Lecture Notes on Data Engineering and Communications Technologies 58

S. Smys
Ram Palanisamy
Álvaro Rocha
Grigorios N. Beligiannis *Editors*

Computer Networks and Inventive Communication Technologies

Proceedings of Third ICCNCT 2020

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We are honored to dedicate the proceedings of ICCNCT 2020 to all the participants, reviewers, and editors of ICCNCT 2020.

Preface

The written versions of the majority of the contributions presented at ICCNCT 2020 are included in this conference proceedings volume. The conference has provided a setting for discussing the recent developments in a wide variety of topics including network operations and management, QoS and resource management, wireless communications, and delay-tolerant networks. The conference has been a good opportunity for participants who came from different destinations across the globe to present and discuss the topics in their respective research areas.

ICCNCT 2020 tends to collect the latest research results and applications on computer networks and next-generation communication technologies. It includes a selection of 97 papers from 348 papers submitted to the conference from universities and industries all over the world. All the accepted papers were subjected to a strict peer-reviewing purpose by 2–4 expert referees. The papers have been selected for this volume because of their quality and relevance to the conference.

ICCNCT 2020 wishes to express our heartfelt gratitude to all authors for their contributions to this book. We would like to extend a special thanks to all the referees for their constructive comments on all papers, and moreover, we would also like to thank the organizing committee for their hard work. Finally, we would like to thank the Springer publications for producing this volume.

Coimbatore, India — Dr. S. Smys
Conference Chair, ICCNCT 2020

Antigonish, India — Ram Palanisamy
Lisbon, Portugal — Álvaro Rocha
Patras, Greece — Grigorios N. Beligiannis

Acknowledgements

ICCNCT 2020 would like to thank our conference organising committee and keynote speakers for their presentations on July 23–24, 2020. The organizers also wish to acknowledge publicly the valuable services provided by the reviewers.

On behalf of the editors, organizers, authors, and readers of this conference, we wish to thank the keynote speakers and the reviewers for their time, hard work, and dedication to this conference. The organizers wish to acknowledge Dr. S. Smys for the discussion, suggestion, and cooperation to organize the keynote speakers of this conference. The organizers also wish to acknowledge speakers and participants who attended this conference. We are very grateful to thank all the faculty and non-faculty members and reviewers, guest editors Dr. S. Smys, Dr. Ram Palanisamy, and Dr. Álvaro Rocha, who helped and supported this conference to become a successful event. ICCNCT 2020 would like to acknowledge the contribution made by the organization and its volunteers and conference committee members at a local, regional, and international level, who have contributed their time, energy, and knowledge.

We also thank all the chairpersons and conference committee members for their extended support.

Contents

About the Editors

Dr. S. Smys received his M.E. and Ph.D. degrees all in Wireless Communication and Networking from Anna University and Karunya University, India. His main area of research activity is localization and routing architecture in wireless networks. He serves as an Associate Editor of Computers and Electrical Engineering (C&EE) Journal, Elsevier, and Guest Editor of MONET Journal, Springer. He is served as a reviewer for IET, Springer, Inderscience, and Elsevier journals. He has published many research articles in refereed journals and IEEE conferences. He has been the General chair, Session Chair, TPC Chair, and Panelist in several conferences. He is member of IEEE and senior member of IACSIT wireless research group. He has been serving as Organizing Chair and Program Chair of several international conferences, and in the Program Committees of several international conferences. Currently, he is working as a Professor in the Department of Information Technology at RVS Technical Campus, Coimbatore, India.

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A Multi-hop Energy-Efficient Cluster-Based Routing Using Multi-verse Optimizer in IoT

Vimal Kumar Stephen, Sanjiv Sharma, Antonio Rutaf Manalang, and Faiza Rashid Ammar Al-Harthy

Abstract Wireless sensor networks (WSNs) constitute an immense number of mobile or stationary sensor nodes that rely on multi-hop and self-organization. Internet of Things (IoT) is based on interconnected objects which are capable of communicating with each other and also collecting data related to their situation. Hence, for IoT networks, rather than energy-efficient communication, the most crucial challenge for conserving the cost of network management is the reduction of Internet connection numbers. To extend the network lifetime and to avoid interference, an extensively applied method is the efficient usage of energy. The objective of the low energy adaptive clustering hierarchy (LEACH) is the selection of sensor nodes as the cluster-heads (CHs) at several cycles such that there is the acquisition of the extreme power excess's outcome and, later, its dispersal in the whole WSN. Tabu search (TS) is a metaheuristic which controls the local heuristic search procedure such that there is the exploration of the solution space beyond its local optimality. Multi-verse optimizer (MVO) algorithm is influenced by astrophysics' multi-verse theory. This work has proposed a multi-hop energy-efficient cluster-based routing with multi-verse optimizer.

Keywords Wireless sensor networks (WSNs) · Internet of Things (IoT) · Efficient energy utilization · Low energy adaptive clustering hierarchy (LEACH) · Tabu search (TS) · Multi-verse optimizer (MVO) algorithm

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1 Introduction

Internet of Things [1] is WSN-based wherein devices are Internet connected and communicate amongst themselves without the intervention of human beings. It is a significant and arduous challenge to ensure security in WSNs and IoT. Generally, IoT devices and battery-powered WSNs are resource limited and not very costly. Hence, it is not reasonable to apply the state-of-the-art security methods which have high power consumption. However, this distributed networks' extremely dynamic nature leads to the inapplicability of key management algorithms and centralized security. The wireless communication nature makes it susceptible to attacks. Moreover, the individual nodes are also prone to be physically trapped.

In WSNs, clustering methods are popularly used to aid in the scalability, effective energy communication amongst sensors, and also extend the network's lifetime [2, 3]. It must be noted that, unlike other standard sensors, IoT network's nodes are likely to be devices that are fitted with continuous power supply in order to execute certain intrinsic functionalities rather than just the sensing function [4]. Figure 1 shows the clustering in WSN.

The low energy adaptive clustering hierarchy [5] protocol is most applicable for WSN routing. An adapted clustering process is the basis of LEACH. Based on a two-stage manoeuvre, the LEACH will manipulate a single-tier structure and the clusters [6]. LEACH with single-hop methods works such that in a WSN, all cluster-heads will transmit its data to the base station (BS), and hence, CH becomes accountable

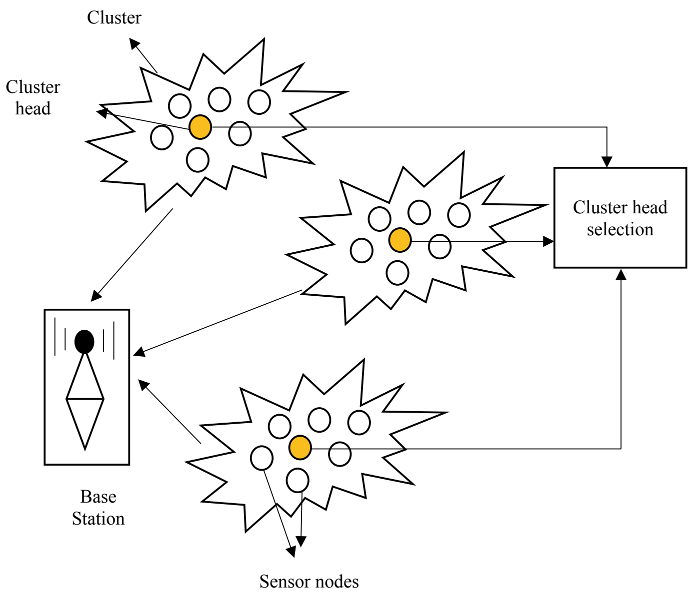

Fig. 1 Clustering in WSN

for data transmission across the whole network. LEACH with the multi-hop method is the single-hop method's extension. In this method, the LEACH functions such that the BS is the transferred data by the maximum number of CHs.

The transmission of data between all sensors and the BS in multi-hop LEACH [7] is accomplished with minimal cost of transmission. This is a result of the cost for data transfer being maximum when data is communicated from the CH to the BS MH-LEACH protocol [8]. This, in turn, offers solutions to those problems related to sensors transmitting information to the CH. This information gets gathered by the CH and is shared with the BS in either a direct or indirect (via the BS) manner. Akin to the basic LEACH, there is random selection of the CH in this method. The route which is best known for energy efficiency is referred to as a path. The selected path for a CH may be such that the CH is situated at a far distance from the BS. The middle CH's election is based on the calculated distance. A CH which is situated nearer to the BS can get information from other CHs that is situated at a far distance from the BS. In this fashion, there can be conservation of the energy of the CH that is a cluster portion. Even so, because of the random CH selection, high power or energy cannot be ensured for a randomly elected node.

Most of the population-based stochastic optimization approaches are nature inspired. These approaches carry out random optimization as signified by their names. An initial random solution set is produced in this optimization procedure. Then, these initial solutions get evolved, moved, or combined over a predefined number of steps known as iterations. Every population-based approaches functions as per this framework. During optimization, the system of evolution, motion, or combination of the solutions makes this algorithm distinct from other algorithm types.

Over the past twenty years, TS algorithms [9] have been employed in numerous problems which are related to practical combinatorial optimization. Various methods, such as maximum throughput, minimum distance, minimum cost, and so on, are used to resolve the issue of optimality. TS algorithm is metaheuristic algorithm that are roughly linked to evolutionary computing. TS algorithms may be able to manage NP-hard problems like combinatorial optimization problems. The search space's critical areas are minimized by the TS. A relatively new swarm intelligence algorithm is the multi-verse optimizer (MVO). The inspiration for this algorithm comes from the multi-verse theory which describes the creation of multiple universes by the big bangs and the interaction of these universes amongst each other via diverse-hole types. For a given optimization problem, the MVO algorithm's goal is the detection of the global solution.

In this work, multi-hop energy-efficient cluster-based routing has been proposed with multi-verse optimizer, and it has been organized as follows: Sect. 2 presents the associated literary works. Section 3 describes the MH-LEACH protocol, TS, and MVO. Section 4 provides the simulation results. Finally, Sect. 5 presents the conclusion.

2 Literature Survey

An efficient cluster-head election scheme was examined by Behera et al. [10] in which rotation of the cluster-head position occurs amongst the higher energy level nodes in comparison with others. For the selection of the succeeding group of cluster-heads, an optimum value of cluster-heads, the residual energy, and the initial energy are taken into account by the algorithm. The network's cluster-head group will be feasible for IoT applications like smart systems, smart cities, and environmental monitoring. The analysis of simulations demonstrates that the modified version does better than the LEACH protocol through enhancement of the residual energy by 64%, the lifetime by 66%, and the throughput by 60%.

In WSNs, for network lifetime prolongation and improvement of the efficiency of data transmission, Tran et al. [11] studied the energy-efficient cluster-based multi-hop routing (ECMR) protocol. The Dijkstra algorithm's weight factor to detect the ECMR protocol's shortest path is determined by each cluster-head's transmission power and residual energy. OMNeT++ -based simulations demonstrate that ECMR protocol surpasses the LEACH protocol's performance with regard to the effectiveness of data transmission, the longevity of network and usage of energy, and in large-scale-sized networks.

An energy-efficient clustering routing algorithm was devised by Wang et al. [12]. An uneven cluster formation strategy has been proposed taking into account the non-uniform traffic distribution. Additionally, for balancing the energy usage inside each cluster, a distributed CH rotation procedure has been suggested. For distant data transmissions to BS, a protocol was developed for the CH nodes that is reliant on a proposed distance-and-energy-aware cost function in order to circumvent the issue of energy hole. Experimental results demonstrate that the proposed algorithm's effectiveness is competitive with regard to the network lifetime, energy efficiency, and throughput.

For prolongation of the lifetime of energy-restricted WSNs, Al-Sodairi and Ouni [13] examined the efficiency of LEACH and LEACH-based protocols. Enhanced multi-hop LEACH, which is an improved LEACH clustering protocol, was devised for reduction and balancing of the WSN's energy usage so as to enable longer network lifetime and maximized packet delivery. The LEACH protocol's drawbacks were also examined in the study. Initially, the introduction of new rules for election of CH and round time calculating on the basis of the residual energy. Secondly, levelling and general multi-hop routing are the two operating procedures which are utilized for the integration of the WSN's multi-hop communication model.

For reduction of the number of needed Internet connections in IoT networks, a multi-hop clustering system was proposed by Sung et al. [14]. The proposed system's goal is to choose the least number of coordinators that acts as the cluster's representative node, that is, having an Internet connection for the remaining nodes in the cluster and to design an IoT node partition into the chosen coordinator set in order to reduce the total distance and the number of hops between the nodes and its corresponding representative. This is an NP-hard problem; due to this, a heuristic approach has been studied to resolve the problem and study the proposed solution's complexity. The results based on experiments by varying the parameters demonstrate that the proposed method has 63–87.3% Internet connection decrease based on the number of the IoT nodes, whilst it was 65.6–89.9% for the optimal solution in a small-scale network. Also, in a large-scale network, it was demonstrated that the proposed scheme's performance characteristics are the same as the optimal solutions expected performance characteristics.

MVO is the latest nature-influenced algorithm devised by Mirjalili et al. [15]. White hole, black hole, and wormhole are the three cosmological concepts which are the basis for the MVO's major influences on as follows: the development of three concepts' mathematical models corresponds to the performance of exploration, exploitation, and local search. Initially, the MVO algorithm is gauged on 19 difficult test problems. For its performance confirmation, the MVO is later applied to five real engineering problems. The MVO is compared with: gravitational search algorithm, genetic algorithm, particle swarm optimization, and grey wolf optimizer for the validation of the results. The outcomes demonstrate that the proposed algorithm is capable of offering extremely competitive results and surpasses the performance of the best algorithms in the literary works on the test bed majority. The MVO's potentiality in the resolution of real problems with unknown search spaces is also exhibited by the outcomes of the real case studies.

3 Methodology

The multi-hop low energy adaptive clustering hierarchy (MH-LEACH) reduces the energy usage during transmission of data between the BS and CHs. Tabu search is a neighbourhood search approach that utilizes "intelligent" search and flexible memory method in order to prevent it from being captured at the local optimum. MVO, a stochastic population-based algorithm, is proposed for the applied for the optimization problem of energy-efficient clustering. The goal of MVO is the location of the global solution.

3.1 Multi-hop Low Energy Adaptive Clustering Hierarchy

The multi-hop communication protocol is utilized for communication of data between the nodes to cluster-head (intra-cluster routing) and cluster-head to destination. The head of each cluster performs aggregation of data in order to conserve the residual energy and to also define the d threshold's value. If the distance of transmission between the CH node and the BS is lower than the value of the threshold, then the CH will send the evaluated aggregated data to the head by using the single-hop transmission. Else, the CH will identify the subsequent hop with minimum cost neighbour as the relay node [16]. Moreover, the selection of this node depends on the residual energy and the distance. A minimum cost relay CH node is chosen in order to transmit the data to a destination, and upon election of CH, the inter-cluster routing is established.

In the multi-hop LEACH technique, each CH which is placed beyond the threshold distance do has the capability to produce its distinct routing table for selection of the shortest route to the BS. Three phases have been proposed by the MHT-LEACH to establish routes:

- **Stage 1:** An announcement message is broadcasted by each CH to all other CHs. These messages assist other CHs in its routing table creation.
- **Stage 2:** The distribution of all CHs based on doing is as two groups. There is an external group that has all CHs which are situated at a distance equivalent to or bigger than do. Then, there is an internal group which comprises all nodes that are situated at a distance lower than the threshold.
- **Stage 3:** The internal CHs directly send data to the BS based on the distance of CHs. Whilst based on the announcement messages, CH in the other group will set up a special routing table that makes it able for each CH to select the next hop to the BS.

3.2 Tabu Search Algorithm

In 1986, Fred W. Glover proposed a Tabu search (TS) which comprised of various basic concepts through application of numerous recommended ideas from the sixteenth century. In 1989, Glover also wrote an article that gave the formularization of the TS. The basic Tabu search algorithm (TSA) refers to the TS's entire principle proposed in 1990. Initially, the TS algorithm was introduced for overcoming the local maxima or local minima which is termed as local optima. Diverse techniques are required for overcoming the problem of local optima. In that time, the TS can offer a drastic change to minimize the problem of local optima.

In the Tabu search, an initial solution is taken as the input. A local search is done with the aid of neighbourhood and memory structures until the satisfaction of a certain stopping criterion. Through allowing for solutions which do not enhance the objective function, the local minima can be avoided. In comparison with other metaheuristics, TS utilizes adaptive memory and special schemes for this memory's exploitation. Generally, memory is partitioned into long-term memory and short-term memory. Intensification and diversification are the two TS techniques for the exploitation of this memory. Recency-based memory is a well-known form of TS short-term memory which functions to temporarily inhibit lately performed moves from being reversed for a span (number of iterations) referred to as the Tabu tenure. Figure 2 illustrates the TS algorithm's flow chart.

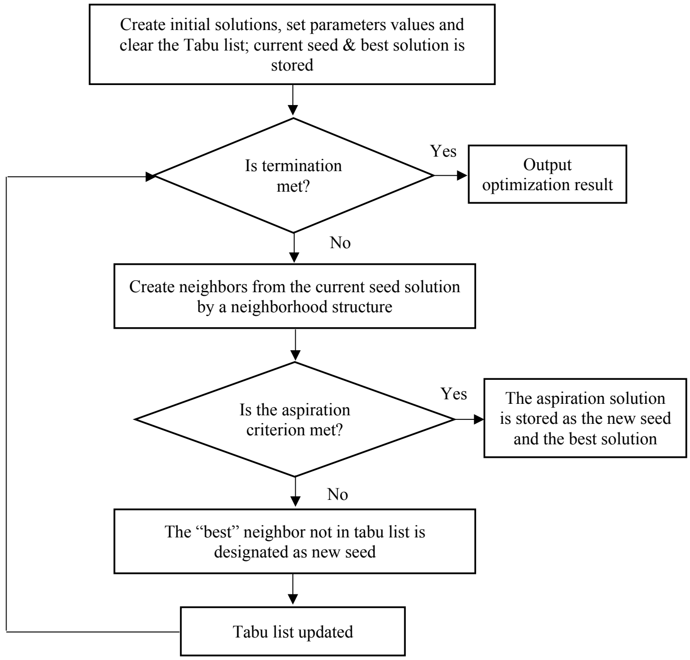

Fig. 2 Flow chart for Tabu search (TS) algorithm

3.3 Proposed Cluster-Based Multi-verse Optimizer (MVO) Routing

In physics, the theory of multi-verse is yet another fairly new and prominent theory. This theory puts forward the idea that there have been more than one big bang and a universe was created with each big bang. Multi-verse is the term used to refer other universes' existence along with the universe in which it exists. According to the theory of multi-verse, there is an interaction between the multiple universes and even collisions with each other. There is also a suggestion in this theory that each of these universes may be governed by distinct laws of physics.

Wormholes, black holes, and white holes were the three key multi-verse theory concepts that were selected to influence the MVO algorithm. Though a white hole has never been detected in the universe, physicists consider the big bang to be a white hole which may be the key component for a universe's origin. There have also been debates in the multi-verse theory's [15] cyclic model that the creation of white holes/big bangs occurred during the collision of parallel universes. There is a frequent observation of the black holes. The behaviour of black holes is quite different from that of white holes. Due to the black hole's immense force of gravitation of the black holes, attract everything inclusive of beams of light. Holes which act as a connection between the diverse parts of a universe are referred to as wormholes. According to the theory of multi-verse theory, wormholes serve as tunnels for space/time travel in which objects can instantly travel from one universe to another or even between any corners of a universe. The expansion of a universe through space is determined by its inflation rate (also known as eternal inflation). A universe's speed of inflation is quite significant with regard to the feasibility for life, formation of physical laws, wormholes, white holes, black holes, asteroids, planets, and stars. In a cyclic multi-verse model [9], there have been debates that a stable situation is arrived at by the interaction of multiple universes through wormholes, black holes, and white holes. The conceptual and mathematical model of the MVO algorithm is based on this definite notion.

The search procedure is divided into two phases in a population-based algorithm: exploration versus exploitation. Search space exploration by MVO makes use of the black holes and white holes concepts. Contrastingly, search space exploitation by MVO is aided by the wormholes. It is assumed that each solution is analogous to a universe, and each solution variable is an object in that universe. Each solution is allocated a rate of inflation that is directly proportionate to the solution's associated value of fitness function. Moreover, rather than utilizing the term iteration, the term utilized is time as it is a prevalent term in cosmology and multi-verse theory. For the MVO universes, the below rules have been employed during its optimization:

- The rate of inflation is proportional to the probability of white holes.
- Higher the rate of inflation, lower the probability of black holes.
- The sending of objects through white holes is more likely in universes with higher rates of inflation.
- The receipt of objects through black holes is more likely in universes with lower rates of inflation.
- Irrespective of the rate of inflation, objects in all universes can experience random motion towards the best universe through wormholes.

Figure 3 shows the proposed MVO routing. The initial population is created, which represents a random set of CHs. The nodes which are considered as CH are represented by 1 and normal nodes as 0. The fitness of the solutions is computed based on the energy level and the distance between the nodes within the cluster. The termination criteria are the maximum number of iteration, which is taken as 250 in this work.

4 Results and Discussion

MATLAB was used as a simulation platform with the Weka tool for evaluating the proposed methods. For the experiment, a number of nodes 300 to 1500 are considered. Table 1 presents the network parameters used. Tables 2, 3 and 4 tabulate the number of clusters formed, Average end-to-end delay (s), average packet loss rate (%), and lifetime of network, respectively, are for multi-hop LEACH, Tabu search, and multi-verse optimizer.

Fig. 3 Proposed MVO flow chart

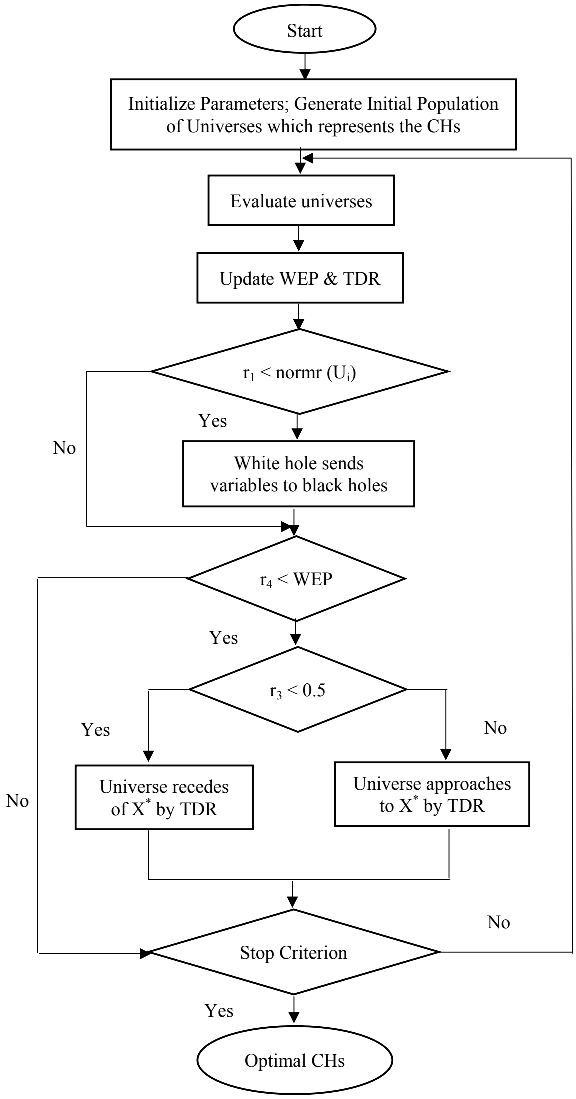

Table 1 Network parameters

Parameter	Value
Number of nodes	300, 600, 900, 1200, 1500
Area of network	1000 m * 1000 m
Initial energy of nodes	1 J
Number of base station	1
Range of transmission	10 m
Data rate	16 kbps

Table 2 Number of clusters formed for multi-verse optimizer

Number of nodes	Multi-hop LEACH	Tabu search	Multi-verse optimizer
300	16	16	16
600	25	26	27
900	41	42	43
1200	46	49	49
1500	46	48	49

Table 3 Average end-to-end delay (s) for multi-verse optimizer

Number of nodes	Multi-hop LEACH	Tabu search	Multi-verse optimizer
300	0.0038	0.0037	0.0036
600	0.0048	0.0047	0.0044
900	0.0428	0.0414	0.0399
1200	0.0716	0.0692	0.0675
1500	0.1403	0.1377	0.1347

Table 4 Average packet loss rate (%) for multi-verse optimizer

Number of nodes	Multi-hop LEACH	Tabu search	Multi-verse optimizer
300	12.33	11.88	11.5
600	19.61	19.24	18.83
900	20.29	19.75	19.19
1200	21.45	20.84	20.05
1500	32.3	31.73	30.61

Figure 4 shows that the number of clusters formed for multi-verse optimizer is higher by 7.7 and by 3.8% than multi-hop LEACH and Tabu search, respectively, for a number of nodes 600. The number of clusters formed for multi-verse optimizer achieves better results by 4.8% and by 2.4% than multi-hop LEACH and Tabu search, respectively, for a number of nodes 900, and the number of clusters formed for multi-verse optimizer performs better by 6.3% and by 2.1% than multi-hop LEACH and Tabu search, respectively, for number of nodes 1500.

Figure 5 shows that the average end-to-end delay (s) for multi-verse optimizer performs better by 5.4 and by 2.7% than multi-hop LEACH and Tabu search, respectively, for number of nodes 300. The average end-to-end delay (s) for multi-verse optimizer performs better by 7.01% and by 3.7% than multi-hop LEACH and Tabu search, respectively, for number of nodes 900, and the average end-to-end delay (s) for multi-verse optimizer performs better by 4.1 and by 2.2% than multi-hop LEACH and Tabu search, respectively, for number of nodes 1500.

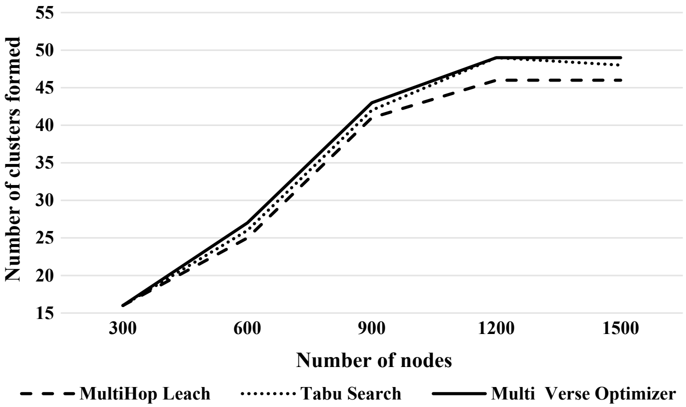

Fig. 4 Number of clusters formed for multi-verse optimizer

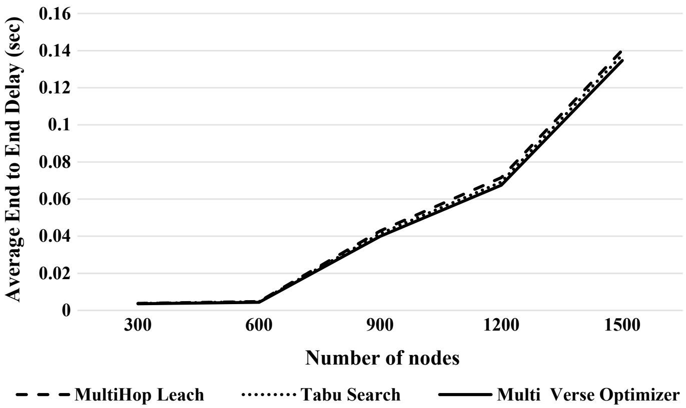

Fig. 5 Average end-to-end delay (s) for multi-verse optimizer

Figure 6 shows that the average packet loss rate (%) for multi-verse optimizer performs better 6.9 and by 3.3% than multi-Hop LEACH and Tabu search, respectively, for number of nodes 300. The average packet loss rate (%) for multi-verse optimizer performs better 5.6 and by 2.9% than multi-hop LEACH and Tabu search, respectively, for number of nodes 900, and the average packet loss rate (%) for multi-verse optimizer performs better 5.4 and by 3.6% than Multi-Hop LEACH and Tabu search, respectively, for number of nodes 1500 (Table 5).

Figure 7 shows that the lifetime computation percentage of nodes alive for multi-verse optimizer for multi-verse optimizer performs better by 5.5% and by 3.3 than multi-hop LEACH and Tabu search, respectively, for a number of rounds 100. The lifetime computation percentage of nodes alive for multi-verse optimizer for multi-verse optimizer performs better by 23.2 and by 15.4% than multi-hop LEACH and Tabu search, respectively, for number of rounds 300, and the lifetime computation

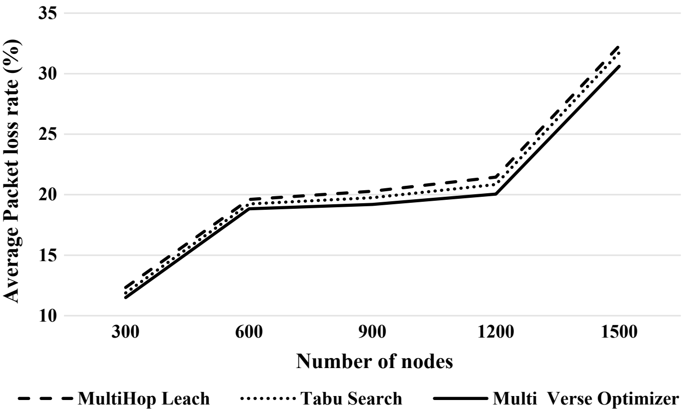

Fig. 6 Average packet loss rate (%) for multi-verse optimizer

Table 5 Lifetime computation for multi-verse optimizer

Number of nodes	Multi-hop LEACH	Tabu search	Multi-verse optimizer
0	97	97	99
100	88	90	93
200	72	75	86
300	61	66	77
400	23	44	65
500	10	31	42
600	3	10	21
700	0	1	5
800	0	2	6

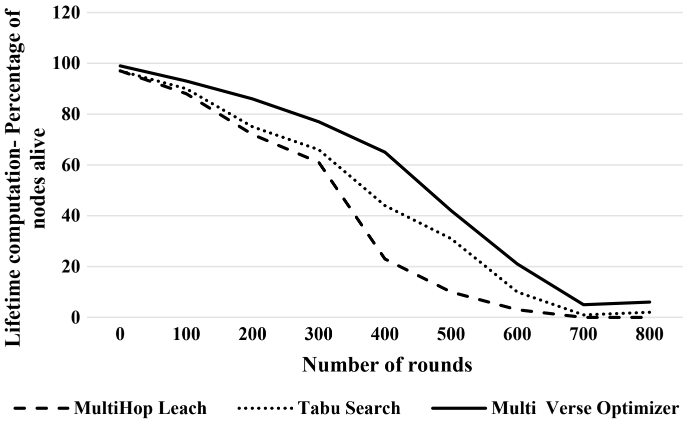

Fig. 7 Lifetime computation for multi-verse optimizer