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

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Abstract: Wireless MeshNetworksoffers cost efficient andhighernetworkefficiency through utilizing multiplechannelmultipleradio(MCMR).In addition, theamalgamation ofmultiple radionodesand multiple hopsmeshframework tends toovercomethe limitationofsingle radionetworkslike inabilityto achieve therising accessible systembandwidth.Inspiteofthesebenefit,certain MCMR wirelessmeshnetworksstillsufferfrom performance issueslike network connectivity, network throughputdegradationwhenevernetworksizeincreases. Thus, aneffective channelassignment(CA)approach couldminimize thenumberofinterferenceco-channelsandenhance thethroughput 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 is 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 search using PSO and GSA operations. The goal of this methodology is the minimization of number of interfering link and maximization of network connectivity and throughput. The experimental results for this approach is 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 cause behind these evolutions are certain eminentfeatures of WMNs like self-organizing,spatial reusability, and fault tolerance. The WMN attains thesefeatures through nodes with bi-functionalities which spontaneouslycreateand control the associations amongst themselves.Themulti-hopstrategy ofWMNsand thequickprogressin throughputtends tomultiple channels andmultiple radiosarchitectures inthe meshnetworks,however the interferingofassociated channels is the vital issue that minimizes the complete throughput specifically inmulti-hopnetworks.InMCMR nodes,every nodeisarmed withtwo or moreradio and communicating channelsarechosen depending onchannelassignmentapproaches.

Thechannelassignmentapproaches in MCMR WMN requires toallot numerous channelstoits radiosatanodeandsimultaneously mustselectasingle channelforevery connection inthepathusing routingalgorithm. Thus, theprocedures in MCMRWMNs require much superioritytomonitor the space requirementand optimize efficiency of the network.Else,WMNsmight process poorlybecause of incompetentusage ofseveral accessible channels andthenumerous radiosatitsdisposal[1, 2].

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The Significant goal in any MCMR Wireless Mesh network in minimization of Network Interferences and Maximization of Network Through and Connectivity. This is achieved by constructing an efficient Channel Assignment Algorithms. An extensive research has also been done using the 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 GSA approach to maximize the capabilities of exploration and exploitation. GSAis motivated with the Newtonianlawsofgravityandmotion[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 portion of search region and capability to exploit the finest outcomes. Probingin the entire problem domain is known as exploration while moving toward the finest outcome to obtain 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 arbitraryconstraints (G_0 and a), the exploration is assured however slower movement of denser agents could not always assure exploitation capability.

1.1. Gravitational Search Algorithm

GSA is one of the heuristic approach that is attaining attention amongstthe scientific communitiescurrently. This is a naturedmotivated 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 andexploitation of any population aided methods, depending on rules of gravity.Nevertheless, in current days GSA is beingcomplainedfor not honestlydepending law ofgravity [6]. This is stated to ignore distance amongst masses,while mass and distance are in combined the fundamentalportion of law of gravity. In spite ofthe complaints, the approach is further been investigated and recognized by scientificcommunities.

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

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

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

Depending on Equation (1), F refers to magnitude of gravitational force, G isthe constant, M1 and M2 refers to mass of initial and subsequent elements andR refers to the distance amongst the two elements. Equation (1) exhibits that in Newtonlaw of gravity, the gravity force amongst two elements is directly proportionate to product of its masses and inversely proportionate to 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, agents has four constraints such as location, mass of inertia, activeand passive gravity mass[4]. The location of the masssignifies the outcome of the issue, where the gravity and mass of inertial massare defined

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employing the fitness evaluation. The approach is directedthrough tuning these gravity and inertia masses, while every mass signifies an outcome.Masses are fascinatedwith the heavier mass. Therefore, the higher mass gives an optimal outcome in the searching domain.

1.2 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 on 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 is illustrated in section 4. The conclusions for the paper and reference is addressed in section 5 and section 6.

2. Literature Survey

There are numerous investigation that suggest numerous channel assignment approaches to mine the finest solutions. Severalresearch studies [7, 8, 9, 10, 11, 12, 13] tried to examine the priori suggested approaches from dissimilar perceptions.CLICA [14] is a DFS dependent channel assignment approach that employs the greedy technique to determine the linked lower interferencenetwork in a multiple channel WMN.CLICA allots channels to the connections depending on importanceof ensuing a greedy technique with identical spiritof graph coloring.It employs an adaptivepriori approach that modifiesthe node's importance in course of implementation to assure the association. Lastly, it combines un-allotted radios in the similar greedy way or depending on the load of the traffic. The other approach, Interference SurvivalTopology Control (INSTC) [15] reduces the maximal connected co-channel interference using a basic fitness evaluation functionthat is similar to the diminishing of maximal connected conflictload in CLICA.

Genetic Algorithm (GA) is a stochasticexploration technique. GA aided channel assignment [16] is the integratedand stationaryapproach for allotting the channels to WMN. This approach endeavors to diminish the whole interferingtraffic weight on the network. This methodology uses a distinctiveillustration of individuals for assignment of 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 localizedoptimum employing a mutationoperation. Nevertheless, this approach do not have any fitness evaluation function to regulate the connectivity of the network. Hence, theconsequent channel assignment strategy might lose the connections. Furthermore,it do not take into account the exterior interference, traffic weights and environment effect.

NSGA-II dependent channel assignment [17] is one the integrated andsemi-static approach for allotting channels to network links.This approach tries to obtain two optimized evaluation functionsthat subjects to two parameters. The fitness functions optimization comprises of maximizing the connectivity of network andminimizing the interference.The other NSGA-II based strategy [18] employs identical operations and constraint values as given in [17] and tries to enhancea joint channel assignment and multicasting routing issues in multiple radio WMNs. NSGA-II dependent channel assignmentapproach guarantees connectivity along with demonstratinga quick convergencefrequencyhaving definite escape from the localminimum. Nevertheless, these proceduresdisregard the presence ofnon-overlapping channels, exterior interferences, and trafficweightand environmentinfluences.

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 a collaborationamongst the searching techniques of the fundamental PSO approach andgenetic operations like crossover and mutation so as to guarantee the optimization. The other assignment strategy depends on ImprovedGravitational Search Algorithm (IGSA) [3] that enhances the notion of DPSO-CA approach. GSA is analternativefor 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

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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 andstatic approach that possibly allot channels to the Maximal Independent Set (MIS) of Mesh Network. This approach initiates with certain arbitrarilypicked channel assignmentsfor any conflict graph. GTS enhances allotment using numerous generations. An enhanced adjoining outcome is deposited in a restricteddimension 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 tabu search aided approach in [23] amalgamates handoff and traffic load disparityconstraints in the fitness evaluation function. This enhanced optimization prototype enablesattainingmuch optimized channel assignment resolutions.

3. Proposed Swarm Optimization based Gravitational Search Algorithm for Channel Assignment

The channelassignmentapproach conserves networkconnections in a way that both the nodesin the transmitting rangecould connectwithone another ifa 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 MCMRWMN.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 ofGSA.The "No Free Lunch Theorem"in [24] defines that no unique approach could resolve the entire issues in an optimum manner. For certain heuristicoptimization approaches, the hybridization has been a significant device for enhancing the efficiency of the network connectivity..

3.1 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. Forany twonodesin transmitting rangesof one another,thereis 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 linksthatinterferewith one another. This transforms the channelassignmentissues tothe MaxK-cutandMinK-cutpartitioningissue.The conflicting graph $G_c(V_c, E_c)$ is given where $V_c$refers to the verticesandI_{xy}represents the communication link amongst (x, y). Thereisaconflict edgebetween (I_{xy}, I_{ab}) if andonlyif (x, y) and (a, b)interferewithone another where these links are on similar channelandintheinterfering rangeofone another.If $G\ (V, E)$exhibits the standard network,then $G_c(V_c, E_c)$ is aconflicting graphsuch that $V_c \in E$.Thecompletenetworkinterferenceisthesummationofentire connections thatareintervening 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:

$$P_x = ({p_x}^1, {p_x}^2, {p_x}^3, \ldots..{p_x}^d), \qquad x = 1, 2, \ldots \ldots N \qquad (1)$$

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:

$${F_x}^d(t) = G(t)\frac{M_{px}(t) \times M_{ax}(t)}{R_{xy}(t)+\varepsilon}({p_y}^d(t) - {p_x}^d(t)) \qquad (2)$$

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

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Euclidean distance amongst the two agnets$x$ and y. The gravitational constant and Euclidean distance amongst the two agents$x$ and y is estimated as:

$$G(t) = G_0 \times \exp\left(-\alpha \times iter/\text{maximum}_{iter}\right) \qquad (3)$$

$$R_{xy}(t) = \left\|X_i(t) - X_j(t)\right\|_2 \qquad (4)$$

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 is given as:

$$a_x^d(t) = \frac{F_x^d(t)}{M_x(t)^i} \qquad (5)$$

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

$$V_x(t+1) = w \times V_x(t) + c_1' \times random \times ac_x(t) + c_2' \times random \times (g_{best} - P_x(t)) \qquad (6)$$

Here, $V_x(t)$ refers to the velocity agent x at iteration t, c_y' 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 agent is given as:

$$P_x(t+1) = P_x(t) + V_x(t+1) \qquad (7)$$

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:

$$Fit(f) = \sum interences\ number\ of\ links\ (x, y) \qquad (8)$$

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 minimization of complete network interference. In this evaluation entire significant parameters comprises of linked or conservation network and radio constrictions.

In the proposed approach, the quality of solution is obtained from the fitness evaluation and good solutions attempts to fascinateanother agent through searching from diverse portions of search domain. Gbest assists in providing the global value. This approach, employs the memory to save best solution. Through adjusting c_1' and c_2', the capability of global and local searching could be stabilized.

Pseudo code for the Proposed Methodology

1. Randomly initialize the agents $P_x(t)$ as given equation (1)
2. Estimate the Fitness function for the complete population using equation (8).
3. Update the values $F_x{}^d(t)$, $gbest$ for all $x = 1, 2, \ldots \ldots N$ using equation (2)
4. Evaluate the passive and active gravitational forces, constants and accelerations using the equation (3), (4) and (5)
5. Update the Agents subsequent position and Velocity using the equation (6) and (7).
6. Check for the Termination Criterion

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7. Repeat the steps 2 to 5 till the termination conditioned is attained.

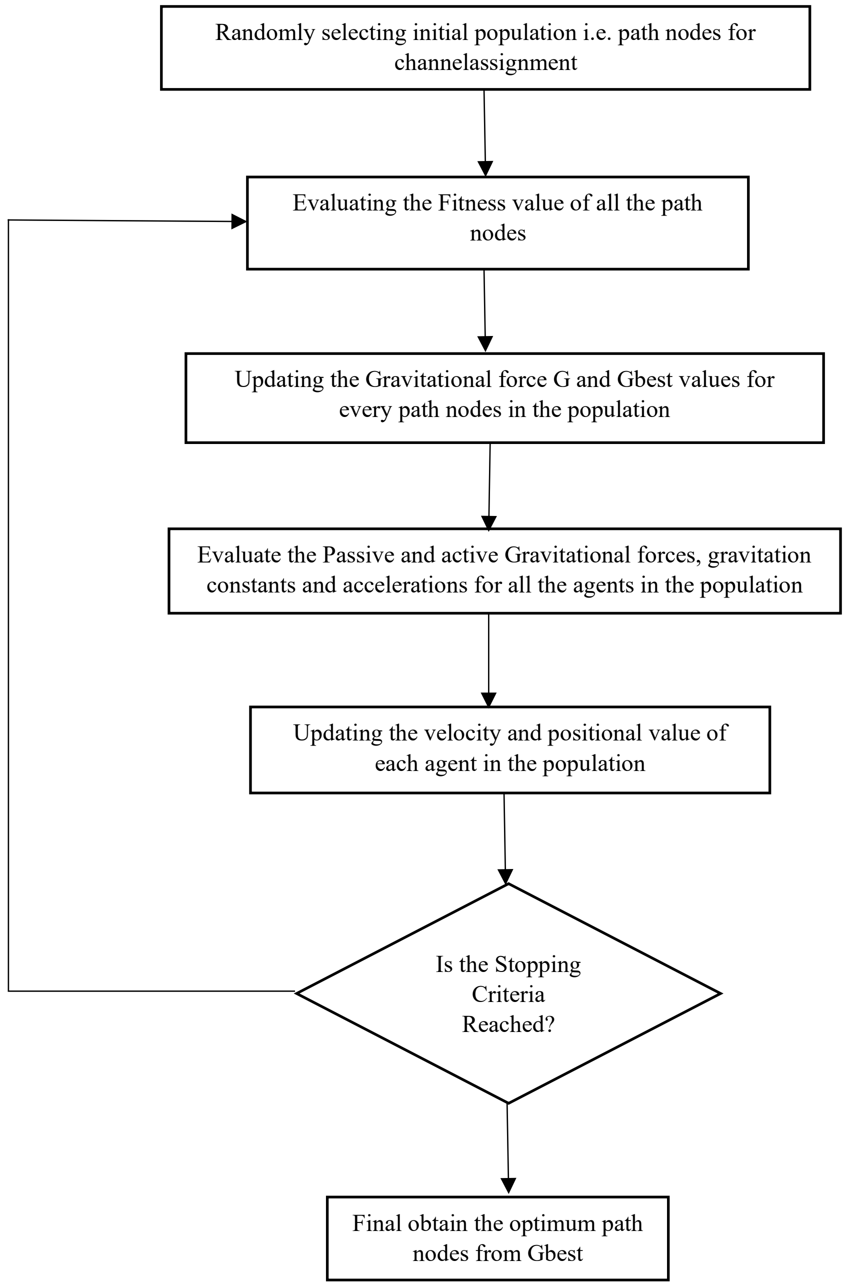

Fig 1: Flow Chart of SOGSA based Channel Assignment Algorithm

4. Experimental Results and Its Analysis

The Performance evaluation of the suggetsed 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

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1000*1000 with simulation period of 150 milli-seconds. Table 1 represent 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

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 size of packets obtained through receiver over the needed time to provide the number of packets averaged on entire multicast receivers.

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

Where $NRP(MR_i)$refers to the number of obtained packet at i^{th} multicast receiver. Also $|MRS|$ specifies cardinality of multicast receiver set and RT is the required time to deliver the number of packets.

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

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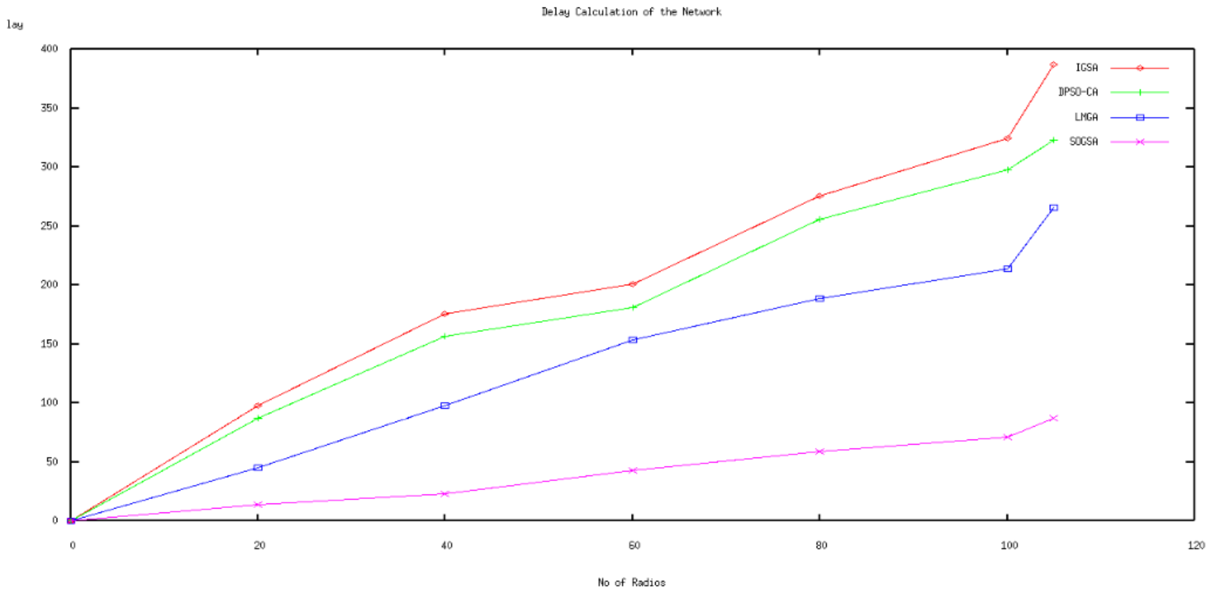

Fig 2: Comparison of Network End-to End Delay Evaluation

The efficiency of proposed channel assignment algorithm is compared existing assignment algorithms such as Learning Automata and Genetic Algorithm Based Channel Assignment Approach, 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 comparisonof 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.

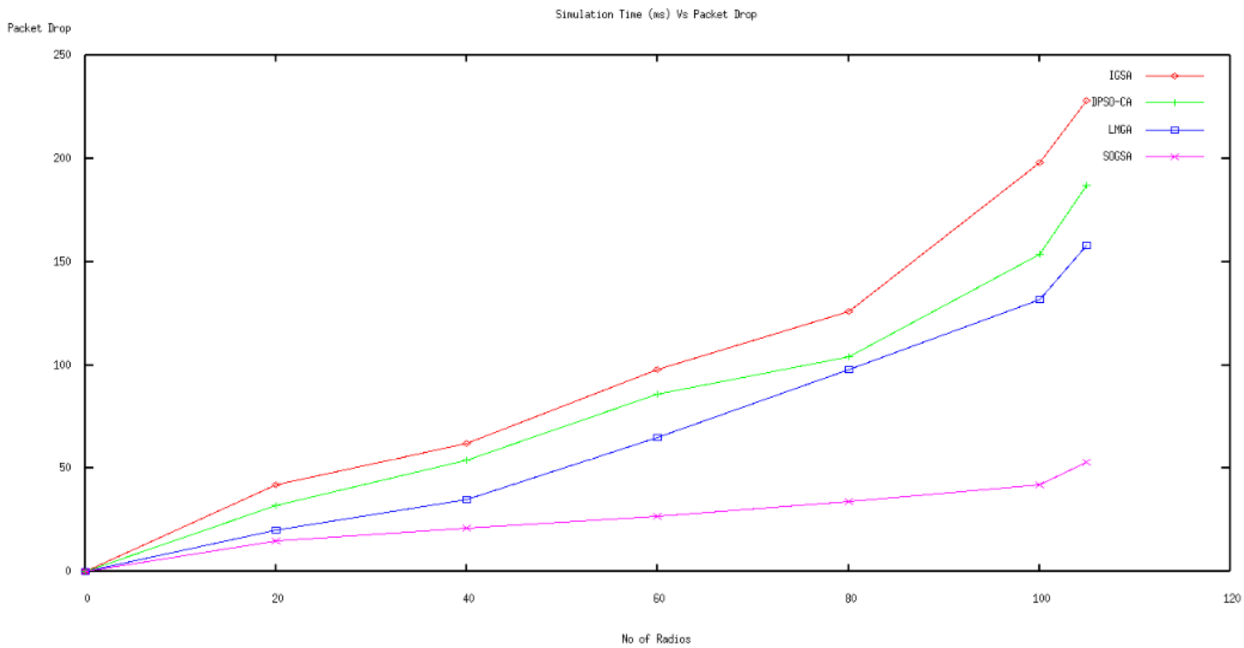

Fig 3: Comparison of Network Packet Drop

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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 LAGO, 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.

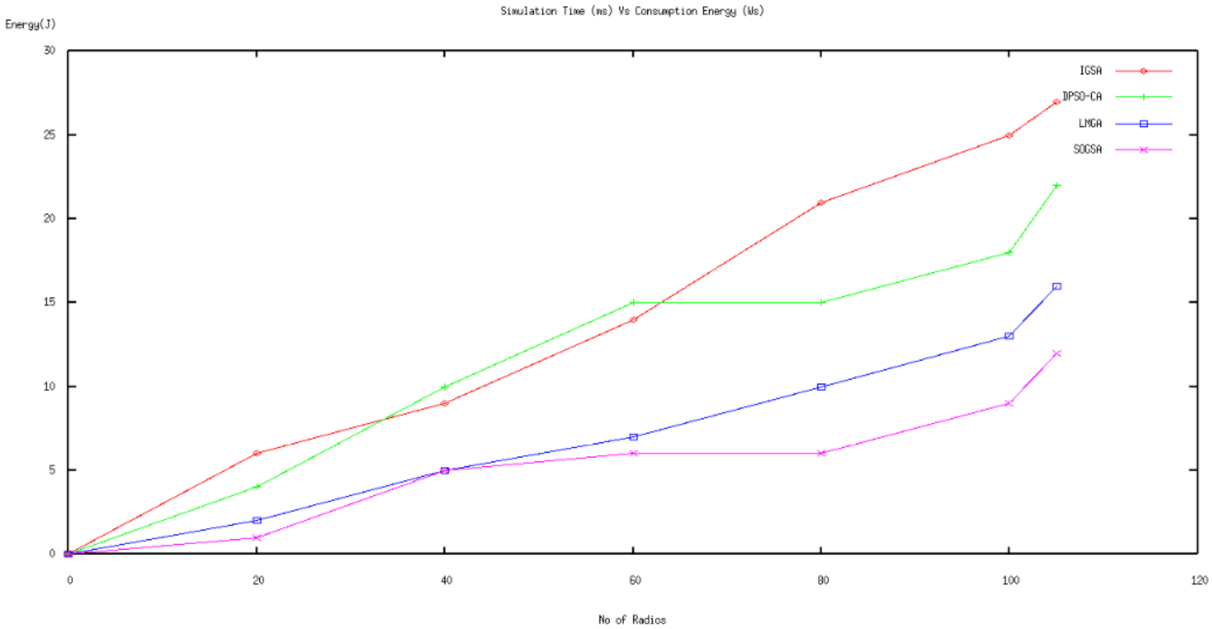

Fig 4: Comparison of Energy Consumption Vs Simulation time

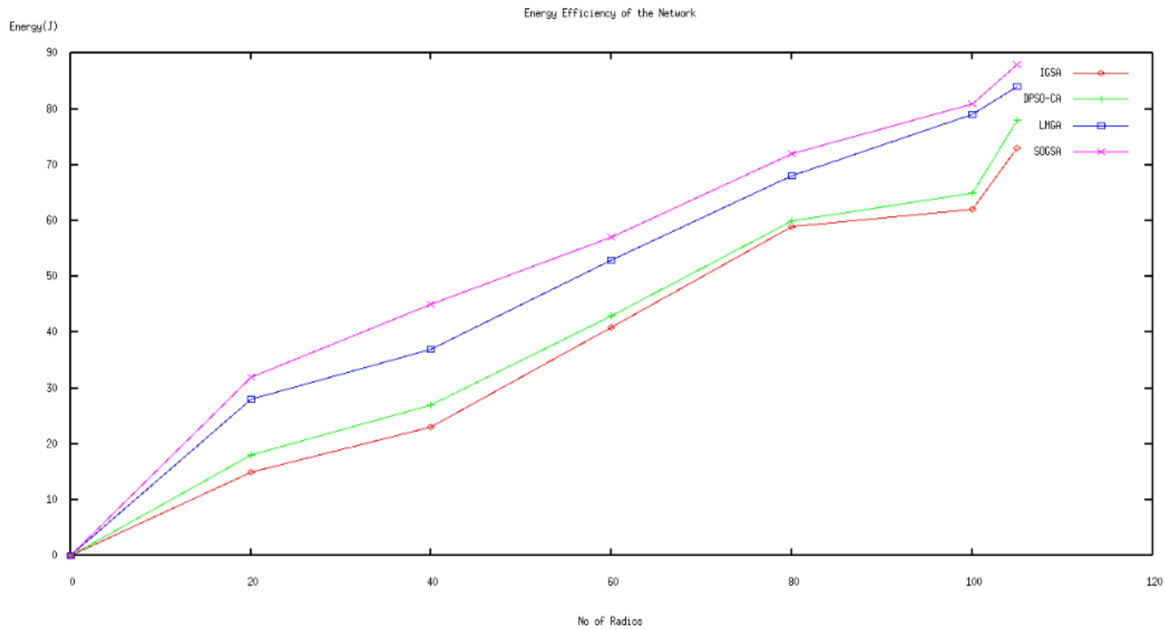

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Fig 5: Comparison of Network Energy Efficiency

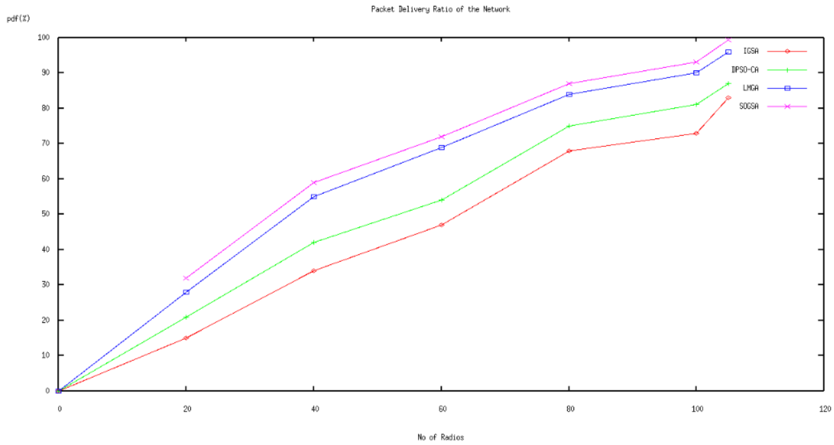

Fig 6: Comparison of Network Packet Delivery Ratio

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 is 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.

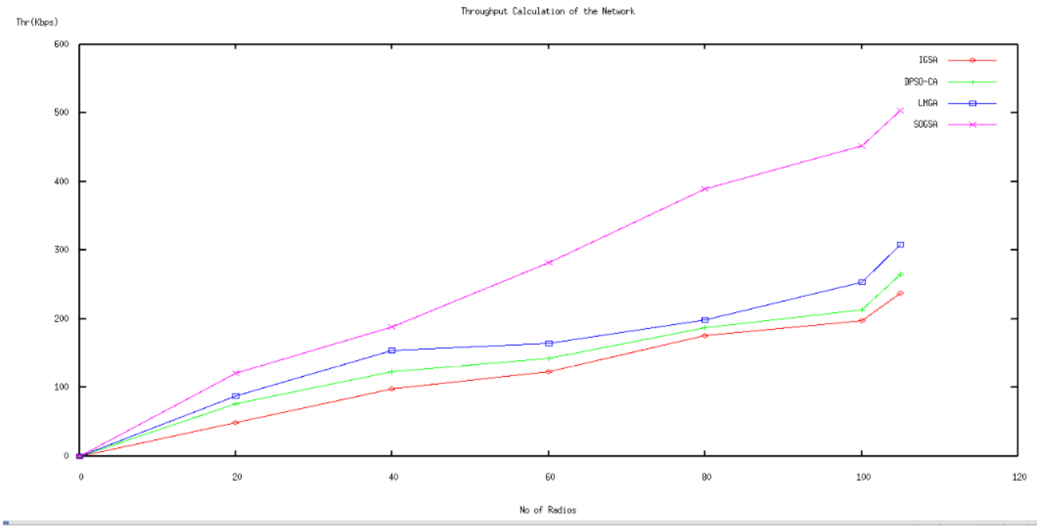

Fig 7: Comparison of Network Throughput Calculation

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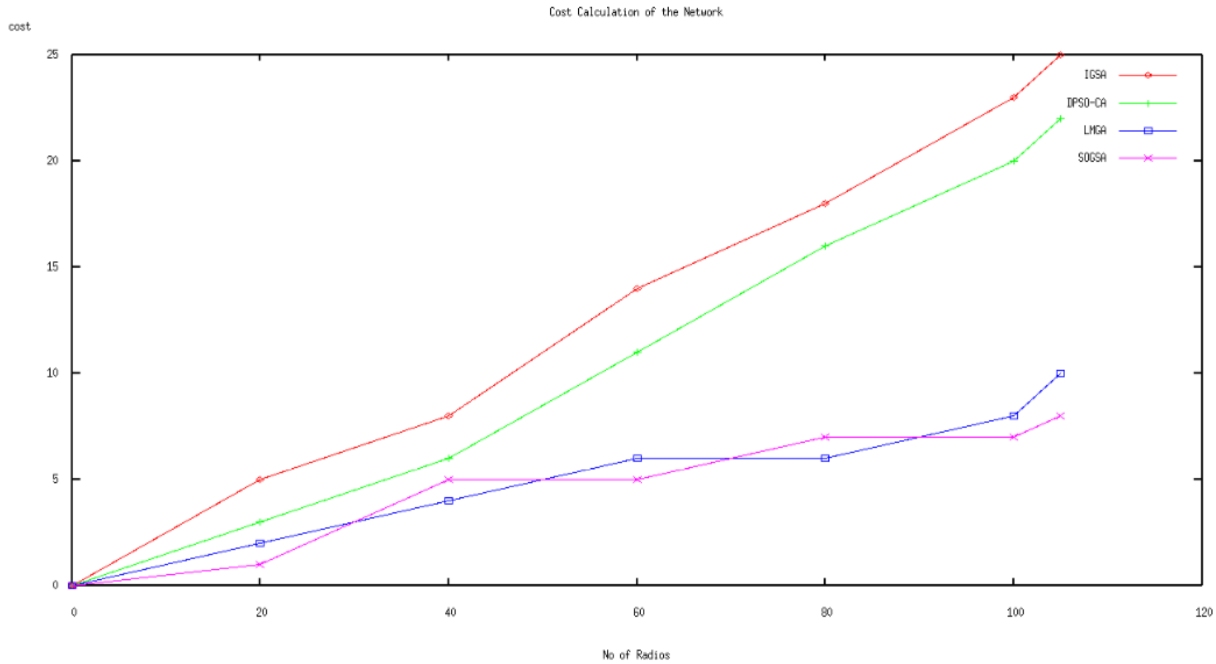

Fig 8: Comparison of Network Cost Evaluation

5. Conclusions

MCMR WMN highly rises the potential for efficient channel selection by means of employing numerous approaches in the literature. In this paper, a novel methodology is presented for assignment of minimum interference channels so as to maximize the network connectivity and network throughput. The operations of Gravitational Search Approach is 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 GSA algorithm and G_{best} from 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 compared previously suggested methodology in terms of Network end-to-end delay, packet delivery ratio, network through, energy consumption, energy efficiency and packet drop.

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