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Multi-channel Scheduling with Interference Avoidance and Precedence Based Algorithm in Wireless Mesh Networks

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Abstract: Wireless Mesh Networks (WMNs) is the wireless networking domain that has been preferentially attracted by many researchers. Multi radio and multichannel WMN has limited channels due to the constraints given by interferences caused internally and externally within the channels. The research is focused on maximizing the performance in multi radio and multi channel WMNs. The channel overlapping that happens partially can overcome this limitation of resources. Interference Avoidance and Precedence Based Algorithm(IAPB) is proposed to reduce the interferences that occur in WMNs and improve the performance.The interference involved during the usage of channels can be reduced by using the channels with less interference. The interference involved is reduced by consideration of precedence level of interference during assignment of channel. The proposed algorithm results in performance improvement in terms of network throughput, the packet loss, delay involved in the reduction of interference.

Keywords: *Interference, Multi-Radio Multi-Channel, Channel Overlapping, Wireless Mesh Network, Network Throughput.*

1. Introduction

Wireless Mesh Networks (WMNs) consists of multiple hops which can be used in number of applications that are used in recent days. Internet usage has increased due to the availability of smart devices with internet facility in different areas of applications. The users count is also increasing in different sectors of internet. WMNs come with feature of increased stability, avoidance of single point of failure, transmission over a long distance and simple topology. Many applications can be controlled and monitored by WMNs with low cost.

A WMN consists of a number of mesh router and mesh clients connected to each other to create a mesh network which is wireless and wired as show in the Figure 1. It is created to allow transmissions to happen along multiple routes. Here the mesh routers are configured to provide multiple radios, and mesh clients can utilize those radios conveniently by using multiple channels available in the multiple radios which in turn improve the capacity of WMN. Mesh networks may provide wireless connections either to act as point of access serving different WLANs or to provide peer to peer wireless communication [1]. Multi Radio Multi Channel (MRMC) mesh networks working with wireless facility consists of Mesh Clients (MCs) and Mesh Routers (MRs). MC can move or can be static, MR is usually static. The distribution of available traffic within mesh network is done by MR. Mesh Gateways (MGs) are available in WMN,which act as gateway to provide connectivity to MRs, MCs and other wireless networks by having wired connectivity. The network considered is Wireless Local Area Network represented as 802.11. In Time Division Multiple Access (TDMA) a single time slot is assigned to the multiple devices which have no interference with each other [2]. It has channels referred to as Quadratic

Channels (QC) and Preferential Channels (PC). The capacity of the entire network can be tremendously more provided the channels being assigned are non-interfering or orthogonal [3]. Given the radio frequency for the nodes in WMNs QC channels does not mix or overlap with other channels but the PC channels may involve the preferential overlap with few other channels. The channel allocation in multi-channel wireless mesh networks is the most challenging task [4].

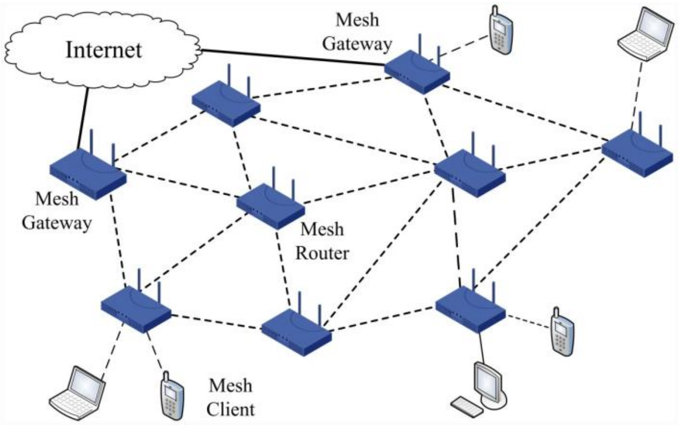

Figure 1: Wireless Mesh Network Tolpology

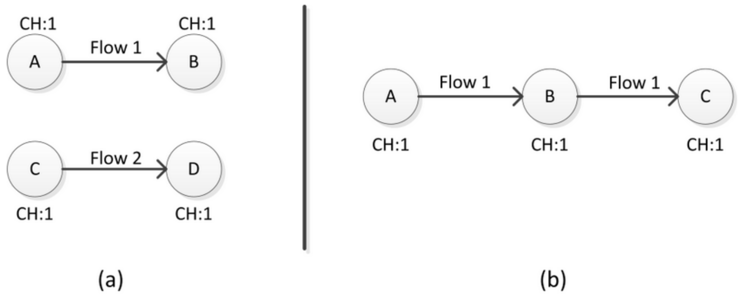

Figure 2. (a) Quadratic Channels interflow (b) Quadratic channels intraflow

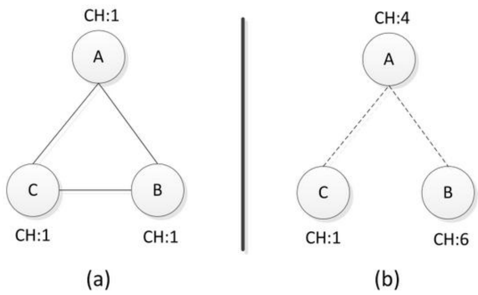

Figure 3. (a) Preferential Channel Co interference (b) Preferential Channel adjacent interference

WMNs consists of wired and wireless connections, the capacity of a given channel is represented by the maximum impartment of packets done through the channel. Enhancing the spatial channel reuse results in minimizing the number of channels required [5]. The interference caused during transmission by numerous nodes by using different links results in bound on the network capacity. The links with the shorter route and less interference links had a higher priority to access channels [6]. The communication that happens in the link may result in interference due to the same instance communication between pair of mesh nodes. The interference resolving has got more exposure and is categorized into NP hard problem. Many procedures are followed to make efficient usage of channels for transmission in WMNs. To avoid co-channel interference among the distributed nodes, all the resources in the 1-hop neighbor nodes can be allocated orthogonally in the frequency domain [7].MRMC infrastructure involves transmitting through multiple channels using multiple radio interfaces by avoiding interference involved during transmission. The interdependency exists between interference and usage of channel and frequent switches between channels. The channel usage by using different links of the same may result in avoidance of the interference. Baeconmethod improves the channel utilization and the network throughput, and in the meantime, reduces the collision probability [8]. However the frequent utilization of the channel with least focus to interference leads to over loading of interference in total. The performance of the network gets affected due to the interference, since the retransmissions occur substantially. The channels not existing at the time of requirement occurs due to the usage of same channel frequently. This creates a limitation on the overall throughput which in turn results in decrease in simultaneous transmissions.

PC utilization boosts the performance, in spite the limitation of QC is caused by the overall interference. [10]Network layer security mechanisms can deal with few routing attacks; however, these mechanisms cannot tackle at- tacks that target transport, Medium Access Control (MAC) and physical layers.Shows the usage of PCs results to improvement in simultaneous transmissions and in turn boosts the performance of the network. Further the interference gets reduced and the overall performance gets improved. The level of interference is dependent on the distance between the channels. The interference increases beyond the limit by increase in the distance among the channels. The PCs utilization for switching between the channels may result in minimum occurrences of interference.The same is mentioned in where the usage of PCs boosts the performance of the network. There is interference between two users in the same channel when their distance is less than a certain distance [9]. The MRMC provides mutilple radios, the utilization of these radios along with PCs results in remarkable boost in the performance of network and simultaneous transmissions. Sufficient transmission of data and dependable capacity of the network is achieved by the WMN using MRMC infrastructure. QoS (Quality of Service) is great feature to be achieved by the WMNs, since it make sure that evaluative data gets transmitted with priority.

The four sections are represented here. WMNs with MRMC are mentioned in the first section. The switching between the channels is elaborated in the second section. IAPB algorithm is proposed that considers precedence level for assigning channel in contrast to the existing algorithms which is detailed in the third section.Simulation results are presented in the fourth section.

2. Related Work

Switching of the channels by avoiding the interference is the important feature to be considered. [12] Traffic heap available in the network considers sorting of the links in decreasing order and assigning the links of appropriate channels is mentioned. [13] assigns ranks to the links based on the heap of traffic, distance among the gateways and each node facilitated with interface. [14] Considers the length of the link and the available interfaces for making the combination of efficiency of connection and linking of heap of the link with the length. Here the PCs are not used by the MRs which are fixed and configured with a pair of radio facility. The interference avoidance can be improved by the reducing the interference among the PCs. Presently many algorithms are focused on the avoidance of interference. [15] considers network performance improvement by focusing on the three constraints. Connection of network and being stable while switching between the channels. The delays involved for making use of queue and switching is not considered. And it does not satisfy the interference minimization and improving the performance of the network.

[16] Considers lesser delays involved in transmission of packets and improving the performance of the network. The traffic heap with congestion and interferences involved is more in this proposed idea. In [17] while assigning channels to the available links the color of the edge is considered, with focus on reducing the interference among the adjacent channels. This uses centralized approach and doesn’t consider the consequences of the interference caused by the exterior interferences. It also doesn’t focus on heap of traffic, the queues utilized, delay involved and exterior environments effects. [18] Focuses on the channel assignment done in MRMC infrastructure with a centralized approach. Here the performance of the network is increased by reducing the interference while assigning the PCs channels. [19] Says the radios considered have a frequency which is important and has limitation.

A lot of research activities are conducted to avoid the interferences involved which in turn improve the throughput. The enhanced performance is gained by completely using the available QCs and PCs. Further it is reversely dependent on the available number of MCs MRs and interfaces. PCs can make sure of better network performance by considering connectivity of the network.

[20] [21] Focuses on loss of path of the signal, interference among the co channels calculation of power of node and gain by an antenna. The distance between the channels and interference among the PCs are predicted through results obtained theoretically. [20] doesn't consider the channel assignment in distributed way to reduce the interference. It minimizes the number of channels which in turn improves the performance of the network. It utilizes PCs create links with the neighboring nodes. But the interference involved is more with focus to gain performance of the network consequently degrades the performance. [21] Reveals the assigning of channels improvement considering the traffic heap, which results in better network performance. But it involves the infrastructure that is complex.

[22] Minimizes interference by making reuse of the channels that are jointly working. The connectivity of the network is maintained by distributing the resources evenly with the links that are in interference. [23] The connectivity of the network is compensated with network connectivity and users listen till the next window response in the form of message. The delay involved in average is higher. WMNs with multiple hops involves interference among the links that are neighbors. [24] mentions about forwarding the packets received from other mesh nodes in WMNs with multiple hops. [25] Considers the methods used mathematically and interfaces utilized. It uses graph that is undirected to model the WMN to reduce the interference. [25] [26] considers the graph that has conflicts and [27] graph with connectivity based on communication that is unit-casted while utilizing QCs for transmission of the data.

3. Interference Avoidance and Precedence Based Algorithm

The proposed IAPB algorithm avoids interference by considering precedence of the channels to allocate during requirement. The proposed algorithm is compared to Interference-Aware Expected Transmission Time Routing IAEETR algorithm. The IAPB algorithm has a look at end to end traffic, then assigns channels based on precedence. WMNs are configured with multiple hops where all the channels available are selected based on the parameters considered for selection. The channel that is optimally useful in terms of avoidance of interference is selected. The precedence based selection is made in each iteration,so that the interference is lesser in total. The main goal here is to minimize the interference. WMN consists of MCs and MRs configured with wireless interfaces in the network. IEEE 802.11 is utilized where the node involved in transmission is free of interference, this can be achieved by avoiding the links in the scope of interference being forbidden for transmission. Figure 4 shows the mesh nodes and the links available in WMNs, the distance between the mesh nodes is also depicted.

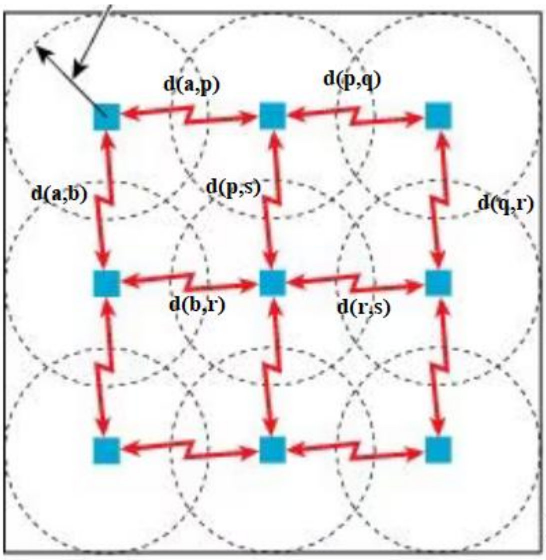

Figure 4 Distances among the Mesh Nodes

IAPB algorithm considers a network topology where the distance between the mesh nodes and interference involved during communication is determined. The number of hops in the WMN topology is represented by the distance between the MC or MR and the MG. IAPB selects a channel between the two mesh nodes by assigning a connection to channel, which is based on the interference and the precedence given to the links. It also considers the hop count which is lesser from the MG. IAPB motto is to avoid interference during communication among all the mesh nodes in the network. WMN has MR having connection to another MR providing communication among multiple hops. Usually the MRs are fixed, acting as backbone of WMN. [28]

Suggests the collection of MRs acting as backbone of WMN is helpful in determining the network performance. The packets transfer that happen between the mesh nodes p and q, considers link distance represented by d(p,q). The minimum distance is computed by Eq.(1) :

$$d(p,r) = min\ (d(p,q)+ d(q,r), d(p,s)+ d(r,s)) \qquad (1)$$

[29] The scope of interference is twice its scope of communication when the interference topology considers two hops. The topology computes the interference depending on the distance that is there between the nodes. 11 channels are there in 802.11 WMN. The division among the nodes channels decides the scope of interference. Suppose there are two links represented by d(p,q) and d(q,r) the scope of interference can be denoted by S. The bounds between the channels denoted by b may occur as 0, 1,2,3,4 and 5. The bound can be greater than 5 so the last value that separates them is a value 5 or greater than 5. It implies the bound value lesser then 5 denotes there is no interference. The bound distance and the scope of interference can be represented by an equation shown by below Eq.(2). Interfer(p,r) is the scope of interference for bound between p and r. The interference happens when the mesh nodes are in the scope of interference.

$$Interfer(p,r) =\{ 1 ,d(p,r) \le S[p-r] \quad or \quad 0 ,d(p,r)\ge S[p-r] \quad \} \qquad (2)$$

The interference differentiates link that is directed to an undirected connection. The link that is directed has interference which is asymmetric and a symmetric interference is involved in link that has no direction. The sending mesh node receives a packet on successful submission by a receiving mesh node. The link layer sends an acknowledgement to the sending mesh node, transmissions of packets should not happen in the scope of interference. As a consequence of this the transmission from the sender within the scope of interference scope need not happen. The connection is provided for channel for transmitting the packet, this happens among all the mesh nodes available in the network. The successful happening of this results in no changes to be done later on. The traffic heap changes in the network and appropriate strategy gets applied to the condition available in the network. The undirected link in the channel available provide the transmission to happen correctly. Subsequent transmissions results in avoidance of interference detected in its scope of interference. The nodes that are involved in interference as mentioned in the Eq.(2) validates that the interference get avoided. Suppose the node p in the available WMN has a weight w_p, there are n_p nodes that may have possibility of interference and hc_p is the number of counts of hop to the MG from the sender mesh node n_p.

$$w_p = n_p / hc_p \quad (3)$$

The average number of nodes that are involved in interference for a given node p can be computed by the equation represesnted below.

AVG_INTERp =
SUMMATION(number of nodes involved in interference in each hop/no of hops in the Mesh) (4)

Algorithm : IAPB.

For each node p in the mesh

Compute(AVG_INTER_p)

If (AVG_INTER_p is ≤ AVG_Threshold)

For each channel assigned in CH_SET

Setting the Threshold based on the interfering nodes count

End of For

For each channel within the AVG_Threshold

Assign the channel

End of For

End If

End of For

The number of mesh nodes involved in successful transmission of packets is improved by the usage of IAPB algorithm. The channels involved in transmission without possibility of interference is identified and the mesh nodes do the successful transmission without interference.

4. Implementation and Simulation

The WMN topology can be represented by using the simulation environment ns3. The infrastructure of WMNs consists of MRs, MCs and MGs. All MRs in the WMNs are simulated to be fixed and the mesh nodes are placed within the distance of 250 m from each other. The mesh topology created has a dimension consisting of 150 nodes. Each node has the data flow defined in the network.

ns3 Parameters	Values
Transport Layer Protocol	UDP
Simulation Time	250s
Max Number of Mesh nodes in Topology	150
Bandwidth Set	6 Mbps
Packet size	512 bytes
Range of transmission	250 m
Flow count	5-16
Channels used	1-11
Simulator	Ns3
CCA Threshold	82 dBm

Table 1: ns3 configuration with parameters and values

The parameters defined for the simulation model of ns3 is mentioned in the Table 1. The parameters are set based on the working nature of WMNs and the considered constraints. The metrics that are used in terms of performance evaluation of the simulation scenario are throughput of the network, the delivery ratio of the packets, the delay involved from sending end to the receiving end. The throughput of the network is the ratio of total amount of data received at the destination mesh node to the time taken from sending to receiving of the data. The delivery ratio is the ratio obtained during simulation which is the total packets send by mesh sending node to the packets lost at the destination mesh node in the WMN. The network throughput is simulated considering different number of nodes active in the network. The delivery ratio is computed by considering the number of hops in the configured WMN scenario. The MR positions are also considered during simulation. The average of all the considerations is made and then the values are plotted in the graph. The simulation is done for network throughput analysis by plotting the graph of number of nodes available in the grid with the throughput gained. IAPB algorithm is used during simulation for varying number of nodes where the throughput also varies as compared to IAEETR algorithm shown in the Figure 5.IAPB algorithm is simulated for working with the sending mesh node to receiving mesh node packet delivery ratio compared to IAEETR algorithm shown in the Figure 6.

The throughput performance in the simulated WMN is shown in Figure 5. The observation shows that IAPB is continuously outperforming IAEETR algorithm using different sizes of flows with varied number of mesh nodes. IAPB avoids interference thus improves the performance of the WMN. The WMN throughput improves with the increase in the number of mesh nodes and the flows in the network, the results show end to end delay is reduced and overall throughput of the WMN is increased.

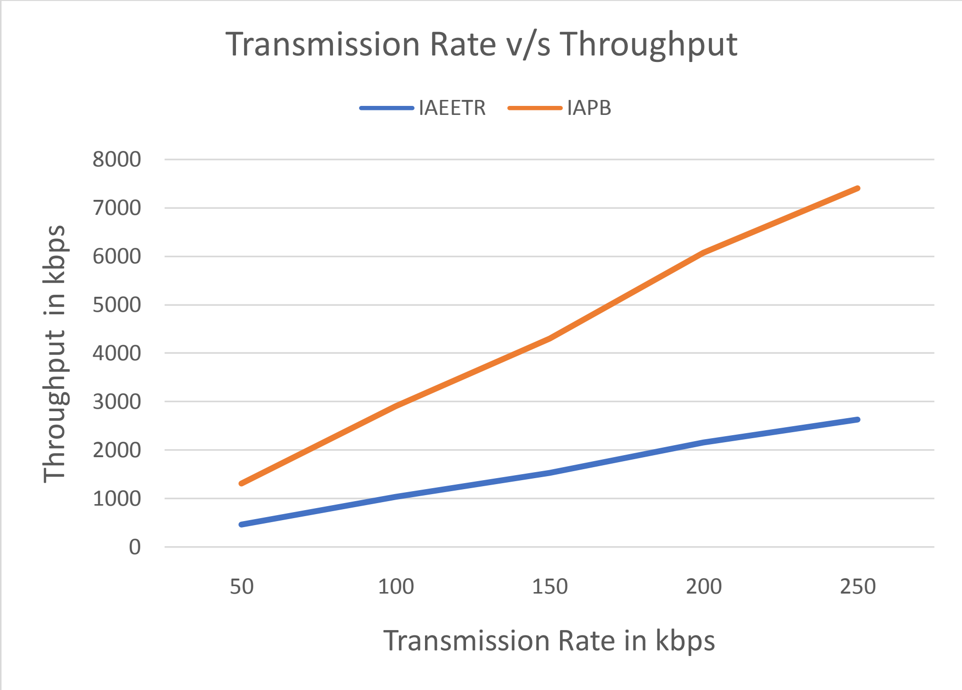

Figure 5 Transmission Rate v/s Throughput using IAEETR and IAPB

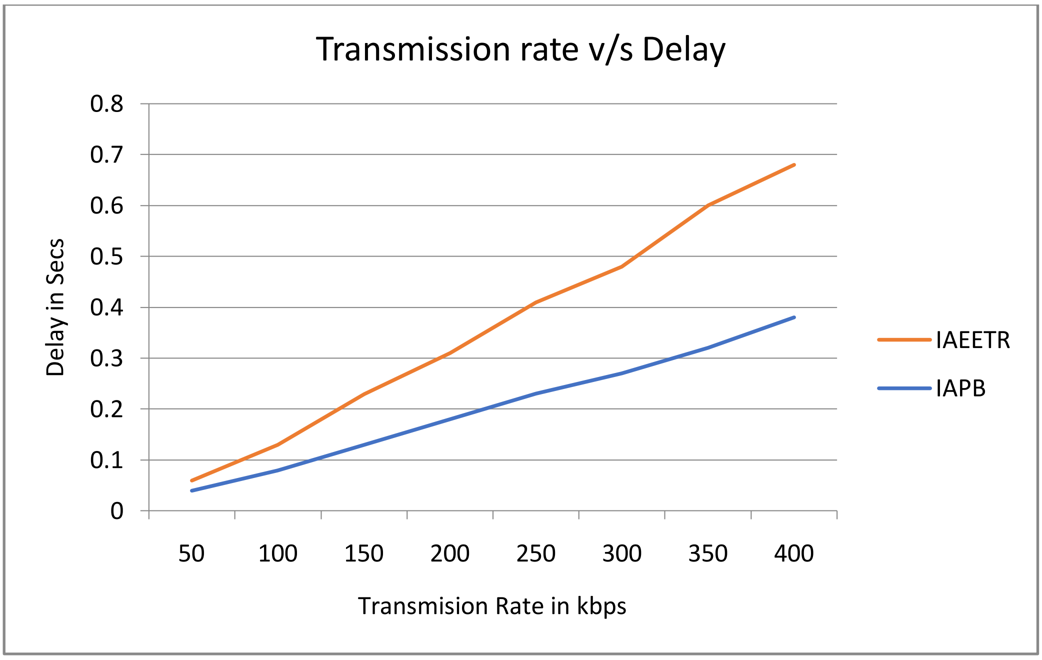

Figure 5 Transmission Rate v/s Delay using IAEETR and IAPB

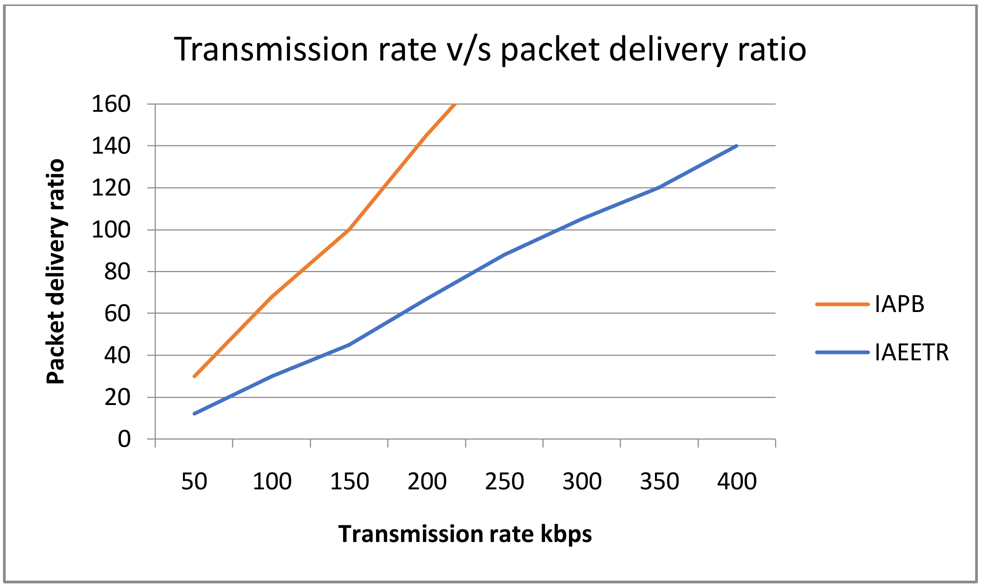

Figure 6: Transmission rate v/s packet delivery ratio using AIEETR and IAPB

The simulation shows that as the resources available in the network are fully utilized, IAPB has 55% higher throughput as compared to IAEETR. The delay involved from sending node to receiving node by utilizing PCs in the WMN is around 34% lesser as compared to IAEETR.

5. Conclusion

The interference avoidance along with complete utilization of the channel resources available in the WMN infrastructure significantly improves the performance of the network. IAPB algorithm is proposed that avoids the interference among the mesh nodes in WMN. Mesh nodes with more interfaces sending the packets by utilizing different channels improves the capability of the WMN. The PCs and QCs that remain unutilized in the existing algorithm are being utilized in IAPB algorithm which indirectly improves network throughput by 55% . The results show that in MRMC scenario of WMN the focus is on channel utilization in multi radio environment. Further the research shows new issues to be considered for improving efficiency of WMN by combining resource utilization using efficient routing algorithms. The delay that is involved for sending packets from sending mesh node to the receiving mesh node is considered which results in packet delivery ratio being gained to around 34% as compared to the existing algorithm as compared to proposed IAPB algorithm.

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