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Research Article

Performance Evaluation of OLSR Using Swarm Intelligence and Hybrid Particle Swarm Optimization Using Gravitational Search Algorithm

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Abstract: The aim of this research is to evaluate the performance of OLSR using swarm intelligence and HPSO with Gravitational search algorithm to lower the jitter time, data drop and end to end delay and improve the network throughput. Simulation was carried out for multimedia traffic and video streamed network traffic using OPNET Simulator. Routing is exchanging of information from one host to another in a network. Routing forwards packets to destination using an efficient path. Path efficiency is measured through metrics like hop number, traffic and security. Each host node acts as a specialized router in Ad-hoc networks. A table driven proactive routing protocol Optimized Link State Protocol (OLSR) has available topology information and routes. OLSR's efficiency depends on Multipoint relay selection. Various studies were conducted to decrease control traffic overheads through modification of existing OLSR routing protocol and traffic shaping based on packet priority. This study proposes a modification of OLSR using swarm intelligence, Hybrid Particle Swarm Optimization (HPSO) using Gravitational Search Algorithm (GSA) and evaluation of performance of jitter, end to end delay, data drop and throughput. Simulation was carried out to investigate the proposed method for the network's multimedia traffic.

Keywords: Ad hoc network, gravitational search algorithm, Hybrid Particle Swarm Optimization (HPSO), multimedia traffic, Optimized Link State Routing (OLSR)

INTRODUCTION

Ad hoc networks are a special wireless network mode. A Mobile Ad hoc Network (known as MANET) is a collection of two or more devices equipped with wireless communications, networking capability and mobility. Most MANET applications are concentrated at military, tactical and security related operations. There is no need for fixed infrastructure like base stations/mobile switching centers in MANETs, i.e., all MANET nodes are mobile hosts with the same transmission power and computation abilities. Not having fixed infrastructure makes MANETs reveal antagonistic characteristics. For example, this feature ensures that MANETs are deployed at places where wired networks are impossible while at the same time, this makes MANETs vulnerable to attackers.

Although MANET deployments are sensitive to messages transmitted in the application layer, they lack security mechanism in the network layer or MAC layer. For instance, MANETs are susceptible to many attacks with IEEE 802.11 standard in MAC and PHY layers. Host mobility within MANETs adds complexity in the network layer including routing and security. Such complexity is seen from the fact that mobile devices or nodes security level keeps changing, always as Zhang (2011).

A MANET is a self-configuring mobile router (associated hosts) network connected by wireless links. Some main MANET features are listed below (Shrivastava *et al*., 2005):

- MANETs are formed without infrastructure
- It follows dynamic topology where nodes join/leave network any time and multi-hop routing changes when nodes join/leave network
- It has limited physical security and so increasing security is a concern
- Every MANET node assists packet routing in the network
- Limited Bandwidth or Power

Conventional wired networks routing protocols are based on distance vector or link state routing algorithms. Such algorithms need periodic routing advertisements for router broadcasting. Each router broadcasts to all neighboring routers its view of distance to other nodes in distance vector routing; neighboring routers compute shortest path to nodes. In link-state routing, a router broadcasts to neighboring nodes the status of each of adjacent links; neighboring

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routers compute shortest distance to nodes based on complete network topology.

Such conventional routing algorithms are inefficient for dynamic changes in ad-hoc networks. Routers do not move around and rarely leave or join a network in conventional networks. In a mobile nodes environment, changing topology triggers frequent route re-computation but overall convergence to stable routes may be infeasible due to high mobility. Hence, MANET routing must consider node mobility (Mueller *et al*., 2004).

As Optimized Link State Protocol (OLSR) is a proactive routing protocol, routes are available when needed. It is a pure link state protocol's optimization version. Hence, topological changes flood topological information to available network hosts. To reduce network overhead it uses Multi Point Relays (MPR) the idea being to reduce broadcasts flooding by lowering same broadcast in some network regions. This chapter deals with MPR details later. Another way to reduce is by providing the shortest path. Reduction of time interval for control messages transmission ensures more reactivity to topological changes.

OLSR uses Hello and Topology Control (TC) messages. Hello messages find information about link status and host's neighbors. Hello message constructs the MPR Selector set describing which neighbor is using this host to act as MPR. The host has its own set of MPRs from this information. Hello messages are sent one hop away, but TC messages are broadcast through the entire network. TC messages broadcast information about advertised neighbors including the MPR Selector list. TC messages are broadcast periodically and only MPR hosts forward TC messages (Aleksandr, 2004).

Modelling multimedia traffic is challenging. Multimedia traffic has different characteristics unlike ordinary network traffic which is modelled using Poisson distribution function; this can be modelled better using M/Pareto distribution (Kumar and Singh, 2011; Kumar, 2003). A Multimedia traffic characteristic is that it is busty and shows self-similarity. Conventional network traffic was modelled using Poisson distribution and similar mathematical functions. Application of this technique to multimedia traffic was unsuccessful.

This study proposes to modify OLSR using swarm intelligence, Hybrid Particle Swarm Optimization (HPSO) with Gravitational search to lower end to end delay and improve network throughput. Simulation has been carried out for multimedia traffic and video streamed network traffic and much improved results have been obtained over the existing methods.

LITERATURE REVIEW

A survey algorithm simulating bee swarm intelligence was proposed by Karaboga and Akay (2009). Bee swarm intelligent behavior inspired researchers in the last decade to develop new algorithms. The study presents a survey of algorithms based on intelligence of bee swarms and their applications.

Kumar and Singh (2011) proposed routing optimization techniques using swarm intelligence which introduced the preliminary studies for MANETs and an emerging routing optimization technique inspired by the biological concept of Swarm Intelligence (SI).

Saleem *et al*. (2011) introduced SI based routing protocol for Wireless Sensor Networks (WSN) survey and future directions. The authors discussed SI's general principles and its application to routing. They also introduced a new taxonomy for routing protocols in WSN using it to classify surveyed protocols. It ended with a critical analysis of the status of the field, pointing out many fundamental issues related to misuse of scientific methods and evaluation procedures identifying future research directions.

Wu *et al*. (2009) proposed load-based route discovery through searching range adaptation for MANET throughput improvement. Investigating and analyzing link distance impact on end-to-end throughput in mutilated multi hop wireless networks was studied. Analysis simulation proved that changing link distance affected network throughput.

Edward *et al*. (2011) suggested Hybrid approaches in Network Optical Routing with QoS based on GA and PSO which defined hybrid approaches and performance to solve NP-complete routing problem.

Priyadharshini and Rubini (2012) introduced integration of route life prediction algorithm and PSO algorithm to select reliable MANET routes. The authors implemented an algorithm integrating route life prediction algorithm with PSO algorithm. As PSO is used for network centric localization purpose, this generates in-network navigational decisions obviating centralized control and reducing congestion and delay. Hence, this approach is effective in a MANET scenario involving node mobility, huge deployment and energy limits.

A mechanism to improve MANET packet delivery ratio and throughput was proposed by Shakkeera (2010), based on an OLSR adapted optimization scheme. The greedy algorithm is used for MPR selection in traditional OLSR which creates nodes overlap resulting in reduced network performance. An optimization scheme selects neighbor nodes in the proposed method through which control packets are transmitted reducing network control overhead. The new method introduced "Necessity First Algorithm (NFA)" to select optimal MRPs.

Liang and Pond (2011) suggested using linear optimization and swarm intelligence heuristic to locate MANET routes. The study aimed to explore potential routing protocols for MANET software development of peer-to-peer system used in the battle field radio communications. MANET consists of many mobile devices communicating over radio. A MANET with Cell Phones (MANET-WCP) is the underlined research's physical infrastructure. A big challenge in such networks is locating a route between source node and destination node via intermediate mobile nodes. The author presented a routing protocol using Swarm Intelligent Heuristic (SIH) for MANET-WCP which refers to protocol as Swap Intelligent Heuristic Associate Based Routing (SIH-ABR). This replaces route selection mechanism with an ant colony optimization heuristic. The objectives of this approach include:

- To test SIH-ABR adaptation
- Verify service efficiency
- Explore scalability with many nodes in a land battle scenario

Ad-Hoc networks have many problems categorized as optimization problems like energy routing, consumption, localization and node deployment. Many researchers attempted to offset such issues resulting in a new routing algorithms class on Swarm Intelligence coming up. Ant Colony algorithm is inspired by ants self-organizing behavior under Swarm Intelligence. A survey based on various ant colony based routing algorithms for WSN and MANETs was introduced by Shirkande and Vatti (2013). A comparison of algorithms based on performance metrics, pheromone function is made to select next node, simulator used and energy awareness.

Shrestha and Tekiner (2009) proposed MANET Routing Protocols for Mobility and Scalability which focused on the performance of reactive and proactive MANET routing protocols like AODV, DSR, TORA and OLSR. MANET is an Ad Hoc network and its functionality here is based on 802.11 IEEE standards to communicate in a discrete/disperse environment without central management. Hence, the main investigation was on MANET's discrete feature and routing. MANET's main issue is link breakage at specific moments and link re-generation at certain state consisting of mobile routers, i.e., it can roam independently and arbitrarily. Hence, the author compared performances of selected MANET routing protocols of varying network sizes with increasing area and node size to check routing process mobility and scalability.

Performance of ad hoc network routing protocols in IEEE 802.11 which focused on performance evaluation of such categories using NS2 simulations was presented by Broch *et al*. (1998). The first concerns distributed operation, loop-freedom, security and sleep period operation. The second assesses performances of various routing protocols suggested. End-to-End data delay, packet delivery ratio and routing load were listed. Comparative study was with many networking context consideration with results revealing the appropriate routing protocol for data and voice communication services.

A multi-objective approach for proactive routing in MANET was developed by Guo *et al*. (2011). Three routing objectives were considered: reducing average end-to-end delay, increasing network energy life and maximizing packet delivery ratio. Three routing metrics were developed: each node's mean queuing delay, a node's energy cost and links stability. For the suggested multi-objective approach, the authors created efficient prediction methods:

- Predicting queuing delay/energy consumption using double exponential smoothing
- Predicting residual link life using distributions heuristic of MANET link life

Thorough simulation (using NS2) compared the multi-objective OLSR with current OLSRs. The results reveal that the former is effective in locating optimal routing through trade-offs among proposed objectives.

METHODOLOGY

This study proposes modified OLSR using swarm intelligence, Hybrid PSO (HPSO) with Gravitational Search Algorithm to lower end to end delay and improve network throughput. Simulation was tried out for multimedia traffic and video streamed network traffic.
The methods used are:

PSO: PSO initializes with random particles or solutions cluster searching for optima through generations updating. In each iteration, two "best" particle values are updated. The first is called pbest-the best solution (fitness) achieved till then. Another PSO tracked "best" value obtained till then by any population particle i.e., the global best and is called gbest. Another best value used is 'lbest' which is the best value of particle participating with topological neighbors (Shi and Eberhart, 1998).

PSO is economical computationally needing only primitive mathematical operators and optimizes network clustering and as such networks have limited resources. Particle positions/velocities are generated randomly at the start. The algorithm proceeds iteratively, updates velocities and positions of all particles as follows:

$$v_i^d = wv_i^d + c_1 r_1 \left(p_i^d - x_i^d \right) + c_2 r_2 \left(p_g^d - x_i^d \right)$$
$$x_i^d = x_i^d + v_i^d$$

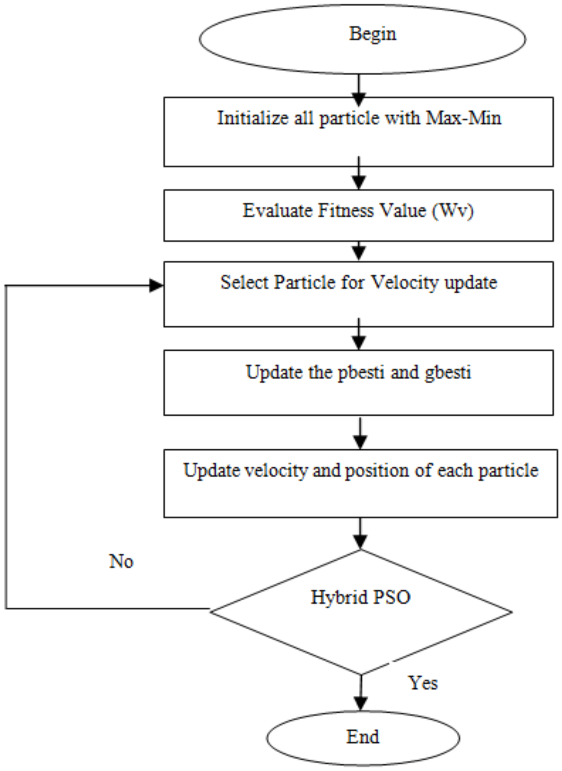

Fig. 1: Flowchart of optimizing using particle swarm optimization

where, d is number of dimensions, i the size of the population, w the inertia weight, c_1, c_2 positive constants called cognitive parameter and social parameter, respectively, r_1 and r_2 random values in range (0, 1). v_i^d is new velocity of i^{th} particle computed, based on the particle's previous velocity, distance between previous best position and current position and distance between best swarm particle which calculates the particle's new position.

In conventional PSO, when gbest is far from the global optimum then particles get trapped in the gbest region's local optimum. To offset this, particles are moved to a bigger search space to fly and pbest position of a particle is updated based on pbest position of swarm particles increasing the ability to avoid local optimum and improve swarm diversity. The particle's updating velocity is given by:

$$V_i^d = w * v_i^d + c * rand_i^d * \left(pbest_{fi(d)}^d - x_i^d \right)$$

where $f_i = \left[f_i(1), f_i(2), ..., f_i(d) \right]$ refers to pbest that particle i is used and is the dimension of particles pbests. Two particles are randomly selected and the particle whose velocity is updated is excluded. The particles pbests fitness values are compared and the dimension of the better one is chosen to update velocity (Agarwal *et al*., 2005). The flowchart for optimization using Particle Swarm Optimization is given in Fig. 1.

Hybrid PSO: In HPSO, PSO component guides search to promising regions of the search space using iterative improvement methods to exploit such regions. HPSO's basis is gbest PSO algorithm. Other variants could have been selected and lead to different behavior. The velocity update rule used is that of Equation and w (t) is modified using nonlinear function:

$$w(t) = (1 - g(t))^{w_e}.\left(w_{initial} - w_{final}\right) + w_{final}$$

which calculated inertia weight at iteration t, where g (t) returns many in the range (0; 1) and w_e; $w_{initial}$; $w_{final} \in \mathbb{R}$ are constants. The function g (t) returns 0 at search start and increases each iteration till it reaches 1 at search end. The constant $w_{initial}$; is the initial value of inertia weight and w_{final} desired value of inertia weight at the end of the search process. If a linear varying inertia weight is desired, it is set to 1. A constant inertia weight is obtained if $w_{initial}$ and w_{final} are equal. The convergence criterion is also important for the new algorithm.

Here, it is met for n-dimensional objective function f, if $dmax = d_{domain} < 0{:}001, where\ d_{max} \in \mathbb{R}+$ $is\ the\ maximal\ Euclidean\ distance\ to\ x*$ over current particles positions. The value d_{domain} = $\sqrt{n(b_u - b_l)^2}$ is the length of the search space diameter. NMS and PDS are used as iterative improvement methods, respectively (Gimmler *et al*., 2006).

The pseudo code for the structure of the PSO model is given in Fig. 2 and t the pseudo Code for the structure of the HPSO is given in the Fig. 3.

Genetic 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:

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, R. 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

Algorithm 1 Particle swarm optimization.

Require: [Default recommended values for FMS]
– $\mathbf{c}_1, \mathbf{c}_2$: individual/social behavior weights; $[\mathbf{c}_1 = \mathbf{c}_2 = 2]$
– **m**: swarm size; $[\mathbf{m} = 5]$
– **I**: number of iterations; $[\mathbf{I} = 50]$
– $\mathbf{F}(\Psi \rightarrow \mathbb{R})$: fitness function; $[\mathbf{F}(\Psi \rightarrow \mathbb{R}) = 2\text{–fold } CV\ BER]$
– **W**: Inertia weight $\mathbf{W} = (1.2, 0.5, 0.4)$
Set decrement factor for W $(w_{dec} = \frac{w_{start} - w_{end}}{I \times w_f})$
Initialize swarm $(\mathbf{S} = \{\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_m\})$
Compute $f_{\mathbf{x}_{1,\ldots,m}} = F(\mathbf{x}_{1,\ldots,m})$ (Section 3.3)
Locate leader $(\mathbf{p}_g)$ and set personal bests $(\mathbf{p}_{1,\ldots,m} = \mathbf{x}_{1,\ldots,m})$
$t = 1$
while $t < I$ **do**
  for all $\mathbf{x}_i \in \mathbf{S}$ **do**
    Calculate velocity $\mathbf{v}_i$ for $\mathbf{x}_i$(Equation (1))
    Update position of $\mathbf{x}_i$ (Equation (2))
    Compute $f_{\mathbf{x}_i} = F(\mathbf{x}_i)$
    Update $\mathbf{p}_i$ (*if necessary*)
  end for
  Update $\mathbf{p}_g$ (*if necessary*)
  if $t < \lfloor I \times w_f \rfloor$ **then**
    $W = W - w_{dec}$
  end if
  t^{++}
end while
return $\mathbf{p}_g$

Fig. 2: The structure of the PSO model

begin
  initialise
  while (not terminate-condition) **do**
    begin
      evaluate
      calculate new velocity vectors
      move
      breed
    end
end

Fig. 3: The structure of the hybrid model

force acting on system divided by inertia mass (Rashedi *et al*., 2009). The flowchart for the general principle of GSA is given in Fig. 4.

SIMULATION STUDY AND RESULTS

The simulation setup using OPNET Modeler consists of 20 nodes. The nodes are spread over 2000 by 2000 m 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 carried out for 400 sec. The results obtained by the proposed methods are as follows: The Fig. 5 to 8 indicates the simulation results of the OLSR, proposed OLSR, PSO and GAPSO using OPNET simulator. The

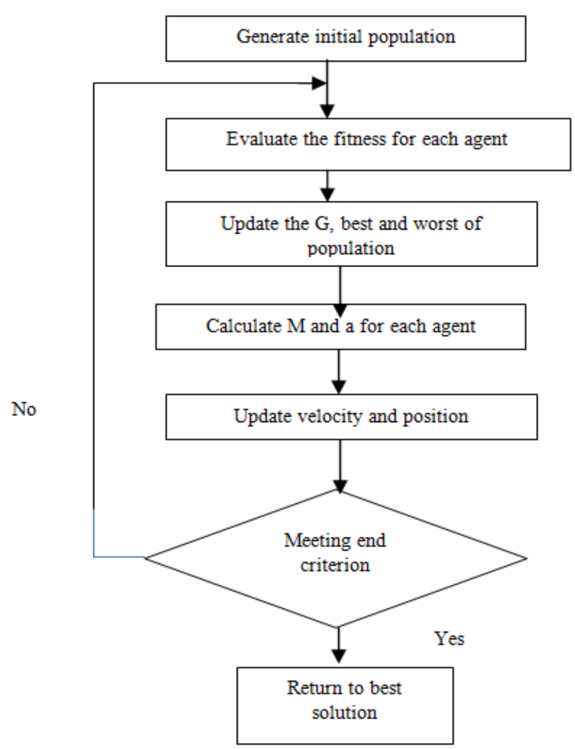

Fig. 4: Flow chart of general principle of GSA

evaluation of parameters: jitter time average in seconds, the time average of data dropped in bits per second,

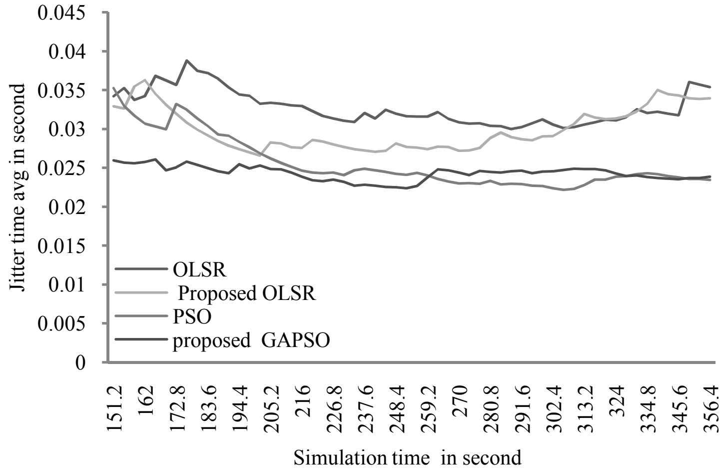

Fig. 5: Jitter time average in second

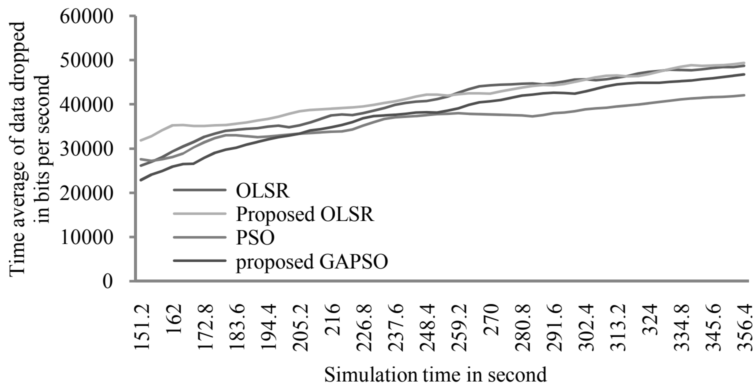

Fig. 6: Time average of data dropped in bits per second

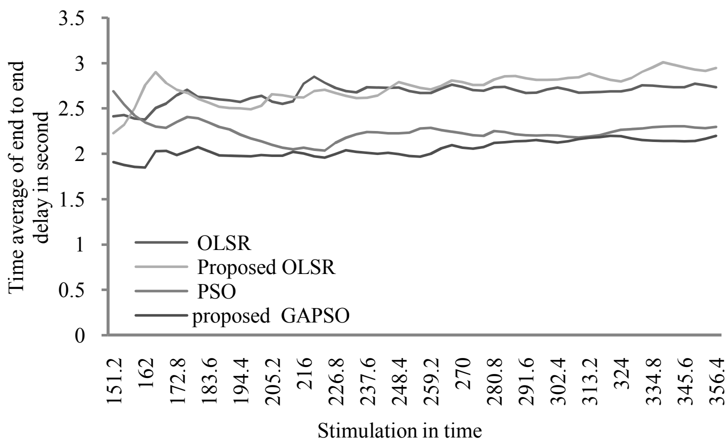

Fig. 7: Time average of end to end delay in second

time average of end to end delay in seconds and time average of throughput are studied in respect of OLSR using Swarm intelligence and HPSO using GSA.

The Fig. 5 above indicates that there is a decrease in percentage of average Jitter time in sec using HPSO as compared to OLSR by 25.7%, the proposed OLSR by 18.84% and PSO by 4.89%.

Figure 6 indicates that there is decrease in percentage of average Time for Data drop in bits per second using HPSO as compared to OLSR by 6.7%,

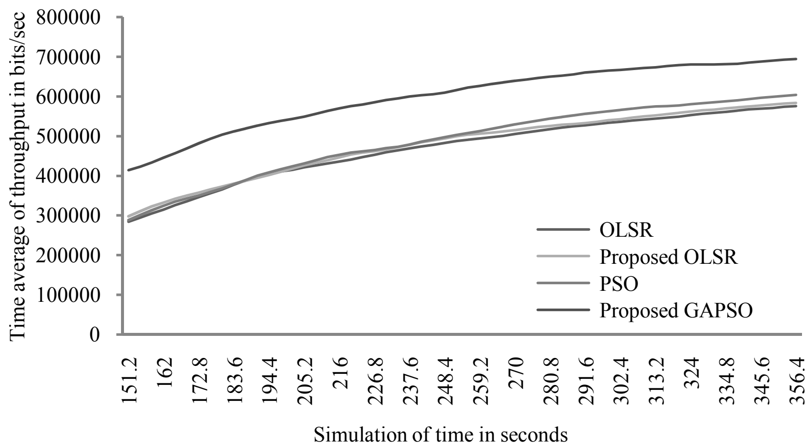

Fig. 8: Time average of throughput

the proposed OLSR by 9.29% and an increase of 4.3% using PSO.

The Fig. 7 indicates that there is a decrease in percentage for average end to end delay in sec using HPSO as compared to OLSR by 22.98%, proposed OLSR by 24.76% and PSO by 8.5%.

Figure 8 indicates that there is an increase in percentage for time average of throughput in bits/sec using HPSO as compared to OLSR by 27.51%, the proposed OLSR by 25.24% and PSO by 22.89%.

CONCLUSION

This study proposes to evaluate the performance of OLSR using swarm intelligence and HPSO with Gravitational search algorithm to lower the jitter time, data drop and end to end delay and improve the network throughput. Simulation was carried out for multimedia traffic and video streamed network traffic. The performance evaluation shows a decrease in percentage for average Jitter time in sec using HPSO as compared to OLSR by 25.7%, proposed OLSR by 18.84%, PSO by 4.89%. There is a decrease in percentage of average Time for Data drop in bits per second using HPSO as compared to OLSR by 6.7%, proposed OLSR by 9.29% and an increase of 4.3%. using PSO. There is also a decrease in percentage for average end to end delay in sec using HPSO as compared to OLSR is 22.98%, proposed OLSR by 24.76% and PSO by 8.5%. There is an increase in percentage for time average of throughput in bits/sec using HPSO as compared to OLSR by 27.51%, proposed OLSR by 25.24% and PSO by 22.89%. The results prove that the modified HPSO using GSA is better in improving the throughput with reduced jitter, end to end delay and packet data drop as compared to the traditional OLSR.

REFERENCES

Agarwal, S., J. Padhye, V. Padmanabhan, L. Qiu, A. Rao and B. Zill, 2005. Estimation of link interference in static multihop wireless networks. Proceeding of ACM Internet Measurement Conference (IMC), pp: 28-28.

Aleksandr, H., 2004. Comparing AODV and OLSR routing protocols. Proceeding of Seminar on Internetworking, Telecommunication Software and Multimedia Laboratory, Helsinki University of Technology, Sjokulla, pp: 1-9.

Broch, J., D.A. Maltz, D.B. Johnson, Y.C. Hu and J. Jetcheva, 1998. A performance comparison of multi-hop wireless ad hoc network routing protocols. Proceedings of the 4th Annual ACM/IEEE International Conference on Mobile Computing and Networking, pp: 85-97.

Edward, G., C. Yeison and E. Paola, 2011. Hybrid approaches in network optical routing with QoS based on genetic algorithms and particle swarm optimization. Int. J. Network Secur., 2(4).

Gimmler, J., T. Stützle and T.E. Exner, 2006. Hybrid particle swarm optimization: An examination of the influence of iterative improvement algorithms on its behaviour. Proceeding of the 5th International Conference on Ant Colony Optimization and Swarm Intelligence (ANTS'06), pp: 436-443.

Guo, Z., S. Malakooti, S. Sheikh, C. Al-Najjar and B. Malakooti, 2011. Multi-objective OLSR for proactive routing in MANET with delay, energy and link lifetime predictions. Appl. Math. Modell., 35(3): 1413-1426.

Karaboga, D. and B. Akay, 2009. A survey: Algorithms simulating bee swarm intelligence. Artif. Intell. Rev., 31(1-4): 61-85.

Kumar, R., 2003. A protocol with transcoding to support QoS over internet for multimedia traffic. Proceeding of International Conference on Multimedia and Expo (ICME '03), pp: 1-465.

Kumar, A. and R. Singh, 2011. Mobile ad hoc networks routing optimization techniques using swarm intelligence. Int. J. Res. IT Manage., 1(4).

Liang, Y. and G. Pond, 2011. Using linear optimization and swarm intelligent heuristic to find a route for MANET. Proceeding of 7th International Conference Natural Computation (ICNC), 4: 2368-2372.

Mueller, S., R.P. Tsang and D. Ghosal, 2004. Multipath Routing in Mobile Ad Hoc Networks: Issues and Challenges. In: Calzarossa, M.C. and E. Gelenbe (Eds.), MASCOTS 2003. LNCS 2965, Springer, Berlin, Heidelberg, pp: 209-234.

Priyadharshini, C. and K.T. Rubini, 2012. Integration of route lifetime prediction algorithm and particle swarm optimization algorithm for selecting reliable route in MANET. Proceeding of International Conference on Computing, Communication and Applications (ICCCA), pp: 1-6.

Rashedi, E., H. Nezamabadi-Pour and S. Saryazdi, 2009. GSA: A gravitational search algorithm. Inform. Sci., 179(13): 2232-2248.

Saleem, M., G.A. Di Caro and M. Farooq, 2011. Swarm intelligence based routing protocol for wireless sensor networks: Survey and future directions. Inform. Sci., 181(20): 4597-4624.

Shakkeera, 2010. Optimal path selection technique for flooding in link state routing protocol using forwarding mechanisms in MANET. Proceeding of International Conference on Communication and Computational Intelligence (INCOCCI), pp: 318-323.

Shi, Y. and R.C. Eberhart, 1998. Parameter selection in particle swarm optimization. Lect. Notes Comput. Sci., 1447: 591-600.

Shirkande, S.D. and R.A. Vatti, 2013. ACO based routing algorithms for ad-hoc network (WSN, MANETs): A Survey. Proceeding of International Conference on Communication Systems and Network Technologies (CSNT), pp: 230-235.

Shrestha, A. and F. Tekiner, 2009. On MANET routing protocols for mobility and scalability in parallel and distributed computing. Proceeding of IEEE International Conference on Applications and Technologies, pp: 451-456.

Shrivastava, A., A.R. Shanmogavel, A. Mistry, N. Chander, P. Patlolla and V. Yadlapalli, 2005. Seminar, Overview of Routing Protocols in MANET's and Enhancements in Reactive Protocols. Retrieved form: http://cs.lamar.edu/faculty/disrael/COSC5100/Seminar.pdf.

Wu, X., G. Ding and W. Zhu, 2009. Load-based route discovery through searching range adaptation for MANET throughput improvement. IEEE T. Veh. Technol., 58(4): 2055-2066.

Zhang, Z., 2011. A novel secure routing protocol for MANETs, mobile ad-hoc networks: Protocol design. University of Southern Queensland, Australia, pp: 455-466.