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Research Article

Selection of Devices Based on Multicriteria for Mobile Data in Internet of Things Environment

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Internet of Things (IoT) is a computing term which describes universal Internet connectivity, transforming everyday objects into connected devices. Many smart devices are interconnected to sense their surroundings, send, and process the sensed data. The IoT connects the real world with the global world by interconnecting edge devices. The main goal of the IoT is to attain high operating performance, improve throughput, and control the assets and processes of the industry. Many heterogeneous devices in IoT settings are linked with each other to transfer huge amount of information for operations of organizational efficiency. The appropriate and proper device may hinder the main goals of the IoT which seems difficult to achieve. However, not a single research study is focused on the selection of devices based on multicriteria properties. For solving the dilemma of the IoT device selection, "Properties Based Device Selection Using Ant Colony Optimization (PBDS-ACO)" is implemented in this paper which selects a device based on multicriteria properties. By exploiting the suggested model, the effectiveness and efficiency of the IoT are shown.

1. Introduction

IoT paradigm is a blend of three "visions," namely, "things," "Internet," and "semantic-oriented." IoT is a network of heterogeneous devices that are linked and addressed via shared communications protocol, either from things oriented or via Internet point of view [1]. IoT connects the real world with the global world by interconnecting edge devices [2]. The "Internet of Things" terminology is for the explosion of network communication and computing power to various devices, objects, sensors, and other noncomputer-like devices. These "smart objects" create, share, and consume data with little human interaction, and they often provide access to analyzing, collecting, and controlling distant. The IoT devices are linked in industrial setting for consumer, national, and commercial use [3]. Devices, computers, and people can communicate and connect with each other more efficiently and effectively due to the Internet of Things [4]. IoT provides universal Internet connectivity, by transforming ordinary objects into connected devices. The IoT concept is based on the deployment of many smart devices that are interconnected to sense their surroundings, send, and process the sensed data. Connecting unusual objects to the Internet would enhance industry and society's sustainability and protection, as well as aid efficient communication between the digital and real world, referred to as a cyber-physical system (CPS). The IoT concept is also viewed as a revolutionary technology capable of addressing many of today's societal challenges, including smart cities, intelligent transportation, radiation emissions, and allied healthcare [5].

Industrial IoT is being developed as a result of the introduction of new technological developments and implementations of the IoT in Industrial Internet of Things (IIoT). IIoT is an industrial concept that automates intelligent objects for the detection, storage, processing, and transmission of events in industrial real-time networks environment. IIoT seeks to achieve high operating efficiency, higher productivity, and appropriate planning of industrial assets and processes by customizing products, by integrating intelligent applications for manufacturing and mechanical health services, and by maintaining industrial preventive machinery [6]. People and companies now connect and conduct business electronically thanks to the Internet. As a result, the new concept the "Industrial Internet of Things" encompasses a variety of devices, software, and services that link the virtual and physical worlds [7]. In the industrial environment, different sensors and wireless devices have become widely implemented because of the fast-developing requirements for industrial production/service for protection, efficiency, and reliability. The IIoT, a subset of the IoT developed for industrial applications, is being built on this basis. The IIoT gathers massive quantities of data regularly [8].

Various devices properties were extracted from the literature with the intention of using them for selecting appropriate devices in IoT settings. According to our analysis, the proposed "PBDS-ACO" is a novel approach since no prior research has used the ant colony approach for addressing the dilemma of device selection in IoT settings. The efficacy and reliability of IoT would significantly be improved if this technique was used as it selects appropriate devices based on multicriteria properties.

The structure of the current paper is as follows. The literature review is briefly shown in Section 2. The methodology of the proposed research along with details is presented in Section 3. The results and discussions are comprehensively presented in Section 4. Conclusion of the paper is given in Section 5.

2. Literature Review

The practice of combining computers and networks to track and manage devices is known as "Internet of Things." Several technological and business developments are combining to make it possible to attach more and smaller devices cheaply and easily. The IoT is the result of the integration of many computing and networking technologies. At this time, a wide variety of industries, including automotive, healthcare, engineering, home and consumer electronics, and many others, are exploring how IoT technology can be integrated into their products, services, and operations [9]. Millions of sensor-equipped devices are interconnected to gather and share data. The Internet of Things is considered as the daily object phenomena, which are linked by an interconnected system. These sensors create a mass of data simultaneously and constantly, often known as big data, from a broad range of appliances or products. If we reduce time, energy, and processing capacity, this large data volume and various variants pose critical issues. Therefore, for data acquired by IoT, big data analytics are more complex. IoT big data issues were identified and managed with respect to data management, data analysis, unstructured data analysis, data visualization, interoperability, data semantic, scalability, data fusion, data integration, data quality, and information discovery [10]. In today's IoT environment, policymakers, entrepreneurs, the academia sector, and even the general public are highlighting the connection between technology-driven (data), copyrights, privacy law, and competitive legislation. For instance, business people can build resources; analysts can readily gather, evaluate, and share information; and now everyone recognizes that collecting and distributing personal data might lead to data privacy issues [11].

The industry 4.0 aims to increase the efficiency, adaptability, and digitization of core operations that integrate value chains so that companies may plan and interact with available data from various technologies. This makes it difficult for firms to comprehend how the technology of industry 4.0 may be used to improve the available processes by providing the current and new users a more compelling value proposition [12].

The IoT keeps spreading in previously inaccessible sectors. These areas may present specific limitations that make IoT systems challenging to create and execute. For instance, the lack of specific protocols, restricting the information that may be accessed, and the necessity to facilitate the public and monitor the communications operations are some of these restrictions. Fast and efficient implementation of these initiatives is crucial if such restrictions are to be collected, evaluated, and exploited [13]. Connectivity is one word, which summarizes the transformation of industry 4.0. Due to the increased globalization and industry 4.0, the relevance of IoT and Industrial IoT (IIoT) has increased substantially. With global increase in upcoming opportunities, data protection and data security have become crucial features of IIoT. Considerable significance is devoted to the identification of industrial networks (IIoT). For instance, it is a vital component for the safe running of intelligent grid systems and for safeguarding the privacy of the client. Data transmission is also a feasible method for transferring cloud research into the fog for industrial networks, providing quick intrusion detection and time to prevent networks attack [14].

The notion is very engaging for most industrial sectors due to increased operational effectiveness in production processes, smart item identity methods, and intelligent control applicability. It reduces employee intervention in hazardous industrial circles. The IIoT phenomenon is built on the IoT (Internet of Things) technologies, which presently guarantee effective working performance in many domains, both in the sector and business and commercial sectors [15]. Enhanced sensing, data collecting, and communication technologies lead to an enormous expansion of the IIoT in recent years, which intensifies the transformation in the monitoring and management of electronic asset values. An open environment is an essential necessity so that users may connect freely on user terminals via web or mobile apps with power devices and servers, thereby improving IIoT flexibility. The fundamental open ecosystem technology for the future IIoT includes strong sensor technologies, broad-based ways for communication, a big data services platform, data processing algorithms, and intelligent maintenance. In the management of wind farms, the potential IIoT ecosystem should be addressed. Wind farm quality and efficiency are demonstrated through enabling an open future ecology IIoT which provides an advanced insight into electrical assets control and maintenance with high dependability [16].

The fundamental open technological platform for the future IIoT includes strong sensor technologies, broad-based ways for communication, a big data services platform, data processing algorithms, and intelligent maintenance. In the management of wind farms, the potential IIoT ecosystem should be addressed. Wind farm quality and efficiency are demonstrated through enabling an open future ecology IIoT which provides an advanced insight into electrical assets control and maintenance with high dependability. The adaptive transmission architecture is proposed by SDN and EC for IIoT. The dominance Internet of Things is a ground-grained algorithm that satisfies time restrictions in the short-term context (IoT). The path difference degree (PDD), taking into consideration the time limit, traffic load balances, and energy consumption additive, has been used for an optimum scheduling route. A well-designed strategy is introduced in a tight time to establish a powerful transmission channel using a low latency adaptive power approach when the gross grain technology is beyond the scope. Finally, the simulation assesses the plan's success. Results demonstrate that the system suggested exceeds the average time, commodities, output, PDD, and download time for the corresponding techniques. The approach described provides an improved way to manage IIoT data [17].

3. Methodology

In the Internet of Things ecosystem, heterogeneous devices are linked to form a network. The selection of the appropriate device is a daunting activity. The selection of devices will be based on multicriteria properties. These properties were discovered by analyzing the literature. As heterogeneous devices combine to form the IoT ecosystem, the properties set of these devices will be broad and there may exist redundancy which influences the proper selection. To eliminate complexity and redundancy, these were filtered out.

3.1. Selection Based on Device Properties. Feeding a large number of device properties into a detection system not only makes computation more difficult but also causes the dimensionality curse. A broad and complex dataset is reduced, and suitable properties are sorted out using properties based filtering. The properties based selection technique is used to pick a subset of the original set while maintaining the original set's accuracy. The effectiveness and scalability of a system can be enhanced by eliminating unnecessary and redundant device properties. When working with a large number of device properties datasets, it is important to choose the right device based on its specific properties. Properties based selection is needed in real-world problems owing to the proliferation of noisy, unnecessary, or misleading properties. The IoT ecosystem is made up of a wide range of heterogeneous devices, each with its own set of characteristics. The properties of devices are gathered from previous research studies. It was important to identify these properties in order to differentiate between appropriate and inappropriate devices. The inconsistency and complexity are then removed by filtering these properties. As a result of reviewing the literature, a set containing multiproperties shown in Table 1 was formed. Our proposed method would pick different types of devices that will be used in an IoT environment based on these multicriteria properties.

3.2. Properties Based Device Selection Using Ant Colony Optimization (PBDS-ACO). Dorigo and Blum in year 1990 presented ant colony optimization as a technique related to swarm intelligence [27]. After inspiring from a vast utilization mechanism, the ant follows strategies and techniques which are well recognized for optimizing purposes, and the applications of ant colony optimization are widely used. Ant colony optimization (ACO) is a conceptual focusing mechanism based on various ant species scavenging. If the ants migrate from one place to the next, they lay the pheromones on the planet to indicate encouraging indications in the colony for other ants (members). Ant optimization utilizes a similar method to address problems of optimization [28]. Heuristic information and the frequency of pheromones are two factors that ants use to solve problems. The mutual communication among artificial ants can result in high-quality outcomes. Pheromone trail values are obtained by indirect communication (sensed the pheromone) of various ants. Ants do not change themselves; instead, they adapt how other ants represent and perceive the dilemma [28]. ACOs may be used to solve a variety of issues in the industrial sector.

In the IoT ecosystem, the ACO method can be used to solve the device selection dilemma. The proposed system "Properties Based Device Selection Using Ant Colony Optimization (PBDS-ACO)" depicts the various steps involved in implementing the ACO algorithm for device selection optimization (see Figure 1). The approach presented will handle the problem of device selection. The selection procedure starts with the creation of ants that go through numerous pathways (ranges) and choose devices depending on the edged pheromone information. If the crossover of ants does not satisfy the stop criterion, the pheromone levels are altered and the cycle is reinitiated.

Devices present in the IoT ecosystem possess unique properties that are identified from the existing literature in Table 1. A device set (D) is formed by combining the positive and alternative properties shown in Table 2. The properties based device selection technique will reduce the original set in Table 2 by eliminating inappropriate devices. The higher degree of precision in the depiction of the entire set, however, will be preserved. As a result, only a portion of the devices is selected. The previous device attached to a node has no influence on the subsequent device selection.

Table 1: Properties of heterogeneous devices in IoT environment.

S. no	Properties of IoT devices	Citations
1	Flexibility	[5, 8, 18]
2	Scalability	[5, 6, 18, 19]
3	Efficiency	[3, 5, 8, 19–21]
4	Reliability	[4–6, 20]
5	Security	[3–5, 19, 22, 23]
6	Privacy	[5, 6, 22, 24]
7	Interoperability	[5, 7]
8	Real time	[3, 5, 25]
9	Intelligent	[3, 6, 8, 18, 21]
10	High sensing	[3, 4, 8]
11	Availability	[5, 18, 19]
12	Cost effective	[8, 25]
13	Increase throughput	[5]
14	Compatibility	[26]
15	Adaptability	[18]

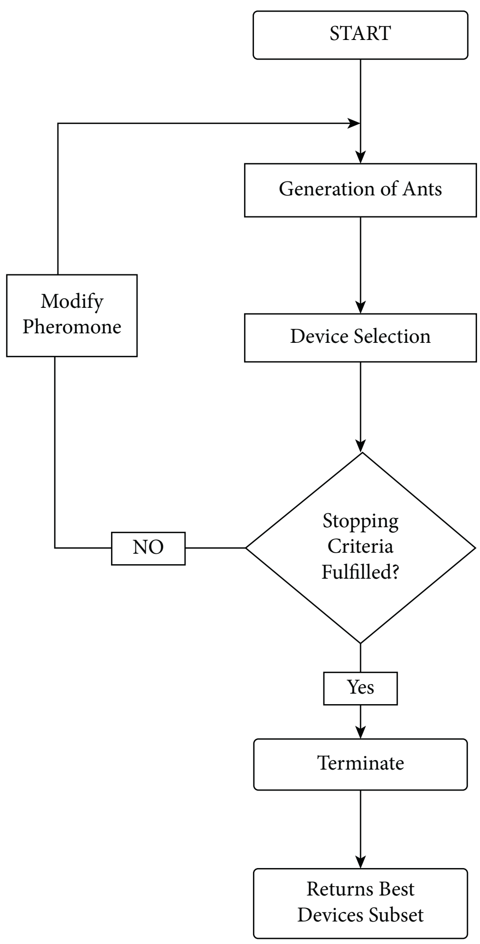

Figure 1: Properties based device selection using ant colony optimization (PBDS-ACO).

The device selection dilemma is mapped using the steps as follows:

(i) Graphical illustration method
(ii) The heuristic desirability and pheromone intensity
(iii) Modifying the pheromone value
(iv) Results

Table 2: IoT devices set.

Devices	Multiproperties of IoT devices
D1	Flexible, interoperable, cost effective
D2	Nonflexible, noncompatible, expensive
D3	Insecure, decrease throughput, low sensing
D4	Security, increase throughput, high sensing
D5	Intelligent, reliable, compatible
D6	Nonintelligent, nonreliable, noncompatible
D7	No privacy, inefficient, nonadaptable
D8	Privacy, efficiency, adaptable
D9	Available, scalable, real time
D10	Unavailability, nonscalable, asynchronous

(1) *Graphical Illustration Method*. Ant colony optimization usually represents a problem in graphical structure, as shown in Figure 2. The nodes represent different devices, and the edges indicate the appropriate selection of the device. The nodes are connected to make it possible to pick any IoT device. When an ant navigates the graph or visits different nodes, an ideal collection of devices is picked. The traversal of ants must satisfy the terminating requirements (i.e., select optimal devices). In Figure 2, the ants 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 are allowed to leave their nest and begin moving to various nodes such as D1 or D2 and then to D3, D4, D5, D6, D7, D8, D9, and D10.

(2) During the traversal process, these ants leave pheromones as shown in Figure 3, a chemical material, on various edges. The traveling of ants depends on the probabilistic values of pheromone intensity on distinct paths (if the levels of the pheromones are high, then the ant will only choose those edges (bold lines) and only those specific nodes). The ants from the nest will choose node D1 and then D4 using the transition law. It then selects D5, D8, and D9.
When the ant traversal reaches D9, it meets the stopping criterion and stops, providing a partial solution to the original device set "D," which consists of devices D1, D4, D5, D8, and D9 shown in Figure 4. As a result, high degree of precision is achieved. The device subset is then used as a nominee in IoT settings.

(3) *The Heuristic Desirability and Pheromone Intensity*. Devices are evaluated on the basis of optimal properties. The initial selection of device substitutes is made using a simple multistate local search process. In the ACO algorithm, the (ηi) heuristic function is utilized in accumulation with the pheromone score, to make a correct transition. Evaluating the pheromone and heuristic meaning yields the best devices subset. A device selection occurs if the value of pheromone on connected edge is higher. Inappropriate devices, on the other

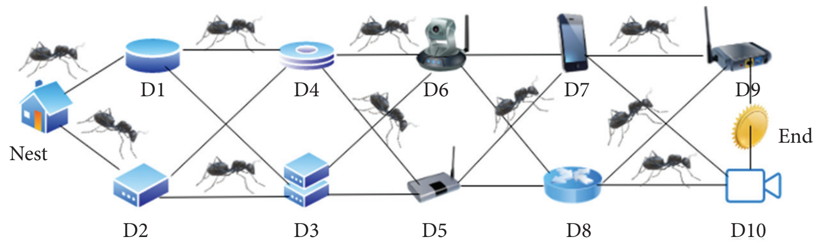

Figure 2: Ant's traversal on edges.

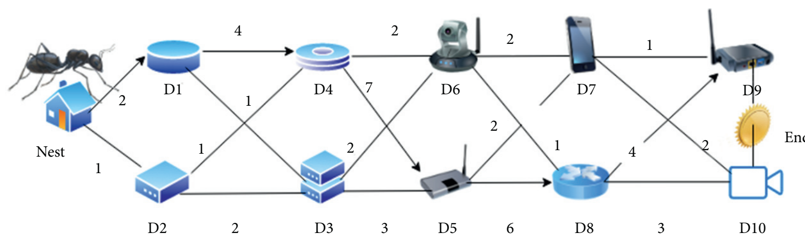

Figure 3: Pheromones secretion by ants on paths.

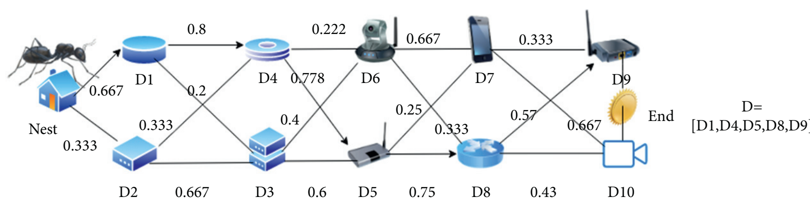

Figure 4: Probability of pheromones on edges.

hand, are rejected based on the pheromone score in addition to the respective path, which is lower. An ant in D1 decides whether D3 should be picked or not, and the decision is based on the likelihood of the highest value of pheromones on its path. The probability of pheromones on path can be calculated using the following equation:

$$P(\text{edge}) = \frac{P(\text{pheromones}(Xi)\eta i)}{\sum(P(\text{pheromones}(Xi))\eta i)}. \quad (1)$$

Equation (1) is used for evaluating ant's probability for selecting a node, probability is represented by P, edges or path are represented by Xi, and the heuristic intensity is represented by ηi. If an edge is to be chosen, the ηi value should be held higher; otherwise, it should be lower. The pheromone value has an effect on node traversal and selection (i.e., device). The ant will follow the path having highest value of pheromone.

(4) *Modifying the Pheromone Value*. In a case where terminating requirement for ant traversal is not met, the value of pheromone is modified, new ants are initialized, and the cycle continues further. The pheromone is modified using the following equation:

$$\tau\iota(\tau+1) = (1-\rho)\tau_{\iota}(\tau) + \rho\Delta\tau_{\iota}(\tau), \quad (2)$$

where ρ is considered as pheromone decay coefficient and the cost assigned to it ranging from 0 to 1, $\tau\iota$ is considered as pheromone limit that still resides on specific path, and $\Delta\tau\iota$ is considered as pheromone increment for updated iteration process. Best ants leave more pheromones on optimal solution nodes, and as outcomes, optimal properties of devices are revealed

(5) *Results*. The PBDS-ACO procedure starts with the formation of a specific number of simulated ants that are positioned on the graph with an equal number of connected devices. The traversal of each ant starts the process of constructing a graph from a specific (device) node. Ant moves in a probabilistic fashion from a starting point, crossing different nodes while following strategic criteria which are fulfilled. The resulting device set is collected and evaluated for an ideal subset. The experiment ends when the best devices are identified, and the results are revealed in Figure 4. When the terminating requirements are not fulfilled, the pheromone are updated and new ACO is generated, and then the iteration of device selecting process initiates.

Table 3: Probability-wise nodes selection.

Devices	Selected devices	Ants	Pheromone quantity paths	Paths selection probability	Path selection	Probability
D1, D2 D3, D4, D5, D6, D7, D8, D9, D10	D1, D4, D5, D8, D9	1	2, 4, 7, 6, 4	0.667, 0.8, 0.778, 0.75, 0.57	3.565	0.143
	D2, D3, D5, D8, D9	2	1, 2, 3, 6, 4	0.333, 0.667, 0.6, 0.75, 0.57	2.92	0.117
	D1, D3, D6, D7, D10	3	2, 1, 2, 2, 2	0.667, 0.2, 0.4, 0.667, 0.667	2.601	0.104
	D2, D3, D6, D8, D9	4	1, 2, 2, 1, 4	0.333, 0.667, 0.4, 0.333, 0.57	2.303	0.092
	D2, D3, D6, D7, D9	5	1, 2, 2, 2, 1	0.333, 0.667, 0.4, 0.667, 0.333	2.4	0.096
	D1, D4, D6, D8, D10	6	2, 4, 2, 1, 3	0.667, 0.8, 0.222, 0.333, 0.43	2.452	0.098
	D2, D4, D6, D8, D10	7	1, 1, 2, 1, 3	0.333, 0.333, 0.222, 0.333, 0.43	1.651	0.066
	D1, D3, D5, D7, D9	8	2, 1, 3, 2, 1	0.667, 0.2, 0.6, 0.25, 0.333	2.05	0.082
	D1, D4, D5, D7, D9	9	2, 4, 7, 2, 1	0.667, 0.8, 0.778, 0.25, 0.333	2.828	0.113
	D2, D3, D6, D8, D10	10	1, 1, 2, 1, 3	0.333, 0.667, 0.4, 0.333, 0.43	2.163	0.087
					$\sum = 24.932$	

4. Results and Discussion

Attention must be given when choosing appropriate devices for the IoT as the quality of operation improves with the selection of suitable devices. A device set (10 devices "D1, D2, D3, D4, D5, D6, D7, D8, D9, and D10") with multiple properties (appropriate and inappropriate) is positioned in a graphical structure in our framework of device selection based on properties. The devices are represented as a sequence of nodes linked by edges; an equal number of ants are generated to navigate along multiple edges and select devices, resulting in a partial solution of the device collection. If a partial solution fulfills the stop criteria, the ants will finish exploring and generate the optimal device subset with several properties (i.e., it selects the appropriate devices subset D). If the ant's traversal does not meet the stopping criterion, the pheromones are updated and the process restarts. The pheromone value at each edge is considered as the decision system for the selection and rejection of devices; if the value is greater, nodes are picked and the best devices subset is formed in the ant's process of path discovery; if the value is lower, edges and device connected to nodes are rejected. Table 3 shows the ants and their preferred direction. The probability of pheromones is determined to identify the optimum navigational path so that only appropriate IoT devices are selected. For the proposed device selection, the device subsets D1, D4, D5, D8, and D9 are selected by ant 1 route discovery mechanism because the likelihood of the pheromone values at their appropriate node (device) edges has been greater than that of other node edges (devices).

5. Conclusion

The IoT is a universal Internet connectivity phenomenon where smart objects are associated and linked to sense their surroundings, transmit, and process the data. Both the cyber and physical world are connected by IoT. The main goal of IoT is to attain high operating performance and improved throughput and to control the assets and processes in industry. various research articles have been published. However, our research focusses on the device's selection problem in IoT setting. Properties Based Device Selection Using Ant Colony Optimization for the device selection problem in IoT settings was proposed that selects appropriate devices. Our study makes a significant contribution by assisting in the selection of the suitable device based on multicriteria properties. The performance and effectiveness of IoT will be improved by identifying the suitable device. The method is theoretically discussed in this article with fewer devices. We will utilize the method in the future since the system is effective (i.e., it selects devices based on multicriteria properties) and will play a crucial role in the device selection process in IoT environments.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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