INFERENCE AND PERFORMANCE AWARE MULTI-CHANNEL SCHEDULING AND ROUTING SCHEME WITH CALL ADMISSION CONTROL IN WIRELESS MESH NETWORKS

K. S. Mathad (1), M. M. Math (2)

(1) Department of Information Science and Engineering;
(2) Department of Computer Science and Engineering;
K. L. S. Gogte Institute of Technology, Belagavi, Karnataka
India

* Corresponding Author, e-mail: ksmathad22@gmail.com

Abstract: As wireless mesh networks have been deployed in the urban area, dynamic channel allocation is more challengeable because co-located wireless mediums are likely to be tuned to the same channels and may interfere with communication. Further, existing model doesn't consider reutilizing routing resource. This paper presents an efficient scheduling and routing model considering an external interference and routing resource reutilization for multi-channel wireless mesh networks. Each mesh node uses a novel technique to estimate the usage status of all the channels within its interference range and assigns channels dynamically to radios to minimize interference within the mesh network and between the mesh network and collocated wireless networks. Simulation results demonstrate that our proposed algorithm can improve the network throughput, reduce packet failure rate and consume more energy while transmission substantially compared to other algorithms by removing the interference overestimation problem and assigning channels aggressively with priority.

Key words: IEEE 802.11s, Interference, Routing, Scheduling, WMN.

1. INTRODUCTION

The Wireless Mesh Networks (WMNs) plays a significant part in constructing the future generation wireless network such as the fifth and sixth generation network due to self-healing and ease of deployment nature. The WMNs provides benefits such as reducing initial cost of deployment, increases network capacity, increases network coverage, increased bandwidth, and flexible network deployment. The WMNs have been used in different IEEE wireless standards under high path loss on

60 GHz channel such as IEEE 802.11ad and IEEE 802.11s where have relaying capability. In relaying huge traffic and assure enhanced network coverage multi-radios and multi-channel have been used. Alongside, the current wireless mesh networks provide several non-overlapping channels aiding in simultaneously transmit and receive packet less interference. Channel scheduling in WMNs becomes very critical part in providing efficient quality of service to end-users. The channel scheduling is generally either static or dynamic; the static channel scheduling reduces switching overhead at the cost of resource utilization. On the other side, the dynamic channel scheduling improves resource utilization but induces channel switching overhead. Recent work shows dynamic channel scheduling is very efficient in utilizing resource efficiently; however, effective interference management technique is required to mitigate interference from co-located mesh device.

Interferences management in WMNs is difficult due to dynamically varying traffic pattern and presence of hidden nodes. Poor channel scheduling leads to increased delay and performance degradation. The capacity of mesh device faraway is expected be less in comparison to mesh device closer to gateway server; thus, provisioning QoS constraint application such as video streaming are very difficult. However, when employed to multi-hop mesh network the model exhibit very poor performance i.e., less throughput and higher collision. In addressing the problem, number of work have used TDMA MAC rather than CSMA/CA MAC for wireless mesh network. Since TDMA is a contention less scheduling scheme. Thus, aid in avoiding packet collision (similar to back-off method used in CSMA/CA MAC) and improve throughput performance. However, dynamically varying traffic condition and presence of hidden model increases congestion in multi-hop wireless mesh network. For addressing this issue used adaptive scheduling, which integrates delay and bandwidth as parameters. However, the existing scheduling and routing scheme induce delay and routing resource wastage. This, is because they do not consider reutilizing routing resource. For overcoming research issues, this work presented Efficient Scheduling and Routing (ESR) model for call admission control in multi-channel wireless mesh network wireless mesh network. The contribution of research work are as follows:

- Presented an efficient scheduling algorithm that handle collision in network more efficiently.
- Presented a new routing metric that handle interference problem of reutilizing routing resource efficiently based on device classification.
- The proposed Efficient Scheduling and Routing (ESR) model minimize packet collision and attain better throughput performance when compared with existing model.

2. LITERATURE SURVEY

In [1], the goal of the research is to design an algorithm that will provide better strong connection and coverage in Wireless Mesh Networks (WMNs). In this paper, they have proposed a Harris-Hawkins Optimization (HHO) algorithm to determine where to put the mesh routers in WMN to achieve maximum throughput and coverage. The model was evaluated by comparing with the existing works, Gray-Wolf's Optimization (GWO), Sine-Cosine Algorithm (SCA), and Particle-Swarm Optimization. The results of the simulations showed that the proposed algorithm, HHO, provides better network coverage and connection than the other methods. It's clear from the results that HHO is a viable strategy for improving WMN's efficiency. In this model, they could not achieve higher connectivity (bandwidth) and coverage. Hence, in [2], in this research, they have analyzed several distribution strategies for WMNs intending to maximize throughput and coverage. Moreover, Firefly-Optimization Algorithm [3] tackles the difficult issue of placing the optimal router. This proposed algorithm mainly focuses on maximizing both network-connectivity and client coverage. In this, they have not addressed the rate control and delay guaranteed. So, in [4], they have proposed a Distributed-Rate-Control and Delay-Aware-Scheduling algorithm (DRDA). The construction of two virtual queues is done so that the flow of delay constraints and arrival rate can be satisfied. The Lyapunov-Drift-Optimization [5, 6] technique is used to maintain equilibrium across all queues, both real and imagined. As a result, each flow's scheduling policy is fine-tuned based solely on contextual data collected locally. Further in all the above models, no paper has addressed the multi-path retransmission issue. Due to this, in [7], they have proposed an algorithm that has been designed that takes into account the inconsistent availability of spectrum for the selection of the channels and relay nodes necessary for a multicast session. The goal of this method is to reduce the amount of energy that is being consumed while still meeting the requirement of the multicast. In terms of the amount of energy that was consumed, the presented approach performed significantly better than the flooding approach for the instances that were supplied in multicasting. Also, in [8], for the muti-path retransmission in the Wireless Sensor-Actuator Networks, they have presented a resource-efficient technique for scheduling transmissions. This technique's goal is to make better use of available time slots and communication channels. The performance of the proposed method has been tested in an actual industrial setting, and it has been both implemented and simulated in hardware. The outcomes obtained demonstrate that the suggested technique considerably boosts schedule-ability without compromising on dependability or real-time performance. Because of all these reasons, in [9], they have compared and contrasted the approaches taken by the Wireless Sensor Network (WSN) [10], WMN [9], Computer Network Operation [11] and offer an analytical foundation between these two nodes. In [9], they first defined WMN and WSN and further examined various examples of these networks. This paper stimulates additional study in the area of integrated Wireless Mesh Sensor Network (WMSN).

3. EFFICIENT SCHEDULING AND ROUTING MODEL FOR CALL ADMISSION CONTROL IN MULTI-CHANNEL WIRELESS MESH NETWORK

This work presents Efficient Scheduling and Routing (ESR) model for call admission control in multi-channel wireless mesh network. In Figure 1, topology of WirelessHart Mesh Network has been given [12]. In this figure, it can be seen that how the mesh access point and mesh access routers are connected to the mesh devices in mesh network. For efficient scheduling and routing in wireless mesh network, we have assumed a radius of $50\sim300\ meters$, where the link delays can be ignored and it is assumed that all the packets are transmitted from the mesh access point or mesh routers to the mesh devices coherently [13]. Further, for this small radius range the synchronization can be achieved, which is called as synchronization prefixes [13]. However, larger radius range, establishing synchronization among the mesh routers can be difficult. As this work only considers the efficient scheduling and routing for call admission control in multi-channel wireless mesh networks by reducing packet collision and meeting system throughput requirement, the synchronization of the mesh routers is out of scope for this work. Nonetheless, the work introduces pair-wise classification to mitigate interference in the WMNs which significantly works well for larger user-density; thereby meeting challenges enforced by fifth and sixth generation network in interference management in both synchronous and non-synchronous network.

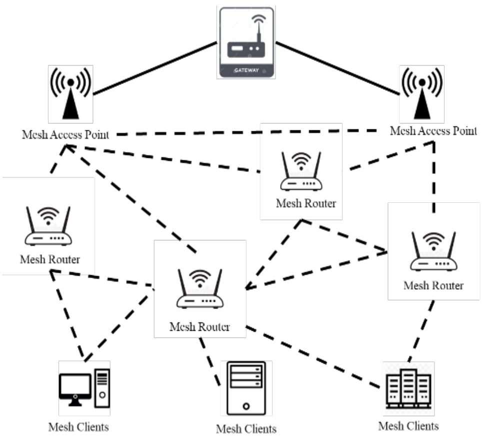

Figure 1. Topology for WirelessHART Mesh Network [12]

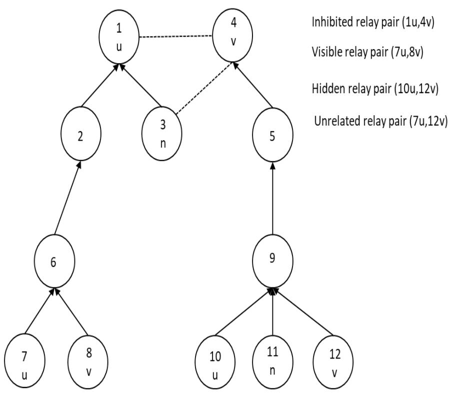

Figure 2. Device pair classification for IEEE 802.11s wireless mesh network.

3.1. System Model

For building ESR model, this work adop ted a approach based on slotted multi-access system where every devices can communicate and receive information from a mesh routers or mesh access point (MAP) on a control channel (CCH). All devices in the wireless mesh network receive information from the corresponding mesh routers by insisting their packet transmission successfulness status. The transmitter is presumed to be in synchronous state and the link delays are ignored. The device run in a full-duplex mode and is equipped with multiple antennas. The packets that are transmitted have the same length and require a slot time for packet transmission. In a q^{th} time slot considers that there are P packets collided. Let assume that the data transmitted by n^{th}device in q slot consist of Q symbol which can be expressed using following equation

$$a_n(q) \triangleq \left[a_{n,0}(q), \dots, a_{n,Q-1}(q)\right] \tag{1}$$

Let $I(q)$ be the collection of devices that act as an intermediate or relay devices (RD) which can described using following equation

$$I(q) = \{i_1, .., i_{\hat{P}-1}\} \tag{2}$$

and $C(q)$ be the collection of source which can be described using following equation

$$C(q) = \{n_1, \dots, n_P\} \tag{3}$$

The signal received by the mesh access point and also device other than source in q^{th}slot is represented by as follows

$$b_i(q) = \sum_{n \in C(q)} x_{ni}(q) a_n(q) + e_i(n) \tag{4}$$

where $e_i(n)$ represent the noise, $i \in \{r\} \cup I(q), i \notin C(q); x_{rn}(q)$ represent channel coefficient among the n^{th}source and i receiver devices and $\{r\}$represent the destination devices. Once collision has been detected in the wireless mesh network channel, the WMN enters in to optimization mode (OM). The mesh access point transmits a control message to all its devices in the wireless mesh network specifying the process of OM and continues this process till the OM is completed. The OM consisting of $P-1$ slots, were $\hat{P} \geq P$. The devices that do not involve in communication will remain in idle till the OM is completed. For the duration of slot $i + p, 1 \leq p \leq \hat{P} - 1$, a device is nominated as to behave as an intermediate or a relay and transmit the signal back that it obtained during q^{th}slot. The selection process of the intermediate or relay devices i is done using following equation

$$i = mod(q + p, S) + 1 \tag{5}$$

Only one relay is considered during every slot of OM if the selected devices are sources device then it transmit back the packet. The signal scaling constant $l(q + p)$, is chosen so that the transmission power is maintained considering the relay transmitter. The mesh access point then receives the

$$f_r(q+p) = \begin{cases} x_{ir}(q+p)a_i(q) + e_r(q+p), \ i \in I(q) \cap C(q) \\ x_{ir}(q+p)l(q+p)b_i(q) + e_r(q+p) \ i \in I(q), i \notin C(q) \end{cases} \tag{6}$$

where $e_r(q + p)$ represent noise parameter at mesh access point and $f_r(q + p)$ is $1 \times Q$ vector. Based on these factors this work presents an efficient scheduling and routing method to reduce collision and reduce delay in communication of WMN.

3.2. Efficient Scheduling Model for WMN

Here we consider a flat fading channel considering that channel among OM slots does not change, the work assumes that the non-relay source h is proportional to h, though practically the network channel is frequency selective. However, it is difficult to handle this nature. Nonetheless, if handled properly it can be seen as source of frequency diversity. For handing the frequency diversity the work considers a scenario that it has a T channel. The accessibility of V separable sub-channel is denoted as

$$C_v(v = 0, \ldots, V - 1). \tag{7}$$

A wireless mesh user can simultaneously transmit data using sub-channel that are available but cannot transmit or obtain signal from same sub-channels. This work considers a set-up where a device becomes active only when there are d or $(1 \leq d \leq V)$ data packets in its buffer. Every device that is active is permitted to transmit d data packets in single slot but using varied sub-channels that is chosen in arbitrary manner. For ease the work consider that each sub-channel is chosen with identical probability. The sum of packets transmitted for every active devices, d, can be chosen by considering the traffic density, so that the bandwidth or data rate can be maximized and the collision can be minimized. The work presents an optimization method for choosing d. By considering the traffic density in the previous and present slot(t), as well as channel state condition parameter, the mesh access point will take one of the following decisions: reduce d by 1, increase d by 1, or keep d as same. Then the mesh access point broadcast its action taken to all devices by using one bit at the end of a slot (1 sent: increase d by 1;0 sent: reduce d by 1; nothing sent: keep d unchanged i.e., same as in previous slot). During the initializing stage the assessment of d can be determined or approximated by the mesh access point. For resolving the collision and reduce the processing delay the mesh access point decides how to allocate the sub-channel by following strategy. Let consider a strategy for resolving packets that collided over S_v as OM_v, In the process of OM_v the chosen relays will use a collection of sub-channels specified to them by the mesh access point. If the relay device is a source device that conveyed over S_v it will retransmit its data, or else it will retransmit the signals that it received over S_v during the collision slot. Let $P(q)$ signify the sum of data that is transmitted in the q^{th} slot, and $P_v(q)$ the sum of data that were over sub-channel S_v in the q^{th} slot. It represented using following equation

$$P(q) = \sum_{v=0}^{V-1} P_v(q) \tag{8}$$

The packet delay time or the processing time is known as the time take for packet to be recovered by the mesh access point once it moves out of the source. The mean packet processing or delay time is formulated as follows

$$\overline{D}_q = \frac{1}{P(q)} \sum_{n=0}^{V-1} P_v(q) D_v(i) \tag{9}$$

where $D_v(i)$ represent the processing time for every collide packet on S_v, or equivalently considering the time taken of $OTS_v + 1$.

3.3. Relay Selection Optimization

For relay devices selection the work presents a methodology that introduces a predetermined order. A counter, signified by e is preserved by every device and is increased by 1 for each request for relaying. It is assumed that it may be increased by more than one time in a single slot if multiple relays are needed in that slot. The device is numbered or $i = mod(e, S) + 1$ is selected as relay devices. In this manner the frequencies of relays do not overlap that helps in aiding data packet recovery at the mesh access point. The most important thing to be noted is a source relay might use varied sub-channel to retransmit its data packet. More intricate cases, i.e., the collisions that are occurring on more than one sub-channel can be handled in an analogous manner. Based on this methodology, a relay will not be reused till all relays have been used within the same OM.

3.4. An Efficient Routing Metric for Enhancing Resource Utilization

For utilizing resource efficiently this work considers reutilizing routing resource. However, presenting such routing is challenging due to presence of hidden nodes. The device pair classification for reutilizing routing resource is presented in Fig. 2. In our method the device pair is classified into inhibited relay pair (IRP), visible relay pair (VRP), hidden relay pair (HRP), and unrelated relay pair (URP). IRP- u and v are physical neighbors, and either u or v has a child; or, u and v are not physical neighbors, but u and v have a common neighbour which is a child of either u or v. VRP- u and v are physical neighbors but neither u nor v has any child. HRP- u and v are not physical neighbors but have physical neighbors in common, although all these physical neighbors are neither $u's$ nor $v's$ children. URP- u and v are not physical neighbors, neither do they have physical neighbors in common. In our work we consider reutilizing routing resources of VRP, HRP, and URP. Further, consider that reutilizing routing resource will have collision probability of $VRP > HRP > URP$ (i.e., VRP will have higher collision probability when compared with HRP and URP will have least collision probability of reutilizing routing resource). Thus, for high priority service that require minimal collision reutilization routing resource of URP and HRP can be considered. Similarly, for certain service that doesn't worry about packet collision reutilization routing resource of VRP can also be considered.

Let us consider a wireless mesh network that is composed of m mesh devices. Let R depicts a set of mesh access points (MAP) and Access routers (AR). The active user devices of the wireless mesh network are $(m - R)$. The wireless mesh network is described as tree representation (TR) with number of conceivable children of any device is L . The TR is described as $G_m(R, D, L)$, where D depicts death of mesh tree. The user devices carryout communication operation with its respective nearest AR and packet is communicated via hop-based method over the mesh TR of R devices.

The communication from the u^{th} to v^{th} mesh device is affected because of reutilizing routing resource is measured probabilistically as $P(u,v): \forall u,v \in R$. The communication success probability is therefore, $\left(1 - P(u,v)\right)$. Thus, communication delay is dependent of routing resource reutilization success probability. Higher successful communication probability outcome reduces communication delay. Hop to hop transmission in wireless mesh network is used in this work. Let $N(u) \subset R$, denotes the physical neighbors of u mesh device. The forthcoming hop device amongst $N(u)$ devices is chosen by computing below equation

$$P_u = \max_{k \in N(u)} \{1 - P(u,k)\} \tag{10}$$

Communication delay of i^{th} packet communication from u^{th} to P_u device is defined as $P_u^i(t)$. The cumulative communication delay witnessed is estimated using following equation

$$\sum_{i=1}^{I} \sum_{j=1}^{J} P_j^i(t) \tag{11}$$

where I depicts the overall packet communications and J depicts the overall hops per packet communication. The proposed ESR model attain significant performance when compared with existing scheduling and routing model which is experimentally shown below.

4. SIMULATION RESULT AND ANALYSIS

The results are obtained using NS3, intel i-3 class, 64 bit, quad core processor, 4 GB RAM. The tests are directed to assess the exhibition of ESR over existing Adaptive Allocation algorithm model in terms of collision. Successful packet transmission and throughput achieved considering dynamic environmental condition is recorded. The simulation parameter used for experimental study are shown in Table 1.

Table 1. Simulation parameter considered

SL.No	*Network Parameter*	*Value*
1.	*Network Size*	*100 m *100 m*
2.	*Number of Mesh Device*	*1200*
3.	*Modulation Scheme*	*BPSK, QPSK and QAM*
4.	*Number of Frequency channels*	*2*
5.	*Number of time slots*	*8 µs*
6.	*Bandwidth*	*30-60 Mbps*
7.	*Mobility of devices*	*3 cycles per frame*
8.	*Coding rate*	*0.75*
9.	*Message information size*	*40 bytes*

4.1. Packet Success Ratio vs Transmission Rate for Varied Mesh Device

In this section the results have been evaluated for packet success ratio for transmission rate which has been shown in the Figure 3. From the figure it can be seen that as the transmission rate increases, the packet success rate for the proposed ESR model keeps on increasing, whereas for the existing model the transmission rate for the packet success ratio decreases. As the transmission rate increases there are spectrum issues, lack of connectivity in the existing system due to which it decreases. In the proposed model, we have defined a routing metric which will keep the packet success ratio constant throughout the transmission at different transmission rate.

4.2. Throughput vs Transmission Rate for Varied Mesh Device

In this section the results have been evaluated for throughput achieved for varied transmission rate which has been shown in the Figure 4. From the figure it can be seen that as the transmission rate increases, the throughput for the proposed ESR model keeps on increasing, whereas for the existing model the transmission rate for the throughput decreases. It can be seen that the throughput of the proposed model remains constant as the transmission rate increases.

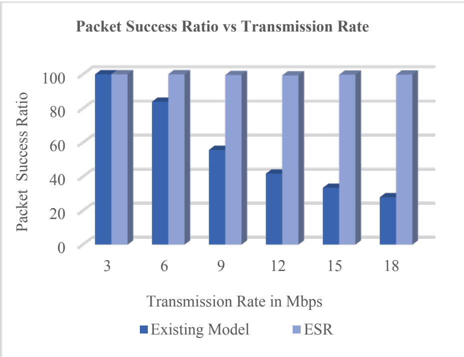

Figure 3. Packet Success Ratio vs Transmission Rate.

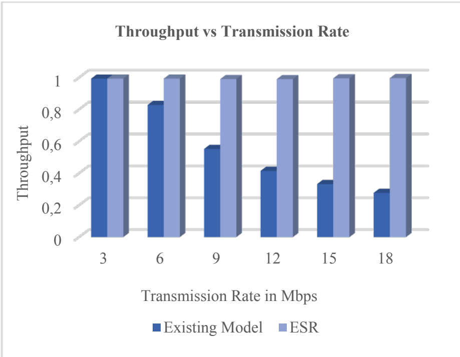

Figure 4. Throughput vs Transmission Rate.

4.3. Successful Packet Transmission vs Number of Packets for Varied Mesh Device

In this section the results have been evaluated for Successful packet transmission for varied packets which has been shown in the Figure 5. From the below figure it can be seen that when the number of packets increase the proposed system transmits more successful packets whereas the existing system too transmits successful packets but fails when the number of packets increases.

4.4. Packet Drop Rate vs Number of Packets for Varied Mesh Device

In this section the results have been evaluated for Packet drop rate for varied packets in the Figure 6. From the below figure it can be seen that the existing model increases the packet drop or it can be said that it there is a failure during the transmission of the packets when the number of packets increase. Further, it can also be seen that for the proposed model there is very less packet drop and the packet drop increases slightly as the number of packets increases but is very less when compared with the existing system.

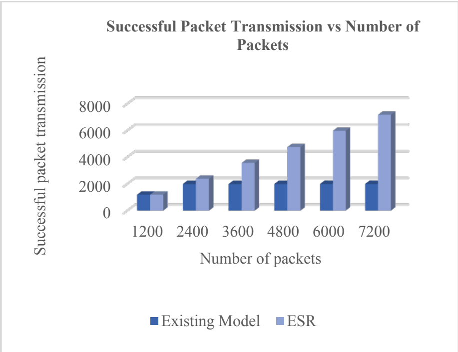

Figure 5. Successful Packet Transmission vs Number of Packets.

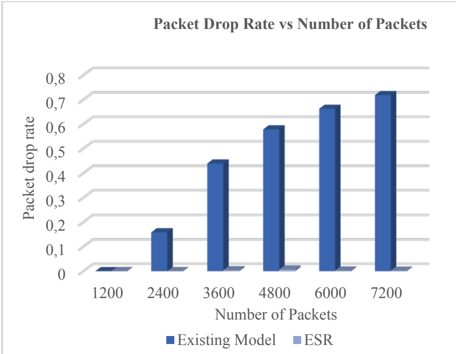

Figure 6. Packet Drop Rate vs Number of Packets.

4.5. Energy Consumption for Varied Mesh Device

In Figure 7 and Figure 8, the energy consumption for number of packets and during the transmission has been evaluated. In the Figure 7, the energy consumption for transmitting the packets is more in the existing system, whereas in the proposed system, the energy consumption reduces as the number of packets increase. Similarly in the Figure 8, it can be seen that the transmission rate for transmitting each packet, the existing system consumes more energy whereas the proposed system consumes less energy.

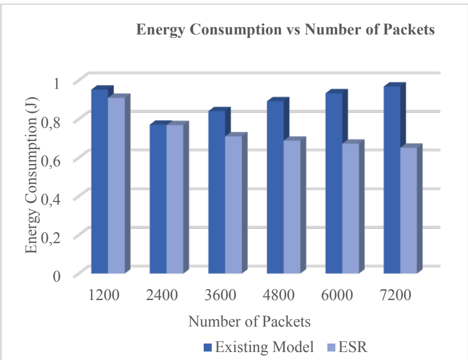

Figure 7. Energy Consumption vs Number of Packets.

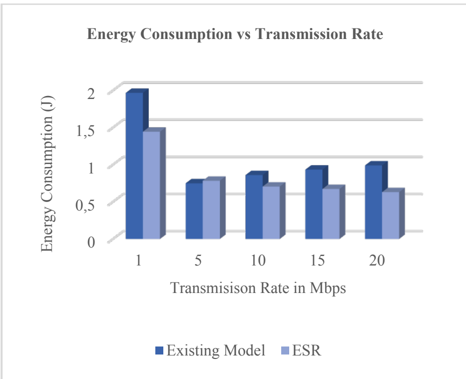

Figure 8. Energy Consumption vs Transmission Rate.

5. CONCLUSION

As wireless mesh networks have been deployed, dynamic channel allocation considering co-located wireless networks is more challengeable because these networks are likely to be tuned to the same channels of WMNs. This paper proposes an efficient scheduling and routing model for multi-channel wireless mesh networks. Each mesh node uses a novel technique to estimate the channel usage status (i.e., collision probability) of all the channels within its interference range and assigns channels dynamically to radios to minimize interference within the mesh network and between the mesh network and co-located wireless networks. Simulation results demonstrate that our proposed algorithm can improve the network throughput, reduce packet failure rate and consume more energy while transmission substantially compared to other algorithms by removing the interference overestimation problem and assigning channels aggressively with priority.

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Information about the authors:

K.S. Mathad – Assistant Professor at Gogte Institute of Technology, Belagavi, Karnataka, India. He Holds a M.Tech degree in Computer Science and Engineering. His research areas are Wireless Networks, Wireless Mesh Networks, Network analysis and congestion control. He is member of Indian Society for Technical Education. He is a recipient of Best Paper in Springer chapter in Lecture Notes in Networks and Systems.

M.M. Math – Professor at Gogte Institute of Technology, Belagavi, Karnataka, India. He obtained his Ph.D. in Computer Science and Engineering from Graphic Era University, Dehradun, Uttarkand in the year 2014. He has published many research papers in International Conferences and Journals. He is serving the institution from past 28+ years. He has been actively involved in Research work in the area of Autonomic Computing and Pervasive Computing.

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