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Cloud of Things and fog computing in Iraq: Potential applications and sustainability

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Abstract

This paper depicts the principles of Cloud of Things and fog computing and discusses its possible uses in Iraq with sustainability measures. The capacity of cloud computing to supply elastic, as-needed computer resources has garnered widespread interest worldwide. However, fog computing and a Cloud of Things enhance the Internet of Things by relocating computation to devices on the network's periphery. This study looks at how the Cloud of Things and fog computing are used now in Iraq, the obstacles, and the future uses of these technologies in various fields. To fully reap the benefits of the Cloud of Things and fog computing in Iraq, the study also emphasizes the significance of infrastructure development, policy design, cybersecurity, and other measures. This study will discuss the use of questionnaires in research. There are two distinct components to this. The first section includes questions regarding the respondents' affiliations, including their roles, departments, organization sizes, and ministries. The rest of the study's factors are discussed with inquiries in line with issues of cyber security, privacy, sustainability, cost of implementation, feasibility, trust, IT infrastructure, and government support. The survey's final open-ended inquiry will help us to compile a wide range of perspectives on what kinds of Cloud of Things and fog computing services based on the Iraqi government's needs.

Keywords: Cloud of Things, Fog computing, IoT, Iraqi IT infrastructure, Sustainability

1. Introduction

The advent of cloud computing has dramatically altered how people and companies make use of computer systems. It's a scalable and low-cost option for dealing with massive data. However, in some cases, the needs

of real-time applications that require minimal latency cannot be met by depending entirely on centralized cloud infrastructures. Fog computing is a decentralized computing paradigm that moves computation closer to the edge devices, hence overcoming this restriction [1-3].

Two related ideas that address data processing in the context of the Internet of Things (IoT) are the Cloud of Things (CoT) and Fog Computing. Figure 1 illustrates how the concept of CoT—a network of intelligent devices with communication capabilities and a cloud connection—allows for the gathering and processing of vast volumes of data to boost production and efficiency across a range of industries. Fog computing, on the other hand, is a decentralized computing architecture that lowers latency and increases data processing speed and efficiency by bringing the cloud closer to edge devices. This is especially helpful in scenarios requiring real-time data processing, such as industrial automation or driverless cars. In conclusion, Fog computing brings the cloud closer to edge devices for quicker and more effective data processing, whereas CoT concentrates on centralized data processing in the cloud. Both ideas have certain advantages and uses that make them significant to the growth of the IoT [4-5]. Iraq's adoption of cloud computing is just beginning. Difficulties include low internet penetration, inadequate infrastructure, and a lack of knowledge about cloud computing. However, steps are being taken to overcome these obstacles, such as the National Cloud Computing Strategy and collaborations with international cloud service providers. Iraqi government agency cooperation, business operation efficiency, and data analytics and storage capacities could all benefit from cloud computing [2–3]. Fog computing has much to offer Iraq, particularly in areas where real-time data processing is essential to mission success. By facilitating intelligent parking management, real-time traffic monitoring, and accident detection, fog computing has promise for enhancing the nation's transportation infrastructure. Numerous aspects of healthcare could be improved by fog computing, such as efficient resource management, real-time data analysis for outbreak diagnosis, and remote patient monitoring. Precision farming methods can be applied in the agricultural sector with the help of fog computing, giving farmers the ability to make well-informed decisions about things like pest control, fertilization, and irrigation [6–12].

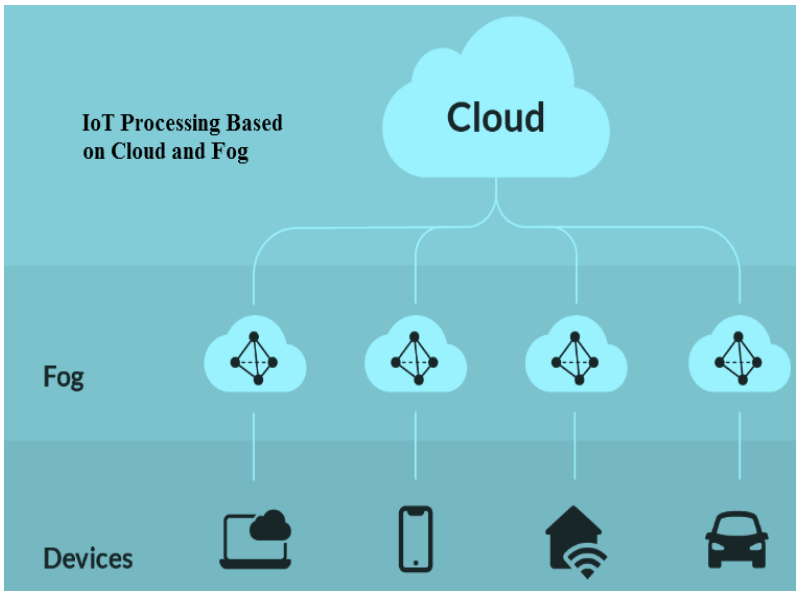

Figure 1. IoT system based on cloud and fog computing technologies

2. Method

Our team has leveraged its extensive network of personal contacts, niche internet communities, and reliable social connections in Iraq to conduct the required survey. One hundred and thirty individuals in Iraq were asked to fill out a questionnaire since they had sufficient knowledge of the Cloud of Things and fog computing. 114 people answered the survey. Even though follow-up texts and emails were issued to encourage participation, only roughly 88 % of people responded. This rate of response, though, was very adequate, and it did include useful suggestions. The goal of this research is to provide a comprehensive depiction of the conditions under

which Cloud of Things and fog computing can flourish in Iraq. In it, members of the Iraqi community summarize their hopes for the Cloud of Things and fog computing. About 114 answers to each questionnaire question are provided. Each question has been characterized in terms of the response given, which illustrates various details. IBM's Statistical Package for the Social Sciences (SPSS 25) has been used to analyze the data, together with the results of the surveys. We can make the following inferences from the collected and summarized data about the survey's results. In the first section of the questionnaire, we asked basic questions about the respondents' familiarity with Cloud of Things and fog computing as well as their role, department, organization size, and ministry. Expressive research was used to gain insight into the opinions of numerous Iraqi residents who are specialists or knowledgeable about the current Cloud of Things and fog computing usage in Iraq.

As can be seen in Figure 2, the majority of responders (53%) are employees, while 26% are department managers, 12% are section managers, and 9% are top managers.

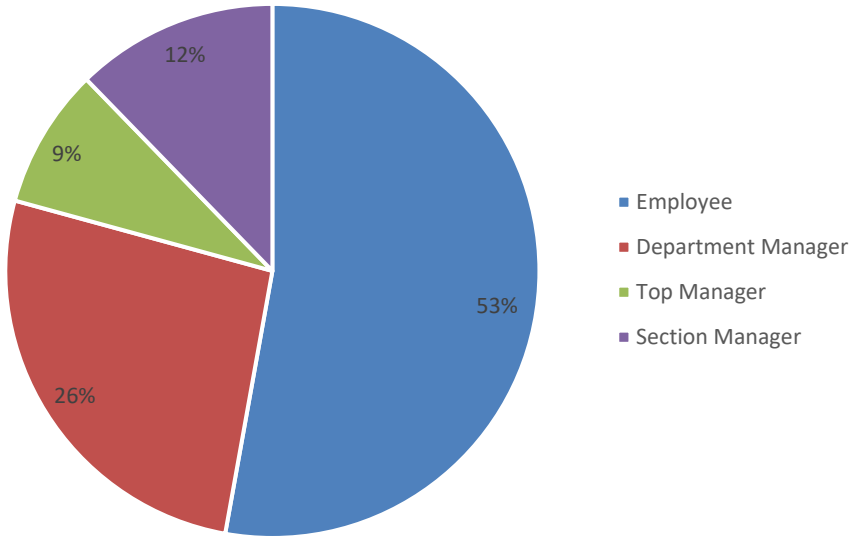

Figure 2. Organizational role of questionnaire respondent

In response to the second question, the majority of respondents (60%) work in information technology, followed by the planning department (30%), the operations department (5%), and other departments (5%) as in Figure 3.

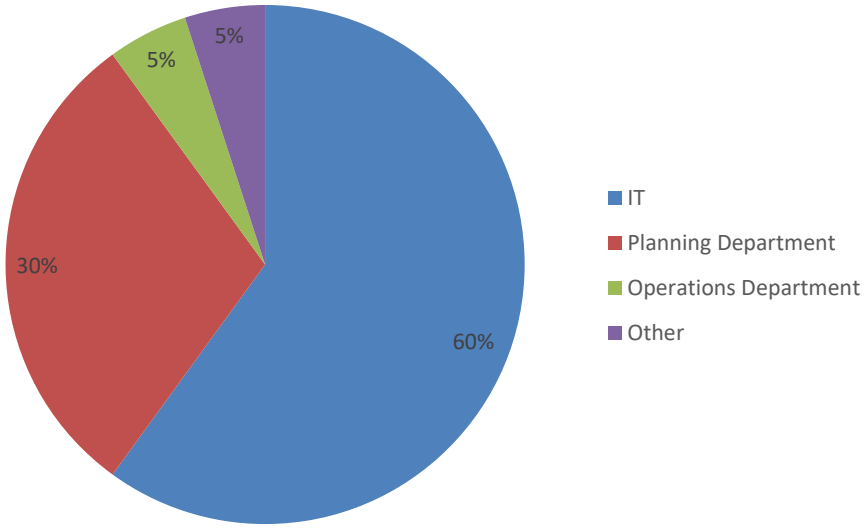

Figure 3. Respondent department percentages at their organizations

Figure 4 shows the distribution of Recorded Answers for the issue of company size, with 39% belonging to the 250-500 employee group, 11% to the 50-100 employee group, 18% to the 100-250 employee group, and 32% to the 500-1000 employee group.

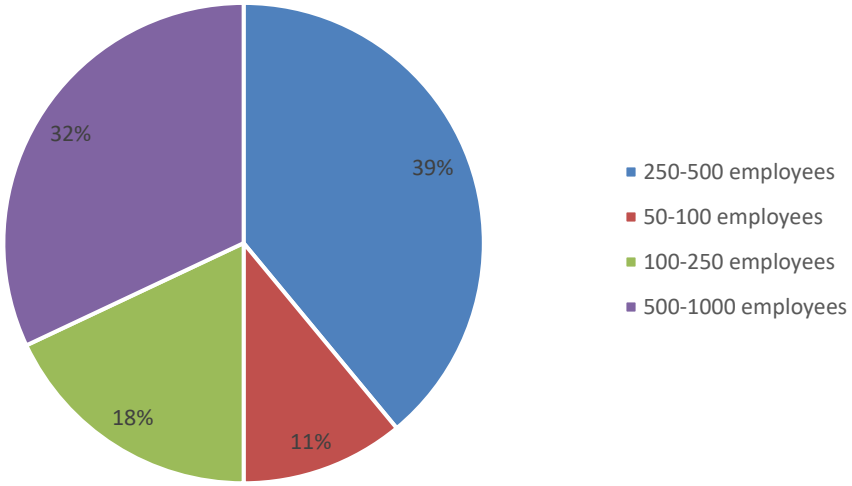

Figure 4. Organization size based on questionnaire respondents

Figure 5 shows that 42% of respondents work for the Ministry of Communication, 25% for the Ministry of Higher Education and Scientific Research, 9% for the Ministry of Industry and Minerals, and 24% for other ministries. This poll also includes the ministries of science and technology, education, and the environment and water resources.

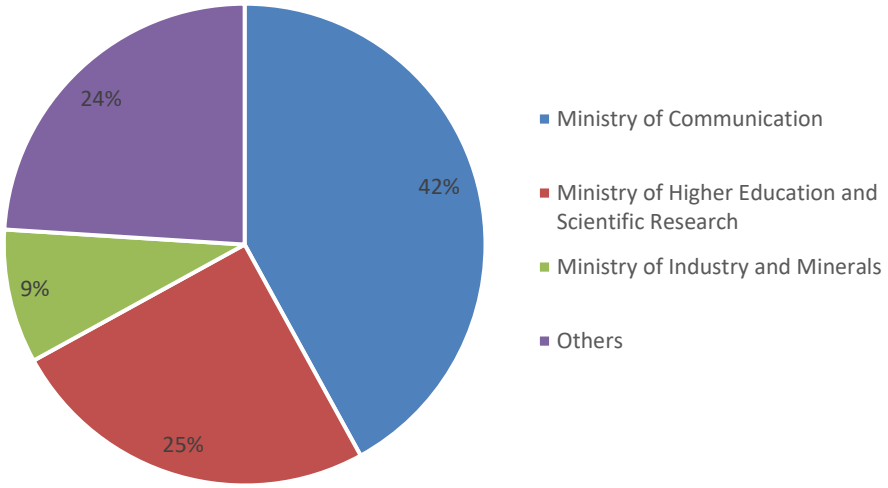

Figure 5. Ministry affiliation of questionnaire respondents

Likert scales are utilized, with a score of "1" indicating very unimportant, "2" indicating unimportant level, "3" being neutral, "4" being important, and "5" being very important [13]. The " I don't know " choice, on the other hand, has come to signify the absence of knowledge. Statistics on how respondents to the questionnaire rated various factors on a Likert scale, such as cyber security, privacy, sustainability, cost, feasibility, trust, IT readiness, and government support, are presented. Each question item, as well as their respective means and standard deviations, are included. Based on the diffusion of innovation (DOI), technology–organization–environment (TOE), and Loccovo theories, respondents' responses revealed widely varying priorities when it came to other challenges related to the Cloud of Things and fog computing's organizational, technological, and environmental variables [14].

Questionnaire participants' mean and standard deviation on the Likert scale for Recorded Answers for cybersecurity-related questions were 3.92 and 1.184, respectively, indicating an activist mentality. The minimal mean value is 3.75, which is quite near to 4 and may be seen, for instance, in the fifth sub-question. Overall, questionnaire respondents had a favorable view of privacy-related questions, with a mean and standard deviation of 4.2 and 1.163, respectively, on the Likert scale. Since averages are more reliable, it follows that respondents place a higher value on privacy than security.

Table 1. Recorded answers for cyber security concerns items by questionnaire respondents

What exactly is it that has you most concerned about cyber security?	M	SD
Risk of system failure (if one of the programs or devices fails).	3.77	1.2
Someone else is getting their hands on your data or controlling it by cyber-attacks.	4.13	1.15
Deleted files, cyber-attacks, infected computers, etc.	4.14	0.99
When data is deleted from the cloud and fog computing environment, there are no backup copies.	3.97	1.14
Your office PC is the only acceptable location for data storage.	3.75	1.23
The potential for Cloud of Things and fog computing to be used in dangerous environments.	3.76	1.27
Is it more secure to use private or community Cloud of Things and fog computing from cyber-attacks?	3.99	1.31
Average total	3.92	1.184

Table 2. Recorded answers for privacy concerns items by questionnaire respondents

What exactly are your biggest privacy worries?	M	SD
Keeping files in a location apart from the working environment.	4.1	1.17
Your data could be acquired by a third party.	4.4	1.12
Loss of privacy on account of variations in data protection regulations among nations.	3.8	1.13
If your service provider is based in a different country, you may need more access to your data.	4.5	1.2
I have no idea who can log in or see what files they can see.	4.2	1.15
I have no idea where the data is saved.	4.2	1.21
Average total	4.2	1.163

With a mean and standard deviation of (M = 4.03; SD = 1.178) and (M = 3.8; SD = 1.193) for sustainability and reliability along with cost issues, respectively, questionnaire respondents have responded to the average for cost items. They have yet to reach the pivotal point on the Likert scale.

Table 3. Recorded answers for the sustainability and reliability items by questionnaire respondents

To what extent are you concerned about issues of sustainability and reliability?	M	SD
Cloud of Things and fog computing depend entirely on your internet connection, which may or may not be available at any given time.	4.19	1.21
In an internet blackout, using a mobile phone provider's data services may incur additional costs.	3.54	1.34
In the event of a Cloud of Things or fog computing service provider outage, your organization cannot afford to pause or restart.	3.93	1.181
During an outage or possible attack, you will have no access to data or services.	4.45	0.98
Average total	4.03	1.178

Table 4. Recorded answers for cost items by questionnaire respondents

Please explain your significant worries regarding the expenses.	M	SD
Bandwidth-intensive apps incur additional costs.	3.93	1.294
It is more expensive to have a storage and security system that is effective.	3.79	1.131
The cost of application installation and reconfiguration can be substantial.	3.96	1.14
Hidden fees associated with backup, restore, disaster recovery, and problem resolution.	3.91	1.12
Purchasing services as opposed to hardware and software can make long-term operating expenses more expensive.	3.41	1.279
Average total	3.8	1.193

Respondents ranked feasibility, trust, and IT readiness as four pressing issues, with respective mean and standard deviation values of (M = 4.28; SD = 1.067), (M = 4.22; SD = 1.006), and (M = 4.32; SD = 1.056). These results show that the majority of respondents have a good impression and consider them very imperative issues, as measured by the Likert scale.

Table 5. Recorded answers for feasibility issues by questionnaire respondents

If you're considering the Cloud of Things and fog computing, what should you keep in mind?	M	SD
Is it possible in terms of technology?	4.06	1.23
Can it be done for the expense proposed?	4.24	0.987
Will there be gains and advantages?	4.37	0.876
When one or more components in any tier fail, does service to the underlying applications continue without interruption?	4.28	1.11
If the Cloud of Things and fog computing services have good real-time performance.	4.34	0.951
Is it safer to use than the conventional method?	4.37	0.946
Average total	4.28	1.067

Table 6. Recorded answers for trust issues by questionnaire respondents

Which features should be prioritized while choosing a Cloud of Things and fog computing service provider?	M	SD
Reputation	4.28	1.158
Geographical location, employee count, and customer roster	3.79	1.069
Methods of protection	4.31	0.991
Information security protocols	4.37	0.891
Observance of applicable standards and regulations	4.22	0.994
Continuity and emergency recovery strategies	4.33	0.932
Average total	4.22	1.006

Table 7. Recorded answers for IT infrastructure readiness issues by questionnaire respondents

What are your primary concerns regarding the issue of infrastructure readiness?	M	SD
Is the PC, hardware, and operating system environment prepared to support the Cloud of Things and fog computing service requirements, then what is the status of your Cloud of Things and fog computing service requirements?	4.14	1.075
Can the IT infrastructure support the additional Cloud of Things and fog computing service demands?	4.27	1.063
Does your company provide a high-quality Internet connection and bandwidth, can it reap the benefits of the Cloud of Things and fog computing technology?	4.38	1.057
Can the existing IT applications be incorporated with the Cloud of Things and fog computing?	4.24	1.061
Is it challenging to migrate an existing system to a Cloud of Things and a fog computing environment, and how?	3.95	1.029
Is the IT infrastructure readiness the service provider's responsibility?	4.95	1.051
Average total	4.32	1.056

Finally, the questionnaire participants' Likert-scale replies to questions about government support are indicative of a positive outlook because they are near an important level with a mean value of 4.07 and a standard deviation of 1.074, respectively. The final question is a free-form suggestion box for answering how you feel about the future of the Cloud of Things and fog computing in Iraqi institutions. They are summarized in the analysis and recommendation sections of this study, along with our team's points of view.

Table 8. Recorded answers for the government support issues by questionnaire respondents

When it comes to government aid, what exactly are your most significant worries?	M	SD
Will government laws and regulations aid the widespread implementation of the Cloud of Things and fog computing?	4.21	0.913
When it comes to the Cloud of Things and fog computing, will the government fund the essential training programs and research to ensure that the relevant skills are acquired?	4.24	0.983
To what extent will the government assist non-profits in overcoming their budget constraints?	4.13	1.021
Is the government willing to facilitate the adoption of the Cloud of Things and fog computing by reducing the number of meetings and permits required?	4.13	1.077
Does the government establish stringent data storage and privacy rules to safeguard business information, how effective will these measures be?	4.24	1.076
Do you need help from the government to implement the Cloud of Things or fog computing at your company?	3.48	1.372
Average total	4.07	1.074

Cronbach's Alpha displays the dependability of field study. The questionnaire is a highly trustworthy instrument that may be used by the Iraqi government with confidence due to a Cronbach's alpha range of 0.71 to 0.85. According to George and Mallery (2003), a Cronbach's Alpha value of 0.9 is considered excellent, 0.8 is good, 0.7 is acceptable, 0.6 is questionable, 0.5 is poor, and less than 0.5 is unacceptably low [15-16]. It also explains the median importance rating on an ordinal scale used in field studies, as in Table 9.

Table 9. Reliability and average ordinal scale percentage of the field study

Variable	Mean	Cronbach's Alpha	Average Ordinal Scale %
Cybersecurity	3.92	0.77	73
Privacy	4.2	0.78	80
Sustainability and reliability	4.03	0.71	75.75
Cost	3.8	0.78	70
Feasibility	4.28	0.84	82
Trust	4.22	0.85	80.5
IT readiness	4.32	0.82	83
Government support	4.07	0.84	76.75

3. Questionnaire findings and analysis

The survey targeted individuals with expertise in the Cloud of Things and fog computing technologies, and the questions were planned out in advance to maintain proportion and homogeneity. The results showed that the various government agencies in Iraq have a positive attitude and high ambitions toward implementing these technologies, with high mean values for IT readiness and feasibility. However, there is still work to be done in creating a supportive culture for innovation and change.

As a direct result, each of the responders is working on constructing an original prototype for the Cloud of Things and fog computing in Iraq right now, intending to improve IoT and e-services. They are educated about the possibilities for the Cloud of Things and fog computing technologies to save money, time, and the necessary resources for increasing the quality of IoT and e-services suitably.

The dependability measure is provided by Cronbach's Alpha, which has a range that goes from 0.71 to 0.85 and indicates that the selected survey has both a positive outcome and a high level of reliability. This questionnaire has the potential to serve as a road map for the development of the Cloud of Things and fog computing technologies inside the governmental organizations of Iraq.

In addition, specialized opinions and recommendations have been obtained, both of which will help put the Cloud of Things and fog computing technologies into practice and make significant improvements. Both of these will be helpful in the future. It is required to analyze and address the obstacles that slow down the development of a Cloud of Things and fog computing environment in Iraq, according to the thoughts of some of the people who participated in the survey. These people's opinions were gleaned from the results of the survey. Issues of a political nature, workers working in information and communication technology (ICT), electricity, and an internet connection are some of the challenges that must be overcome. In addition, some of the people who took part in the survey believe that there is a demand for official gateways of the Cloud of Things and fog computing technology in the organizations that are administered by the government of Iraq. This is one of the opinions that was expressed in the survey. These gateways supply a variety of future efforts and research on the alterations in the manner in which internet services are employed, as well as enhancements in performance. This gateway also illustrates that it is essential in the expansion and growth of future government schematics for the goal of encouraging electronic transactions and attracting investments in Iraq. This is to motivate electronic transactions, and IoT, and attract investments in Iraq.

According to some expert opinions and suggestions provided by respondents to an applied survey, e-governance in Iraq based on the Cloud of Things and fog computing technology is strategic and has numerous benefits to an organization. These benefits include less distributed data storage, cheaper resource availability, more security control, scalability, and responsibility. Because of this, developing an e-government system in Iraq is of the

utmost importance. This is in contrast to the current state of Cloud of Things and fog computing technology, which are relatively close to the ground at this point.

In the Cloud of Things, IoT, and fog computing technologies, microstrip filters, and antennas are employed in various applications, such as smart home devices, industrial sensors, and autonomous vehicles. They enable these devices to interconnect with each other wirelessly, constructing a network of interconnected devices that can share data and information in real-time. Overall, miniature microstrip filters and antennas are necessary constituents and recommended in developing Cloud of Things, IoT, and fog computing technologies. Their significance will only continue to grow as these technologies become more widespread [17-21].

4. Conclusion

Cloud of Things and fog computing have the potential to revolutionize several different industries in Iraq by enabling real-time data processing, improving decision-making capabilities, and increasing operational efficiency. However, for its implementation to be successful, there must be concentrated efforts made by the government, the private sector, non-governmental organizations, and academic institutions to address the problems and establish an atmosphere that is conducive to their success. The process of Iraq's digital transformation can be sped up, and its competitiveness in the international economy can be improved if the country makes use of cloud and fog computing technology with sustainability measures.

Adopting the Cloud of Things and fog computing in Iraq confronts many obstacles despite the potential benefits of these types of computing. A limited internet connection worries regarding the privacy of data, a lack of technical skills, and an inadequate infrastructure are some of these issues. To overcome these issues, it is essential to make more and more investments in the improvement of the country's internet infrastructure, to provide training and education programs on Cloud of Things and fog computing, to implement legislation for data privacy, and to promote public-private partnerships for the development of infrastructure and enhance the quality of data storage and e-services with sustainability measures.

5. Recommendations

Based on this study's findings and the responses to the survey, the following sustainability dimensions need to be considered:

- Environmental sustainability: Evaluate the environmental impact of expanding cloud and fog computing infrastructure. This covers the energy usage of data centers, the technology's carbon footprint, and the possibility of powering these establishments with renewable energy sources. Environmental sustainability can be enhanced by supporting green data centers and putting energy-efficient measures into operation.
- Resource efficiency: The elastic, on-demand resources that cloud computing offers are consistent with resource efficiency. Iraq can guarantee the sustainability of its cloud and fog computing services concerning resource allocation by maximizing resource usage and eliminating resource wastage.
- Long-term viability: Taking sustainability into account means taking investments in cloud and fog computing into account. To prevent technological obsolescence, this entails estimating the lifespan of infrastructure, software, and hardware components and making plans for replacements and updates.
- Skills development: Long-term sustainability depends on developing a workforce with the necessary skills to manage and maintain cloud and fog computing systems. The sustainability of the technology can be improved, and reliance on outside expertise can be decreased by funding education and training initiatives that develop local talent.
- Data security and privacy: Trust-building and sustainability depend on guaranteeing the security and privacy of data handled and stored in cloud and fog computing environments. To preserve sensitive data, Iraq should put strong data protection and cybersecurity safeguards in place.

- Regulatory compliance: For cloud and fog computing programs to be sustainable, compliance with national and international rules is essential. The ethical and legal use of these technologies is ensured by adhering to industry standards, cybersecurity rules, and data protection laws.
- Infrastructure development: The foundation of sustainability is infrastructure development. To meet the increasing demand for cloud and fog computing services, Iraq needs to make investments in developing robust and scalable network and data center infrastructure.
- Policy design: It's critical to create transparent, flexible policies that control the implementation and application of cloud and fog computing. The sustainability of the economy, society, and environment should all be taken into account when creating new policies, which should also be updated to take advantage of new opportunities.
- Government support: The effective acceptance and expansion of cloud and fog computing depend heavily on the continued support of the government. The government's financial assistance, political commitment, and regulatory frameworks can guarantee the survival and stability of these technologies.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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References

[1] A. Al-Dulaimi and M. Shibly, "Cloud Computing Adoption in Iraq: Opportunities and Challenges," *Journal of Engineering Research and Technology (JERT)*, vol. 6, no. 3, pp. 137–146, 2019.

[2] J. Al-Jaroodi and N. Mohamed, "Fog Computing: Architecture, Applications, and Research Challenges," *International Journal of Advanced Computer Science and Applications (IJACSA)*, vol. 9, no. 1, pp. 161–171, 2018.

[3] S. Al-Maqsood and S. Bakri, "The Role of Fog Computing in Enhancing Smart Agriculture in Iraq," *International Journal of Emerging Trends in Engineering Research (IJETER)*, vol. 8, no. 5, pp. 2445–2449, 2020.

[4] H. Atlam, R. Walters, and G. Wills, "Fog computing and the Internet of Things: A review," *Big Data Cogn. Comput.*, vol. 2, no. 2, p. 10, 2018.

[5] V. Kumar, School of Control Engineering, Harbin Institute of Technology Harbin, 150001, China, A. A. Laghari, S. Karim, M. Shakir, and A. Anwar Brohi, "Comparison of fog computing & cloud computing," *Int. J. Math. Sci. Comput.*, vol. 5, no. 1, pp. 31–41, 2019.

[6] *Ministry of Communications - Republic of Iraq. (2017). National Cloud Computing Strategy for Iraq*. [Online]. Available: http://moc.gov.iq/uploaded/2017/Cloud%20Computing%20Strategy.pdf. [Accessed: 22-Oct-2023].

[7] A. S. Shukur and J. Al-Jaroodi, "Fog Computing Applications in Smart Transportation Systems: A Comprehensive Review," *IEEE Access*, vol. 8, pp. 151193–151208, 2020.

[8] K. H. Abdulkareem *et al.*, "A review of fog computing and machine learning: Concepts, applications, challenges, and open issues," *IEEE Access*, vol. 7, pp. 153123–153140, 2019.

[9] A. A. Mutlag, M. K. Abd Ghani, N. Arunkumar, M. A. Mohammed, and O. Mohd, "Enabling technologies for fog computing in healthcare IoT systems," *Future Gener. Comput. Syst.*, vol. 90, pp. 62–78, 2019.

[10] M. Al-khafajiy, T. Baker, H. Al-Libawy, A. Waraich, C. Chalmers, and O. Alfandi, "Fog computing framework for Internet of things applications," in *2018 11th International Conference on Developments in eSystems Engineering (DeSE)*, 2018.

[11] M. M. Sadeeq, N. M. Abdulkareem, S. R. Zeebaree, D. M. Ahmed, A. S. Sami, and R. R. Zebari, "IoT and Cloud computing issues, challenges and opportunities: A review," *Qubahan Academic Journal*, vol. 1, no. 2, pp. 1–7, 2021.

[12] F. E. F. Samann, A. M. Abdulazeez, and S. Askar, "Fog computing based on machine learning: A review," *Int. J. Interact. Mob. Technol.*, vol. 15, no. 12, p. 21, 2021.

[13] Q. Kalsoom and A. Khanam, "Inquiry into sustainability issues by preservice teachers: A pedagogy to enhance sustainability consciousness," *J. Clean. Prod.*, vol. 164, pp. 1301–1311, 2017.

[14] M. Amini and A. Bakri, "Cloud computing adoption by SMEs in Malaysia: A multi-perspective framework based on DOI theory and TOE framework," *Journal of Information Technology & Information Systems Research*, vol. 9, no. 2, pp. 121–135, 2015.

[15] D. G. Bonett and T. A. Wright, "Cronbach's alpha reliability: Interval estimation, hypothesis testing, and sample size planning: CRONBACH'S ALPHA RELIABILITY," *J. Organ. Behav.*, vol. 36, no. 1, pp. 3–15, 2015.

[16] F. Franceschini, M. Galetto, and M. Varetto, "Qualitative ordinal scales: The concept of ordinal range," *Qual. Eng.*, vol. 16, no. 4, pp. 515–524, 2004.

[17] J. K. Ali and Y. S. Miz'el, "A new miniature Peano fractal-based bandpass filter design with 2nd harmonic suppression," in *2009 3rd IEEE International Symposium on Microwave, Antenna, Propagation and EMC Technologies for Wireless Communications*, 2009.

[18] Y. S. Mezaal and H. T. Eyyuboglu, "A new narrow band dual-mode microstrip slotted patch bandpass filter design based on fractal geometry," in *2012 7th International Conference on Computing and Convergence Technology (ICCCT)*, IEEE, 2012, pp. 1180–1184.

[19] Y. S. Mezaal, H. H. Saleh, and H. Al-saedi, "New compact microstrip filters based on quasi fractal resonator," *Adv. Electromagn.*, vol. 7, no. 4, pp. 93–102, 2018.

[20] F. Abayaje, S. A. Hashem, H. S. Obaid, Y. S. Mezaal, and S. K. Khaleel, "A miniaturization of the UWB monopole antenna for wireless baseband transmission," *Periodicals of Engineering and Natural Sciences*, vol. 8, no. 1, pp. 256–262, 2020.

[21] Y. S. Mezaal and S. F. Abdulkareem, "New microstrip antenna based on quasi-fractal geometry for recent wireless systems," in *2018 26th Signal Processing and Communications Applications Conference (SIU)*, 2018.

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