CHAPTER 5

POWER AWARE TRAFFIC STATE INFORMATION BASED DYNAMIC CHANNEL ASSIGNMENT

5.1 INTRODUCTION

Lalitha et al. (2014) Mesh Router provided with multiple radios is an optimal solution to enhance the performance of Wireless Mesh Networks (WMNs). Major issue of routing protocol traffic flows & assigning optimal channels to multi radio in Multi-Channel Multi Radio. Wireless mesh network has attained a lot of response in present years. Switching multi radio in on-state and utilizing more channels for communication is always favorable for network capacity, but it may not be desirable from the perspective of energy efficiency.

MC-MR networks consumes more energy due to the frequent switching among Multiple Radios and Multiple channels. Most of the approaches mainly concentrated on reducing interference or increasing the throughput. Minimum attention has been given to the energy consumption of wireless mesh networks.

Hence, in this research work power aware traffic state information based dynamic channel assignment approach has been proposed to provide an energy efficient error free communication. The system model and problem formulation is same as the section 4.2. But in addition to it, energy wasted during retransmission due to interference and congested channel has been
considered in the problem formulation. The next section describes the proposed channel allocation for mesh nodes.

5.2 TRAFFIC STATE INFORMATION AWARE DYNAMIC CHANNEL ASSIGNMENT (TSIDCA)

In TSIDCA, the loosely coupled cross layer design has been used (Yanbing Liu & Dan 2011), where the optimization is performed without crossing layers while concentrating on one protocol layer.

![Figure 5.1 Traffic State Information of DCA structure](image)

Here the flow rate, link capacity information from the MAC layer and the packet drop, round trip time from the Transport layer are taken and the information is generated as a traffic state matrix and reported to the Network layer in the form of channel state information. The reported information has the capability to define the fading channels. The proposed cross layer information taken from the different protocol stack has been explained in the next section.
5.3 PROPOSED CROSS LAYER DESIGN

5.3.1 Cross Layer Metrics

5.3.1.1 Link capacity

Estimating the link quality will provide the information about the link is perfect or not for data transmission. The author (Jonathan Guerin et al. 2010) proposed an Effective Link Capacity (ELC) utilizing the local information available from the MAC layer such as packet delivery ratio (PDR) and count of data packet transmitted on that link (TXC). Here any active probing is not used to estimate the link quality, where the overhead is reduced. TMT is the maximum throughput that can be accomplished on a link with perfect, error free situations, which can be determined analytically (Gupta et al. 2009). The TXC is the average number of data transmissions per frame over the certain period of time. PDR is the fraction of data frames that have been transmitted successfully to the total number of data frames transmitted over a certain period of time.

5.3.1.2 Packet drop

TCP is the most important protocol of the transport layer to provide the basic structure of the Internet. TCP is responsible for reliable data packet delivery between applications. Moreover, some packets may be dropped due to the long delay or/and congestion in a channel. The amount of packet drop of a node at the channel is the difference between the number of packets transmitted and the number of packets received.

5.3.1.3 Round trip time

The round trip time (RTT) is a good measure to know the channel congestion in the TCP transport protocol. The RTT estimates the time duration from the time the data have been transmitted till the time the positive acknowledgement received at the sender side. RTT also reveals the service time information at the communication endpoints.
5.3.2 Three Level Threshold (TLT) Algorithm

In this Traffic state Information dynamic channel allocation uses TLT algorithm to provide the service of transmission based on 3 levels (low, medium and high level) of prioritization. This algorithm dynamically adjusts the up/down thresholds based on prioritization.

Three level threshold algorithm based on inter block nodes and prioritization of data transmission categorize into 3 levels.

The data to be transmitted from source to destination is classified into low priority, medium priority, high priority based on the nature of the data. For example the data is a acknowledgment it is given low priority. The data to be transmitted is a static data and does not have time constraints then it is considered medium priority. The real time and time data is considered as high priority data.

In general, when the data is transmitted from source to destination, the routing protocol selects the route based on OSPF. In which, the low prioritized data may select the better routing path among the available path. Instead a three level threshold algorithm is introduced in this work, which will prioritize the routing path into category, in which PDR, interference level, packet drop ratio is considered as threshold level.

Low level prioritization: Through which the low priority data is delivered. Here packet delivery ratio below 60.

Medium level prioritization: Sub optimal model transmission, in between of low and high strength path takes data transmission. Packet delivery ratio and link strength details are dynamically received from neighbor one among another in the path through IIT method.

High lever prioritization: High prioritized data will be provided high delivery ratio path with the help of IIT algorithm. IIT algorithm selects
the transmission path with the help of optimized details from neighbor node and local monitoring node.

**3LT algorithm**

1. Initially perform routing and establish the multiple paths between the source and the destination
2. For N number of user requesting the service from the network
3. Call channelAssignment (i)
4. End for
5. Calculate the transmission energy and the types of prioritization nodes
6. For N number nodes prioritization service from the channel
7. If ( low prioritization)
8. Consume low energy and low secure quick allocation
9. Else if( medium prioritization)
10. Consume medium energy and partial secure sub optimal allocation
11. Else
12. Consume high energy and secure optimal path allocation
13. For each path, check the first hop information
14. If first hop is same
15. Insert the first path in to route list and discard the succeeding paths
16. Else
17. Insert the path in to route list
18. End if
19. End if
20. End if

**Figure 5.2 Three Level Threshold algorithm**
5.3.3 Channel Assignment

Channel assignment in MC-MR WMN involves assigning a channel for each mesh radio interface to attain optimal channel utilization and minimize interference between channels. In other words, it tries to maximize throughput of the system with better utilize of resources such as channel and radio interfaces. In dynamic channel allocation, K-channels can be allocated to radio interface of the mesh network. The channel is selected out of the common channel set for the link between a pair of nodes. While selecting a channel dynamically in a mesh network, it should remember that the selected channel should ensure the error free communication for forthcoming demands. So, in this proposed approach, the channel set available at each node has been categorized in order to select the best channel to obtain an error free communication. After completion of every data transmission, the channel has been categorized into optimal, suboptimal and non-optimal based on the channel analysis of every channel at each node in the network using the cross layer interaction.

The Link Capacity (LC) is computed using Flow rate (Fr). The resultant value is termed as acceptable flow rate through the channel at a link between two nodes, which is then compared to the threshold value. Here the resultant value is 0 then the channel is said to be optimal channel that is best in cases of an analyzed parameters, as if the resultant value is a non-zero value, minimum than the defined threshold value, then the channel is said to be suboptimal channel, that the channel can be chosen but has to be shifted or replaced after a time interval. While the resultant value is greater than the threshold value, then the channel is said to be non-optimal channel, that the channel is congested such that no request can be serviced through it for a particular instance of time.
Afterwards the traffic matrix has been generated for each channel, which involves the outage capacity and RTT. Figure 5.2 illustrates the algorithm for the traffic matrix generation of K channels.

- **Optimal**: best in terms of examining parameters

- **Suboptimal**: the channel can be preferred but has to be replaced or shifted after a time interval.

- **Non-optimal**: this indicates that the channel is congested such that no request can be serviced via it for a specific period of time.

**TRAFFIC MATRIX GENERATION ALGORITHM**

**Priority abbreviation**

\[ T_x \rightarrow \text{Transmission} \]

\[ A_c \rightarrow \text{Acceptance Capacity} \]

\[ F_r \rightarrow \text{Flow Rate} \]

\[ O_c \rightarrow \text{Outrange Capacity} \]

\[ L_c \rightarrow \text{Link Capacity} \]

\[ \text{RTT} \rightarrow \text{Round Trip Time} \]

\[ \text{Th} \rightarrow \text{Threshold Value} \]
Generation algorithm

1. If $T_x > 1$
2. For $j=0$ to $n$ nodes
3. For $i=0$ to $k$ channels in a node $j$
4. $\text{drop}(i) = \sum_i (\text{snt}_p \_ \text{packet}(i) - \text{rcvd}_p \_ \text{pkt}(i))$
5. $A_c = Fr(i) \% Lc(i) \quad // \text{channel categorization based on the channel analysis}$
6. If $A_c ==0$
7. Optimal Channel
8. Else if $A_c > Th$
9. Sub-optimal channel
10. else if $A_c < Th$
11. non-optimal channel
12. end if
13. $Oc(i) = drop(i) / A_c(i)$
14. $Tx(i) = [Oc(i), RTT(i)]$
15. End for
16. $csi(i) = Tx(i)$
17. End for
18. End if

Figure 5.3 Algorithm for traffic matrix generation for K channels
The channel allocation algorithm using the traffic matrix is given in the Figure 5.3. Using the cross layer interaction the transmitting node determines the occurrence of traffic in each channel by forwarding the probe packet to destination. After receiving the broadcasted packet the neighbour or destination node forward the channel state information by integrating the channel state information for each channel. After receiving the RREP, with the CSI, the channel allocation relies upon the minimum traffic matrix value of optimal and sub optimal channel has been performed.

In case, whenever there is no availability of optimal and suboptimal channels, then foreach channel determine the wait time (wt) for non-acceptable flow rate of data. If the Round trip time is less than the wait time for n number of data transmission in channel x, where the node can wait and obtain the channel x to link establishment between a pair of nodes, otherwise they should initiate a new broadcast for selecting the next node to avoid the delay by unnecessarily waiting for the channel x that ultimately results in performance degradation of the network. The delay incurred by waiting for the channel is given as follows,

\[ Delay(x) = time(TX(x) + wt(x) + RTT(n)) \]  

(5.1)

Depending on channel state information, assigning the optimal and sub optimal channel will mitigate the co channel interference with minimum number of retransmission will ultimately provide an optimal power consumption in the network. Furthermore, optimal channel utilization is done by avoiding non optimal channel for a particular time period.
1. if node I is a source node then
2. node I bcstchannel(i, D)
3. if D receivesbcst(i, N) from node i then
4. Pass_CSI(tm(i))
5. Allocatechannel[node(i)] = min{ channel[tm(i)], channel[tm(j)],..., channel[tm(n)] }
6. Initiate RREQ for node i
7. If tm(i) & tm(j)....tm(n) is not available then
8. remainder= drop(i)/ac(i)
9. If remainder > 0 then
10. lc=ac(i)−fr(i)
11. Calculate wt(i) for all remaining fr(i) //calculate the wait time for all the non-accepted flow rate
12. If wt(i) < RTT(n) then
13. Initiate BCST to choose another intermediate’s node to reach the dest
14. Else
15. allocatechannel(i)
16. End if
17. End if
18. End if
19. End if

Figure 5.4 TSIDCA Channel Assignment Algorithm

The principle behind power optimization of the proposed TSIDCA is that it uses only optimal channel for communication, it does not use both sub-optimal and non-optimal until the situation arises. Thus, limiting the number of channel usage significantly optimizes the energy. Furthermore,
reducing the number of retransmission in the network by using only the optimal channels will be a good sign for the power consumption.

5.4 SIMULATION AND RESULTS

The NS2 simulation has been used to test the performance of the proposed QSDCA algorithm and the simulation setup is shown in the table 5.1. The performance are measured in terms of channel access probability, Throughput and end-to-end delay and the results are compared with the existing network coding based channel allocation (NCbDCA).

Table 5.1 Simulation Setup

<table>
<thead>
<tr>
<th>Simulation Parameters</th>
<th>Assigned value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routing protocol</td>
<td>AOMDV</td>
</tr>
<tr>
<td>Medium Access Control (MAC)</td>
<td>IEEE 802.11s</td>
</tr>
<tr>
<td>Number of Channels</td>
<td>12</td>
</tr>
<tr>
<td>Coverage area</td>
<td>1200X1200</td>
</tr>
<tr>
<td>Transmission Range</td>
<td>550 meters</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>250</td>
</tr>
</tbody>
</table>

5.4.1 Discussions

The number of channels utilized in the network is less then the co-channel interference will be less as much as possible, which will automatically increase the throughput. Figure 5.5 shows the Number of channels with respect to Throughput and the corresponding values are tabulated in the Table 5.2. The TSIDCA attains 228.32Kpbs for 12 channels, while NCbDCA attains 173.25 Kbps.
Table 5.2 Throughput Vs Number of channels

<table>
<thead>
<tr>
<th>No of Nodes</th>
<th>NCbDCA (Kpbs)</th>
<th>TSIDCA (Kpbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25</td>
<td>82</td>
</tr>
<tr>
<td>3</td>
<td>56</td>
<td>171</td>
</tr>
<tr>
<td>6</td>
<td>92</td>
<td>242</td>
</tr>
<tr>
<td>9</td>
<td>126</td>
<td>343</td>
</tr>
<tr>
<td>12</td>
<td>173</td>
<td>405</td>
</tr>
</tbody>
</table>

Figure 5.5 Throughput (bps) Vs No of channels

In TSIDCA, the number of retransmissions has been reduced by choosing the optimal and suboptimal channels which will automatically minimize the transmission power in the network. The Table 5.3 depicts the value obtained using different methods and Figure 5.6 shows the transmission power with respect to the number of nodes. It can observe that the TSIDCA consumes less transmission power than the NCbDCA.
Table 5.3 Transmission Power Vs Number of channels

<table>
<thead>
<tr>
<th>No of Nodes</th>
<th>NCbDCA</th>
<th>TSIDCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>14.5</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>9</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td>14</td>
<td>22</td>
</tr>
</tbody>
</table>

Figure 5.6 Transmission power (dBW) versus Number of nodes

Figure 5.7 shows the packet delivery ratio for N number of nodes. The PDR attains only a slight variation with respect to network size in both the proposed approaches. The average packet delivery ratio attained by TSIDCA is 85.6% and NCbDCA is 65.2%. Table 5.4 shows the corresponding table values for the attained packet delivery ratio with respect to network size.
Table 5.4 Packet Delivery ratio(%) Vs Number of nodes

<table>
<thead>
<tr>
<th>No of Nodes</th>
<th>NCBDCA</th>
<th>TSIDCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>53</td>
<td>74</td>
</tr>
<tr>
<td>100</td>
<td>57</td>
<td>79</td>
</tr>
<tr>
<td>150</td>
<td>58</td>
<td>81</td>
</tr>
<tr>
<td>200</td>
<td>62</td>
<td>84</td>
</tr>
<tr>
<td>250</td>
<td>67</td>
<td>89</td>
</tr>
</tbody>
</table>

Figure 5.7 Packet Delivery ratios (%) for N number of nodes
The assessment in terms of channel access probability with respect to the total number of users of the channel is given in the Table 5.5 and corresponding readings are displayed in the Figure 5.8. From the figure, it can be observed that the TSIDCA model outperforms the existing NCbDCA for any number of users considered for the experimentation.

**Table 5.5 No. of user’s vs. access probability**

<table>
<thead>
<tr>
<th>No of Users</th>
<th>TSIDCA</th>
<th>NCbDCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.81</td>
<td>0.94</td>
</tr>
<tr>
<td>2</td>
<td>0.76</td>
<td>0.87</td>
</tr>
<tr>
<td>3</td>
<td>0.71</td>
<td>0.8</td>
</tr>
<tr>
<td>4</td>
<td>0.64</td>
<td>0.71</td>
</tr>
<tr>
<td>5</td>
<td>0.61</td>
<td>0.68</td>
</tr>
<tr>
<td>6</td>
<td>0.56</td>
<td>0.64</td>
</tr>
<tr>
<td>7</td>
<td>0.52</td>
<td>0.62</td>
</tr>
<tr>
<td>8</td>
<td>0.47</td>
<td>0.52</td>
</tr>
<tr>
<td>9</td>
<td>0.44</td>
<td>0.47</td>
</tr>
<tr>
<td>10</td>
<td>0.4</td>
<td>0.42</td>
</tr>
</tbody>
</table>

**Figure 5.8 Access Probability for N number of Users**
Table 5.6 No. of channels vs. Loss (%) throughput=100kbps

<table>
<thead>
<tr>
<th>No of Channels</th>
<th>TSIDCA</th>
<th>NCbDCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.5</td>
<td>63.28</td>
</tr>
<tr>
<td>3</td>
<td>18.6</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>11.5</td>
<td>40</td>
</tr>
<tr>
<td>8</td>
<td>7.8</td>
<td>23</td>
</tr>
<tr>
<td>12</td>
<td>1.2</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 5.6 gives the performance of the TSIDCA against the NCbDCA with respect to the Packet Loss % with the total number of channels used. In the case of 12 channels, the proposed model yields 1.29 whereas NCbDCA obtained the packet loss % of 10.87, which shows the TSIDCA model performs nearly 10% better than the existing model. The Loss (%) w.r.t the total number of channels is also depicted in the Figure 5.9.

![Figure 5.9 Packet Losses (%) Vs No. of channels (throughput =100 kbps)](image-url)
The analyses of the TSIDCA model with respect to the network overhead with increase in the size of the network are given in the Table 5.7. From the table, it can be proved that the overhead of the network is reduced at a very high rate using the model proposed. It can also be observed that the overhead increases gradually with an increase in the network size. The Figure 5.10 illustrates that the TSIDCA produces lesser overhead regardless of the increase in the number of nodes in the network.

Table 5.7 Overhead (pps) Vs Number of nodes

<table>
<thead>
<tr>
<th>No of Nodes</th>
<th>TSIDCA</th>
<th>NCbDCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>60</td>
<td>145</td>
</tr>
<tr>
<td>100</td>
<td>65</td>
<td>157</td>
</tr>
<tr>
<td>150</td>
<td>102</td>
<td>258</td>
</tr>
<tr>
<td>200</td>
<td>145</td>
<td>354</td>
</tr>
<tr>
<td>250</td>
<td>185</td>
<td>460</td>
</tr>
</tbody>
</table>

Figure 5.10 Overhead for N number of nodes
5.5 SUMMARY

In this chapter Traffic State Information Aware Dynamic Channel Assignment (TSIDCA) approach that has been proposed for dynamic channel allocation based on the dynamic traffic state information in the mesh network. Initially discussed are system model and problem formulation for the proposed approach. Then, a cross layer design has been proposed using two different measures Cross Layer Metrics and Channel Assignment. A comprehensive algorithm has been developed for the traffic matrix generation for K channels and the effective channel allocation. Finally, simulation is performed to evaluate the performance of the proposed approach and is compared with the existing NCbDCA. The results show that the TSIDCA outperforms than the NCbDCA in terms of throughput, transmission power, access probability, loss%, overhead and packet delivery ratio.