# An Approach Based on Decision-Making Algorithms for Qos-Aware IoT Services Composition

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**Abstract**

Because there is now so many Internet of Things–based service providers globally, it will be hard to choose an Internet of Things service that is appropriate for the demand from the huge pool of Internet of Things services that are already available and display comparable characteristics. When making an acceptable choice, one can take into account the quality-of-service, or QoS, factors that characterize a certain service. In this article, we consider the Internet of Things to be the combination of its three potential parts, which are things, a connectivity unit, and a computational object. A definition of an IoT may contain the quality of service metrics for every one of these elements. We suggest a methodology that creates utilizes multi-criteria decision-making (MCDM) as a known approach using the MABAC method for the goal of carrying out the choice process where the quality of service parameters of different components of the internet of things act as criteria. Together, the data and our demonstration of the efficiency of the suggested strategy form a coherent whole.

**Keywords:** MABAC; MCDM; Quality-of-service; IoT; Internet of Things; Operational risk.

## 1. Introduction

The Internet of Things, more often known as "IoT," is a breakthrough in technology advancement and is anticipated to be one of the innovations that will see the greatest amount of growth in the years to come. It is possible to interpret it as the idea of linking anything, at any moment, from any location, and at any other time. It opens up an infinite number of possibilities for connecting different devices that are outfitted with short-range sensors to a network that permits communication not just among devices but also among people and equipment. It is an idea that "not only can change how we live but also the way we work," as stated by Forbes. In this light, the new facet of technology for communication and information (ICT) that is being referred to as the Internet of things (IoT) today has the objective of connecting every item in our immediate environment to the Internet to create a global network of linked things[1]–[3].

In terms of the Internet of Things specifically, consists of smart devices and networks, connectedness, and machine–human interfaces. It may be broken down into its constituent parts, which are the Internet and the goods. When we talk about the Internet of Things (IoT), we often refer to it as a network-centric concept. When we talk about "things," however, we are referring to physical items or electronic devices that have sensors built into them and are intended to be included in a single framework. In addition to networking and physical objects, the Internet of Things requires a certain amount of processing power to make intelligent decisions. This power may be provided via the cloud or through fog computing. It is possible to see that the Internet of Items (IoT) is a communal system that consists of three fundamental components. These elements involve physical things, a telecommunication subsystem, and computational nodes[4]–[6].

The Internet of Things has such great potential that it provides a wide variety of apps that may be built based on it, including smart cities, remote surgery, and instructional experiences. The growing use of such intelligent services paves the way for the development of new application options. And these

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Internet of Things apps provides services by linking together a variety of different data sources with the web. The most difficult aspect of delivering services is ensuring that customers get the appropriate assistance at the appropriate time and location. As a result, choosing an Internet of Things service and the services it offers is a difficult procedure. It is becoming more difficult to choose the most appropriate service from among other services of the same sort as the number of gadgets and items available on the market continues to rise in tandem with this trend. To overcome the difficulty of selecting the appropriate service, it is necessary to possess some tools that can describe both the services and the preferences of the users. According to how the services are specified, there are both functional and non-functional qualities available for this purpose. The non-functional characteristics that are referred to as quality-of-services (QoS) characteristics are the most important aspects to consider when choosing an acceptable service[7]–[9].

The Internet of Things industry is still in its developmental stage, and numerous services will emerge to provide services that are functionally equivalent to one another. Given the level of competition in the industry, finding a service that fits your needs will be quite difficult. Consumers, marketers, and three distinct types of service providers make up the components of the Internet of Things economic plan. These components are referred to as IoT internet services (IoTSP), wireless network operators (WSP), and cloud providers (CSP) (CSP). In addition to that, they spoke about the three distinct types of interactions that might occur between the providers. We explain the Internet of Objects from the perspective of its 3 fundamental components, which are things, computation, and communication. This description was inspired by their work as well as the challenge involved in selecting IoT-based services. We were able to determine the QoS qualities connected to these IoT components, which are the ones that allow the most accurate quantification and analysis of the services provided by the providers. In addition, we think that this significant facet of service selection must be exhaustively specified before the process of developing a structure for picking a service provider. In addition to the QoS features that were established in the prior study, we have identified a few additional QoS characteristics that explain service selection in this research. After determining all of the necessary QoS characteristics that separately identify a specific IoT-based service, we first specified those characteristics, and then we built a system for choosing service offerings on the QoS characteristics. These qualities of service characteristics serve as criteria that may be used to rate the various services available[10]–[12].

The rise of the Internet of Objects (IoT) platform is directly correlated with the expansion of all three of its constituent parts: things, communication, and computation. As is already common knowledge, the idea of the Internet of Things (IoT) seems to improve upon the "Everything as a Service" paradigm. This model's primary objective is to provide services with a predetermined degree of quality of service; hence, it may be recast as a kind of business model. To begin with, to deliver a service that is effective for IoT, it is necessary to first identify the features of the system, which can be understood most effectively by the QoS parameters. It is beneficial for service providers as well as service applicants to have a better understanding of how well the products function and how easily they may be used. A service contract (SLA) may be enforced among an Internet of Things service provider and an Internet of Things service requestor with the assistance of quality of service measures. Therefore, it assists service submitters in identifying the most appropriate IoT service for their particular application[13]–[16].

To handle IoT services on their own, we need to investigate each of the three factors that were covered in the prior part together with the quality-of-service metrics that are specific to each of them. As a result of the fact that these elements have an equivalent component in the implementation and growth of an Internet of Things application, they must provide the forwarding service to get broader adoption of the recently developed technology. From this point of view, some of the most important quality of service metrics have been uncovered for each of the three aspects of the Internet of Things.

Within the context of the Internet of Things (IoT), the conveyance of real-time data across wireless links is handled via communications infrastructure. The network then provides service to several applications, perhaps without compromising the quality of the service provided. IoT systems can be either pause perceptive or delay tolerant; as a result, to satisfy the requirements of such a large number of applications, it is constantly recommended to add a few little values by diagnosis and treatment and then improving the network infrastructure. This will allow for the fulfillment of the needs of such implementations. To properly assess the quality of the services provided by an IoT network, it is necessary to take into account the following quality metrics: dependability, accessibility of the channel, bandwidth, jitter; data protection; interoperable; financial cost; and manufacturer warranty.

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It is possible to construct an IoT out of a wide pool of devices, each of which would need to be implanted with detectors, outfitted with RFID technology, and implicitly supplied with a link to a smart network. A low-weight device is personally preferred over a higher-weight device, the diploma of the accuracy of the device, also named the highest score needs to be high, and connection speed is always recommended to be lesser for any implementation. These are some of the specifications that are used to assess IoT devices. In a broad sense, users always command high gadgets. In a similar vein, some of the subsequently recognized quality metrics of things that would bring a new aspect to the applications of the Internet of Things are presented in the second paragraph.

The Internet of Things (IoT) holds the promise of connecting objects located all over the globe through a network and creating enormous amounts of data. The enormous quantity of unstructured data generated by the Internet of Things devices has to be saved, handled, and analyzed at the internet, fog, or edge nodes, depending on the scenario. These data are then converted into resources that may be used, and the information that is created is sent back via some kind of interface. As a result, we can claim that the compute units play a very essential role in the provision of IoT services that are efficient and dependable. Now that we've gotten that out of the way, let's talk about some important quality-of-service indicators that may be used to evaluate different IoT services.

As a result, the most important contribution made by this work, as well as what makes it original, may be summed up as follows:

1. To recognize and establish a variety of QoS criteria that are connected to each specified component of the Internet of Objects, particularly things, computing, and connectivity.

2. To develop and build a framework that uses the MCDM approach to solve the challenge of selecting IoT-based services as the solution to the problem.
3. The MABAC MCDM is the first time to be used for this kind of problem.

The following is the structure of this work: The summary of QoS awareness may be found in Section 2. The MABAC method is broken out in detail in Section 3. In Section 4, a case study is used to illustrate the methodology being discussed. The last portion of the work, the conclusion, may be found in Section 5.

## 2. QoS-Aware

In the latest days, in response to the growing need for the development of smart cities and smart transportation systems, several routing protocols that are QoS-aware for multimedia apps have been suggested. These protocols include the following:

The Quality of Service (QoS) conscious routing system, also known as the StAC-multi-rate-backup protocol, is suggested in [17]. This method is an improvement on their previously investigated protocols, which were QAR and AC. Its objective is to enhance the QoS-aware packet delivery ratio for MANET networks despite the presence of roaming, shadowed, and variable link SINR. The combined benefits of the already-existing QAR and AC protocols, as well as the suggested method for the Utilization of Several Backup Paths, are the primary focuses of the study. According to the findings of the simulation, the newly suggested StAC-multi-rate-backup protocol improves upon and excels in the dependability of guaranteed bandwidth services when compared to the already existing series StAC protocol.

M. H. Eiza and colleagues in [18] suggested a graph-based credible routing algorithm that they named EG-RAODV (the Evolving Graph-Reliable Ad hoc On-demand Distance Vector). This procedure is an improvement on the conventional AODV protocol and its objective is to choose the dependable routes to support QoS for vehicle-to-vehicle communication in VANET. The developing graph theory will be used as the primary tool in this research project to represent the VANET communications infrastructure on a roadway. This solution assists in the fast determination of the changes to the network topologies and locates the routes that are the most trustworthy. In other transportation and size distribution VANET scenarios, the outcomes of the modeling show that using the EG-RAODV protocol results in a significant improvement in terms of the packet-to-packet ratio as well as the data packet sizes when compared to using the AODV and PBR network algorithms that are currently in use.

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To provide quality of service (QoS) for multimedia apps on diverse MANET, Z. Li et al. introduced a QoS routing protocol that they named the QOD (Computation Scattered) protocol in their work[19]. This work's primary emphasis is on transforming the routing issue into a capacity scheduling issue, and the proposed solutions, which comprise five methods, are as follows: (1) the QoS-aware neighbor choice algorithm to guarantee propagation delay, (2) the decentralized packet scheduling problem with the least slight delay, (3) the maneuverability sequence scalable automated system depending on transportation endpoints to reduce propagation delay, (4) the traffic superfluous eradication classifier to enhance bandwidth, and (5) the multiple data removal transmitting algorithm to support QoS; these are the five algorithms that make up the QoS-aware neighbor selection algorithm. When compared to several QoS-aware routing protocols, the QOD protocol demonstrates considerable improvements in terms of network congestion, latencies, and quality of service evaluation criteria, as shown by the results of simulations based on different simulators.

Improved from the previously used AOMDV protocol, the MAODV-BB proper procedure (Multihoming Ad hoc On-demand Vector with Backup Branches) was proposed by X. Li et al. This protocol, which was given the name MAODV-BB (Multipathing Ad hoc On-demand Vector with Backup Branches), is a multicast routing protocol. The primary purpose of this study is to provide a proposal for the combined benefits of the binary tree and the mesh structure. This will allow for the construction of a multiplex tree with fallback parts and the updating of shorter tree limbs. The findings of the simulation reveal that using the MAODV-BB protocol to route traffic in high-density MANETs greatly increases network performance in comparison to using another current MAODV-based routing mechanism.

S. Rehman et al. published a paper in which they presented a cross-layer routing protocol that they termed CLDBRP (Cross-Layer Decision Dependent Routing Protocol). This protocol was designed to enable QoS for multimedia applications of the IoV. (Internet of Vehicle). This paper proposed to obtain routing performance measures from layers, including data rate (channel quality) measurement from the physical layer and traffic metrics from the network layer. Once these metrics have been obtained, they will be taken into consideration in the minimization problem to select the QoS that will make sure of routes. The findings of the simulation reveal that the CLDBRP method performs much better in terms of the ratio of packets delivered as well as other performance measures when contrasted to several other routing protocols used in various mobility and volume urban VANET situations.

To enhance the overall connection speeds for interaction among aircraft and the ground, Q. Luo et al. suggested multiple QoS-aware variables routing that they referred to as the MQSPR protocol (Numerous Quality of Service Parameters-based Forwarding). It is proposed that performance indicators, like the path accessibility period, the residue left maximum throughput, and route time delay measurements, should all be taken into account during the decision-making process. Additionally, it is suggested that a scheme for minimizing flooding should aim to enhance longer-lasting, task scheduling, and end-to-end delay. The results of the simulation reveal that the suggested protocol is superior to the AODV and GPSR methods in numerous real-world circumstances in terms of improving route dependability, task scheduling, and the transportation of packets.

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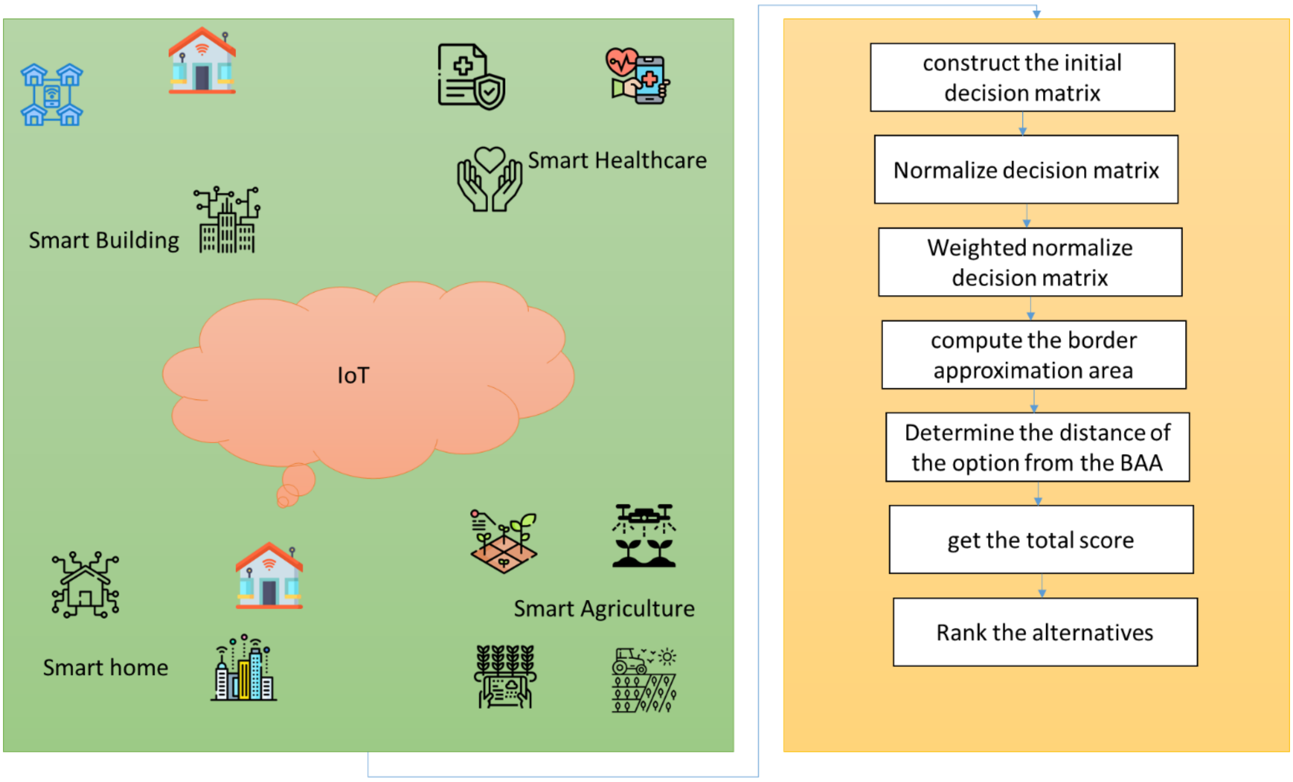


Figure 1: The methodology of QoS-aware IoT services composition

### 3. QoS-aware IoT services based MABAC Methodology

Models of decision-making based on several criteria are quite helpful when it comes to selecting and ranking the various options available in a collection. The multi-attributive border approximation area comparison (MABAC) approach is only one example of the many multiple criterion analysis methods that are now available. The decision matrix is the starting point for the suggested approach to assessing effectiveness[20]–[23]. The four principles of the decision matrix are as follows: (i) prospective options; (ii) choice factors; (iii) comparative weights of every criterion; and (iv) key metrics of options based on the criteria. Figure 1 shwos the propose methodology.

This section presents an overview of the numerical method of the MABAC approach, which is comprised of the following six steps:

Step1: The first step is to construct the initial decision matrix, denoted by $E = [e_{ij}]_{mn}$.

Step 2: Apply the formula $O = [o_{ij}]_{mn}$ to the decision, matrix to normalize it.

Using the equation, we can find out what the individual elements of the normalized matrix (N) are.

(a) About criteria for types of benefits,

$$o_{ij} = \frac{e_{ij}-e_i^-}{e_i^+-e_i^-} \quad (1)$$

For negative criteria

$$o_{ij} = \frac{e_{ij}-e_i^+}{e_i^- -e_i^+} \quad (2)$$

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$$e_i^+ = \left(\max_I e_i\right) \quad (3)$$

$$e_i^- = \left(\min_I e_i\right) \quad (4)$$

Step 3: Construct a decision matrix that is weighted and normalized (K).

$$k_{ij} = w_j * o_{ij} \quad (5)$$

Step 4: The following formula is used to compute the border approximation area (BAA) for every criterion.

$$B_i = \left(\prod_{j=1}^{m} k_{ij}\right)^{\frac{1}{m}} \quad (6)$$

Where $i = 1,2,3 \ldots.m; j = 1,2,3, \ldots..n$

Step 5 Determine the distance of the option from the BAA for each of the matrix members by using the following formula:

$$F = K - B \quad (7)$$

Step 6 The following calculation should be used to get the total score of each of the options.

$$T_i = \sum_{j=1}^{n} f_{ij} \quad (8)$$

Step 7: Rank the alternatives

The options are ranked according to the least value of $T_i$

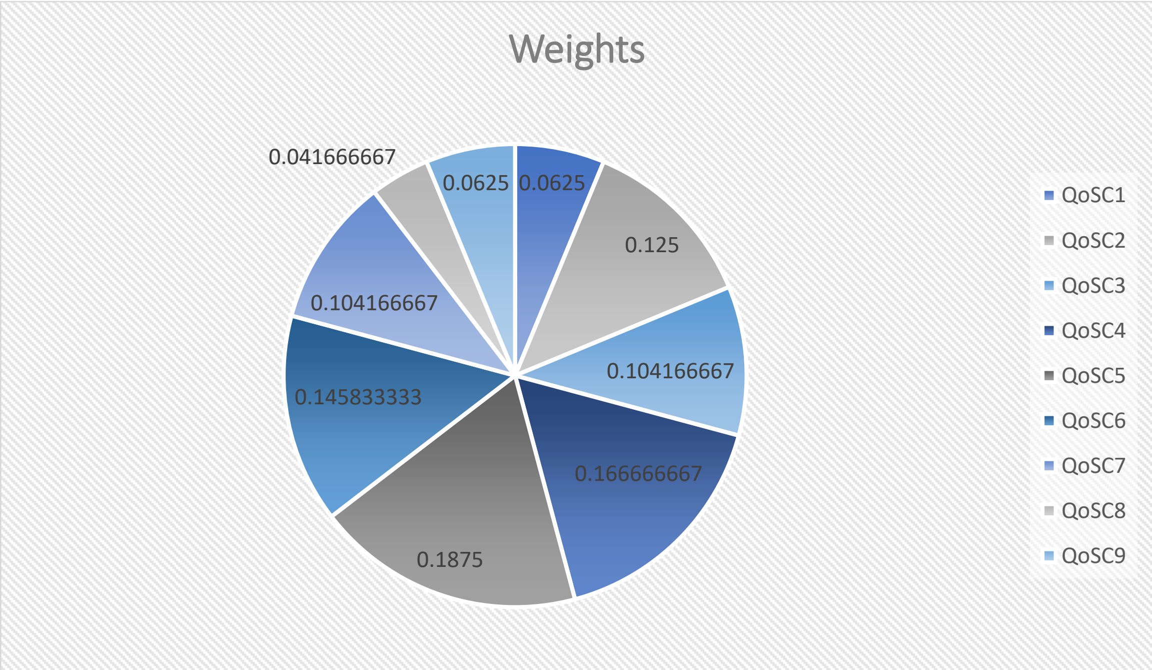


Figure 2: The weights of the criteria

**4. Application of MABAC Methodology**

When comparing these two or more network operators according to specific criteria, the priority that should be allocated to each factor has to be determined by evaluating the relative relevance of those factors. Following the establishment of the requirements and the establishment of the telecom operators, a hierarchical structure is established. To select services for an Internet of Things-based

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medical system, we have considered the following nine quality of service (QoS) attribute expected to operate average temperature, pixel density, correctness, postpone, jitter, bandwidth, accessibility, cost structure, and speed of response. The arbitrary use of the internet of things gives each criterion a priority rating based on how important the other criteria are. In addition to this, the relative importance of each of the criteria is determined by the average method shown in figure 2.

Step 1: The decision matrix is built on the opinion of experts.

Step 2: Then normalize the decision matrix by Eqs. (1,2,3,4) as shown in table 1. All criteria are positive.

Step 3: Use Eq. (5) to obtain the weighted decision matrix as shown in table 2.

Step 4: Eq. (6) is used to compute the BAA as shown in table 3.

Step 5: The distance from the BAA is computed by Eq. (8) as shown in Table 4

Step 7: Rank the alternatives in figure 3.

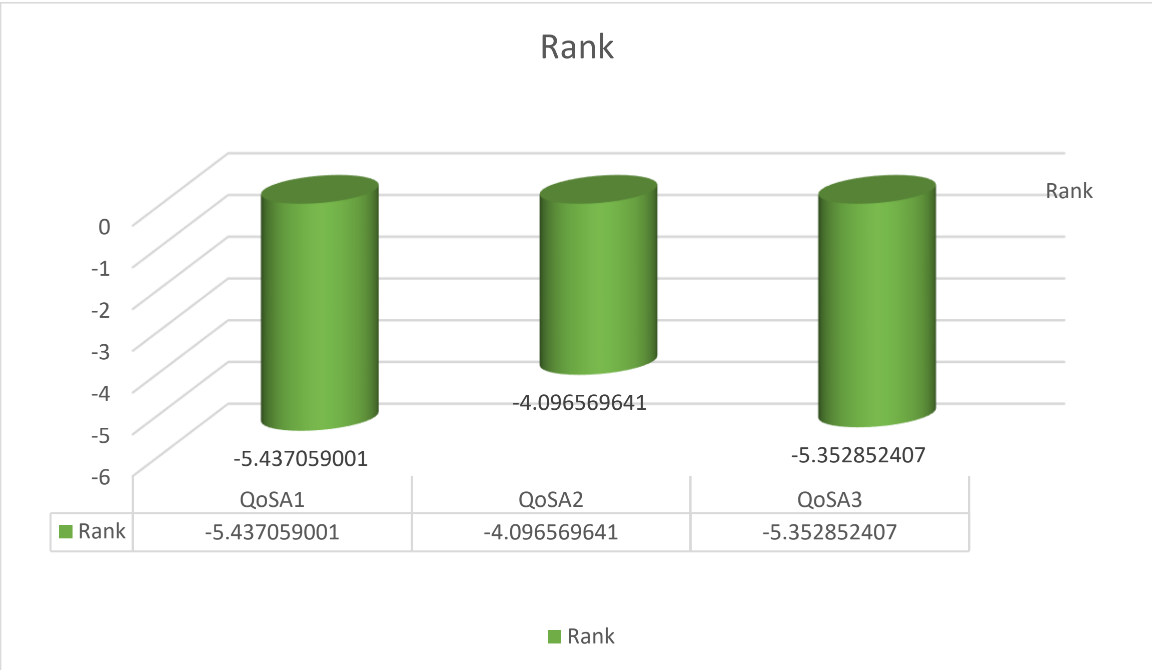


Figure 3: The rank of alternatives.

Table 1: The normalized decision matrix

| | QoSC1 | QoSC2 | QoSC3 | QoSC 4 | QoSC5 | QoSC6 | QoSC7 | QoSC8 | QoSC9 |
|---|---|---|---|---|---|---|---|---|---|
| **QoSA 1** | 6.96794 2 | 4.63840 9 | 12.2484 1 | - 13.467 | 16.3417 7 | 11.9104223 1 | 3.84365 7 | 5.09317 6 | 7.90266 1 |
| **QoSA 2** | 3.21841 | 14.6372 4 | 10.1058 4 | - 9.7174 7 | 16.3417 7 | 15.4394189 | 15.5302 7 | 14.467 | 3.56586 5 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **QoSA 3** | 1.343645 | -0.36101 | 16.53354 | -15.3418 | 14.467 | 10.14592401 | 10.85562 | 6.967942 | 5.734263 |

Table 2: The weighted normalized decision matrix

| | QoSC1 | QoSC2 | QoSC3 | QoSC4 | QoSC5 | QoSC6 | QoSC7 | QoSC8 | QoSC9 |
|---|---|---|---|---|---|---|---|---|---|
| **QoSA 1** | 0.494012 | 0.186067 | 0.543185 | -0.17454 | 0.537595 | 0.593879426 | 0.426242 | 0.158423 | 0.320496 |
| **QoSA 2** | 0.261541 | 0.516029 | 0.45534 | -0.12204 | 0.537595 | 0.756213269 | 1.454664 | 0.402142 | 0.164371 |
| **QoSA 3** | 0.145306 | 0.021087 | 0.718875 | -0.20078 | 0.479477 | 0.512712505 | 1.043295 | 0.207166 | 0.242433 |

Table 3: The BAA values

| | QoSC1 | QoSC2 | QoSC3 | QoSC4 | QoSC5 | QoSC6 | QoSC7 | QoSC8 | QoSC9 |
|---|---|---|---|---|---|---|---|---|---|
| **BAA** | 0.989614 | 0.96811 | 1.05557 | -0.792305105 | 1.045114 | 1.064184047 | 1.113271 | 0.973915 | 0.96866 |

Table 4: The distances from BAA

| | QoSC1 | QoSC2 | QoSC3 | QoSC4 | QoSC5 | QoSC6 | QoSC7 | QoSC8 | QoSC9 |
|---|---|---|---|---|---|---|---|---|---|
| **QoSA1** | -0.49135 | -0.74723 | -0.407 | -1.03839 | -0.38977 | -0.36988057 | -0.6049 | -0.75915 | -0.6294 |
| **QoSA2** | -0.72382 | -0.41727 | -0.49484 | -0.98589 | -0.38977 | -0.20754673 | 0.423524 | -0.51543 | -0.78553 |
| **QoSA3** | -0.84005 | -0.91221 | -0.2313 | -1.06463 | -0.44788 | -0.4510475 | 0.012155 | -0.7104 | -0.70747 |

## 5. Conclusion

The Internet of Things (IoT) is continuing to develop, which has led to a growth in both the demand for IoT services and the number of service suppliers. As a result, it will be challenging to choose an appropriate IoT solution from the selection of services to fulfill the requirements of the consumers. In this research, we looked at the issue of making decisions about IoT service providers. At first, we conceived of the Internet of Things framework as being made up of three primary components, namely information technology, information exchange, and things. After that comes a discussion on the quality-of-service (QoS) characteristics that are connected to every one of the three separate aspects. To pick IoT-based services based on the quality of service, we created a framework that describes an approach. This approach is a blend of the MABAC approach. The MABAC approach is used to determine the relative significance of the criterion (i.e., quality of service), which is then utilized by the MABAC method to rank the IoT services.

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