

Research Article

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Optimized routing with efficient energy transmission using Seline Trustworthy optimization for waste management in the smart cities

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Abstract: Rapid development in technology provides an emerging growth based on innovation, invention, and diffusion, where the diffusion of resources stands with the proper disposal of wastes, due to the over-utilization of resources, growing population growth, and migration increases the accumulation of wastes especially, in Indian cities. Therefore, managing the wastes effectively is a raising challenge in the metropolitan cities of India, where the continuous monitoring of the wastes and disposal needs to be initiated. In this research, an internet-of-things-based smart waste management system in smart cities (IoT-SWMS) is focused on proposing an optimal path selection protocol that facilitates the continuous monitoring and disposal of wastes. The proposed optimal path selection protocol named Seline trustworthy optimization developed to determine the optimal routing path in IoT network renders the faster communication of the collected data regarding the level of the dustbins, which is disposed properly at the right time. The analysis of the proposed Seline trustworthy optimization-based IoT network for SWMS is performed based on the performance measures, such as delay, throughput, energy, and Packet Delivery Ratio (PDR) in comparison with the traditional methods. The proposed methodology yields the maximal PDR of 99%, a minimum delay of 0.11 s, and a maximal throughput of 38,400 kbps.

Keywords: IoT; optimal routing; optimization; Seline Trustworthy Algorithm; smart cities; smart waste management.

Introduction

As per the world report by United Nations, the maximum of the world population would become the inhabitants of metropolitan cities by 2050. The migration of people from urban to inner cities results in the drastic development of technology and culture, populated cities become densely-populated and finally, results in messy lifestyle. As a result, the available facilities become insufficient for fulfilling the basic needs of the people (Rupapara et al. 2021). The fundamental component of a smart environment adopted for systems deals with environmental pollution. The efficient management of waste has a significant impact on the quality of life of citizens. The reason is that the waste disposal has a clear connection with negative impacts in the environment and thus on the health of citizens. Thus we adopted a new method for waste management using internet-of-things (IoT). When IoT's are applied in a city, they are responsible for collecting and processing ambient information and thus, to upgrade the infrastructure of legacy city to Smart Cities. Particularly, wastes generated in large quantities become unable to be handled, creating a hectic task for the municipality for the proper disposal of routinely non-degradable waste before its overflowing period (Kansara et al. 2015; Nidhya et al. 2020).

The improper disposal of routinely non-degradable waste is mainly due to the inefficient way of waste deposition, collection, and disposal (Ali et al. 2020; Kansara et al. 2015). Moreover, there is a lack of smart technologies with the municipal departments. Hence, there is a need for the continuous monitoring of wastes mainly, to collect information regarding the amount of waste disposed to the environment by the citizens, the overflowing level of the dustbins, the shortest path to the garbage location, and its final decomposition stage. Thus, for continuous monitoring of the smart cities, IoT plays a major role thereby, introducing the term Smart Waste Management System (SWMS) that assists in controlling the function and

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operation of the waste management techniques in the smart cities, which would avoid the risk factors of hygiene and environment (Ali et al. 2020; Catarinucci et al. 2015; Nielsen, Lim, and Nielsen 2010; Pardini et al. 2020).

IoT is the interconnection of smart devices, engaged in the collection of information regarding the sensing environment (Alqahtani et al. 2020; Guillemin and Friess 2014). In SWMS, IoT sensors send and track the location of the smart bins for the communication of the collected data and in turn, the IoT sensors can track the system holding the same Internet Protocol (IP) (Alqahtani et al. 2020; Lingling et al. 2011). With the help of the IP, computers with the same IP address are identified and the communication of information between two systems has been communicated successfully. The major advantage of the IoT is regarding the transmission process (John and Rodrigues 2019) that is fully automated and complicated, which is better than the manual operation in handling the wastes (Alqahtani et al. 2020). Thus, IoT is a communication prototype, enabling the effective monitoring and control of day-to-day activities, like waste disposal through several smart devices, such as microcontrollers along with some communication protocols (Nidhya et al. 2020). A notorious example for the smart city is Riot, where one can find smart technologies (Rupapara et al. 2021; Shaik and Ganesh 2020), collaboration, and people (Meijer and Bolívar 2016; Sheng et al. 2020). In terms of managing the wastes, the effectiveness of the smart system mainly depends on the communication distance between the source and destination, which is nothing but the distance between the collection center and its grabbing point (Sheng et al. 2020). Thus, SWMS is the major component of smart cities as it is one of the essential services (Alqahtani et al. 2020; Gutierrez et al. 2015; Hannan et al. 2010).

In SWMS, on-time operation of data collection and waste disposal is facilitated and mainly, the fill levels of the smart bins are monitored effectively (Hannan et al. 2010). The fill levels or the maximum level of waste that can be aggregated in the waste bin is continuously monitored through the sensors fixed to the smart bin and the information related to the bin level is communicated continuously through the shortest routing path. Smart waste bins are convenient for operation and the system has more moldability and chances to set the waste management at minimal cost for operation. For instance, consider smart neo utilizing two types of ultrasonic sensors. The category of the bin and its size is predicted by a sensor while the other measures the fill level of the bin. The process of collecting the wastes based on the sensor neo technology in cities enables smart integration techniques for the waste collection in cities and it reduces the 40% and 60% carbon emissions based on its

operational costs (Alqahtani et al. 2020). For placing the smart waste bins, the zonal regions in the metro are subdivided into several zones, in which the moveable waste bins are placed at a particular distance for the collection of waste (Idwan et al. 2020). The filling level of trash in each dumpster is calculated on the basic probability with the help of Logistic Regression (LR) applicable in Machine Learning (MR). The process of routing or the computation of waste collection paths at various timing patterns to reduce the congestion in the environment is performed with the help of graph theory-based optimization (Anh Khoa et al. 2020). The truck receives the information related to the filling level of the bins from the sensors, which get soldered to the bin. The communication takes place with the help of cloud computing for the operation of feasible levels in managing the waste. The data collected from the cloud sensors (Ashok Kumar and Vimala 2020) is getting transmitted to the safety and health authorities (Alqahtani et al. 2020; Ishaq et al. 2021). The classical methods limits in finding the exact location of the dumpster, selecting the optimal path automatically, and scheduling of wastes, which motivates the author to propose a new method. In the proposed method, waste management authority is used, which updates the information to the truck drivers on daily basis for the collection of waste from the respective dumpsters. The traveling salesman problem is considered for solving the shortest path selection problem.

In this paper, the SWMS is developed for addressing the transmission challenge in the Indian smart city using the proposed Seline Trustworthy Algorithm-Traveling and Salesman Problem (TSP), which declares the shortest path between the source and destination node for collecting the wastes from the bin level, without any delay. The proposed optimized algorithm inherent the features of foraging behavior (Gao and Liu 2012) from honey bees and Paracrine signaling (Dorigo, Birattari, and Stutzle 2006) behavior from real ants for finding the shortest path between the truck manager and the dumpster with fill-level above 90% such that the congestion and the dynamic routing is ensured for the SWMS in smart cities. The prime significance of this research includes:

- **Optimal path selection for disposing of the dumpster:** In the Indian smart city, the optimal path for the truck manager to reach the filled dumpster ensures congestion-free communication with minimal time for disposal so that the dumpster never overflows.
- **Traveling and Salesman Problem (TSP):** The optimal path for traversal in the Indian smart city is selected through the TSP problem, where the shortest routing path selection problem is solved through the proposed Seline Trustworthy Algorithm.

- **Proposed Seline Trustworthy Algorithm:** The proposed Seline Trustworthy Algorithm decides the optimal routing path for communication in the smart city, for which the coalition of foraging behavior from honey bees and Paracrine signaling from the real ants are interpreted through updating the waft trails.

The organization of the manuscript is as follows: Section “Motivation” highlights the need for the optimization-based classification model along with the problem statement. Section “Proposed SWMS in the smart city using the modified Travel and Salesman Algorithm (TSA)” briefs the block diagram explanations with proposed optimizations along with the mathematical model of the proposed routing model for the smart city is explained. Section “Results and discussion” provides the result and discussion based on the comparative analysis with the conventional methods. In Section “Conclusion”, the conclusion with the future scope is detailed.

Motivation

In this section, a comprehensive analysis of the conventional models was evaluated to illustrate the system importance and their drawbacks, which motivates to find the shortest path between the source and destination for providing effective routing in the smart city. Here, is a deep insight into the review and challenges of the traditional methods.

Literature survey

The review of the existing literature is elucidated below. Nidhya et al. (2020) elucidated Enhanced Route Selection (ERS) and Waste Management System (WMS) technology to exhibit the optimal performance of the system to classify the garbage type based on its nature. To avoid the delay in the system, the authors have to consider and evaluate the performance of the corresponding factors, like link reliability, bandwidth availability, and energy availability along with the buffer size, hop count, and distance of the system. Alqahtani et al. (2020) elucidated a Genetic Approach and Support Vector Machine (GASVM) along with the Learning Neural Network Structures with Ant colony algorithms (LNNACs) with the help of Artificial Neural Networks and Particle Swarm Optimization (PSO-ANN), which helped in reducing the overall error rate in the identification of the waste material. However, the quality of waste management was affected by providing improper logical information and

receiving inefficient data. Anh Khoa et al. (2020) developed a Machine learning-based idea and graph theory, which helps in saving time by finding the best route in the management of the waste collection. The devised system provided better operations for optimizing employee use, saving operating costs, and collecting data on time, but for the multi-classification of waste, the system utilized the extra machine learning algorithm. Sheng et al. (2020) elucidated LoRa communication protocol and Tensor Flow-based deep learning model. The model was more compact and flexible as it runs waste detection on a mobile micro-controller platform and at the same time, it can transfer data at a longer range and with lower power consumption. Here, the system undergoes waste detection compartment-by-compartment before waste enters the correct compartment, which leads to longer processing time and also the classification of data does not hold any mobility and the system is not flexible. Pardini et al. (2020) estimated Radio-Frequency Identification (RFID) technology sensors and actuators, wireless mobile communication technologies, embedded systems, and cloud computing technologies that helped in the efficient improvement of the way that the people deal with their garbage and optimize economic and material resources. Here, the system requires more time to calculate the best path in collecting routes and is less efficient with a high cost of operating the fleet of trucks. Sohag and Podder (2020) estimated an automated lid system and an integrated Arduino program, which provides sophisticated service in every sector along with a complete automated system capable of sharing information and also, eliminating spillover of waste. Here, the automated lid may misbehave in certain conditions by providing poor information about how the communication system works. Kang et al. (2020) elucidated e-waste management techniques including Extended Producer Responsibility (EPR) schemes, where small opening prevents any unauthorized access to the e-waste deposited in the collection box, also multiple data being pushed and pulled at the same time, at multiple collection boxes. Here, the system provides unreliable measurement from the ultrasonic sensor and also, difficult to estimate the flow of waste. Idwan et al. (2020) estimated a two-step heuristic algorithm, Multiple Trucks Routing Algorithm (MITRA), and Genetic algorithm to improve the waste collection process by reducing the congestion on the road. However, the system has the drawback of providing only limited time to constrained vehicle routing. Ali et al. (2020) elucidated an IoT-based smart waste bin monitoring and municipal solid waste management system for the collection of waste effectively and performed the detection of fire in waste material for the forecasting of future waste generation, which holds long driving distance.

Problem statement

The challenges considered for the research include:

- The reliable routing in the smart city between the source and destination is based on the six major factors, where the transmission of data is a major contributing factor. The messages need to be transmitted to the waste management authority in the proper time for the collection of wastes from the dumpster before its overflow time else, the delay will occur in the disposal of wastes and leads to hygienic issues (Nidhya et al. 2020).
- For the smart city, the implementation stages for selecting the optimal path automatically increase the selection time of the shortest path between the source and destination. Hence, there is a need for an algorithm that could declare the optimal path in a short time (Anh Khoa et al. 2020).
- Sometimes the location of the dumpster is often neglected by the users in the smart city therefore, finding the exact location of the dumpster for collecting the wastes becomes a difficult task for the truck drivers that directly affect the optimal path for finding the routing (Kang et al. 2020).
- In the smart city, the substance collected from the dumpster has to be recycled most of the time, where the scheduling of wastes acts as a logistics management problem that enables the routing problem with real windows (Nielsen, Lim, and Nielsen 2010).
- When wastes from multiple dumpsters are to be collected in the smart city then, finding the optimized shortest between the source and destination is difficult because it develops confusion in choosing the shortest path for multiple bins (Nidhya et al. 2020).

System model of the IoT network in waste management

In an Indian smart city, IoT sensors are employed for monitoring the waste levels to ensure the disposal of wastes before the bin overflows. Let us assume that there is ‘ U ’ number of IoT nodes and ‘ V ’ number of Cluster Heads (CHs). Generally, IoT nodes are deployed in the sensing environment, where the collected information is communicated with the Base Station (BS) or the waste management authority. Thus, the network suffers from the energy efficiency problem when the IoT nodes initiate the communication with BS directly as nodes are engaged in the random communication of the collected data with the base station. Therefore, CH selection is considered as a significant step in such a way that the

collected data from the IoT nodes are sent to the CHs, which forwards the data to the BS. Accordingly, the information regarding the fill levels is continuously collected by the IoT nodes in the dumpster, which is forwarded to the CH and when the fill level reaches the threshold fill level of 90%, the CH requests the waste management authority for sending the truck to dispose the wastes at the appropriate time, assuring the clean surroundings.

Proposed SWMS in the smart city using the modified Travel and Salesman Algorithm (TSA)

The research focuses on developing an SWMS for an Indian smart city through continuous monitoring of the dumpster levels, using IoT nodes. The block diagram of the proposed methodology is illustrated in Figure 1. The IoT sensors are placed at the top of the dumpsters, which collects the fill levels and continuously updates the fill levels to the waste management authority, which enables the collection of the wastes using the shortest path through the truck manager. From the waste management authority, the information is updated to the truck drivers on daily basis for the collection of waste from the respective dumpsters through the shortest path to avoid congestion. The challenge is regarding the selection of the shortest routing path, for reducing the time taken for collecting the wastes from the dumpsters. The traveling salesman problem is considered for solving the shortest path selection problem, for which the proposed Seline Trustworthy Algorithm is designed based on the foraging behavior of honey bees and Pheromone signaling of the real ants. The proposed routing algorithm declares the shortest path between the truck manager (source) and the dumpster (destination). The proposed routing model for the smart city not only helps in analyzing the bin fill levels and shortest path but also updates the congestion-related data and routing experience to enable the prediction of communication time in such a way that the truck driver collects the waste without any delay.

Smart Waste Management System (SWMS) in the smart city

The proposed SWMS (Ebadinezhad 2020) in the Indian smart city monitors the fill level of the dumpsters through the IoT sensor nodes, and enables the collection of the wastes without any delay, promoting a clean and hygiene

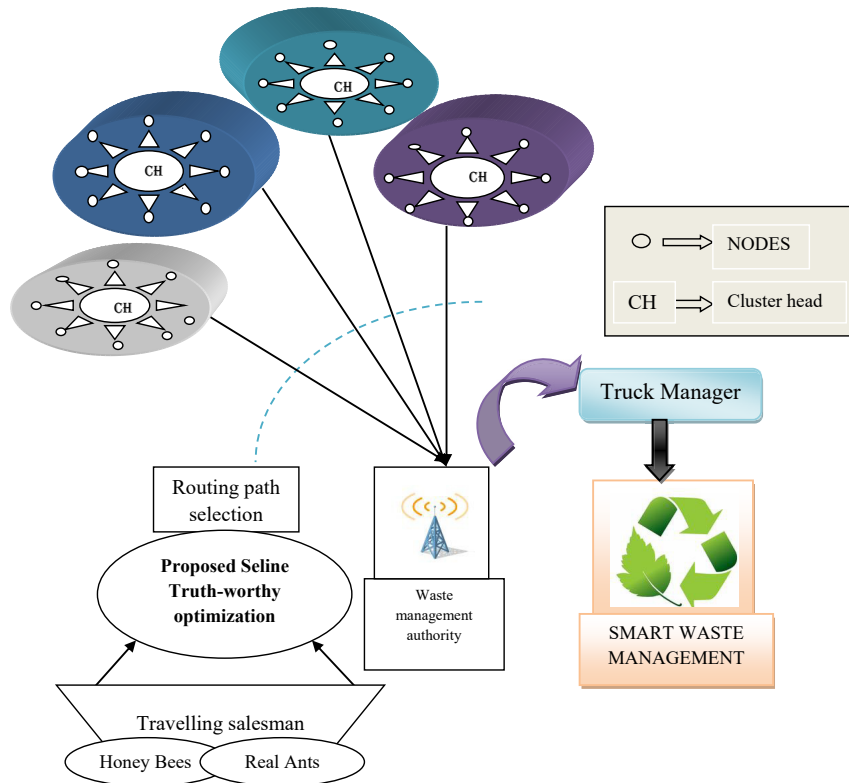


Figure 1: Proposed smart waste management system in the smart city.

environment. Generally, the waste disposal carried out manually takes huge time and effort, resulting in a messy and untidy environment, which promotes the development of the SWMS that in collaboration with the proposed routing protocol ensures the faster disposal of the wastes. In the proposed SWMS, the IoT sensors are placed at the top of the dumpsters, which evaluates the distance between the sensor and the waste level through the sonar. At this point, it is important to note that the extended lifetime of the sensors is based on the energy efficiency of the IoT nodes, for which the clustering phenomenon is initiated in the system. Therefore, the IoT nodes are grouped as clusters, in such a way that the data collected by the IoT nodes are communicated with the CHs, which intimate the waste management authority for evacuating the wastes from the dumpsters. Thus, the proposed SWMS enables the fast transmission of messages from the sensor nodes to the waste management authority through unicast communication. As mentioned above, fast communication is enabled through finding the shortest path between the CH dumpster and the truck driver for which the travel and salesman problem is used, which is solved using the proposed Seline Trustworthy Algorithm is proposed. Algorithm 1 portrays the SWMS in smart cities using the proposed routing approach.

Algorithm 1. Smart Waste Management System in smart cities.

Inputs	Fill level of the dumpsters Total dumpsters in the IoT network TSP-based Saline is trustworthy for declaring the shortest routing path
Output	Optimized routing path Waste disposal

S. No.	#Proposed SWMS for the smart city
1.	The IoT dumpsters are deployed in the sensing environment δ ; $(1 \leq d \leq U)$.
2.	For all dumpsters $\forall d$
3.	{
4.	Form clusters using PSO algorithm; $(1 \leq v \leq V)$
5.	}
6.	Define the threshold value for the fill level of dumpsters
7.	#Continuous monitoring of the fill levels in CHs
8.	If (fill level $\leq$ threshold)
9.	{
10.	Communication of IoT nodes with respective CHs
11.	Else
12.	Communication of CH with waste management authority
13.	}
14.	#Waste disposal
15.	Truck manager is signaled by the authority
16.	{
17.	# route discovery – shortest path Call the proposed TSP-based Seline Trustworthy Algorithm
18.	}
19.	Memorize the communication experience
20.	Iterate
21.	End

As per the aforementioned algorithm, there are three monitoring stages for the SWMS in the smart city, which facilitate the continuous monitoring and faster disposal of the wastes. At first, the nodes in the sensing environment are clustered using the PSO (Shyam, Manvi, and Bharti 2017) to facilitate energy-efficient communication among the IoT nodes, rendering extended life. Thus, the communication flow in terms of three monitoring stages is explained below.

Case 1: Initial level communication: In this stage of waste management, the IoT nodes placed at the top of the dumpsters gather the information regarding the fill level of the dumpsters and communicate with their respective CHs.

Case 2: Intimation to the waste management authority: In the smart city, the CHs keep an eye on the fill level of the dumpsters through their deployed IoT nodes, and upon reaching the 90% fill level of any dumpster (threshold), their respective CH requests the authority for sending the truck manager and in addition, the location of the dumpster to be cleaned, is communicated with the waste management authority.

Case 3: Waste disposal through the shortest path in the Indian smart city: Once the authority receives the request for the waste disposal, the truck manager is intimated with the respective location, provided by the CH. The truck manager uses the location details, to traverse and finally, collects the waste before the dumpster overflows. Moreover, the shortest path is decided based on the TSP-based proposed Seline Trustworthy Algorithm that enables the communication through the shortest path to reach the filled-up dumpster in the smart city. Hence, the waste overflow is avoided and the environment is kept clean and tidy without any spilling.

Traveling salesman problem for shortest path discovery

The TSP is used to find the shortest path between the Truck manager and the destination (IoT nodes) to collect the wastes from the dumpster before the waste overflows. The optimized routing path deployed with the graph connectivity is given by $G = (N, \xi)$ where, N denotes the total number of nodes in the network and ξ represents the cost function for finding the connectivity between the IoT nodes and the truck manager, where the optimal shortest distance for routing is estimated using the Seline trustworthy optimization in the smart city. The number of IoT nodes in the smart city is represented by,

$$N = \{N_1, N_2, \dots, N_d, \dots, N_U\} \quad (1)$$

where, N denotes the nodes in the smart city, N_d highlights the d th IoT node within a CH, and U denotes the total number of nodes within the wireless communication range of the smart city. The shortest path for communicating in the smart city is estimated by the cost function and it is given by,

$$\text{Cost function}(\xi) = \{N_d, BS\}; 1 \leq d \leq U \quad (2)$$

where, ξ is the cost function to find the minimal distance between the source and destination communication terminals in the smart city and BS terms the base station. To find the optimal minimum distance with maximum energy efficiency and minimal delay to avoid congestion in traffic with proper waste management in the smart city, the proposed Seline Trustworthy Algorithm is proposed.

a) **Proposed Seline-Trustworthy Optimization for solving TSP:** The proposed Seline-Trustworthy algorithm is developed by integrating the hybrid features, such as foraging and Paracrine signaling behavior of the honey bees (Gao and Liu 2012) and real ants (Dorigo, Birattari, and Stutzle 2006) and the major focus of the proposed optimization relies on estimating the shortest path between the source and destination communication terminals in the smart city. The proposed algorithm locates the best position of the food source in a short time, which in heuristics terms is named as global optimal convergence. The algorithm steps for the Seline-trustworthy optimization are as follows:

Motivation: The Paracrine signaling behavior and foraging characteristics of real ants and honey bees are inherited in the proposed Seline-trustworthy algorithm solving the shortest path convergence problems. Real ants find the best food source within the neighboring location while in search of the food and it secretes a chemical known as waft, which is secreted all along the way between the source (anthill) and destination (best search space) for finding the minimal distance for other ants. This characteristic feature of the real ants is inspired for finding the minimal paths. Moreover, the characteristics of the Paracrine signaling optimization enable the convergence to the global optimal solution with the higher tendency to avoid local convergence of the optimization.

Main phases of the Seline Trustworthy Algorithm: The main phases included in the optimization are considered as the initialization phase, construction of the individual solution, and search for the local agents to find the shortest path. The phase-wise explanation of the Seline Trustworthy Algorithm is discussed below:

- i) **Initialization phase:** The significant step is the initialization of the waft and foraging, and Paracrine signaling behavior of the Seline. The Seline forages in the transverse left waft values, while the waft is volatile over time therefore, the higher the concentration of waft, the probability of attraction towards the Seline is higher. In the beginning, 'B' ants are placed randomly as given by,

$$B_{ij} = \frac{[F_{ij}]^\alpha [E_{ij}]^\beta}{\sum_{e \in k_n} [F_{i0}]^\alpha [n_{i0}]^\beta} \quad (3)$$

where, F_{ij} represents the amount of data transmitted between the edge of nodes, the attractiveness of edge from i to j is calculated through dividing the length of the edge, which is denoted by E_{ij} and α, β are the parameters used to weight the relative influence of the Seline and attractiveness of the edge and k_n represents the set of unvisited nodes.

- ii) **Construction of solutions:** A constructive heuristic probability method is used to design the construction of solutions. A constructive method helps in the assembling of solutions from finite sets of solution components. In each construction, the current partial solutions are extended by adding the feasible solution component from the set. The process of constructing the solutions is considered as a walk or path on the construction graph given by,

$$GB = (B, \Omega) \quad (4)$$

The above Eq. (2) is a fully connected graph, whose vertices are the solutions of the component derived from the (1) and Ω is considered as the edges of the elements, which helps in finding the direction of the food source by considering the trails of the waft. Once the graph is constructed, the minimal paths are estimated as explained in the next phase.

- iii) **Estimation of the fitness value for the solutions:** Once the solutions are constricted, the fitness of the solutions is estimated so that the optimal solutions are declared. The distance measure considered is the distance, which should be minimal between the source and the destination nodes in such a way that the truck manager uses the shortest path or the optimal distance to dispose of the wastes dumped into the dumpsters.
- iv) **Searching for the local agents:** In this phase, the solution search is done and the solution is the connectivity between the nodes or the routing path, and the solution search in the proposed Seline optimization algorithm is improved, which boosts the performance of the application. The best search agent helps in finding the nearest distance between the source

and the destination in minimal time. Moreover, the convergence to the local optima is avoided through the selection of the global optimal solution for which the characteristics of the paracrine signaling characteristics and foraging characteristics play a major contribution. The optimal path based on the paracrine signaling characteristics is given by,

$$F_{ij} = (1 - \rho)F_{ij} + \sum_{n=1}^W \Delta_{ij}^n \quad (5)$$

where, ρ denotes the evaporation parameter in different nodes. The packet finding for the optimal path $\Delta_{F_{ij}}^n$ is given below,

$$\Delta_{F_{ij}}^n = \begin{cases} \frac{L}{G_n}; & \text{if } nth \text{ packet finding optimal path} \\ 0; & \text{otherwise} \end{cases} \quad (6)$$

where, (L/G_n) denotes the 'n' number of search agents using the vertices of edge nodes considering the optimal arc cost-effective function $acr(i, j)$ in its Hamiltonian tour. Once the search agent updates the position, the best source is explored through the evaluation of the fitness value. Moreover, during the signaling phase, the memory of the path traversed is stored, which assists in storing the experience of the traversing path during the routing process. The detail regarding the congestion and delay is stored as the experience factors for a routing path. Thus, the updated equation specifying the paracrine signaling characteristics with $p + 1$ iterations is given by,

$$F_{i,j}^{p+1} = (1 - \rho)F_{i,j}^p + \sum_{n=1}^W \Delta_{F_{ij}}^{np} \quad (7)$$

The characteristics of foraging are explained through the Waft updation trails, which aim to increase the trails based on the foraging behavior of honey bees for an individual solution to provide high-quality solutions. The characteristics of the foraging behavior are formulated as,

$$F_{i,j}^{p+1} = C_{best}^p + \varphi_{i,j} * (C_{best}^p - F_{i,j}^p) \quad (8)$$

where, C_{best}^p determines the best solution at p th iterations, $\varphi_{i,j}$ denotes the randomly generated values, and $F_{i,j}^p$ is the solution obtained at p th instance. Eq. (8) is reordered as,

$$F_{i,j}^{p+1} = C_{best}^p + \varphi_{ij} * C_{best}^p - \varphi_{ij} \cdot F_{ij}^p \quad (9)$$

$$\varphi_{ij} \cdot F_{ij}^p = C_{best}^p + \varphi_{ij} * C_{best}^p - F_{ij}^{p+1} \quad (10)$$

$$F_{ij}^p = \frac{1}{\varphi_{ij}} [C_{best}^p + \varphi_{ij} * C_{best}^p - F_{ij}^{p+1}] \quad (11)$$

On substituting (11) in (7),

$$F_{ij}^{p+1} = \frac{(1-\rho)}{\varphi_{ij}} [C_{best}^p + \varphi_{ij} * C_{best}^p - F_{ij}^{p+1}] + \sum_{n=1}^N \Delta F_{ij}^{np} \quad (12)$$

$$F_{ij}^{p+1} + \frac{(1-\rho)}{\varphi_{ij}} F_{ij}^{p+1} = \frac{|(1-\rho)|}{\varphi_{ij}} [C_{best}^p + \varphi_{ij} C_{best}^p] + \sum_{n=1}^N \Delta F_{ij}^{np} \quad (13)$$

$$F_{ij}^{p+1} \left(1 + \frac{(1-\rho)}{\varphi_{ij}} \right) = \frac{(1-\rho)}{\varphi_{ij}} [C_{best}^p + \varphi_{ij} C_{best}^p] + \sum_{n=1}^N \Delta F_{ij}^{np} \quad (14)$$

The finalized optimized equation for the proposed Seline Trustworthy Algorithms is given by,

$$F_{ij}^{p+1} = \frac{\varphi_{ij}}{(\varphi_{ij} + 1 - \rho)} \left\{ \frac{(1-\rho)}{\varphi_{ij}} (C_{best}^p + \varphi_{ij} C_{best}^p) + \sum_{n=1}^N \Delta F_{ij}^{np} \right\} \quad (15)$$

In the final Eq. (15), the position update of the search agents is illustrated. The regular updates in the solutions are done iteration-wise to enable the declaration of the global optimal solution. The fitness is computed for the updated solution to find the optimal solution in such a way that the shortest path is determined for waste disposal without delay. Moreover, the experience of the track manager in the best path C_{best}^p of the previous iteration is recorded so that the best optimal solution of the current iteration is declared. $\varphi_{i,j}$ represents the random value and the value ranges from [0, 1]. The solution update at the current instance is represented by F_{ij}^{p+1} and ρ rate is used to reduce the unwanted redundancy.

- v) **Feasibility of the solutions:** The feasibility of the solutions is verified by checking the fitness of the current best solution with the fitness of the best solution in the previous instance. The solution with the maximal fitness measure is considered as the best solution of the iteration, while the other solution is discarded.
- vi) **Termination:** The steps are repeated for the maximal iterations and the best solution, which is the shortest path between the trust manager and the filled dumpster of the waste management system in the smart city, is declared.

Algorithm 2. Pseudo code of proposed Seline Trustworthy Optimization.

Sl. No	Pseudo code of proposed Seline Trustworthy Optimization
1.	Input: F_{ij}^p
2.	Output: F_{ij}^{p+1}
3.	Initialization phase
4.	Initialize the coefficients B, F, E, α , β
5.	Estimate the Fitness for all the solutions l_i
6.	Set
7.	{
8.	Random solution $\varphi_{i,j}$ [0, 1]
9.	C_{best} as best solution
10.	}
11.	Finding fitness for remaining nodal solutions $F(l, m)$
12.	While [$F^p(l, m) > F^{p+1}(l, m)$]
	{
13.	Set the previous solution as optimal cost
14.	}
15.	Restrain the optimal solution
16.	Update the coefficients ρ , np , C_{best}^p , ΔF_{ij}^{np}
17.	End

Results and discussion

This section portrays the analysis of the proposed routing protocol for SWMS in the smart city, where the comparative analysis of the methods is done in comparison with the existing methods.

Experimental setup

The network is simulated in MATLAB software running in windows 10 operating with 8 GB RAM internal memory.

Simulation results

In the smart city, the SWMS is implemented in IoT-based network simulation, where the efficient disposal of the wastes is facilitated through finding the shortest path between the source and destination communication terminals. As a result, the message regarding the fill-up level of the dumpsters is provided to the waste management authority, who intimates the truck driver for disposing of the wastes without any delay. Moreover, in the smart city, the navigation location with the optimal shortest path is

updated effectively along with the future prediction of the traffic to avoid congestion in the communication path and keep away from the delays in the future while the truck manager traverses towards the dumpster. The optimal shortest path for communicating the waste level information in the Indian smart city is determined using the proposed Seline Trustworthy Algorithm that solves the TSP regarding the shortest path discovery.

In the smart city, the TSA algorithm helps in enabling the dynamic performance of the routing, where the estimated shortest path helps the truck manager to collect the wastes before it overflows in the dumpster. Thus, a clean and tidy environment is established in the smart city through the frequent evacuation of the dumpsters.

Using 50 nodes in the simulation area: Figure 2 shows the simulation area with 50 nodes or 50 dumpsters in the smart city. Figure 2a illustrates the location of

dumpsters that are connected with the nodes for continuous monitoring of fill levels in the dustbins, within a CH. Figure 2b represents the 90% fill levels of the dustbin in red color, while the nodes with the blue, pink and yellow color represent the 10, 50, and 70% fill levels of the dumpster. Once the dumpster reaches its fill level, the information from the CH is delivered to the Truck driver through the waste management authority, for the collection of wastes. The optimized path for the collection of wastes without congestion is illustrated in Figure 2c.

Using 100 nodes in the simulation area: The optimized path for routing by considering the location of a dustbin and its fill levels is elucidated in Figure 3. The position of the 100 dumpsters at different locations controlled by different CHs is depicted in Figure 3a. In Figure 3b, the fill levels of the dumpsters are mentioned in red colors. Once the dumpster reaches 90% of the fill level, the messages

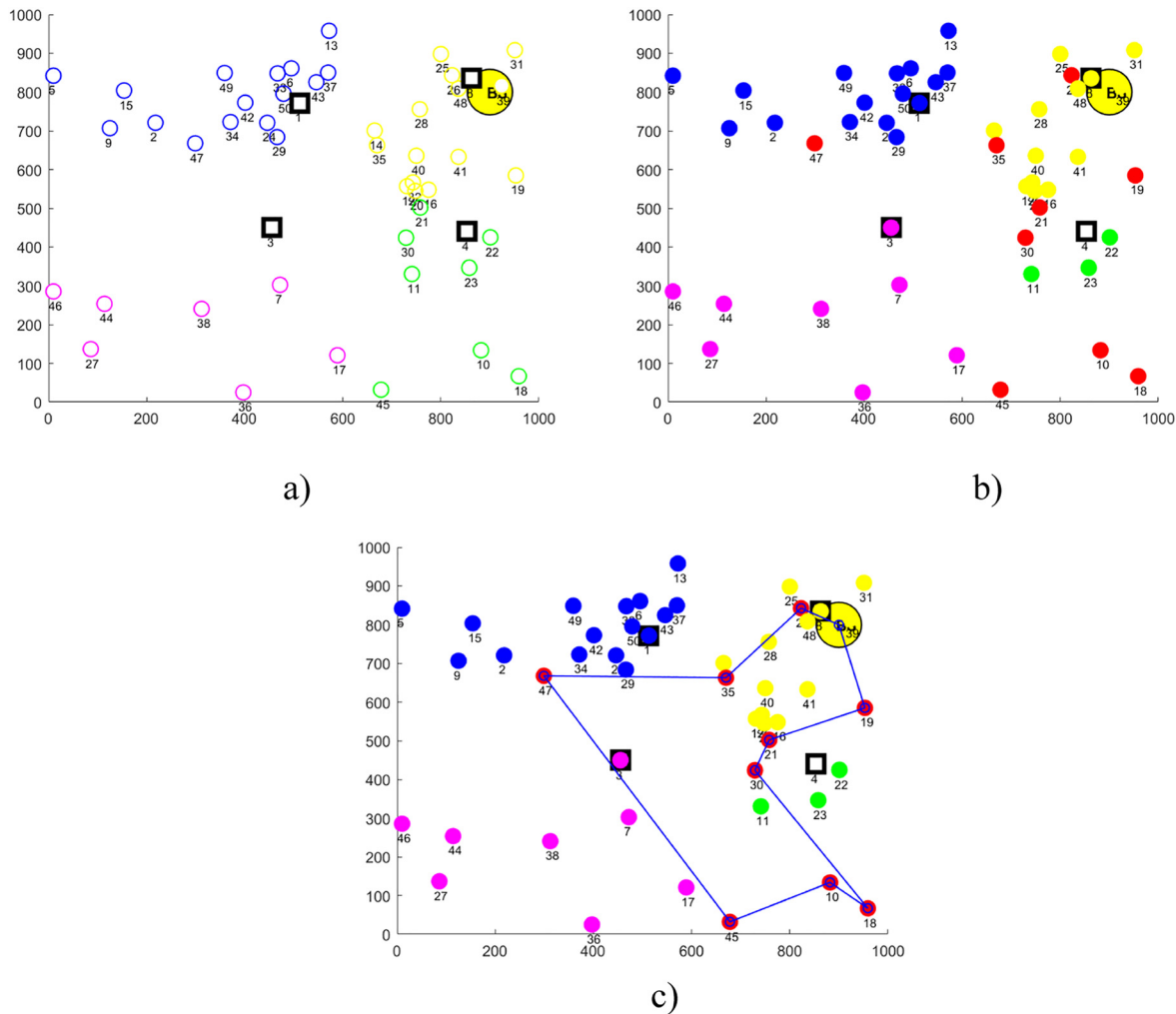


Figure 2: Simulation results for optimized routing using 50 nodes at 100th iteration, (a) Simulation area with 50 nodes, (b) Nodes illustrating the fill levels, and (c) Routing path declared by the proposed Seline optimization algorithm.

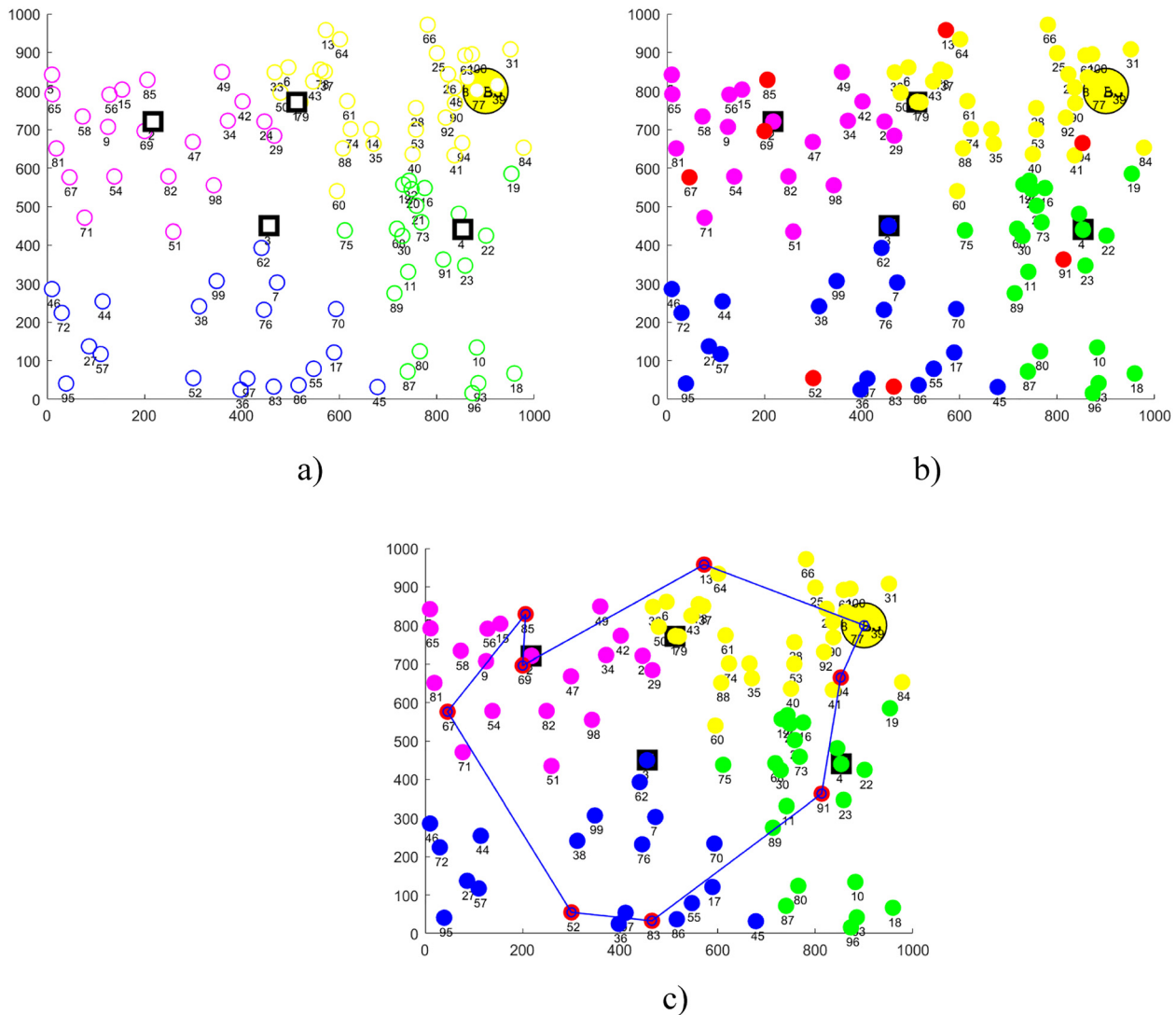


Figure 3: Simulation results for optimized routing for 100 nodes at 100th iterations, (a) Simulation area with 100 nodes, (b) Nodes illustrating the fill levels, and (c) Routing path declared by the proposed Seline Optimization Algorithm.

from the CH are provided to the BS (waste management authority), from the BS, the message is intimated to the truck driver for the collection of wastes for which the location is communicated through the CH. The optimized path established for routing is shown in Figure 3c.

Performance metrics

The proposed method is compared with the traditional state-of-art approaches based on the performance metrics namely, Delay, Throughput, Packet Delivery Ratio (PDR), and Energy. The performance metrics mentioned above enable predicting the future and support the selection of the shortest path with less congestion in traffic, which adds

sufficient value in the waste management process of the smart cities.

Delay: Delay is defined as the maximum time required by the network for the transmission of data from source to destination. A communication/routing path with minimum delay is considered as the best path for waste disposal, which minimizes energy consumption and reduces the disposal time. The delay in the network is represented in the following equation,

$$A_a = \sum \frac{J_a}{N_a} \quad (21)$$

where, A_a represents the delay in the network and J_a , N_a denotes the number of packets received in the network and the number of packets to be transmitted.

Packet Delivery Ratio (PDR): The PDR is described as the ratio of the number of packets to be transmitted to the total number of packets being received by the destination. The PDR is mathematically represented as,

$$PDR = \frac{N_a}{N_r} \quad (22)$$

where, N_a represents the number of packets to be transmitted and N_r denotes the number of packets to be received by the network.

Throughput: Throughput is described as the quantity of data that can be transferred within a certain period between the source and destination in the smart city. The network throughput is also defined as the rate at which the bits or the packets are successfully delivered over the network channel.

$$Q_N = \frac{J_a}{R_N} \quad (23)$$

where, Q_N denotes the throughput of the network and J_a represents the number of packets transmitted successfully, and R_N represents the measurement period.

Energy: The amount of energy left on each sensor node and the cluster head at the end of the communication process in the smart city is the average energy of the network. In smart cities, energy is considered a very important factor since it defines the lifetime of the network and the formulation of energy for sensor nodes (24) and cluster heads (25) is represented as follows,

$$\xi_{y+1}(Z_Z^t) = \xi_{y+1}(Z_Z^t) - \xi_k(Z_Z^t) \quad (24)$$

$$\xi_{y+1}(Z_X^t) = \xi_{y+1}(Z_X^t) - \xi_k(Z_X^t) \quad (25)$$

where, $\xi_{y+1}(Z_Z^t)$ and $\xi_{y+1}(Z_X^t)$ represents the updated energy of the sensor nodes and cluster heads respectively. $\xi_{y+1}(Z_Z^t)$ denotes the initial energies of sensor nodes and $\xi_{y+1}(Z_X^t)$ represents the initial energies of cluster heads. $\xi_k(Z_Z^t)$ and $\xi_k(Z_X^t)$ denotes the energy dissipated for the nodes and cluster heads, respectively.

Comparative methods

The methods used for the comparative analysis include Artificial Bee Colony with TSP (Gao and Liu 2012), Ant Colony Optimization with TSP (Dorigo, Birattari, and Stutzle 2006), and Particle Swarm Optimization with TSP, and the results of the existing optimizations are compared with the proposed Seline-Trustworthy-based TSP to justify the performance.

Comparative analysis

In this section, the comparative analysis for nodes 50, 100, 150, and 200 based on the performance metrics is carried out in comparison with the traditional methods to prove the effectiveness of the SWMS using the proposed Seline trustworthy-based TSP algorithm.

Using 50 nodes

Figure 4 depicts the comparative analysis of the proposed method based on the delay, throughput, PDR, and Energy with the traditional methods for 50 nodes. Figure 4a demonstrates the analysis of the comparative methods based on the delay. At round_50, the delay of 0.17, 0.37, and 0.29 s is obtained for the traditional methods, such as ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing, while the proposed Seline Trustworthy-TSP routing provides a lesser delay of 0.11 s in comparison with the traditional methods. Figure 4b shows the analysis of the methods based on the energy. In terms of energy, the conventional methods, like ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing dissipate more energy during the communication, while the proposed method enables the communication through the shortest routing path, which lessens the energy dissipation in the nodes comparative with the traditional methods. Figure 4c illustrates the analysis of the methods based on the PDR. The traditional methods, like ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing yield a PDR value of 0.94, 0.91, and 0.96, respectively at round_50, while the proposed method provides an increased PDR of 0.99 at round_50. In Figure 4d, the throughput analysis of the methods is presented. The existing methods ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing possess the throughput of 1751, 1645, and 1500 kbps, respectively, while the proposed Seline Trustworthy-TSP routing provides the throughput of 2300 kbps. On analyzing the method based on the performance metrics, it is proved that the proposed method provides better performance in comparison with the existing methods.

Using 100 nodes

Figure 5 demonstrates the analysis of the comparative methods based on the performance metrics. At round_50, the delay of 0.23, 0.36, and 0.28 s is obtained for the traditional methods, such as ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing, while the proposed Seline

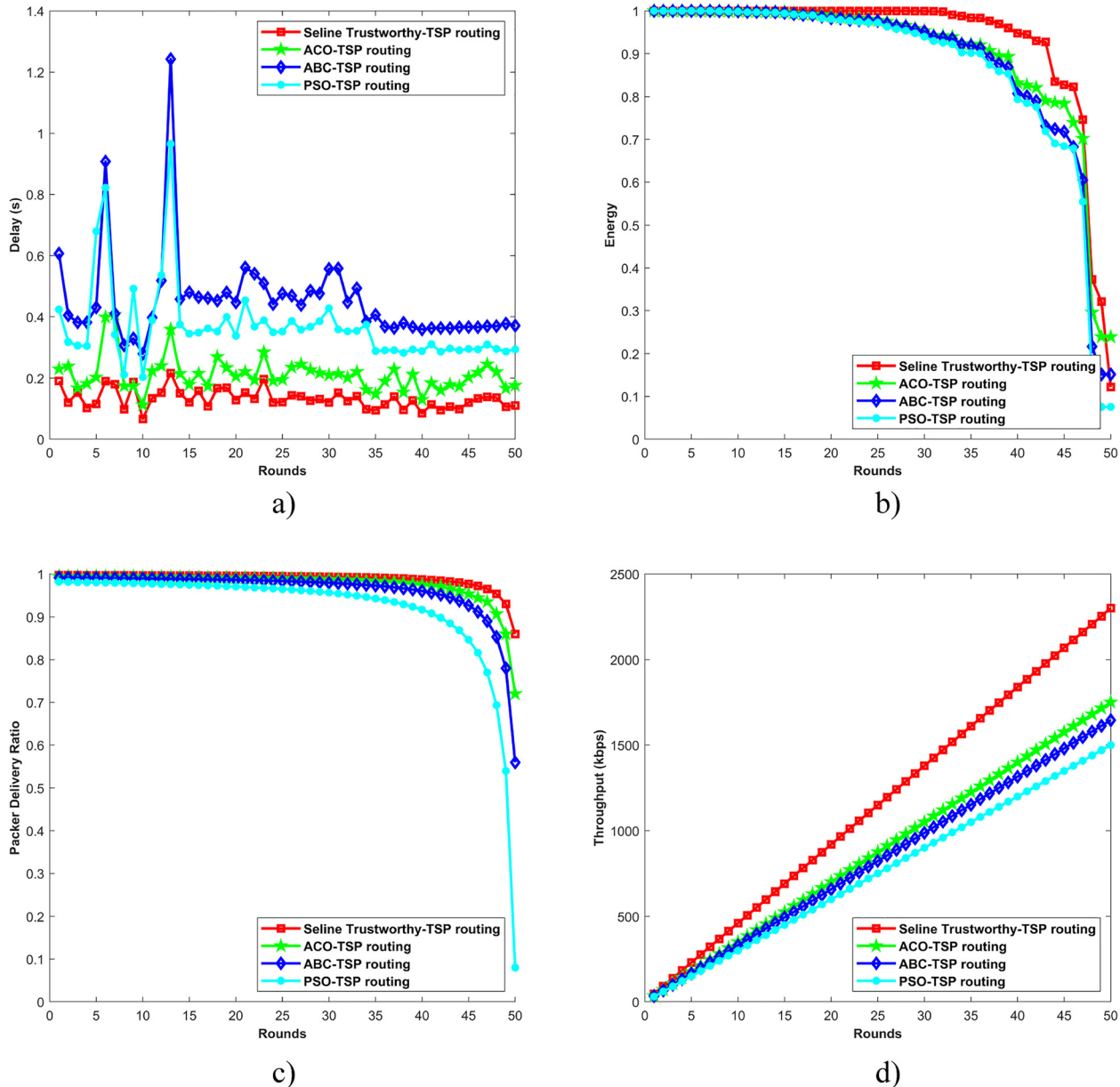


Figure 4: Comparative analysis of the methods with 50 nodes in the simulation area, (a) Analysis based on Delay, (b) Analysis based on Energy, (c) Analysis based on PDR, and (d) analysis based on the Throughput.

Trustworthy-TSP routing provides a lesser delay of 0.14 s in comparison with the traditional methods is illustrated in Figure 5a. In Figure 5b, the performance metrics of energy for the conventional methods, such as ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing are depicted, where the traditional method used more amount of energy at the time of collecting the wastes for round_100 from the IoT nodes, whereas the proposed method dissipates lesser energy in comparison with the traditional methods. Figure 5c illustrates the analysis based on the PDR of the methods. The PDR ratio for the

traditional methods, such as ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing are 0.9968, 0.9947, and 0.9905, respectively for the 100th round, while the proposed method acquired an increased PDR of 0.9981. In Figure 5d, the analysis of the methods based on throughput is enumerated. The existing methods, such as ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing yielded the throughput of 7600, 6892, and 5750 kbps, respectively, while the proposed Seline Trustworthy-TSP routing provides an improved throughput of 9400 kbps in comparison with the traditional methods. Based on the

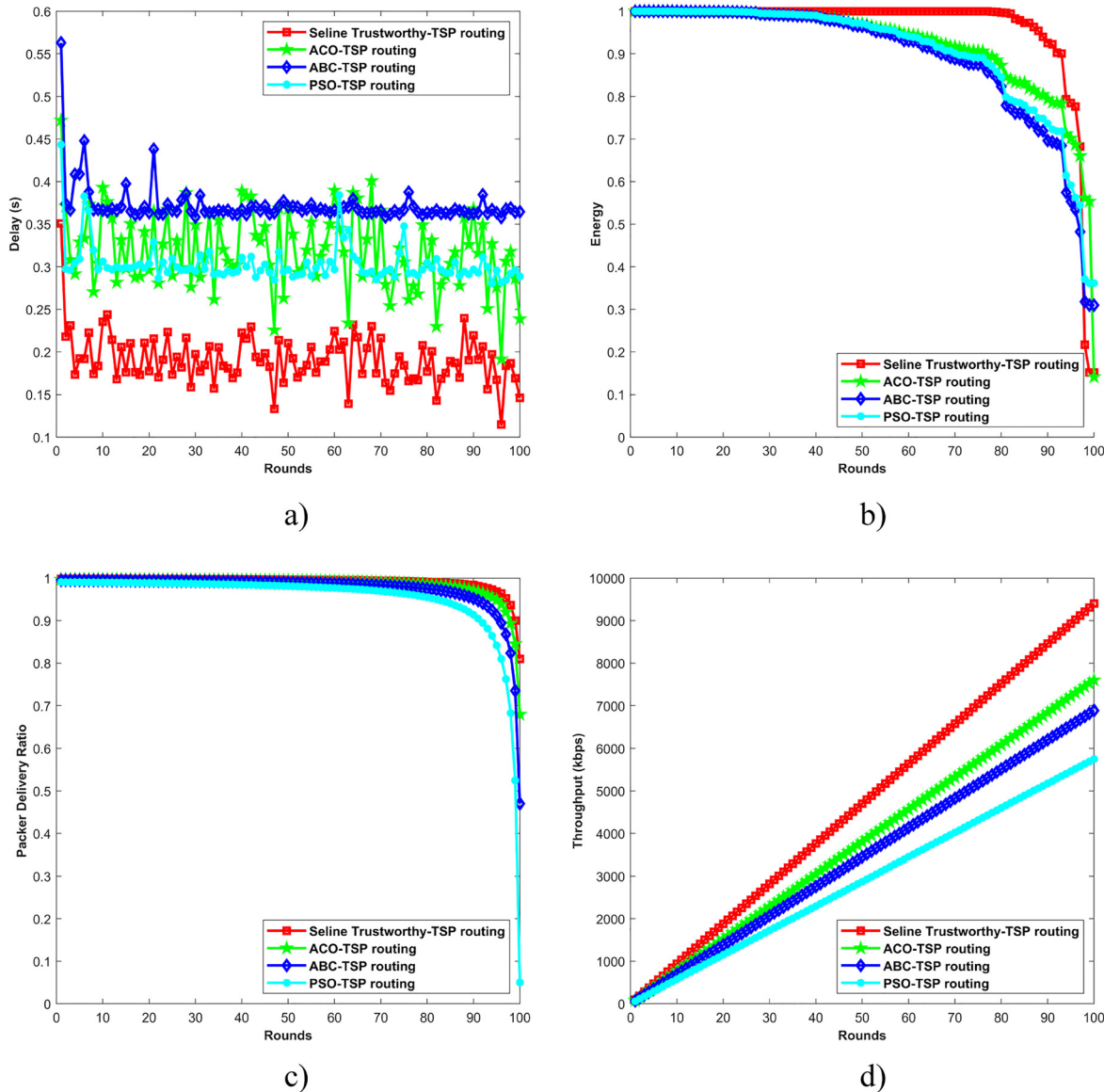


Figure 5: Comparative analysis of the methods with 100 nodes in the simulation area, (a) Analysis based on Delay, (b) Analysis based on Energy, (c) Analysis based on PDR, and (d) Analysis based on the Throughput.

above analysis, it is evaluated that the proposed method exhibited improved performance than the existing ones.

Using 150 nodes

The comparative analysis of delay, throughput, Packet Delivery Ratio, and Energy for the proposed method in comparison with the traditional methods for 150 nodes is illustrated in Figure 6. The estimated delay for the existing methods, such as ACO-TSP routing, ABC-TSP routing, PSO-TSP routing is 0.46, 0.36, and 0.3 s, while the proposed Seline Trustworthy-TSP routing provides a lesser delay of 0.26 s as illustrated in Figure 6a. In Figure 6b, the

performance metrics of energy is shown, where the conventional methods, such as ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing dissipate more energy from the IoT nodes at the time of collecting the wastes from the dumpsters for ACO-TSP routing and ABC-TSP routing, while the proposed Seline Trustworthy methods dissipate minimal energy in comparison with the traditional methods. Figure 6c shows the performance analysis based on the PDR. The traditional methods, such as ACO-TSP, ABC-TSP, and PSO-TSP yield the PDR of 0.997, 0.99, and 0.993 respectively at the 150th round, while the proposed method achieved an increased PDR of 0.998. In Figure 6d, the throughput analysis of the routing methods is presented. The existing

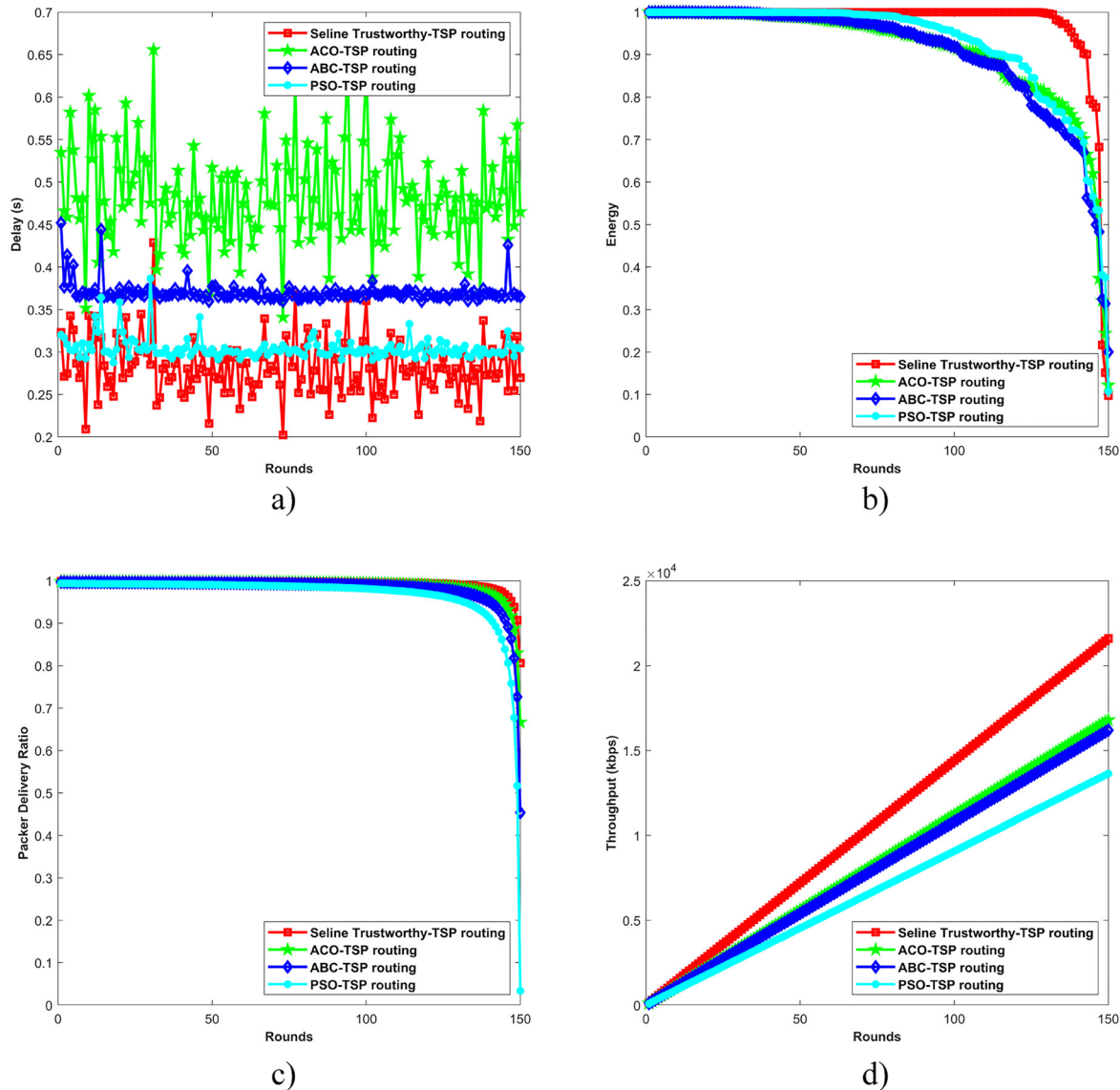


Figure 6: Comparative analysis of the methods with 150 nodes in the simulation area, (a) Analysis based on Delay, (b) Analysis based on Energy, (c) Analysis based on PDR, and (d) Analysis based on the Throughput.

methods, such as ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing acquired the throughput of 16,800, 16,196, and 13,635 kbps respectively, while the proposed Seline Trustworthy-TSP method provides an increased PDR value of 21,600 kbps. On analyzing the method based on the performance metrics, it is proved that the proposed method provides better performance in comparison with the existing methods.

Using 200 nodes in the simulation area

Figure 7 depicts the comparative analysis of the methods based on delay, throughput, Packet Delivery Ratio, and

Energy when the simulation is established using 200 nodes. The delay acquired by the existing methods, like ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing are 0.632, 0.37, and 0.422 s, respectively, while the proposed Seline Trustworthy routing provides a lesser delay of 0.23 s in comparison with the traditional methods is illustrated in Figure 7a. Figure 7b shows the analysis based on the energy remaining in the nodes. Here, the conventional method dissipates a higher amount of energy at the time of collecting the wastes from the dumpster, whereas for the proposed method, the minimal energy is dissipated in comparison with the traditional methods. In Figure 7c, the PDR analysis is enumerated, where the traditional

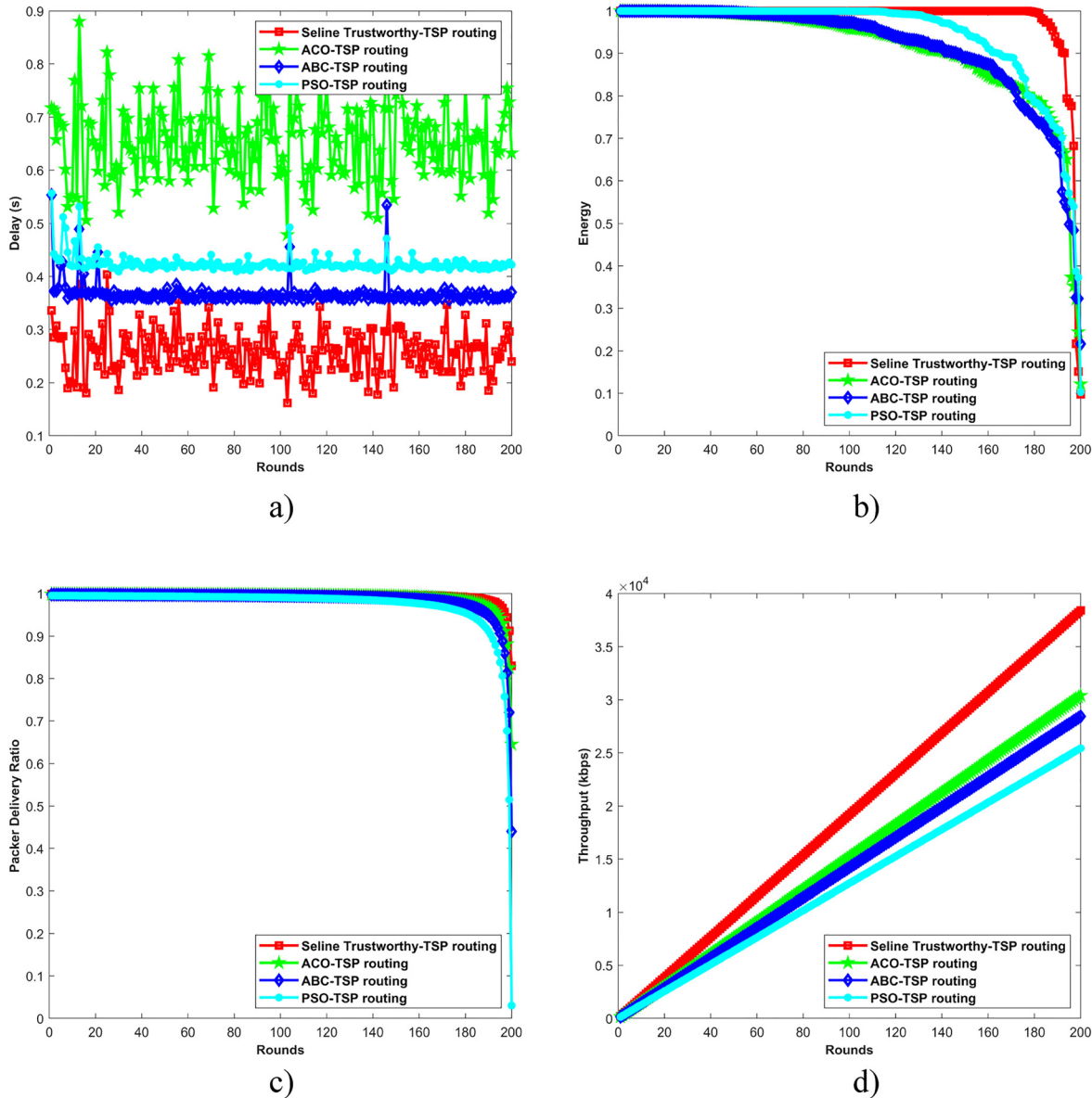


Figure 7: Comparative analysis of the methods with 200 nodes in the simulation area, (a) Analysis based on Delay, (b) Analysis based on Energy, (c) Analysis based on PDR, and (d) Analysis based on the Throughput.

methods, such as ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing reported the PDR of 0.998, 0.997, and 0.991, respectively at 200th round, while the proposed method achieved an increased PDR of 0.99. In Figure 7d, the throughput analysis of the methods is shown. The existing methods, such as ACO-TSP routing, ABC-TSP routing, and PSO-TSP routing record the throughput of 30,400, 28,426, and 25,431 kbps, respectively, while the proposed Seline Trustworthy-TSP routing obtains the throughput of 38,400 kbps. Based on the above analysis, it is evaluated that the proposed method provides improved performance compared with the conventional methods.

Comparative discussion

The comparative discussion is performed based on the performance metrics, such as delay, energy, throughput, and PDR, where the proposed optimization provides positive outcomes with a higher degree of energy-efficient transmission. The proposed method acquires a minimum delay of 0.11, 0.14, 0.26, and 0.23 s for 50, 100, 150, and 200 nodes, respectively. In addition to the delay, the PDR of the proposed method is maximal with a rate of 0.99, 0.9981, 0.998, and 0.99 when 50, 100, 150, and 200 nodes are simulated in the network. At the same time, the proposed

method attained a better throughput of 30,400, 28,426, 25,431, and 38,400 kbps with 50, 100, 150, and 200 nodes, respectively in the simulation area (see Table 1).

Conclusions

The paper concentrates on the SWMS in the smart cities to keep the city clean and hygienic through frequent evacuation of the wastes. In smart cities, the proper disposal of wastes is found to be a difficult task as the manual disposal strategies are time-consuming, before which the wastes overflow in the dumpsters. Hence, there is a need for the efficient disposal of wastes in smart cities. Hence, the proposed TSP-based Seline Trustworthy Algorithm dependent SWMS is designed for the smart cities, which succeeded by collecting the wastes from the dumpsters

before they overflow. The optimized Seline Trustworthy Algorithm provides an optimal minimum path for the truck manager for the disposal of the wastes from the dumpsters at 90% of the fill level. Particularly, the proposed optimization algorithm is developed by considering the foraging characteristics and Paracrine signaling characteristics of honey bees and real ants. The proposed method is analyzed with the existing methods to reveal the effectiveness and the analysis is done based on the performance metrics, such as delay, energy, throughput, and PDR. The proposed Seline Trustworthy-based TSP-dependent SWMS for the smart cities yield a minimum delay of 0.11 s, maximal throughput of 38,400 kbps, and a maximal PDR comparative with the existing methods. The future dimension of the research relies on applying new techniques and algorithms for providing efficient routing mechanisms for waste management in smart cities. Also, advanced technologies, such as blockchain, digital twins will be considered to improve waste management, and also the future scope includes, identifying more real datasets to test out the model behavior.

Table 1: Comparative discussion.

Performance metrics	Methods	50 Nodes	100 Nodes	150 Nodes	200 Nodes
Delay (s)	ACO-TSP routing	0.17	0.23	0.46	0.63
	ABC-TSP routing	0.37	0.36	0.36	0.37
	PSO-TSP routing	0.29	0.28	0.3	0.42
	Seline trustworthy	0.11	0.14	0.26	0.23
Remaining energy in the sensor nodes	ACO-TSP routing	0.15	0.30	0.12	0.122
	ABC-TSP routing	0.122	0.15	0.10	0.10
	PSO-TSP routing	0.07	0.14	0.07	0.13
	Seline trustworthy	0.23	0.36	0.20	0.21
Throughput (kbps)	ACO-TSP routing	230	7600	16,800	30,400
	ABC-TSP routing	1500	6892	16,196	28,426
	PSO-TSP routing	1645	5750	13,635	25,431
	Seline trustworthy	1751	9400	21,600	38,400
PDR	ACO-TSP routing	0.94	0.9968	0.907	0.98
	ABC-TSP routing	0.91	0.9947	0.97	0.97
	PSO-TSP routing	0.96	0.9905	0.93	0.91
	Seline trustworthy	0.99	0.9981	0.998	0.99

The proposed method results are mentioned in “bold”.

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