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A Comprehensive Study of Fog Computing and The Internet of Things, Fog Architecture, Challenges in Fog, Applications of Fog Computing

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ABSTRACT

Network latency, limited capacity, and network failure are just a few of the issues that traditional centralized cloud computing technology is up against in light of the explosive growth of applications for The Internet of Things. The problems can be avoided with the use of fog computing, which moves cloud resources nearer to IoT gadgets. In the fog, data from IoT devices is processed and stored locally rather than uploaded to a central server. Services provided by the fog are faster and of greater quality than those provided by the cloud. Therefore, fog computing may be seen as the ideal choice for making IoT to provide effectual and resilient services to a outsized number of IoT users. In this study, we explore the current status of fog computing and how it relates to the Internet of Things, highlighting the advantages and difficulties of implementing such a system. In addition, the design of the fog and new IoT applications that can take use of it will be discussed. Finally, we examine some of the remaining questions and potential areas for future study in fog computing and the IoT.

Keywords: Internet of Things; Fog Computing; Cloud Computing; Fog Architecture; Applications; Challenges;

1. INTRODUCTION

Network latency, limited capacity, and network failure are just a few of the issues that traditional centralised cloud computing technology is up against in light of the explosive growth of applications for The Internet of Things. The problems can be avoided with the use of fog computing, which moves cloud resources nearer to IoT gadgets. In the fog, data from IoT devices is processed and stored locally rather than uploaded to a central server. Services provided by the fog are faster and of greater quality than those provided by the cloud. Therefore, fog computing may be seen as the ideal choice for making IoT to provide effectual and resilient services to a outsized number of IoT users. In this study, we explore the current status of fog computing and how it relates to the Internet of Things, highlighting the advantages and difficulties of implementing such a system. In addition, the design of the fog and new IoT applications that can take use of it will be discussed. Finally, we examine some of the remaining questions and potential areas for future study in fog computing and the IoT.

The incorporation of fog computing with IoT opens up a new service opportunity known as fog as a service (FaaS), in which a service provider builds an array of fog nodes across its geographic footprint and acts as a landlord to many tenants from various vertical markets. Each fog node provides local computation, networking, and storage [9]. Customers will be able to receive services through new business models enabled by FaaS. Contrary to clouds, most of which are operated by large corporations that can pay to build and operate massive data centers, FaaS will enable both large and small businesses to implement and operate private or public computing, backup, and regulation services at various scales to meet the needs of a diverse set of customers [10].

The remainder of this paper is organized as follows: Section two discusses the challenges of incorporating the IoT with cloud computing; the Third section introduces fog computing with its features, architectural style, and benefits; Section four presents the difference between Fog and Cloud; Section five provides various IoT applications that depend on fog computing; Section six describes the challenges facing the inclusion of the fog with the IoT; Section Seven discusses open issues in Fog Computing; Section Eight is the Conclusion.

2. CHALLENGES IN CLOUD COMPUTING

CoTs, which incorporate cloud computing and the Internet of Things, offer various benefits. It helps with things like IoT resource management and delivering more efficient and cost-effective IoT services. Additionally, it streamlines the movement of information and processing inside the IoT and offers quicker, lower-cost incorporation for sophisticated data processing and mobilization [4, 11]. The CoT structure is complicated., and it presents the IoT with new difficulties that the conventional centralized cloud computing system cannot address [12]. These include packet delay, capacity issues, devices with limited resources and network failure with wireless connections, and strong authentication. Then again, Internet of Things (IoT) applications cannot make use of the centralised cloud strategy due to time-sensitive tasks or poor Web connectivity. In many fields, including remote patient monitoring and healthcare, milliseconds matter. This is also true for inter vehicle communications, where the latency introduced by the centralised cloud solution makes it impossible to avoid collisions or accidents [8]. An enhanced cloud architecture that progresses storage and latency restrictions is necessary to meet the difficulties [5]. Fog computing [6] is a novel approach put forth by Cisco to address these issues.

3. FOG ARCHITECTURE

In fog computing, certain functions that are traditionally carried out in a data centre are moved to the edge of a network. The fog only offers a small amount of compute, storage, and networking capabilities to end devices in comparison to normal cloud computing data centres.. Fog computing aims to provide time-critical IoT applications with low and predictable latency [14].

The six levels are what the authors of Mukherjee et al. [15], Aazam and Huh [11,16], and Muntjir et al. [17] all agree make up the fog computing architecture. shown in Figure 1: physical and virtualization, monitoring, pre-processing, temporary storage, security, and transit layer.

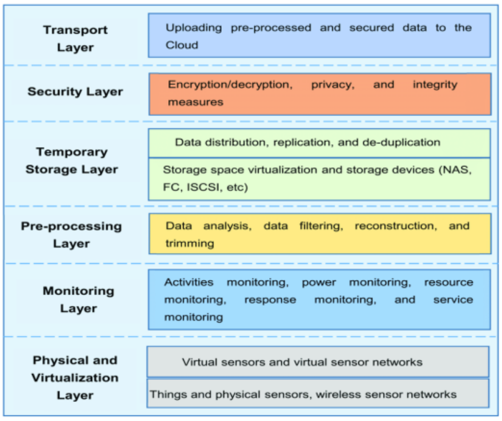

Fig.1 The layered architecture of fog computing.

The physical and virtualization layers include physical nodes, virtual nodes, and virtual sensor networks. How these nodes are cared for and preserved depends on their individual properties and the services they require. Sensors of varying types are placed around a given area to gather data about their surroundings, which is then sent on through gateways to the next layer for further analysis and refinement [13]. Consumption of resources, accessibility of sensors and fog nodes, and status of network nodes are all tracked at this level. At this level, every action taken by nodes is monitored, including which node is doing what task, for how long, and what happens subsequently. The health and functionality of all hosted applications and services is tracked and analysed [15]. Because fog computing uses several computers with varied power requirements, it is possible to create efficient energy management strategies rapidly [15, 16]. This is made possible by monitoring fog nodes' energy use. Data manipulation is the domain of the pre-processing layer. In this stage, information is gleaned from collected data through analysis, cleansing, and trimming. The intermediate storage layer is then used to store the precompiled data until additional processing is finished.. Once information has been uploaded to the cloud, it is no longer needed on local storage devices, therefore they can be discarded [16, 17]. The security layer employs encryption and decryption to protect sensitive information. Moreover, the data can have integrity controls applied to them to avoid any tampering. At the transport layer, the pre-processed data are sent to the cloud for further service extraction and development [16, 17]. Only a small portion of the gathered data is transferred to the cloud in order to save energy. Therefore, before transferring the data to the cloud, the gateway device that creates the link between the Internet of Things and the cloud processes it in some way. This kind of entry is what we call a "smart gateway" [18]. The cloud receives information from sensor networks and Internet of Things devices via smart gateways. The cloud archives collected data and employs it in the improvement of user services [11]. A fog-based communication protocol needs to be effective, lightweight, and flexible due to the fog's limited capacity. Therefore, the communication protocol to utilise is dependent on the fog application scenario [19].

4. WHAT SETS FOG APART FROM CLOUDS?

For IoT applications, the present centralized cloud computing architecture faces significant hurdles. It cannot, for example, handle time-sensitive IoT applications like video streaming, gaming, or augmented reality [22]. Furthermore, because it is a centralized paradigm, it lacks location awareness. Fog computing can help with these problems. The distinctions between cloud and fog computing are summarized in Table 1.

Table 1. Comparison between cloud and fog computing.

Items	Cloud Computing	Fog Computing
Latency	High	Low
Hardware	Storage and computing server properties are inadequate.	Storage and computing server are ascendable
Server nodes Location	Inside the web	At the edge of the local network
Distance between client and server	Several Hops	Single Hop
Environment of work	Building with air-conditioned systems	Outdoor or Indoor
Security Precautions	Defined	Hard to define
Attack on Data	Less Probability	High Probability
Deployment	Centralized	Distributed
Location Awareness	No	Yes

4. DIFFERENT APPLICATIONS THAT RELY ON FOG COMPUTING

Fog computing establishes a connection between Internet of Things gadgets and massive cloud computing and storage facilities. It provides a model of processing, storage, and networking resources that is highly virtualized amongst end devices and traditional cloud servers. [23].

For IoT applications to function at their optimal level, The significant number of connected device data must be handled and analysed in real-time. [24]. By bringing networking, processing, and storage capabilities from the cloud to the network's edge, fog computing will solve the real-time problem of IoT devices while simultaneously guaranteeing the safety and efficacy of IoT applications [25]. There are many beneficial services and applications offered by fog computing. that can be used in a wide range of settings. Different Internet of Things applications, including connected cars, can effectively communicate in real time thanks to proxies and access points set up throughout lengthy stretches of highways and trains in the fog. Fog computing is often regarded as the most viable choice for latency-sensitive applications including video streaming, gaming, and augmented reality [26].

Fog computing's integration into the IoT can help a variety of IoT applications. The fog allows for real-time interactions between IoT devices to reduce latency, which is especially beneficial for time-sensitive IoT applications. In addition, the growing number of Internet of Things devices, which could reach the billions, presents a significant challenge that can be mitigated by deploying fog computing to support massive sensor networks. See Figure 2 below for an illustration.

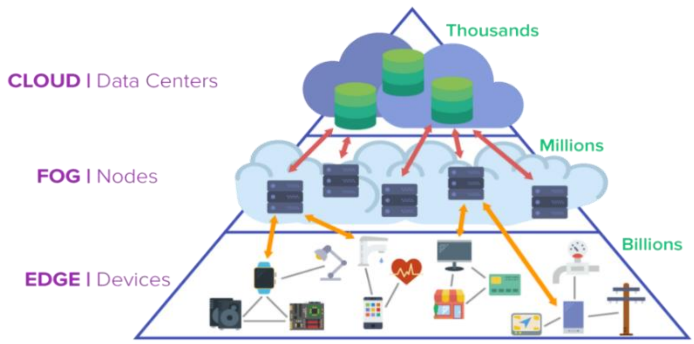

Fig.2 Applications of fog computing

Table 2. Fog computing provides new solutions to many IoT challenges.

IoT Challenge	How the Challenge can be solved by Fog
Latency Constraints	Due to the fog's ability to perform time-sensitive functions, such as data management and analysis, in close proximity to end users, it provides a suitable solution for the latency constraints faced by many IoT applications.
Restricted Bandwidth Constraints	Processing hierarchical data is made possible by fog computing by extending the capabilities of the cloud to Internet of Things (IoT) devices. This makes it possible to alter processing of data. in accordance with the needs of the application. and the accessibility

	of networking and computing resources. Because of this, less information needs to be sent to the cloud, which conserves bandwidth.
Machines with limited resources	Instead of having devices that do resource-intensive tasks in the cloud, fog computing can be used to handle these jobs. This means that gadget complexity, lifecycle costs, and energy usage can all be minimised.
Uninterrupted services	Fog computing may function autonomously even if cloud connectivity is spotty, guaranteeing continuous service.
Challenges in Security	Due to their limited capabilities, these devices rely on fog computing to have their software and credentials updated on their behalf. In addition, The fog can be utilized to keep an eye on the security of surrounding gadgets.

There are several ways in which fog computing can be an integral feature of Internet of Things (IoT) implementations. An overview of the many Internet of Things (IoT) applications that can profit from fog computing is given in this study.

5.1. CONNECTED CAR

The development of fully autonomous vehicles is a hot topic in the automotive industry at the moment [27]. Autonomous steering and "hands-free" operation are just two examples of the convenient features that can be added to Internet-connected and fog-resistant automobiles. [27] Similarly, self-parking systems can remove the need for a driver altogether.

All newly produced cars are anticipated to be capable of communicating with one another and the Web in the upcoming years. Fog computing, which facilitates real-time communication, will be utilised in the automobiles. In addition, vehicles, WiFi hotspots, and traffic lights can all coordinate to better serve drivers [7].

Fog, as opposed to cloud, has the potential to reduce collisions and other incidents without the time lag associated with the centralized cloud solution, therefore potentially saving lives right away [7].

5.2. SMART TRAFFIC LIGHTS

Traffic lights can be programmed to turn on depending on the detection of a flashing signal thanks to fog computing. It can recognise cyclists and pedestrians and assess the distance and speed of approaching vehicles. Movement activates the sensor lights, and when no motion is detected, the lights turn off [27].

One way to think of intelligent traffic lights is as fog nodes that share information and send out alerts to passing vehicles. Wi-Fi, 3G, smart traffic signals, and roadside equipment improve the way that vehicles interact with access points in fog. [7].

5.3. SMART HOME

In today's modern home, numerous sensors and appliances can be found online. It might be challenging to get these devices to work together because they are developed by various businesses and operate on different platforms. In addition, there are activities that call for a lot of computing and storing power. Fog computing resolves many of these problems. It links every system and gives smart home apps access to many tools [28].

There are many ways in which fog computing might improve home security systems. A standardised protocol is provided for connecting various peripherals. It provides a scalable storage capacity, near-real-time processing, and low latency [28].

5.4. WIRELESS SENSOR AND ACTUATOR NETWORKS

Battery life can be greatly increased in WSNs because they run on minimal power. Actuators control the measurement process and the behaviour changes to create a closed-loop system. For the sake of controlling sensor-equipped end devices, actuators can be viewed as fog nodes that carry out a number of different functions. These WSNs are less powerful in terms of bandwidth, energy consumption, and processing power [7].

5.5. HEALTHCARE AND ACTIVITY TRACKING

Fog computing has several applications in healthcare. It enables instantaneous processing and responses to events, both of which are vital in the medical field [29]. Moreover, a stable network connection is currently lacking, which is a major barrier to the interoperability of a huge figure of healthcare equipment for the widespread storage, manipulating, and cloud-based medical record retrieval. Issues with traffic and network connectivity are also addressed [30].

6. CHALLENGES IN FOG COMPUTING

Many different Internet of Things (IoT) applications could benefit from the fog computing paradigm, but it also has a number of limitations that prevent it from being broadly adopted. Some of the difficulties that must be overcome are scalability, complexity, heterogeneity, latency, and security.

6.1. SCALABILITY:

With billions of connected devices, the Internet of Things generates and stores vast volumes of data, which in turn requires vast amounts of computing power and memory. Therefore, fog servers must be sufficiently powerful to accommodate such a large number of endpoints. The main challenge will be in being able to retort to the exponential growth of IoT gadgets and usages [31, 32].

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6.2. COMPLEXITY:

With so many IoT device and sensor manufacturers on the market, it can be tough to determine which ones will meet your specific needs and objectives, especially when factoring in the wide range of possible software and hardware combinations. In addition, the usage of specialized hardware and protocols is a prerequisite for some applications that have stringent security requirements, which further complicates the process [31].

6.3. DYNAMICITY:

One of the most significant benefits of IoT devices is their capability to adapt and energetically modify the configuration of their workflows. This problem will affect the features and functionality of IoT gadgets on the inside. In addition, as mobile devices' software and hardware age, the devices' workflow behaviour and characteristics shift. As a result, fog nodes will need to have their topological structure and resources automatically reconfigured in a highly complex manner [31].

6.4. HETEROGENEITY:

Various companies produce a wide range of IoT gadgets and sensors. These gadgets come equipped with a wide range of radios for communication, sensors, processors, memory, and other functions. A significant challenge of managing and coordinating networks with a variety of IoT devices and choosing the right resources will be important. [28].

6.5. LATENCY:

One of the primary advantages of fog computing over cloud computing, especially for time-sensitive applications, is its lower latency. However, excessive delay in the functioning of applications or services on fog computing systems is caused by a number of factors. Fog's extreme latency will cause user dissatisfaction [32].

6.6. SECURITY:

While the same policies, controls, and processes for protecting cloud nodes, as well as the same physical security and cyber security solutions [27], will be necessary for protecting fog nodes, the fog atmosphere itself is susceptible and ill-protected. Existing cloud computing safety and confidentiality assessments cannot be readily applied to the fog because of its mobility, heterogeneity, and large-scale geo-distribution [33].

7. OPEN ISSUES IN FOG COMPUTING

In this piece, we will review the current challenges and potential new challenges in fog computing research and how it connects to the Internet of Things.

7.1. COMMUNICATIONS BETWEEN THE FOG AND THE CLOUD

Cloud computing, of which fog computing is a subset, acts as an overarching system administrator for dispersed fog servers around the world. All of the system's programmes and data are stored and managed in the cloud. A fog where only a few of locally installed apps are provided and synced with the cloud [34].

Since the cloud serves two purposes, communications sessions created by fog node processing can interfere with cloud-to-fog data transfer and updates. In order to guarantee the high performance and low latency of fog nodes, figuring out the optimal fog-cloud connection is a significant challenge [31].

7.2. COMMUNICATIONS BETWEEN FOG SERVERS

A common pool of resources spread across various data centres is managed by each fog server. To ensure service delivery and content, coordination and communication across fog servers are required. Better communication is the key to a high-performing system [31].

In order to successfully share information across fog servers, some obstacles must be surmounted. Fog servers, for instance, need service policies to let them adjust to the varying requirements of their many owners, especially if they are deployed in numerous places with different types of entities [35]. Furthermore, when sending data among fog servers, connectivity issues must be taken into account.

7.3. FOG COMPUTING DEPLOYMENT

In order to quickly respond to service requests in a given area, fog computing enhances the edge of the system with additional processing and storage capacity. Since fog servers can be located everywhere, they must adapt their services to the unique administrative and maintenance requirements of each spot. Furthermore, the fog computing system's network operator requires to cooperate between the application and the fog server to meet the needs of each IoT [31].

7.4 SECURITY

Many precautions must be taken to ensure the safety of data stored in the cloud, but these risks have been thoroughly researched. The mobility, heterogeneity, and widespread geo-distribution that characterise fog computing render these methods inefficient [33, 36]..

7.5 END USER PRIVACY

Due to their proximity to end-users, fog nodes are able to more delicate information, such as monetary and personal details, as well as information about how and where utilities are used [33]. Furthermore, centralised control is challenging to sustain because Fog nodes are dispersed over a wide area.. Attackers can enter the network and giveaway user data that is being transmitted between fog objects if the fog nodes themselves are not properly secured [37, 38]. Privacy protection in fog nodes is a interesting subject that needs more study.

8. CONCLUSION

Recent years have seen a rise in interest in the Internet of Things by academic and corporate institutions alike. It is slowly becoming a habit that we can't live without. It can link nearly everything in our environment to everything else. Internet of Things gadgets are naturally dynamic, yet they have limited storage and processing capacity. However, there are drawbacks to the usual centralised cloud, such as increased latency and a greater chance of network outages. The solution to these problems IoT devices are more compatible with fog computing, which is an extension of the cloud where all data processing takes place at fog nodes to reduce latency, particularly for time-sensitive applications.. Several IoT applications can benefit from fog computing's incorporation into the IoT. This research looks at the current status of fog computing, discussing its features, architecture, and advantages. Several Internet of Things (IoT) applications that can take use of the fog were also discussed. Both the successes and failures of previous attempts to combine the IoT and fog are examined. The aim of this study is to deliver a appraisal that summarises current research on fog computing, the Internet of Things, and their applications in the real world, and to show where the field of fog computing and the Internet of Things could go in the future and what questions still need to be answered.

REFERENCES:

[1] Atlam, H.F.; Alenezi, A.; Walters, R.J.; Wills, G.B. An Overview of Risk Estimation Techniques in Risk-based Access Control for the Internet of Things. In Proceedings of the 2nd International Conference on Internet of Things, Big Data and Security (IoTBDS 2017), Porto, Portugal, 24–26 April 2017; pp. 254–260.

[2] Giang, N.; Kim, S.; Kim, D.; Jung, M.; Kastner, W. Extending the EPCIS with Building Automation Systems: A New Information System for the Internet of Things. In Proceedings of the 2014 Eighth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, Birmingham, UK, 2–4 July 2014; pp. 364–369.

[3] Atlam, H.F.; Alenezi, A.; Hussein, R.K.; Wills, G.B. Validation of an Adaptive Risk-Based Access Control Model for the Internet of Things. Int. J. Comput. Netw. Inf. Secure. 2018, 10, 26–35. [CrossRef

[4] Atlam, H.F.; Alenezi, A.; Alharthi, A.; Walters, R.; Wills, G. Integration of cloud computing with the internet of things: challenges and open issues. In Proceedings of the 2017 IEEE 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 (Smart Data), Exeter, UK, 21–23 June 2017; pp. 670–675.
[5] Ai, Y.; Peng, M.; Zhang, K. Edge cloud computing technologies for the internet of things: A primer. Digit. Commun. Netw. 2017, in press. [CrossRef]
[6] Bonomi, F.; Milito, R.; Zhu, J.; Addepalli, S. Fog computing and its role in the internet of things. In Proceedings of the First Edition of the MCC Workshop on Mobile Cloud Computing-MCC '12, Helsinki, Finland, 17 August 2012; pp. 13–15.
[7] Peter, N. Fog Computing and Its Real-Time Applications. Int. J. Emerg. Technol. Adv. Eng. 2015, 5, 266–269.
[8] Wen, Z.; Yang, R.; Garraghan, P.; Lin, T.; Xu, J.; Rovatsos, M. Fog orchestration for the internet of things services. IEEE Internet Comput. 2017, 21, 16–24. [CrossRef]
[9] Yang, Y. FA2ST: Fog as a Service Technology. In Proceedings of the 2017 IEEE 41st IEEE Annual Computer Software and Applications Conference, Turin, Italy, 4–8 July 2017; p. 708
[10] Chiang, M.; Zhang, T. Fog and IoT: An Overview of Research Opportunities. IEEE Internet Things J. 2016, 3, 854–864. [CrossRef]
[11] Aazam, M.; Huh, E.N. Fog computing and smart gateway based communication for a cloud of things. In Proceedings of the 2014 International Conference on Future Internet of Things Cloud, FiCloud 2014, Barcelona, Spain, 27–29 August 2014; pp. 464–470.
[12] Atlam, H.F.; Alenezi, A.; Walters, R.J.; Wills, G.B.; Daniel, J. Developing an adaptive Risk-based access control model for the Internet of Things. In Proceedings of the 2017 IEEE 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 (Smart Data), Exeter, UK, 21–23 June 2017; pp. 655–661.
[13] Liu, Y.; Fieldsend, J.E.; Min, G. A Framework of Fog Computing: Architecture, Challenges, and Optimization. IEEE Access 2017, 4, 1–10. [CrossRe
[14] Shi, Y.; Ding, G.; Wang, H.; Roman, H.E.; Lu, S. The fog computing service for healthcare. In Proceedings of the 2015 2nd International Symposium on Future Information and Communication Technologies for Ubiquitous HealthCare (Ubi-HealthTech), Beijing, China, 28–30 May 2015; pp. 1–5.
[15] Mukherjee, M.; Shu, L.; Wang, D. Survey of Fog Computing: Fundamental, Network Applications, and Research Challenges. IEEE Commun. Surv. Tutor. 2018, PP. [CrossRef]
[16] Aazam, M.; Huh, E.N. Fog computing micro datacenter based dynamic resource estimation and pricing model for IoT. Proc. Int. Conf. Adv. Inf. Netw. Appl. AINA 2015, 2015, 687–694.
[17] Muntjir, M.; Rahul, M.; Alhumyani, H.A. An Analysis of Internet of Things (IoT): Novel Architectures, Modern Applications, Security Aspects and Future Scope with Latest Case Studies. Int. J. Eng. Res. Technol. 2017, 6, 422–447.
[18] Aazam, M.; Hung, P.P.; Huh, E. Smart Gateway Based Communication for Cloud of Things. In Proceedings of the 2014 IEEE Ninth International Conference on Intelligent Sensors, Sensor Networks, and Information Processing, Singapore, 21–24 April 2014; pp. 1–6
[19] Marques, B.; Machado, I.; Sena, A.; Castro, M.C. A Communication Protocol for Fog Computing Based on Network Coding Applied to Wireless Sensors. In Proceedings of the 2017 IEEE International Symposium on High-Performance Computer Architecture, Vosendorf, Austria, 24–28 February 2017; pp. 109–114.
[20] Mouradian, C.; Naboulsi, D.; Yangui, S.; Glitho, R.H.; Morrow, M.J.; Polakos, P.A. A Comprehensive Survey on Fog Computing: State-of-the-art and Research Challenges. IEEE Commun. Surv. Tutor. 2017, 20, 416–464
[21] Agarwal, S.; Yadav, S.; Yadav, A.K. An Efficient Architecture and Algorithm for Resource Provisioning in Fog Computing. Int. J. Inf. Eng. Electron. Bus. 2016, 8, 48–61. [CrossRef
[22] Mouradian, C.; Naboulsi, D.; Yangui, S.; Glitho, R.H.; Morrow, M.J.; Polakos, P.A. A Comprehensive Survey on Fog Computing: State-of-the-art and Research Challenges. IEEE Commun. Surv. Tutor. 2017, 20, 416–464.
[23] Agarwal, S.; Yadav, S.; Yadav, A.K. An Efficient Architecture and Algorithm for Resource Provisioning in Fog Computing. Int. J. Inf. Eng. Electron. Bus. 2016, 8, 48–61. [CrossRef]
[24] Atlam, H.F.; Alassafi, M.O.; Alenezi, A.; Walters, R.J.; Wills, G.B. XACML for Building Access Control Policies in the Internet of Things. In Proceedings of the 3rd International Conference on Internet of Things, Big Data and Security (IoTBDS 2018), Setúbal, Portugal, 19–21 March 2018; pp. 253–260.
[25] Ketel, M. Fog-Cloud Services for IoT. In Proceedings of the Southeast Conference, Kennesaw, GA, USA, 13–15 April 2017; pp. 262–264.

[26] Skarlat, O.; Schulte, S.; Borkowski, M.; Leitner, P. Resource provisioning for IoT services in the fog. In Proceedings of the 2016 IEEE 9th International Conference on Service-Oriented Computing and Applications, SOCA 2016, Macau, China, 4–6 November 2016; pp. 32–39.
[27] Fog Computing and the Internet of Things: Extend the Cloud to Where the Things Are. White Paper. 2016.
[28] Yi, S.; Hao, Z.; Qin, Z.; Li, Q. Fog computing: Platform and applications. In Proceedings of the 3rdWorkshop on Hot Topics in Web Systems and Technologies, Hot Web 2015, Washington, DC, USA, 24–25 October 2016; pp. 73–78.
[29] Nikoloudakis, Y.; Markakis, E.; Mastorakis, G.; Pallis, E.; Skianis, C. An NF V-powered emergency system for smart enhanced living environments. In Proceedings of the 2017 IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN), Berlin, Germany, 6–8 November 2017; pp. 258–263.
[30] Dastjerdi, A.V.; Buyya, R. Fog Computing: Helping the Internet of Things Realize Its Potential. IEEE Comput. Soc. 2016, 112–116. [CrossRef]
[31] Luan, T.H.; Gao, L.; Li, Z.; Xiang, Y.; Wei, G.; Sun, L. Fog Computing: Focusing on Mobile Users at the Edge. arXiv 2015, arXiv: 1502.01815.
[32] Choi, N.; Kim, D.; Lee, S.; Yi, Y. Fog Operating System for User-Oriented IoT Services: Challenges and Research Directions. IEEE Commun. Mag. 2017, 55, 2–9. [CrossRef]
[33] Mukherjee, M.; Matam, R.; Shu, L.; Maglaras, L.; Ferraz, M.A.; Choudhury, N. Security, and Privacy in Fog Computing: Challenges. IEEE Access 2017, 5, 19293–19304. [CrossRef]
[34] Giang, N.K.; Blackstock, M.; Lea, R.; Leung, V.C.M. Developing IoT applications in the Fog: A Distributed Dataflow approach. In Proceedings of the 5th International Conference Internet Things, IoT 2015, Seoul, Korea, 26–28 October 2015; pp. 155–162
[35] Alenezi, A.; Zulkipli, N.H.N.; Atlam, H.F.; Walters, R.J.; Wills, G.B. The Impact of Cloud Forensic Readiness on Security. In Proceedings of the 7th International Conference on Cloud Computing and Services Science (CLOSER 2017), Porto, Portugal, 24–26 April 2017; pp. 511–517.
[36]. Hu, P.; Ning, H.; Qiu, T.; Song, H.; Wang, Y.; Yao, X. Security and Privacy Preservation Scheme of Face Identification and Resolution Framework Using Fog Computing in the Internet of Things. IEEE Internet Things J. 2017, 4, 1143–1155.
[37] Wang, L.; Liu, G.; Sun, L. A secure and privacy-preserving navigation scheme using spatial crowdsourcing in fog-based VANETs. Sensors 2017, 17, 668. [CrossRef] [PubMed]
[38] Al Hamid, H.A.; Rahman, S.M.M.; Hossain, M.S.; Almogren, A.; Alamri, A. A Security Model for Preserving the Privacy of Medical Big Data in a Healthcare Cloud Using a Fog Computing Facility with Pairing-Based Cryptography. IEEE Access 2017, 5, 22313–22328.