Adaptive Ontology-Based IoT Resource Provisioning in Computing Systems

Ashish Tiwari, National Institute of Technology, Kurukshetra, India*
https://orcid.org/0000-0001-6278-9607
Ritu Garg, National Institute of Technology, Kurukshetra, India

ABSTRACT

The eagle expresses of cloud computing plays a pivotal role in the development of technology. The aim is to solve in such a way that it will provide an optimized solution. The key role of allocating these efficient resources and making the algorithms for its time and cost optimization. The approach of the research is based on the rough set theory RST. RST is a great method for making a large difference in qualitative analysis situations. It’s a technique to find knowledge discovery and handle the problems such as inductive reasoning, automatic classification, pattern recognition, learning algorithms, and data reduction. The rough set theory is the new method in cloud service selection so that the best services provide for cloud users and efficient service improvement for cloud providers. The simulation of the work is finished at intervals with the merchandise utilized for the formation of the philosophy framework. The simulation shows the IoT services provided by the IoT service supplier to the user are the best utilization with the parameters and ontology technique.

KEYWORDS

High-Performance Computing, Internet of Things, Ontology Method, Ontology Tools, Rough Set Theory, Scheduling Technique, Service Providers, Simulator

1. INTRODUCTION

Cloud computing is playing the eagle view in the upcoming technology. The Research is going on a vast speed of development in cloud computing. Ontologies are sets of classes with characteristics, relations, and occasions between one another which permit the elaboration of metadata to rapidly recognize the articles. “Ontology is an information model that addresses a bunch of ideas inside an area and the connections among those ideas.” Semantic peculiarities are set free. All over the world cloud computing is a big idea in which work is going on. But nowadays cloud computing, providing a lot of practical features for researchers. The researchers are seeing the developing of computational intelligence. The Computational Intelligence makes the stating of the cloud research by the researchers in a rapid way (Buyya et al., 2010). The “intelligent Systems” are giving the best performance in the field of cloud and IOT by making use of biological and intelligence through nature. In the early days over than new half centuries there are a lot of upcoming technologies in the communication in which computing is becoming an essential equipment of the day today life of the human beings after water, electricity, gas, and telephony. In coming few years, it is the vast going technology of the world due to which it becomes very difficult to survive (Genez et al., 2013). The heights of computing are
increasing day by day Figure 1.1. The cloud ontologies in this work addresses the relations among Cloud administrations to work with the cloud service agents in thinking about the relations between and among cloud administration ideas. The best suited for the users are the computing which makes each and every work very easy and suitable. With the event of this point there’s utilized, reused, and known with numerous ontologies, and additionally desires to be well-kept. A philosophy consists with those obligations in musings. To make philosophy on a typical best philosophy and also the use of a selected define ordinarily manner less advanced utilize and maintenance (Geeta et al., 2018).

Figure 1. Eagle view of Internet of Thing with Ontology

A lot of research is going on computing to formulate and define the clusters, peers, web, grids, IOT, fog and cloud. The definition of Cloud Computing is being provided according to use of different researches. Keen Ontology-based vaults are utilized for the powerful disclosure of computing assets across different computing stages of IoT. It very well may be utilized to give a keen customization system to Saas. Facilitating the plan of safety frameworks by demonstrating job-based admittance control utilizing philosophy (Chui et al., 2022).

2. LITERATURE REVIEW

In this rapid growing world this technology is going to play a vital role for the researchers and the most suitable for the end users. In the computing actors are performing the work. The usefulness of ontology catalogs ascertained through this evaluation has encouraged their ongoing growth and maintenance. The computing system deals with the business ways by which the scope is being calculated. It is important to catch fundamental properties of the situation. The growth of its infrastructure is like a speed of light in every field of the technology is properly shown with the help of figure 2.1 like servers, virtualizations, database storage systems, security systems and many more which are fulfilling the concept of cloud computing i.e., pay and use model in anywhere, anytime and any service for the end users (Sarkar et al., 2015). According to few researchers’ grid is the system where resources are not controlled by the centralized way. It is an open, standard, rule based, nontrivial quality system which provide the services.

The designed a scalable framework to deal with variety, volume, and real-time data generated within smart cities (Zhang et al., 2018). The framework employs semantic Web technologies combined with machine learning techniques. The semantics-based framework has been used for
two use cases in smart cities: 1) pollution detection and 2) traffic pattern decision. The designed a proof-of-concept of the Italian Padova smart city. This paper focuses on architecture, Web services, and data format (XML and EXI) but without employing semantic Web technologies (Zanella et al., 2014). It highlights heterogeneity issues (e.g., communications and devices) within the application layer, transport layer, and link layer technologies from the OSI model. This paper highlights the main application domains for smart cities.

1) Smart building.
2) Waste management.
3) Air quality.
4) Noise monitoring.
5) Traffic congestion.
6) City energy consumption.
7) Smart parking.
8) Smart lighting.

This is an ontology catalog for biomedical ontologies. It provides a friendly user interface for users, and REST API for developers (BioPortal et al., 2011). Numerous functionalities are providing such as searching for a specific class, finding an ontology, and ontology statistics. The author provides a set of tools (BioPortal et al., 2011).

1) Ontology browser to browse the library of ontologies.
2) Search to look for a class in multiple ontologies.
3) Annotator to get annotations with specific ontologies.
4) Mapping between a selected ontology and all ontologies referenced
5) Recommender for the most relevant ontologies.
6) Resource index to display all ontologies. Such ontology catalogs and its functionalities should be provided for smart cities and IoT.

A survey on IoT ontologies (Bajaj et al., 2017) was published on ARXIV in July 2017. An analysis of IoT ontologies as a classification of ontologies has been done and mainly focused on IoT ontologies since 2012. They classified ontologies in the following categories.

1) Sensor ontologies.
2) Context-aware ontologies.
3) Location ontologies.
4) Time-based ontologies.

Each category is split into generic ontologies and domain specific ontologies. The need to evaluate ontologies has been highlighted and explained. What is missing is the explanation of the evolution of such ontologies and a deep comparison.

3. RESEARCH CHALLENGES

Cloud offerings inside the IaaS layer sub isolated as cipher, Network, and Storage offerings which may be the standard issue throughout this teach. The research issues in the ontology are which techniques can help ontology engineers in reusing existing IoT and shrewd city ontologies as well as What technique would assist with picking the ontology meeting our requirements among a bunch of comparable ontologies? (Bajaj et al., 2017). And how the cutting-edge examination could be shared in an inventive manner to decrease the expectation to learn and adapt of exploring, contemplating, and characterizing it? And What might be the arrangement of standards and best practices to think about ontologies and ontology indexes? How is it that we could direct engineers and cosmology architects to assess ontologies?
(Tiwari et al., 2020). The external issues of cloud computing are its protocols, standardized system of maintaining the services. The research challenges in the cloud computing are as follows:

Computing simple use: Information and data use within the potency approach. Why the user would like these resources? WHO is that the real sender of the data? What area unit controls given to the tip users? What ought to be the standards of deleting the knowledge? However, the information is maintained within the accounts?

Cloud Service Providers: Amazon Cloud Drive: Its space for storing is of- ten accessed from up to eight specific devices.

Software Workflow: On account that grids are virtually carrier and job oriented, they indicate they have got to perform the coordination of the services workflow and place which isn’t crucial in on-demand deployments equivalent to these in the Clouds.

Standardization: Grids have devoted enormous efforts to arrive standardization both in the consumer interface and in the internal interfaces (for having access to assets), and so reach seamless interoperability. The user entry interface to the Cloud may be very usually founded on ordinary technologies akin to these utilized in grids, however internal interfaces standardization is still a most important trouble.

Payment Model: Preliminary Grid efforts have been as a rule centered on public funding whilst the Cloud has been driven with the aid of business presents. An essential difficulty going through by means of cloud users is find out how to take advantage of these storage classes to serve a software (Mansouri et al., 2017).

Quality of Service: Most of the time, offering dedicated cloud offerings that be certain user’s dynamic QoS necessities by way of fending off SLA violations is a giant assignment in cloud computing (Singh et al., 2017).

Framework Systems: The purpose of framework for estimating price and verify have the benefit of Cloud Computing as an alternate to traditional IT infrastructure, like in private in hand and managed IT hardware. Cloud service suppliers host applications and supply computing power from its information centers, cashing in on huge economies of scale and dramatically lowering the prices of IT. Virtualization could be a key feature of cloud.

Cloud knowledge Management: the data is incredibly vital that is being keep within the cloud system. What ought to be the situation of the info stored? What’s the importance of the cloud knowledge centers?, however info ought to be recovered?, however knowledge or info ought to be segmented?

Resource procedure Services: Its giving procedure blessings for cloud customers at this layer, where the patrons show signs of improvement coarse-ness flexibility since they commonly get super-customer access to their VMs, and should use it to control the item stack on their VM for execution and viability.

Application Security: It deals with the factors and risks that could prevail in securing application software for a cloud. Is customer done the detailed assessment of attack factors and risk in the cloud? Is there traceability between security assurance features and all identified risk threats?

Sharp Ontology System: There is the use of classes in the ontology. The class attribute is making the relations with the other attributes. Ontologies are widely spread to the knowledge database. Axioms also play an important role in the ontology. These are dealing with the natural language for preparing the ontology. Its works like an interface.

Elasticity Ontology: It should offer a conceptual foundation for a range of anticipated tasks, and the representation should be crafted so that one can extend and specialize the ontology monotonically. The users are able to define any terms according to their use.

Minimal ontological commitment: The way the ontologies are sharing the knowledge should be its minimal commitment. Ontological commitment is based on consistent use of vocabulary; ontological commitment can be minimized by specifying the weakest theory.
In the research issues the ontology metrics counts the number of classes or properties is mostly used. The second major issue is the datasets structured according to ontologies. Integration with tools which improves the reusability of ontology. The ontology collection has been done by reviewing the literature, standards, looking up ontology catalogs and search engines, dataset investigation, and stakeholders. To validate ontologies, we conceived the ontology quality methodology like Serialization supports the OWL ontology format because it is a W3C recommendation (Tiwari et al., 2013). Syntactic validation is necessary during the compilation to load the ontology. It is an important step for the ontology quality methodology due to the fact that all ontologies must be proceeded by tools. Interlinking enhances interoperability, integration, and browsing among ontologies (Sicilia et al., 2013).

4. PROPOSED METHODOICAL STRUCTURE

A quick move of enthusiasm for unpleasant unadulterated arithmetic and its applications will be hitherto observed inside the assortment of global workshops, meetings and courses that are either straightforwardly committed to hash sets, grasp the point in their projects, or simply make do with papers that utilization this way to deal with unwind issues within reach.

An outsized assortment of best quality papers on differed parts of unpleasant sets and their applications are uncovered as of late as an aftereffect of this consideration. In the approach of the research in this paper is divided into two major parts i.e., step 1 deals with the ontology model used in the IoT computing services which detects numerous ontology pitfalls (Figure 4). Our research goal is to automatically evaluate ontology quality and in step 2 the mathematical model works for the service optimization in computing system.

Figure 4. Proposed Structural Computing System

4.1 Step 1: Ontological Model

In the world of ontology system, the research develops the algorithms so that the knowledge can be used with the technology. The Ontology plays an important role in the performance of computing. Ontology sys team is the knowledge based mathematical structure based on the domain. In cloud computing the researchers are using the concept of knowledge to generate the ontologies for the services. The ontologies are kept in different servers of ontology (Figure 5). There are different
configuration and capabilities of ontology servers. We surveyed ontology catalogs based on OWL ontologies since OWL is a W3C recommendation. Further, we selected ontology catalogs supporting the activity of ontology reuse.

The following parameters we have calculated in ontology like Ontology number counts the number of ontologies referenced within the catalog (Figure 6).

Figure 5. Ontological Proposed Model

Figure 6. Work flow diagram Model
Maintenance of the system which can be automatic, semiautomatic, or manual. Ontology quality evaluates ontologies referenced within ontology catalogs. Ontology collection explains the way ontologies have been integrated within the catalogs.

4.2 Step 2: Mathematical Method

The theory has been trailed by the occasion of numerous code frameworks that execute unpleasant set tasks. In rough math’s sets area unit printed by approximations. Rough sets cannot be defined by victimization offered information. Thus, with every rough set to associate a pair of crisp sets, said as its lower approximation by eq 2 and better approximation by eq 1. Intuitively, the lower approximation of a bunch consists of all components that certain as shooting belong to the set, whereas the upper approximation of the set constitutes of all components that in all probability belong to the set.

If the fuzzy relation between the concepts is flexible i.e.

\[ R(i,j) = \text{COMP}(x,y) = \max(x,y) = \begin{cases} x & \text{if } x > y \\ y & \text{otherwise} \end{cases} \] (1)

If the virtual relationships between the concepts is tight and limited i.e.

\[ R(i,j) = \text{COMP}(x,y) = \min(x,y) = \begin{cases} y & \text{if } x > y \\ x & \text{otherwise} \end{cases} \] (2)

The excellence of the upper and so the lower approximation might be a boundary region. Data area unit sometimes given as a table, columns of that area unit labeled by attributes, rows by objects of interest and entries of the table area unit attribute values. For each CSP, whenever it logs in to the middleware, it has to produce associate account which has respondent of bound relevant queries supported our known parameters by the eq 3. The data set are represented as a table where every row represents an object, which is simply a cloud service provider. Each column represents an attribute (a variable, an observation, a property etc) that can be measured for an object. The properties can be considered depending on the system information. So that the table is called as information table. This relevance generates a threshold value \( \gamma_i \) for each attribute. For each attribute \( \rho_i \) the value of

\[
\rho \gamma_i \geq 1 \text{ or } True \\
0, \text{ Otherwise}
\] (3)

The half a pair of the rule executes at the consumer aspect. Once logged in and availing the services of cloud service supplier, the tenant has to answer some queries as the same as service supplier.

In this research work we have been allocating the jobs to the service providers based on the \( \delta \) value. The CSP and its Fuzzy cost values from the equation 4. The fuzzy cost of the service provider is the sum of all the membership values of each attribute as per the equation.

\[
\mu = \sum_{i=1}^{n} \delta_i
\] (4)
So we have a tendency to name it as User adaptive Approach. During this analysis paper we’ve increased our rule, removed some bugs and even offer a user interface atmosphere so the users feel it simple to control. As per our rule, there are a unit variety of Cloud Service suppliers which can contain the quantity of datacenters.

The inspiration for unpleasant unadulterated arithmetic has returned from the prerequisite to speak to subsets of a universe as far as proportionality classifications of a bunch of the universe. The research proposed their own algorithm that deals with the concept that fulfills the requirements of the basic obstacles to get the best and efficient results.

**4.3 Proposed Algorithm: OMIS (Ontological Methodology for IoT Services)**

The proposed algorithm OMIS works with the step 1 and step 2. The algorithm performance provides the best optimal services to the end users. OMIS is the utilization of a semantic ontology to address fabricating machines information, including machine arrangement information, machine attributes information, machine analysis information, producing administration information, producing process information, etc.
information, and so on. This metaphysics is viewed as an upper cosmology. Upper ontology is a lightweight cosmology restricted to ideas that are conceptual and nonexclusive enough to address an expansive scope of articles in the space of interest. When dealing with incomplete information systems, there are two ways to achieve knowledge reduction: First consists in changing the incomplete information system into a complete one through data remove or complement. Second is to set null as default value for missing data. After pre-processing data, attributes are reduced and the minimum set of rules is deduced.

1. Step 1 (discernibility matrix)
2. Step 2 (Attributes Reduction)
3. Step 3 (Core of the attributes)
4. Step 4 (Generated rules)

Cloud users can rely on these rules to make efficient decision. And cloud service providers can improve the quality of the cloud service focusing on particular aspects according to these decision rules. Our work is from the perspective of data mining and the indicators of evaluation system of cloud service as the focus to give a solution help cloud users to make the decision.

5. EXPERIMENTAL RESULTS AND SIMULATION

The simulation of the results field unit being created exploitation Google App engine is also a platform for setting up ascendant internet applications which may be run on excessive of server forming the surroundings. It provides a group of associate degree software model that enables developers to require knowledge of further services furnished by means of Google like Mail, information retailer, buffer store, and others. These functions are run inside of a sandbox and App Engine can watch out for robotically scaling as soon as required. The CloudSim toolkit supports each and every approach and behavior modeling of Cloud approach elements like skills centers, virtual ma-chines (VMs) and useful resource provisioning policies. The satisfactory of CloudSim is incontestable via a case learn involving dynamic provisioning of software offerings within the hybrid federate clouds surroundings. The outcome of this case gain knowledge of proves that the federate Cloud computing mannequin substantially improves the applying QoS necessities underneath unsteady useful resource and restores demand patterns. The data sets which are taken are explained in the Figure 6,7,8,9 in the form of tables. The core rate of Aneka could also be a provider directed runtime surroundings. Code as a carrier solutions field unit at the perfect concludes of the Cloud computing stack and those they present finish customers with accomplice measure built-in carrier comprising hardware, development systems, and applications. Customers do not appear to be allowed to customize the provider however get access to a selected application hosted within the Cloud. Aneka is a software platform and a framework for developing distributed applications on the Cloud.

It harnesses the computing resources of a heterogeneous network of desktop PCs and servers or datacenters on demand. Aneka provides developers with a rich set of APIs for transparently exploiting such resources and expressing the logic of applications by using a variety of programming abstractions is shown with the help of Figures.

5.1 Results Between Cloud Users and Cloud Parameters

Result 1: With the aim of checking the potency of the algorithms, in the research 12 parameters are taken for the calculation of efficient total time taken and processor utilization of the algorithmic program for fastened values. The below graph represents efficient total time taken in Millisecond (ms) to execute the algorithmic program by totally different CSPs with increasing range of Users. It can easily observe that the time taken is increasing exponentially as we have a tendency to increase the quantity of users. The increasing range of Datacenters conjointly affects the ensuing graph. It
has calculated for 20 datacenters. The efficient total time taken by the CSP is directly proportional to the number of Cloud Parameters. The research taken 12 Parameters specifically Virtualization, Application Security, Risk Management and Compliance and Audit, etc. However, the algorithmic program is subject to expand for any range of parameters.

Result 2: The CPU Utilization by the End Users is directly proportional to the number of Cloud Parameters. It has taken 12 Parameters namely Virtualization, Application Security, Risk Management and Compliance and Audit. The system Configuration affects the CPU Utilization. The Below graph shows the CPU Utilization running on Windows 7 (Operating System), Intel Core i5 Processor, Ram 4GB, Hard Disk (620GB). The System Parameters which are effecting the CPU Utilization are CPU Usage time, Disk I/O(Active Time), Network I/O(Network Utilization time) and Hard Disk (Faults/sec) usage Physical Memory.

### Algorithm 1. Proposed OMIS (Ontological Methodology for IoT Services) Algorithm

**Input:** Set of parameters P, Set of IoT service Providers IoT (SP), Cloud Broker (CB), Set of Datacenters (DC), and End Users (EU)

**Output:** Optimal allocation of set of services by cloud Service providers of IoT to the End Users.

1. **Begin:**
2. **For Each:** \( P \neq \emptyset \)
3. {  
4. IoT (SP) = Select (DC)
5. \[ R(i,j) = \text{COMP}(x,y) = \max(x,y) = \begin{cases} x & \text{if } x > y \\ y & \text{otherwise} \end{cases} \]
6. \[ R(i,j) = \text{COMP}(x,y) = \min(x,y) = \begin{cases} y & \text{if } x > y \\ x & \text{otherwise} \end{cases} \]
7. **Provide DC to CB**
8. **If DC is selected**
9. {  
10. IoT (SP) = IoT (SP) – 1;
11. \[ p_i \gamma \geq 1 \text{ or } 0, \text{ Otherwise} \]
12. }
13. }
14. **Select (Rendered Output)**
15. {  
16. Flag Bit = Match (Best IoT (SP) to the DC)
17. \[ \mu = \sum_{i=1}^{n} \delta_i \]
18. if (Flag Bit = True)
19. {  
20. The suitable service of IoT (SP) is provided by IoT (SP) to DC
21. if (Flag Bit = True)
22. {  
23. The suitable service of IoT (SP) provided by CB to the EU.
24. }
25. }
26. }
27. The Best IoT (SP) is provided by CB to EU.
28. **End.**
Table 1. Data Matrix for Evaluation of CPU Performance between End Users and Parameters

| CPU UTILIZATION | IoT Users |
|-----------------|-----------|
| Parameters      | 5  | 10 | 15 | 20 | 25 |
| 4               | 0.502 | 0.628213 | 0.729 | 0.786 | 1.35 |
| 6               | 0.557 | 0.7405 | 1.008 | 1.258 | 1.292 |
| 8               | 0.709 | 0.7924 | 0.86444 | 1.401 | 2.823 |
| 10              | 0.4001 | 1.01 | 1.36 | 1.81 | 3.056 |

Table 2. Data Matrix for Evaluation of CPU Performance between Datacenters and Parameters

| CPU UTILIZATION | IoT PARAMETERS |
|-----------------|----------------|
| DATACENTERS     | 4  | 6  | 8  | 10 | 12 |
| 5               | 0.7418 | 0.755 | 0.8655 | 0.9765 | 1.42 |
| 10              | 0.5343 | 0.644 | 0.7554 | 0.876 | 1.32 |
| 15              | 0.4554 | 0.45645 | 0.6544 | 0.7543 | 1.22 |
| 20              | 0.4001 | 0.4223 | 0.4554 | 0.5444 | 1 |

Table 3. Data Matrix for Evaluation of efficient time Evaluation between End Users and Parameters

| Time Taken | IoT Users |
|------------|-----------|
| Parameters | 5  | 10 | 15 | 20 | 25 |
| 4          | 384.5 | 385.5 | 388 | 410.75 | 413.25 |
| 6          | 350.5 | 396.75 | 406.75 | 419 | 438.25 |
| 8          | 332.75 | 376 | 396.75 | 403.75 | 461.25 |
| 10         | 300.5 | 316.25 | 418.25 | 508.5 | 551.25 |

Table 4. Matrix for Evaluation of efficient time Evaluation between Datacenters and Parameters

| Time Taken | IoT PARAMETERS |
|------------|----------------|
| DATACENTERS | 4  | 6  | 8  | 10 | 12 |
| 5          | 1310 | 1259 | 562 | 531 | 530 |
| 10         | 1176 | 1168 | 570 | 570 | 565 |
| 15         | 1124 | 1100 | 498 | 543 | 542 |
| 20         | 1115 | 1102 | 480 | 475 | 325 |
Figure 9. Graph Showing Evaluation of CPU performance between IoT End Users and Parameters

Figure 10. Graph Showing Evaluation of CPU performance between Datacenters and Parameters

Figure 11. Graph Showing Evaluation of efficient time Evaluation between End Users and Parameters
6. CONCLUSION

Involving IoT advances for empowering fabricating over Internet has a colossal guarantee in cutting edge modern creation and mechanization. Distributed computing is likewise a new and promising worldview offering IT administrations as processing utilities. This work examines the design of the evaluation of ontology quality. It will encourage the reuse of ontologies and improve semantic interoperability. Unifying and aligning ontology catalogs would enable to update all catalogs with new ontologies automatically. Another challenge is to automatically improve and fix ontologies. Finally, we could design an ontology ranking algorithm to recommend ontologies to reuse. To achieve this intention, we have a tendency to designed algorithms with full and partial future employment information. Further elaborated stories for the period of this course will definitely characterize subsequent step from this work.

Figure 12. Graph Showing Evaluation of efficient time Evaluation between Datacenters and Parameters
REFERENCES

Abawajy, J. H., & Dandamudi, S. P. (2003, December). Parallel job scheduling on multicluster computing systems. In *Null* (p. 11). IEEE.

Ahamed, J., & Chishti, M. A. (2021). Ontology based semantic interoperability approach in the Internet of Things for healthcare domain. *Journal of Discrete Mathematical Sciences and Cryptography*, 24(6), 1727–1738.

Akhani, J., Chuadhary, S., & Somani, G. (2011, March). Negotiation for resource allocation in IaaS cloud. In *Proceedings of the Fourth Annual ACM Bangalore Conference* (p. 15). ACM.

Awad, A. I., & El-Hefnawy, N. A., & Abdel kader, H. M. (2015). Enhanced particle swarm optimization for task scheduling in cloud computing environments. *Procedia Computer Science*, 65, 920–929.

Ayush Kumar, Deepak, & Santhanavijayan. (2020) HeTOnto: A Novel Approach for Conceptualization, Modeling, Visualization, and Formalization of Domain Centric Ontologies for Heat Transfer. 2020 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT), 1-6.

Bajaj, G., Agarwal, R., Singh, P., Georgantas, N., & Issarny, V. (2017). *A study of existing ontologies in the IoT-domain*. arXiv:1707.00112.

Buyya, R., Beloglazov, A., & Abawajy, J. (2010). *Energy-efficient management of data center resources for cloud computing: a vision, architectural elements, and open challenges*. arXiv preprint arXiv:1006.0308.

Buyya, R., Broberg, J., & Goscinski, A. M. (Eds.). (2010). *Cloud computing: Principles and paradigms* (Vol. 87). John Wiley & Sons.

Buyya, R., Yeo, C. S., Venugopal, S., Broberg, J., & Brandic, I. (2009). Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. *Future Generation Computer Systems*, 25(6), 599–616.

Calheiros, R. N., Ranjan, R., Beloglazov, A., De Rose, C. A., & Buyya, R. (2011). CloudSim: A toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms. *Software, Practice & Experience*, 41(1), 23–50.

Cellary, W., & Strykowski, S. (2009, November). E-government based on cloud computing and service-oriented architecture. In *Proceedings of the 3rd international conference on Theory and practice of electronic governance* (pp. 5-10). ACM.

Chui, K. T., Ordóñez de Pablos, P., Shen, C. W., Lytras, M. D., & Vasant, P. (2022). Towards Sustainable Smart City via Resilient Internet of Things. In *Resilience in a Digital Age* (pp. 117–135). Springer.

Cvitić, I., Peraković, D., Gupta, B., & Choo, K. K. R. (2021). Boosting-based DDoS Detection in Internet of Things Systems. *IEEE Internet of Things Journal*.

Deepa, O., & Senthilkumar, A. (2016). Swarm intelligence from natural to artificial systems: Ant colony optimization. *Networks (GRAPH-HOC)*, 8(1).

Dubois, D., & Prade, H. (1992). Putting rough sets and fuzzy sets together. In *Intelligent Decision Support* (pp. 203–232). Springer.

Gaurav, A., Gupta, B. B., & Panigrahi, P. K. (2022). A comprehensive survey on machine learning approaches for malware detection in IoT-based enterprise information system. *Enterprise Information Systems*, 1–25.

Geeta, C. M., Raghavendra, S., Buyya, R., Venugopal, K. R., Iyengar, S. S., & Patnaik, L. M. (2018). Data Auditing and Security in Cloud Computing: Issues, Challenges and Future Directions. *International Journal of Computer*, 28(1), 8–57.

Genez, T. A., Bittencourt, L. F., & Madeira, E. R. (2013, December). On the performance-cost tradeoff for workflow scheduling in hybrid clouds. In *Utility and Cloud Computing (UCC), 2013 IEEE/ACM 6th International Conference on* (pp. 411-416). IEEE.

Gupta, S., Garg, R., Gupta, N., Alhumay, W. S., Ghosh, U., & Sharma, P. K. (2021). Energy-efficient dynamic homomorphic security scheme for fog computing in IoT networks. *Journal of Information Security and Applications*, 58, 102768.
Gupta, S. K., Agrwal, S., Meena, Y. K., & Nain, N. (2011, November). A hybrid method of feature extraction for facial expression recognition. In *Signal-Image Technology and Internet-Based Systems (SITIS), 2011 Seventh International Conference on* (pp. 422-425). IEEE.

Herawan, T., Deris, M. M., & Abawajy, J. H. (2010). A rough set approach for selecting clustering attribute. *Knowledge-Based Systems, 23*(3), 220–231.

Jensen, R., & Shen, Q. (2009). New approaches to fuzzy-rough feature selection. *IEEE Transactions on Fuzzy Systems, 17*(4), 824.

Jiao, R., Wang, S., Zhang, T., Lu, H., He, H., & Gupta, B. B. (2021). Adaptive Feature Selection and Construction for Day-Ahead Load Forecasting Use Deep Learning Method. *IEEE eTransactions on Network and Service Management, 18*(4), 4019–4029.

Juarez, F., Ejarque, J., Badia, R. M., Rocha, S. N. G., & Esquivel-Flores, O. A. (2018). Energy-Aware Scheduler for HPC Parallel Task Base Applications in Cloud Computing. *International Journal of Combinatorial Optimization Problems and Informatics, 9*(1), 54–61.

Kaur, M., Singh, D., Kumar, V., Gupta, B. B., & Abd El-Latif, A. A. (2021). Secure and Energy efficient based E-health Care Framework for Green Internet of Things. IEEE Transactions on Green Communications and Networking.

Khosravi, A., Andrew, L. L., & Buyya, R. (2017). Dynamic vm placement method for minimizing energy and carbon cost in geographically distributed cloud data centers. *IEEE Transactions on Sustainable Computing, 2*(2), 183–196.

Komorowski, J., Pawlak, Z., Polkowski, L., & Skowron, A. (1999). Rough sets: A tutorial. *Rough fuzzy hybridization: A new trend in decision-making, 3-98.*

Konar, A. (2005). An introduction to computational intelligence. *Computational Intelligence: Principles, Techniques and Applications, 1-35.*

Krishna, P. V., Misra, S., Joshi, D., & Obaidat, M. S. (2013, May). Learning automata based sentiment analysis for recommender system on cloud. In *Computer, Information and Telecommunication Systems (CITS), 2013 International Conference on* (pp. 1-5). IEEE.

Krishna, P. V., Misra, S., Saritha, V., Raju, D. N., & Obaidat, M. S. (2017, May). An efficient learning automata based task offloading in mobile cloud computing environments. In *Communications (ICC), 2017 IEEE International Conference on* (pp. 1-6). IEEE.

Liu, Y., Esseghir, M., & Boulahia, L. M. (2016). Evaluation of parameters importance in cloud service selection using rough sets. *Applied Mathematics, 7*(06), 527.

Lytras, M. D., & Visvizi, A. (2018). Who uses smart city services and what to make of it: Toward interdisciplinary smart cities research. *Sustainability, 10*(6), 1998.

Lytras, M. D., Visvizi, A., & Sarirete, A. (2019). Clustering smart city services: Perceptions, expectations, responses. *Sustainability, 11*(6), 1669.

Mansouri, Y., Toosi, A. N., & Buyya, R. (2017). Cost optimization for dynamic replication and migration of data in cloud data centers. IEEE Transactions on Cloud Computing.

Mathur, N., Meena, Y. K., Mathur, S., & Mathur, D. (2018). Detection of Brain Tumor in MRI Image through Fuzzy-Based Approach. In *High-Resolution Neuroimaging-Basic Physical Principles and Clinical Applications. InTech.*

Meena, Y. K., & Gopalani, D. (2016). Efficient Voting-Based Extractive Automatic Text Summarization Using Prominent Feature Set. *Journal of the Institution of Electronics and Telecommunication Engineers, 62*(5), 581–590.

Meena, Y. K., Jain, A., & Gopalani, D. (2014, May). Survey on graph and cluster based approaches in multi-document text summarization. In *Recent Advances and Innovations in Engineering (ICRAIE), 2014* (pp. 1-5). IEEE.
Mirsadeghi, F., Rafsanjani, M. K., & Gupta, B. B. (2021). A trust infrastructure based authentication method for clustered vehicular ad hoc networks. *Peer-to-Peer Networking and Applications, 14*(4), 2537–2553.

Peng, X., Ren, J., She, L., Zhang, D., Li, J., & Zhang, Y. (2018). BOAT: A Block-Streaming App Execution Scheme for Lightweight IoT Devices. *IEEE Internet of Things Journal, 5*(3), 1816–1829.

Plageras, A. P., Psannis, K. E., Stergiou, C., Wang, H., & Gupta, B. B. (2018). Efficient IoT-based sensor BIG Data collection–processing and analysis in smart buildings. *Future Generation Computer Systems, 82*, 349–357.

Rani, R., & Garg, R. (2021). Reliability aware green workflow scheduling using e-fuzzy dominance in cloud. *Complex & Intelligent Systems, 1*-19.

Rathee, P., & Malik, S. K. (2021). Ontology concept semantic similarity matching based on Ant Colony Optimization algorithm. *Journal of Information and Optimization Sciences, 42*(8), 1987–2000.

Samanta, A., & Misra, S. (2018). Energy-efficient and distributed network management cost minimization in opportunistic wireless body area networks. *IEEE Transactions on Mobile Computing, 17*(2), 376–389.

Sampson, D. G., Lytras, M. D., Wagner, G., & Diaz, P. (2004). Ontologies and the Semantic Web for E-learning (Guest editorial). *Journal of Educational Technology & Society, 7*(4), 26–28.

Sarkar, S., Chatterjee, S., & Misra, S. (2015). Assessment of the Suitability of Fog Computing in the Context of Internet of Things. IEEE Transactions on Cloud Computing.

Sarkar, S., Chatterjee, S., Misra, S., & Kudupudi, R. (2017). Privacy-Aware Blind Cloud Framework for Advanced Healthcare. *IEEE Communications Letters, 21*(11), 2492–2495.

Sharma, A., & Kumar, S. (2020). Bayesian rough set-based information retrieval. *Journal of Statistics and Management Systems, 23*(7), 1147–1158.

Sicilia, M. A. (Ed.). (2013). *Handbook of metadata, semantics and ontologies*. World Scientific.

Singh, S., Chana, I., & Buyya, R. (2017). STAR: SLA-aware autonomic management of cloud resources. *IEEE Transactions on Cloud Computing*.

Singh, S., & Sharma, R. M. (2018). Heuristic Based Coverage Aware Load Balanced Clustering in WSNs and Enablement of IoT. *International Journal of Information Technology and Web Engineering, 13*(2), 1–10.

Stergiou, C., Psannis, K. E., Kim, B. G., & Gupta, B. (2018). Secure integration of IoT and cloud computing. *Future Generation Computer Systems, 78*, 964–975.

Sundareswaran, S., Squicciarini, A., & Lin, D. (2012, June). A brokerage-based approach for cloud service selection. In *Cloud computing (cloud), 2012 IEEE 5th international conference on* (pp. 558-565). IEEE.

Tewari, A., & Gupta, B. B. (2020). Security, privacy and trust of different layers in Internet-of-Things (IoTs) framework. *Future Generation Computer Systems, 108*, 909–920.

Tiwari, A., Mahrishi, M., & Fatehpuria, S. (n.d.). *A Broking Structure Originated on Service accom-modative Using MROSP Algorithm*. Academic Press.

Tiwari, A., Nagaraju, A., & Mahrishi, M. (2013, February). An optimized scheduling algorithm for cloud broker using adaptive cost model. In *Advance Computing Conference (IACC), 2013 IEEE 3rd International* (pp. 28-33). IEEE.

Tiwari, A., Sah, M. K., & Gupta, S. (2015). Efficient Service Utilization in Cloud Computing exploitation victimization as Revised Rough Set Optimization Service Parameters. *Procedia Computer Science, 70*, 610–617.

Tiwari, A., Sah, M. K., & Malhotra, A. (2015, September). Effective service Utilization in Cloud Computing exploitation victimisation rough pure mathematics as revised ROSP. In *Reliability, Infocom Technologies and Optimization (ICRITO)/Trends and Future Directions, 2015 4th International Conference on* (pp. 1-6). IEEE.

Tiwari, A., & Sharma, R. M. (2016, August). Potent Cloud Services Utilization with Efficient Revised Rough Set Optimization Service Parameters. In *Proceedings of the International Conference on Advances in Information Communication Technology & Computing* (p. 90). ACM.
Tiwari, A., & Sharma, R. M. (2021). OCC: A Hybrid Multiprocessing Computing Service Decision Making Using Ontology System. *International Journal of Web-Based Learning and Teaching Technologies, 16*(4), 96–116.

Tiwari, A., Sharma, R. M., & Garg, R. (2020). Emerging ontology formulation of optimized internet of things (IOT) services with cloud computing. In M. Pant, T. K. Sharma, O. P. Verma, R. Singla, & A. Sikander (Eds.), *Soft Computing: Theories and Applications* (pp. 31–52). Academic Press.

Tiwari, A., Sharma, V., & Mahrishi, M. (2014). Service Adaptive Broking Mechanism Using MROSP Algorithm. In *Advanced Computing, Networking and Informatics-Volume 2* (pp. 383–391). Springer.

Tiwari, A., Tiwari, A. K., Saini, H. C., Sharma, A. K., & Yadav, A. K. (2013). A Cloud Computing using Rough set Theory for Cloud Service Parameters through Ontology in Cloud Simulator. *ACYT–2013 Conference at Chennai, in CS and IT Proceedings.*

Venugopal, S., Chu, X., & Buyya, R. (2008, June). A negotiation mechanism for advance resource reservations using the alternate offers protocol. In *Quality of Service, 2008. IWQoS 2008. 16th International Workshop on* (pp. 40–49). IEEE.

Vieira, C. C., Bittencourt, L. F., & Madeira, E. R. (2014, December). Reducing costs in cloud application execution using redundancy-based scheduling. In *Proceedings of the 2014 IEEE/ACM 7th International Conference on Utility and Cloud Computing* (pp. 117–126). IEEE Computer Society.

Wang, C., Shen, J., Vijayakumar, P., & Gupta, B. B. (2021). Attribute-Based Secure Data Aggregation for Isolated IoT-Enabled Maritime Transportation Systems. *IEEE Transactions on Intelligent Transportation Systems.*

Whetzel, P. L. (2011, July). BioPortal: Enhanced functionality via new Web services from the national center for biomedical ontology to access and use ontologies in software applications. *Nucleic Acids Research, 39*, W541–W545.

Xu, M., Cui, L., Wang, H., & Bi, Y. (2009, August). A multiple QoS constrained scheduling strategy of multiple workflows for cloud computing. In *Parallel and Distributed Processing with Applications, 2009 IEEE International Symposium on* (pp. 629–634). IEEE.

Yadav, J., & Meena, Y. K. (2016, September). Use of fuzzy logic and wordnet for improving performance of extractive automatic text summarization. In *Advances in Computing, Communications and Informatics (ICACCI), 2016 International Conference on* (pp. 2071-2077). IEEE.

Yan, Z., Xie, H., Zhang, P., & Gupta, B. B. (2018). Flexible data access control in D2D communications. *Future Generation Computer Systems, 82*, 738–751.

Zadeh, L. A. (1996). On fuzzy algorithms. In *Fuzzy Sets, Fuzzy Logic, And Fuzzy Systems: Selected Papers by Lotfi A Zadeh* (pp. 127-147). Academic Press.

Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014, February). Internet of Things for smart cities. *IEEE Internet Things J., 1*(1), 22–32.