to get the fair chance of channel acquisition and perfect utilization. As the traffic load increase, the sharing of channels as increases in turn has clear effect on the throughput.  For 50 mesh nodes, a similar study is carried out and the comparative study is presented
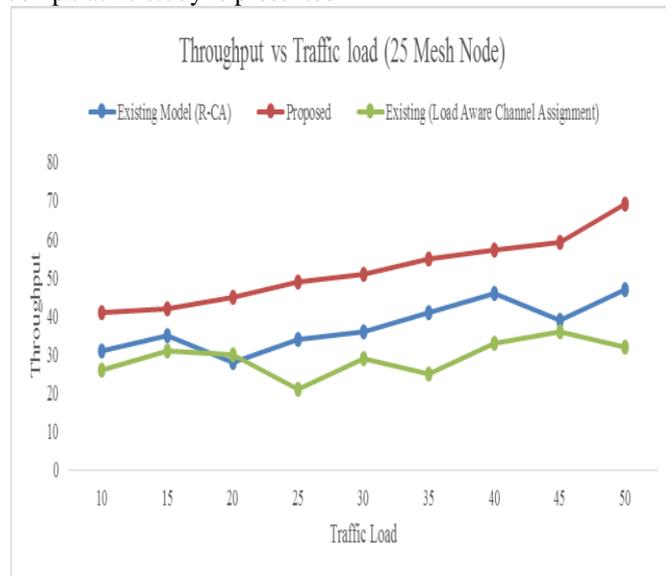


**Figure 1.6 Throughput against Traffic Load offered (performance for 25 nodes)**
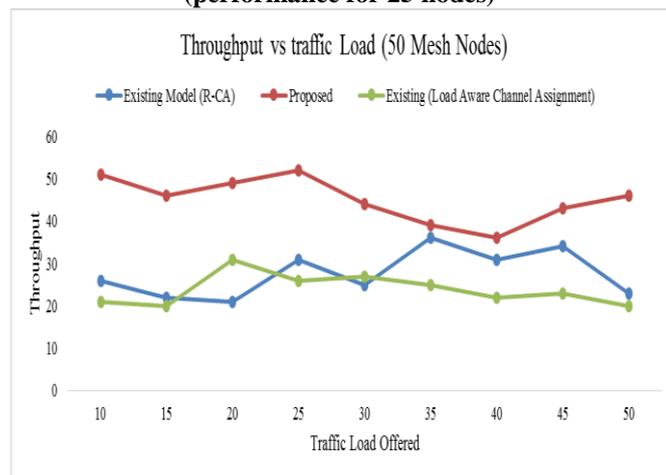


**Figure 1.7 Throughput against Traffic Load offered (performance for 50 nodes)**
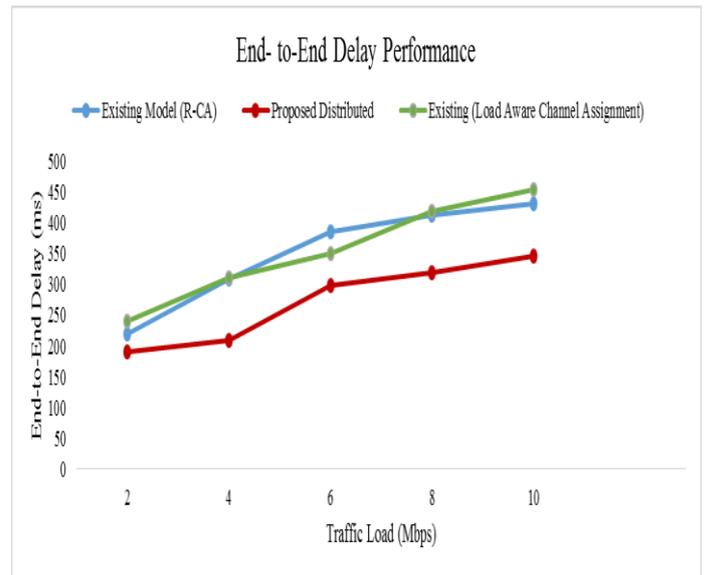


**Figure 1.8 End-to-end Delay against Traffic Load offered**

Above fig depicts the comparative performance of proposed and existing approach in terms of End-to-End Delay. This analysis is also carried out by applying the same methodology as presented for throughput performance analysis. Delay is reduced by 12.80% in proposed system when compared with existing model for varied traffic load scenario.

The fig 1.9 shows the average throughput of distributed channel allocation carried out with varying traffic load. The comparison is made by considering existing protocols for 25 mesh nodes. During first round with 25 nodes, low delay is recorded against the 50 nodes. This is because distributed channel allocation allows nodes to share the channel efficiently with less interference. All nodes in the network will be able to get the fair chance of channel acquisition and perfect utilization.
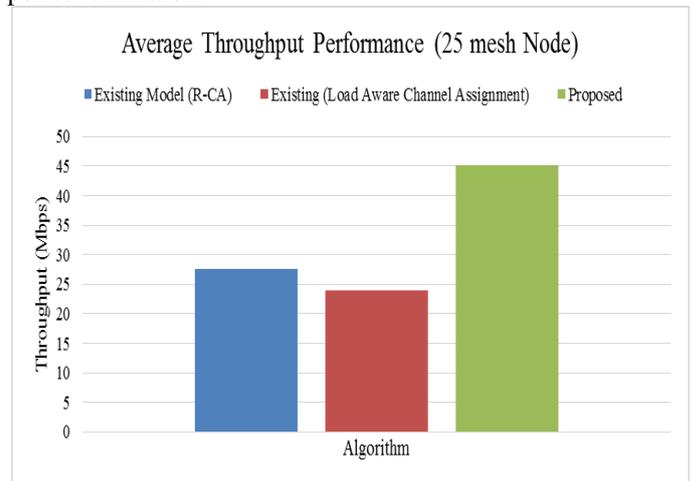


**Figure 1.9 End-to-end Delay against Traffic Load offered**

The fig 1.10 shows the packet loss due to distributed channel allocation was carried out with varying traffic load. The comparison is made between two set of mesh nodes. During first round with 25 nodes. This is because distributed channel allocation allows nodes to share the channel efficiently with less interference. Due to less interference, has an effect on less number of packet losses. All nodes in the network will be able to get the fair chance of channel acquisition and perfect utilization. As the traffic load increase, the sharing of channels as increases in turn has clear effect on increase in packet loss.
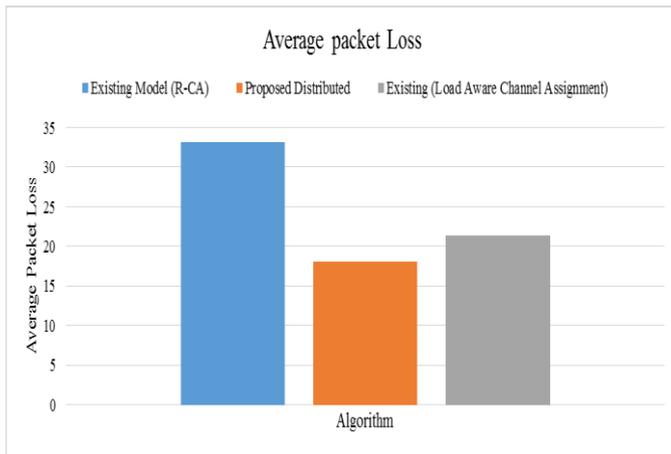
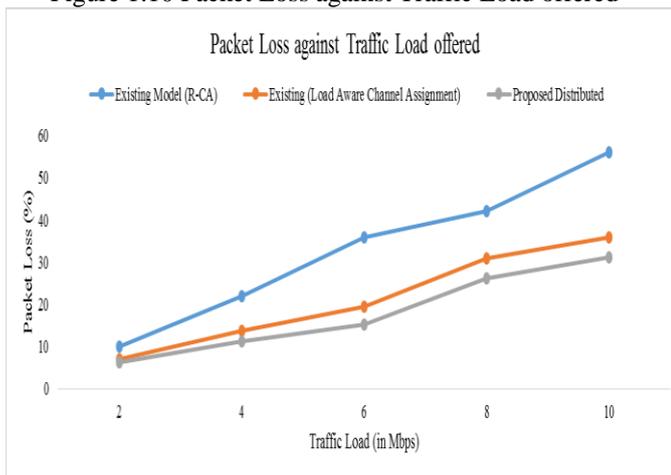Figure 1.10 Packet Loss against Traffic Load offered



**Figure 1.11 Packet Loss against Traffic Load offered**

Another performance evaluation performance parameter is computed in terms of packet loss during communication using similar simulation parameters. In this model, traffic load is varied and packet loss is estimated. Figure 5.15 shows comparative study of packet loss of proposed model and existing approach.

## 1.8 Conclusion

The performance evaluation of fully distributed channel allocation algorithm which assigns available channels to multi-radios nodes in wireless mesh networks is carried out using MATLAB simulation tool. This distributed algorithm which optimizes the channel allocation of links in a multi-radio wireless mesh network to increase throughput of the network by reducing interference between links in the network. From the simulation study it can be concluded that the performance of wireless mesh network is improved by 10 to 35 % when compared to state of art techniques. The assignment algorithm stabilizes to a required configuration which multipath routing can exploit to provide better end-to-end system performance. The existing devices are to be equipped with distributed nature to make ensure that it is sufficiently executed on a large scale mesh networks. Experimental study shows that proposed distributed approach shows better performance in terms of throughput, packet loss and End-to-End delay when compared with other existing protocol. The experiments are run over moderate mesh wireless mesh networks and as future work it can be extended to a large size mesh networks.

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