Resource Allocation Management in Multi-Radio Multi-Channel joint with Routing Protocol in ad-hoc Wireless Network

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Abstract:- Channel bandwidth allocation management is one of the research issues in multi-channel multi radio interface wireless network, inappropriate selection of the channel leads to the probability of choosing congested channel which may not satisfy QoS requirement, it results in the significant reduction of the network performance, by increasing in delay and loss of the packets due to collision between them. In this paper, we propose a mechanism that selects a channel based on lowest comparable distributed expected bandwidth consumer. Network layer takes the decision for allocating the channel after receiving the information about the estimated bandwidth in each channel through its attached MAC layer in a cross layer manner. We consider a wireless network is multiple-hop with IEEE802.11 multi-radio channels interfaces. The efficiency and effectiveness of the proposed work has been evaluated by NS-2 and a comparison has been made with random channel allocation. Simulation results show that our proposed work has clearly improved the network performance in terms of end-to-end delay and throughput.

Keywords: *Channel bandwidth allocation, Multi-channel, busy channel time, cross-layer*
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1. Introduction

Wireless networks have appeared now adayes as prominent candidate to a wired networks, they provide cost-effective and connectivity solutions better than wired network. Recently, the use of wireless networks has been proliferated in the world. Several wireless standards like IEEE 802.11, IEEE802.16, and IEEE 802.15.4 have been implemented in different technology like WLAN, Ad-hoc, wireless mesh network, and WiMax. Although that, wireless links of those technologies still cannot provide the seamless connectivity with comparable data rates and satisfy QoS requirement.

With growing of demand in bandwidth and the scarcity of available resources like spectrum, power, processing capability, and

storage space at the wireless nodes, keeping the design of new wireless network paradigm with efficient resource management is a challenge Issue. The multi-hop wireless networks are identified as valuable networking which is able to fulfill flexible, easy deployment, self-configuration, and adaptation to the working condition [1]. However, the multi-hop wireless networks suffer from low throughput and high end-to-end delay, improving of wireless network is big task, due to intra- flow interference, introduced by contention of adjacent transmitting nodes on the same path and inter-flow interference generated by transmitting of nodes from different paths.

A great attention has been dedicated lately to understand the challenges relate to resource allocation in wireless networks in which each node has multi radio interfaces and can operate with multiple channels simultaneously, wherein the bandwidth is divided into multiple channel frequencies, thus, the multiple devices can exchange data packets in parallel on distinct channels. The key idea is to increase the capacity of the network. Inexpensive commodity of IEEE 802.11 hardware and the reducing in cost of IEEE 802.11 interfaces, encouraging us to equip node with multiple IEEE802.11 interfaces, it sustain to apply in multi-hop wireless network, in which the IEEE802.11 presents multiple non-overlapping channels attached with multi interfaces with fixed transmission power, for example IEEE802.11a offers 12 non overlapping channels, while IEEE802.11b/g offers 3 non-overlapping channels[2,3].

To achieve efficient bandwidth utilization, improvement in the network transmission capacity and gains a better traffic management, there should be ability to exploit multiple radios interfaces and multiple frequency channels with proper manner. In this paper, we are going to investigate the channel bandwidth management in multi-channel multi interfaces, by doing the following contribution:

- We propose a mechanism to estimate channel available bandwidth, which can adapt based channel condition dynamically and take the activity of neighbors nodes into considerations.

- We use loosely coupled scheme [4] to design cross layer. In such away that, each radio interfaces is used for collecting the information of each channel condition and pass it to MAC layer, the cross layer assist to forward the estimated bandwidth of each channel to the routing layer.

- Finally, we implement the proposed scheme which based on DSDV routing protocol and IEEE 802.11DCF MAC layer protocol in NS-2. Extensive simulation experiment demonstrates that our proposed work outperforms random channel allocation in terms of END-to-END delay and throughput.

The reminder of the paper is organized as follows: section 2 discusses the related work. Section 3 presents proposed work, the simulation environment for the proposed work has been discussed in section 4.The detailed analyses for the results and discussions have been described in section5, followed by conclusion and references.

2. Related Work

The resource allocation management in wireless network is very broad topic, it includes management of memory, power, security, channel allocation and bandwidth[5,6],some research efforts focus on issue of adjusting MAC layer parameters according to the changes of surrounding situations, e.g. channel conditions and number of nodes [7,8] in single channel single interface scenario.A number of research papers have presented a resource allocation as optimization formulation problem, they propose a jointly algorithms which takes a number of variables like congestion control, channel allocation, scheduling and power control operation together for multi-hop wireless networks in a general communication and interference[9,10,11,12,13], while the authors in [14], define source rate as an optimization problem, that is solved by a dynamic algorithm in multi-channel multi-radio interfaces. The problem of video streaming over multi-channel multi-radio multi-hop wireless networks, has been studied in [15], the proposed work aims to optimize the system at each Scheduling by intelligently utilizing the available network resources, to meet each video's Quality of Service (QoS) requirement.

The network resource allocation in multi-channel, multi-interface topology essentially depends on channel allocation, interface assignment and routing.

Channel selection has been classified based on two strategies dynamic assignment to radio interfaces and fixed assignment to radio-interfaces. In dynamic assignment the interfaces are switched from channel to channel

dynamically over the time [16-20], while in static assignment [21-23], each channel is permanently tuned to the interfaces or for long time, some research efforts have been made recently on channel allocation joint with routing protocol in multi-hop networks [24-27]. The bandwidth management issue for VoIP application has been addressed in [28], where the author's have discussed the unfair traffic distribution between downlink and uplink flows in WLANs impacts the perceived VoIP quality.

3. Motivations

The multi channels multi radio interfaces technology has been paid an attention recently. It is capable to increase the capacity of wireless network, the most of previous work of resource allocation management focused on single channel, single interface ad hoc or sensor networks, it gives concentration in resource allocation from sight of isolation approach, it has been seen from only routing layer or TCP layer or MAC layer.

Thus, it is imperative to address the issues of how to improve resource allocation management by exploiting multi channel- multi interface paradigm.

In multi-hop wireless network, there are multiple flows from different sources to different destinations with different applications. The total traffic in each link is limited by link capacity; the channel condition is different at the transmitter side from the receiver side.

The multi-channel is considered as one type of resource which is necessary to be allocated properly. The suitable management and utilization of multi-channel multi-interface, helps to improve the performance of overall network.

The limitation in channel bandwidth and the variation in channel situation over time, makes allocating channel to the interface of the node is a very hard decision. The main difficult in wireless channel stems from shared medium in

nature. Basically, The nodes that can communicate with each other, may still contended for same channel.

In multi-channel multi interface, there might be a multiple links between two successive nodes, it is necessary to select a proper link to forward packet to next hop. This is to guarantee that the data packets will be delivered successfully. When two nodes select the same channel for transmitting their packets and those nodes have a common destination node within their transmission range, if they decide to transmit their data packets concurrently, the collision between packets may occur at the particular destination. This collision will affect the network performance, in such a way that, the retransmission process will occur for transmitting the same losing packets, hence the utilization of the channel bandwidth will be reduced as this process is repeated again and again. Moreover, waiting time of fresh packets that queued at interfaces are high, thus end-to-end delay is increased. Also the total end-to-end delay is increased. The unfairness issue in obtaining the required channel bandwidth can happen, in case the node selected the channel randomly, and unfortunately, it found that, the channel is busy for long time, as a result of traffic exchange between other transmitter and other receiver nodes, in this situation the packets will be continuous waiting at its queue interface, while the transmitter node still not acquired the channel. Therefore, the free length in queue size will not increase. On the contrary, the buffer size will be reduced as long as it is queued a new arrived packets at its interface. At a particular time the buffer interface becomes full, this implies that, the next arrived packets will be dropped. The loss in packets will results in degradation of throughput in overall network.

All these above said issues motivated us to propose a mechanism for improving resource allocation through managing the bandwidth, and selecting the channel properly and dynamically

over time to send packets. The objective of our work gains a better and guarantee QoS.

4. Proposed Work

In the present work, we assume that, the multi-channel multi interfaces wireless network with IEEE802.11 DCF MAC protocol, since the IEEE 802.11DCF MAC layer is not designed to operate with multiple channels [29], thus, each MAC layer can sense only one channel at each time. We assume that each radio interface has its own MAC layer and it is own physical layer. The node works in half duplex mode, thus at any given time, it can be a transmitter or a receiver. We can claim, that two nodes I and J are to be neighbors on channel M, if their radio interfaces are operating on common channel M
(i.e. $I(M) \cap J(M) \neq \emptyset$) and both of them are within their transmission range, we consider, that there are Q number of orthogonal channels in the system, each radio interface has been tuned to single orthogonal channel in long time, to sake an efficiency, to guarantee the connectivity in the network and to keep continuous measures of all channels status, figure 1 illustrates an architecture of layout.

In the proposed model, we have N number of nodes; each node is equipped with multi- radio interfaces, which have homogenous characteristics in term of modulation, power level and data rates. The concurrent transmission occurs only if it can satisfy one of the two conditions as follows:

$$1\text{-} \quad u \cup v \not\subset I_{R_{x,y}} \quad \text{OR} \quad x \cup y \not\subset I_{R_{u,v}}$$

Where u, v are two active pairs nodes and x,y are two active pairs nodes too, $I_{R_{x,y}}$ is interference range of node x,y. $I_{R_{u,v}}$ is interference range of u and v nodes

$$2\text{-} \quad C_i(u,v) \neq C_j(x,y)$$

Where C_i and C_j are two distinct orthogonal channels.

Any node N can receive and transmit the information at same time (i.e. full duplex mode) if and only if $C_I(N) \neq C_J(N)$. Where C_I and C_J are two distinct channels

The calculation of bandwidth estimation using IEEE802.11 DCF MAC in multi-hop networks is still ongoing research problems in wireless network [27].

Basically, it is difficult to obtain the available bandwidth by the wireless node, because, the channel could be shared with other available nodes which are same transmission range. (i.e. interfering neighbors of its co-channel) also variations of radio environment in every moment, thus we need to take into an account the dynamic change in channel conditions, every node has different idea about the state of the communication channel in the multi hop wireless network, because, the node depends on its location in the network, its carrier sense range, and if it is a mobile or a static, so that, each node can only predicate the bandwidth on its own basis.
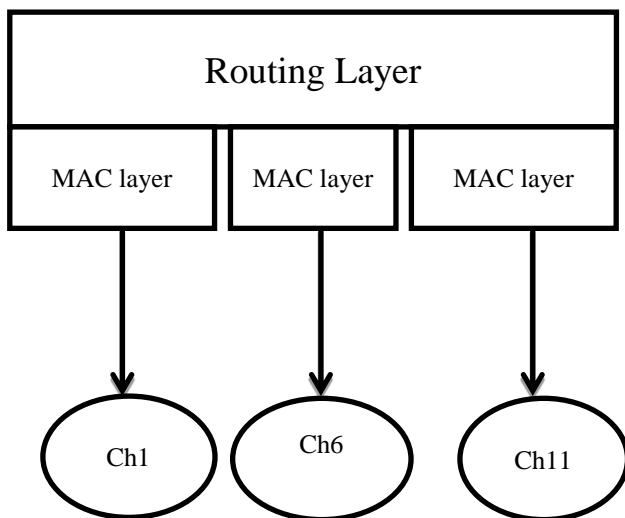

Figure 1: Layout Architecture.

In this paper we introduce the local bandwidth consumer to calculate the estimated available bandwidth for each associated channel in the node. Since the local bandwidth consumer is defined as an available bandwidth consumed by a given node, therefore any node can calculate the consumed bandwidth in the channel. Actually, we can say that, our method for calculating bandwidth is totally based on channel utilization. The available bandwidth on each channel in multi-channel multi interface depends on channel usage by the nodes which are located within their interference range.

We use a fraction of busy time as an indication of local consumer bandwidth for each channel. The busy channel time in IEEE802.11DCF includes back-off time and retransmission time, thus it seems to be more accurate to use idle channel state for calculating the available bandwidth rather than in [27][30]. The aim of our work is to select channel with less contention in comparison with other channels, thus this channel will have a high available bandwidth. When the node intended to send packet to next hop, it might have multiple links to the same received node, especially when it has multiple channels, we need to keep measuring every channel state through its radio interface. We use loosely coupled scheme [4], in such away that, each radio interface passes the information about its attached channel to the MAC layer, Then, the MAC layer is computing the available channel bandwidth and forward the result to the routing layer, after that, the routing layer gathers all the required information regarding the bandwidth availability in each channel, and will decide which channel will be used for sending packets.

The IEEE 802.11DCF MAC layer exploits physical layer sense and virtual carrier sense to decide whether the channel state is busy or idle.

In our approach to select an appropriate channel, we keep sensing the channel to measure the channel state periodically every T time. We assign a small value T to an accurate estimation

of traffic load in each channel. Each node will continuously monitor every channel associated with it, and then begins counting when the channel is busy and stops counting when the channel changes to idle state; the busy time is composed of numerous busy time intervals during a period of T. The MAC layer accumulates all busy periods during time T to obtain the total busy time T_B, as shown in flow chart of figure2, , the ratio of busy time for channel N per T time can expressed as

$$R_B(N) = \frac{T_{B(N)}}{T(N)} \qquad 1)$$

The local consumer bandwidth of each channel, can be estimated by using the well-known exponential weighted moving average to measure the occupiedness of channel bandwidth. It combines the estimation of sample state information of channel bandwidth consumer at time T and old state information. The expected bandwidth consumer can calculated :

$$C_{Bc}current = (1-\beta) \times CHold + \beta \times C_{Bc}sample \qquad 2)$$

Where, CHold is previous value of C_{Bc} current and C_{Bc} sample is new instantaneously channel bandwidth consumer value, which can be expressed as:

$$C_{Bc}sample = R_B \times R_{CB} \qquad 3)$$

Such that R_{CB} is channel bandwidth raw and β is weight factor ranging between [0, 1].Once the MAC layer computes the C_{Bc}sample, it sends up to the routing layer. The selection index (S_i) employs to all channels based on C_{Bc} values.

The channel index of channel k can be calculated based on following formula:

$$S_i(k) = \frac{C_{Bc}(k)}{\sum_{i=0}^{l} C_{Bc}(i)} \qquad 4)$$

So that, the best channel will be:

$$C_s = Min\{S_i(i), S_i(j), S_i(k), S_i(l), \ldots \ldots\}$$
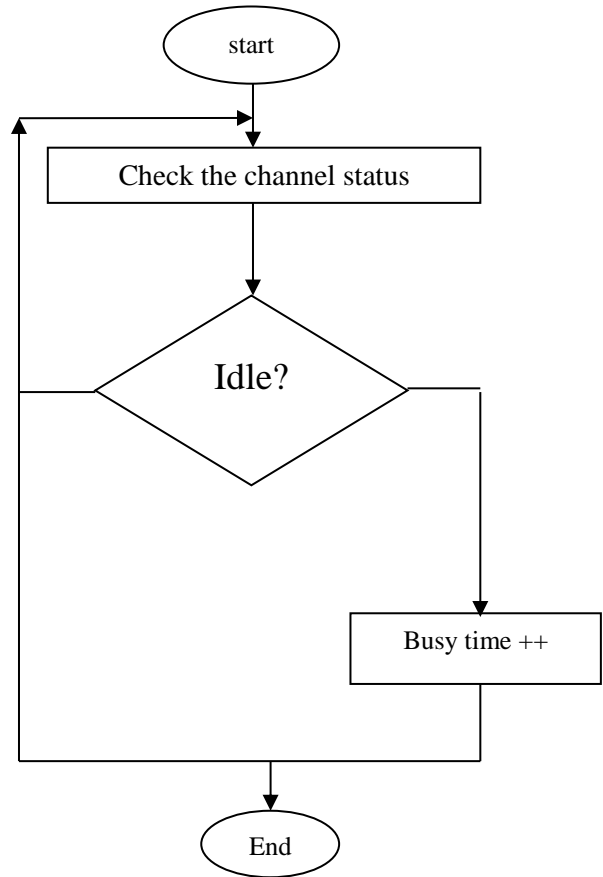

Figure 2: Calculation of Busy Time

The routing layer will choose channel based on : C_s value, which represent the minimum estimation value of local bandwidth consumer at particular time , The i,j,k,l are available channels bandwidth. From the above equations, we can also conclude the total available bandwidth instantaneously from all channels at each node by following equation:

$$B_{(i)} = \sum_{a}^{k} RAW_{Bandwidth} - S_i(a) \qquad 5)$$

Such that, $B_{(i)}$ is the total available bandwidth instantaneously for node i. The Pseudo code is shown in figure 3, the figure 4 gives a brief description of model component.

The selection process will be invoked hop by hop from source to destination, whenever the node intends to send packets to the next node in the path, here we consider DSDV [31] as a routing protocol for construction the path from the source to the destination, our proposed work can corporate with any other routing protocol without piggybacking the bandwidth information in IP header of the packet or add any further field in routing table. Thus there is no extra overhead in the routing protocol. Our proposed work gives the advantage that, the channel is dynamically assigned based on channel bandwidth. In our proposed methodology, TCP layer is responsible for reordering the packets that comes from different channels for the same flow [32].

The flowchart that shows our proposed technique and in figure 6.

// Initialization

Recive traffic from application layer.

Call MAC layer get information about each channel

Calculate bandwidth consumer
Pass information to Routing layer.
1.   Start
    {
2-The channel index of channel k

$$S_i(k) = \frac{C_{Bc}(k)}{\sum\limits_{i=0}^{l} C_{Bc}(i)}$$

3-Next_selected_channel=Min(C1,C2,......)
    pass Packet to Next_selected_channel.
}
4.   End

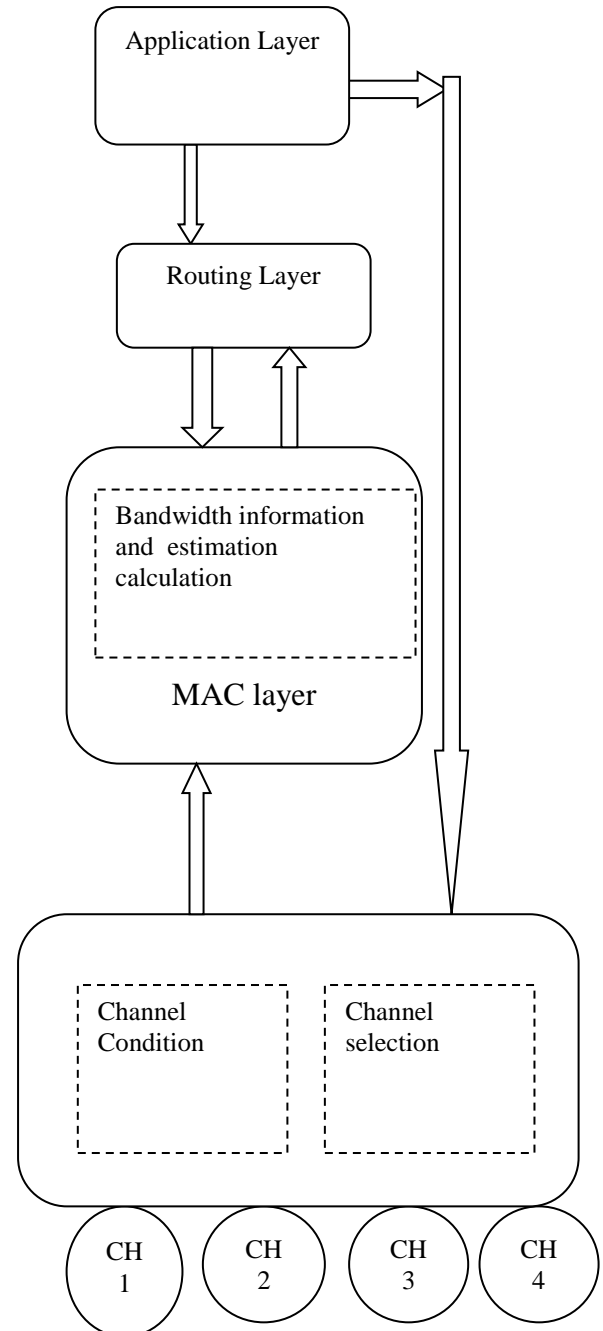**Figure 3.**Pseudo-Code for the Proposed Technique

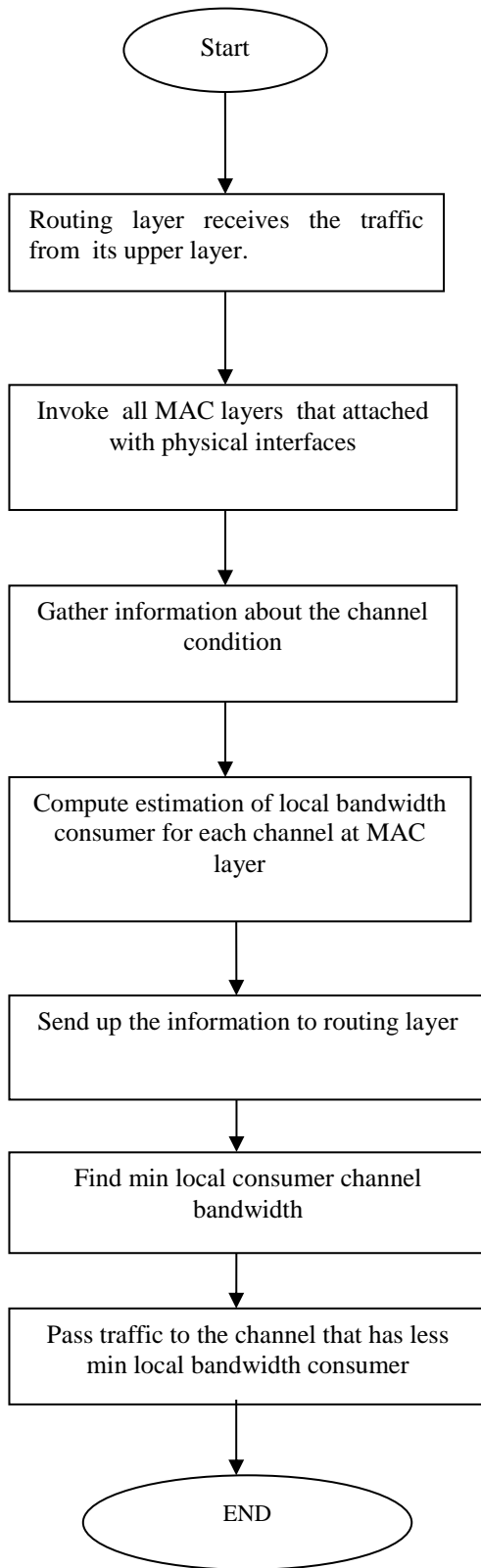**Figure4**:Model Component of Proposed Work.

Figure 5: Flowchart Our Proposed Work.

5. Simulation Parameters

Our proposed work has been simulated by using network simulator version 2.33 [32] for evaluating the performance.

5.1 Simulation Assumptions:

While conducting simulation, following assumptions have been made:-

• In all simulation scenarios, we use Flat topology as shown in figure6.

• Number of gateway nodes is fixed in all simulation scenarios as mentioned in table 1.

• Number of mobile nodes is considered as variant while studying the effect of network size as mentioned in table 1. It is made fixed, when we study the effect of number of flows, varying number of channels and varying sending rate (i.e. Packet rate).

• While studying the effect of traffic flow. It is made varied as given in Table 1. It is made fixed, when we study the effect of changing in network size, varying number of channels and varying sending rate (i.e. Packet rate).

• Speed of mobile nodes is made fixed at 10m/s, while pause time for mobile nodes is made fixed at 0 sec for all simulations scenarios.

• While studying the effect of number of channels. It made varied as given in Table 1; we make it fixed, when we study the effect of changing in network size, varying number of flows and varying sending rate (i.e. Packet rate).

• When we study the effect of the number of sending rate(packet rate) is made varied as mentioned in table 1, it made a fixed, when we study the effect of change in network size, number of flows and number of channel.

- Most of the traffics are considered from gateway to the mobile nodes and from

Parameter	Value
Application Type	Constant bit rate (CBR).
Transport Type	User Datagram Protocol(udp).
Number of CBR connection	20.
Routing Protocols	DSDV.
Simulation time	300 seconds.
Packet Size	512 bytes.
Packet sending Rate	25 Packets/Second.
Simulation area	1200m × 1200m.
Speed of mobile nodes	10 (m/s)
Pause Time	0
Number of gatewayes (i.e. assumed).	2.
Number of mobile nodes .(i.e in case of network size scinario).	23,48,73,98,123,148.
Mobility model.	Random way point.
Propagation model.	TwoRayGround.
Number of flows	10,20,30,40,50
Packet rate	20,25,30,35,40
Transsmission Range.	250m.
MAC layer.	IEEE 802.11.
Antenna model.	Omni Antenna.

Table1 : Simulation Parameters

mobile nodes to gateway and also among mobiles nodes themselves.
- Every radio interface works in half duplex mode.

All simulation parameters which have been applied in this simulation environment are given in the table 1 and the simulation topology is illustrated in figure5

5.2 Performance Metrics:

Following performance metrics have been considered in case of different number of mobile client, varying in number of flows, varying number of channels and varying number of sending rate.
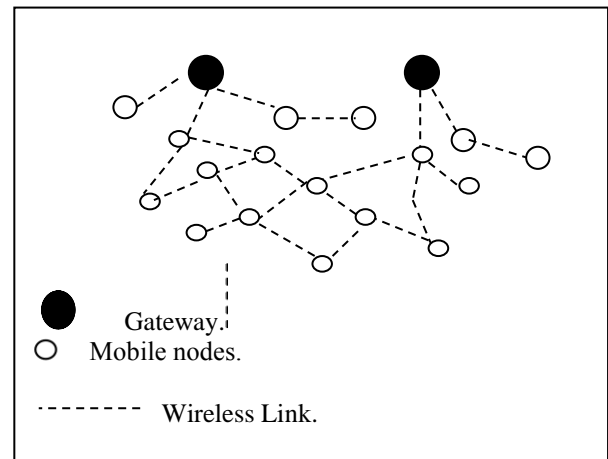

Figure 6: Simulation Topology.

- *Average Throughput:* The average number of data packets delivered during a session.

$$\text{Average Throughput} = \frac{\sum_{i=1}^{n} P_r[i]}{T_r - T_s} \qquad 6)$$

Where , T_r The time at which packet is received by receiver, $P_r[i]$ is the total number of successfully received data packet by node i.
T_S The time at which packet is sent by sender.

- *Average End To End Delay (AEED):* Total time taken by all data packets from source to destination over total number of successful received data packets (N).

$$\text{AEED} = \text{End\_to\_End\_delay} \times 1000 (\text{ms}). \qquad 7)$$
Where

$$\text{End\_to\_End\_delay} = \frac{\text{TDT}}{\sum_{i=1}^{N} P_r} \qquad 8)$$

$$\text{TDT} = \text{TDT} + \sum_{i=0}^{N} \text{delay}[i] \qquad 9)$$

delay[i]=T_r[j] − T_s[i].   10)

Where TDT is total delay time, T_r[j] is the time when receiving the packet by node j and T_s[i] is the time when sending the packet by node i.

6. Results and Discussion

The simulation experiments have been conducted for four (4) different scenarios as follows:
1) Varying number of Nodes.
2) Varying number of Flows.
3) Varying number of Channels.
4) Varying sending rate (i.e. Packet rate).
The simulation results of the proposed work have been compared with the simulation results of random channel allocation. Using a simulation model described in previous sections, End to End Delay and Throughput have been determined and plotted .The performance metrics are obtained by average results over 100 simulations runs. Each data point represents an average of at least five simulation runs with identical traffic models, but randomly generated by different mobility scenarios. Identical mobility and traffic scenarios are used across our work and across random channel allocation.

6.1. Impact of Varying Number of Nodes

In this scenario we study the impact of network density on the performance of the network, by varying the number of nodes.
From figure7, we can observe that by increasing the number of nodes, the end to end delay is increased in both of random channel allocation and our approach. The reason is that, the number of nodes that share same channel is growing and the contention time for acquiring the channel bandwidth is high at MAC layer, thus the sending packets from node to node will take a

longer time, however, our approach has less delay compared with random selection. Our proposed work has an advantage of selecting the appropriate channel that has maximum available bandwidth, so the node can send more packets than in case of random channel allocation. The simulation results reveal with the proposed approach an average reduction of 18.739% in end to end delay has been achieved.
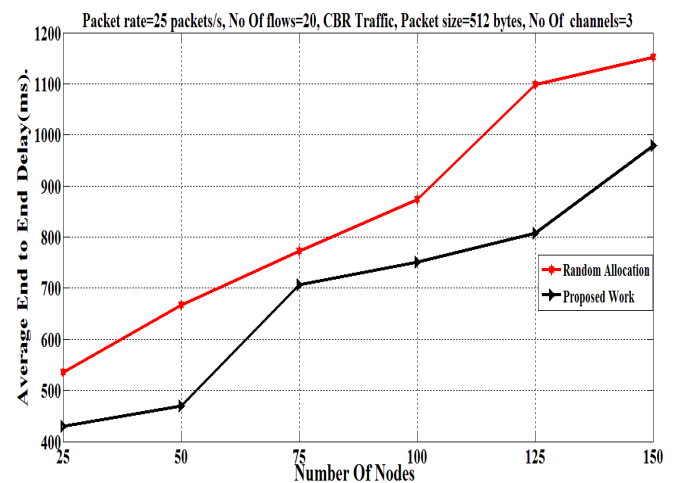

Figure7. Average End to End Delay (ms). Vs. Number of Nodes.

It can be seen from figure 8, the throughput has inversely proportionality with number of nodes, because the number of packets that received at destinations is decreased with increasing the number of nodes. We can deduce that, the interference level is affected by number of nodes which are within same transmission range, and intend to send the packets. But, our proposed shows the significant improvement in average throughput is about 6.78% comparisons with random channel selection.
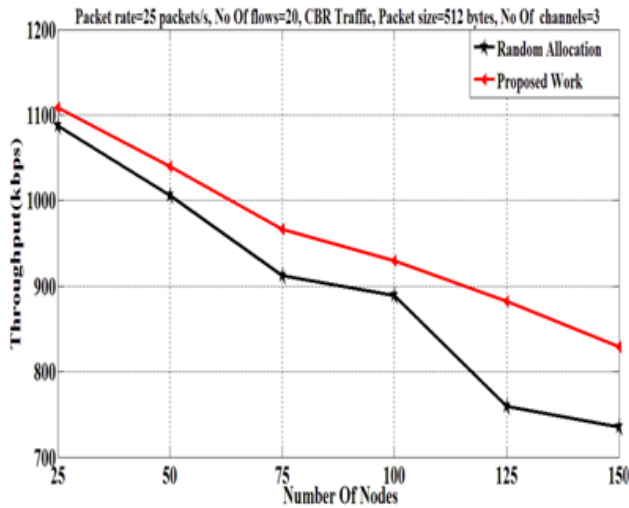
Figure8. Throughput .vs. Number of Nodes

6.2   Impact of Varying Number of Flows

In this scenario, we study the influence of changing the number of flows. The number of packets that is transmitted throughout the network is increased by increasing the number of flows; this is coming from the fact, that every packet takes long time to be sent, although, there is more than one channel, which can be used at same time. Our work performs better than random channel allocation, it can provide a better channel allocation management in comparison with random channel allocation, due to the privilege of selecting the suitable channel, as such a less contention time at each MAC layer will be taken in each channel. From figure 9, it can be observed that with the proposed modifications a reduction of 10.226% has been achieved in end to end delay as compared to random channel allocation
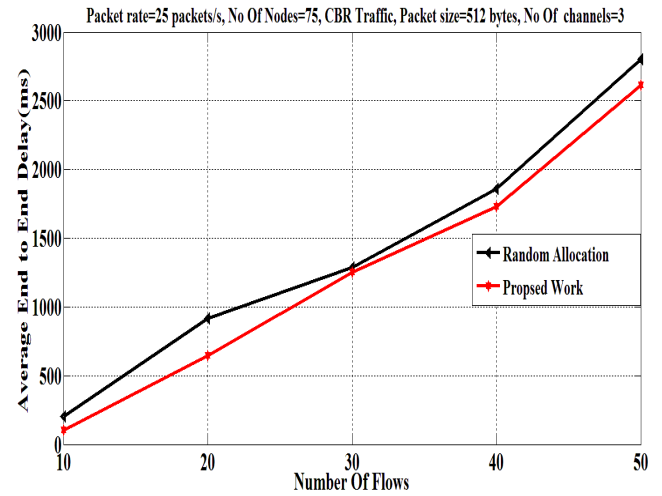

Figure 9. End-to-End-Delay .vs. Number of Flows

Figure 10 shows the comparison of proposed work and the random channel allocation, it is clearly that, the number of flows causes to increment in the number of packets that received by destinations, the graph of the throughput, will raise in both of random channel allocation and in proposed work, but, the proposed work has further improvement, because, it has taken into an account the bandwidth size of each channel that pass the packets. Our proposed approach has better performance for all values of number of flows. The enhancement of throughput achieved on an average is 5.0059%.
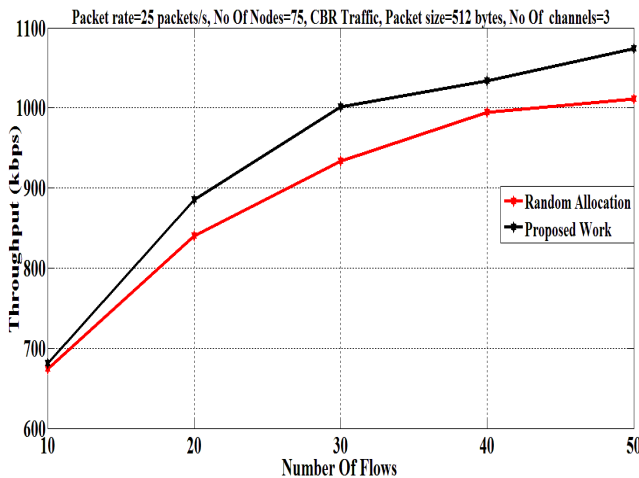
Figure 10. Throughput.vs.Number of Flows

6.3 Simulation Results and Analysis by Varying Number of Channels

The number of channels have been examined, to study the effect of network capacity, from figure 11, we can notice that, the reduction in end to end delay with increasing in number of channels. In our proposed modification, the network layer protocol of the sender node tries to assign different channels to different Flows, hence, the number of concurrent transmission of packets will be more, while, in random channel allocation, the channel that is assigned to pass the packets, may have less than the required bandwidth, thus it cannot send the packet, so that the packets will remain in the queue of node's radio interface, until they get sufficient channel bandwidth. In our work, the total average of end to end delay is reduced by 34.1250%.
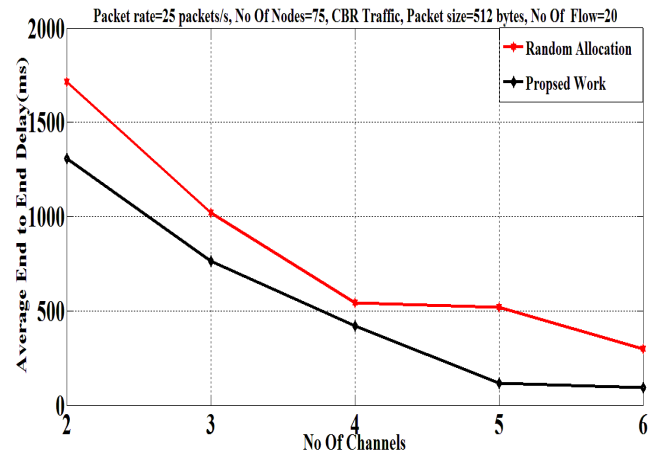

Figure 11. End-to-End-Delay .vs. No. Of .Channels

It can be clearly observed that our proposed work has a very sharp improvement in throughput, figure 12 shows that. The proposed work used the best channel among all channels with highest available bandwidth, so that the number of packets are sent and received successfully is more than in case of the random channel allocation at different number of channels. As such, the number of packet loss will be reduced with increasing in number of channels. The results demonstrate that the proposed work acquires a better throughput than random channel allocation. The proposed work improves throughput by 10.48%.
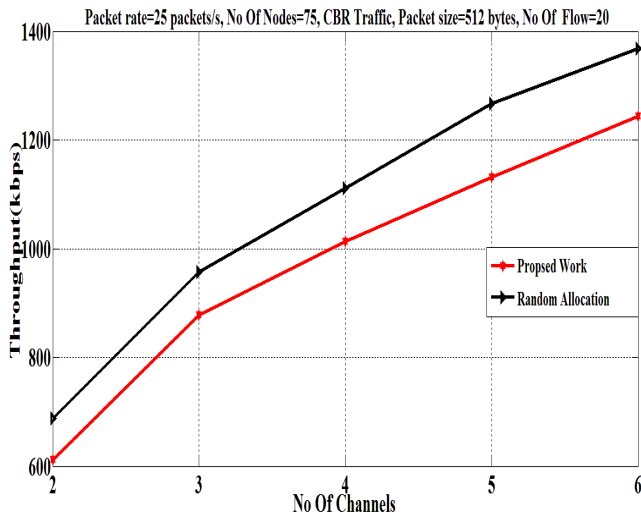
Figure 12. Throughput .vs. Number of Channels

6.4 Simulation Results and Analysis by Varying Packet Sending Rate

Here, we vary the transmission rate to study the scalability in the network. The packet sending rate varies from 20 to 40, while the number of flows from source to destination is 20, and the number of nodes is 75. From the plot in figure 13, the traffic load has direct relationships with end to end delay. With increasing in the transmission rate, the contention time at MAC layer will increase. The random channel allocation does not have any criteria to allocate channel to send data packets to next hop, it may choose channel, which has more congestion (i.e. high bandwidth consumer), thus the possibility of packets drop is high and the retransmission process will occur for the same lost packets, while in our work, we use the channel that has less bandwidth consumer for sending the packets. This means that waiting time of packets in the queue of the interface will be reduced. For example, when the sending rate is 25 the end to end delay of random channel allocation is

915.279(ms), while in our work is 647.1225 ms, Compared to random channel allocation the average end-to-end delay reduced about 18.00967%.
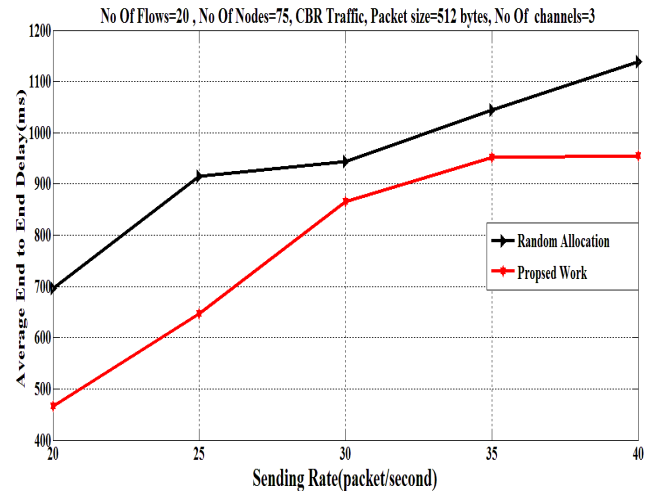

Figure 13. End-to-End-Delay .vs. Sending Rate

Figure 14, summarizes the difference in the performances between random channel allocation and the proposed methodology in term of average throughput, where the number of the packets that travel in the network are increased by increasing in the traffic load. Hence, the throughput will also grow. The performance results of simulation experiments reflects the difference approach for managing the channel allocation between proposed work and random channel allocation, our proposed work has an apparent improvement over random channel allocation with about 7.9361%, proving that, the random channel allocation is not managing the channels bandwidth properly.
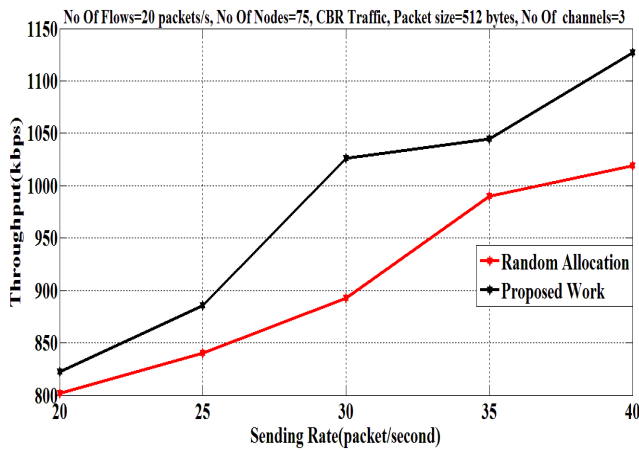
Figure 14. Throughput .vs. Sending Rate.

7. Conclusion

A proposed for resource allocation management issue in multichannel multi radio interfaces has been presented, the proposed work has used the information of channel estimation condition for allocating the channel in cross layer manner. The selection criteria based on estimation of comparable lowest bandwidth consumer. The proposed work is applied in multi hop environment. We consider DSDV(i.e. Destination-Sequenced Distance-Vector Routing) routing protocol in our work as network layer for taking the decision for selecting the channel in each hop link of each path, thus choosing network path will have a less congestion with highest delivery bandwidth rate in the presence of intermediate nodes. The objective of our work is to maximize the bandwidth utilization, which reflects in the improvement of traffic management, and obtained the better performance in overall network.

The simulation results under different number of nodes, different number of channels, different number of flows and different packet rate., show us that significant improvement in key performance metrics in terms of delay, throughput.

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