

SWARM OPTIMIZATION BASED GRAVITATIONAL SEARCH APPROACH FOR CHANNEL ASSIGNMENT IN MCMR WIRELESS MESH NETWORK

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ABSTRACT

Wireless Mesh Networks offers cost-efficient and higher network efficiency by utilizing multiple channels multiple radio(MCMR) nodes. Also addition, the amalgamation of multiple radio nodes and multiple hops mesh framework tends to overcome the limitation of single radio networks like the ability to achieve the rising accessible system bandwidth. In spite of these benefits, certain MCMR wireless mesh networks still suffer from performance issues like network connectivity, network throughput degradation whenever network size increases. Thus, an effective channel assignment (CA) approach could minimize the number of interference co-channels and enhance the throughput of the network. Thus, a hybridized form of gravitational search approach and particle swarm optimization is presented in this paper to resolve the issue of CA. The velocity and position updates of PSO are merged with the GSA operations to obtain the best channel with good connectivity. This approach maximizes the capability of exploration and exploitation for global and local searches using PSO and GSA operations. The goal of this methodology is the minimization of a number of interfering links and the maximization of network connectivity and throughput. The experimental results for this approach are carried out using NS2 and compared with previously suggested heuristic optimization algorithms such as Learning Automated and Genetic Algorithm Approach, Improved Gravitational Search Approach and Dynamic particle swarm optimization Approach. The simulation outcome showed a better performance of the suggested methodology compared to existing methodologies.

KEYWORDS

Wireless Mesh Network, Channel Assignment, Multi-Channel Multi-Radio, Particle Swarm Optimization, Gravitational Search Algorithm.

1. INTRODUCTION

Wireless Mesh Networks (WMNs) is being evolved the significant technique in the wireless networks over the previous few decades. The causes behind these evolutions are certain eminent features of WMNs like self-organizing, spatial reusability, and fault tolerance. The WMN attains these features through nodes with bi-functionalities which spontaneously create and control the

associations amongst themselves. The multi-hop strategy of WMNs and the quick progress in throughput ends to multiple channels and multiple radios architectures in the mesh networks; however, the interfering of associated channels is the vital issue that minimizes the complete throughput specifically in multi-hop networks. In MCMR nodes, every node is armed with two or more radio and communicating channels are chosen depending on channel assignment approaches.

The channel assignment approaches in MCMR WMN require allotting numerous channels to its radios at a node and simultaneously must select a single channel for every connection in the path using a routing algorithm. Thus, the procedures in MCMRWMNs require much superiority to monitor the space requirement and optimize the efficiency of the network. Else, WMNs might process poorly because of the incompetent usage of several accessible channels and the numerous radios at its disposal [1, 2].

The significant goal in any MCMR wireless mesh network is minimization of network interference and a maximization of network throughput and connectivity. This is achieved by constructing an efficient channel assignment algorithm. Extensive research has also been done using metaheuristic algorithms such as Genetic Algorithm, Particles Swarm Optimization, Ant Bee Colony, and Gravitational Search Algorithm to develop an optimum channel assignment algorithm.

In [3], an enhanced type of gravitational search approach (IGSA) is suggested to resolve the channel assignment issue for WMNs by merging the velocity and particle updating operation of PSO for global and local search. However, IGSA still suffers from the exploitation i.e. from slow search speed, particularly in the last iteration. Therefore, to maximize exploitation and exploration property, in this paper particle swarm optimization is employed along with the GSA approach to maximize the capabilities of exploration and exploitation. GSA is motivated with by Newtonian laws of gravity and motion [4].

In population aided approaches having social actions such as PSO and GSA should take into consideration two internal features i.e. capability to explore the compete for a portion of the search region and capability to exploit the finest outcomes. Probing in the entire problem domain is known as exploration while moving toward the finest outcome to obtain a better solution is known as exploitation. In PSO, exploration capability is achieved through evaluating Pbest and exploitation capability is achieved through evaluating. Whereas, in GSA, by means of selecting appropriate values for arbitrary constraints (G_0 and a), the exploration is assured however slower movement of denser agents could not always assure exploitation capability.

Gravitational Search Algorithm

GSA is one of the heuristic approaches that are attaining attention amongst the scientific communities currently. This is a natured motivated approach that depends on Newton's law of gravity and motion [4]. This algorithm is gathered beneath the population aided methodology and is stated to be much instinctive [5]. This approach is aimed to enhance the efficiency of exploration and exploitation of any population aided methods, depending on the rules of the gravity. Nevertheless, in current days GSA is being complained of not honestly depending law of gravity [6]. This is stated to ignore distance amongst masses, while mass and distance are in combined the fundamental portion of law of gravity. In spite of the complaints, the approach is further been investigated and recognized by scientific communities.

GSA was initially introduced in [4] and is aimed to resolve the issues of optimization. The population-aided heuristic approach depends on the law of gravity and mass communication. This methodology consists of a group of searching elements that communicate with one another by means of gravity force [4]. The agents are termed to be elements and their efficiency is measured through its masses. The gravitational force performs a globalized movement such that the entire elements travel in the direction of other elements having huge mass. The gentle movement of huge masses assures the exploitation phase and in turn, results in the best outcomes. The masses are essentially following the gravitational law as given in (1) and the law of motion as in (2).

$$F = G \left(\frac{M_1 M_2}{R^2} \right) \quad (1)$$

$$a = F/M \quad (2)$$

Depending on Equation (1), F refers to the magnitude of gravitational force, G is the constant, M1 and M2 refer to a mass of initial and subsequent elements and R refers to the distance amongst the two elements. Equation (1) exhibits that in Newton law of gravity, the gravity force amongst two elements is directly proportionate to the product of its masses and inversely proportionate to the square of distance amongst the elements. Whereas in Equation (2), Newton's second law exhibit that whenever a force, F, is employed on an element, its acceleration, *a*, hinges on force and its mass, M.

In GSA, an agent has four constraints such as location, a mass of inertia, active and passive gravity mass [4]. The location of the mass signifies the outcome of the issue, where the gravity and mass of inertial mass are defined employing the fitness evaluation. The approach is directed through tuning these gravity and inertia masses, while every mass signifies an outcome. Masses are fascinated with the heavier mass. Therefore, the higher mass gives an optimal outcome in the searching domain.

Organization of the Paper

A brief description of MCMR Wireless Mesh Network, Traditional Gravitational Search Approach, and motivation for the suggested methodology is given in this section. A brief review of previously suggested channel assignment techniques both heuristics and non-heuristics is given in section 2. The suggested Swarm Optimization based Gravitational Search Algorithm for Channel Assignment is explained in detail in the section 3. The experimental results and its brief analysis are illustrated in section 4. The conclusion for the paper and reference is addressed in section 5 and section 6.

2. LITERATURE SURVEY

Numerous investigations that suggest numerous channel assignment approaches to mine the finest solutions. Several research studies [7, 8, 9, 10, 11, 12 and 13] tried to examine the priori suggested approaches from dissimilar perceptions. CLICK [14] is a DFS dependent channel assignment approach that employs the greedy technique to determine the linked lower interference network in a multiple channel WMN. CLICK allows channels to the connections depending on a greedy technique with identical spirit of graph colouring. It employs an adaptive prior approach that modifies the node's importance in course of implementation to assure the association. Lastly, it combines unallotted radios in the a similar greedy way or depending on the load of the traffic. The other approach, Interference Survival Topology Control (INSTC) [15] reduces the maximal connected co-

channel interference using a basic fitness evaluation function that is similar to the diminishing of maximal connected conflict load in CLICA.

Genetic Algorithm (GA) is a stochastic exploration technique. GA aided channel assignment [16] is the integrated and stationary approach for allotting the channels to WMN. This approach endeavours to diminish the whole interfering traffic weight on the network. This methodology uses a distinctive illustration of individuals for the assignment of the channel. In this approach, each gene signifies an assigned channel for the network as to denote an individual. This approach tries to reduce the complete interference by evading of localized optimum employing a mutation operation. Nevertheless, this approach does not have any fitness evaluation function to regulate the connectivity of the network. Hence, the consequent channel assignment strategy might lose the connections. Furthermore, it does not take into account the exterior interference, traffic weights, and environmental effect.

NSGA-II-dependent channel assignment [17] is of one the integrated and semi-static approaches for allotting channels to network links. This approach tries to obtain two optimized evaluation functions those subjects to two parameters. The fitness functions optimization comprises maximizing the connectivity of the network and minimizing the interference. The other NSGA-II based strategy [18] employs identical operations and constraint values as given in [17] and tries to enhance a joint channel assignment and multicasting routing issues in multi radio WMNs. NSGA-II-dependent channel assignment approach guarantees connectivity along with demonstrating a quick convergence frequency having a definite escape from the local minimum. Nevertheless, these procedures disregard the presence of non-overlapping channels, exterior interferences, and traffic weight and environment influences.

DPSO-CA [19] is a PSO aided assignment strategy that refers to the distinct searching domain and intends to obtain the minimal interference channel assignment with the network conservation [20]. DPSO-CA exploits collaboration amongst the searching techniques of the fundamental PSO approach and genetic operations like crossover and mutation to guarantee the optimization. The other assignment strategy depends on Improved Gravitational Search Algorithm (IGSA) [3] that enhances the notion of the DPSO-CA approach. GSA is an alternative for PSO, where elements are defined to be a group of masses that communicates with one another depending on the Newtonian gravity and laws of motion. This approach proposed a localized searching aided operation to enhance the efficiency of fundamental GSA through improving the exploration abilities. IGSA aided channel assignment is identical to DPSOCA that intends to minimize the entire channel interference along with guaranteeing the network conservation.

GTS aided channel assignment [21] is an integrated and static approach that possibly allot channels to the Maximal Independent Set (MIS) of Mesh Network. This approach initiates certain arbitrarily picked channel assignments for any conflict graph. GTS enhances allotment using numerous generations. An enhanced adjoining outcome is deposited in a restricted dimension centralized memory in addition to the older ones. Moreover, identical to this step, the other approach in [22] similarly employs Tabu search for channel assignment. Furthermore, an enhanced a tabu search aided approach in [23] amalgamates handoff and traffic load disparity constraints in the fitness evaluation function. This enhanced optimization prototype enables attaining much-optimized channel assignment resolutions.

3. PROPOSED SWARM OPTIMIZATION BASED GRAVITATIONAL SEARCH ALGORITHM FOR CHANNEL ASSIGNMENT

The channel assignment approach conserves network connections in a way that both the nodes in the transmitting range could connect if a common link is associated to them. In this section, a modified Gravitational Search Approach is presented by incorporating the abilities of PSO for optimum channel assignment strategy for MCMR WMN. The preliminary notion of proposed approach is to amalgamate the capability for societal intellectual obtained through G_{best} in PSO along with localized exploitation competence of GSA. The “No Free Lunch Theorem” in [24] defines that no unique approach could resolve the entire issues in an optimum manner. For certain heuristic optimization approaches, the hybridization has been a significant device for enhancing the efficiency of the network connectivity.

Network Model

A WMN having static wireless nodes are considered where every node comprises of radios having antennas in Omni direction. This is a homogenous network having similar specifications in terms of radios and transmission range. The network topology is defined using the graph $G(V, E)$, here V refers to the group of mesh nodes and E refers to the link amongst the nodes. For any two nodes in transmitting ranges of one another, there is a link (x, y) amongst x and y . The nodes must always be within in the interference range of one another.

The Conflict graph is extensively employed to model the interference that specifies the communication links that interfere with one another. This transforms the channel assignment issues to the Max K-cut and Min K-cut partitioning issue. The conflicting graph $G_c(V_c, E_c)$ is given where V_c refers to the vertices and I_{xy} represents the communication link amongst (x, y) . There is a conflict edge between (I_{xy}, I_{ab}) if and only if (x, y) and (a, b) interfere with one another where these links are on similar channel and in the interfering range of one another. If $G(V, E)$ exhibits the standard network, then $G_c(V_c, E_c)$ is a conflicting graph such that $V_c \in E$. The complete network interference is the summation of entire connections that are intervening with one another.

In the proposed approach, initially all the agents are arbitrarily initialized considering every agent as a candidate solution nothing but the channel assignment in this paper. The location of every agent is given as:

$$P_x = (p_x^1, p_x^2, p_x^3, \dots, p_x^d), \quad x = 1, 2, \dots, N \quad (3)$$

Here p_i^d is the location of x^{th} element in d^{th} dimension and N is agent count or swarm dimension. In course of the generation, the gravitational force from element y on to the element x at a defined time is given as:

$$F_x^d(t) = G(t) \frac{M_{px}(t) \times M_{ax}(t)}{R_{xy}(t) + \epsilon} (p_y^d(t) - p_x^d(t)) \quad (4)$$

Here M_{ax} refers to the active gravitational mass associated to element y , M_{px} refers to the passive gravitational mass associated to the agent x , $G(t)$ refers to gravity constant at time t , ϵ is a constant

value and $R_{xy}(t)$ refers to Euclidean distance amongst the two agents x and y . The gravitational constant and Euclidean distance amongst the two agents x and y is estimated as:

$$G(t) = G_0 \times \exp(-\alpha \times iter / maximum_{iter}) \quad (5)$$

$$R_{xy}(t) = \|X_i(t) - X_j(t)\|_2 \quad (6)$$

Here, α is descent coefficient, G_0 refers to original gravitational constant, $iter$ is the present iteration value and $maximum_{iter}$ is the iterations dimension.

Once the gravitational force, gravitational constant and consequent forces are evaluated, the accelerations of elements are given as:

$$a_x^d(t) = \frac{F_x^d(t)}{M_x(t)^i} \quad (7)$$

Here, d is the dimension t defines the definite time and M_x is mass of the agent x . In every generation, the finest solution is updated. Once the acceleration, and updated best solution, velocities and position of entire agents are evaluated using the PSO Velocity and position as given below:

$$V_x(t+1) = w \times V_x(t) + c'_1 \times random \times ac_x(t) + c'_2 \times random \times (g_{best} - P_x(t)) \quad (8)$$

Here, $V_x(t)$ refers to the velocity agent x at iteration t , c'_1 is the acceleration coefficient, w refers to the weight function, $random$ is the randomized number amongst 0 and 1, $ac_x(t)$ is the acceleration agent x at iteration t , g_{best} refers to the finest solution. The location of the agent is given as:

$$P_x(t+1) = P_x(t) + V_x(t+1) \quad (9)$$

The velocity and position update of PSO selects few nodes having the best solutions and enhances it through selecting the best nodes for channel assignment. For this purpose, every chosen node, PSO arbitrarily alters few channel that allocated with nodes amongst the available channel.

The Fitness function $Fit(f)$ is sum of the interferences amongst the link x and y i.e. (x,y) which is given as:

$$Fit(f) = \sum interencesnumberoflinks(x,y) \quad (10)$$

In the initialization phase, a common channel is employed to neighbor nodes. Every agent is channel assignment outcome and fitness evaluation function is estimation of interference in the complete network. In this evaluation entire network is considered with radio constraints.

In the proposed approach, the quality of a solution is obtained from the fitness evaluation and good solutions attempt to fascinate another agent through searching from diverse portions of the search domain. Guest assists in providing global value. This approach employs the memory to save the best solution. Through adjusting and, c'_1 and c'_2 , the capability of global and local searching could be stabilized.

Pseudocode for the Proposed Methodology

1. Randomly initialize the agents $P_x(t)$ as given equation (3)
2. Estimate the Fitness function for the complete population using equation (10).
3. Update the values $\|F_x\|^{d(t)}$, g_{best} for all $x=1,2,\dots,N$ using equation (4).
4. Evaluate the passive and active gravitational forces, constants and accelerations using the equation (5), (6) and (7).
5. Update the Agents subsequent position and Velocity using the equation (8) and (9).
6. Check for the Termination Criterion.
7. Repeat the steps 2 to 5 till the termination conditioned is attained.

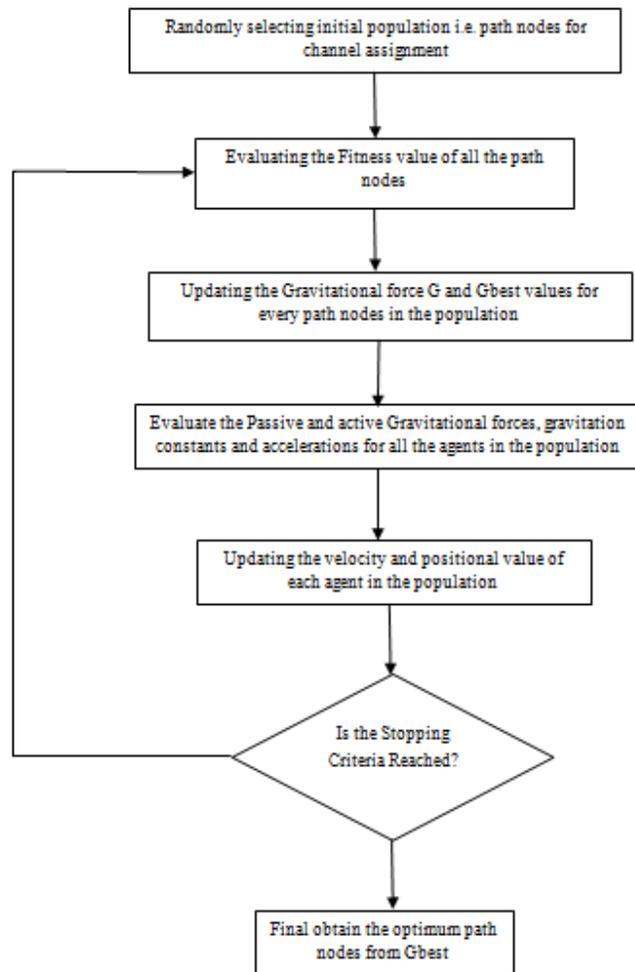


Fig 1: Flow Chart of SOGSA based Channel Assignment Algorithm

4. EXPERIMENTAL RESULTS AND ITS ANALYSIS

The Performance evaluation of the suggested channel assignment algorithm is given in this section and is carried out using Network Simulator – 2 (NS2). An MCMR WMN is randomly generated using 105 nodes among which 97 are client nodes, 4 are mesh routers and 4 are mesh gateways. The experiment is carried out in a coverage area 1000*1000 with a simulation period of 150 milliseconds. The Table represents the parameter values employed for the proposed assignment algorithm.

Parameters	Values
Simulation Period	150ms
Coverage Area	1000*1000
No of Nodes	105
No of Mesh Routers	4
No of Mesh Gateways	4
No of Mesh Clients	97
Traffic Type	FTP
Agent Type	TCP
Routing Protocol	AODV
Initial power	1000 J
Idle Power	0.1 J
Queue Type	Drop-Tail

Table-1: Simulation Parameters

The channel assignment algorithm is evaluated using seven different performance metrics namely Network end-to-end delay, Average Cost Ratio, Packet Delivery Ratio, Packet Data Loss, Energy Efficiency, Energy Consumption, and network throughput. Some of the performance metrics are defined as:

➤ Average packet delivery ratio: This is defined as packets obtained for all multicast receivers above the packets sent by the source averaged on entire multicast receivers. This criterion specifies the packets count delivered to the multicast receivers over the packets expected to be received by multicast receivers.

➤ Average end-to-end delay: This is given as average time elapsed amongst packets send using multicast source and receiving the packets to the entire multicast receivers. This criterion is averaged on entire receivers.

➤ Average throughput: This is given as the size of packets obtained through the receiver over the needed time to provide the number of packets averaged on entire multicast receivers.

$$AverageThroughput = \frac{1}{|MRS| \times RT} \sum_{i=1}^{|MRS|} NRP(MR_i)$$

Where $NRP(MR_i)$ refers to the number of received packets at i^{th} multicast receiver. $|MRS|$ specifies cardinality of Multicast Receiver Set and RT is the required time to deliver the number of packets.

➤ Total cost: This is given as a number of links forming a multicast routing tree.

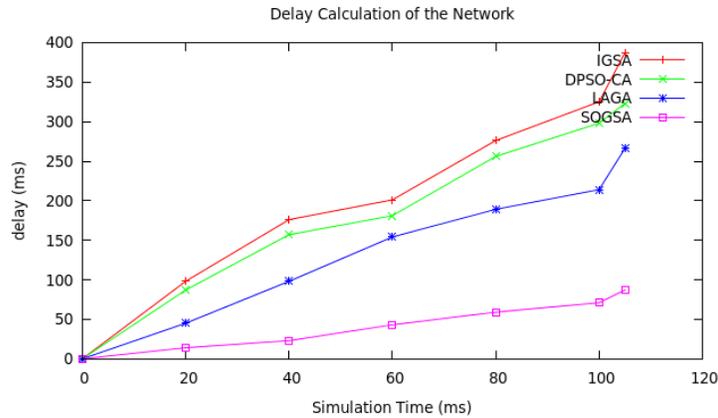


Fig 2: Comparison of Network End-to-End Delay Evaluation

The efficiency of the proposed channel assignment algorithm is compared with existing assignment algorithms such as Learning Automata and Genetic Algorithm Based Channel Assignment Approach [25], Improved Gravitational Search Algorithm based Channel Assignment [3] and DPSO based Channel Assignment [19]. As exhibited in Fig 2, Fig 3, Fig 4, Fig 5, Fig 6, Fig 7 and Fig 8, the comparison of Network End to End Delay evaluation, Packet Drop, Energy Consumption, Network Energy Efficiency, Packet Delivery Ratio, Network Throughput and Network Cost Evaluation against the no of nodes are illustrated.

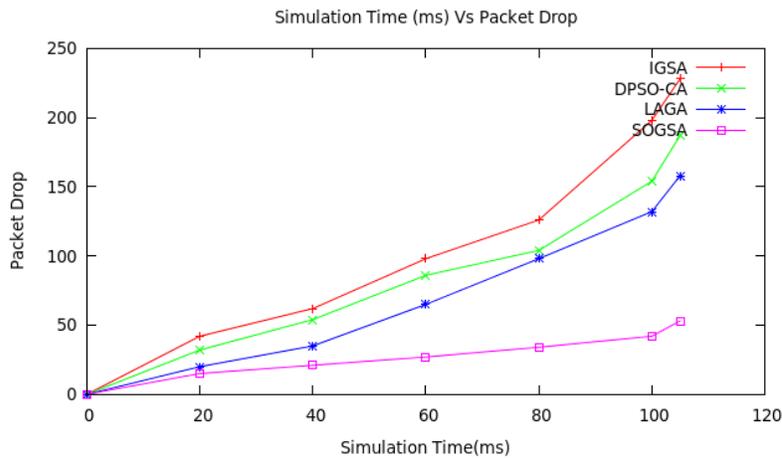


Fig 3: Comparison of Network Packet Drop

From Fig 2, Fig 3 and Fig 4, it can be inferred that the network End-to-End Delay, packet drop and energy consumption of the proposed Swarm Optimization based Gravitational Search Algorithm for Channel Assignment (SOGSA) is less when matched with the existing approaches such as LAGA, IGSA, and DPSO-CA. From Fig 2 and Fig 3, it is also inferred that the end to end delay and packet drop of very less compared to the existing algorithm which depicts a better network efficiency from other approaches.

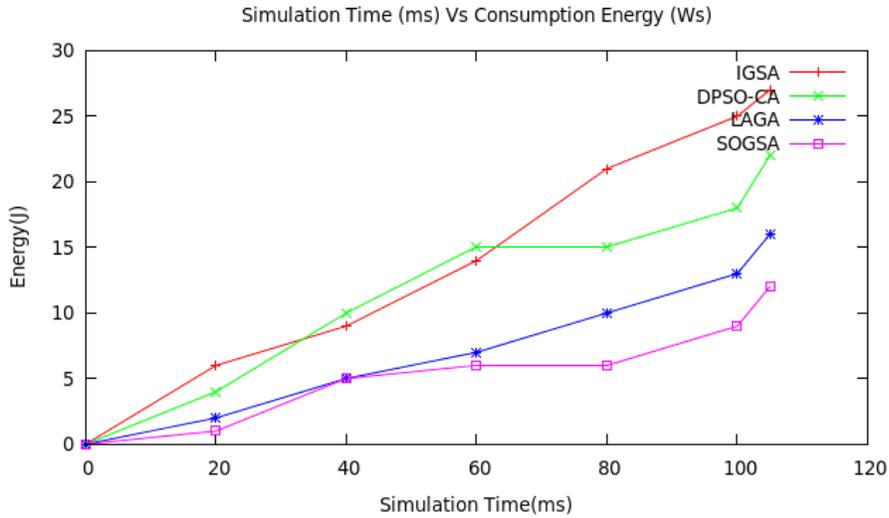


Fig 4: Comparison of Energy Consumption Vs Simulation time

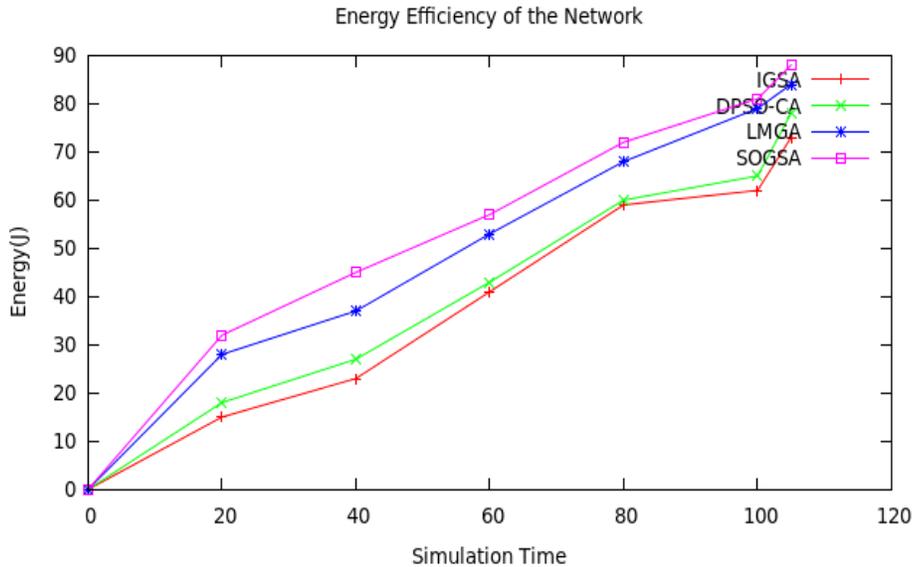


Fig 5: Comparison of Network Energy Efficiency

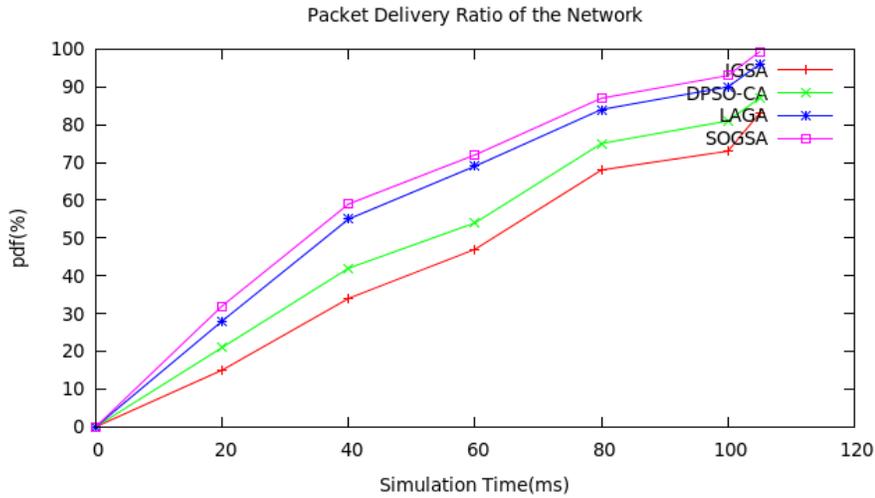


Fig 6: Comparison of Network Packet Delivery Ratio

From Fig 5, Fig 6 and Fig 7, it can be inferred that the Network energy efficiency, Packet delivery ratio and network through evaluation of the proposed SOGSA based Channel Assignment approach is more when matched with existing techniques like LAGA, IGSA, DPSO-CA algorithms. From Fig 7, it can also be depicted that network throughput is far higher compared to the previously suggested algorithms. Fig 8 depicts the network cost evaluation comparison of the suggested algorithms. From Fig 8, it is exhibited that the cost of the suggested SOGSA methodology is comparatively in similar lines with the Learning Automata and Genetic Algorithm based Channel Assignment approach and lesser than the other suggested methodologies such as IGSA and DPSO-CA methodologies.

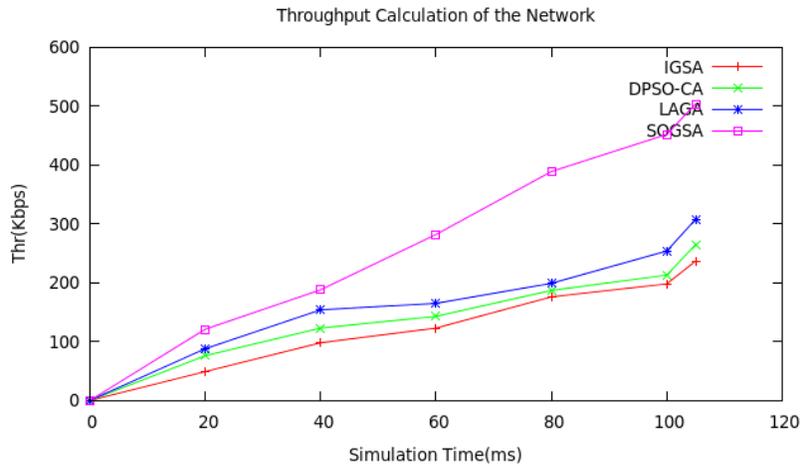


Fig 7: Comparison of Network Throughput Calculation

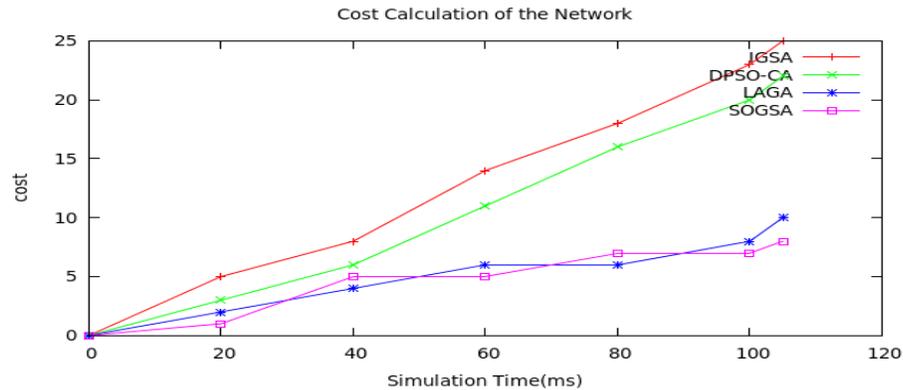


Fig 8: Comparison of Network Cost Evaluation

5. CONCLUSIONS

In the literature numerous approaches employed for efficient channel selection in Multi-Channel Multi-Radio Wireless Mesh Networks. In this paper, a novel methodology is presented for the assignment of minimum interference channels to maximize network connectivity and network throughput. The operations of the Gravitational Search Approach are merged with the operation of Particle Swarm Optimization such that the capabilities of exploration and exploitation are maximized for obtaining optimum channel assignment. The best solutions are obtained by evaluating the gravitational force from the GSA algorithm and G_{best} from the PSO approach along with fitness function for optimum channels in WMN. The Performance of the suggested Swarm optimization Gravitational Search Algorithm based channel assignment methodology is compared with the previously suggested heuristics-based algorithms. The experimental results exhibited that the suggested technique has better performance when compared with previously suggested methodology in terms of Network end-to-end delay, packet delivery ratio, network throughput, energy consumption, energy efficiency, and packet drop.

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