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A Study of Moving from Cloud Computing to Fog Computing

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***Abstract*—The exponential growth of the Internet of Things (IoT) technology poses various challenges to the classic centralized cloud computing paradigm, including high latency, limited capacity, and network failure. Cloud computing and Fog computing carry the cloud closer to IoT computers in order to overcome these problems. Cloud and Fog provide IoT processing and storage of IoT items locally instead of sending them to the cloud. Cloud and Fog provide quicker reactions and better efficiency in conjunction with the cloud. Cloud and fog computing should also be viewed as the safest approach to ensure that IoT delivers reliable and stable resources to multiple IoT customers. This article discusses the latest in cloud and Fog computing and their convergence with IoT by stressing deployment's advantages and complexities. It also concentrates on cloud and Fog design and new IoT technologies, enhanced by utilizing the cloud and Fog model. Finally, transparent topics are addressed, along with potential testing recommendations for cloud storage and Fog computing, and IoT.**

Keywords*— *Cloud Computing, Fog Computing, Internet of Things (IoT).

I. INTRODUCTION

In the following period sector, cloud storage will be growing increasingly. Cloud systems may be easily configured to conduct detailed analytical activities and time orchestrates for IT run, from storage and measurement to database and functions. The modern cloud infrastructure platform promises to fulfill IT requirements more positively [1]. Various organizations utilize cloud computing to process and interpret large amounts of data sets. Also, cloud facilities vendors began to combine systems for related data management in their bundles to help customers access cloud services [2]. The Cloud infrastructure model provides the correct access to networks with many aligned, fast, and convenient computer sources. Fog computation is a distributed computing paradigm that expands the conventional computing cloud capabilities at the grid[3]. Fog computing offers manuscript computing, storing, networking, and application services in an exceptionally visually oriented platform at the edge of end devices and cloud computing data centers [4]. For fog computation when it is isolated, virtualization is a simple technology. Physical infrastructure for establishing independent dedicated services to run multiple operating systems and programs on a single resource simultaneously [5]. The fog model has been planned as a cloud extension. Cisco's description of the meaning of "fog" was first described to explain the need for a network to meet the requirements of the essential Internet of Things (IoT) services [6]. Fog computing has a virtual architecture targeted at globally distributed services and Software [7-9]. Fog Computing minimizes time for requests to applications provided and delivers local computing facilities for terminal devices and network access to centralized networks where required [10]. In 1997, Professor Ramnath Chellappa launched the software computing, Fog computing, and cloud computing framework. This shifts the computing limits from technological limits to economic purposes. Users will get a single and reliable service from the cloud everywhere in the cloud infrastructure concept without paying attention to the complexities and heterogeneity. CISCO systems first adopted Fog computing, described as a modern computing paradigm [11]. Instead of sending data to remoter servers in the cloud, the data, computing, storage, and application resources have been provided by clients and end-users near devices. The usage of Fog computing will increase network reliability and improve the protection of the network. It can dramatically increase bandwidth and energy usage by sending vast data from numerous devices to cloud storage or centralized networking facilities [12, 13]. Today the Internet of Things is linked to each other through some particular agency, business, or foundation such as universities. Besides, every individual people have often connected to others through or successful Internet communications. The IoT consists of physical artifacts ("objects"), which allow communications components, sensors, Software, and electronics to capture and share data [14]. The prevalence of IoT technologies and the expanded digitation of our culture, of which the sharing of knowledge over the Internet has been regularly made up of millions to millions of mobile devices (for example, in smart houses, smart towns, imaginative metering schemes, intelligent vehicles, and large size wireless sensor networks) [7, 15].

This paper discussed cloud and Fog computing and presented IoT applications improved by cloud and Fog. This paper aimed to evaluate up-to-date research contributions on cloud and Fog computing and IoT and its implementations in our environment, as well as explain potential avenues for research and open topics concerning cloud computing and Fog computing integration with IoT

The organization of the remaining paper is as follows: Section II contains a background theory about cloud computing, fog computing, the architecture of cloud-fog computing, security issues related to cloud and fog computing, and IoT; Section III includes related works; Section IV is discussion; Section V is the conclusion.

II. Background Theory

A. Cloud Computing

A paradigm that allows the network to enter a shared computer pool with comfortable demand [16]. The Cloud computing technology renders this pool possible. Cloud storage technology offers consumers a way of saving, retrieving, or storing information from an online store [17].

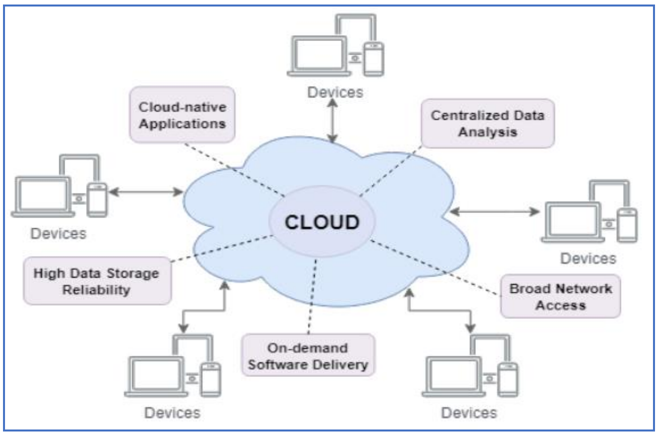

Fig. 1. Cloud-based IoT network [18].

This is possible using cluster software, network infrastructure, distributed file systems, and many more [19]. Cloud computing, together with IoT, is a groundbreaking platform for online data management devices. By implementing parallel computation, cloud computing falls in as a remedy [20]. Parallel computing helps a remote processor systematically transform functions into subroutines [21]—figure 1 shown a cloud-based IoT network and certain of its established functionality. While cloud infrastructure has major strengths over conventional structures, it still has some threats [22].

B. Fog Computing

Fog computing is an extended cloud computing model from the heart to the network's edge is a term launched by CISCO in 2012 [11]. It allows for computation near IoT and/or the end-user computers at the edge of the network, where virtualization is also assisted, as shown in figures 2 and 3. However, unlike the cloud, Fog is closely correlated with the presence of the planet. The relations between the Fog and the cloud were given special attention [18]. Fog computing is characterized as a horizontal system-level architecture that distributes the user's Cloud to Thing functions employing computing, storing, controlling, and networking functions [23]. Cloud and Fog complement each other to form an interdependent service continuum and mutually beneficial between the endpoints and cloud to make storage, control, computing, and communication available anywhere along the continuum [24].

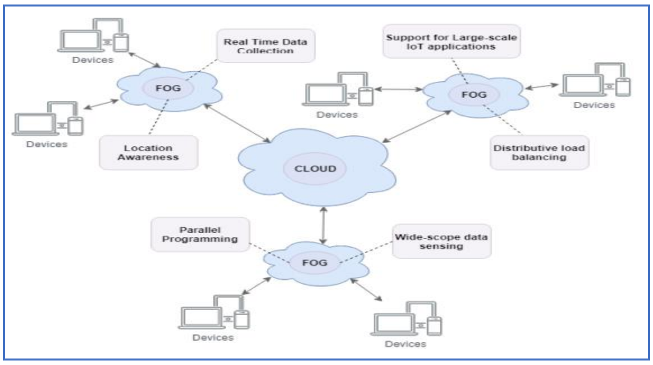

Fig. 2. Fog-based IoT network [18].

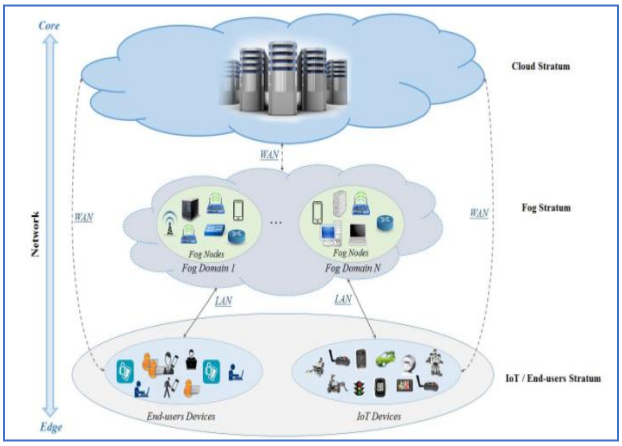

Fig. 3. The Fog System [25].

However, it can be concluded that fog computing presents multiple benefits of cloud computing. Besides, it is excellent to address performance and locality issues because its specific services and resources are virtualized where it is located at the network's edge.

C. The architecture of Cloud-Fog Computing

As seen in figures 4 and 5, cloud-fog computing architecture consists of core layers, terminal access layers, and Fog computing layers [26]. The core layer consists of cloud resource providers, involving server clusters with strong computing ability and large storage capacity. The computers are interconnected in the leading layer, and virtual machines are transferred from servers for dynamic programming activities [27]. The terminal layer consists mainly of end-use devices like highway monitors, mobile phone tablets, intelligent reloaders, computers, and other devices [28]. The cloud-fog technology architecture is based on three types of job requests; time-sensitive requests, such as sports, the autopilot, and the data database requirements, such as information, medical storage similarities, and others [29].

Besides, for bandwidth demands, the last is AR, drone, and others, for example. All tasks are produced at this layer, and the results are processed to return to that layer [30]. The fog calculation layer consists of the supplier of fog resources with fog processors and fog units. The fog processor is a hub that connects terminals, fog devices, and core devices and sends different applications to different places [31]. Fog systems, including microservers and base stations, are located to the network's edge and active in caching, computing, and transmitting equipment [32]. In real-time, the fog computing layer detects terminal requests and offers various resources, such as data processing and system access. This will resolve delays in manufacturing and lower the core layer strain [33].

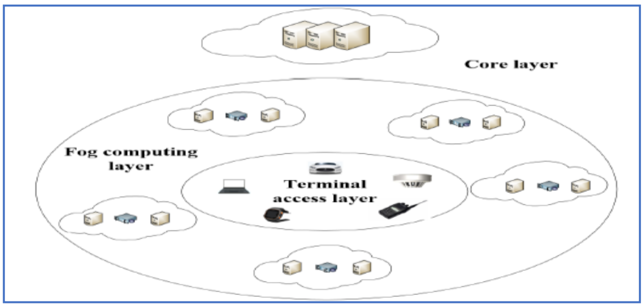

Fig. 4. Cloud-Fog computing architecture [33].

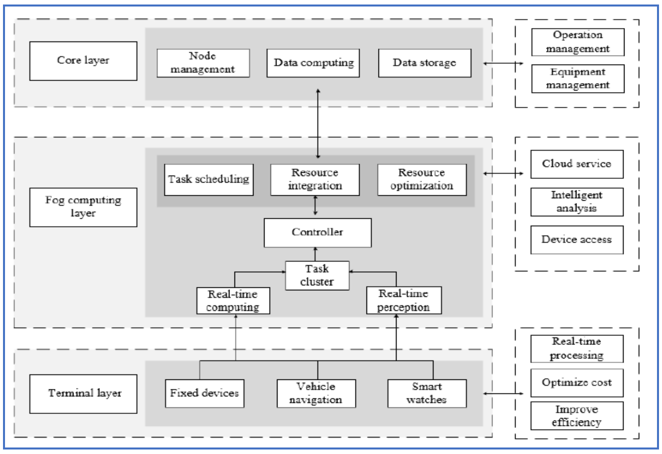

Fig. 5. The workflow of the architecture [33].

D. Security Issues of Cloud Computing

Corporate data security in the cloud is complicated since it provides a variety of services, including network as a Service (NaaS), Platform as a Service (PaaS), Software as a Service (SaaS), and Infrastructure as a Service (IaaS) [34-36]. The protection issues of each provider are their own.

E. Data Security

Data Protection applies to confidentiality, integrity, and availability. Confidentiality is characterized as data protection [37]; it intends to prevent classified knowledge from unwanted or inaccurate parties. Integrity has defined as the correctness of the data[38]. There are no universal policies for agreed data share. Availability is described as data that is time-accessible. The essence of data privacy systems, structures, and processes depends on data integrity and confidentiality [39]. Three-dimensional network protection problems can be classified: data life cycle, cloud features, and data-safety features. Problems with data protection rely on many criteria that particular cloud storage data security concerns address: Form of data (personal, private, used and identifying), size of data (small or big), and data state (stocked, used, or transferred) [40].

F. Data Locations

When people use cloud services, they typically will not know precisely where their data will be processed and when it will be stored. They do not even know whether, in truth, the country it is stored in [41]. For instance, photos uploaded to Facebook and emails can reside anywhere, and Facebook users are not concerned. Nevertheless, a firm may need to know its location if the confidential data is stored in a cloud [42]. You would also like to indicate a specific desired location. That means that the client and cloud provider has contractual arrangements for data to live or remain in a specified available server [43].

G. Privileged User Access

Using cloud computing, a delicate balance is required between the desire to share resources online with various client populations and the critical need to protect those online resources from unauthorized access, data leakage, and any other exposures [44, 45]. In order to control privileged user access effectively to cloud platforms (IaaS and PaaS), (SaaS) applications, and social media, the organization's octenyl struggle, creating operational complexity and compliance risks [46, 47]. When sensitive data is offloading to the cloud, it means losing direct physical, logical, and personnel control over the data [48].

H. Data Recovery

Data recovery is the process of retrieving data that has been corrupted, lost, or accident [49]. The data stored in cloud storage may be deleted from the data centers either by human-made without their knowledge or by natural disasters like volcanoes or earthquakes. Nowadays, a large quantity of data has been generated, requiring data recovery techniques or services [50]. For this reason, there is a need to design an efficient data recovery technique in order to recover the lost data. The researchers have proposed various techniques of data recovery [51].

I. Security Issues of Fog Computing

Because of its computer framework and consolidated storage, cloud computing paradigms are susceptible to specific security threats [52]. Its protection has emerged as a critical issue that limits its growth. On the other hand, the detailed variant of Fog is known to be a more stable architecture, and the explanations for this involve threats, as seen in Figure 6 [53].

Data security is a critical challenge in fog computing, especially when data and fog nodes frequently transfer in their environment [54]. The collected data is processed on local Fog nodes closest to the data source and analyzed, thereby minimizing internet dependence. It is hard for network attaches to access data while processed, shared, and evaluated locally [55]. The cloud and computers are not sharing details in real-time, and so eavesdrop attackers find it very difficult to perceive any user's personal information [56]. Since Fog computing inherits several cloud-based functions, it also inherits threats. It cannot be treated as entirely secure. To satisfy the consumer requirements and sometimes wherever a customer wishes it, Octenyl is required for Fog [57]. Fog systems cannot cover themselves as many resources as in the clouds because many Fog systems are considerably smaller than clouds, such as Fog nodes. Besides, in any Fog scheme, no global intelligence for threats is required [24].

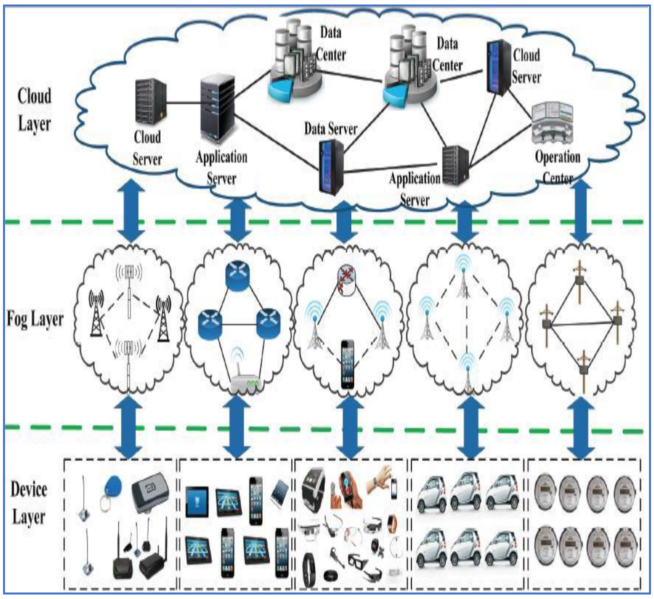

Fig. 6. The three-level architecture of Fog [53].

J. Internet of Things (IoT)

The computer, sensor, and integrated communications technology are integrated [58]. IoT's main objective is the smooth provision of services everywhere, wherever, and wherever. In all regions, this technology plays an essential role in bringing the 4th technological revolution following ICT and the Internet [59]. IoT is set to become the next massive trend following the Internet's growth itself [60]. It would be anticipated that millions and potentially billions of 'intelligent machines would communicate and share knowledge and data over the Internet [61]. Typical representations of these autonomous systems are the sensors. IoT reflects the communication and mobility future as the technology transition. "Things" in IoT mean some entity on the Earth's face, whether it is a communication system or a stupid non-communicating entity. Anything may be part of the Internet, from an intelligent computer to a tree leaf or a glass of drink [62]. There are different IoT applications, e.g., human administration systems, where they made a significant modification to people's daily life, decision, and work. It had a positive and significant effect on numerous ventures [63].

III. Related Works

Despite the widespread utilization of cloud technology, some services and applications still cannot benefit from this broad computing paradigm because of inherent problems of cloud, e.g., lack of mobility support, lack of location awareness, and unacceptable latency. Fog computing has emerged as an excellent infrastructure to provide resources at the edge of network elasticity [64]. Many researchers have focused on Fog computing. Therefore, in this section, we will study some of its utilizations and how it has performed under different implementations and approaches.

Hong [65] suggested an environment for the Fog computing ecosystem and brought into service an accurate testbed for various scenario uses. In particular, they researched three user situations and customized their platform for Fog computing for them. These scenarios are: a) disseminating content in challenged networks, b) Fog computing of crowd-sourced, and c) programmable IoT analytics. They solved the problems of optimization in each scenario via novel algorithms. Study findings revealed that their proposed algorithms outperform baseline algorithms regarding the three usage scenarios' key efficiency metrics by at least 30.3 percent, 20.0 percent, and 89.4 percent, respectively. Several ongoing activities are aimed at enhancing the proposed Fog computing framework for (i) provision of network services, (ii) adaptation of system dynamics, and (iii) prediction of device availability.

Osanaiye et al. [7] Fog outlined and revised the varied applications and services in Fog Computing and addressed privacy and security issues by concentrating on resources and service availability. Since these systems required low latency, the cloud had to be extended to the network's edge, and the Fog computation was achieved. Cloud computing and Fog computing are called virtualized networks that can include storage, networking, and computing. The demands of availability highly through end users required the suggested smart migration before copy, which evaluated downtime via the iterative pre-copy process, to decide whether the stop and copy phase should be taken. This guarantees a low downtime. In future function, the frame is used to refinish and validate the system in a test setting or in a real world.

Fu et al. [66] The integration of fog computing and cloud computing to address safe data stocking, data analysis, and complex data collection and effective data recovery in Industrial IoT created an economical and scalable platform (IIoT). The retrieval tree is specifically designed to provide efficient, accurate data recovery, and the Stable KNN (Index Encryption Scheme) algorithm enables a privacy-protected data search. Data will be processed and stored via the cloud server or edge server, depending on the latency requirements. The edge server is the first to handle all raw data. Afterward, time-sensitive data (such as control data) are used and stored locally. Non-times critical information is transferred to the cloud service (such as tracked data) to facilitate data recovery and further mining. Various simulations and tests are performed in order to test the efficiency of the proposed scheme. The findings showed that the proposed architecture could significantly improve data storage and retrieval safety and reliability in IIoT.

Garcia et al. [67] Presented a broad image of the current situation in an actual smart city with a rough estimate of the city's comprehensive range of Fog capital, which will boost Fog computing technology's potential growth services. Although not suggested as formal analysis, since various actors involved in the envisioned Fog scenario, the authors felt that the statistics given are useful to Fog scientists and developers to have a more comprehensive view of the actual potential for this modern and demanding computing model in the smart cities. As a result, they clarified that Fog computing has arisen to complement cloud computing's capabilities by leveraging locality possibilities. Also, Fog computing has emerged as a new and challenging technology developed to enhance the cloud model's functionality by taking advantage of local opportunities.

Guan et al. [68] discussed significant problems in addressing data security and privacy concerns in Fog computing and clarified that cloud computing cannot specifically apply data management strategies in Fog computing. Their article is intended as a starting point for the creation of safe Fog computing data resources, and they addressed data protection and privacy architecture concerns in Fog computing. In specific, they presented the Fog layer's particular challenges to data security and data protection architecture and demonstrate the explanations why cloud storage data protection strategies cannot be used explicitly in Fog computing. Where in Fog computing, there are four types of data services: data computation, data query, data storage, and data sharing. These four types of data services respectively demand various privacy requirements and unique data security.

Aazam et al. [69] presented an integration issue of cloud-IoT followed by comparing Fog and cloud computing and identified Fog computing directions in future research. They evaluated Fog computing's performance via applying performance metrics like processing costs, processing delay, and processing power. Then they derived the performance gains resulted in comparison to a cloud only approach. The authors brought to the light an overall architecture of Fog along with its limitations and benefits. The evaluation results of the performance and analysis which is provided in their research open up the issue of the Fog suitability based to the tasks size being executed. They explored that Fog minimizes the processing delay generally to a noticeable level, however there is a limitation to its efficiency, and this limitation depends on the task length the Fog can handle. So, as the task size increases noticeably, the difference between processing delay by Fog and cloud reduces. They also found that according to the capabilities of processing, if tasks are greater than the feasible processing limitation of the Fog, then Fog has to offload the tasks to the cloud. Finally, they discussed and identified some Fog research challenges that must be tackled in the future to render Fog a promising and sustainable option for new services with somewhat different requirements.

Delfin et al. [70] Fog Computing researched as a new cloud age. They examined the focal points for administrations of Fog computing in a few spaces. They said that Fog computing is like the cloud, where the main difference lies in the method that has found closer end users to process and provide a reaction to the client in a less amount of time. Furthermore, the term "fogging", is a work framework in which a robust tool deals with certain application services or procedures at the edge of the system. Future studies would establish the worldview of Fog computing in the Brilliant Grid. Two versions for Fog tools can be created in this case. The interconnected Fog tools counsel one another; also make alliances for additional enhancements. While autonomous Fog tools may counsel with the cloud specifically for intermittent updates on requests and cost. Traffic light management may also be helped by the Fog computing concept. Finally, portability between Fog hubs and between Fog and Cloud can be explored.

Rabay'a et al. [71] A peer-to-peer (P2P) fog model was proposed for improving fog computing by introducing a P2P system to the fog level, enabling user-friendly coordination of nodes. Thus, cloud requests are kept to a minimum, and the fog nodes positioned near the user meet most of the requests. The recommended P2P fog model was assessed in the case of the application for file sharing. They demonstrated that the model introduced is more excellent than fog computing and cloud computing models in bandwidth. They then simulated P2P fog, fog, and cloud computing conditions and then compared and analyzed the effects of each of them.

Ali et al. [72] A contrast was made between Fog and cloud computing in order for both systems to consider the distinctions. The distinction examined Fog's flexibility and superior data management service than cloud storage with low network latency, instead of moving all the data to the cloud. Cloud technology is now advanced, and many development tools are now available for cloud application design and implementation. While Fog computing is in the early stages of the study, the implementation tools and test models are still under study, Fog computing definitely would have a major effect on modern computing technology and would progress quickly. Their research compared Fog computing's advantages with cloud computing. Fog computing is also a promising paradigm for service providers.

Ema et al. [73] Discussed the Fog computing preprocessing phase in providing facilities in real-time. They proposed the design of real-time service with the use of Fog computing. Besides, the Cloud Data Center implemented a load balance preprocessing step. Since data centers of cloud computing are too expensive and time-consuming to handle massive volumes of data storage. Fog computing has the potential for load balancing, which can reduce conventional cloud data center's pressure. They also designed third-party memory management to provide real-time services because Fog devices have small memory for processing data. They also concentrated on how to address the cloud storage crisis.

Jindal et al. [74] The theoretical algorithm proposed for mission downloading to cloud data center nodes and clouds with different parameters has been proposed. If Fog finds it hard to calculate the job alone because of a small capacity, heavy calculations would be discharged from Fog into the cloud. A judgment on whether the mission should be downloaded from Fog to the cloud will be decisive with the proposed process. In three phases, the proposed study is carried out. Phase 1 determines whether the end system will perform the generated task itself (generated by an end device). In stage 2, the decision is made to process data through Fog nodes unless the end device can. Data were not discharged otherwise. In phase 3, if the Fog node can process the information within a given time, the Fog node processes the operation. Data are otherwise discharged into the data center in the cloud. The bandwidth used to unload the Fog data is generally less than the bandwidth needed for the server to discharge the data. Besides, leasing cloud data center resources and their capacities are higher than Fog node prices and capacities.

Abedi and Pourkiani [75] proposed a Task Distribution (AI) algorithm to minimize internet traffic and response times by spreading tasks between cloud and fog servers. Their case study was a delay-sensitive program that runs if the computer capability of the fog servers is limited. The Internet connection is volatile (e.g., vessels on the oceans). The primary test of the proposed algorithm reveals that this system reduces internet traffic and responsive time significantly in comparison with fog-based and cloud-based methods. The effect of the proposed approach is thus more evident as the amount of tasks available in the broker increases (tasks sent to the servers to be processed).

Karagiannis and Schulte [8] represented the main architectures used commonly for Fog computing (i.e., flat and hierarchical) via creating a unique system model. Besides, they designed algorithms that can be utilized to create Fog computing systems that follow these architectures. They also performed different experiments that focused on bandwidth utilization and communication latency. Their study can provide guidelines to select an appropriate Fog computing distributed architecture while considering the fina applications requirements. Notably, their results showed that the hierarchical architecture is better than flat architecture for the applications of no dependency on the cloud (i.e., does not involve any resource-demanding tasks). The communication latency is reduced by 13% with the flat architecture. In contrast, for applications with resource-demanding tasks, the communication latency is reduced by 16% using flat architecture comparing with the hierarchical.

Srirama, Satish et al. [76] Proposed an Actor Model-based framework for the Akka distributed Fog applications. For concurrent measurements, the Actor Model is a universal structure, whereas the Akka toolkit refers to the model that often offers additional specifications such as resilience and scalability. Besides, the distributed Software has been deployed smoothly in Fog networks using a Docker contamination technique. A case study has been developed on the Wireless Sensor Network to demonstrate that applications in the Fog networks can be developed for testing the proposed actor-based architecture. A comprehensive analysis also shows the performance and parallel reliability of the proposed model resource-controlled door and fog devices.

Guevara, Judy et al. [77] Presented two schedulers that work in the club or on fog tools based on integrated linear programming. Different schedules are used to pick processing components for which tasks are to be performed, using the service type. Numerical findings show that the proposed schedulers outperform conventional algorithms such as Random and Round Robin without breaching QoS specifications.

IV. Discussion

The Fog computing interoperability function guarantees full support for various applications. Fog's interactions with cloud computing and IoT mean that Fog devices on the fringes are close to the source of evidence so that incidents and processes can be answered more quickly. The data can be stored and stored in the cloud subsequently. We have addressed Fog's definitions, similar conceptions, and a more detailed definition in this article. The following: Fog computer usage for real-time applications. This study clarifies the new research subject of Fog Computing Technology. Table 1 shows a comparison among the researches mentioned in section 3. From the comparison table, it is clear the authors in [65] suggested an environment for Fog computing ecosystem and brings into service an accurate testbed for various scenario uses to serve better applications that rely on time, place, colossal scale, and sensitivity to latency. The study [7] Cloud and Fog computing is a computer environment capable of providing services, such as storage, networking, and computing. While [66] supposed a system that will dramatically enhance IoT data stock and recovery's reliability and protection.

Furthermore, [67] clarified that Fog computing has arisen to complement cloud computing's capabilities by leveraging locality possibilities. The research [68] clarified that cloud computing could not specifically apply data management strategies in Fog computing. The study [69] recognized and explored a range of problems for Fog research that must be tackled in the future to render Fog a promising and sustainable option for new services with somewhat different needs. The research in [70] found that Fog computing is like the cloud, where the main difference lies in the method that has found closer end users to process and provide a reaction to the client in a less amount of time. The reference [71] offered a clear base for potential attempts to refine P2P Fog computing. The authors in [72] presented a distinction because, by using the network's low bandwidth instead of changing any data into the cloud, Fog has a much more versatile architecture with a superior data processing service. The reference [73] explored that the conventional cloud data center cannot support a massive volume of data storage because it is too pricey and requires time. They also found that Fog computation can manage load and reduce the conventional cloud data center burden. The research [74] Exploring the heavy calculations from the fog into the cloud can be unloaded if Fog finds it impossible to calculate the mission on its own because of its limited power. The bandwidth used to discharge the Fog data is less than that used to discharge data into the cloud. The reference [75] proposed a method that notably minimized the internet traffic and response time compared to the Fog-based and cloud-based approaches. The authors in [8] provided guidelines to select an appropriate Fog computing distributed architecture while considering the final application's requirements. The authors in [76] Proposed a frame for the Akka distributed Fog applications based on the Actor Model. The authors in [77] present two schedulers based on integer linear programming that schedule tasks either in the cloud or on fog resources.

TABLE I. SUMMARY OF LITERATURE REVIEW RELATED TO FOG AND CLOUD COMPUTING.

Reference	Year	Tools	Objectives	Significant Results
Hong [65]	2017	CloudSim	To better serve applications that rely on time, place, colossal scale, and sensitivity to latency.	The suggested algorithms outperform the baseline algorithms by at least 30.3%, 20.0%, and 89.4%, respectively, in the three instances' primary utility metrics. Many continuing activities have improved the network service supply Fog computing frame (ii) adjusting to system dynamics (iii) and offering access to the machine interface.
Osanaiye et al. [7]	2017	Linear regression approach	To minimum downtime of applications.	The low latency requirements of applications required the cloud to the edge of the network to be extended to Fog computing. Cloud computing and Fog computing are called virtualized networks that can include storage, networking, and computing.
Fu et al. [66]	2018	CloudSim	To solve the issues related to secure data storage, data processing, dynamic data collection, and efficient data retrieval in Industrial IoT (IIoT).	The findings indicated that the supposed system would dramatically enhance IoT data stock and recovery's reliability and protection.
Garcia et al. [67]	2018	MNIST	To enhance the functionality of the cloud model by taking advantage of local opportunities.	As a result, they clarified that Fog computing has arisen to complement cloud computing's capabilities by leveraging locality possibilities.
Guan et al. [68]	2018	VANET	To offers a starting point in the creation of stable Fog computing data services.	They clarified that cloud computing could not specifically apply data management strategies in Fog computing. Also, they presented the particular challenges faced by the Fog layer to data security and data protection architecture and demonstrate.
Aazam et al. [69]	2018	CloudSim	To address issues of cloud IoT convergence and equate Fog with cloud computing.	The performance appraisal and review findings presented in their study pose Fog suitability based on the scale of the tasks being carried out. Finally, they recognized and explored a range of problems for Fog research that must be tackled in the future to render Fog a promising and sustainable option for new services with somewhat different needs.
Delfin et al. [70]	2019	CISCO	To examine the focal points for administrations of Fog computing in a few spaces.	They found that Fog computing is like the cloud, where the main difference lies in the method that has found closer end users to process and provide a reaction to the client in a less amount of time.
Rabay'a et al. [71]	2019	PeerfactSim.KOM	To quantify the theoretical Fog P2P model, which demonstrates that the cloud and Fog computing architectures' bandwidth efficiency is superior with the file transfer method.	The findings of the study offer a clear base for potential attempts to refine p2p Fog computing.
Ali et al. [72]	2019	CloudSim	To explain the distinctions between these systems, the author presented a distinction between Fog computing and cloud computing.	The comparison explored that Fog has a more flexible infrastructure and provides better data processing service than cloud computing via consuming low bandwidth of network instead of shifting all data to the cloud.
Ema et al. [73]	2019	Blockchain Technology	To address how to provide Fog infrastructure facilities in real-time—concentrating on addressing cloud store problems.	They explored that the conventional cloud data center cannot support a massive volume of data storage because it is too pricey and requires time. They also found that Fog computation can manage load and reduce the conventional cloud data center burden.
Jindal et al. [74]	2020	FogSim	They proposed a method that can help make a crucial decision about when the task should be offloaded from Fog to the cloud.	If Fog finds it hard to calculate the job alone because of a small capacity, heavy calculations would be discharged from Fog into the cloud. The bandwidth used to unload the Fog data is generally less than the bandwidth needed for the server to discharge the data. Besides, leasing cloud data center services and their capacities are higher than Fog node prices and capacities.
Abedi and Pourkiani [75]	2020	Matlab	To minimize the Internet traffic and response time by distributing the tasks between cloud and fog servers	Compared to the fog and cloud-driven methods, the proposed solution significantly reduced internet traffic and response time. However, the effect of this proposed approach is pronounced when the amount of tasks required in the broker is increased (tasks sent to the servers to be processed).
Karagiannis and Schulte [8]	2020	Java	To provide guidelines to select an appropriate Fog computing distributed architecture while considering the fina applications requirements.	The hierarchical architecture is better than flat architecture for no dependency on the cloud, where the communication latency is reduced by 13% compared with the flat architecture. In contrast, for applications with resource-demanding tasks, the communication latency is reduced by 16% using flat architecture comparing with the hierarchical.
Srirama, Satish et al. [76]	2021	Actor Model, Akka toolkit	The author Proposed a frame for the Akka distributed Fog applications based on the Actor Model.	A case study on the network of wireless sensors has been developed to show the feasibility of designing applications on the Fog networks to test the proposed actor-based framework.
Guevara, Judy et al. [77]	2021	integer linear programming	presents two schedulers based on integer linear programming that schedule tasks either in the cloud or on fog resources.	Numerical results evince that the proposed schedulers outperform traditional ones, e.g., Random and Round Robin algorithms, without causing the violation of QoS requirements.

V. CONCLUSION

Cloud computing technology has been established as an alternative infrastructure of Information Technology (IT) and service model. In architecture, IoT systems are complicated and have small storage and recycling capacity. However, as with service provisioning infrastructures and centralized resources logically, cloud computing cannot handle local issues very well, including many IoT elements. It is also not responsive enough for the applications that require instant attention of a local controller. Therefore, Fog computing had emerged. Fog computing has developed as an extension of the cloud, where it is closer to IoT elements, in which data has been stored at the cloud and Fog nodes. The incorporation of cloud computing and Fog computing in various IoT implementations would offer several advantages to them. This paper discussed cloud and Fog computing and presented IoT applications improved by cloud and Fog. This paper aimed to evaluate up-to-date research contributions on cloud and Fog computing and IoT and its implementations in our environment and explain potential avenues for research and open topics concerning cloud computing and Fog computing integration with IoT. As a result, Fog computing presents multiple benefits of cloud computing. Besides, it is an excellent position to address performance and locality issues because its specific services and resources are virtualized where it is located at the network's edge.

REFERENCES

[1] S. Zeebaree, "Energy Management for Internet of Things via Distributed Systems," *Journal of Applied Science and Technology Trends,* vol. 2, pp. 59-71, 2021.

[2] H. Shukur, S. Zeebaree, R. Zebari, D. Zeebaree, O. Ahmed, and A. Salih, "Cloud Computing Virtualization of Resources Allocation for Distributed Systems," *Journal of Applied Science and Technology Trends,* vol. 1, pp. 98-105, 2020/06/27/ 2020.

[3] Z. S. Ageed, S. R. Zeebaree, M. M. Sadeeq, S. F. Kak, H. S. Yahia, M. R. Mahmood*, et al.*, "Comprehensive Survey of Big Data Mining Approaches in Cloud Systems," *Qubahan Academic Journal,* vol. 1, pp. 29-38, 2021.

[4] L. M. Abdulrahman, S. R. Zeebaree, S. F. Kak, M. A. Sadeeq, A.-Z. Adel, B. W. Salim*, et al.*, "A State of Art for Smart Gateways Issues and Modification," *Asian Journal of Research in Computer Science*, pp. 1-13, 2021.

[5] R. O. Aburukba, M. AliKarrar, T. Landolsi, and K. El-Fakih, "Scheduling Internet of Things requests to minimize latency in hybrid Fog–Cloud computing," *Future Generation Computer Systems,* vol. 111, pp. 539-551, 2020.

[6] S. N. Shirazi, A. Gouglidis, A. Farshad, and D. Hutchison, "The extended cloud: Review and analysis of mobile edge computing and fog from a security and resilience perspective," *IEEE Journal on Selected Areas in Communications,* vol. 35, pp. 2586-2595, 2017.

[7] O. Osanaiye, S. Chen, Z. Yan, R. Lu, K. R. Choo, and M. Dlodlo, "From Cloud to Fog Computing: A Review and a Conceptual Live VM Migration Framework," *IEEE Access,* vol. 5, pp. 8284-8300, 2017 2017.

[8] V. Karagiannis and S. Schulte, "Comparison of alternative architectures in fog computing," in *2020 IEEE 4th International Conference on Fog and Edge Computing (ICFEC)*, 2020, pp. 19-28.

[9] M. M. S. Maswood, M. R. Rahman, A. G. Alharbi, and D. Medhi, "A novel strategy to achieve bandwidth cost reduction and load balancing in a cooperative three-layer fog-cloud computing environment," *IEEE Access,* vol. 8, pp. 113737-113750, 2020.

[10] M. Iorga, L. Feldman, R. Barton, M. J. Martin, N. S. Goren, and C. Mahmoudi, "Fog Computing Conceptual Model," 2018/03/14/T00:03-04:00 2018.

[11] P. Eugen and A.-O. Petac, "About Security Solutions in Fog Computing," *Analele Universitatii Ovidius Constanta,* vol. XV, pp. 373-379, 2019/01/26/ 2019.

[12] M. Ziqian, Z. Guan, W. U. Zhengang, L. I. Anran, and C. Zhong, "Security Enhanced Internet of Vehicles with Cloud-Fog-Dew Computing," *ZTE Communications,* vol. 15, pp. 47-51, 2018/02/09/ 2018.

[13] R. Mahmud, A. N. Toosi, K. Ramamohanarao, and R. Buyya, "Context-aware placement of Industry 4.0 applications in fog computing environments," *IEEE Transactions on Industrial Informatics,* vol. 16, pp. 7004-7013, 2019.

[14] L. M. Haji, O. M. Ahmad, S. R. Zeebaree, H. I. Dino, R. R. Zebari, and H. M. Shukur, "Impact of cloud computing and internet of things on the future internet," *Technology Reports of Kansai University,* vol. 62, pp. 2179-2190, 2020.

[15] A. Al-Qerem, M. Alauthman, A. Almomani, and B. Gupta, "IoT transaction processing through cooperative concurrency control on fog–cloud computing environment," *Soft Computing,* vol. 24, pp. 5695-5711, 2020.

[16] O. Alzakholi, H. Shukur, R. Zebari, S. Abas, and M. Sadeeq, "Comparison among cloud technologies and cloud performance," *Journal of Applied Science and Technology Trends,* vol. 1, pp. 40-47, 2020.

[17] P. Y. Abdullah, S. R. M. Zeebaree, H. M. Shukur, and K. Jacksi, "HRM system using cloud computing for Small and Medium Enterprises (SMEs)," *Technology Reports of Kansai University,* vol. 62, p. 04, 2020 2020.

[18] M. J. Baucas and P. Spachos, "Using cloud and fog computing for large scale iot-based urban sound classification," *Simulation Modelling Practice and Theory,* vol. 101, p. 102013, 2020.

[19] H. Shukur, S. R. Zeebaree, A. J. Ahmed, R. R. Zebari, O. Ahmed, B. S. A. Tahir*, et al.*, "A State of Art Survey for Concurrent Computation and Clustering of Parallel Computing for Distributed

Systems," *Journal of Applied Science and Technology Trends*, vol. 1, pp. 148-154, 2020.

[20] H. Shukur, S. Zeebaree, R. Zebari, O. Ahmed, L. Haji, and D. Abdulqader, "Cache coherence protocols in distributed systems," *Journal of Applied Science and Technology Trends,* vol. 1, pp. 92-97, 2020.

[21] Z. S. Ageed, R. K. Ibrahim, and M. A. Sadeeq, "Unified Ontology Implementation of Cloud Computing for Distributed Systems," *Current Journal of Applied Science and Technology*, pp. 82-97, 2020.

[22] L. M. Haji, S. Zeebaree, O. M. Ahmed, A. B. Sallow, K. Jacksi, and R. R. Zeabri, "Dynamic resource allocation for distributed systems and cloud computing," *TEST Engineering & Management*, vol. 83, pp. 22417-22426, 2020.

[23] M. A. Yami and D. Schaefer, "Fog Computing as a Complementary Approach to Cloud Computing," in *2019 International Conference on Computer and Information Sciences (ICCIS)*, 2019, pp. 1-5.

[24] M. Chiang and T. Zhang, "Fog and IoT: An Overview of Research Opportunities," *IEEE Internet of Things Journal,* vol. 3, pp. 854-864, 2016/12// 2016.

[25] C. Mouradian, D. Naboulsi, S. Yangui, R. H. Glitho, M. J. Morrow, and P. A. Polakos, "A comprehensive survey on fog computing: State-of-the-art and research challenges," *IEEE communications surveys & tutorials,* vol. 20, pp. 416-464, 2017.

[26] S. R. Zeebaree, H. M. Shukur, and B. K. Hussan, "Human resource management systems for enterprise organizations: A review," *Periodicals of Engineering and Natural Sciences (PEN),* vol. 7, pp. 660-669, 2019.

[27] R. R. Zebari, S. Zeebaree, K. Jacksi, and H. M. Shukur, "E-business requirements for flexibility and implementation enterprise system: A review," *International Journal of Scientific & Technology Research,* vol. 8, pp. 655-660, 2019.

[28] I. M. Ibrahim, "Task Scheduling Algorithms in Cloud Computing: A Review," *Turkish Journal of Computer and Mathematics Education (TURCOMAT),* vol. 12, pp. 1041-1053, 2021.

[29] M. A. Sulaiman, M. Sadeeq, A. S. Abdulraheem, and A. I. Abdulla, "Analyzation Study for Gamification Examination Fields," *Technol. Rep. Kansai Univ,* vol. 62, pp. 2319-2328, 2020.

[30] D. Puthal, M. S. Obaidat, P. Nanda, M. Prasad, S. P. Mohanty, and A. Y. Zomaya, "Secure and sustainable load balancing of edge data centers in fog computing," *IEEE Communications Magazine,* vol. 56, pp. 60-65, 2018.

[31] Z. Ageed, M. R. Mahmood, M. Sadeeq, M. B. Abdulrazzaq, and H. Dino, "Cloud computing resources impacts on heavy-load parallel processing approaches," *IOSR Journal of Computer Engineering (IOSR-JCE),* vol. 22, pp. 30-41, 2020.

[32] H. I. Dino, S. R. Zeebaree, O. M. Ahmad, H. M. Shukur, R. R. Zebari, and L. M. Haji, "Impact of Load Sharing on Performance of Distributed Systems Computations," *International Journal of Multidisciplinary Research and Publications (IJMRAP),* vol. 3, pp. 30-37, 2020.

[33] S. Wang, T. Zhao, and S. Pang, "Task Scheduling Algorithm Based on Improved Firework Algorithm in Fog Computing," *IEEE Access*, vol. 8, pp. 32385-32394, 2020 2020.

[34] Z. N. Rashid, S. R. Zeebaree, and A. Shengul, "Design and analysis of proposed remote controlling distributed parallel computing system over the cloud," in *2019 International Conference on Advanced Science and Engineering (ICOASE)*, 2019, pp. 118-123.

[35] Z. N. Rashid, S. R. Zebari, K. H. Sharif, and K. Jacksi, "Distributed cloud computing and distributed parallel computing: A review," in *2018 International Conference on Advanced Science and Engineering (ICOASE)*, 2018, pp. 167-172.

[36] S. R. Zeebaree, H. M. Shukur, L. M. Haji, R. R. Zebari, K. Jacksi, and S. M. Abas, "Characteristics and analysis of hadoop distributed systems," *Technology Reports of Kansai University,* vol. 62, pp. 1555-1564, 2020.

[37] F. Q. Kareem, S. R. Zeebaree, H. I. Dino, M. A. Sadeeq, Z. N. Rashid, D. A. Hasan, *et al.*, "A Survey of Optical Fiber Communications: Challenges and Processing Time Influences," *Asian Journal of Research in Computer Science,* pp. 48-58, 2021.

[38] S. Zeebaree, B. Salim, R. Zebari, H. Shukur, A. Abdulraheem, A. Abdulla, *et al.*, "Enterprise Resource Planning Systems and Challenges," *Technol. Rep. Kansai Univ,* vol. 62, pp. 1885-1894, 2020.

[39] A. S. Abdulraheem, A. I. Abdulla, and S. M. Mohammed, "Enterprise Resource Planning Systems and Challenges."

[40] A. Albugmi, M. O. Alassafi, R. Walters, and G. Wills, "Data security in cloud computing," in *2016 Fifth International Conference on Future Generation Communication Technologies (FGCT)*, 2016, pp. 55-59.

[41] H. M. Shukur, S. R. Zeebaree, R. R. Zebari, B. K. Hussan, O. H. Jader, and L. M. Haji, "Design and Implementation of Electronic Enterprise University Human Resource Management System," in *Journal of Physics: Conference Series*, 2021, p. 012058.

[42] D. A. Hasan, B. K. Hussan, S. R. Zeebaree, D. M. Ahmed, O. S. Kareem, and M. A. Sadeeq, "The Impact of Test Case Generation Methods on the Software Performance: A Review," *International Journal of Science and Business,* vol. 5, pp. 33-44, 2021.

[43] Z. Mahmood, "Data Location and Security Issues in Cloud Computing," in *2011 International Conference on Emerging Intelligent Data and Web Technologies (EIDWT)*, 2011, pp. 49-54.

[44] V. Shelley, "Protecting Privileged Identity in Cloud Environments," *Security Intelligence*, 2014/11/03/ 2014.

[45] A. A. Yazdeen, S. R. Zeebaree, M. M. Sadeeq, S. F. Kak, O. M. Ahmed, and R. R. Zebari, "FPGA Implementations for Data Encryption and Decryption via Concurrent and Parallel Computation: A Review," *Qubahan Academic Journal*, vol. 1, pp. 8-16, 2021.

[46] A. Kuokkanen, "Newcomer's introduction to Privileged Access Management," 2020.

[47] S. S. R. Zeebaree, S. Ameen, and M. Sadeeq, "Social Media Networks Security Threats, Risks and Recommendation: A Case Study in the Kurdistan Region," *International Journal of Innovation, Creativity and Change*, vol. 13, pp. 349-365, 2020.

[48] N. Fernando, S. W. Loke, and W. Rahayu, "Mobile cloud computing: A survey," *Future generation computer systems*, vol. 29, pp. 84-106, 2013.

[49] M. Kaur and H. Singh, "A review of cloud computing security issues," *International Journal of Advances in Engineering & Technology*, vol. 8, p. 397, 2015.

[50] A. I. Abdulla, A. S. Abdulraheem, A. A. Salih, M. A. Sadeeq, A. J. Ahmed, B. M. Ferzor, *et al.*, "Internet of Things and Smart Home Security," *Technol. Rep. Kansai Univ*, vol. 62, pp. 2465-2476, 2020.

[51] P. Challagidad, "Efficient and Reliable Data Recovery Technique in Cloud Computing," pp. 13-18, 2017/01/01/ 2017.

[52] M. Sadeeq, A. I. Abdulla, A. S. Abdulraheem, and Z. S. Ageed, "Impact of Electronic Commerce on Enterprise Business," *Technol. Rep. Kansai Univ*, vol. 62, pp. 2365-2378, 2020.

[53] A. Aljumah and T. A. Ahanger, "Fog computing and security issues: A review," in *2018 7th International Conference on Computers Communications and Control (ICCCC)*, 2018, pp. 237-239.

[54] T. D. Dang and D. Hoang, "A data protection model for fog computing," in *2017 Second International Conference on Fog and Mobile Edge Computing (FMEC)*, 2017, pp. 32-38.

[55] A. S. Abdulraheem, A. A. Salih, A. I. Abdulla, M. A. Sadeeq, N. O. Salim, H. Abdullah, *et al.*, "Home automation system based on IoT," 2020.

[56] A. A. Salih, S. R. Zeebaree, A. S. Abdulraheem, R. R. Zebari, M. A. Sadeeq, and O. M. Ahmed, "Evolution of Mobile Wireless Communication to 5G Revolution," *Technology Reports of Kansai University*, vol. 62, pp. 2139-2151, 2020.

[57] A. M. Abdulazeez, S. R. Zeebaree, and M. A. Sadeeq, "Design and Implementation of Electronic Student Affairs System," *Academic Journal of Nawroz University*, vol. 7, pp. 66-73, 2018.

[58] 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, pp. 1-7, 2021.

[59] S. N. Swamy and S. R. Kota, "An Empirical Study on System Level Aspects of Internet of Things (IoT)," *IEEE Access*, vol. 8, pp. 188082-188134, 2020 2020.

[60] M. A. Sadeeq, S. R. Zeebaree, R. Qashi, S. H. Ahmed, and K. Jacksi, "Internet of Things security: a survey," in *2018 International Conference on Advanced Science and Engineering (ICOASE)*, 2018, pp. 162-166.

[61] A. B. Sallow, M. Sadeeq, R. R. Zebari, M. B. Abdulrazzaq, M. R. Mahmood, H. M. Shukur, *et al.*, "An Investigation for Mobile Malware Behavioral and Detection Techniques Based on Android Platform," *IOSR Journal of Computer Engineering (IOSR-JCE)*, vol. 22, pp. 14-20.

[62] M. Aazam and E. Huh, "Fog Computing and Smart Gateway Based Communication for Cloud of Things," in *2014 International Conference on Future Internet of Things and Cloud*, 2014, pp. 464-470.

[63] R. H. Saeed, H. I. Dino, L. M. Haji, D. M. Hamed, H. M. Shukur, and O. H. Jader, "Impact of IoT Frameworks on Healthcare and Medical Systems Performance," *International Journal of Science and Business*, vol. 5, pp. 115-126, 2021 2021.

[64] S. Yi, Z. Hao, Z. Qin, and Q. Li, *Fog Computing: Platform and Applications*, 2015.

[65] H.-J. Hong, "From cloud computing to fog computing: unleash the power of edge and end devices," in *2017 IEEE international conference on cloud computing technology and science (CloudCom)*, 2017, pp. 331-334.

[66] J. Fu, Y. Liu, H. Chao, B. K. Bhargava, and Z. Zhang, "Secure Data Storage and Searching for Industrial IoT by Integrating Fog Computing and Cloud Computing," *IEEE Transactions on Industrial Informatics*, vol. 14, pp. 4519-4528, 2018/10// 2018.

[67] J. Garcia, E. Simó, X. Masip-Bruin, E. Marín-Tordera, and S. Sànchez-López, "Do we really need cloud? Estimating the fog computing capacities in the city of Barcelona," in *2018 IEEE/ACM International Conference on Utility and Cloud Computing Companion (UCC Companion)*, 2018, pp. 290-295.

[68] Y. Guan, J. Shao, G. Wei, and M. Xie, "Data security and privacy in fog computing," *IEEE Network*, vol. 32, pp. 106-111, 2018.

[69] M. Aazam, S. Zeadally, and K. A. Harras, "Fog Computing Architecture, Evaluation, and Future Research Directions," *IEEE Communications Magazine*, vol. 56, pp. 46-52, 2018/05// 2018.

[70] S. Delfin, N. P. Sivasanker, N. Raj, and A. Anand, "Fog Computing: A New Era of Cloud Computing," in *2019 3rd International Conference on Computing Methodologies and Communication (ICCMC)*, 2019, pp. 1106-1111.

[71] A. Rabay'a, E. Schleicher, and K. Graffi, "Fog Computing with P2P: Enhancing Fog Computing Bandwidth for IoT Scenarios," in *2019 International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData)*, 2019, pp. 82-89.

[72] S. Ali, V. Kumar, A. Laghari, S. Karim, and A. Brohi, "Comparison of Fog Computing & Cloud Computing," *International Journal of Mathematical Sciences and Computing,* pp. 31-41, 2019/01/01/ 2019.

[73] R. R. Ema, T. Islam, and M. H. Ahmed, "Suitability of Using Fog Computing Alongside Cloud Computing," in *2019 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*, 2019, pp. 1-4.

[74] R. Jindal, N. Kumar, and H. Nirwan, "MTFCT: A task offloading approach for fog computing and cloud computing," in *2020 10th International Conference on Cloud Computing, Data Science Engineering (Confluence)*, 2020, pp. 145-149.

[75] M. Abedi and M. Pourkiani, "Resource Allocation in Combined Fog-Cloud Scenarios by Using Artificial Intelligence," in *2020 Fifth International Conference on Fog and Mobile Edge Computing (FMEC)*, 2020, pp. 218-222.

[76] S. N. Srirama, F. M. S. Dick, and M. Adhikari, "Akka framework based on the Actor model for executing distributed Fog Computing applications," *Future Generation Computer Systems*, vol. 117, pp. 439-452, 2021.

[77] J. C. Guevara and N. L. da Fonseca, "Task scheduling in cloud-fog computing systems," *Peer-to-Peer Networking and Applications,* vol. 14, pp. 962-977, 2021.