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Retraction

Retracted: Resource Selection from Edge-Cloud for IIoT and Blockchain-Based Applications in Industry 4.0/5.0

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] M. Kaur, A. Jadhav, and F. Akter, "Resource Selection from Edge-Cloud for IIoT and Blockchain-Based Applications in Industry 4.0/5.0," *Security and Communication Networks*, vol. 2022, Article ID 9314052, 10 pages, 2022.

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Research Article

Resource Selection from Edge-Cloud for IIoT and Blockchain-Based Applications in Industry 4.0/5.0

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Industrial Internet of Things (IIoT) is attempting to integrate the real world into the digital world through smart devices, information technology, and Internet. IIoT is connecting enormous devices in industry 4.0/5.0 which may be heterogeneous in nature. With the evolution of IoT, diverse technologies have been employed to deliver the quality of services to the end users in a seamless manner. Cloud computing has considerably boosted the growth of IIoT by serving the computational and data storage needs of IIoT- and blockchain-based applications in industry 4.0/5.0. However, cloud is providing services to IIoT users, but still, there is a need to improve the latency rate of delivery of services, the transmission rate of end-to-end delivery, and overall throughput of the network channels in industry 4.0 and blockchain-based distributed systems. The cloud servers those are located at remote locations are not capable to offer the quality of services to users who require real-time responses, minimum network latency, and optimum throughput. The advancements in Edge computing are making Edge-Cloud more suitable for end users in blockchain-based transactions and industry 4.0 to serve the requirements of IIoT-based applications. This paper aims at providing the resources of Edge-Cloud to the end users by proposing a soft-computing technique for selecting the most suitable resources from the pool of available resources at Edge-Cloud. This paper is proposing a multicriteria statistical approach for resource selection to exploit the benefits of Edge-Cloud and to suffice the needs of IIoT and blockchain-based applications in industry 4.0. The results obtained from the proposed research assist in enhancing the service providing rate, minimizing the delay in transmission, and optimizing the throughput of Edge-Cloud servers.

1. Introduction

To realize the vision of IIoT in industry 4.0, there must be a mechanism to select the resources based on their capabilities and to allocate the most appropriate resource to the IIoT- and blockchain-based applications. Thus resource selection becomes a fundamental requirement of any IIoT application in industry 4.0. The key characteristic of Internet-based discovery is to use the web crawlers across the Internet and fetch the matching resource for an IIoT application. However, the implied assumption in this method is the seamless availability of the cloud servers, but it is conflicting with the actual scenario of intermittent connectivity of the Internet and the availability of required resources at cloud servers. Enormous technologies have been evolved to ensure the smooth functioning of IoT devices such as Edge-Cloud that provides several advantages to IIoT users in industry 4.0 by providing storage infrastructure, high-performance computing for compute-intensive applications, and by analysing the IIoT data as shown in Figure 1.

IIoT and blochchain consumers require cloud services with short response time to execute the compute or data-intensive applications. In this context, the Internet connectivity between the cloud servers and IoT devices can prevent IIoT consumers from exploiting the seamless services of cloud servers. Edge-Cloud provides solution to this

Figure 1: Edge-Cloud fulfils resource requirements of diverse IIoT applications in industry 4.0.

problem; Edge-Cloud switches the services of cloud servers to Edge-Cloud and makes the usage of cloud services and resources convenient for IIoT users. Several Edge-Cloud services are required for the smooth functioning of industry 4.0/5.0, and the service providers should improve the response time for delivering the required services and resources to the end users. Edge-Clouds are also termed as cloudlet that is located at the edges of the network to provide seamless services to IIoT users.

The acceptance of IoT in the society has been derived from its adoption in the industry and then from industry to home automations. The need for compute-intensive and data-intensive applications is on high rise in industry 4.0. There are "*n*" numbers of resource providers available at cloud to serve the needs of IIoT users, but the allocation of the most applicable resources to IIoT applications is a very challenging task. Therefore, to exploit the resources optimally and to allocate the suitable resources to IIoT- and blockchain-based applications, there is a need of an automated resource selection mechanism based on soft computing techniques. Hence, we are proposing a resource allocation mechanism where Edge-Cloud maintains a pool of resources and IIoT applications can make use of these resources for the fulfilment of computational and data storage needs.

Internet of Objects envisages the integration of digital world into physical world by binding people with smart devices through Internet as shown in Figure 2. The people-centric applications such as intelligent transportation systems, home control, environmental monitoring, vehicle automation, and eHealth monitoring systems are growing rapidly. These applications need computational and data-storage resources available at cloud. Edge-Cloud is addressing the problem of latency or delay in resource provisioning by providing the on-demand resources to the end users on time. Resource discovery and resource selection mechanisms cannot perform well without retrieving the static and dynamic information about the resources available at cloudlets.

For resource discovery, every resource at Edge-Cloud is conceptualized as a solution for satisfying data and computational needs of the users in industry 4.0 [1]. Each resource has its properties, capabilities, and underlying ways to access that particular resource. The resources can be computational processors, physical things, associated metadata, or the storage servers. The resource discovery system can retrieve all the resources which are capable to fulfil the need of the IoT application, but the selection of particular resources should be based on some intelligent mechanism. Hence, we are proposing PROMETHEE-II (Preference ranking organization method for enrichment evaluation)-based multicriteria statistical mechanism to select the best resource for IIoT applications from the available resources at Edge-Cloud.

The resource selection mechanism should support the dynamic availability of internet-connected objects at Edge-Cloud, in response to dynamically defined requests of IIoT users [2]. The proposed MCDM-based resource selection mechanism should be able to deliver the best suitable resource according to the utility computing model. Each resource should be compared with other resources in a pairwise manner with respect to each competing criterion. The dynamism implies the ability of resource changes in a volatile environment where resources can be added or removed at any point of time. Secondly, the dynamic status of each resource should also be considered. For example, if half of the resource capacity is already utilized, then this scenario should be dynamically updated in the system before the selection of the resource. The proposed resource selection mechanism should be flexible, dynamic, and robust to select the most suitable resources for IIoT applications. Therefore, the PROMETHEE-II multicriteria statistical approach is devised as the resource selection mechanism that has all the capabilities to rank the resources as per their capabilities and properties and to allocate the appropriate resources to IIoT applications. The successful completion of any job or application highly depends upon the availability of the

FIGURE 2: The IIoT-based devices are exploiting cloud resources.

required resource. To choose the appropriate resource from the pool of resources at Edge-Cloud is a cumbersome job due to the combination of "m" applications with "n" resources, and PROMETHEE-II statistical approach is certainly a good solution to fetch the suitable resources out of the available resources for end users.

Multiple-criteria (MCDM) methods are utilized for determining the potential of finite number of alternatives by considering multiple criteria with respect to each alternative for decision-making [3, 4]. PROMETHEE-II is one of the most viable MCDM decision-making approaches [5] as presented in Figure 3 which can determine the potential of alternatives and assist the decision maker to locate the most suitable alternative for completion of the job. Edge-Cloud allows the allocation of resources to IoT users in industry 4.0 based on certain criteria. The resources possess distinct characteristics. The existing methods rely on direct matchmaking of resource attributes during the allocation of resources. However, the corresponding resources to the job requirement may not be the proper resources for the IIoT applications. Therefore, there is a necessity to cogitate the dynamic state of the resources in order to locate the most suitable resources for user jobs. PROMETHEE MCDM technique is certainly a solution to decide upon the alternative resources and to allocate the best-matched or top-ranked resource to the end users.

In our proposed PROMETHEE-II-based selection approach, the resource requirement in industry 4.0 can be investigated, and then, the resources available on cloudlets or Edge-Cloud can be allocated optimally to the end users. PROMETHEE-II-based approach allows rankings of the alternative resources. Stable and dynamically altered resource attributes are analysed during the decision-making of the selection of resources. The resource with the highest rank is assigned to the IIoT-based application.

1.1. Highlights of the Proposed Research

(i) To explore the usage of soft computing and statistical methods such as PROMETHEE-II for locating the most "suitable" resources at Edge-Clouds for IIoT and blockchain-based applications

(ii) To consider both stable and dynamic resource characteristics and also the user preferences for resources characteristics based on the category of IIoT-based applications

(iii) To make pairwise contrast between the alternative resources corresponding to each characteristic and to determine the ranks of the cloud resources

(iv) To rank the alternate resources and to assign the most useful resource for the IIoT applications in industry 4.0 rather than allocating the best matching resource

1.2. Paper Organization. This paper is systematized into five sections. The paper begins with the introduction section with background details, and the second section discusses about the existing work in the research area, while the third section provides insights into our proposed work. The fourth section highlights the results obtained from the proposed work. The last section concludes our research study and also provides road map for the future work.

2. Existing Works

There are several research approaches linked to the assignment of resources to user applications, but this paper considers IoT-based applications and resources of Edge-Cloud to provide optimal solutions to the users of industry 4.0. The selection problem of cloud resources and services for IoT applications is one of the major problem in the evolution of industry 5.0, and it has attracted the attention of many researchers [6–8]. With the rapid growth of industry 4.0, and ICT technologies, the IoT experts are concerned about the storage of big data on clouds. Executing user application at the remote resource is another important aspect which requires complete control of the remote environment for the successful execution of the IoT- or mobile-based application. For this reason, the selection of

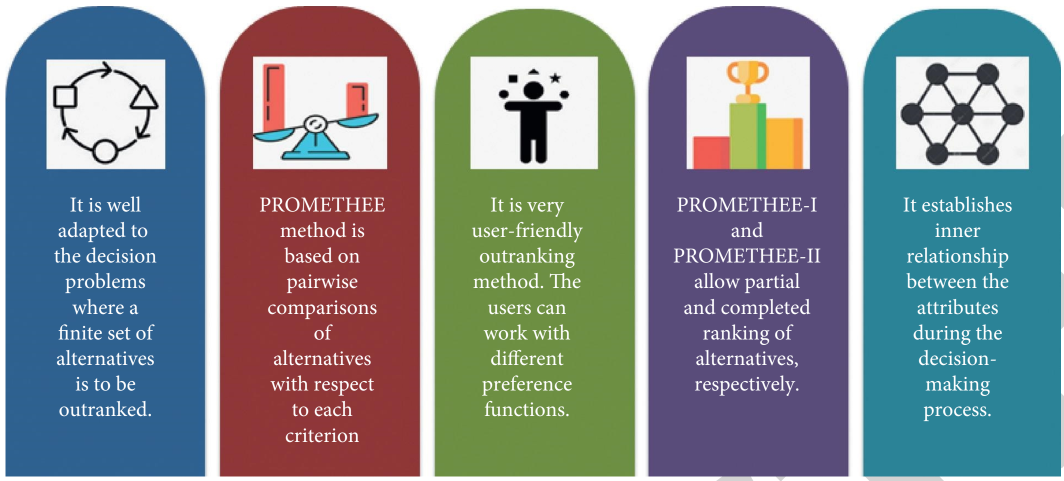

Figure 3: Properties and capabilities of PROMETHEE method.

Edge-Cloud-based resources has to be performed by a soft-computing-based technique for the optimal utilization of resources and for the successful completion of smart user jobs. However, in industry 4.0, much attention has been paid towards the improvement of computational infrastructure, but no attempt has been made towards optimal selection of available computational resources for the optimal usage of resources of Edge-Cloud. For exploiting the cloud services, many approaches are devised based on MCDM methods [9], fuzzy-based approaches [10], and soft computing-based techniques, but now in industry 4.0, the resources are available at Edge-Cloud, and research focus is required to exploit the resources in an optimal manner to provide quality services to users. The proposed mechanism is not only used for Edge-Cloud-based resources but also this technique can be universally applied for the allocation of resources such as water, electricity, and solar energy where multiple alternatives are available and optimal selection is required.

The fuzzy AHP method is integrated with TOPSIS method in many research approaches to assist decision-making system based on numerous criteria such as Taylan [11] has used FAHP and TOPSIS to assist the real estate holders in the selection of construction projects. In [12], the authors describe the fuzzy AHP-TOPSIS-based integrated framework to determine the best solutions for the supply chain management. In [13], the authors have proposed a hybrid approach where fuzzy AHP is integrated with TOPSIS for locating the best ERP (enterprise resource planning) system. In [14], the authors have used AHP-TOPSIS as a clubbed method for ranking of choices or alternatives. In [15], fuzzy AHP is integrated with PROMETHEE-I for prioritizing the location of the power substation for optimal power flow. The integration of ANP (analytical network process) with PROMETHEE is also exemplified in paper [16] to find out the best solution for a given application. In [17], ANP and PROMETHEE are used in collaboration to locate the best ERP system based on the ranking of ERP systems. Several other researches have used AHP, fuzzy AHP, PROMETHEE, and TOPSIS as hybrid frameworks to make decisions for assigning the resources while there are multiple alternatives available, and the best alternative has to be selected to save time and cost [18–20].

The popular related approaches for resource selection use only static criteria as presented in [21–24]. In [21], the authors make use of hotspot and coldspots for handling the resources on clouds. The load balancing is also performed for allocating resources to user applications. The proposed work is implemented on "OpenNebula" framework of cloud. This research work maximizes the usage of resources in their idle times. In [22], the authors present a Fog framework that optimizes the assignment of Fog resources using TOPSIS method. The assignment of resources is made on the basis of customized user requests. TOPSIS uses multiple factors before assigning the Fog resources optimally. In [23], the authors propose resource assignment method for device-to-device (D2D)-based networks. The clusters are formed for similar resources and comprise alike attributes. Then by using VIKOR, the resources are selected based on the resource attributes matching to the requested attributes. In [24], the authors employ social IoT and self-learning methods to allocate the resources to edge computers. The self-learning methods are trained to understand the matching requirements between the requested attributes and available resource attributes. The data set taken for training the methods is considered from the real world.

There is a need for optimal resource assignment approach for satisfying the needs of IoT applications in industry 4.0/5.0 that considers stable as well as dynamic attributes for resource selection from Edge-Cloud [25]. The matching resources are ranked according to the IIoT application requirements of the users of blockchain technology and industry 4.0. Hence, the PROMETHEE-II-based approach for resource selection is proposed in this paper that studies both stable and dynamic criteria of the edge resources and also offers grading to the indistinguishable edge resources. The proposed approach assists in allocating the best resource from Edge-Cloud to IIoT application.

3. Proposed Work

The proposed resource selection mechanism uses status_info service that provides information on the dynamic status of the resources iteratively. We are proposing the PROMETHEE-II-based mechanism to assign the suitable resource to IIoT applications from the available resources at Edge-Cloud. The proposed resource selection mechanism is summarized as follows:

(1) An IIoT-based application raises a request query for edge-resource along with the required attributes for running the application

(2) The request is dispatched to the resource allocator manager which is integrated with the connected gateway of the network, and it forwards the query to the nearest Edge-Cloud

(3) The nearest Edge-Cloud uses the resource manager to respond back to the requesting gateway by searching the matching resources out of the available alternatives

(4) The resource manager uses the matchmaker service and status_info service for getting the static as well as dynamic information about the resources and later applies the PROMETHEE method for ranking of the matched resources

(5) The highest ranked resource is assigned to IIoT-based application as a response to the query raised by the requesting gateway

The proposed methodology is divided into two phases as shown in Figure 4.

3.1. Phase 1 of the Proposed Methodology. The gateway receives the resource request from the IIoT application and forwards the request to the connected Edge-Cloud. The matchmaker at Edge-Cloud finds alternative resources by finding equality between the properties of the resources with the required properties as mentioned in the resource request query. The matchmaker handles exact queries and range queries. An exact match finds the resources with the properties exactly matching with application requirements, and range queries locate all the resources with similar properties to the requested properties. The matchmaking also considers "must" and "want" criteria. In "exact" matching, "must" criterion is considered, and during "range" matching, "want" criterion is considered. The "must" criteria consider stable characteristics of the resources that are mandatory for running the IIoT application. An application that requires Apple Mac platform cannot be allocated Android platform. An application that wants a 32-bit processor is not suitable for executing on a 64-bit processor. The parameters of "want" criteria are desirable but not necessary. These parameters can be scaled up. For example, if an application is looking for a storage space at

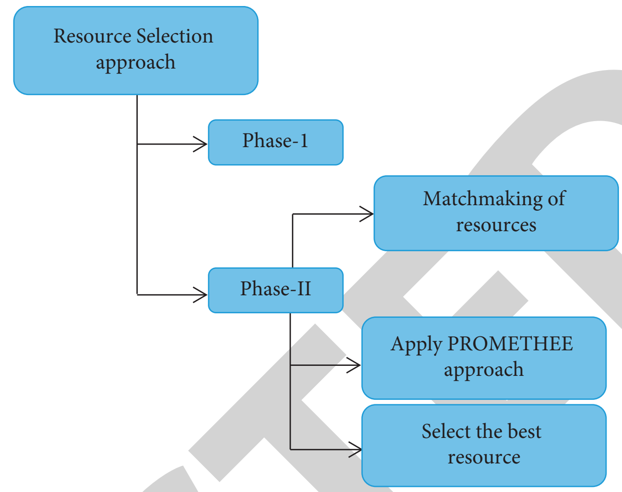

Figure 4: Proposed resource selection (RS) strategy.

Edge-Cloud, and there are two alternatives with storage spaces of 512 GB and 1024 GB, then the resource with 1024 GB will be assigned more weightage under "want" criterion. The information about the resources is maintained by edge_resource_info service which keeps record of each resource and properties of that particular resource. The information about the current status of the resource is maintained by status_info service. The current status provides information about the availability of the resource and utilized percentage of the resource. For example, a data-storage resource has 1 TB storage capacity, and its 500 GB storage is utilized, then the current status will be updated as 500 GB available capacity. Before invoking the PROMETHEE-based resource selection mechanism, these two services provide the information about the permanent and dynamic characteristics of the resources. We are presenting a research study in this paper based on the proposed methodology. The IIoT application request for resource with the required properties is mentioned in Table 1.

There are five resources available at Edge-Cloud that can satisfy the request of an IIoT application. The properties of the matched resources have been mentioned in Table 2.

Operating system platform and software requirements are fixed, but rest of the parameters can be scaled up under "want" criteria. The application requirement for physical memory is 4 GB, and resource R1 has 12 GB of physical memory. The "must" criterion is 4 GB for physical memory, and greater attribute value comes under "want" criterion. Physical memory, CPU speed, and secondary storage are presented as "want" criteria. The resources with more attribute values will be considered as better resources. The decision of the resource selection cannot be made just looking at the static values of the resource attributes. It is important to consider the dynamic status of the resources before making the resource selection.

The dynamic attributes of the matched resources are presented in Table 3. These dynamic attributes reveal the current status of the resources. The resources with good configuration may be loaded with the existing application requests and cannot be allocated to the upcoming IIoT

Table 1: Resource request with required properties/attributes.

Platform	macOS Catalina
APP	Apple Arcade
RAM	4 GB
Storage_space	500 MB
CPU_speed	2.6 GHZ
Bandwidth	5 Mbps

applications. The current status of the resources is important before their allocation irrespective of their configuration.

This status_info service provides these values to the matchmaker, and the matchmaker supplies this information to the resource selection module. The selection module uses PROMETHEE-II, a complete ranking method for finding the most suitable resource for IIoT-based application. This resource selection module belongs to phase-2 of the proposed methodology.

An attempt has been made to apply PROMETHEE-II directly on the decision matrix (Table 3) with n alternatives and m criteria without normalizing the decision matrix. However, most of the MCDM methods require normalized decision matrices to obtain the complete ranking of the alternatives for resource selection. We have also tried to apply PROMETHEE-II method on normalized matrix using two techniques as mentioned below.

Method 1—Min-Max: this method uses the highest and the lowest values in the measured set. The formulas are described for criteria with maximization values in equation (1) and for minimization criteria in equation (2). For example, "working memory (RAM)" is maximization criterion, whereas "CPU utilization" is minimization criterion.

$$a_{ij} = \frac{x_{ij} - \min_{ij}\left(x_{ij}\right)}{\max_{ij}\left(x_{ij}\right) - \min_{ij}\left(x_{ij}\right)}, \tag{1}$$

$$a_{ij} = \frac{\max_{ij}\left(x_{ij}\right) - x_{ij}}{\max_{ij}\left(x_{ij}\right) - \min_{ij}\left(x_{ij}\right)}. \tag{2}$$

Method 2—Max method: this method uses the greatest and the least values in the considered set. The formulas are described for maximization criteria in equation (3) and for minimization criteria in equation (4).

$$a_{ij} = \frac{x_{ij}}{\max_{ij}\left(x_{ij}\right)}, \tag{3}$$

$$a_{ij} = 1 - \frac{x_{ij}}{\max_{ij}\left(x_{ij}\right)}. \tag{4}$$

3.2. Phase 2 of the Proposed Methodology. In this phase, PROMETHEE-II is employed to pick the finest resource from Edge-Cloud for IoT application. This approach allows the smart cities and users of industry 4.0 to satisfy the consumers by ranking the alternative resources and comparing each alternative with other alternatives with respect to each criterion. PROMETHEE-II does not support any inbuilt method for estimating the attribute weights. In our research study, we have considered the opinions of experts for assigning weights to criteria, and then, the aggregation method has been applied for approving the weights (Table 4).

Relevance importance to criteria—PROMETHEE MCDM technique is not employing any formal method to estimate the weights of the parameters [16, 17]; hence, we have used the aggregation method for approval of weights. Initial weights have been defined by the experts with mutual consent, and then, the aggregated method has been applied to find the relevant importance of each parameter. The weights have been normalized using the aggregation method as shown in Table 5.

The PROMETHEE method is based on common contrast of each alternative pair with respect to each characteristic in the decision-making problem. After defining the criteria, it is mandatory to consider preference function $P\ (a, b)$ for resources a and b. The evaluation of a and b alternatives is based on criterion f. The scaled values for preference can be taken from 0 to 1 as shown below.

$P\ (a, b) = 0 \Rightarrow$ indifference, means no preferences,
$P\ (a, b) \approx 0 \Rightarrow$ weak preference,
$P\ (a, b) \approx 1 \Rightarrow$ strong preference,
$P\ (a, b) = 1 \Rightarrow$ strict preference.

PROMETHEE method has six inbuilt preference functions. In our research study, we have used "Type-V preference function based on indifference area is used" for the experimental study to introduce an indifference threshold for neglecting very small differences.

Type-V linear preference function—In this preference function, the algorithm considers that a and b are entirely unconcerned until the deviation between $f(a)$ and $f(b)$ is not surpassing p. Above this value, the preference increases gradually until this deviation equates $p + q$ as given in the following equation:

$$\begin{cases} 0, & x \leq p, \\ \dfrac{x - p,}{q} & p \leq x \leq p + q, \\ 1, & x \geq p + q. \end{cases} \tag{5}$$

After determining the relevance importance of criteria and selecting the preference function, pairwise comparison of each alternative with all other alternatives has been performed with respect to each criterion. After making pairwise comparison of alternative resources,

Table 2: Matched resources found at Edge-Cloud with the "must" criteria.

Alternatives/resources	RAM (GB)	CPU speed (GHz)	Secondary storage (MB)	Network bandwidth (Mbps)	Platform	APP
A1	12	4	9000	12	Mac Catalina	Apple Arcade
A2	16	3.4	8000	8	Mac Catalina	Apple Arcade
A3	32	3.6	5000	6	Mac Catalina	Apple Arcade
A4	8	3.9	9000	8	Mac Catalina	Apple Arcade
A5	8	2.6	6000	10	Mac Catalina	Apple Arcade

Table 3: Dynamic resource attributes of the matched resources.

Alternatives/ resources	RAM (GB)	CPU speed (GHz)	Load on resource (MIPS)	Network bandwidth (Mbps)	CPU utilization (%)	Free RAM	Free secondary storage	Available bandwidth
A1	12	4	10000	12	50	8	5000	4
A2	16	3.9	7000	8	10	12	5000	4
A3	32	3.6	5000	6	20	8	3120	3
A4	8	3.4	9000	8	5	3	4000	4
A5	8	2.6	6000	10	30	5	3000	4

Table 4: Relative importance considered to criteria for an IoT application.

Criteria	Importance
RAM	1
CPU speed	3
Load on resource	5
Network bandwidth	4
CPU utilization	5
Available RAM	4
Free secondary storage	2
Available bandwidth	3

Table 5: Relative importance of criteria based on aggregation method.

Resource characteristics	Normalized values
RAM	0.037
CPU speed	0.111
Load on resource	0.185
Network bandwidth	0.148
CPU utilization	0.185
Free secondary storage	0.148
Available RAM	0.074
Available bandwidth	0.112

aggregated preference function is calculated using the following equation:

$$\pi(a,b) = \sum_{i=1}^{k} \omega_i * p_i(a,b). \tag{6}$$

Net outranking for each alternative is ascertained on the basis of positive and negative outflows. The positive flow Φ^+ is calculated by using equation (7), and the negative flow Φ^- is determined by equation (8).

Table 6: Ranking of the A1 to A5 resources using alternative normalization methods.

Complete ranking	No normalization	Min-max normalization	Max normalization
1	A2	A3	A2
2	A4	A2	A3
3	A3	A4	A4
4	A5	A5	A5
5	A1	A1	A1

$$\Phi^+(a) = \frac{1}{n-1} \sum_{x \in A} \pi(a,x), \tag{7}$$

$$\Phi^-(a) = \frac{1}{n-1} \sum_{x \in A} \pi(x,a). \tag{8}$$

The complete ranking of alternatives has been obtained by using two types of normalization methods and without normalizing the decision matrix as shown in Table 6.

4. Research Outcome and Discussion

The results represent the outcome of the empirical research discussed in this paper. PROMETHEE-II gives complete ranking and provides the most suitable resources. The impact of using PROMETHEE-II is to make pairwise comparison among the alternative resources corresponding to all the criteria which allows ranking of alternatives to give the most suitable solutions for the multicriteria decision-making problem.

Table 6 shows the ranking of alternative edge resources. A1 is the best edge resource based on its configuration in comparison to other alternative edge resources. After

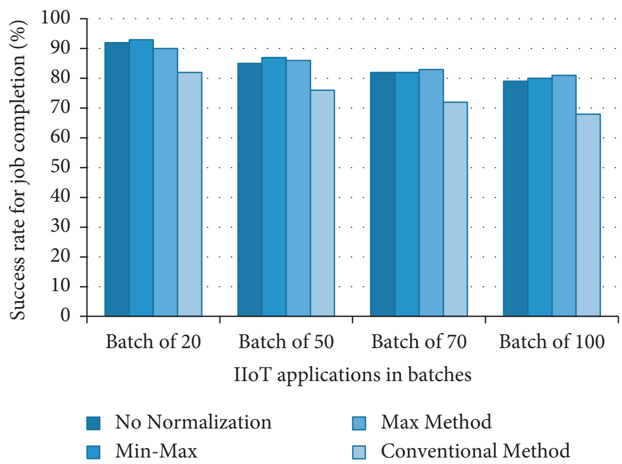

Figure 5: Success rate of jobs with PROMETHEE-II variants vs. conventional approach.

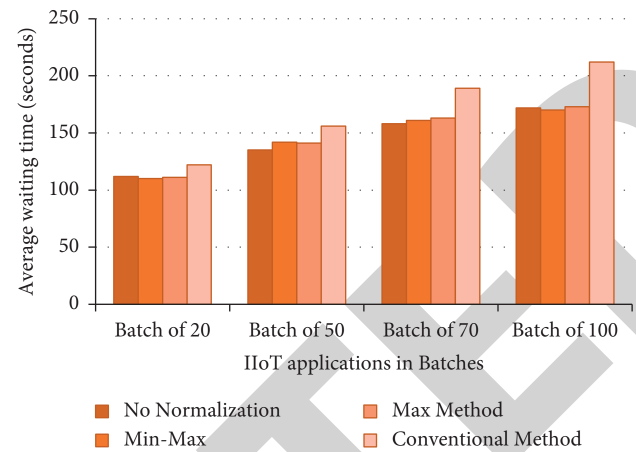

Figure 6: Average waiting time for IoT jobs with PROMETHEE-II variants vs. conventional approach.

applying the proposed PROMETHEE-based mechanism, it shows 5th ranking based on the PROMETHEE scores due to existing loads of jobs. Consequently, A1 has not obtained the highest ranking in the rank chart of the edge resources. In IoT and cloud-based collaborative environment, many IIoT and mobile applications compete for the edge resources, and obtaining the edge resource for job completion is the need of users of industry 4.0. Hence, it is necessary to fulfil the requirements of the IIoT-based applications to satisfy the user needs and to utilize the resources of Edge-Cloud optimally. If the resource from Edge-Cloud is selected by looking at its configuration, then the job will wait in the waiting queue until the requested resource is busy with other jobs. The conventional mechanisms search the resources for required characteristics and do not bother about the current status of the resource such as the waiting time of the job in a queue before allocation of the resource to user job. From Table 6, it is concluded that alternative A2 is the best alternative for a computational IoT application. Similarly, A5 is the resource with good configuration but has obtained the second lowest rank after applying the PROMETHEE-based approach as its CPU is almost fully utilized with the prevailing load of running jobs.

A4 is the next attractive resource, but it has obtained 3rd rank using normalization techniques, and it has obtained 2nd rank as per PROMETHEE-II without normalization. A3 and A2 alternatives are comparatively better options due to lesser utilization of CPU, working memory (RAM), and lower job loads. In this paper, we have demonstrated a small case study, whereas in our empirical experimental setup, the research work is performed on the batch applications to prove the robustness of the PROMETHEE-II MCDM technique for resource selection in IIoT and cloud-based collaborative environment in industry 4.0. We have attempted to use PROMETHEE-II on the batch applications with similar requirements, and the results have been stated below. There are four batches with 20, 50, 70, and 100 applications. The number of resources is from 10 to 50 which

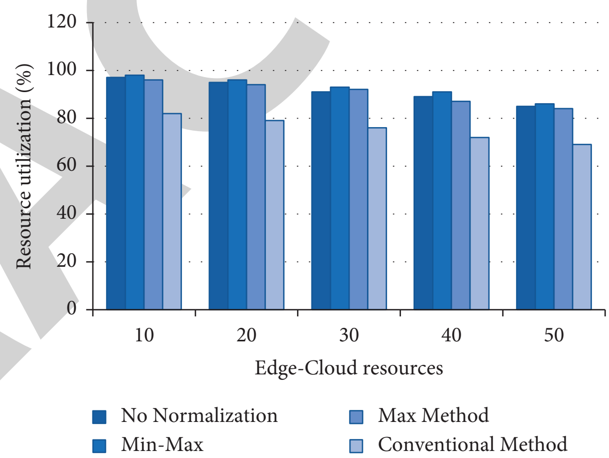

Figure 7: Utilization of resources offered by Edge-Cloud.

are to be distributed among the batch applications for the completion of computational tasks.

Figures 5 and 6 depict that PROMETHEE-II variants show better results for application success rate and average waiting time of jobs in a queue. Figure 7 depicts the utilization of the resources available at Edge-Cloud. PROMETHEE-based MCDM resource selection techniques outperformed the conventional method of resource selection where a matching resource is selected based on resource attributes.

4.1. Discussion. In the existing and conventional methods, the matchmaker at Edge-Cloud matches the resource attributes with the application requirements without considering the dynamic status of the resources. The proposed PROMETHEE-II multiple-criteria-based resource selection scheme provides ranking of the alternative resources available on Edge-Cloud and permits the IIoT applications to choose the best resource for the running their applications based on the criteria preferences. It also validates the applicability of knowing the dynamic status of the resources at the time of selection of resources. PROMETHEE-II-based resource selection scheme enhances job completion success rate upto 98% and reduces the average waiting time of IIoT applications in the waiting queue upto 40%. The IoT devices considered for the research study are heterogeneous in nature. The Edge-Cloud considered for the research study also provides dedicated services to IIoT applications considered for the study. The research study reveals the advantage of using the PROMETHEE-II method for resource selection when there are multiple alternatives and diverse criteria. PROMETHEE-II-based resource selection mechanism not only considers static parameters but also dynamic parameters of the resource and presents complete ranking of the resources. In industry 4.0, computational resources are very important to fulfil the needs of smart devices using 5G- or 6G-based networking infrastructure. The proposed work is carried out on 5G-based networks. If the proposed method is incorporated in the resource allocation manager at the Edges of cloud networks, then optimal resource utilization can be achieved and the end users can also be satisfied by providing the required resources.

5. Conclusion

In this article, two-phased PROMETHEE-II-based resource selection mechanism for IIoT applications in industry 4.0 is designed and implemented. An IIoT application raises a request for the resource. The query is forwarded to resource allocator manager which is integrated with the connected gateway of the network, and it forwards the query to the nearest Edge-Cloud. The nearest Edge-Cloud uses the resource manager to respond to the requesting gateway. The resource manager searches for the required resource and executes the status_info service for obtaining the information about the resources and later applies the PROMETHEE method for ranking of the matched resources. The top-ranked resource is provided as a response to the query raised by the requesting gateway. The results obtained by the PROMETHEE-II method are promising for the selection of the most appropriate resource for IIoT application, and these results outperformed the conventional resource allocation technique. In comparison to the conventional resource allocation technique, the success rate of execution of IIoT application is increased significantly as presented in Section 3 between 80% and 98%. The resource utilization is also enhanced optimally from 85% to 98% as displayed in Section 3 of the paper. The waiting time is also minimized upto 40% of IoT jobs in queues by the proposed mechanism as exhibited in Section 3. In the future, we will attempt to analyse the impact of choosing different preference functions on the resource selection and will also make sensitivity analysis on the result outcomes by altering the attribute weights.

Data Availability

The data are available for experimental study on request.

Ethical Approval

The research presented in this paper has no involvement of human beings and animals to obtain ethical approval. The research is based on computational data.

Consent

No informed consent is required to perform this research study as the research is purely based on computational and data resources where no human intervention is involved.

Conflicts of Interest

The authors declare that there are no conflicts of interest involved in this manuscript.

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