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Interference Aware Channel Assignment in Wireless Mesh Network

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Abstract - *Wireless mesh networks have numerous advantages in terms of connectivity as well as reliability. Traditionally the nodes in wireless mesh networks are equipped with single radio, but the limitations are lower throughput and limited use of the available wireless channel. In the proposed research, algorithms are developed to improve throughput, minimise delay, reduce average energy consumption and increase the residual energy for multi radio multi-channel wireless mesh networks. Interference is the main factor which directly impacts the network capacity. In literature, the existing channel assignment algorithms fail to consider both interflow and intra flow interfaces. The limitations are inaccurate bandwidth estimation, throughput degradation under heavy traffic and unwanted energy consumption during low traffic and increase in delay. In the present research, a protocol called Priority Based Interference Aware Channel Assignment with Bandwidth Reservation is proposed to estimate the required bandwidth accurately. All the nodes calculate its bandwidth availability for its links. The nodes check the available links that can be used for the requirements of the incoming flow in the admission control process. Priority is given to each link based on the interference information. If any link is not able to meet the flow requirements while data transmission, it will be reported to the sender node to stop the transmission. Though interference is minimized in this algorithm, the performance is degraded due to congestion.*

Keywords - *Channel assignment, priority, wireless mesh network, bandwidth, channel radio.*

1. INTRODUCTION

Amongst the quickly budding wireless technologies, Wireless Mesh Network becomes a significant player. Autonomous, self-healing and self-configuring are the characteristics of wireless mesh network. The administrative intervention required is only minimal after setting up the WMN. There may be a considerable amount of interflow interference and intra flow interference present in wireless links among the nodes in a same geographical area. Interference affects the capacity of the network. To reduce the interference and to increase the capacity of a network, efficient channel assignment algorithms are required. Fig. 1 shows the illustration for interference aware channel assignment method. Each mesh router in a WMN calculates the external interference periodically from the collocated wireless networks and it is informed to central server. The mesh gateway is called as central server. It will maintain the link interference matrix for the interfering link. For example, consider there are 7 mesh routers connected to one another, the total number of links can be calculated using the formula $n\,(n-1)/2$, the number of links always is equal to 21. For every 21 links the interference matrix is maintained by CAS.

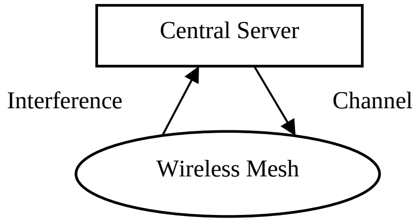

Fig.1 Illustration for interference aware channel

The central server runs the channel assignment algorithm to find the channels of other interfaces for every router. The calculated CA structure is sent to all mesh routers. The central server periodically reallocates the channels to adapt the changes in external interference. Many solutions are proposed for wireless mesh networks, but mesh network vary from other networks in terms of its architecture, its traffic pattern and the requirements of users. A survey of QoS solutions specifically for mesh networks focusing on single radio single channel is given in Gupta et al. [1].

For multiple radio multiple channel, minimum number of solutions are considered in [2] [3]. The unique importance of interflow interference and intra flow interference are not considered in the available MRMCWMN. Mao et al. [4] and Hu et al. [5] proposed a Distributed Call Admission Control (DCAC) algorithm for TDMA based MR-MC WMN. Xue et al. [6] proposed that bandwidth is calculated at every node by measuring the self-traffic of a particular node and its neighbours. Abdrabou et al. [7] used model-based estimation methods in wireless networks to provide end to end delay guarantees. Liu et al. [8] proposed QoS solution for MRMRWMN. Threshold triggered bandwidth calculation is done, where the residual bandwidth is predicted by distributed call and admission control mechanism. In most of the popular applications of WMN like mobile TV, video conferencing etc are based on multicast communication. Banik et al. [9] described the delay constrained multicasting in which the receiving nodes can simultaneously receive packets from the source node.

Priority-Based Interference Aware Channel Allocation with Bandwidth Reservation (PBIACA-BR) algorithm is proposed for WMN. The algorithm is model-based algorithm which seizes the effect of interflow interference and intra flow interference for precise estimation of bandwidth. In PBIACA-BR load balancing is carried out by sharing the traffic of every flow over a many links in a wireless network based on the presence of interference on the links.

II. NETWORK MODEL

The network is considered as a graph $G = (N, L)$ where the nodes are represented as $'N'$ and $'L'$ represents the wireless links. All the nodes in the network are connected by means of wireless links. To improve the network performance, each node is provided with multiple radio interfaces. Each node in the network is associated with priority corresponds to the path delay. If the priority of the node $'i'$ is greater than the priority of node $'j'$, the path delay of node $'i'$is lighter than node $'j'$. In this network model, 100 dynamic nodes are deployed on random topology. The interference region is assumed to be twice the transmission region.

III. PBIACA - BR ALGORITHM

There are five phases for the proposed Priority Based Interference Aware Channel Allocation with Bandwidth Reservation Algorithm and it is given in Fig. 2.

1. Neighbour identification
2. Interference minimization
3. QoS aware path finding and admission control
4. Prioritisation
5. QoS violation recognition and retrieval

A. Neighbour identification

Node in the network periodically sends HELLO packets contain its node ID through its all existing radio interfaces. Nodes within its transmission range will receive this and note its neighbour ID, the link with which it received the HELLO packets and the channel which is assigned to that particular interface. With all this information, all nodes in a network must build a neighbour table. Neighbours are connected to the node directly within its communication range. Using neighbour identification phase each node can identify its multiple link neighbours.

B. Interference minimisation

Wireless links are broadcast in nature. Due to this, the data transmission of any node $'i'$ may interfere with the packet transmission of other node $'j'$. This happens only when node $'j'$ is situated within the range of interference of node $'i'$. Nodes interference range is twice its transmission range. This is often referred as two hop interference model. Depends on two-hop interference model, the interfering nodes are classified into intra flow interfering nodes and interflow interfering nodes. In two hop interference model, the interference is estimated with the help of distance between any two nodes. The channel separation among any two nodes i, j is given as $|C\,i - C\,j|$. Where $C\,i$—> channel used by node $'i'$, and
$C\,j$—> channel used by node $'j'$. In Fig. 3, the inner dotted line circle shows the communication range of node $'i'$ and node $'j'$. The outer circle shows its corresponding interference range. For link (i, j) the links $(j, k), (k, l), (j, m)$ and (m, n) are considered as conflict links. The conflict links are the links that are in the interference range.

The proposed PBIACA-BR approach all the nodes know the reserved bandwidth for every flow that is passing through the node and all the nodes know the link with which the flow is passing. So, using this two information the aggregate flow rate is calculated. This ensures the accurate bandwidth estimation. Since the interference region is twice the transmission range, each node sends HELLO packets to cover all the nodes within the transmission region. Each node that receives the kind of HELLO packets from all its neighbours who are in its interference range and their identities are updated in its routing table. The HELLO packet has the details about the outgoing links of a node and the amount of traffic it has reserved for a flow. Using this information local conflict graph is constructed and clique constraints are derived. A clique is formed based on the two hops information of the hop table. Similarly, the routing table of every node is updated with the next hop neighbour's information so that the node can access this routing table during packet transmission.

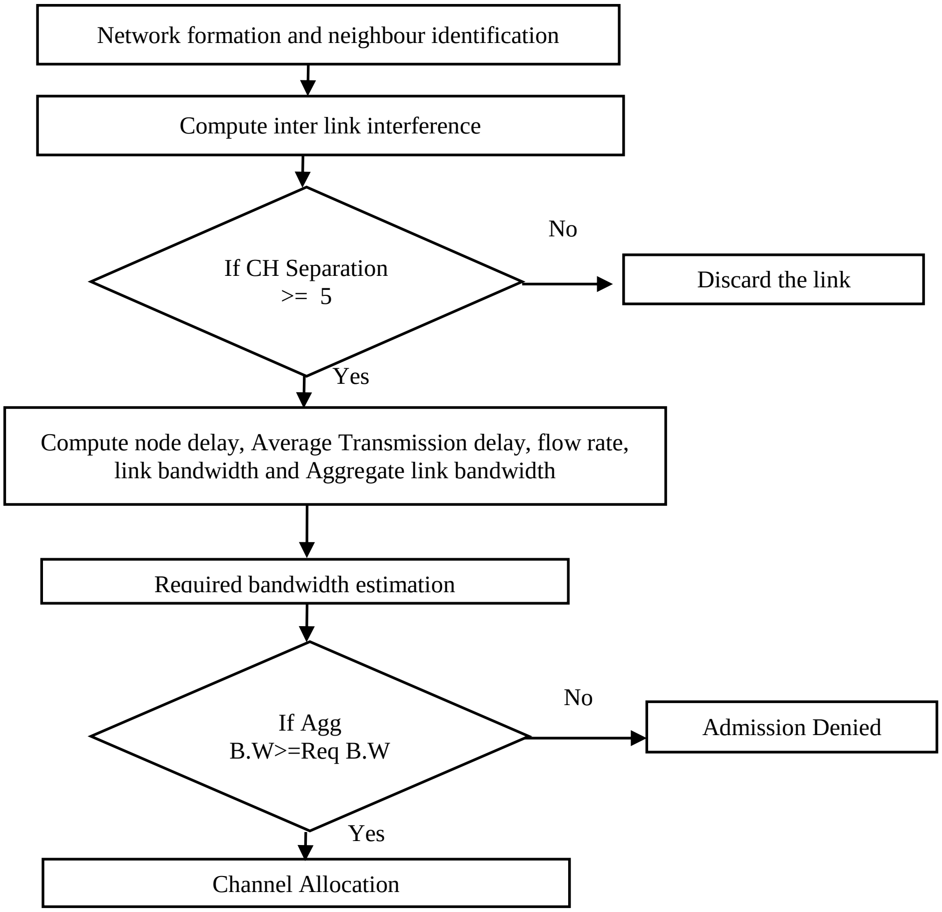

Fig. 2 Process flow diagram for PBIACA-BR

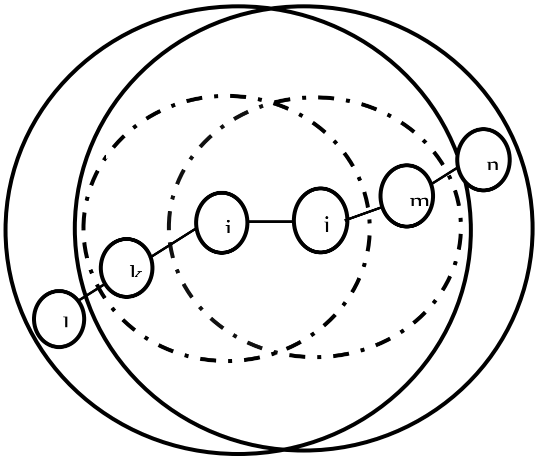

Fig. 3 Interference range for node (i, j).

Interference interrupts the information as it travels along the network between the sender and the receiver. The term interference typically refers to the addition of unwanted information to useful information. To calculate the expected interference for each node, a temporary list is created. It gives the detail about the number of neighbour for every node. Finally, the node with minimum number of neighbouring nodes is selected as intermediate node to route the packets. In this way from source to destination all the connected neighbours are selected so that the expected interference is minimum for the selected path. By using the expected interference information, a critical vertex is formed. In critical vertex the nodes are sorted in an ascending order fashion, started with nodes that have minimum expected interference to till node which has maximum expected interference. For each link the flow rate should be determined. Flow rate is defined as the rate at which the packets to be sent in a link. To calculate the flow rate, the nodes calculate the existing bandwidth for every outbound links by constructing conflict graphs locally by considering the interference of the existing flows. The node must consider the intra-flow interference that can be generated within the new incoming flow too. All the existing bandwidth of several links is summed up to estimate the bandwidth required for the incoming flow. For the packet to be sent, the bandwidth required is calculated in such a way that the path which has both minimum expected interference and more residual bandwidth than the required bandwidth is selected. If both of these are satisfied, link is created and request packet is sent to that destination node. Once the destination node receives the packet, the route replay is sent through that established links. As soon as the source node receives the route reply, path is created and data packet is sent to the destination through the established path. The node which does not have the required bandwidth and if it involves in forwarding the packet, the respective node is considered as violating node. These nodes are removed from the routing table and if violation is detected, routing table should be re-updated and the process should start from first. Proactive algorithm takes care of link diversity. The delay analysis of wireless networks IEEE 802.11 [10] is analysed the delay using double Marchov chain model. The average transmission delay $E[D]$ can be calculated as,

$$E\,[D] = E\,[L] * E\,[X] \tag{1}$$

$E[L]$ → average length of each slot time. The slot time is set as 20 µs as per the IEEE 802.11 standard, Direct Sequence Spread Spectrum Physical layer (DSSS-PHY)

$E[X]$ → average number of solutions necessary for successful transmission of new frame.

Bianchi et al. (2002), derived E[X] as,

$$E[X] = \frac{(1-2p)*(W+1)+p*W*(1-(2p)^m)}{2*(1-2p)*(1-p)} \tag{2}$$

m → maximum back off stage

W → size of the contention window

Minimum value of m can be 7 and the contention window size W is set to 32 in IEEE 802.11 DSSS.PHY

p → probability in which the transmitted packet encounters a collision and it is given as,

$$p = 1 - \left(1 - \frac{2}{W}\right)^{INi} \tag{3}$$

INi → the number of interfering nodes for node i.

The average transmission delay mainly depends on the number of interfering nodes.

C. QoS aware path finding and admission control

QoS aware path finding has four sub-phases. If a node wants to identify a path for an incoming flow which demand for QoS sends route request. During route discovery phase the below mentioned steps are performed.

Step 1: Bandwidth estimation

All the nodes in the networks calculate the available bandwidth for its entire links with the help of conflict graphs by considering the interference from the existing flow.

Step 2: Admission control

The details of admission control process are explained as follows. $L(i,j) = \{l_1, l_2 \ldots l_k\}$ shows the set of links on wireless channels between the nodes $'i'$ and $'j'$. The bandwidth between the nodes $'i'$ and $'j'$ can be denoted as $(av.bw)_{(i,j)}$ and it is obtained by adding the bandwidths of all links in wireless hop.

$$(av.bw)_{(i,j)} = \sum_{l \in L(i,j)} (av.bw)_l \tag{4}$$

where $(av.bw)$ is available bandwidth and $req.Bw$ is required bandwidth. To check the availability of bandwidth and to admit the flow, the following process is performed as shown in Fig. 4.

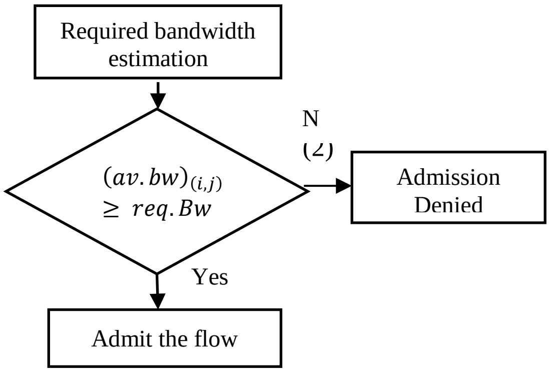

Fig. 4 Process flow diagram for admission control.

Step 3: Load balancing

In load balancing, the traffic load of an incoming flow is simultaneously distributed to multiple links. The traffic distribution is done by checking the interference on all the links.

Step 4: Resource reservation

In resource reservation, the reservation is finalized as soon as the intermittent nodes get the route reply from destination. The node which wants to transmit data packets can broadcast route request message.

D. Prioritisation

In this method, priority factor is considered to stop high priority multicast sessions from experiencing heavy interference than low-priority multicast sessions thereby reducing interference.

E. QoS violation recognition and retrieval

If the bandwidth requirements are not met, it is considered as QoS violation. Any violation in the guaranteed bandwidth is identified and it is reported to the source, source needs to stop its transmission and it has to continue with retrieval process.

IV. PERFORMANCE EVALUATIONS

A. Experimental setup

To test the performance of the network interference aware, congestion aware and traffic aware channel assignment algorithms are proposed in the research.

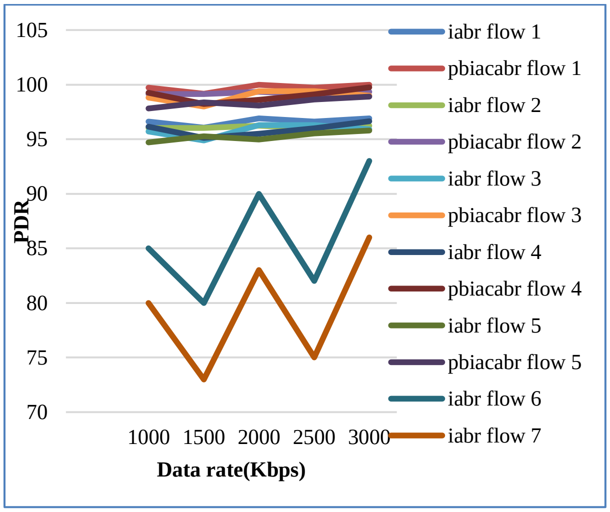

Fig. 5 Comparison of PBIACA-BR performance based on PDR.

Fig.5 shows the comparison of PBIACA-BR performance based on PDR. In terms of PDR, PBIACA-BR performs well for low data rate as well as high data rate. PBIACA-BR consistently performs better than existing method.

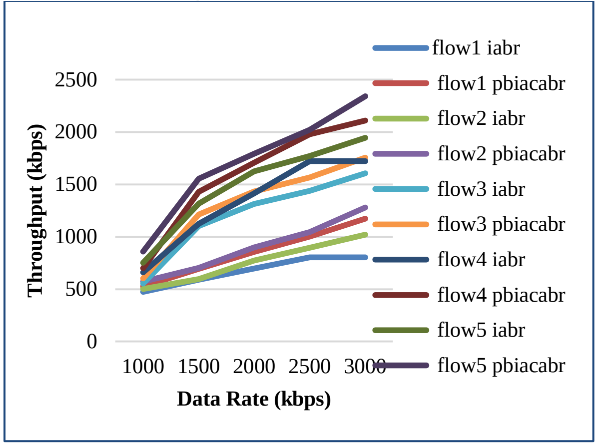

Fig. 6 Comparison of PBIACA-BR performance based on throughput.

Fig. 6 shows the comparison of PBIACA-BR performance based on throughput performance. As per the analysis the throughput in PBIACA-BR is improved on the average of 7.7% than IABR and delay in PBIACA-BR is improved to an average of 16.9% when compared with IABR.

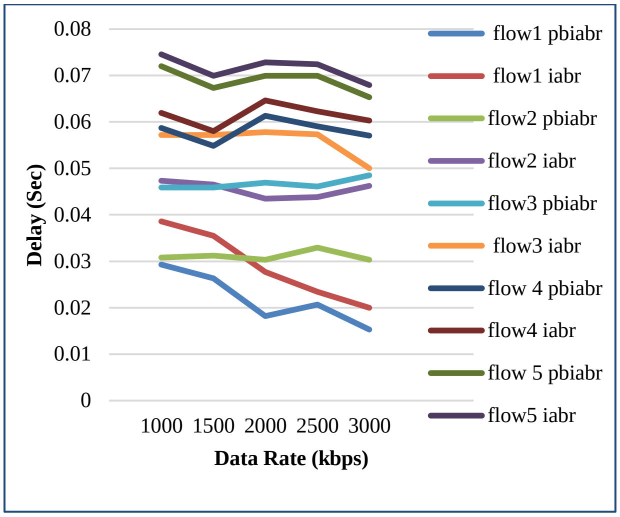

Fig. 7 Comparison of PBIACA-BR performance based on delay.

Fig.7 shows that delay is low in PBIACA-BR compared to IABR as because the channel is more efficiently allocated and high priority is given for the less interference nodes. Fig. 8 shows the analysis of average energy is made between PBIACA-BR and IABR. Average energy consumption is low in PBIACA-BR compared to IABR as because the data is transmitted through the least interference nodes. As per the analysis the average energy in PBIACA-BR is improved to an average 15% when compared with IABR.

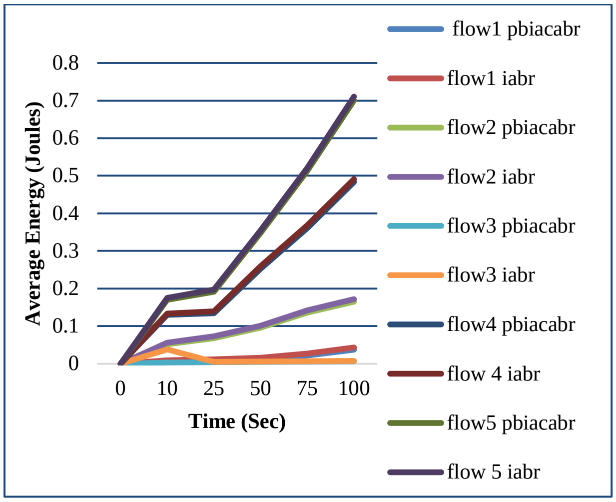

Fig. 8. Comparison of PBIACA-BR performance based on average energy.

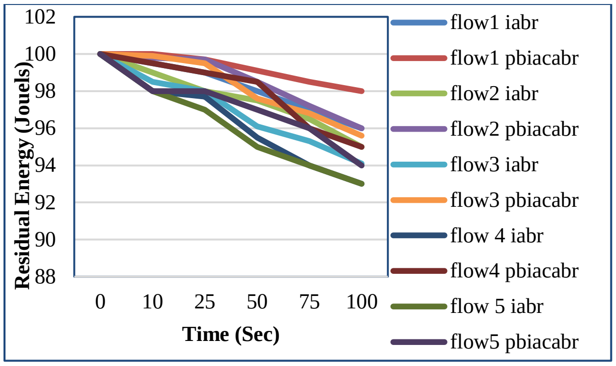

Fig. 9 Comparison of PBIACA-BR performance based on residual energy.

Fig.9 shows the comparison of PBIACA-BR performance based on residual energy. As per the above analysis the residual energy in PBIACA-BR is improved to an average of 1.9% when compared with IABR.

V. CONCLUSIONS

Priority-based interference aware channel allocation with bandwidth reservation algorithm which seizes the effect of interflow interference and intra flow interference and contribute precise estimation of bandwidth. In bandwidth estimation, the entire node calculates its bandwidth availability for its links. The node checks the available link that can be utilized for the requirements of the incoming flow in admission control process. In load balancing, the traffic load of the flow is distributed to multiple links to avoid delay and overloading of links. When the intermittent nodes receive route reply message from the destination node, resource reservation is finalized. Priority is given to each link based on the interference information. Low interference links will have high priority. In QoS violation recognition and retrieval phase, during the data transmission if any of the links is not able to meet the requirements, it should be reported to the sender node and sender node has to stop its transmission. Sender node has to start the recovery process. Recovery process is another phase of route request to identify the alternate path to fulfil the QoS requirement. Using the proposed algorithm throughput and delay parameters are improved with various data rate. Though interference is minimized, due to congestion the performance is degraded. In order to improve the performance of the network congestion is also considered in future.

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