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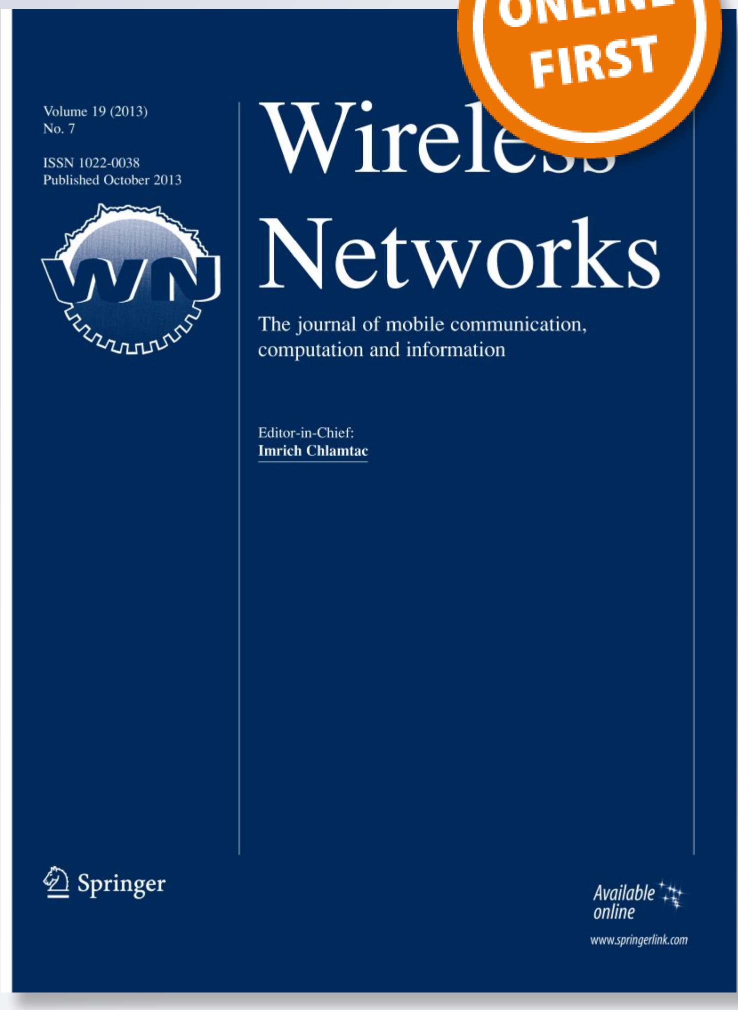
ONLINE FIRST

Wireless Networks
The Journal of Mobile Communication, Computation and Information

ISSN 1022-0038

Wireless Netw
DOI 10.1007/s11276-019-02170-9



Springer

Wireless Networks
https://doi.org/10.1007/s11276-019-02170-9

A hybrid approach for the optimization of quality of service metrics of WSN

Shalli Rani[1] · M. Balasaraswathi[2] · P. Chandra Sekhar Reddy[3] · Gurbinder Singh Brar[4] · M. Sivaram[5] · Vigneswaran Dhasarathan[6,7]

Abstract

The core objective behind this research paper is to implement a hybrid optimization technique along with proactive routing algorithm to enhance the network lifetime of wireless sensor networks (WSN). The combination of two soft computing techniques viz. genetic algorithm (GA) and bacteria foraging optimization (BFO) techniques are applied individually on destination sequence distance vector (DSDV) routing protocol and after that the hybridization of GA and BFO is applied on the same routing protocol. The various simulation parameters used in the research are: throughput, end to end delay, congestion, packet delivery ratio, bit error rate and routing overhead. The bits are processed at a data rate of 512 bytes/s. The packet size for data transmission is 100 bytes. The data transmission time taken by the packets is 200 s i.e. the simulation time for each simulation scenario. Network is composed of 60 nodes. Simulation results clearly demonstrates that the hybrid approach along with DSDV outperforms over ordinary DSDV routing protocol and it is best suitable under smaller size of WSN.

Keywords Optimization techniques · Quality of service · DSDV routing protocol · Network lifetime · Wireless sensor networks

1 Introduction

Numerous sensor nodes deployed in field of wireless sensor networks, facilitate the working of diverse applications having different needs. WSN provides many open opportunities in several areas like military, transportation, health care, industry etc. [1–3]. In the last few years, an intensive research has been conducted on the various activities of sensors such as: data gathering, communication and processing, filtering, compression etc. in which coordination among the nodes is must. However, WSN have many constraints due to the tiny size, low memory, low processing power, limited battery and bandwidth. Among them main constraints are time and energy. New techniques are still required to optimize the energy conservation and real time communication techniques. Along with these constraints, deployment of the nodes in the typical scenarios, pose a major challenge in the protocol stack of networks. In the network layer, routing is the primary concern for the researchers to conserve the energy of the nodes to enhance the network lifetime which is necessary

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Published online: 25 October 2019

to transmit the data to the sink or the base station (BS). Most of the times, in these scenarios, nodes are not able to transmit the data directly to the BS or the sink, and they require the help of some other nodes for the transmission of data in indirect way i.e. with the help of relay nodes. It is very challenging process in WSN due to some intrinsic features that discriminate them from the traditional ad-hoc networks: (1) Number of nodes deployed in WSN is very large in number (hundreds to thousands) as compared to ad-hoc networks. (2) Global addressing scheme is not possible for the unique identification of the nodes. (3) Various applications of WSNs have different needs and their requirements are quite different from each other. (4) Gathered data comes from several sources and from several areas which means high heterogeneity of data. (5) A huge amount of data from several nodes may have redundancy and which is required to be removed, up to some extent to enhance the channel utilization and to enhance the network lifetime. (6) A large number of sensors needs more management as they are constrained in energy, memory and processing [4]. Due to the above mentioned differences, many novel approaches have been proposed for the routing issues in WSNs. On the basis of network structure [5], routing can be categorized as network, location based and hierarchical routing. In the flat category, all nodes are on the same level and they play equal role in routing process while in the hierarchical (for energy efficiency and scalability), some nodes act as the cluster heads (CHs) and other nodes transmit their data to the CHs. Recently an efficient approach used for this purpose is EEICCP [6]. In location based routing, nodes are location aware which helps in the energy efficient routing. Among the three categories, the hierarchical approach is considered as the best approach in the energy efficient communication and scalability [7]. In this approach clusters are formed to gather the data via CHs and nodes having shortest distance to the CHs mark them as the relay nodes. Till date, many cluster based algorithms have been proposed and from different perspectives. Most of the approaches are empirical in nature and their aim is to generate the minimum number of clusters and minimum distance among the nodes while others prove that large number of clusters save more energy as described in LEACH and ERP [8]. Even after a remarkable improvement in the energy attribute of the WSNs, still many nodes drain their battery quickly due to dynamic clustering. Many biological systems require scalability, and a feature to stand against the failures. These systems have motivated the researchers to develop the evolutionary algorithms which are based on cluster based communications. The primary goal of these algorithms is to dynamically form the clusters and enhance the network lifetime. These algorithms have optimized the energy attribute but at the cost of stability. This limitation is due to the fitness function used in these scenarios. To achieve the optimization objectives, an alternative approach, meta-heuristic was also adopted by the researchers. Swarm intelligence algorithms are developed to exploit insects' phenomenon of strength solutions. Bacteria forging optimization (BFO) is used to tune in the special attributes of PID controller [9]. In comparison to traditional algorithms, BFO approach is easy to implement, optimized for scientific research and is best for engineering applications. It is population based technique to optimize the non-linear functions. By considering the benefits of BFO and genetic algorithms, in this paper, we have employed a hybrid approach to enhance the network lifetime of WSN. The motivation behind the work is discussed as below:

1. Utilization of genetic algorithms results in better random deployment of nodes, therefore we have used GA technique in proposed hybrid approach.
2. Use of GA also helps in locate minimum number of aggregate nodes while sending data to its base station which results in decrease in overall communication distance and minimization of energy.
3. The combination of two meta-heuristic approaches genetic algorithm and bacteria foraging optimization helps to achieve shortest and secure path to maximize the life time of the network, which we have proposed in this paper.

Rest of the paper is organized as follows: Sect. 2, reviews the some hierarchical, Meta heuristic and heuristic algorithms along with their merits and demerits. Energy expenditure model is elaborated in section and performance metrics are presented in Sect. 3. The novel hybrid approach is discussed in Sect. 4. Section 5, throws light on the results accessed from the simulations performed in

Table 1 Literature review

References	Technique	Merits	Problem
Tripathi et al. [10]	DSDV over wireless sensor network in both static and dynamic environment	Delay is constant when source and sink nodes are mobile and In static environment if density of nodes/km^2 is medium then delay is very less	Under static environment it is difficult to find out exact number of sensor nodes/density that can be deployed in/km^2 in order get less delay
Sengar and Shrivastav [11]	Evaluation of AODV and DSDV routing protocol in WSN	DSDV is far better than AODV protocol when compared on the basis of delay metric	Unable to predict, which protocol suits better under a particular application of WSN
Kambayashi [12]	Ant colony optimization technique is implemented on DSDV, AODV, etc. in dynamic environment	Forward ants help in reducing overhead of backward ants by updating the routing table of intermediate nodes in DSDV	In a dynamic environment, the technique of proactive ant-like agents does not perform well due to the short lives of the route
Ben-Othman and Yahya [13]	Energy efficient and QoS aware multipath routing protocol for WSN	Proposed protocol helps in reducing delay and increase in packet delivery ratio than MCMP protocol	More metrics need to be evaluate by varying network size, path length etc.
Bara'a and Khalil [8]	Biologically inspired evolutionary based clustered routing protocol is implemented in WSN	Author formulates new fitness function of evolutionary algorithm in order to cope with stability time of WSN and success in the same	Need to implement on both pure heterogeneous and homogenous environment and then compare the stability period of WSN
Kenchannavar et al. [14]	Jumper Firefly Algorithm is applied in order to achieve better lifetime in WSN	Optimized the lifetime of the network by applying bio-inspired algorithm along with dynamic and centralized clustering algorithm	More QoS related parameters needs to be considered along with energy and also need to implement on some application specific environment

MATLAB followed by the concluding observation in Sect. 6.

2 Related work

Table 1, demonstrates various optimization techniques used by researchers in order to optimize the lifetime of WSN. It has been observed from the survey that bio-inspired algorithms along with routing techniques provides better results in terms of various parameters of WSN like throughput, PDR, bit error rate, routing overhead, congestion, and end to end delay.

In [10] DSDV routing protocol was implemented in both static as well as in dynamic environment. Simulation results show that delay remains constant in dynamic environment and in static environment if number of nodes/km^2 is medium then delay decreases as compared to dynamic environment. It is also very difficult to predict number of nodes/km^2 in order to minimize the value of delay metric. DSDV is far better in [11] than AODV protocol when compared on the basis of Delay metric in WSN. Ant colony optimization technique is implemented on DSDV, AODV, etc. in dynamic environment [12]. In the proposed technique forward ants help in reducing overhead of backward ants by updating the routing table of intermediate nodes in DSDV. Energy efficient and QoS aware multipath routing protocol for WSN was proposed by author in [13] that results in reduction of delay and increase in packet delivery ratio than MCMP protocol. In [8] biologically inspired evolutionary based clustered routing protocol is implemented in WSN, in this author formulates new fitness function of evolutionary algorithm in order to cope with stability time of WSN. Other bio-inspired algorithm along with dynamic and centralized clustering algorithm was proposed by author in [14] in order to achieve better lifetime in WSN.

Authors in [15] have solved the scheduling problem by linear programming and simulated the algorithm on varied number of nodes, network length and target points. A GA-TBR [16] is used to gather the state information from smart grid in WSN and optimized the quality of service metrics

(QoS). Self-organizing clustering method is proposed in literature to optimize the WSN [17]. K-coverage model based on genetic algorithm for network lifetime maximization is formulated in search of optimal path and energy consumption [18]. Different genetic algorithm and performance evaluation is done in past to evaluate the most energy efficient algorithm [19].

However, none of the described algorithm has worked on the utilization of the hybrid techniques over GA which gives the best results in terms of energy conservation. In this paper we have proposed the novel technique to maximize the lifetime of the network by the hybrid model.

3 Network model and performance attributes

To compute the energy consumption, first order radio model, [11] is used like LEACH. This model uses E_{elec} = 50 nj/bit by the electronic component. But the energy consumption used in transmission and reception, is based on the distance. Distance is based on the free space and multi path fading channel. Radios are proficient with the adjustable power levels to make it sure that data is transmitted to the recipients properly. To conserve the energy, radios can be turned off when they are not in use. For the transmission of l bit data, from source to destination, the following equations are used for the energy computation:

$$E_{Tx}(\ell, d) = \ell * E_{elec} + \ell * E_s * d^2 \quad \text{if } d \le d_o \tag{1}$$

$$\text{Else } \ell * E_{elec} + \ell * E_l * d^4 \tag{2}$$

where the shortest distance can be computed as $d_o = \sqrt{E_l/E_s}$. For the reception of data, the energy consumed is computed as $E_{Rx} = \ell * E_{elec}$. For the data aggregation, a beam forming approach can be used and computation of the energy can be done accordingly.

3.1 Performance attributes

From the literature survey, it is found that probability of the node to be elected as the cluster head depends upon the function of spatial density; however nodes should be deployed uniformly over the network field. In this case, the clustering is also optimal and consumption of energy is minimized. Sometimes, when the nodes are deployed randomly over the field, it is necessary to find the optimal path to transmit the data to enhance the network lifetime. In that case, the algorithm should enhance the stability period. In this paper, we have used the hybrid technique over DSDV routing protocol which has also enhanced the stability period. To compute the network lifetime, the time interval of is counted from the start of the operation till the death of first node in the network. It can be computed from both the ends, (1) when the first node dies and (2) when the last node depleted its energy. The computation from the first method shows the stability period. To work for the long time, to retrieve data in real time applications, it is required that network is stable. Number of dead nodes per round, reflects the nodes, which have depleted their energy totally and their function is carried out by other nodes.

4 The proposed approach

The genetic and meta-heuristic algorithms are based on the fitness function as discussed in ERP. An optimized fitness function can enhance the quality of service metrics of WSN. In the proposed methodology, we are first discussing the DSDV with GA and then with BFO. We have also used the hybrid approach over DSDV i.e. we have used both GA and BFO over DSDV and proved that hybrid approach is much better than the single technique.

4.1 DSDV with GA

DSDV protocol adds sequence number attribute for every route table in every node. A routing table is maintained and this table helps to transmits data packets to other nodes in the network. If the next hop of source S is not active then use standard DSDV protocol to transfer a data packet to the destination (Algorithm 1).

Algorithm 1 (DSDV with GA)

1. Start
2. $S = Source, D = Destination\ , BL = Buffer\ Length$
$S = Source, D = Destination\ , BL = Buffer\ Length$
3. $if\ (s.Next\ Hop() == Does\ not\ alive\ )then$
$if\ (s.Next\ Hop() == Does\ not\ alive\ )then$
$(Deliver\ the\ packet\ from\ source\ to\ destination\ by\ DSDV)$
$(Deliver\ the\ packet\ from\ source\ to\ destination\ by\ DSDV)$
4. $Else\ if(s.BL() == filled\ then$ {Reject packet}
$Else\ if(s.BL() == filled\ then$ {Reject packet}
5. $if\ S.BL() == NULL\ then$ {S.recieved_pecket}
$if\ S.BL() == NULL\ then$ {S.recieved_pecket}
6. $S.Broadcast(Route_{Request}, 1, D, S);S.Broadcast(Route_{Request}, 1, D, S);$
7. $if(Source.Next_{Neighbor} has\ route\ to\ D\ then$
$if(Source.Next_{Neighbor} has\ route\ to\ D\ then$
8. $\{S.Receive(Route_{ACK});\}\{S.Receive(Route_{ACK});\}$
9. $Max\_no\_of\_Hops = 0;Max\_no\_of\_Hops = 0;$
10. $Min\_no\_of\_Hops = \infty;Min\_no\_of\_Hops = \infty;$
11. $Next\ hop = 0;Next\ hop = 0;$
$Update_{time} = 1;$
12. Else $(S\ has\ route\_Ack\ packets)(S\ has\ route\_Ack\ packets)$

$(if\ Route_{Ack}.no_{hops} \le Max\_no\_hops)(if\ Route_{Ack}.no_{hops} \le Max\_no\_hops)$
$(if\ Route_{Ack}.updated_{time} > updated\_time)$
$(if\ Route_{Ack}.updated_{time} > updated\_time)$
$Host_{port_{no}} = Route_{Ack}.Host_{Port};Host_{port_{no}} = Route_{Ack}.Host_{Port};$
$Updated_{time} = Route_{Ack}.Updated_{Time}:\}Updated_{time} = Route_{Ack}.Updated_{Time}:\}$

13. Else $Max_{no_{of_{Hops}}} = Route_{Ack}.no\_of\_HopsMax_{no_{of_{Hops}}} = Route_{Ack}.no\_of\_Hops$
$Host_{port_{no}} = Route_{Ack}.Host_{Port};$

$Updated_{time} = Route_{Ack}.Updated_{time};\}$

14. $Route_{Ack}.Updated\_timeRoute_{Ack}.Updated\_time$
15. $P = path\ of\ source\ to\ destination;P = path\ of\ source\ to\ destination;$
16. $for\ each\ P_i\ in\ source\ routing\ P for\ each\ P_i\ in\ source\ routing\ P$
17. $Pop.Size = P.Elements.CountPop.Size = P.Elements.Count$
18. $F_c = Current\ feature\ set\ of\ current\ element$
$F_c = Current\ feature\ set\ of\ current\ element$
19. $F_t = mutated\ feature\ value F_t = mutated\ feature\ value$
20. Fitness function
$1\ \ if\ \ f_s < f_t 1\ \ if\ \ f_s < f_t$
$0\ \ if\ \ f_s > f_t 0\ \ if\ \ f_s > f_t$
$1\ \ if\ \ f_{s==f_t} 1\ \ if\ \ f_{s==f_t}$
21. $if\ f == 1 if\ f == 1$
22. Add node to path
Else
23. Drop node;
24. $Node++; if\ (Node == d)then\ path\ found;Node++; if\ (Node == d)then\ path\ found;$
25. Evaluate Parameters
26. Stop

4.2 DSDV with BFO

Initialize the first step as S denotes source; D denotes destination and BL denotes buffer length. If the nodes are not alive on next node then deliver the packet from source to destination by DSDV. Otherwise the buffer length filled up then rejects the packet. When the buffer length is NULL then receive source packet and broadcast to route and if route got the next destination point through source then the source receives the route acknowledgement and initialize maximum no. of hopes equal to zero, minimum number of hopes infinity and next hop equal to zero. If root acknowledgement is less than or equal to maximum number of hopes and if route acknowledgement time greater than updated time then maximum number of hopes are equal to the root acknowledgement number of hopes and the updated time would be equal to the route acknowledgement updated time. After that BFO is initialized and bacteria swim length gives the path of elements count. Through GA, it got fit value from fitness function for BFO. If iteration is between 1 to number of bacteria then it would find fit value and then sort the fit value and in the end it will get the destination (Algorithm 2).

implementing BFO, output is applied to the GA as a population and the fitness function is computed for GA and then selection, crossover and mutation are performed for the routing optimization. Subsequently evaluation of the performance parameters takes place based on the hybridization technique. The whole process is based on the number of iterations to get the fittest solutions for the optimization so that we could calculate the parameters through which we can compare the performance in terms of network lifetime of the WSN for the energy minimization (Algorithm 3).

Algorithm 2 (DSDV with BFO)

1. Start
2. $S = Source, D = destination, BL = Buffer\ Length$
   $S = Source, D = destination, BL = Buffer\ Length$
3. $if\ (S.Next\ hop() = Does\ not\ alive) then$ { Deliver the packet from source to destination byDSDV}
   $if\ (S.Next\ hop() = Does\ not\ alive) then$ { Deliver the packet from source to destination byDSDV}
4. $Else\ if\ S.BL() == filled then$
5. $if\ S.BL() == NULL\ then$ {reject packet}$if\ S.BL() == NULL\ then$ {reject packet}
6. $S.Broadcast(Route_{Request}, 1, D, S); S.Broadcast(Route_{Request}, 1, D, S);$
7. $if\ (Source.Next_{Neighbour} hasroute\ to\ D) then$
   $if\ (Source.Next_{Neighbour} hasroute\ to\ D) then$

$S.Receive(Route_{ACK});$
$Max_{no_{of_{Hops}}} = 0; Min_{no_{Hops}} = \infty;$
$Next\ hop = 0;$
$Update_{Time} = 1;$

8. $Else\ (S\ has\ Route_{Ack} packets) Else\ (S\ has\ Route_{Ack} packets)$

$if\ \left(Route_{Ack}.no_{of} hops \leq Max_{no_{hops}}\right)$
$if\ (Route_{Ack}.updated_{time} > updated\ time)$
$\{Host_{port_{no}} = Route_{Ack}.host_{Port};$

$Updated_{time} = Route_{Ack}.Update\ d_{time};\}$

9. Else
   $\{Max_{no_{of_{hops}}} = Route_{Ack}.no_{of_{Hops}}$

   $\{Host_{port_{no}} = Route_{Ack}.Host_{Port};$

   $Updated\_time = Route_{Ack}.updated\_time$
10. $Route_{Ack}.Updated\_Time Route_{Ack}.Updated\_Time$
11. Initialize BFO
12. $Swim.Length = Element\ Count.Path$
    $Swim.Length = Element\ Count.Path$
13. $fit_{value} = fitness\ fn\ BFO(x, S); fit_{value} = fitness\ fn\ BFO(x, S);$
14. $itr = Iterationitr = Iteration$
15. $fit_{value} = []; fit_{value} = [];$
16. $for\ each\ itr = 1: nfor\ each\ itr = 1: n$
17. $find\ fit.value(); find\ fit.value();$
18. $S_k = Sort(fit.value) S_k = Sort(fit.value)$
19. $if\ S_k == destinationif\ S_k == destination$
20. End
21. Stop

4.3 Hybrid algorithm

This hybrid approach involves GA and bacterial BFO. First BFO technique is applied which includes the chemo taxis process, reproduction process and the fitness function that is called in the BFO for the optimization and then reproduction and elimination process occurred. After

Algorithm 3 (DSDV with BFO and GA)

1. Initialize parameter$n, N, N_c, N_{re}, N_{ed}, P_{ed}, C(i)(i = 1,2, \ldots .N), \emptyset^i, \emptyset$ $n, N, N_c, N_{re}, N_{ed}, P_{ed}, C(i)(i = 1,2, \ldots .N), \emptyset^i, \emptyset$, Where,

   nn: Dimension of the search space,
   NN: The number of bacteria in the population,
   $N_c N_c$: Chemo tactic steps,
   $N_{re} N_{re}$: The number of reproduction steps,
   $N_{ed} N_{ed}$: The number of elimination–dispersal events;
   $P_{ed} P_{ed}$: Elimination–dispersal with probability,
   $C(i)C(i)$: The step size taken in the arbitrary way precise by the tumble.

2. Elimination – dispersal loop$l = l + 1l = l + 1$

3. Reproduction loop $k = k + 1k = k + 1$

4. Chemo taxis loop $j = j + 1j = j + 1$

5. For$i = 1,2, \ldots Ni = 1,2, \ldots N$, take a chemo tactic step for bacterium ii.

6. Compute fitness function, $ITSE(i,j,k,l)ITSE(i,j,k,l)$

7. Let $ITSE_{last} = ITSE\ (i,j,k,l)ITSE_{last} = ITSE\ (i,j,k,l)$ to save the value

8. Tumble: A random vector is generated i.e.
   $\Delta(i) \in R^n \Delta(i) \in R^n$, with each element$\Delta_m(i), m = 1,2, \ldots, p\Delta_m(i), m = 1,2, \ldots, p$, a random number on$[-1,1][-1,1]$.

9. Move: Let $\emptyset^x(i + 1.j,k) = \emptyset^x(i,j,k) + C(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}}$
$\emptyset^x(i + 1.j,k) = \emptyset^x(i,j,k) + C(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}}$

10. Compute $ITSE\ (i,j\ +1,k,l)ITSE\ (i,j\ +1,k,l)$

11. Swim; Let $m = 0; while\ m < N_s m = 0; while\ m < N_s$

Let $m = m + 1m = m + 1$

12. If$ITSE\ (i,j + 1,k,l) < ITSE_{last} = ITSE\ (i,j + 1,k,l)$
$ITSE\ (i,j + 1,k,l) < ITSE_{last} = ITSE\ (i,j + 1,k,l)$, and let
$\emptyset^x(i + 1,j,k) = \emptyset^x(i + 1,j,k) + C(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}}\emptyset^x(i + 1,j,k) = \emptyset^x(i + 1,j,k) + C(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}}$

13. Else, let$m = N_s m = N_s$, end of while statement, IF

    $j < N_C j < N_C$, go to step 3

14. Reproduction; for the given k and l, for each $i = 1,2, \ldots .Ni = 1,2, \ldots .N$

    Let $ITSE^i_{health} = \sum_{j=1}^{N_c+1} ITSE\ (i,j,k,l)ITSE^i_{health} = \sum_{j=1}^{N_c+1} ITSE\ (i,j,k,l)$

15. if$k < N_{re} k < N_{re}$, go to step 3

16. Eliminate dispersal

17. $(rs, cs) = size\ of\ (bfo - input)(rs, cs) = size\ of\ (bfo - input)$

18. For each $P_l P_l$ in source routing P

    Pop. Size =P. Elements. Count
P is the path from source to destination

19. $F_C F_C$ = current feature set of current element

20. $F_T F_T$= Mutated feature value

21. Fitness function

    $1\ \ if\ \ f_s < f_t 1\ \ if\ \ f_s < f_t$
    $0\ \ if\ \ f_s > f_t 0\ \ if\ \ f_s > f_t$
    $1\ \ if\ \ f_{s==f_t} 1\ \ if\ \ f_{s==f_t}$

23. If$F == 1F == 1$

24. Add node to path

25. Else

26. Drop node;

28.$Node + +Node + +$; if ($Node == dNode == d$) then path found;

29. End

30. Evaluate Parameters

31. Stop

5 Simulation results and discussions

For the design of our hybrid approach, two well-known meta-heuristics: GA and BFO [1, 8] are considered. In order to optimize the energy of WSN, various algorithms and protocols are used and their comparisons are used through routing (Algorithm 4).

According to the simulation model demonstrated in Fig. 1, the various simulation parameters used in the research are: throughput, end to end delay, congestion, packet delivery ratio, bit error rate and routing overhead. The bits are processed at a data rate of 512 bytes/s. The packet size for data transmission is 100 bytes. The data transmission time taken by the packets is 200 s i.e. the simulation time for each simulation scenario. Network is composed of 60 nodes. The detailed simulation parameters are shown in Table 2.

We calculated the performance of protocols using the throughput, packet delivery ratio, end to end delay, routing overhead, congestion, and bit error rate (quality of service metrics of WSN).

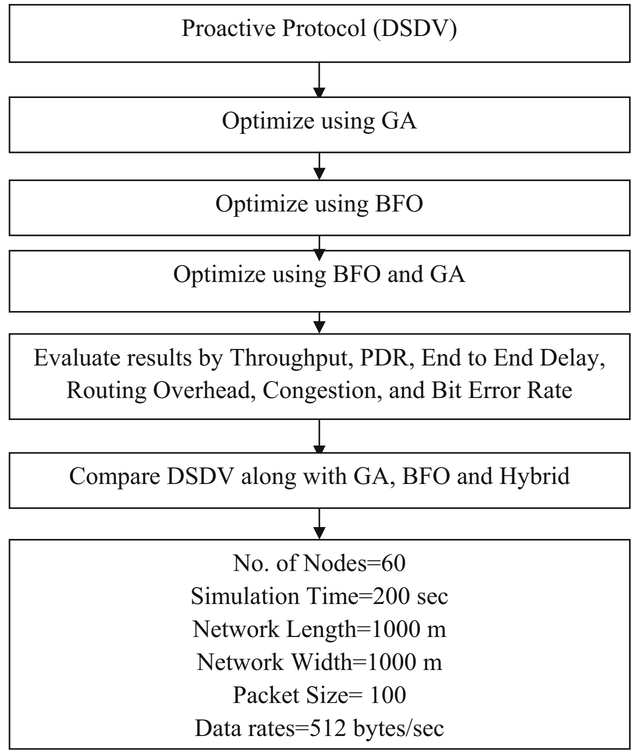

Fig. 1 Simulation model for the proposed approach

Table 2 Simulation parameters

Number of nodes	60
Simulation time	200 s
Network length	1000 m
Network width	1000 m
Packet size	100
Data rate	512 bytes/s

Algorithm 4: Internal Working of Hybrid Protocol

1. Let nn=Total number of nodes in the architecture.

2. Initialize the network DSR/ DSDV, according to the program adjustment.

3. Let PPbe the path; SS be the Source; DDbe the Destination.

4. Let $covcov$ be the coverage set of all nodes

5. Initial Population=$_{i=1}^{k}Cov_{path}\,_{i=1}^{k}Cov_{path}$, where $kk$is the total number of nodes in the path. // BFO Application

6. $JHealth = 0; JHealth = 0;$ // $JHealthJHealth$ is the health at each bacterial (Node). The aim is to find the healthiest bacteria for BFO. Here, a paradox would be accomplished i.e. here the rotten bacteria has to be find. Hence, the fitness function would be reverse in the nature and termed as$f'f'$.

7. Chromosome=0.05; // it is the initial chromosome which has to be considered. We can change the value of the chromosome as per requirement but the provided value is standard.

8. Let mm be the total number of iteration for which the health of each bacteria (node) has to be evaluated.

9. for each a in m;

$JHealth_a = \sum_{i=1}^{k} f'.ch JHealth_a = \sum_{i=1}^{k} f'.ch$, where $chch$ is the chromosome

End for

$f' = \left(\frac{\sum E_{all} - E_c}{E_c}\right) f' = \left(\frac{\sum E_{all} - E_c}{E_c}\right)$,

Where, $E_{all}E_{all}$ is the total Energy of all nodes and E_cE_c is the current energy of the node.

10. Find least heath according to the chemo taxis complexity.

11. Nodes or bacteria with least health would be dropped from path.

12. Let $G = (P, E, E')G = (P, E, E')$ where P=remaining path with dropped node using BFO, E is the total energy vector at the remaining nodes and $E'E'$ is all energy of all nodes.

13. Initialize GA for G.

$pop_{site} = Total\ element\ remaining pop_{site} = Total\ element\ remaining$

$Mutation = 0.5; Chromsome = 0.8 Mutation = 0.5; Chromsome = 0.8$

$Chromosome_{type} = Linear, Boundary\ Region: typecasted$
$Chromosome_{type} = Linear, Boundary\ Region: typecasted$

$iteration = 1000\ (may\ be\ less\ or\ more)$

14. For every $itritr$ in iteration

$f'' = f'' =$
$1\ \ if\ \ (\sum_{i=1}^{n} E/_N) - E'_{itr} > 0$, $where\ n\ is\ the\ total\ no.of\ nodes\ in\ that$
0 $\quad otherwise$
$1\ \ if\ \ (\sum_{i=1}^{n} E/_N) - E'_{itr} > 0$, $where\ n\ is\ the\ total\ no.of\ nodes\ in\ that$
0 $\quad otherwise$

15. Remove node with value =0

Table 3 Score of various metrics with varied number of nodes in DSDV with GA

Number of nodes	20	30	40	50	60
Throughput	76	82	88	92	94.5
Packet delivery ratio	81	84	91	95	95.5
End to end delay	0.4	0.6	0.8	1.0	0.29
Routing overhead	0.6	0.8	0.12	0.14	0.16
Congestion	0.4	0.7	1.0	1.3	1.7
Bit error rate	0.21	0.225	0.3	0.35	0.4

5.1 Performance with varied nodes of DSDV with GA

Table 3, demonstrates the score of various parameters when GA is applied on DSDV routing protocol. In case of throughput the score lies in between 76 and 94.5. It means as the number of nodes increases correspondingly the throughput also increases. The value of packet delivery ratio goes up to 95.5 from 81, gradually rise in packet delivery ratio as the number of nodes increases. The end to end delay is quite less when the number of nodes is more than 50. During the route discovery the degree of the routing overhead is less for the considerable network density and it is getting lessen from 0.6 to 0.16. To overcome the jamming of new connections, the congestion should be less and it is value lies in between 0.4 when number of nodes is 20 and 1.7 when the node count is 60. The graph corresponding to the socre of various parameters when GA is applied on DSDV is established in Fig. 2.

5.2 Performance with varied nodes of DSDV with BFO

The Table 4, shows the score of various metrics with varied number of nodes in the case when the soft computing technique BFO is implemented on DSDV routing protocol. The value of throughput is better it is going up to 95.6 from 77. As observe, data packet deliver ratio increases with respect to GA as the collision is less so that it can reduces the number of packets drops caused by collisions. Its value is ranging up to 95 from 78. End to end delay is an important constraint for evaluating a protocol to be low for superior performance. Therefore, its value goes up to 0.7. During the route discovery, the DSDV protocol with BFO radically reduces the routing overhead for the extensive network density. So, its value is turn over to 0.54 when the number of packets increases to 60. Above figure shows the error rate recompense with the BFO and its value goes up to 1. The above table shows the value of congestion that ranges from 0.2 to 1 that an abridged

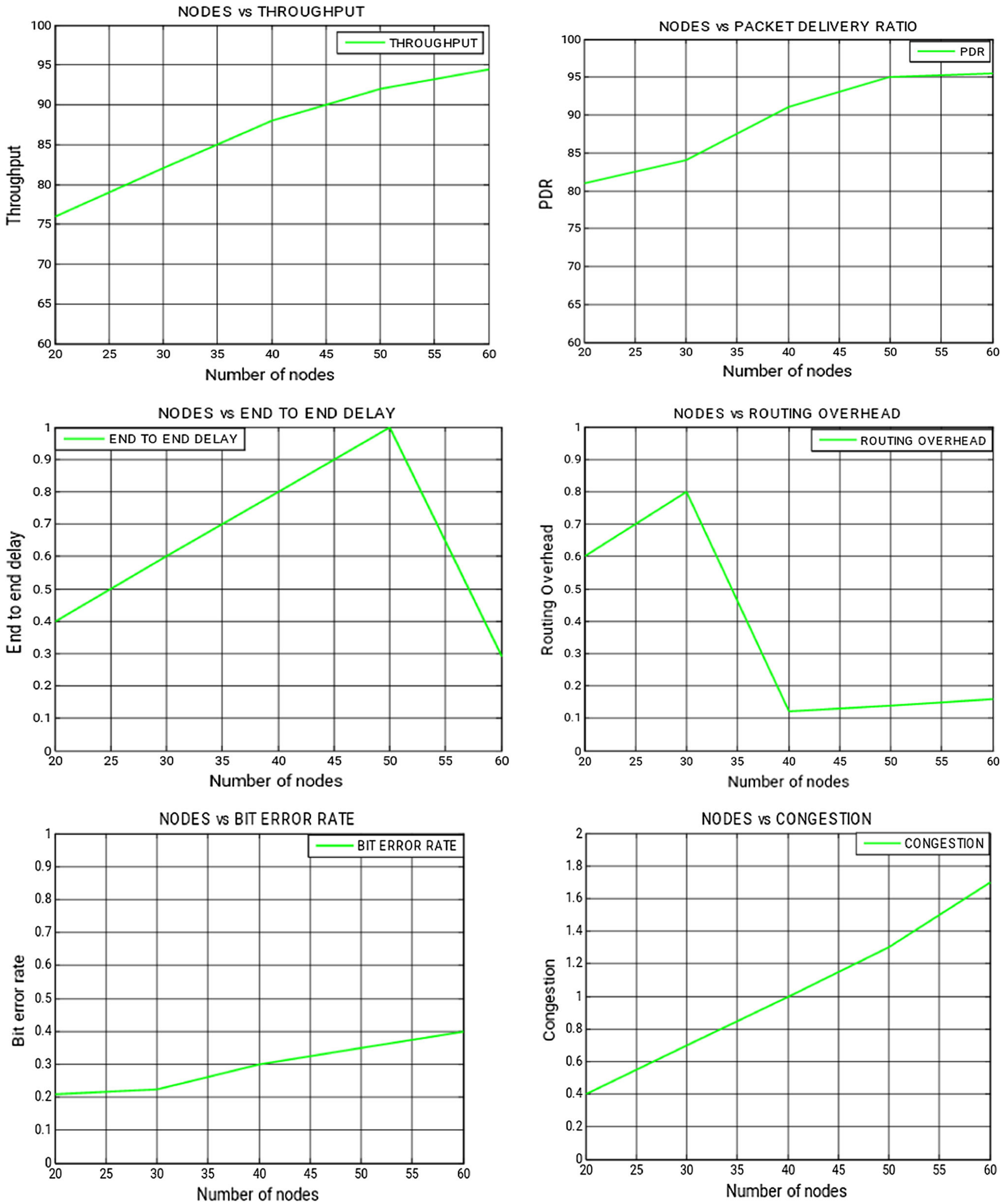

Fig. 2 Performance of various metrics with varied number of nodes of DSDV with GA

Table 4 Score of various metrics with varied number of nodes in DSDV with BFO

Number of nodes	20	30	40	50	60
Throughput	77	83	89	93	95.6
Packet delivery ratio	78	85	86	90	95
End to end delay	0.3	0.5	0.3	0.8	0.7
Routing overhead	0.15	0.41	0.3	0.4	0.54
Congestion	0.2	0.5	0.7	0.9	1.0
Bit error rate	0.2	0.4	0.6	0.8	1

congestion with respect to DSDV with GA. The congestion should be of small amount to conquer the traffic Fig. 3 demonstrates the values of congestion with repeect to number of nodes.

5.3 Performance with varied nodes of DSDV with Hybrid

According to Table 5, when the hybridization of GA and BFO is implemented with DSDV, there is margin increase in the score of throughput. In regard of data packet deliver ratio, above table shows that PDR increases, it came out to be 97.8. The end to end delay in this case is decreases and it is in between 0.15 and 0.16. The routing overhead is quite less which is 0.12 for 20 nodes and 0.01 when the node count is 60, which is almost negligible. The congestion is less in case of DSDV with hybrid. It ranges till 0.1. The number of errors came out to be very less ranging from 0.06 to 0.2 as depicted in Fig. 4.

5.4 Comparison of DSDV protocol with respect to GA, BFO and hybrid algorithm

The various parameters of GA, BFO and hybrid algorithms with respect to number of nodes are compared in Fig. 5. DSDV with GA shows the value from 81 to 94. DSDV with BFO values are from 78 to 93. The values of DSDV with hybrid lie from 84 to 98. Above graph shows the values of various algorithms and their comparison with respect to Bit Error Rate. The values lies in between 0.2 and 0.4 are the value of DSDV with GA and 0.2–1.2 is the value of DSDV with BFO. The value of DSDV with Hybrid lies from 0.1 to 0.2. Values of various algorithms i.e. GA, BFO and Hybrid are shown in the above graph with respect to Throughput. DSDV with GA shows the value from 76 to 94. DSDV with BFO values are from 75 to 95. The values of DSR with hybrid lie from 80 to 97. Values of various algorithms i.e. GA, BFO and Hybrid are shown in the above graph with respect to Throughput. DSDV with GA shows the value from 0.4 to 1.7 DSDV with BFO values are from 0.2 to 1.0.

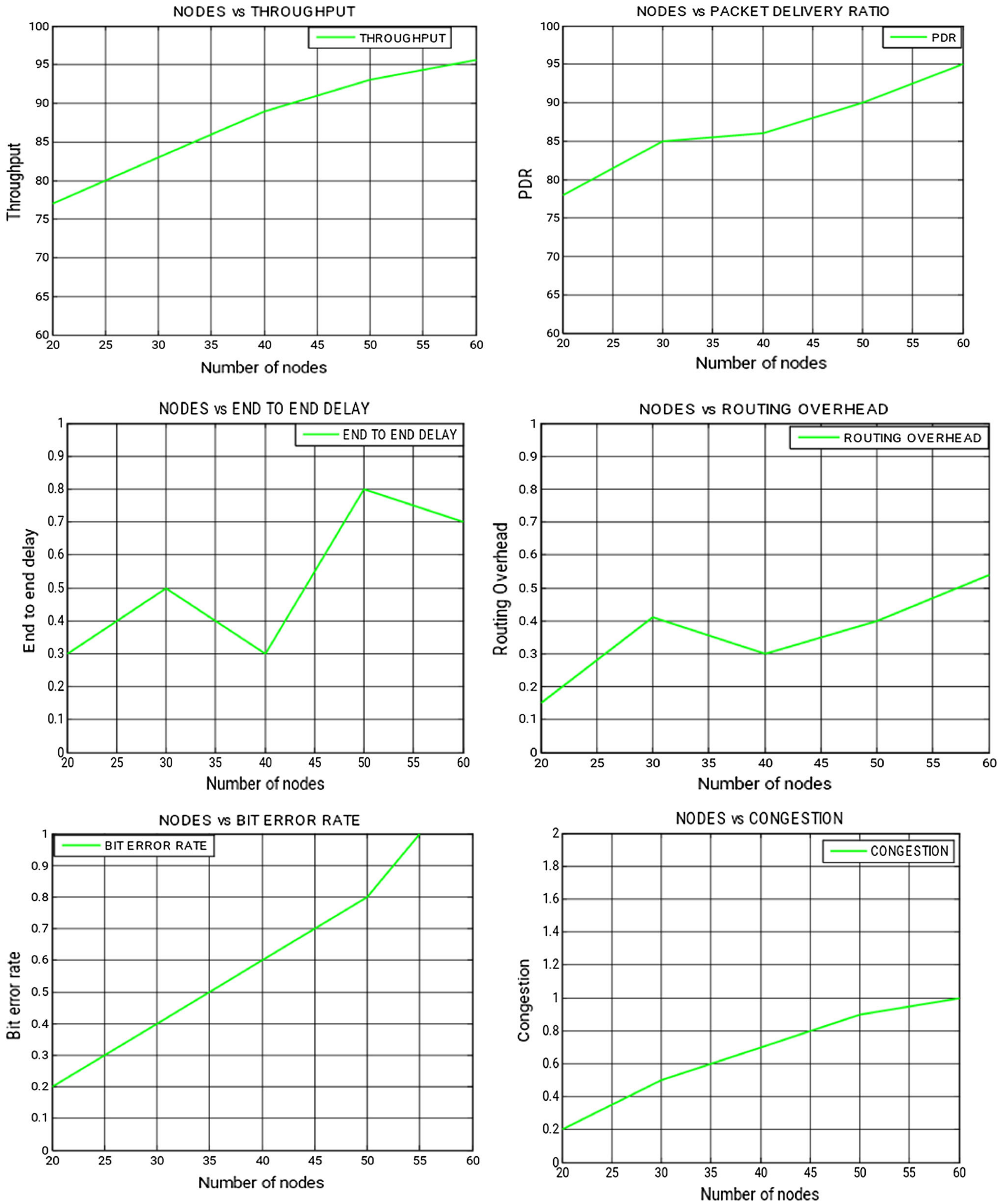

Fig. 3 Performance of various metrics with varied number of nodes of DSDV with BFO

Table 5 Score of various metrics with varied number of nodes of DSDV with hybrid

Number of nodes	20	30	40	50	60
Throughput	80	84	90	94	97.30
Packet delivery ratio	84	88	92	96	97.8
End to end delay	0.15	0.28	0.23	0.25	0.16
Routing overhead	0.12	0.17	0.03	0.02	0.01
Congestion	0.1	0.3	0.5	0.7	0.1
Bit error rate	0.06	0.04	0.1	0.14	0.2

The values of DSR with hybrid lie from 0.0.5 to 0.04. The value of hybrid in above graph decreases instantly after increasing. Different algorithms that are DSDV with BFO, GA and Hybrid have been compared with end to end delay. DSR with GA show the value as of 0.4–0.3. DSDV through BFO values came out to be from 0.3 to 0.7. The values of DSR with hybrid lie from 0.15 to 0.16. The values of various algorithms i.e. GA, BFO and Hybrid are shown in the above graph with respect to Routing Overhead. DSDV with GA shows the value from 0.6 to 0.15. DSDV with BFO values are from 0.18 to 0.53. The values of DSR with hybrid came out to be 0.12–0.01 as shown in Fig. 5.

6 Conclusions

For the application of WSNs, the selection of routing strategy depends upon many factors like network stability, fault tolerance, delay, network lifetime etc. A hybrid algorithm, with optimized fitness function is proposed here with the objective of optimizing the quality of service traits of WSNs. It is clearly depicted from the simulation results that the combination of two optimization approaches along with DSDV routing protocol outperforms rather than using a DSDV alone in a WSN scenario. The proposed approach can be best utilized in a small size of WSN. In future combination of more bio-inspired optimization techniques can be implemented on other energy aware routing protocols in order to prolong the lifespan of WSN.

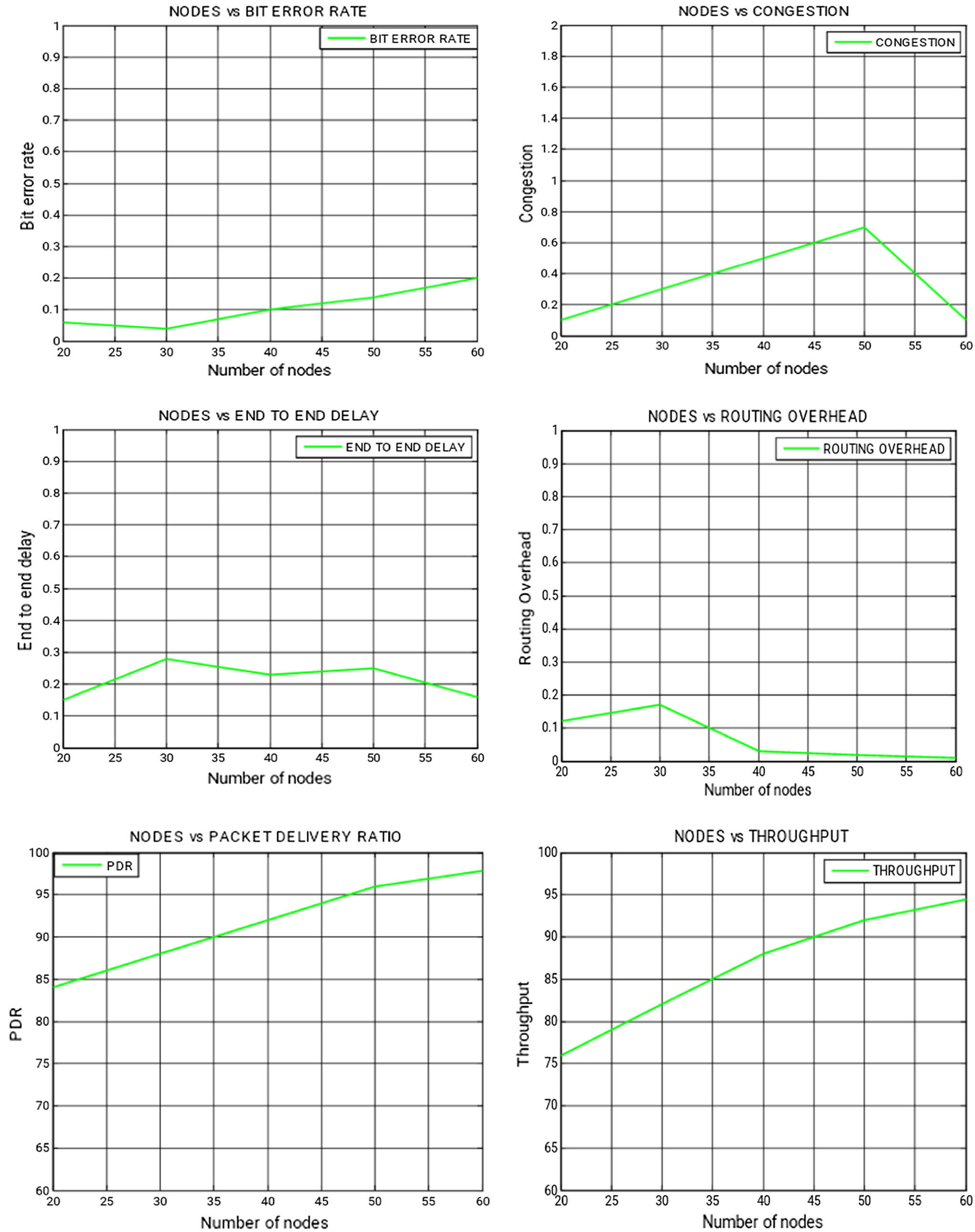

Fig. 4 Performance of various metrics with varied number of nodes of DSDV with hybrid

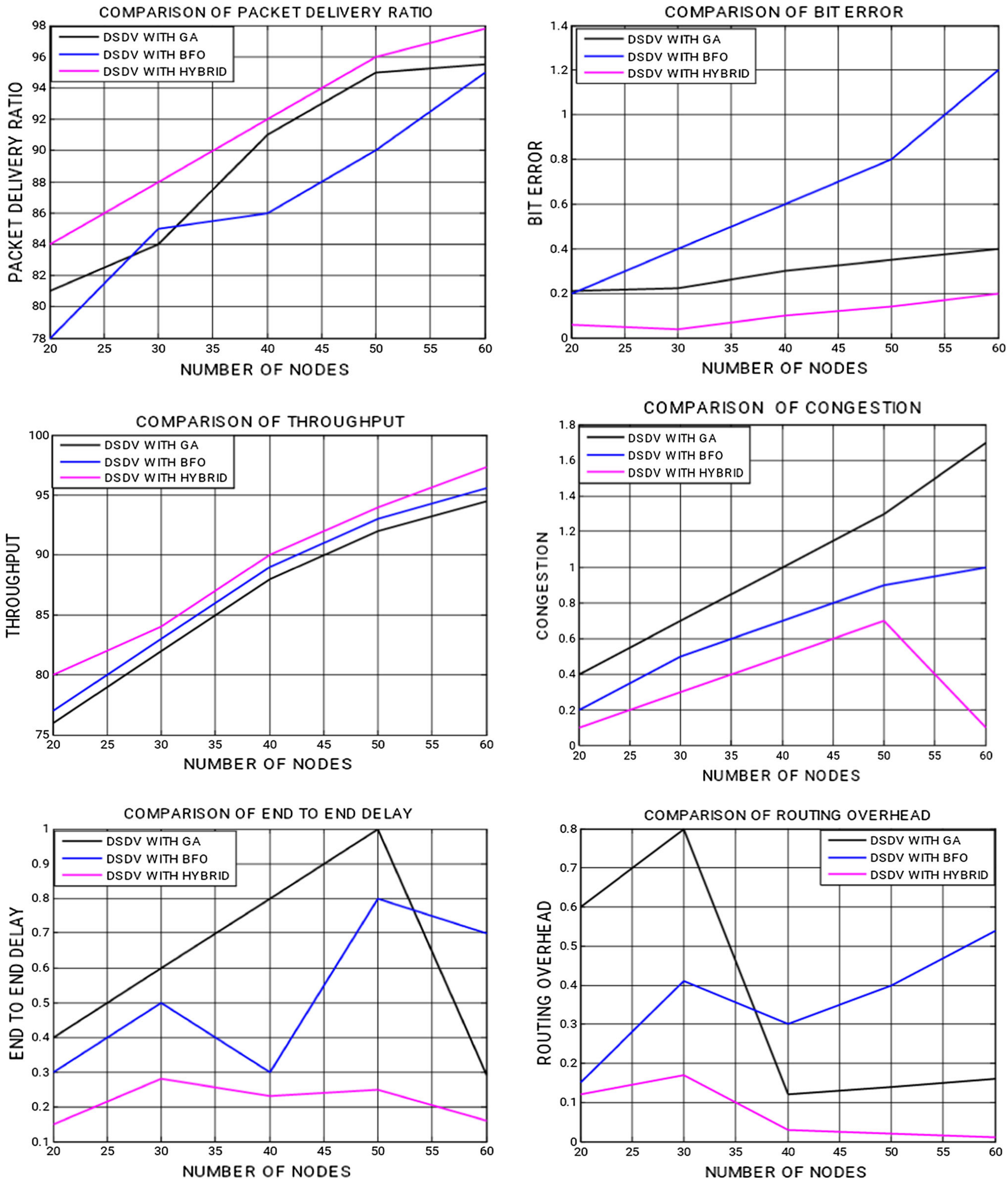

Fig. 5 Comparison of various metrics with varied number of nodes of DSDV with respect to GA, BFO and hybrid

Acknowledgements The authors would like to express their sincere thanks to Prof. Dr. Truong Khang Nguyen, Division of Computational Physics, Institute for Computational Science, Ton Duc Thang University, Ho Chi Minh City, Vietnam for giving his value suggestion, comments and support to complete this work as effective.

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