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Performance analysis FIFO and WFQ models employing IWO and GSA techniques to OLSR Protocol in MANETs

Dr.S.Meenakshi Sundaram[1] K.Kalyanakrishnan[2] M.S. Divya Shree[3]

[1] Professor, Department of C.S.E., Don Bosco Institute of Technology, Bangalore, India

[2] Associate Professor, Department of C.S.E., M.A.M. School of Engineering, Tiruchirappalli, India

[3] Under Graduate Student (ECE), TRP Engineering College (SRM Group), Irungalur Tiruchirappalli, India

ABSTRACT: MANETs are unplanned, self organizing networks composed of mobile nodes that utilize mesh networking principles for interconnectivity. They are capable of self-forming and self-managing which eliminates the need for intensive central management of network links, thus reducing support personnel and equipment requirements in forward located areas. The hello interval of the OLSR protocol plays a crucial role in improving the QoS parameters and the same is dependent on the mobility of the nodes. Local search algorithms are meta heuristic methods which are used to solve NP Hard optimization problems employing different candidate solutions in the search space. The candidate solutions are generated by making local changes and are searched continuously till the termination criterion is reached. In this study, Gravitational Search and Invasive Weed Optimization (IWO) are implemented to search for the ideal OLSR parameters in the search space to reduce end to end delay and improve network throughput. A novel fitness function based on PDR and jitter is proposed. The gravitational search algorithm's performance is poor for local search technique. This affects the convergence, speed and accuracy. It is further required to investigate using other optimization methods like Particle Swarm Optimization (PSO) for improving the efficiency of the OLSR

Keywords: ***Mobile Ad hoc Networks (MANETs), Optimized Link State Routing (OLSR) Protocol, Quality of Service QoS, Gravitational Search Algorithm(GSA), Invasive Weed Optimization(IWO) Algorithm.***

1 INTRODUCTION

The QoS of the network can be improved by varying hello interval and the same is dependent on the mobility of the nodes. To further optimize the performance of the network, factors like mobility, packet delivery ratio, jitter and so on is to be considered which makes routing a NP hard problem. Local search algorithms are meta heuristic methods to solve NP Hard optimization problems using different candidate solutions in the search space. The candidate solutions are generated by making local changes and are searched continuously till the termination criterion is reached. In this study, Gravitational Search and Invasive Weed Optimization (IWO) are implemented to search for the ideal OLSR parameters in the search space. A novel fitness function based on PDR and jitter is proposed.

Gravitational Search Algorithm (GSA) is a class of optimization algorithm based on the law of gravity and mass interactions. The principle is based on Newtonian gravity which states that every particle attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Invasive Weed Optimization (IWO) (Hajimirsadeghi et al 2009), a bio inspired numerical stochastic optimization algorithm, simulates natural weed behavior in colonizing and finding place for growth/reproduction. Some properties of IWO when compared to other evolutionary algorithms are reproduction method, spatial dispersal, and competitive exclusion. IWO process starts with initializing a population. A population of initial solutions is generated randomly in the solution space. Then population members produce seeds based on comparative fitness in the population. The seed number for each member varies linearly between S_{min} for worst member and S_{max} for best member. Seeds are randomly scattered in the search space by distributed random numbers with mean equal to zero and adaptive standard deviation.

This study is implemented using IWO. Incorporating IWO reproduction / spatial dispersal, enhances the latter's exploration and exploitation in addition to being well balanced (Zhao et al 2013). IWO achieves better OLSR performance.

2 METHODOLOGY

A. Invasive Weed Optimization (IWO)

IWO algorithm is a numerical stochastic search algorithm mimicking natural weed colonizing behavior, finding a suitable place for growth/reproduction.

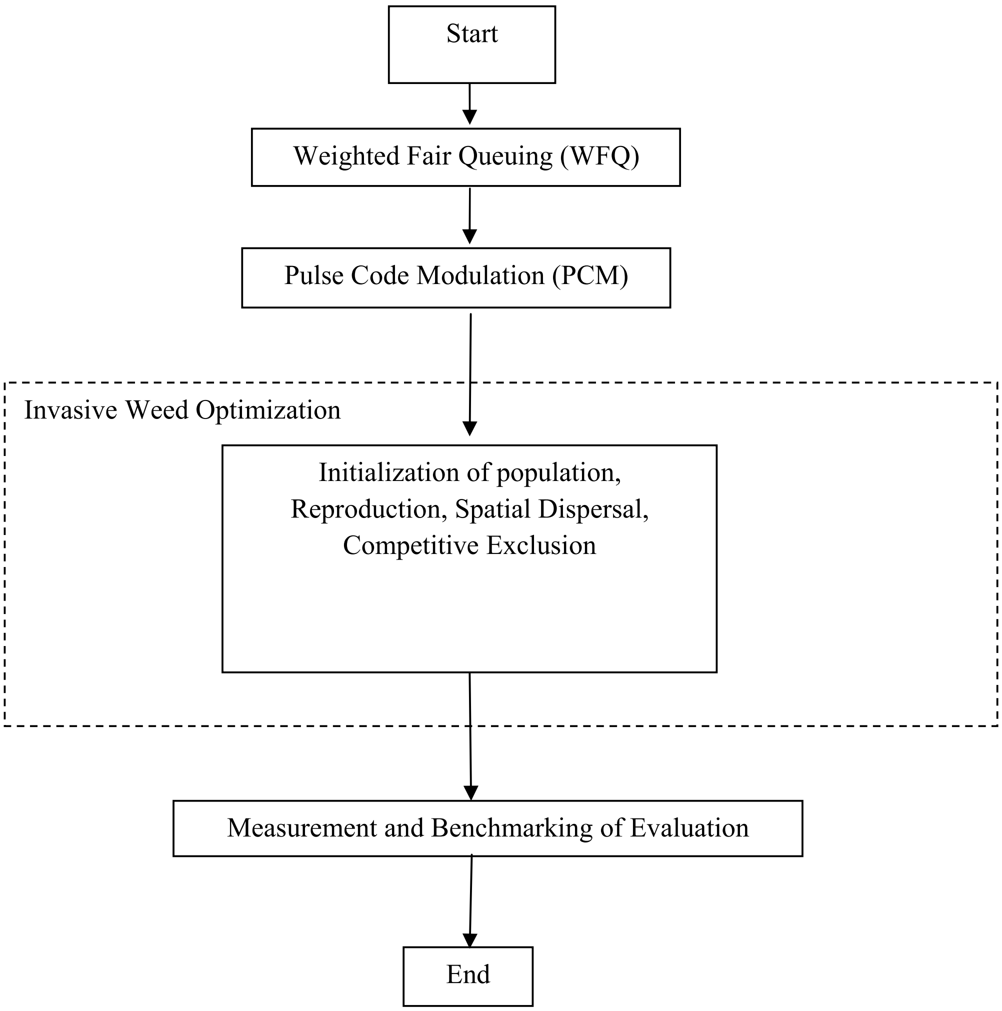

Figure 1: Flow chart for proposed methodology

Figure 1 gives the Flow Chart for the proposed methodology. Invasive Weed Optimization is one of the numerical stochastic optimization algorithms. IWO is successfully applied for determining a global minimum or a maximum of a multi-variables function by representing the problem to be solved (Monavar 2011).

IWO is a population based algorithm and was introduced by Mehrabian & Lucas in 2006. This algorithm is a bio-inspired numerical optimization algorithm which simply simulates a natural behavior of weeds in colonizing and finding suitable place for the growth and reproduction. Some of the typical properties of IWO with the comparison with other evolutionary algorithms are the way of reproduction, spatial dispersal, and competitive exclusion. Basically the characteristic of a weed is that entirely it grows its population or predominantly in a geographically specified area which can be substantially large or small.

The main steps involved in IWO algorithm can be schematically represented as in the Figure 2 given below.

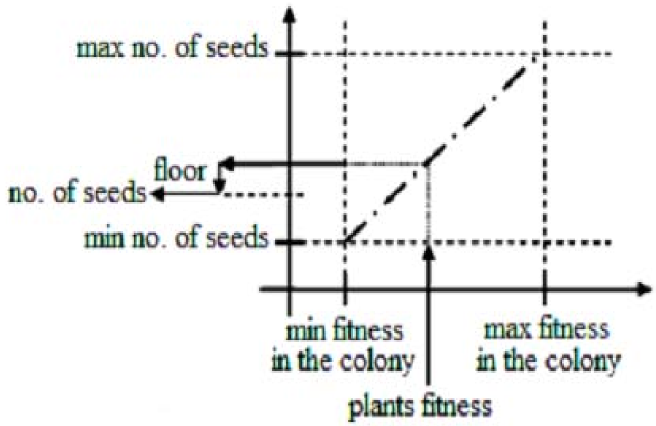

Figure 2 Seed Production in a colony

There are 4 steps for the algorithm as described below:

1) Initialization of a population: A number of weeds are randomly spread over the search space (*D* dimensional). Each generation's initial population is termed as $X = \{x1; x2,. . . ,xm\}$.

2) Reproduction: Each member of population *X* produces seeds in a specified region centered at own position. Number of seeds produced by $xi;\ i \in \{1, 2, . . .,m\}$, depends on relative fitness in the population regarding both, best and worst fitness. The number of seeds produced in any weed varies linearly from the position of min seed to max seed with minimum number of seed for the worst member and maximum number of seed for the best member in the population.

3) Spatial Dispersal: Generated seeds are randomly distributed over d-dimensional search space through normally distributed random numbers with zero mean and variance σ2. This means that the seeds will gets randomly distributed such that they abode near to the parent plant. Accordingly, the position of new seed is presented as in Equations 1 and.2:

$$\sigma_i = \left[\left(it_{\max} - it \right) / it_{\max} \right] \times \left(\sigma_i - \sigma_j \right) + \sigma_j \qquad (1)$$

$$New\ \mathrm{S}_i = Parents\ \text{position}\ \omega_i + \sigma_i \times Randn(0,1) \qquad (2)$$

where itmax is maximum number of iterations, σit is the standard deviation at the present time step, n is the nonlinear modulation index, σi is the initial SD and σf is the final SD, the (0,1). Random means that a normally distributed random number with mean equal to 0 and variance to 1 (Yin 2011).

4) Competitive Exclusion: If a plant has no offspring then it becomes extinct; otherwise they can take over the world. Hence there should be some competition between plants to limit maximum plant numbers in a population. Initially, plants in a colony reproduce quickly, and all weeds are included in the colony, till the plants number reaches a maximum value of *pop max*.

A meta-heuristic algorithm mimicking weed colonizing behavior is IWO (Yin et al 2012).

If sd_max and *sd*_min are the maximum and minimum standard deviation and if *pow* is a real no. , then the standard deviation for a particular iteration is given in Equation (3) below:

$$sd_{ITER} = \left(\frac{iter_{\max} - iter}{iter_{\max}} \right)^{pow} (sd_{\max} - sd_{\min}) + sd_{\min} \qquad (3)$$

This ensures that the probability of dropping a seed in a distant area decreases nonlinearly with iterations, resulting in grouping fitter plants and eliminating inappropriate plants. Hence, this is an IWO selection mechanism.

The following pseudo code represents the IWO algorithm:

1. Generates a random population of N0 solutions.
2. For iter =1 to the maximum number of generations.
   a. Calculate the fitness for each individual.
   b. Compute the maximum and minimum fitness.
   c. For each individual w in W.
      i. Compute number of seeds w, corresponding to its fitness.
      ii. Randomly distribute the generated seeds over search space with normal distribution around the parent plant (w).
      iii. Add the generated seeds to the solution set, W.
   d. if (|W|=N)>Pmax, then
      i. Sort the population W by descending order based on their fitness.
      ii. Truncate the population of weeds with smaller fitness until N=P max.
3. Next iter (Borzabadi 2010).

Figure 3 given below shows the Invasive Weed Optimization algorithm flowchart.

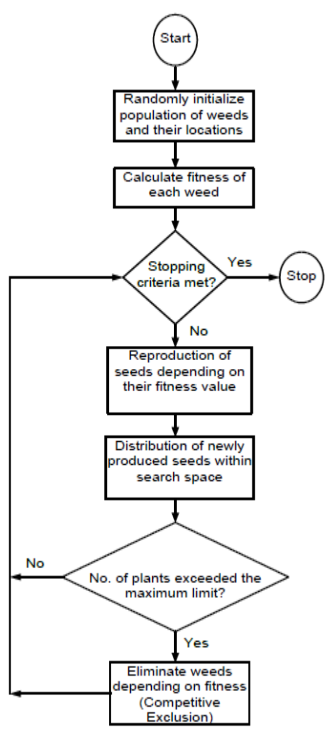

Figure 3 Flow chart for invasive weed optimization algorithm

B Gravitational Search Algorithm (GSA)

Each mass (agent) has four specifications in GSA: inertial mass, position, active gravitational mass, and passive gravitational mass. The mass position corresponds to a solution of the problem and its fitness function determines gravitational and inertial masses. Each mass presents a solution, with the algorithm being navigated by proper adjustments of gravitational and inertia masses. By time lapse, masses to be attracted by heaviest mass which presents an optimum solution in the search space is expected. GSA can be considered as an isolated masses system. It is a small artificial world of masses obeying Newtonian gravitation and motion laws. To be more precise, masses obey the following laws:

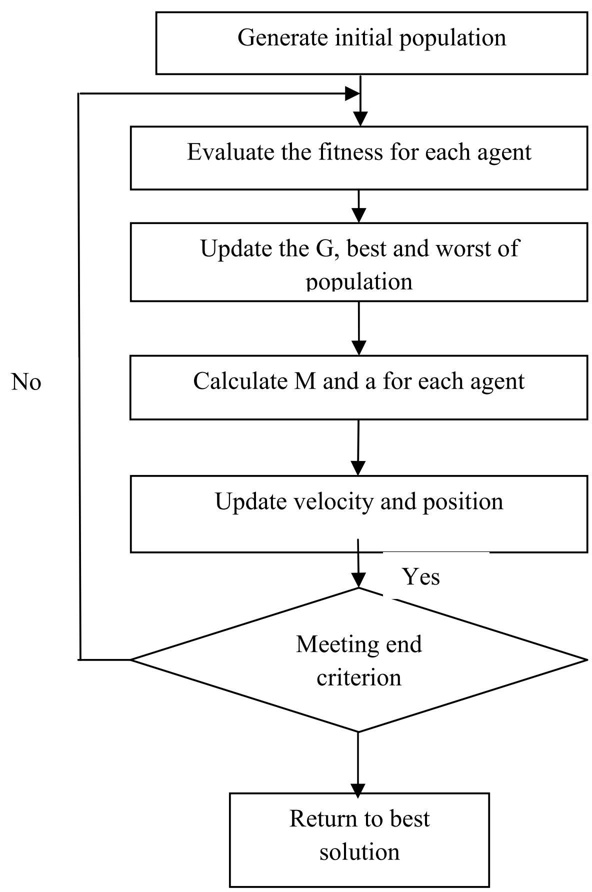

Figure 4 Flow chart for GSA

Law of gravity: each particle attracts other particles and gravitational force between two particles is proportional to product of their masses and inversely proportional to distance between them.

Law of motion: current velocity of a mass is equal to sum of fraction of previous velocity and variation in velocity. Variation in velocity or acceleration of mass is equal to force acting on system divided by inertia mass.

C. Fitness Function

A novel fitness function is proposed and given by

$$F(t)=\frac{\sqrt{\frac{2J_m}{\lambda_{in}}}e^{-\frac{\lambda_g^2}{2\lambda_{in}}J_m}\int_{\sqrt{\frac{2J_m}{\lambda_{in}}\lambda_g}}^{\sqrt{\frac{2J_m}{\lambda_{in}}(\lambda_g+\frac{\lambda_{in}t}{J_m})}}e^{-s^2}ds}{PDR} \quad (4)$$

where PDR is the Packet Delivery Ratio,

J_m is the max_jitter,

λ_{in} is the input_package,

λ_g is the Generated_package_in_node,

$$\lambda_{out}=\lambda_{in}+\lambda_g \text{ , } t\in[0,J_m] \quad (5)$$

3 SIMULATION STUDY AND RESULTS

The simulation is carried out using OPNET Simulator Ver. 14.0, which includes 20 nodes which are spread over 2000 meter by 2000 meter with the trajectory of each node being at random. Each node runs a multimedia application over UDP. The data rate of each node is 11 Mbps with a transmit power of 0.005 watts. The simulations are run for 400 sec. Multimedia traffic with First-in-First-Out and Weighted Fair Queuing are described below. The packet delivery ratio (PDR) for multimedia traffic, end to end delay for multimedia traffic, jitter for multimedia traffic, number of packets for multimedia traffic are measured for various hello intervals 1,2,3,4 and 5 seconds at various mobility speeds of the network for 0,5,10,15 and 20 m/s.

a. For Multimedia Traffic with FIFO

Multimedia traffic with first in first out queuing model is given below. The packet delivery ratio for multimedia traffic with FIFO is measured for hello intervals 1,2,3,4 and 5 seconds for mobility speeds 0, 5, 10, 15 and 20 m/sec. The data collected are shown in the Table 1. The data in Table 1 is transformed to a graph and is shown in Figure 5.

Table 1 PDR for multimedia traffic

m/s	hello interval=5 sec	Gravitational Search	Invasive Weed Search
0	0.9343	0.9133	0.9263
5	0.8289	0.8827	0.8997
10	0.7785	0.8401	0.8354
15	0.7785	0.843	0.8283
20	0.7365	0.8035	0.7987

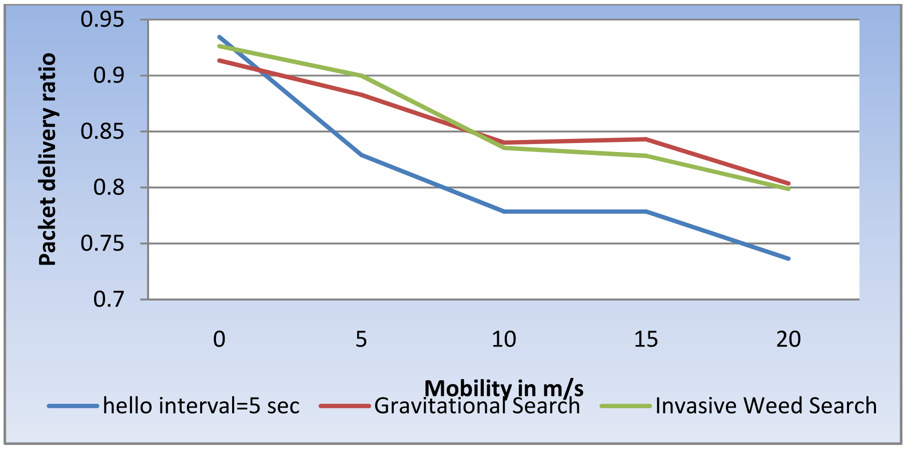

Figure 5 PDR for multimedia traffic

The contents of Table 1 are graphically represented and is shown in Figure 5. From figure 5, it is observed that the PDR achieved decreases with increasing mobility. At mobility speed of 5 m/s, the average PDR achieved using gravitational search is 1.93% lesser compared to invasive weed search. It is higher by 6.49% compared to hello interval of 5 sec. At mobility speed of 20 m/sec, the average PDR achieved is 0.6% higher compared to invasive weed search. It is 9.1% higher compared to hello interval 5 sec.

Table 2 End to end delay for multimedia traffic

m/s	hello interval=5 sec	Gravitational Search	Invasive Weed Search
0	12.113	10.3524	10.0803
5	15.2945	12.263	13.1805
10	18.0605	13.7189	16.1592
15	19.5171	15.5155	16.3744
20	21.0246	17.835	18.9153

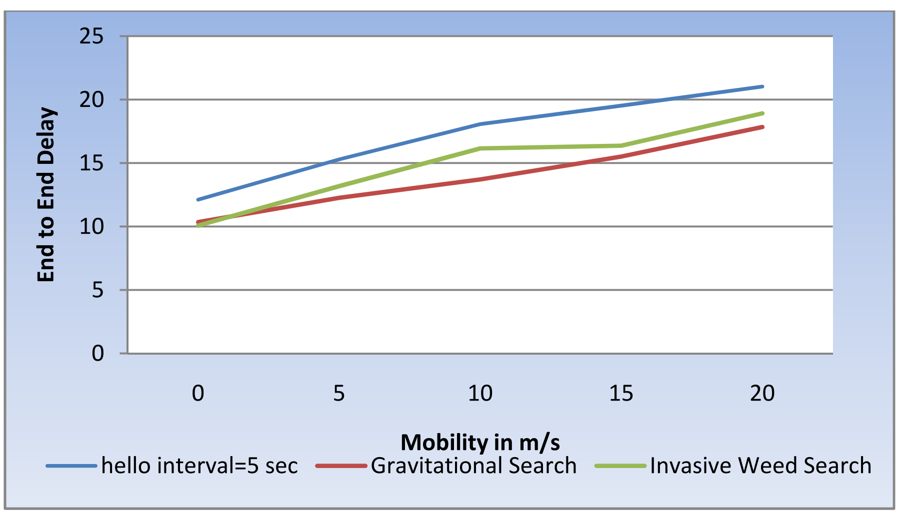

Figure 6 End to end delay for multimedia traffic

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The contents of Table 2 are graphically represented and is shown in Figure 6. From Figure 6, it is observed that the end to end delay increases with increasing mobility. For no mobility, the average end to end delay achieved using gravitation search is higher that 2.7% compared to invasive weed search. It is 14.53% lower compared to hello interval 5. At mobility speed of 20 m/sec, the average end to end delay achieved is 15.17% lower compared to invasive weed search. It is 5.71% lower compared to hello interval 5.

Table 3 Jitter for multimedia traffic

m/s	hello interval=5 sec	Gravitational Search	Invasive Weed Search
0	1.4928	1.0437	1.1443
5	1.0491	1.3924	1.4992
10	1.0996	1.222	1.2569
15	1.5125	1.0438	1.3553
20	1.5311	1.2456	1.1582

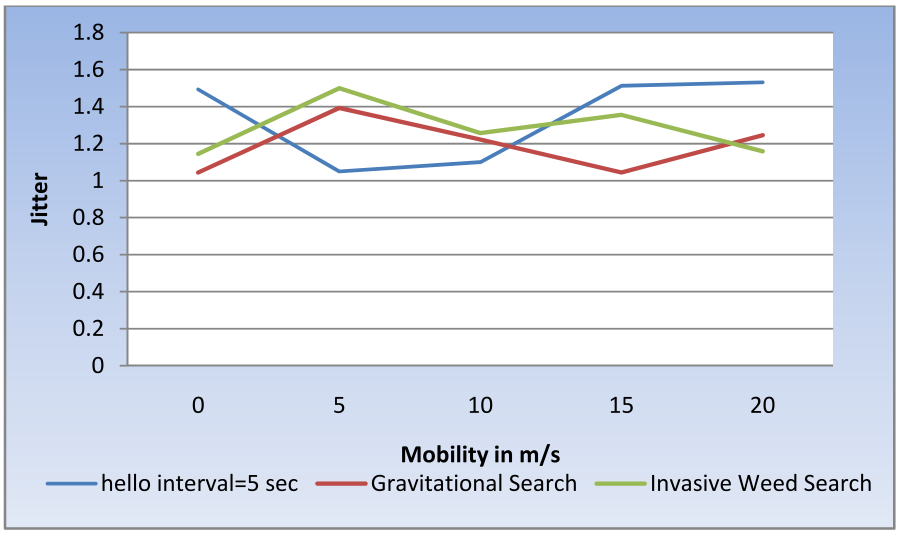

Figure 7 Jitter for multimedia traffic

The contents of Table 3 are graphically represented and is shown in Figure 7. From Figure 7, it is observed that the, the jitter varies with increasing mobility. At zero mobility, the average jitter achieved using gravitational search is 8.79% lower compared to invasive weed search. It is 30.08% lower compared to hello interval 5. At mobility speed of 20 m/sec, the average jitter achieved is 7.55% higher compared to invasive weed search. It is 18.65% lower compared to hello interval 5.

Table 4 No. of TC packets for multimedia traffic

m/s	hello interval=5 sec	Gravitational Search	Invasive Weed Search
0	293	314	288
5	411	452	400
10	459	466	449
15	486	487	474
20	524	510	524

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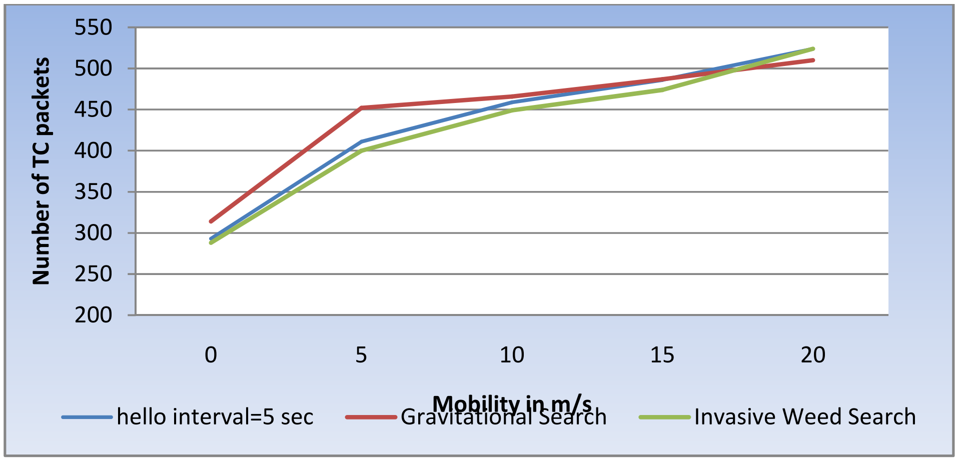

Figure 8 No. of TC packets for multimedia traffic

The contents of Table 4 are graphically represented and is shown in Figure 8. It shows the number of TC packets achieved for gravitational search and invasive weed search techniques for different mobility speeds for multimedia traffic using FIFO. It is observed that the invasive weed search has the lowest number of TC packets compared to gravitational search and hello interval 5 sec.

b. For Multimedia Traffic with WFQ

Multimedia traffic with WFQ queuing model is given below. The packet delivery ratio for multimedia traffic with WFQ is measured for hello intervals 1,2,3,4 and 5 seconds for mobility speeds 0, 5, 10, 15 and 20 m/sec. The data collected are shown in the Table 4.5. The data in Table 5 is transformed to a graph and is shown in Figure 9.

Table 5 PDR for multimedia traffic

m/s	hello interval=5 sec	Gravitational Search	Invasive Weed Search
0	0.9094	0.9056	0.908
5	0.8063	0.8671	0.8736
10	0.7492	0.818	0.8002
15	0.7463	0.8027	0.7792
20	0.7056	0.7654	0.7433

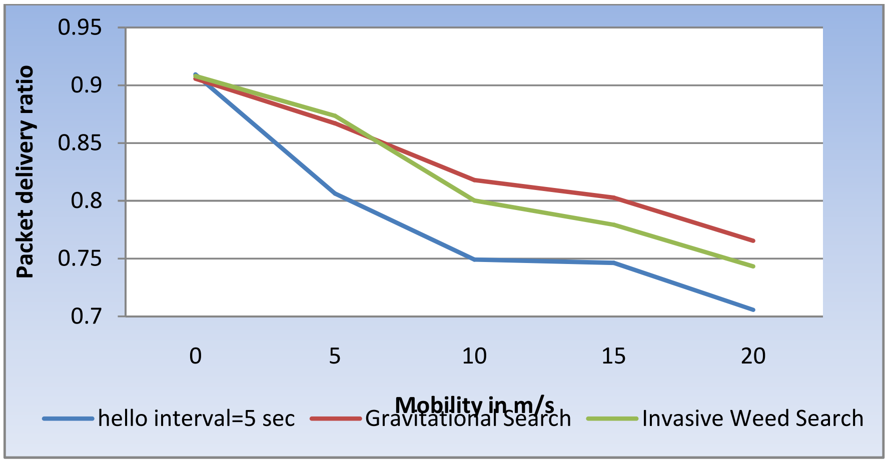

Figure 9 PDR for multimedia traffic

From Figure 9, it is observed that the PDR achieved lowers with increasing mobility. For zero mobility, average PDR achieved is 0.26% lower compared to gravitational search. It is 0.42% lower compared to hello interval 5 sec. At mobility speed of 20 m/sec, the average PDR achieved is 2.97% higher compared to invasive weed search. It is 8.48% higher compared to hello interval 5 sec.

Table 6 End to end delay for multimedia traffic

m/s	hello interval=5 sec	Gravitational Search	Invasive Weed Search
0	11.8296	10.0049	10.1097
5	14.9748	11.7969	13.4738
10	17.7878	13.7524	16.1777
15	19.3278	15.248	15.696
20	20.5158	17.8139	18.9472

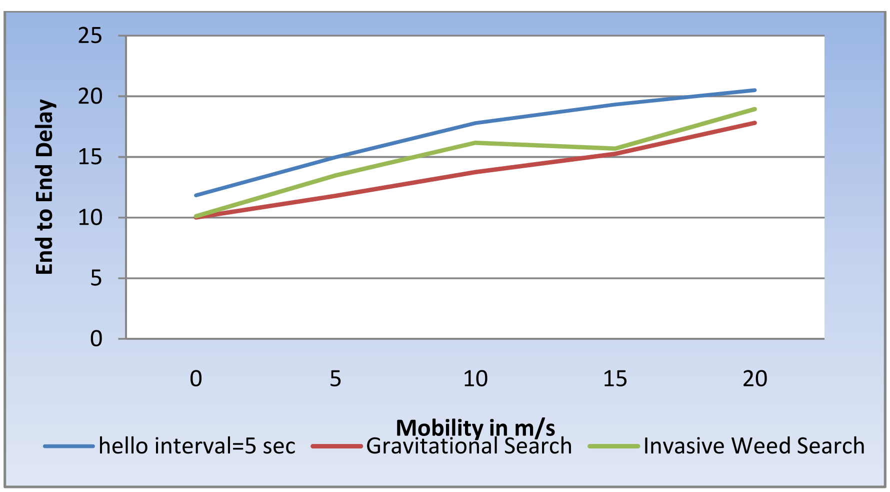

Figure 10 End to end delay for multimedia traffic

The contents of Table 6 are graphically represented and is shown in Figure 10. From Figure 10, it is observed that the end to end delay increases with increasing mobility. For gravitational search, at zero mobility, the average end to end delay achieved is 1.04% lower compared to invasive weed search. It is 15.42% lower than hello interval of 5 sec. For gravitational search, at mobility speed of 20 m/sec, the average end to end delay is 5.98% lower compared to invasive weed search. It is 13.17% lower compared to hello interval of 5 sec.

Table 7 Jitter for multimedia traffic

m/s	hello interval=5 sec	Gravitational Search	Invasive Weed Search
0	1.4701	0.9948	1.1078
5	1.0332	1.3709	1.4224
10	1.0768	1.1833	1.1973
15	1.4819	1.0051	1.3271
20	1.5146	1.1805	1.1404

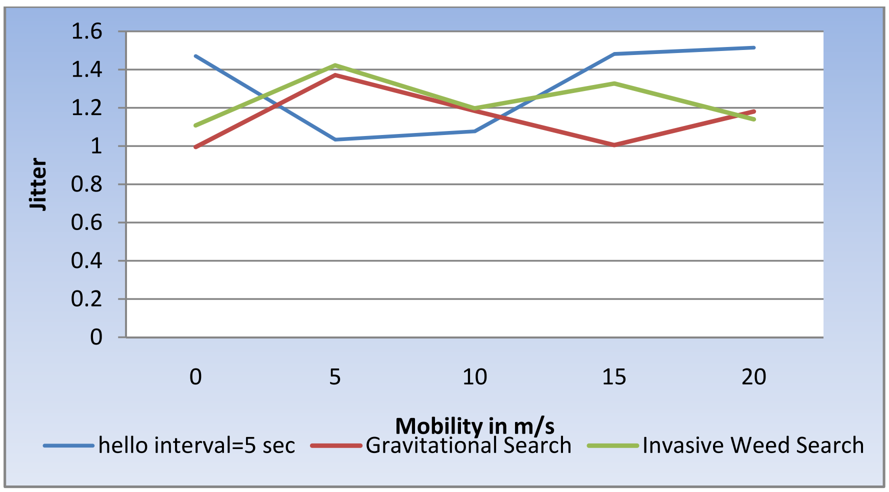

Figure 11 Jitter for multimedia traffic

The contents of Table 7 are graphically represented and is shown in Figure 11. From Figure 11, it is observed that the jitter varies with increasing mobility. For gravitational search, at zero mobility, the average jitter achieved is 10.2% lower compared to invasive weed search. It is 32.33% lower compared to hello interval of 5 sec. For gravitational search, at mobility speed of 20 m/sec, the average jitter achieved is 3.52% higher compared to invasive weed search. It is 22.06% lower compared to hello interval of 5 sec.

Table 8 No. of TC packets for multimedia traffic

m/s	hello interval=5 sec	Gravitational Search	Invasive Weed Search
0	289	315	285
5	401	432	402
10	451	458	450
15	474	468	472
20	513	517	505

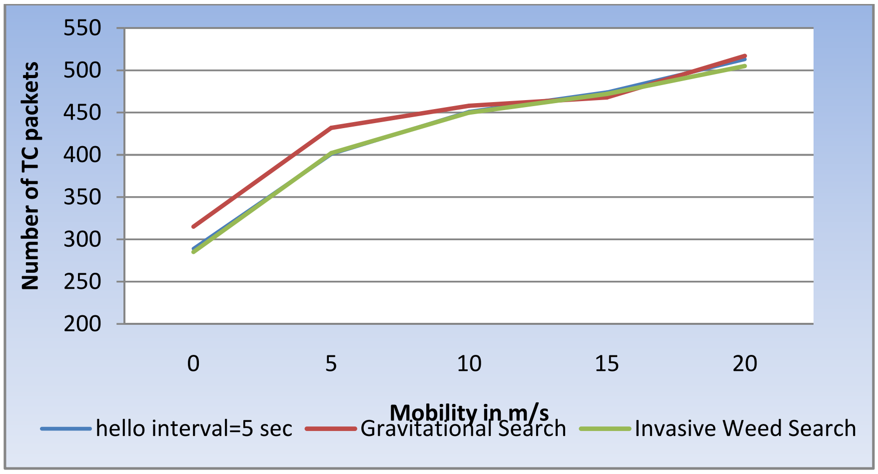

Figure 12 No. of TC packets for multimedia traffic

The contents of Table 8 are graphically represented and is shown in Figure 12. It shows the number of TC packets achieved for gravitational search and invasive weed search techniques for different mobility speeds. Gravitational search, at mobility speed of 5 m/sec the number of TC packets achieved is 10.53% greater compared to invasive weed search. It is 9% higher compared to hello interval of 5 sec.

4 CONCLUSION

1. OLSR generates link state information through nodes elected as MPRs. It is proposed to modify OLSR using IWO and GSA optimization techniques to reduce end to end delay and improve network throughput.

2. For multimedia traffic with FIFO, it is observed that the PDR achieved decreases with increasing mobility. At mobility speed of 5 m/s, the average PDR achieved using gravitational search is 1.93% lesser compared to invasive weed search. It is higher by 6.49% compared to hello interval 5 sec. At mobility speed of 20 m/sec, the average PDR achieved is 0.6% higher compared to invasive weed search. It is 9.1% higher compared to hello interval 5 sec.

3. For multimedia traffic with WFQ, it is observed that the PDR achieved lowers with increasing mobility. For zero mobility, average PDR achieved is 0.26% lower compared to gravitational search. It is 0.42% lower compared to hello interval 5 sec. At mobility speed of 20 m/sec, the average PDR achieved is 2.97% higher compared to invasive weed search. It is 8.48% higher compared to hello interval 5 sec.

4. For multimedia traffic with FIFO, it is observed that the end to end delay increases with increasing mobility. For no mobility, the average end to end delay achieved using gravitation search is higher by 2.7% compared to invasive weed search. It is 14.53% lower compared to hello interval 5 sec. At mobility speed of 20 m/sec, the average end to end delay achieved is 15.17% lower compared to invasive weed search. It is 5.71% lower compared to hello interval 5 sec.

5. For multimedia traffic with WFQ, it is observed that the end to end delay increases with increasing mobility. For gravitational search, at zero mobility, the average end to end delay achieved is 1.04 % lower compared to invasive weed search. It is 15.42% lower than hello interval of 5 sec. For gravitational search, at mobility speed of 20 m/sec, the average end to end delay is 5.98% lower compared to invasive weed search. It is 13.17% lower compared to hello interval of 5 sec.

6. For multimedia traffic with FIFO, it is observed that the jitter varies with increasing mobility. At zero mobility, the average jitter achieved using gravitational search is 8.79%

lower compared to invasive weed search. It is 30.08% lower compared to hello interval 5 sec. At mobility speed of 20 m/sec, the average jitter achieved is 7.55% higher compared to invasive weed search. It is 18.65% lower compared to hello interval 5 sec.

7. For multimedia traffic with WFQ, it is observed that the jitter varies with increasing mobility. For gravitational search, at zero mobility, the average jitter achieved is 10.2% lower compared to invasive weed search. It is 32.33% lower compared to hello interval of 5 sec. For gravitational search, at mobility speed of 20 m/sec, the average jitter achieved is 3.52% higher compared to invasive weed search. It is 22.06% lower compared to hello interval of 5 sec.

8. For multimedia traffic using FIFO, it is observed that the invasive weed search has the lowest number of TC packets compared to gravitational search and hello interval of 5 sec.

9. For multimedia traffic using WFQ, using gravitational search, at mobility speed of 5 m/sec the number of TC packets achieved is 10.53% higher compared to invasive weed search. It is 9% higher compared to hello interval of 5 sec.

10. The gravitational search algorithm's performance is poor for local search technique. This affects the convergence, speed and accuracy. So, it is further required to investigate using other optimization methods like Particle Swarm Optimization (PSO) for improving the efficiency of the OLSR.

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AUTHOR'S PROFILE

Dr. S. Meenakshi Sundaram is working as Professor in the Department of Computer Science and Engineering at Don Bosco Institute of Technology, Bengaluru, India. He obtained Bachelor Degree in Computer Science & Engineering from Bharathidasan University in 1989. He obtained M. Tech in VLSI Systems from National Institute of Technology, Tiruchirappalli in 2006 and Ph.D. in Computer Science & Engineering from Anna University Chennai in 2014. He has presented 3 papers in International Conferences and published 16 papers in International Journals and has attended more than 25 Workshops / Seminars and organized 20 Workshops / Seminars / Faculty Development Programmes. He has 25 years of experience in teaching.

Prof. K.Kalyana Krishnan is working as Associate Professor in the Department of Computer Science and Engineering at M.A.M. School of Engineering, Tiruchirappalli, India. He has obtained M. E. (Computer Science & Engineering) and M.C.A. degrees. He is pursuing Ph.D. at National Institute of Technology, Tiruchirappalli. His area of interest includes Data mining & Data warehousing, Graphics and Multimedia, Automata Languages and Computation, Design and Analysis of Algorithms, Cryptography and Network Security. He has attended 5 AICTE / DRDO funded FDPs. He has attended more than 15 Workshops / Seminars. He has presented 5 papers in National/International Conferences. He has 15 years of teaching experience.

M.S. Divya Shree is studying Under Graduate Degree in Electronics and Communication Engineering at TRP Engineering College (A Unit of SRM Group, Chennai), Irungalur, Tiruchirappalli. Her area of interest includes Digital Electronics, VLSI Design, Simulation and Modelling. She has presented papers in various Technical Symposia and has attended workshops and seminars organized by Engineering Colleges within the State.