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Traffic State Information Based Dynamic Channel Assignment For Multichannel Multi Radio Wireless Mesh Network

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ABSTRACT

Multi-channel communication is a way to minimize the interference and improve spatial reuse. Since channels are a limited resource in a WMN, channel allocation significantly impacts the performance of multi-channel WMNs. This paper proposes a Traffic State Information based Dynamic Channel Assignment (TSIDCA) algorithm to provide an error free communication in mesh network. The traffic state information is incorporated in the network layer by adopting the cross layer design. The information is used to select the channel dynamically while performing routing. The performance of the proposed TSIDCA algorithm has been measured in terms of throughput, channel access probability and delay. The simulation result shows that the overall network performance has been enhanced when compared to the existing channel assignment algorithms.

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INTRODUCTION

Wireless mesh network (WMN)has been seen as an emerging technology for high capacity, flexible, low cost,and ubiquitous broadband Internet access, which can be deployed by multiple users for various kinds of applications like multimedia transmission (T. Parameswaran, *et al*., 2014). It provides the users with backhaul access by usual connection to the internet and benefits the users by combining the advantages of ad hoc networks and wireless local area networking.

The WMN has been incorporated with mesh routers and mesh clients forming a multi-hop wireless network. The mesh routers performs as an access points accumulating traffic from mesh clients and disseminating it hop by hop to destinations. For successful communication, two nearby routers have to construct a logical link that operates on a common channel (Jihong Wang, *et al*., 2015). Due to less available channels, few logical links were using the same channel. If two nearby links operate on the same channel and forward the data at the same time, there exists co-channel interference. The network capacity and the overall performance may degrade considerably due to interference. In order to solve the problem different channel assignment algorithms has been designed eg (Yanbing Liu and Guoping Dan, 2011, IbrarAli Shah, *et al*., 2014).

The channel allocation (CA) algorithms try to discover the possible links between wireless channels and the radio interfaces at each node with the goal of maximizing the network capacity. A channel allocation technique must assure that the number of channel allocated to a node must be the same or minimum than the number of radio interfaces it has and the nearby nodes must have at least a radio at a common channel to have the capacity to communicate with one another. Hence it minimizes the interference between the communication links and promise the quality of communication.In order to provide an optimized network performance, it is essential to have a cross layer approach in the channel allocation algorithm to perform routing.

This paper proposes Traffic State Information aware Dynamic Channel Assignment (TSIDCA) algorithmto enhance the network performance and provide an error free communication. This algorithm incorporates the information of the transport layer (channel information) into the network layer for performing routing based on that information. The algorithm also gives priority to the end user while allocating channel based on the waiting time of the end user and the service time of the servicing node to provide a QoS service to the end user. The proposed algorithm provides an optimized network performance with error free communication.

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The rest of the paper is organized as follows: Section 2 describes the recent related works for channel allocation algorithm in wireless mesh network. The system model and problem formulation are explained in section 3. Section 4 explains the cross layer metrics used in the algorithm. The proposed TSIDCA algorithm has been explained in section 5. The simulation results are discussed in section 6. Finally, section 7 renders the conclusion.

Related Work:

Yanbing Liu and Guoping Dan, 2011), proposes a channel assignment keeping the connectivity of the topology and suggested a QoS routing algorithm for providing the solution for the joint channel allocation and QoS routing problem. The algorithm selects the path by considering the interference of links. The channel assignment does not block the connection request while the link load is heavy and an unsatisfied bandwidth requirement unlike the previous methods. The algorithm achieves a better optimized performance and also improves the bandwidth values.

(Weifeng Sun, *et al*., 2012) proposed a routing information aware channel allocation (R-CA) algorithm based on cross layer design to allocate the channels dynamically for wireless nodes whenever they need communication and after the data transmission the channels will be released. In R-CA, maximum number of wireless nodes can use limited channel resources efficiently to improve the communication throughput. The simulation results show that the R-CA algorithm enhance the network performance by improving the throughput and packet delivery ratio.

(F. Kaabi, *et al*., 2010), focuses the proposal for solving the channel assignment problem. The proposal is classified into three categories based on the dependence degree between routing and channel allocation. In each category, the existing protocol and their channel assignment schemes are identified. The comparison is made based to the pros that they present, the problem and limitation they are facing and the solution they are claiming to offer.

(IbrarAli Shah, *et al*., 2014), proposed a channel assignment protocol, which is dynamic and distributed method and it generates the network topologies by promising better connectivity and less interference. The protocol has the ability to detect the node failures and mobility of the node in a n effective manner. A Quality of Service based AODV routing protocol has been additionally devised to provide end to end path by guarantying the delay. The simulation results shows that the QoSbased delay routing metric integrated with the selective route request forwarding minimizes the routing overhead and produce less delay respectively.

(Sen.A, *et al*., 2007) addressed the issue of detecting as many as possible links in the wireless mesh network to be activated in terms of connectivity, radio and interference constraints. So the interference aware channel assignment algorithm is proposed in order to activate all the links in the network. The overlapping double-disk (ODD) graphs are generated by using the link interference graph and the set of independent ODD graphs are computed by using the Polynomial Time Approximation Scheme through which the proposed algorithm is developed. Finally the proposed algorithm is compared with the existing algorithms for the same purpose and proves the optimal solution in all instances of problem.

A novel backtracking and genetic algorithm based channel assignment is proposed by (Pal.A and Nasipuri.A, 2011) in order to recover from the routing and the joint channel assignment. In addition the quality aware route selection scheme is implemented which as to minimize the computational complexity and improves the overall communication performance. The proposed combination of system is compared with the single channel and random channel selection methods and proves its efficiency and the performance.

(Aizaz U Chaudhry, *et al*., 2013) uses a multi-path routing to attain the maximum network throughput. A heuristic method is developed effectively to discover the minimum number of channels essential for interference free channel assignment. Experimental results show that the approach achieves better network performance in terms of throughput, average node degree, link to channel ratio etc.,

System Model And Problem Formulation:

This paper considers the IEEE 802.11 based multi-channel multi-radio WMNs, where the nodes are mobile and it has n radios with same communication range and the same interference range. Network is modeled as a unidirectional graph G (V, L), where V represents the finite set of nodes and L represents the set of unidirectional link. The nodes are equipped with n radio interfaces and there are K channels will be available.

The nodes operating on the common channel may cause co-channel interference while transmitting the data simultaneously. The objective of this paper is to maximize the network performance by promising the quality of communication by avoiding the interference among two or more receiving ranges as much as possible while allocating channel.

Cross Layer Metrics:

Link Capacity:

Effective Link Capacity (ELC) (Jonathan Guerin, *et al.*, 2010), is determined in the MAC layer utilizing the information such as the transmission count of data packets (TXC)and the packet delivery ratio (PDR). The ETC uses only the locally-available information from the data disseminating node without requiring any active probing. The ELC is estimated using the following equation

$$ELC = \frac{TMT \times PDR}{TXC} \quad (1)$$

Where TMT is the Theoretical Maximum Throughput indicating the maximum throughput that can be attained on a link and it can be estimated analytically (D. Gupta, *et al.,* 2009).

Packet Drop:

TCP is the 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 number of packet drop of a node i at the channel x is the difference between the number of packets transmitted and the number of packet received and it is given in the following equation

$$Packet\ Drop(x) = Number\ of\ packets\ sent - Number\ of\ Packets\ received \quad (2)$$

Round Trip Time:

The round trip time (RTT) estimation for the TCP transport protocol has been viewed as a best indicator for the channel congestion. In this factor, the node i send probe packets to the neighbors and the neighbor responds to the node i by acknowledgement. After receiving the acknowledgement, it computes the RTT between the sending time of probe and the acknowledgement receiving time.

Traffic State Information Aware Dynamic Channel Assignment (Tsidca) Algorithm:

InTSIDCA, channel state information is carried by routing packets. The routing protocol is based on the cross layer design. A loosely coupled cross-layer design is utilized and it has been shown in the figure 1, where the MAC layer information such as flow rate and link capacity and the Round trip time and packet drop information is taken from the Transport layer and these information will be incorporated in channel state information as a traffic matrix, where the information are considered as a more appropriate design criteria for the fading channels and it is reported to the network layer. Then the routing is performed based on that information.

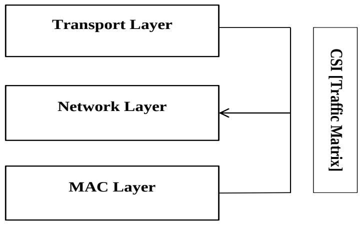

Fig. 1: Cross layer design.

After the initial transmission, the traffic matrix is generated for K channels for each node in the network. The algorithm for traffic matrix generation is given in the algorithm 1. The traffic matrix is used to take the decision on the channel allocation algorithm. The algorithm considers the cross layer metrics to form a traffic matrix for each channel.

Algorithm 1: Traffic Matrix generation for K channel.

```
Tx→ transmission
Ac→ acceptance capacity
Fr→ flow rate
Lc→ link capacity
Oc→ outrage capacity
RTT→ round trip time
1. If TX>1 then
2. For j=0 to n nodes
3. For i=0 to K channels in a node j
4  drop(i)=[sum of(sent packet(i)-received packet(i))]
5. ac(i)=fr(i)/lc(i)
6. remainder=fr(i)%lc(i) // channel categorization based on the channel analysis
7. if remainder = threshold value
8. channel i is optimal
9. else if remainder > threshold value
10.     suboptimal channel
11. else if remainder < threshold value
12.     non-optimal channel
13. end if
14. oc(i)=drop(i)/ac(i)
15. tm(i)=[oc(i),RTT(i)]
16. End for
17. csi (i)=tm(i)
18. End for
19. End if
```

The channel is categorized as optimal suboptimal and non optimal channel based on the metrics to choose the channel for the next transmission.

- Optimal: best in cases of the analyzed parameters
- Suboptimal: the channel can be chosen but has to be shifted or replaced after a time interval.

- Non-optimal: the channel is congested such that no request can be serviced through it for a particular instance of time.

Algorithm 2: Channel allocation.

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. Allocate Channel[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(i)=ac(i)-fr(i)
11. Calculate wt(i) for all remaining fr(i) //calculate the wait time for all the non-accepted flow rate data
12. If wt(i)<RTT(n) then
13. Initiate BCST to choose another intermediate's node to reach the destination
14. Else
15. allocate channel i
16. End if
17. End if
18. End if
19. End if

The channel allocation algorithm is given in the algorithm 2. The process of the algorithm takes place after one complete transmission is done. The transmitting node calculates the traffic occurrence in each of its channel by broadcasting the probe packet to destination. After receiving the broadcast the neighbor node or destination pass the channel state information by incorporating the traffic matrix for each channel. After receiving the CSI, the channel is allocated based on the minimum traffic matrix value of optimal and sub optimal channel. If the sub optimal channel is allocated, then the channel is set to non optimal channel for a particular time interval.

Incase no optimal and suboptimal channels are available, then for each channel calculate the wait time for non acceptable data flow rate. If the wait time is greater than the Round trip time for n transmission in channel x then the node can wait for the channel x to establish link between the node i and node j else the node should broadcast for selecting the next intermediate node to reach destination because the delay incurred will be more in the channel x which ultimately degrade the network performance.

$$Delay\ (x) = time\,(TX(x) + wt(x) + RTT\ (n)) \quad (3)$$

Simulation Results:

The NS2 simulation has been adopted in this paper to test the performance of the proposed TSIDCA algorithm and the simulation setup is shown in the table 1. The performance are measured in terms of packet, retransmission probability, channel access probability, Throughput and end-to – end delay and the results are compared with the existing Network coding based channel allocation (NCbDCA) and QoS aware Dynamic Channel Allocation (QSDCA) algorithm.

Table 1: Simulation Setup.

Simulation Parameters	**Assigned value**
Routing protocol	AOMDV
Medium Access Control (MAC)	IEEE 802.11s
Number of Channels	12
coverage area	100X100
Transmission Range	550 meters
Number of nodes	250

A. Performance metrics:

Channel Access Probability:

Channel Access probability is defined as the multi users may access the channel at the same time.

Retransmission Probability:

The probability of dropped packets may be retransmitted on an end-to-end manner in order to guarantee that all data packets are eventually transmitted from source to destination.

End –to –End Delay:

End – to – End Delay is the time taken by the data packet to reach the destination from the source. It contains the packet waiting time in queue, propagation and processing delay

$$Delay = Queuing\ Delay + Processing\ Delay + Propagation \quad (4)$$

Throughput:

Throughput is the average rate of at which a network sends or receives data. It measures the channel capacity of a communication link and connections to the internet and it usually measured in terms of bits per second.

$$Throughput = \frac{Number\ of\ frames\ transmitted}{Time\ interval}\ (bps) \quad (5)$$

Packet Loss Rate:

The packet loss rate is the ratio between the total number of loss traffic by the total number of input traffic over a certain amount of time

$$Loss\ rate = Total\ number\ of\ dropped\ Packets / Total\ number\ of\ sent\ packets \quad (6)$$

B. Discussion:

When the number of user increases then the channel access probability will decrease automatically, hence more number of users may cause co-channel interference. Figure 2 shows the number of users vs access probability. The proposed TSIDCA attains 0.4 channel access probability for 12 users, while QSDCA, NCbDCA attains no channel access probability. The table 2 shows the corresponding table values for No. of users vs access probability.

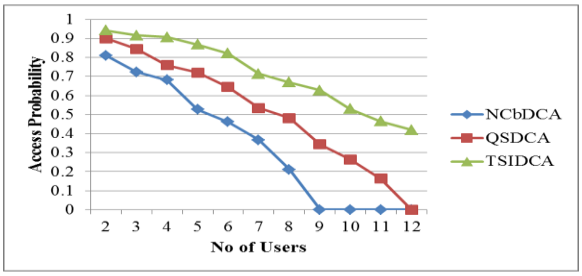

Fig. 2: No. of users vs access probability.

Table 2: No. of users vs access probability.

No of users	NCbDCA	QSDCA	TSIDCA
2	0.81	0.9	0.942
3	0.724	0.845	0.916
4	0.682	0.760	0.907
5	0.527	0.721	0.868
6	0.462	0.644	0.821
7	0.367	0.534	0.714
8	0.211	0.482	0.669
9	0	0.344	0.628
10	0	0.264	0.53
11	0	0.163	0.465
12	0	0	0.419

When the number of channel increases the co channel interference will be less, which will increase the throughput. Figure 3 shows the Number of channels vs Throughput. The proposed TSIDCA attain 228.31 Kpbs for 12 channels, while QSDCA, NCbDCA attains 201.73

Kbps, 173.25 Kbps. Table 3 shows the corresponding tables values for Number of channels vs Throughput (Kbps).

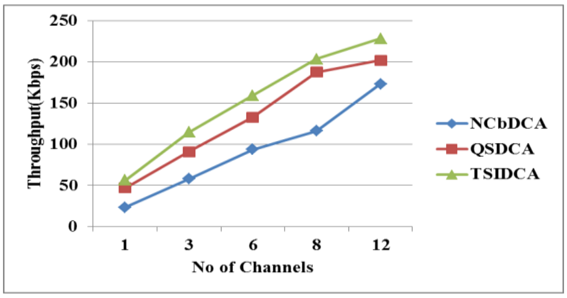

Fig. 3: No. of channels vs Throughput (Kbps).

Table 3: No. of channels vs Throughput (Kbps).

No of Channels	NCbDCA	QSDCA	TSIDCA
1	23.47	47.11	56.46
3	57.82	91.08	114.53
6	93.63	132.75	159.05
8	116.17	187.46	203.64
12	173.25	201.73	228.31

The proposed TSIDCA provides an error free communication by checking the wait time and the RTT for the non-acceptable flow rate to avoid the unnecessary delay by allocating the congested channel. When the number of nodes increases the delay incurred will increase automatically. Figure 4 shows the Number of nodes vs Delay (ms). The proposed TSIDCA attains 218.39 ms for 250 nodes, while QSDCA, NCbDCA incurred 244.73 ms , 306.25 ms. Table 4 shows the corresponding table values for Number of nodes vs Delay (ms).

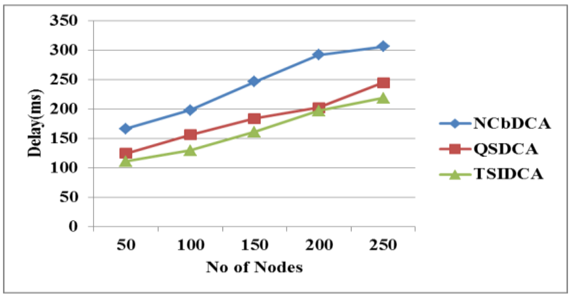

Fig. 4: No. of nodes vs Delay (ms).

Table 4: No. of nodes vs Delay (ms)

No of Nodes	NCbDCA	QSDCA	TSIDCA
50	166.14	124.64	110.88
100	197.82	156.01	129.43
150	246.52	183.96	161.24
200	291.77	202.09	196.67
250	306.25	244.73	218.39

The proposed TSIDCA avoid the congested channel while performing routing to minimize the packet loss in the network. Figure 5 shows the No. of channels vs Loss (%) throughput=100kbps. The TSIDCA incurred 15.95% for 12 channels, while the QSDCA, NCbDCA incurred 27.86, 36.58. Table 5 gives the corresponding table values for No. of channels vs Loss (%) throughput=100kbps.

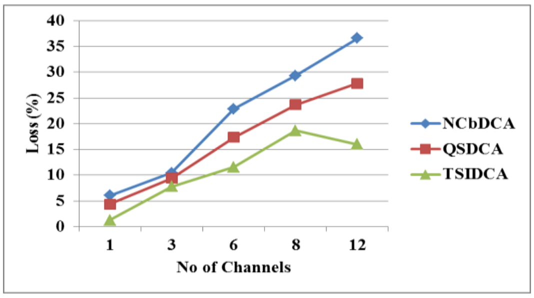

Fig. 5: No. of channels vs Loss (%) throughput.

Table 5: No. of channels vs Loss (%) throughput=100kbps.

No of Channels	NCbDCA	QSDCA	TSIDCA
1	6.07	4.39	1.29
3	10.42	9.41	7.8
6	22.86	17.32	11.55
8	29.33	23.67	18.66
12	36.58	27.86	15.95

Figure 6 shows the number of channel vs Re transmission Probability and the corresponding table values are given in table 6. The proposed TSIDCA incurred 0.40 retransmission probability for 12 channels, while QSDCA, NCbDCA incurred 0.58, 0.63 retransmission probability.

7. Conclusion:

The paper proposed a Traffic State Information based Dynamic Channel Assignment (TSIDCA) algorithm to provide an error free communication in Multichannel multi radio wireless mesh network. Here a cross layer design has been adopted to get the traffic state information while performing routing. This traffic information allows the channel allocation algorithm to allocate an optimized channel dynamically, which avoids the co channel interference. The proposed algorithm is compared with the existing channel allocation algorithms QSDCA and NCbDCA in terms of access probability, throughput, delay, loss percentage and retransmission probability. The simulation results show that the proposed TSIDCA produces a better optimized network performance while compared to the existing channel allocation techniques.

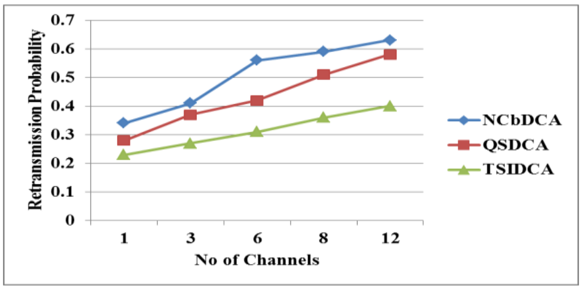

Fig. 6: No. of channels vs Re transmission Probability.

Table 6: No. of channels vs Re transmission Probability.

No of Channels	NCbDCA	QSDCA	TSIDCA
1	0.34	0.28	0.23
3	0.41	0.37	0.27
6	0.56	0.42	0.31
8	0.59	0.51	0.36
12	0.63	0.58	0.40

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