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# Enhancement of Channel Assignment Based on BPSO Algorithm in Multi-Radio Multi-Channel Wireless Mesh Networks

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***Abstract***— The Multi-Radio Multi-Channel Wireless Mesh Network (MRMC WMN) is an emerging technology for promoting a variety of applications. In this paper, the issues of channel assignment have been studied in which channels are assigned to different links and enhance the entire network performance. For MRMC WMN, the issue of channel assignment proved to be NP-complete. In this paper, joint Binary swarm optimization technique (BPSO) and linear programming (LP) has been proposed, in which BPSO algorithm is used to solve the issue of channel assignment by using linear programming model. To deal with these issues, a linear objective function has been used in the BPSO algorithm to evaluate the fitness value of each particle. Moreover, a rate-variable model has been proposed to enhance the network performance, wherein the physical interference model has been used to assess the capacity of the network. The simulation results show that the proposed technique efficiently improve the network performance.

***Keywords***— Multi-Radio Multi-Channel Wireless Mesh Networks, Channel assignment, BPSO algorithm, Transmission rate.

## I. Introduction

Nowadays all-around the world Wireless Mesh Networks (WMN) is being integrated for the objective of allowing internet access and offering many other services to the users in the cities. A WMN is an emerging way of communication because of its low cost and scalable wireless networking, which is the only reason that it is becoming a well-known communication area [1]. Because of the performance of WMN, there are a number of issues and challenges are raised. An essential design goal for WMN is network capacity.

WMNs are self-organizing because the system automatically discovers the quickest and most reliable routes to transmit and receive data, even if nodes are broken or lose their signal. The network instantly has a new node in the present structure without requiring any improvements by a network manager. WMNs are very effective wireless technology when compared to the existing networks like sensor networks and ad-hoc network because of WMNs automatic establishing and maintaining network connectivity it can be used in several applications.

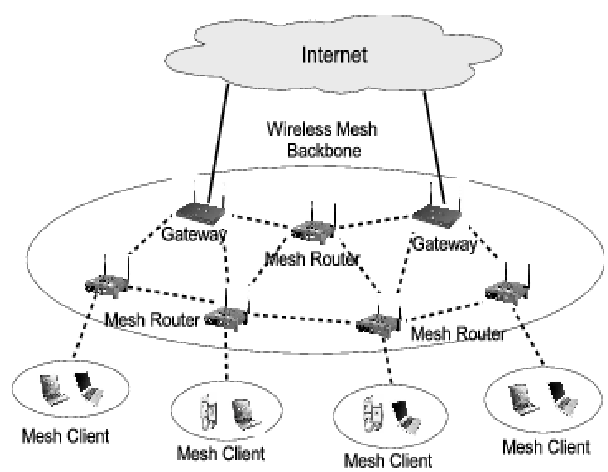

Figure 1. Wireless Mesh Network

Figure.1 illustrates WMN architecture, in which the router uses a common channel to communicate with other mesh routers. Traditionally only one channel used by the entire network because of wireless routers had only one network interface card. In addition, in a multi-hop network throughput reduces tremendously on increasing the network size. In a single-channel multi-hop network, interference can arise not only among neighbourhood flows, but also among neighbourhood hops, it substantially degrades the network performance.

 

In Wireless networks, interference of channels is the major issue that reduced the overall network capacity. The WMN generally contains multiple channels. The nodes in WMN can transfer packets on different channels simultaneously to eliminate the interference on different channels. The performance of WMN is increased drastically by exploring the advantage of Multi-Radio Multi-Channel (MRMC) as compared to single channel wireless mesh network. With multi radios, an acquired capacity cannot be completely recognized, even so, if the process of link scheduling, routing, and channel assignment are not effectively resolved. In MRMC WMN channel assignment is the process of assigning channels to the radio interfaces to obtain the efficient channel utilization and reduce the interference. By channel assignment, the bandwidth is determined available on the network links. In fact, all links in the network which have the same channel in the interference range unable to transmit concurrently and share the common channel capacity [13]. Channel assignment and routing both are dependent on each other. Channel assignment can help to determine the link capacity and routing determine the traffic rate. Channel assignment selection impacts routing selection predictably. According to IEEE standard radio interfaces offer several transmission (TX) rates, 11 Mbps for 802.11b and 54 Mbps for 802.11a/g. Each transmission rate has different transmission range and spectrum efficiency, transmission rates are associated with the capacity of the network.

In this paper, a physical interference model has been proposed which can assess the capacity more accurately. A further aspect included in this paper is LP and BPSO algorithm. To efficiently dissociate these issues, a linear objective function has been used in the BPSO algorithm to evaluate the fitness value of each particle. Moreover, a rate-variable model has been proposed to enhance the network performance, wherein the interference model has been used to assess the capacity of the overall network. The simulation results show that the proposed technique efficiently improve the network performance.

Rest of the paper is structured as follows, section I includes the introduction of Wireless mesh network and channel assignment with its importance in WMN, section II includes the related work of channel assignment and routing techniques in WMN, section III includes basic models such as the network model, transmission and interference model, After that channel assignment problem has been discussed and come up with the LP model in section IV. The performance criteria used in the simulation and the results have been explained in section V, Section VI concludes the research work.

## II. RELATED WORK

In MRMC WMN the channel assignment and routing approaches have been explored by many researchers. The author in [3-6] proposed a channel assignment algorithm merged with time-divided transmission scheduling to improve the network capacity. The main focus on reducing the interference which is theoretically defined by the interference model with no actual traffic delaying loads allocated over wireless links.

In [2] the authors used linear programming within the confinement of a minimum number of radio interfaces. Although in [9] the optimization technique is applied to a tree-based heuristic algorithm. In [7] and [8] authors consider genetic algorithms (GAs) which improves the transmission scheduling and routing. On the contrary, the previous work restricts the radio number and concentrate on single-channel without a deal with channel assignment problems.

In [13] authors proposed a routing method and extend their work on-demand QoS routing dependent on bandwidth approximation. In these studies, the main concentrate on CA and routing techniques with several physical transmission rates considered radio interfaces. The traditional techniques for rate variation in [11, 12] concentrate on increasing throughput on radio links under various channel circumstances. None of the previous studies give the primary knowledge of the impact of transmission rate allocation on the overall network capacity in WMN.

In [16] authors present a centralized and distributed Tabu-based greedy algorithm which goal to reduce network interference. In the first stage of algorithm it attempted to search the optimal results which do not fulfil the confinement radio number from random allocation. In the next phase, the issue of a limited number of radio must be handled since it increased network interference. Therefore, when a radio number constraint is violated the Tab based algorithm did not work effectively.

In [14] edge coloring approach applied to channel allocation and it is assumed that each interface has a distinct transmitter and receiver antennas. Furthermore, in WMNs mostly work on channel assignment focus on analytic studies. In [5] authors investigates channel assignment issue in multi-radio wireless mesh networks with directional antennas, and proposed channel assignment techniques in rural scale WMN test-bed.

In [20] authors developed a centralized approach based on a measurement to cope with channel assignment to radios rather than links. The proposed approach assigns channels to radios to reduce interference in the network and co-located wireless networks. It uses an interference estimation technique integrated at every mesh router. Moreover, it recommended the polling technique for visitors traffic bandwidth evaluation which take less time as compared to suggested in [21], To a default channel for a significant time period, it still needs redirecting traffic. These approaches go through from becoming central and complicated to implement in a real network.

In [17], the researchers proposed a method for the channel assignment model as a game alliance instead of the non-cooperative game and then proving the existence of a Nash equilibrium within such circumstances. That work also presents a single collision domain and non-overlapping channels.

In [18] the authors proposed a collaborative solution for the power and channel allocation examined from the Game Theoretical perspective and they concentrate on the access network problem instead of the backbone.

## III. SYSTEM MODEL

### *A. Network Model*

WMN has been considered with stationary wireless routers wherein every router is set up with a particular number of radio interfaces. Let us assume a graph G having V nodes with E edges, $G = (V, E)$. In graph, a communication link between two nodes known as edge and each link has a common channel assigned to a radio in an actual network, several links have different data transmission rates e.g., IEEE 802.11a/g standard enables only 8 distinct transmission rates: 54, 48, 36, 24, 18, 12, 9 and 6 Mbps. It is assumed that every single link contains a distinct but prearranged data rates $r_m$ and $r_m$ (m=1, 2, 3, 4, 5, 6, 7, 8) to represent distinct rates.

### *B. Transmission and Interference Model*

In this paper it is assumed that all radios have similar transmission power, represented as P. If at receiver the acquired power exceeds a threshold $\lambda_T$ then the transmitted data is decodable. Such as, if obtained power from other transmissions at the receiver exceeds threshold λ then the transmission interferes with other transmissions and cannot transfer simultaneously. Based on the threshold and propagation model, transmission range $R_T$ and interference range $R_I$ has been determined. The physical model of interference has been assumed to effectively consideration for the outcomes of adjusting transmission rate and power. At the receiver, if the Signal-to-Interference and Noise Ratio (SINR) is completely high to interpret signals then model has been considered transmission successful. When a signal is transform by u and SINR at receiver v, is defined as follow:

$$\mathbf{SINR_{uv}} = \frac{\mathbf{G_{uv}\,P(e_{uv})}}{\sum_{\mathbf{x\to y\neq u\to v}} \mathbf{G_{xy} P(e_{uv}) + n_v}} \qquad \textbf{(1)}$$

Where Guv is obtain of the radio channel among u and v, $P(e_{uv})$ power released by u transfer to v, and $n_v$ is noise at receiver v. The receiver v can accurately decode the signal if $SINR_{uv} > \gamma_{rm}$, If u transfers at rate $r_m$, where $\gamma_{rm}$ signifies the minimal SINR mandatory to effectively interpret a signal applying the technique related with rate $r_m$. So, the lowest transmission rate has been select to get a maximum capacity, if the SINR does not fulfil the threshold value.

### *C. CHANNEL ASSIGNMENT ISSUE*

In WMN the capacity of the network is mainly depending on the assignment of channels to the links. The main aim for channel assignment problem is to reduce the total interference in the network. The number of wireless links that are interfering with each other defined the total network interference. However, it should be mentioned that the radio number on the mesh nodes is generally less than the available channels, and on any node the number of different channels allotted to the links should not exceed the number of radios. The radio number restriction for the channel assignment can be designed as follows:

$$|\mathbf{K_i}| \leq \mathbf{R_i} \qquad \textbf{(2)}$$

From the above explanations, the channel assignment issue for the MRMC WMN can be developed as: Given a graph G = (V, E), the set of channels K, the radio number $R_i$, i ∈ V, discover a function for channel assignment f: Vc→K, in which Vc is vertices of the graph G, the main goal is to reduce the overall network interference I (f), where I (f) = |{(u, v) ∈ Ec | f (u) = f (v)} |.The main objective of channel assignment is to increase mesh network capacity. To find a feasible solution to the problem can be difficult for the broad network. Therefore, the BPSO algorithm has been proposed to find the feasible solution for the rest of this content.

## IV. BINARY PARTICLE SWARM OPTIMIZATION (BPSO) TECHNIQUE FOR CA

Many techniques are available to cope with the channel assignment issue in MRMC WMN. This section presented the new strategy based on the BPSO algorithm to resolve it.

Binary Particle Swarm Optimization (BPSO) approach is released by Eberhart and Kennedy. BPSO is motivated from the habits of the birds, bee and school of fishes. Hence, BPSO adheres to the behaviour of the organic bird folk. In providing the data to the population the algorithm contains elegant compositions of the birds. The key idea to develop the BPSO is that the data can be distributed to individuals of the population. It uses the search requirements which can be depending on the particle population [6]. The technique is fully based upon the swapping data between individuals in the population although the population is considered as swarm and individual are known as particles. BPSO usually split into two sections of a search such as global neighbourhood and local neighbourhood. The best position of a particle in swarm can help an individual to determine its encounter which is often intended in local search as well as in global search. In Global best, every particle moves towards the best particle in the swarm generally known as gbest model. However, if a particle moves towards its ideal particle in the confined area known as best model in the swarm.

Every particle has their own position, velocity, and fitness value. BPSO algorithm has usually two updating formulas: velocity weight and position updating formula. They are as follow, respectively.

$$\mathbf{v(t+1) = w * v(t) + c1r1[pBest(t) - x(t)] + c2r2[gBest - x(t)]} \quad (3)$$

$$\mathbf{x(t+1) = x(t) + v(t+1)} \quad (4)$$

Where the parameter used to manage the effect of past velocities on present velocity is w, also called the inertia weight. Acceleration coefficients are denoted as c1 and c2. r1and r2 represents the constant random number between 0&1. The present velocity of the particle is v(t) and present Position of the particle is x(t). Equation (3) calculates the new velocity of every particle depending upon its past velocity v(t). gBest and pBest are the two best values which update the particle after each iteration. pBest is the best solution of particle obtained so far and gBest is the global best value in population. Equation (4) gives the updated position of every particle.

### *A. ENCODING*

The technique of integer encoding has been used depending on a conflict graph. In channel assignment, the particle's position shows an achievable solution. For example, in a graph Gc, At the time t the position of particle i is denoted as xit = (xi1t,xi2t,……,ximt) where xikt refers to the obtainable channels while m refers to the number of nodes.

### *B. POPULATION INITIALIZATION*

First of all, for each particle in the conflict graph a channel is assigned to each vertex. After that randomly select one vertex to swap its initial channel to other to ensure viability. If the achievable resolution cannot be found, then the channel assignment is uniform.

### *C. CROSSOVER OPERATION*

To make sure that by the developed solution the limitation of radio number should not be broken, as the position of each particle denoted as an attainable solution. In a mesh network, if channel swapping takes place on numerous links due to specialization of channel assignment issue. The issue will be improved to acquire the feasible solution. In such case, to obtain an existing channel from gBest and pBest respectively, we only pick a random link.

### *D. COST FUNCTION*

The key goal of the channel assignment algorithm is to improve the network capacity and reduce the network interference. Thus, network interference is used as fitness value in the BPSO algorithm. Fitness function symbolized as I(f).

### *E. ALGORITHM OUTLINE*

Algorithm 1 BPSO Algorithm

- Set the parameters of the BPSO algorithm (such as population size, generations, etc.)
- For each particle calculate the fitness value F in the swarm by using its current position stated as $Xi(t)$.
- Find the best performance particle evaluating it with the current position.
  - If$F(P\ ibest) = F(Xi)$
  - P ibest = Xi$P\ ibest = Xi$
- After evaluating the performance of each particle discover the global best particle.
  - If $F(Xi)It; F(P\ gbest)$then
  - $F(P\ gbest) = F(Xi)$
  - $P\ gbest = Xi$
- Update the velocity of each particle.
- Update the position of each particle.
- Do it again step 2 and assess.

## V. HEURISTIC ALGORITHM

A heuristic algorithm has been described in this section for the issues of channel assignment. Usually, the algorithm can be quicker and generate much better results. To minimize the interference in the network the algorithm has been proposed which can easily discover channel assignment approach.

Initially, a common channel assigned to all links, then channels are exchanged on all links in the decreasing sequence and reducing interference of the network. In line 1 of pseudo-code channel 1 assigned to every node and links are set as possible interference number.

Algorithm: Channel Assignment Algorithm

Input: G = (V, E), C.

- Initially set f(e) = 1, e = (i, j) ∈ E, visit each node in the decreasing order of priority.
- Each unassigned incident link (i, j);
- Every link initially assigned the maximum available transmission rate.
- Randomly choose a channel c2 ∈ (C– c1) till the Condition (1) is satisfying.
- Exchange the original channel c1; if no candidate channel c2 can be found, otherwise follow the next step;
- Stop

## VI. PERFORMANCE EVALUATION

In these experiments, the effect of channel assignment has been studied in increasing capacity in 802.11a/g-based WMN. First of all the effect of distinct transmission rates has been observed and compared with a rate-variable model.

 

After that, the BPSO algorithm compared with ILP algorithm on the best network performance.

*A. NETWORK CAPACITY AND TRANSMISSION RATE*

Two scenarios has been simulated using MATLAB are described in this section. In 6*6 grid network 2-radio 4-channel and 2-radio 8-channel. In IEEE 802.11a/g the radio support 8 different transmission rates (TX), i.e., 1r =54, 2r =48, 3r =36, 4r =24, 5r =18, 6r =12, 7r =9 and 8r =6Mbps. The transmission power of the radio is 15dBm and R1 is 20 m, R2 is 21.2 and R3,..., R8 are achieved as 26.7, 33.6, 39.9, 44.8, 50.2 and 53.2m, respectively.

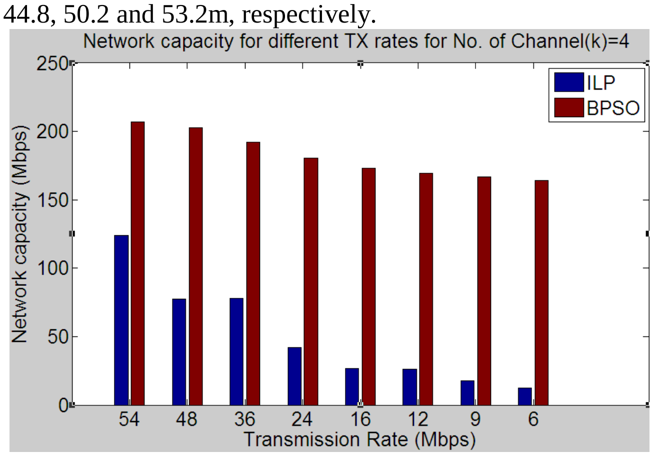


Figure. 2 Network capacity for different TX rates

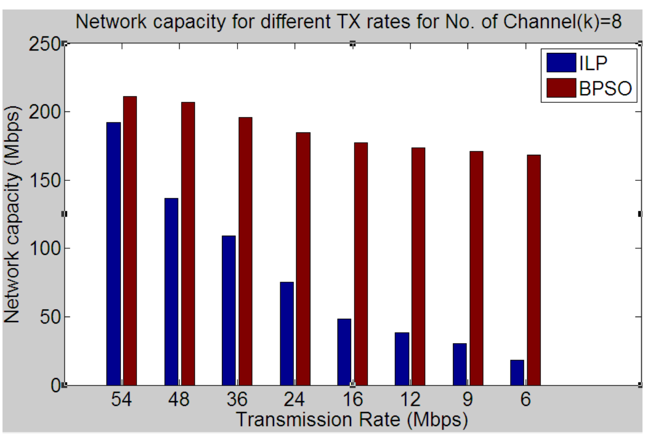


Figure. 2(a) Network capacity for different TX rates

Figure 2 depicts the network capacity vs. transmission rate results for 4 channels. The transmission rate is lower, the network capacity will be automatically low. As the transmission rate increases, more number of packets will be sent. This makes better use of allocated channel and results in increase the channel capacity which further improves the network capacity. As depicted in figure, the channel capacity of BPSO is more than ILP technique for all the variations of transmission rate. Figure 2(a) depicts the capacity vs. transmission rate results for 8 number of channels. The network capacity of BPSO is quite better than the traditional technique.

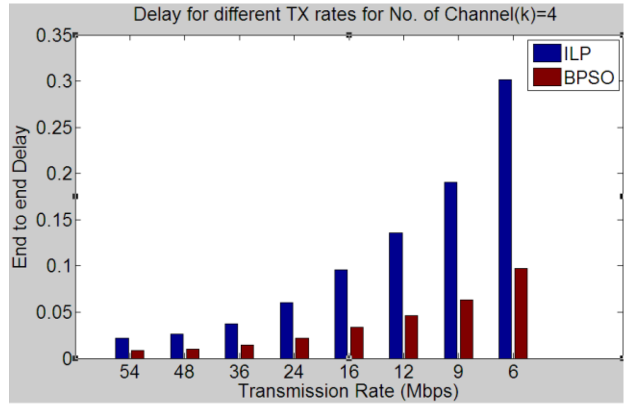


Figure.3. End to end delay for diff. TX rates

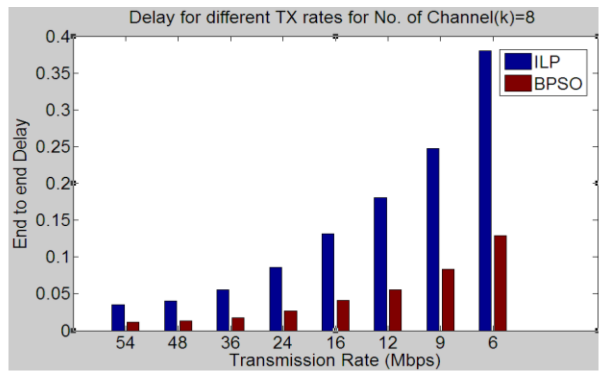


Figure.3. (a) End to end delay for diff. TX rates

Figure 3 and 3(a) demonstrates the end to end delay w.r.t. various transmission rates for the number of channels to be 4 and 8 respectively. Since it takes more transmission time to send a number of packets which are smaller in size than to send a single large packet. The time consumption will be more because the number of transmissions are more in the same channel capacity. This also increases the end to end delay for a particular message. Therefore, end to end delay for lesser transmission rate is more than higher transmission rate. The results show that BPSO improves the end to end delay for various transmission rates to a certain extent. Similarly, for 8-channel, delay is improved than traditional technique, ILP.

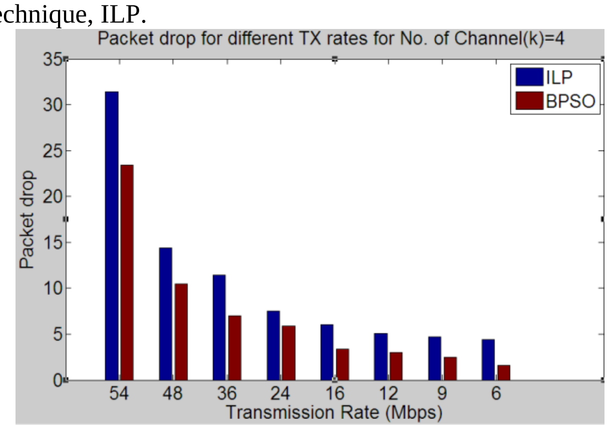


Figure.4. Packet drop for diff. TX rates

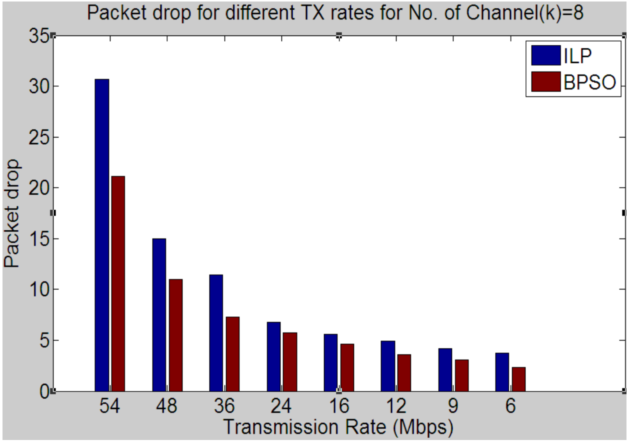


Figure.4. (a) Packet drop for diff. TX rates

Figure. 4 and Figure. 4(a) depicts the packet drop with raising traffic demands. With the increase in transmission rate, as the more number of packets are delivered, there will be more chances to lose those packets. Therefore, packet drop increases with the increase in transmission rate. Due to the non-cooperative retransmissions, ILP technique shows the highest packet loss. As compared to BPSO algorithm, ILP has a slightly higher loss rate.

*B. BPSO ALGORITHM FOR CA*

It has been observed that the described ILP model is NP-hard, the simulator can take a significant improvement in time with the enhancement of the network size. The n*n grid network of various sizes has been set up from 2*2 up to 6*6, wherein every node is taken away by the distance of 30m. In BPSO technique, the population size Q=10, number of iterations T=20, and probability p =0.3. The total network capacity generated by different algorithms within different network sizes is shown in the Figure. 5.

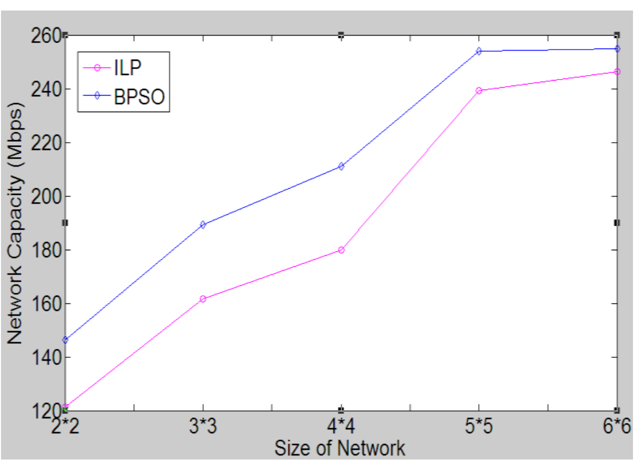


Figure.5. Network capacity comparison of ILP and BPSO

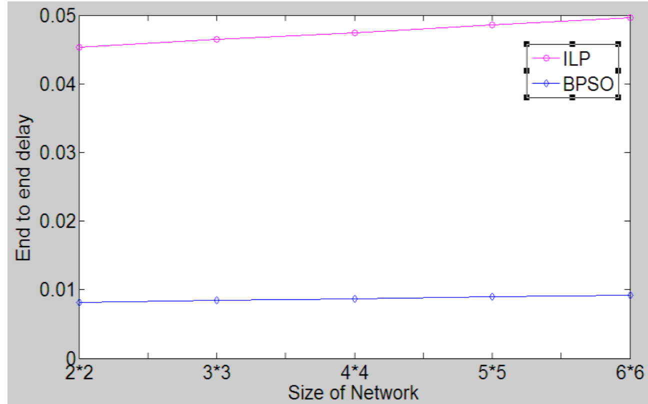


Figure.6. End to end delay comparison of ILP and BPSO

Figure. 6 depicts the results of end-to-end delay for various size of networks. It is seen that the maximum value of end-to-end delay reached in the 6*6 network. The minimum value of delay is achieved in 2*2 network. The proposed technique performs much better as compare to ILP.

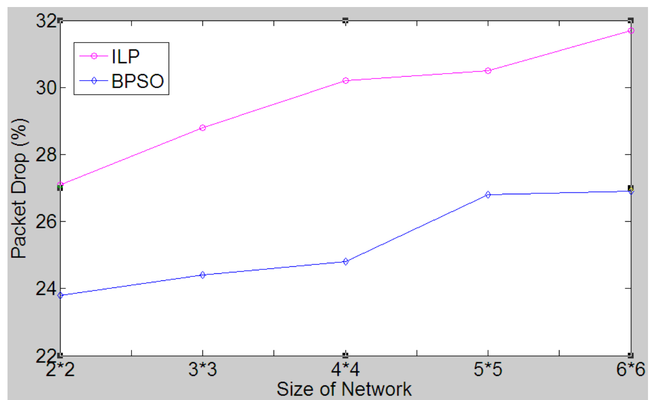


Figure.7.Packet drop comparison of ILP and BPSO.

It is seen that as compared to other algorithms the proposed approach perform much better as network increases in size. On the other hand, ILP produces the lowest network capacity for its tree-based design, without efficiently exploiting multiple channels it leads to single path routing. The performance of BPSO is better than ILP because of multipath data transmission allowed by ILP-based traffic distributions. The throughput enhancement is quite limited because BPSO is self-sufficient of traffic routing and similarly treats each mesh router.

Figure. 7 Depicts that the highest values of packet loss achieved in 6*6 network size. In the 2*2 network size, the lowest value of packet loss has been attained.

## VI. CONCLUSION

In this paper, the channel assignment and routing problem has been addressed in MRMC WMN. A channel assignment algorithm has been proposed based on BPSO and integer linear programming to attain the feasible channel assignment. To efficiently solve these issues, a linear objective function has been used in BPSO algorithm to evaluate the fitness value of each particle. Results have been evaluated from the simulation experiments in terms of network capacity, delay and packet loss. These results have been compared with existing ILP algorithm. The experimental results illustrate that the proposed technique obtain the highest capacity, less packet loss and less end to end delay as compared to ILP algorithm. Considering the performance of every large scale WMNs, it has been explored the extensive WMNs organizing scalability problems for the future work.

## REFERENCES


[1] I.F.Akyildiz and X. Wang, "A survey on wireless mesh networks," IEEE Communications magazine, Vol.43, Issue.9, pp.S23-S30, 2005.

[2] M.Alicherry, R.Bhatia and L.E. Li, "Joint channel assignment and routing for throughput optimization in multi-radio wireless mesh networks," In Proceedings of the 11th annual international conference on Mobile computing and networking, pp. 58-72, 2005.

[3] H. Cheng, N. Xiong, G. Chen and X. Zhuang, "Channel Assignment with Topology Preservation for Multi-radio Wireless Mesh Networks," JCM, Vol.5, Issue.1, pp.63-70, 2010.

[4] J. S. Saini, and B. S. Sohi, "A survey on channel assignment techniques of Multi-Radio Multi-Channel Wireless Mesh Network," Indian Journal of Science and Technology, vol. 9, pp. 1-8, 2016.

[5] P. Kyasanur, C. Chereddi and N.H. Vaidya, "System extensions for Supporting Multiple Channels, Multiple Radios and Other Radio Capabilities" 2006.

[6] X.Y. Li, A. Nusairat, Y. Wu, Y. Qi , j. Zhao, X. Chu and Y. Liu, "Joint throughput optimization for wireless mesh networks," IEEE Transactions on Mobile Computing, Vol.8, Issue.7, pp.895-909, 2009.

[7] L. Badia , A. Botta and L. Lenzini , "A genetic approach to joint routing and link scheduling for wireless mesh networks," Ad Hoc Networks, Vol.7, Issue.4, pp.654-664, 2009.

[8] R. Pries, D. Staehle, M. Stoykova, B. Staehle and P. Tran-Gia, "A genetic approach for wireless mesh network planning and optimization," In Proceedings of the International Conference on Wireless Communications and Mobile Computing, pp. 1422-1427, 2009.

[9] S. Avallone, I.F. Akyildiz and G. Ventre, "A channel and rate assignment algorithm and a layer-2.5 forwarding paradigm for multi-radio wireless mesh networks," IEEE/ACM Transactions on Networking (TON), Vol.17, Issue.1, pp.267-280, 2009.

[10] J. S. Saini, and B. S. Sohi, "Optimal Power Control algorithm for Multi-Radio Multi-Channel Wireless Mesh Network," International Journal of Applied Engineering Research, vol. 13, pp. 2072-2077, 2018.

[11] A. Raniwala and T.C. Chiueh, "Architecture and algorithms for an IEEE 802.11-based multi-channel wireless mesh network," In Proceedings of 24th Annual Joint Conference of the IEEE Computer and Communications Societies, 3, pp. 2223-2234, 2005.

[12] A. Subramanian, H. Gupta and S.R. Das , "Minimum interference channel assignment in multi-radio wireless mesh networks," In Proceedings IEEE Press. pp. 481–490, 2007.

[13] T. Liu and w. Liao,"Interference-aware QoS routing for multi-rate multi-radio multi-channel IEEE 802.11 wireless mesh networks," IEEE Transactions on Wireless Communications, Vol.8, Issue.1, pp.166-175, 2009.

[14] A. Mishra, E. Rozner, S. Banerjee and W. Arbaugh, "Exploiting partially overlapping channels in wireless networks: Turning a peril into an advantage," In Proceedings of the 5th ACM SIGCOMM conference on Internet Measurement, pp. 29-29, 2005.

[15] J.S. Saini and B.S Sohi, "Channel assignment algorithm based on interference reduction for multi-radio multi-channel wireless mesh networks," International Journal of Advanced Research in Computer Science, 9(1), 2018.

[16] P. Dutta, S. Jaiswal , D. Panigrahi and R. Rastogi R., "A new channel assignment mechanism for rural wireless mesh networks," In Proceedings of The 27th Conference on Computer Communications, pp. 2261-2269, 2008.

[17] L. Gao and X. Wang , "A game approach for multi-channel allocation in multi-hop wireless networks," In Proceedings of the 9th ACM international symposium on Mobile ad hoc networking and computing, pp. 303-312, 2008.

[18] Y. Song, C. Zhang and Y. Fang, "Joint channel and power allocation in wireless mesh networks: A game theoretical perspective," IEEE Journal on Selected Areas in Communications, Vol.26, Issue.7, pp.1149 – 1159, 2008.

[19] P. Gupta and P.R Kumar, "The capacity of wireless networks". IEEE Transactions on information theory, Vol.46, Issue.2, pp.388-404, 2000.

[20] N. Ramachandran , E.M, Belding-Royer, K.C. Almeroth and M.M. Buddhikot., "Interference-Aware Channel Assignment in Multi-Radio Wireless Mesh Networks," In Infocom, 6, pp.1-12, 2006.

[21] J. Padhye , S. Agarwal, V,N. Padmanabhan, L. Qiu, A. Rao and B. Zill, "Estimation of link interference in static multi-hop wireless networks," In Proceedings of the 5th ACM SIGCOMM conference on Internet Measurement, pp. 28-28, 2005.

[22] S. Xu and T. Saadawi , "Does the IEEE 802.11 MAC protocol work well in multihop wireless ad hoc networks?," IEEE communications Magazine, Vol.36, Issue.6, pp.130-137, 2001.

[23] C. Yin, R. Yang and W. Zhu , "Improving channel assignment in wireless mesh network with linear programming," In Proceedings of 6th International Conference on Electronics Information and Emergency Communication (ICEIEC), pp. 113-116, 2016.


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