

# A Survey Based Study on Fog Computing Awareness

**Zainab Javed**

Institute of Business Administration (IBA), Karachi, Pakistan  
E-mail: zjaved@khi.iba.edu.pk

**Waqas Mahmood**

Institute of Business Administration (IBA), Karachi, Pakistan  
E-mail: wmehmood@iba.edu.pk

Received: 09 September 2020; Revised: 21 October 2020; Accepted: 05 November 2020; Published: 08 April 2021

**Abstract:** In this day and age, the rise in technological advancements has the potential to improve and transform our lives every day. The rapid technology innovation can have a great impact on our business operations. Currently, Cloud computing services are popular and offer a wide range of opportunities for their customers. This paper presents a survey on a more recent computing architecture paradigm known as Fog Computing. Fog networking is a beneficial solution that offers the greater facility of data storage, enhanced computing, and networking resources. This new concept of fog complements cloud solution by facilitating its customers with better security, real-time analysis improved efficiency. To get a clear picture and understanding of how fog computing functions, we have performed an extensive literature review. We also presented a comparative study of fog computing with cloud and grid computing architectures. In this study, we have conducted a survey that led us to the conclusion that fog computing solution is still not applicable and implemented in most of the IoT industries due to the lack of awareness and the high architecture's cost. Results of the study also indicate that optimized data storage and security are a few of the factors that can motivate organizations to implement the Fog computing architecture. Furthermore, the challenges related to fog computing solution are reviewed for progressive developments in the future.

**Index Terms:** Fog Computing, IoT, Cloud Computing, Grid Computing, Challenges, Comparison, Architecture.

## 1. Introduction

Fog computing, also called edge computing, is a standard that is used to analyze and assess the sensitive data of the Internet of Things (IoT) and to transfer a large volume of data to the cloud in milliseconds. The Internet of Things (IoT) collects an enormous quantity of data from individual levels of devices and improves the output. The devices that are connected to IoT analyze data at a very high-speed. Fog computing in contrast to the cloud provides greater business agility and better security. Fog computing solution analyzes data close to the device at a point where the data produces, and this point of the device is known as fog node [1]. Cisco in 2014, was the first who came up with the idea of the Fog Computing paradigm, which works as an elongation of Cloud Computing. As the word 'Fog' implies, it brings clouds nearer to the edge of the ground. Fog computing can be implemented to reduce the transportation speed and improves performance [2]. Akin to the cloud, fog computing as well delivers application services, storage, and data to their end-users. End-users can access all their application services that are connected to millions of devices via IoT. Basically, both cloud-based framework and fog allow the same functionalities to the customers but fog computing is more convenient and close to the needs of their customers as it supports mobility with lower operational costs [3].

Therefore, the prime research objective of this paper is to find out the significance of Fog Computing which is relatively a new architecture solution for organizations in Pakistan and to get a general idea that if organizations here are ready to deploy/migrate their business applications towards this solution and if not what are the limitations. Fog computing performs an essential part in the management of data and analytics. It consists of the following characteristics: a) less downtime, b) mobility, c) dense geographical distribution, d) wireless access, e) heterogeneity, f) real-time interactions, g) interoperability. It is a platform that works as a bridge connecting the data centers of cloud computing and the end-users or devices as shown in Fig. 1. Network services, data storage, and efficient analysis of the data are the basic elements of fog computing [4]. Fog computing is an architecture where applications and data are needless to reside in cloud data centers. The more devices connected to the network, the more it helps to infer about the business processes easily. Fog computing requires network agility, privacy, and security of data and the management of services. It empowers the end-users to keep and own the authority of their productive data [5].

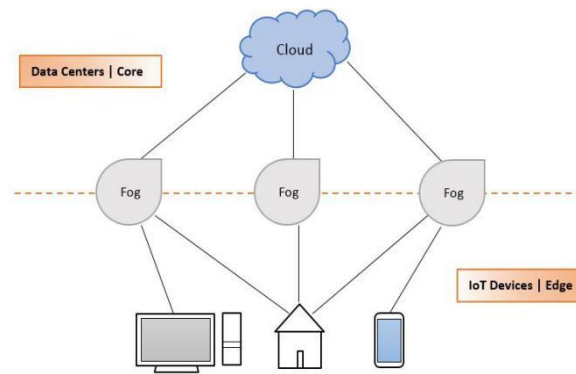


Fig.1. Fog Computing Framework Design

The application devices in IoT scenarios can be examined and organized more effortlessly by an emergent application that is fog computing instead of the centralized cloud-based architecture. Fog computing is capable to tackle the requisites of Internet of Things (IoT) data. It also enables aggregation of facts and figures at the extremity of the network along with pushing and pulling of data from the core of the cloud. The challenges that cloud-based storage faces can be solved by fog computing due to its security, accuracy, improved scalability, and the ability to make decisions in real-time with cost reductions [6]. IoT devices generate data that is gigantic in amount. This data consumes a lot of redundant space and bandwidth in the cloud. Therefore, before transferring data to the cloud, the fog nodes within the fog layer handle that enormous amount of data for the processing which reduces the latency issue and consumes less bandwidth [7].

In this paper, we aim to study and understand the role of fog computing as presented in the literature and by conducting a research survey to determine the common practices being followed. The paper is structured as follows: Section 2 describes the literature review and the related work which has been done in this area, followed by the comparison amongst fog, cloud-based architecture, and grid computing platforms in Section 3. Section 4 presents the methodology that we adopted to carry out the study, Section 5 discusses the research survey based on the results of our questionnaire. In Section 6, we highlighted and elaborated on the challenges one can face during the implementation of fog computing. Finally, the last Section 7 concludes the paper.

## 2. Literature Review

The concept of fog computing also refers as ‘fogging’ has arisen to assist and facilitate the applications of IoT (Internet of Things) which are connected to multiple smart devices in real-time. Fog computing provides centralized access to resources with the ability to minimize latency. Bellavista et al. [8] presented a detailed survey of IoT applications in reference to fog computing. The integration among fog computing and IoT improves the efficiency of an overall system and increases its effectiveness. Fog computing reduces the network load and analyzes the collected information systematically by moving data and storage to end nodes. It works as a middle tier between the layers of cloud computing and the applications of IoT. Dastjerdi et al. [9] examined the principles and applications of the fog computing model in the IoT environment. Prior to fog, big data was supervised and monitored by cloud computing. However, the cloud is incapable of performing real-time analytics due to the tremendous amount of aggregated information. On the other hand, Fog computing has various advantages over previous computing architectures. It promotes mobility and assists in cloud integration with other system interfaces and protocols. Fog computing comprises a layered architecture (as shown in Fig. 1). The devices, applications, and sensors of IoT lies at the bottom layer, the data from this layer connects with the next network layer to create a path towards the next layer of cloud services. The resource management layer comes after the cloud layer to manage raw data and to monitor performance and security concerns. This layer assures better quality and the smooth execution of fog computing services as well. The last layer enables the provision of fog computing applications and network resources to end-users.

Luan et al. [10] discussed the architecture and major attributes of fog with respect to the mobile network and its users. Mobile services and cloud-based internet are the two apparent and most distinct trends in today’s time. To facilitate mobile users, fog provides better location-based services to the verge of mobile networks and enables effortless integration between cloud and mobile services. Mobile users can take advantage of real-time data processing and customized services according to their needs by using fog computing. Zhu et al. [11] discussed the performance optimization of websites within the context of fog computing. End-users are connected to the network via fog boxes i.e. edge servers. Fog computing complements the cloud solution. The major bottleneck of cloud computing is limited network bandwidth which causes a delay in transferring data. Whereas, fog provides services to the verge of the network which reduces the data transfer time drastically [12].

Bonomi et al. [13] examined the concurrent application of Internet of Things (IoT) and analytics in fog architecture

solution. Fog is not a substitution of the cloud solution; it adds more value to cloud services. The implementation of cloud (the core of the internet) and fog computing (edge of the internet) gives a cost-effective solution to their customers. Malic et al. [14] presented a framework that can help organizations to manage and analyze a massive amount of data by implementing fog computing solution. By adopting a fog computing, organizations can have a great influence on business processes. Quality of Result (QoR) satisfies the user requirements and enables a user to detect any problem during the early stages of a process.

In paper [15], the impact of a drastic increase in mobile usage and traffic is discussed. It is a difficult task for cloud computing to manage this much big data of mobile traffic and to handle integration between cloud and mobile applications simultaneously. To overcome such hindrances, fog nodes are installed in the center of cloud hosting servers and end-users. A 5G system architecture is proposed for the computation of cellular network systems by utilizing the concept of fog computing.

Hernández-Nieve et al. [16] proposed a unique approach to Fog computing solution in the field of Fintech. The suggested approach integrates the services of fog computing with the products of the banking sector to strengthen the delivery of services. The department of customer support services plays a fundamental role in every commercial bank. The implementation of fog computing architecture in financial industries not only improves the banking processes but also assures their customers for better user experience, secure transactions, to perform economical operations reliably, and enhances transparency. Fintech (or financial technology) automates financial operations and deals with a big volume of data by reducing operational costs. For this successful integration, a customizable architecture is designed known as FOBA, 'Fog Oriented Banking Architecture', that will serve efficiently and adeptly along with banking enterprise.

McChesney et al. [17] proposed a first fog computing benchmarking suite, named 'DeFog'. Fog computing provides pertinent facilities to the border of the network from the cloud and enhances the Quality of Service (QoS) and Quality of Experience (QoE) of a system. This paper also discussed benchmarking solutions for the challenges of fog computing. Benchmarking is a process that is used to measure the relative performance of an organization's product or service in comparison to another product that works best in the industry. The DeFog benchmarking suite methodology consists of six steps, it automates the development and implementation of applications and then gathers the generated results. The proposed model DeFog operates in distinct three deployment modes: (i) cloud-only mode, (ii) edge (fog) only mode, and (iii) cloud – edge deployment mode. In another work [18], the network applications of fog computing architecture are summarized by investigating its primary aspects. The OpenFog Consortium addressed the abilities of fog using the acronym SCALE, which represents 'Security, Cognition, Agility, Latency, Efficiency'.

As reported by Cisco, approximately 50 billion devices would be linked to IoT by 2020 that will create a huge number of data [19]. Due to some limitations, the efficiency of the cloud reduces while transferring a massive volume of data to the cloud from IoT devices. Cloud-based applications are not able to provide location-aware services and also do not support low-latency requirements. The term Fog Computing has been introduced to address these limitations by operating IoT devices and the cloud as a single connection. The integration of IoT and cloud-based solution forms a new paradigm, named as Cloud of Things (CoT). Cloud of Things (CoT) assures the management of big data more efficiently and profitable [20]. Several applications like smart home, smart vehicle, smart grid, and health data management may largely benefit from fog computing [21]. In another work, Tang et al. [22] addressed the role of big data analysis in smart cities with regard to fog computing architecture. The technology of smart cities provides real-time information and ameliorates the quality of the common man's life. The authors of this paper presented a fog computing architecture consists of 4-layer, for smart pipeline monitoring. The smart pipeline monitoring system has the potential to control and manage smart cities and provides intelligent responses either community-wide or city-wide along with the prevention from hazardous events.

### 3. Comparison between Fog, Cloud and Grid Computing

#### 3.1. Grid Computing and Cloud Computing

The phrase Grid Computing was first conceived in the mid-1990s and aims to provide a distributed architecture paradigm. Grid computing enables its customers to share resources and to demand high-performance computing power. The implementation of grid computing architecture is expensive as compared to cloud computing. It involves resource management, integration of existing applications with other hardware, and security of the infrastructure. The grid protocol architecture comprises of five layers: fabric layer, connectivity layer, resource layer, collective layer, and application layer. However, the design of cloud computing contains four-layer which include the fabric layer, unified resource layer, platform layer, and application layer. Cloud services can easily work alongside web services and technologies like SOAP, REST, AJAX, RSS, etc. [23].

Grid computing is a distributed network for data storage and data management based on the needs of a user. It acts as a middleware for interaction among grid resources, like a virtual computer. Though there are more benefits of cloud computing, nevertheless grids cannot be replaced by cloud applications. On the other hand, physical resources will get a substitution with virtual procedures and promote automation by implementing the cloud computing infrastructure [24]. The grid computing system comprises multiple servers that utilize a single operating system and other software

applications for interaction among other systems as shown in Fig. 2. It provides reliable access to the data and is a more cost-effective solution than cloud computing. Grid computing architecture also offers powerful computing capabilities. Table 1 shows the contrast of grid computing against cloud computing [25]:

Table 1. Comparison of Grid Computing in contrast to Cloud Computing

		<b>Grid Computing</b>	<b>Cloud Computing</b>
1.	Architecture	distributed	client-server
1.	User friendly	more	less
2.	Service type	CPU, power supplies, network interfaces etc.	IaaS, PaaS, SaaS
3.	Response time	need to be scheduled	real-time
4.	Ownership	usually private, owned by an organization	third-party, usually owned by service providers
5.	Network connection	low bandwidth	high bandwidth
6.	Flexibility	low	high
7.	Scalability	normal	high

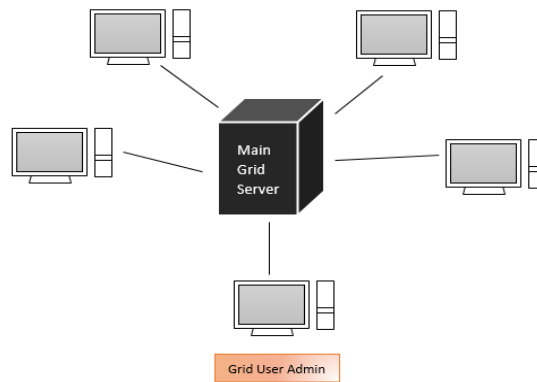


Fig.2. Grid Computing Architecture

### 3.2. Fog Computing and Cloud Computing

After Web 2.0, cloud computing has become quite a prominent and well-liked concept. We can state that cloud-based technology is an evolved form of grid computing having shared attributes [23]. Cloud-based software is an extended edition of grid computing and similarly, fog is also an extension of the cloud. According to technologists, fog infrastructure is more trustworthy and profitable. However, fog cannot be replaced with cloud because at present most of the organizations have already implemented and are using cloud services to manage data. Table 2 shows the key differences between cloud-based applications and fog computing solution [26]:

Table 2. Comparison of Fog Computing in contrast to Cloud Computing

		<b>Cloud Computing</b>	<b>Fog Computing</b>
1.	Latency	High	Low
2.	Bandwidth	Cloud consumes less bandwidth	Consumes high bandwidth
3.	Security	Less secure	High security
4.	Speed	Low	High
5.	Responsiveness	Low	High
6.	Scalability	High	Limited
7.	Cost	Low	High
8.	Architecture	Centralized	Distributed
9.	Storage & Computing capabilities	Better than fog computing	Not powerful
10.	Mobility	Limited mobility	Supports mobility

The influx of data cannot be managed by cloud-based computing solution only. The centralized architecture of the cloud struggles with performance issues and make delays in transferring the information towards data centers of the cloud. Edge computing minimizes all the concerns of their customers by enhancing the performance and speed of data operations. Fog computing is a model that is followed by the edge computing. As the name describes, data repository and computation of devices, applications, or a system are being processed at the edge of the network. *Fog is the*

standard, and edge is the concept' that permits an enterprise for a cost-effective and efficient connection of architecture with IoT devices [27].

#### 4. Methodology

We have conducted an online questionnaire survey owing to an ease in data collection and compilation as most of the participants were IT professionals with busy schedules. This online survey provided them an opportunity to fill the questionnaire according to their availability and feasibility. It helped us to conclude the common practices being followed with regards to fog computing in Pakistan. We designed the questionnaire using Google Forms, which consists of 17 questions that are adapted from several other surveys [28,29]. The survey aims to gather facts about the implementation of fog computing in different organizations. The questions were framed in a way to inquire from the participants about the general awareness of fog computing. Some questions examined the reasons behind its implementation and others asked about the barriers that restrict its deployment in organizations and the level of training required for its employment. Refer to the Annexure to find the questions that helped us to assess the general awareness of fog computing in different organizations.

#### 5. Results & Analysis

Based on the questionnaire survey carried out for this study, 41.6% of respondents belong to Information Technology (IT) sector, approximately 15.6% are from the energy and utility sector and 13% of the respondents work in the education sector. The participants of this survey from the health sector and banking sector are equal in number i.e. 9.1% as shown in Fig. 3.

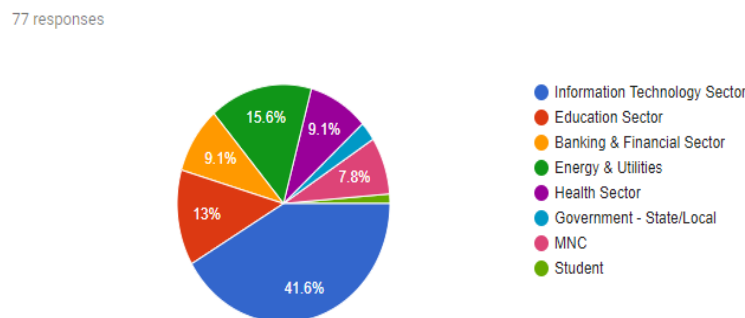


Fig.3. What is your organization's primary domain of operation?

As illustrated in Fig. 4, according to 35.1% of respondents their organizations are big and consist of more than 1000 employees. Whereas the organizational size of 27.3% of respondents is between 500 to 999. The number of employees of 26% of the organizations is between 100 to 499.

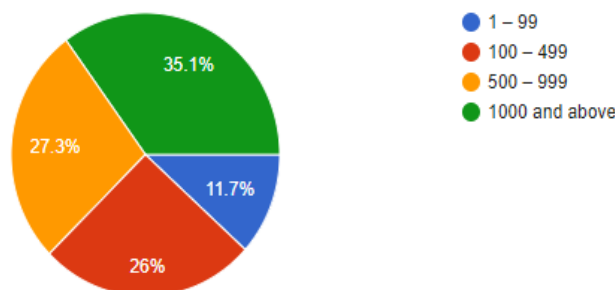


Fig.4. Organizational size

Cloud computing offers flexibility and security to an organization and also reduces IT maintenance costs. It works as a virtual office and connects the user to access its data anywhere at any time. The survey findings in Fig. 5 depicts that around 68.8% of participants have already used or deployed cloud computing services. While according to 31.2% of the audience, they have never used cloud computing services.

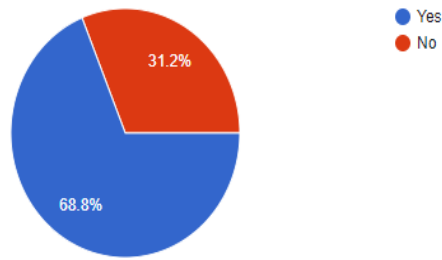


Fig.5. Have you ever used or deployed Cloud Computing?

As shown in Fig. 6, it can be observed from the survey results that the majority of the respondents have no idea about the term Fog Computing. 46.8% of the respondents are not aware of fog computing whereas 44.2% of respondents know about the concept of fog computing and the services it offers. It is an emerging solution that is more efficient and needs less bandwidth to handle data in real-time as compared to cloud computing.

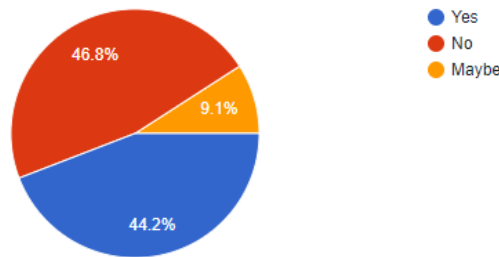


Fig.6. Are you aware of the term Fog Computing?

As fog computing is a nascent technology for most of the people therefore 45.5% of the organizations do not host any applications in the Fog architecture. Few organizations i.e. 27.3% have implemented fog and 27.3% of the respondents don't know whether their organizations are hosting any fog-based applications or not. This shows that organizations and their employees have not yet realized the advantages and importance of fog computing implementation.

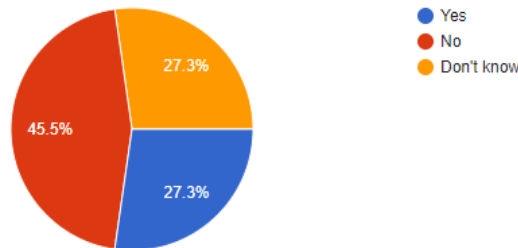


Fig.7. Does your company host any applications in the Fog architecture?

The below survey outcome in Fig. 8 shows that one of the major factors that can motivate an organization to implement and follow fog computing services is the bandwidth that helps to transfer data rapidly i.e. 39%. According to 36.4% of the respondents, fog computing encourages better and continuous collaboration across teams and 33.8% of responses show that it improves business productivity and processes.

## A Survey Based Study on Fog Computing Awareness

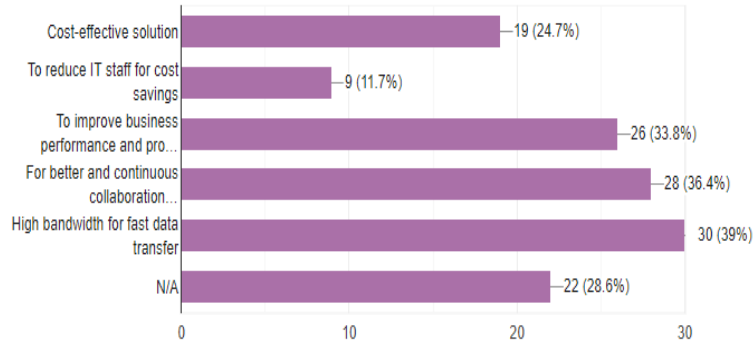


Fig.8. What are or will be the factors that motivate your organization to adopt Fog Computing?

As it can be observed from Fig. 9, 76.6% of the organizations have not shifted to fog computing yet. Only a small number of organizations i.e. 22.1% have adopted and using fog computing which tells us about the lack of general awareness among industries.

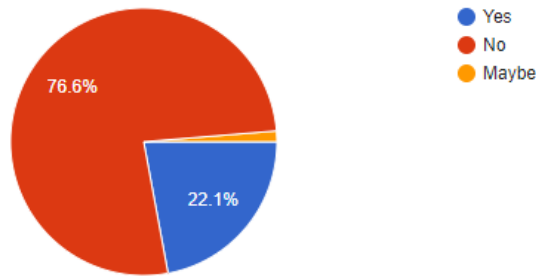


Fig.9. Have you shifted from Cloud Computing to Fog Computing?

The trend in Fig. 10 shows that this question is not relevant for approximately 40.8% audience as they have no idea about fog computing. According to a 36.7% audience, the main reason for migration from cloud computing to fog computing is that the latter deals better with the high traffic volume of data. And 26.5% of responses show that one of the main advantages of a fog system is real-time analytics. 20.4% of the organizations shifted from cloud to fog computing due to improved security and because the cloud requires too much bandwidth.

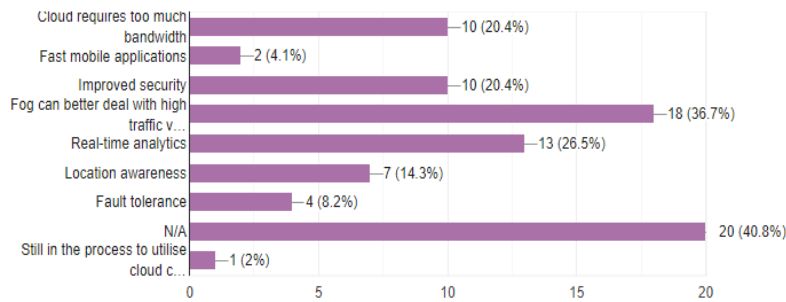


Fig.10. What were the reasons for migration from Cloud Computing to Fog Computing?

As shown in Fig. 11, approximately 30% of the respondents said that security and reliability are some of the fundamental attributes of fog computing. According to 26% of participants, real-time interaction is the major factor that can excite organizations in adopting and hosting fog networking applications. Whereas 11.7% of responses show that they are not interested in the implementation of fog computing architecture yet.

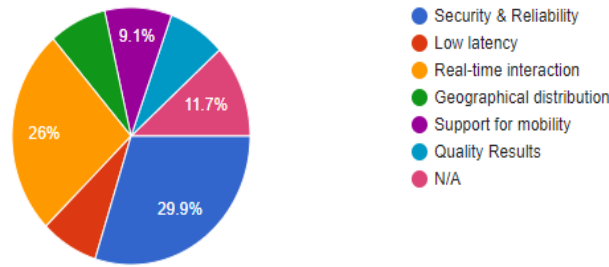


Fig.11. What should be the major factor to promote the implementation of Fog Computing services?

As can be observed from the survey finding of Fig. 12, according to 59.7% of the respondents, poor awareness is one of the major causes that restrict organizations to adopt fog computing. Approximately 22.1% of respondents marked the high cost of fog computing as a factor that stops organizations to implement its framework and 20.8% of respondents think it is due to lack of trust of organizations in fog computing service providers. Inconsistency is also a reason for some organizations i.e. 15.6%.

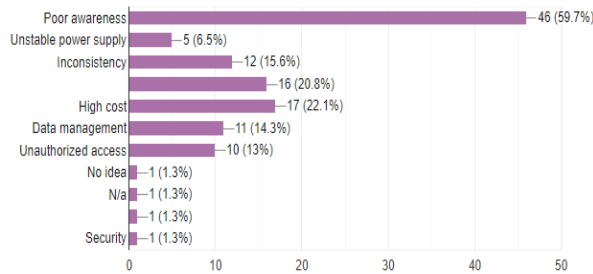


Fig.12. What are the factors that restrict your organization from the adoption of Fog Computing?

A hybrid model is an approach where an organization combines and utilizes Information technology (IT) resources from private (on-premises) and public (off-premises) cloud services environment. It provides and assures the enterprise a flexible, cost-effective, high quality, and well-managed computing services. As shown in Fig. 13, according to 39% of respondents, the hybrid is the most suitable approach to adopt for fog computing implementation. And approximately 32.5% audience sees the private model as a suitable solution for fog computing as it can be managed and owned by an organization itself.

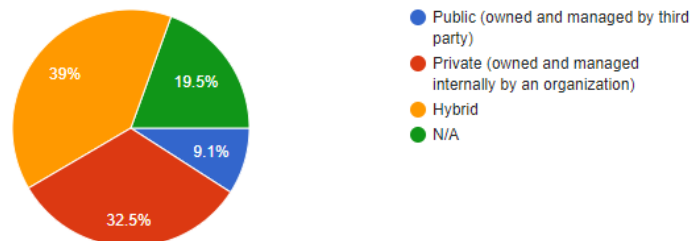


Fig.13. Which solution do you see as the most suitable for your organization according to Fog Computing taxonomy?

As we can have observed from the above results and trends of this survey, we can deduce that most of the respondents and their organizations are unfamiliar with the concept of fog computing. Therefore, this question did not apply to 40.3% of the respondents. According to 31.2% of the audience, their organizations have not outsourced fog and cloud computing applications to multiple providers, and this is followed by 28.6% of the organizations who have outsourced these applications to multiple service providers as shown in Fig. 14.



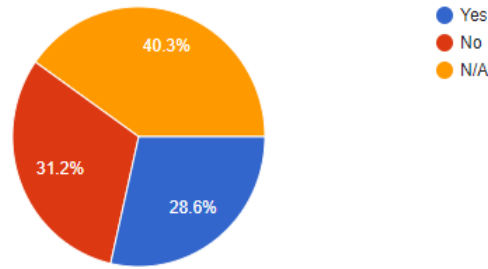


Fig.14. Are the current Fog/Cloud applications in your organization outsourced to multiple providers?

The result in Fig. 15 shows that nearly 49.4% of the organizations, which is a large percentage, haven't faced any barriers because they have not implemented or deployed any sort of fog computing applications. The other 19.5% of the respondents said costs and Return on Investment (ROI) and integration with other existing systems are the barriers they faced during the planning and implementation phase of the fog computing solution. This is followed by compliance and security issues i.e. approximately 17% and 10.4% respectively.

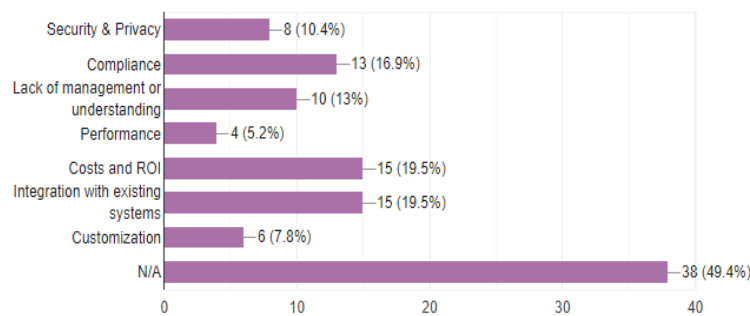


Fig.15. What were or are the greatest barriers your organization faced during the implementation of the Fog Computing solution?

As shown in Fig. 16, 41.6% of the respondents are doubtful and are not clear about the impact of fog computing implementation on other existing business applications and processes. This is followed by 33.8% of the respondents who consider that the existing systems and business applications will not be affected by the implementation of fog computing. The other 24.7% audience thinks that fog computing can become critical for an organization as you can see in Fig. 16.

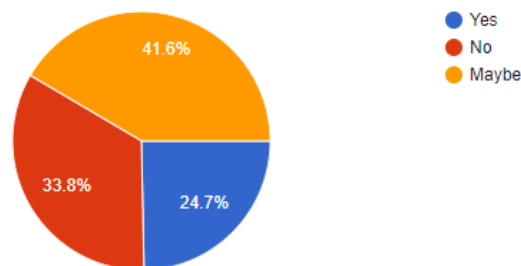


Fig.16. Do you consider the Fog Computing solution critical for your business applications or processes after the implementation?

The result in Fig. 17 shows that 22.1% of respondents plan to use fog computing services for development purposes and to manage data easily. According to 20.8% of respondents, they prefer the deployment of fog computing for enterprise applications of their organizations and again 18.2% of the audience have no idea about fog computing, therefore, they were unable to answer this question. However, 13% of the respondents use or plan to use fog with IoT (Internet of Things) based systems.

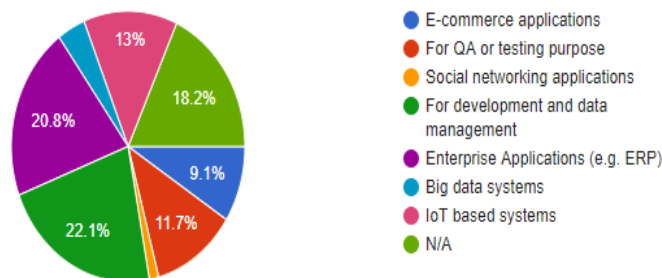


Fig.17. With which applications/systems do you use or plan to deploy a fog computing solution initially in your organization?

As we can see in Fig. 18 the majority of the respondents i.e. approximately 52% were not applicable to answer this question due to the lack of implementation of fog computing solution in most of the organizations. According to 35.1% of the respondents, the information technology (IT) team of their organizations presented the idea of implementation of fog computing services initially.

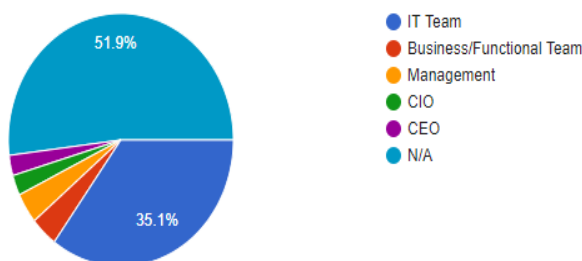


Fig.18. The initial adoption of Fog Computing in your organization was or will be done by?

In Fig. 19, the survey result below shows that to train the staff of an organization for operating a fog computing solution is a somewhat difficult task i.e. 40.3%. Whereas, according to 39% of the respondents it was/is not difficult to train staff. And the remaining 20.8% of the participants were sure that it is an easy task to operate and manage implemented fog computing architecture.

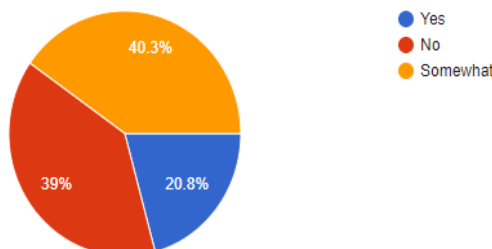


Fig.19. Was/Is it difficult to train staff in operating the Fog Computing solution?

The main objective behind this performed survey is to comprehend the role and value of fog computing applications in the organizations of a developing country. From the results of the questionnaire survey, we can infer the basic ingredients that lead the organization to deploy and implement the architecture of fog. The primary factors that impeded the execution of fog can also be witnessed with the contribution of this survey.

## 6. Challenges

As fog computing solution deals with devices closer to the end-users, it may experience security and privacy issues. Fog devices can experience authorization and authentication issues during connectivity with remote cloud server [3]. Today, none of the information or data is ours. Users are anxious about data vulnerabilities and risks. Therefore, it is needed to identify and address the data exposure problems of fog computing to make its implementation and application a feasible reality. Several prominent pitfalls in fog computing are: a) data management, b) synchronization of applications, c) storage limitation, d) lack of accountability of devices, e) programmability, f) no standard procedures and g) data security [5]. Due to heterogeneity, the key task of the fog network is to maintain a connection with every other fog component. To manage the fog network environment and to create pliability, the techniques of ‘Software-defined networking’ (SDN) and ‘Network function virtualization’ (NFV) are presented in the paper [30]. SDN and NFV

strengthen the scalability and programmability of fog network architecture. The utilization of these architectures mitigates the fog networking issues by reducing costs and by continuously monitoring its performance.

Though fog computing is believed to be a more efficient and well-managed architecture contrary to other existing computing paradigms, but still it may face IoT related challenges. We have identified some of the challenges that organizations and users face based on the literature review and from the results of the questionnaire survey. One of the fundamental features of fog computing is the assurance of privacy and security of data. There are also some structural issues in fog architecture, such as the arrangement of different components from the network to be used for computational tasks. To design web interfaces for data visualization is also a complicated task in fog computing. It is difficult to ensure users that access to services is validated due to the distributed paradigm formation. Utilization of security systems or tools to preserve data integrity can greatly affect the Quality of Service (QoS) of fog computing solution [31]. There exist a few research areas in this domain that needs to be addressed properly. Work [32,33] discussed the following significant issues in terms of fog computing:

- Authentication – The service providers of fog computing can be outsourced to third parties due to several deployment options. This flexibility intricates the authentication process at fog nodes and reduces the effectiveness of this procedure. Biometric-based authentication can be helpful in this situation.
- Trust – One of the essential requirements in fog computing to have trust in IoT services and devices. It is still difficult to assure end-users that the integration between fog applications and IoT devices are reliable enough because we cannot measure trust.
- Security and Privacy – During the employment of services like fog or cloud computing, there is an apparent chance of leakage of data or location or usage. In fog computing, fog nodes control the data of users due to which there is a possibility of security threats. Safety and confidentiality of verifiable computation is also an issue. Sensitive data should be encrypted to prevent all these critical challenges.
- Access Control – It ensures a resource or an end-user that only authorized parties can access the sensitive data. Fog computing also faces this challenge because of the vast amount of distributed data.
- Intrusion Detection – The techniques of intrusion detection are deployed to discover the inside and outside attacks and malicious attempts or threats to destroy data. This security breach can greatly affect the performance and efficiency of fog computing services. A proper Intrusion Detection System (IDS) should be implemented to analyze and monitor log files and user's information.

## 7. Conclusion

This research paper surveyed the magnitude and diverseness of Fog computing and elaborates its notion thoroughly. Fog is an emerging platform that works as an expanded version of cloud computing. In this article, we adopted an approach based on a questionnaire survey to analyze the consequences of fog computing implementation, indicates that the idea of fog is nonetheless unique, and most people are unfamiliar with this new technology. The academic contribution of our survey-based study is to determine and assess the awareness about fog computing, its challenges, and implementation methodology in different organizations with critical analysis which will help us in developing solutions and also in future research work. The fog model is at the early stages of experimentation. Organizations presently are exercising the applications of cloud-based computing solutions and its services. After analyzing the outcome of the survey, we briefly explored the various challenges that are associated with and experienced by the users of fog computing services. Most of the features of fog are outsourced, therefore, it is hard to ensure customers about data integrity. Moreover, self-awareness is very important for end customers in order to perceive the relevance of modern technologies in the most optimal and effective way. We foresee Fog computing to be a platform that unifies existing systems and promotes advanced development of applications.

## References

- [1] CISCO, "Fog Computing and the Internet of Things: Extend the Cloud to Where the Things Are," 2015. [Online]. Available: [https://www.cisco.com/c/dam/en\\_us/solutions/trends/iot/docs/computing-overview.pdf](https://www.cisco.com/c/dam/en_us/solutions/trends/iot/docs/computing-overview.pdf). [Accessed 02 October 2019].
- [2] S. Chan, "Fog brings the cloud closer to the ground: Cisco innovates in fog computing," CISCO, 09 November 2017. [Online]. Available: <https://newsroom.cisco.com/feature-content?type=webcontent&articleId=1894659>. [Accessed 02 October 2019].
- [3] I. Stojmenovic, S. Wen, X. Huang and H. Luan, "An overview of Fog computing and its security issues," *Concurrency and Computation: Practice and Experience*, vol. 28, no. 10, pp. 2991-3005, 2015.
- [4] F. Bonomi, R. Milito, J. Zhu and S. Addepalli, "Fog Computing and Its Role in the Internet of Things," in *Proceedings of the first edition of the MCC workshop on Mobile cloud computing*, 2012.
- [5] L. M. Vaquero and L. Rodero-Merino, "Finding your Way in the Fog: Towards a Comprehensive Definition of Fog Computing," *ACM SIGCOMM Computer Communication Review*, vol. 44, no. 5, pp. 27-32, 2014.
- [6] M. Yannuzzi, R. Milito, R. Serral-Graci, D. Montero and M. Nemirovsky, "Key ingredients in an IoT recipe: Fog Computing, Cloud Computing, and more Fog Computing," in *2014 IEEE 19th International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD)*, 2014.

- [7] S. Rathore, T. Shah, P. Mishra and S. Kumar, "Fog Computing: Extension of the Cloud," *GADL Journal of Inventions in Computer Science and Communication Technology (JICSCT)*, vol. 4, no. 1, pp. 22-26, 2018.
- [8] P. Bellavista, J. Berrocal, A. Corradi, S. K. Das, L. Foschini and A. Zanni, "A Survey on fog computing for the Internet of Things," *Pervasive and Mobile Computing*, vol. 52, pp. 71-99, 2018.
- [9] A. V. Dastjerdi, H. Gupta, R. N. Calheiros, S. K. Ghosh and R. Buyya, "Fog computing: Principles, architectures, and applications," in *Internet of Things: Principles and Paradigms*, Morgan Kaufmann, 2016, pp. 61-75.
- [10] T. H. Luan, L. Gao, Z. Li, Y. Xiang, G. We and L. Sun, "Fog Computing: Focusing on Mobile Users at the Edge," arXiv:1502.01815, New York, 2015.
- [11] J. Zhu, D. S. Chan, M. S. Prabhu, P. Natarajan, H. Hu and F. Bonomi, "Improving Web Sites Performance Using Edge Servers in Fog Computing Architecture," in *IEEE Seventh International Symposium on Service-Oriented System Engineering*, Redwood City, 2013.
- [12] P. Hu, S. Dhelim, H. Ning and T. Qiu, "Survey on Fog Computing: Architecture, Key Technologies, Applications and Open Issues," *Journal of Network and Computer Applications*, vol. 98, pp. 27-42, 2017.
- [13] F. Bonomi, R. Milito, P. Natarajan and J. Zhu, "Fog Computing: A Platform for Internet of Things and Analytics," in *Big Data and Internet of Things: A Roadmap for Smart Environments*, Switzerland, Springer, Cham, 2014, pp. 169-186.
- [14] N. H. Abdul Malic, T. A. T. Izhar and M. R. Abdul Kadir, "Factors Influencing Fog Computing Adoption Based on Quality of Results (QoR) For Heterogeneous Data Analysis: A Proposed Framework," *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 8, no. 2, 2019.
- [15] A. Khakimov, A. Muthanna and M. S. Ali Muthanna, "Study of Fog Computing Structure," in *2018 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus)*, Moscow, 2018.
- [16] E. Hernández-Nieves, G. Hernández, A.-B. Gil-González, S. Rodríguez-González and J. M. Corchado, "Fog computing architecture for personalized recommendation of banking products," *Expert Systems With Applications*, vol. 140, 2020: 112900.
- [17] J. McChesney, N. Wang, A. Tanwer, E. d. Lara and B. Varghese, "DeFog: Fog Computing Benchmarks," in *Proceedings of the 4th ACM/IEEE Symposium on Edge Computing*, 2019.
- [18] M. Mukherjee, L. Shu and D. Wang, "Survey of Fog Computing: Fundamental, Network Applications, and Research Challenges," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3, pp. 1826-1857, 2018.
- [19] A. Yousefpour, C. Fung, T. Nguyen, K. Kadiyala, F. Jalali, A. Niakanlahiji, J. Kong and J. P. Jue, "All One Needs to Know about Fog Computing and Related Edge Computing Paradigms," *Journal of Systems Architecture*, vol. 98, pp. 289-330, 2019.
- [20] M. Aazam and E.-N. Huh, "Fog Computing and Smart Gateway Based Communication for Cloud of Things," in *2014 International Conference on Future Internet of Things and Cloud*, Barcelona, 2014.
- [21] S. Yi, Z. Hao, Z. Qin and Q. Li, "Fog Computing: Platform and Applications," in *2015 Third IEEE Workshop on Hot Topics in Web Systems and Technologies*, Washington, DC, 2015.
- [22] B. Tang, Z. Chen, G. Hefferman, T. Wei, H. He and Q. Yang, "A Hierarchical Distributed Fog Computing Architecture for Big Data Analysis in Smart Cities," in *Proceedings of the ASE BigData & SocialInformatics 2015*, 2015.
- [23] I. Foster, Y. Zhao, I. Raicu and S. Lu, "Cloud Computing and Grid Computing 360-Degree Compared," arXiv preprint arXiv:0901.0131, 2008.
- [24] S. Zhang, S. Zhang, X. Chen and X. Huo, "The Comparison Between Cloud Computing and Grid Computing," in *2010 International Conference on Computer Application and System Modeling (ICCSM 2010)*, 2010.
- [25] S. M. Hashemi and A. K. Bardsiri, "Cloud Computing Vs. Grid Computing," *ARNP Journal of Systems and Software*, vol. 2, no. 5, pp. 188-194, 2012.
- [26] V. Kumar, A. A. Laghari, S. Karim, M. Shakir and A. A. Brohi, "Comparison of Fog Computing & Cloud Computing," *International Journal of Mathematical Sciences and Computing*, vol. 5, no. 1, pp. 31-41, 2019.
- [27] D. Linthicum, "Edge computing vs. fog computing: Definitions and enterprise uses," CISCO, [Online]. Available: <https://www.cisco.com/c/en/us/solutions/enterprise-networks/edge-computing.html>. [Accessed 3 January 2020].
- [28] R. K. Awosan, "Factor Analysis of the Adoption of Cloud Computing In Nigeria," *African Journal of Computing & ICT*, vol. 7, no. 1, pp. 33-42, 2014.
- [29] InfoQ, "SurveyMonkey," [Online]. Available: <https://www.surveymonkey.com/r/cloud-computing>. [Accessed 15 November 2019].
- [30] S. Yi, C. Li and Q. Li, "A Survey of Fog Computing: Concepts, Applications and Issues," in *Mobidata '15 Proceedings of the 2015 Workshop on Mobile Big Data*, Hangzhou, China, 2015.
- [31] R. Mahmud, R. Kotagiri and R. Buyya, "Fog Computing: A Taxonomy, Survey and Future Directions," in *Internet of Everything*, Singapore, Springer, 2018, pp. 103-130.
- [32] S. Yi, Z. Qin and Q. Li, "Security and Privacy Issues of Fog Computing: A Survey," in *International Conference on Wireless Algorithms, Systems, and Applications*, 2015.
- [33] A. Alrawais, A. Alhothaily, C. Hu and X. Cheng, "Fog Computing for the Internet of Things: Security and Privacy Issues," *IEEE Internet Computing*, vol. 21, no. 2, pp. 34-42, 2017.

## Annexure

1. What is your organization's primary domain of operation? \*
  - a. Information Technology Sector
  - b. Education Sector
  - c. Banking & Financial Sector
  - d. Energy & Utilities
  - e. Health Sector
  - f. Government - State/Local

- g. MNC
  - h. Other: \_\_\_\_\_
2. Organizational size? \*
- a. 1 – 99
  - b. 100 – 499
  - c. 500 – 999
  - d. 1000 and above
3. Have you ever used or deployed Cloud Computing services? \*
- a. Yes
  - b. No
4. Are you aware of the term Fog Computing? \*
- a. Yes
  - b. No
  - c. Maybe
5. Does your company host any applications in the Fog architecture? \*
- a. Yes
  - b. No
  - c. Don't know
6. What are or will be the factors that motivate your organization to adopt Fog Computing? \*
- a. Cost-effective solution
  - b. To reduce IT staff for cost savings
  - c. To improve business performance and processes
  - d. For better and continuous collaboration across teams
  - e. High bandwidth for fast data transfer
  - f. N/A
  - g. Other: \_\_\_\_\_
7. Have you shifted from Cloud Computing to Fog Computing? \*
- a. Yes
  - b. No
  - c. Maybe
8. If your answer to Question 7 is "Yes", then what were the reasons?
- a. Cloud requires too much bandwidth
  - b. Fast mobile applications
  - c. Improved security
  - d. Fog can better deal with high traffic volume
  - e. Real-time analytics
  - f. Location awareness
  - g. Fault tolerance
  - h. N/A
  - i. Other: \_\_\_\_\_
9. According to you, what should be the major factor to promote the implementation of Fog Computing services? \*
- a. Security & Reliability
  - b. Low latency
  - c. Real-time interaction
  - d. Geographical distribution
  - e. Support for mobility
  - f. Quality Results
  - g. N/A
  - h. Other: \_\_\_\_\_
10. What are the factors that restrict your organization for the adoption of Fog Computing? \*
- a. Poor awareness
  - b. Unstable power supply
  - c. Inconsistency
  - d. Lack of trust in Fog Computing service providers
  - e. High cost
  - f. Data management
  - g. Unauthorized access
  - h. Other: \_\_\_\_\_
11. Which solution do you see as the most suitable for your organization according to Fog Computing taxonomy? \*
- a. Public (owned and managed by third party)
  - b. Private (owned and managed internally by an organization)
  - c. Hybrid
  - d. N/A
  - e. Other: \_\_\_\_\_
12. Are the current Fog/Cloud applications in your organization outsourced to multiple providers? \*
- a. Yes
  - b. No

- c. N/A
13. What were or are the greatest barriers your organization faced during the implementation of Fog Computing solution? \*
- Security & Privacy
  - Compliance
  - Lack of management or understanding
  - Performance
  - Costs and ROI
  - Integration with existing systems
  - Customization
  - N/A
  - Other: \_\_\_\_\_
14. Do you consider Fog Computing solution critical for your business applications or processes after the implementation? \*
- Yes
  - No
  - Maybe
15. With which applications/systems do you use or plan to deploy a fog computing solution initially in your organization? \*
- E-commerce applications
  - For QA or testing purpose
  - Social networking applications
  - For development and data management
  - Enterprise Applications (e.g. ERP)
  - Big data systems
  - IoT based systems
  - N/A
  - Other: \_\_\_\_\_
16. The initial adoption of Fog Computing in your organization was done by? \*
- IT Team
  - Business/Functional Team
  - Management
  - CIO
  - CEO
  - N/A
  - Other: \_\_\_\_\_
17. According to you, was/is it difficult to train staff in operating the Fog Computing solution? \*
- Yes
  - No
  - Somewhat

## Authors' Profiles



**Zainab Javed** graduated from NED University of Engineering and Technology, Karachi, Pakistan as a Software Engineer. She has recently completed her MS degree from the Institute of Business Administration (IBA), Karachi, in the field of Computer Science. During her master's program, a few research papers also got published in a reputable journal and a conference.

She has worked as an Assistant Manager on the SAP modules along with Oracle application at K-Electric. Currently, she is working at IBA and previously, also did her internship at Sui-Southern Gas Company (SSGC) to gain an insight into the IT architecture of an organization.



**Waqas Mahmood** has done MS in Economics and Finance from IoBM (CBM), Karachi in 2012. Prior to that Waqas did MS in Software Project Management from NUCES (FAST) in 2010. Moreover, he holds a Masters of Engineering (M.Engg) degree from Hamdard University and an M.E degree from NED. He completed his BS (Engg) from Sir Syed University of Engineering & Technology in 1998. From January 2008 till present, he has been working as a Joint Director in the State Bank of Pakistan. He has been a part of IBA's visiting faculty for the past 22 years.

**How to cite this paper:** Zainab Javed, Waqas Mahmood, "A Survey Based Study on Fog Computing Awareness", International Journal of Information Technology and Computer Science(IJITCS), Vol.13, No.2, pp.49-62, 2021. DOI: 10.5815/ijitcs.2021.02.05