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Fog Computing: A Look on Present Scenario and Hopes for Future Research

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Abstract - According to the forecast that billions of devices will get connected to the Internet by 2020. All these devices will produce a huge amount of data that will have to be handled rapidly and in a feasible manner. It will become a challenge for real-time applications to handle this huge data while considering security issues as well as time constraints. The main highlights of cloud computing are on-demand service and scalability; therefore the data generated from IoT devices are generally handled in cloud infrastructure. Though, dealing with IoT application requests on the cloud exclusively is not a proficient result for some IoT applications particularly time-sensitive ones. These issues can be settled by utilizing another idea called, Fog computing. Fog computing has become one of the major fields of research from both academia and industry perspectives. The ongoing research commitments on few issues in fog computing are figuring out in this paper. At long last, this paper also highlights some open issues in fog with IoT, which will determine the future research direction for implementing Fog computing paradigm.

Keywords - Fog computing, Internet-of-Things, Cloud computing, Cloud-based IoT.

I. INTRODUCTION

Basic Concepts

This section reviews the fundamental ideas of Internet-of-Things and cloud computing.

Internet-of-Things

Nowadays Internet-of-Things (IoT) gained an extraordinary consideration from researchers since it turns into a significant innovation that guarantees a smart human being life, by allowing communication between objects, machines and everything together with peoples. The Internet-of-Things alludes to particularly recognizable objects and their virtual portrayals in the framework of the Internet.[1][2] IoT mentions to day to day objects, which are decipherable, identifiable, traceable, addressable, or potentially manageable via the Internet using RFID[3], wide area network, remote LAN, or other means. These kinds of objects includes not just everyday usable electronic gadgets or highly innovate products, but also include things such as automobiles and hardware, as well as incorporate things like nutrition, apparel, and shelter; materials, parts and subassemblies; products and extravagance things; landmarks, boundaries and monuments; and all the variety of business and culture.[4] When every one of these objects is associated with one another, they empower increasingly and more intelligent processes and services that support your fundamental needs, economies, environment, and health. The idea of the IoT was first referenced by Kevin Ashton of Procter & Gamble, later MIT's Auto-ID centre, in 1999,[5] when he expressed that “The Internet of Things can possibly change the world, similarly as the Internet did, maybe even more so.” Pervasive processing alludes to an innovative type of computing in which the gadgets are totally pervaded into a user’s life.[6].

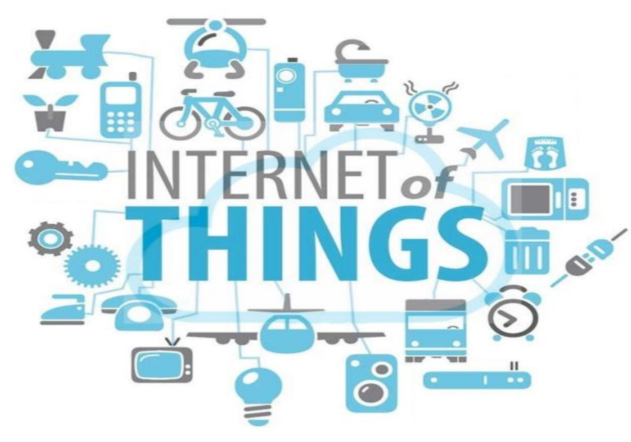

Figure 1. Internet-of-Things

Cloud Computing

Cloud computing is the delivery of computing resources (hardware and software) that are delivered as a service over a network (normally the Internet).[7] In an October 2009 presentation titled **"Effectively and Securely Using the Cloud Computing Paradigm,"**[8] by Peter Mell and Tim Grance of the National Institute of Standards and Technology Information Technology Laboratory, Cloud computing defined as follows:

"Cloud Computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models."[9]

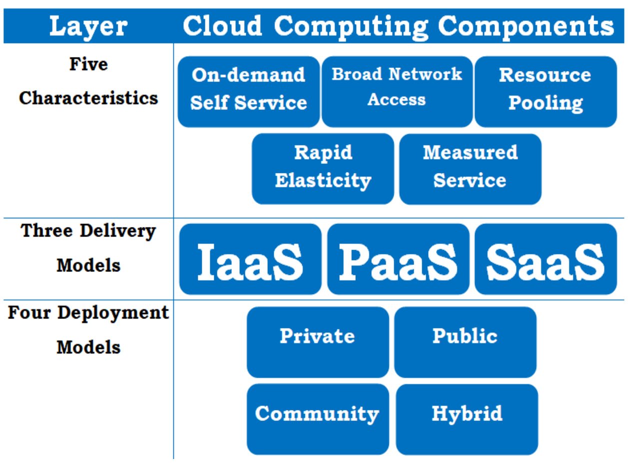

Figure 2. A visual model of cloud computing definition

II. CLOUD OF THINGS: CLOUD IOT INTEGRATION

The Internet of Things will soon reach a phase when each and everything around you will be connected to the internet. IoT and cloud computing has progressed in a manner to bring many numerous noteworthy points of interests to various IoT applications. The IoT produces a massive amount of data, and cloud computing provides a pathway for this data to travel in a cost-effective manner. IoT and cloud computing working in integration makes a new paradigm, which is called Cloud of Things. [10] Internet of everything is presently turning into a need to ease different exercise in enterprises as well as household applications. It has a key role in designing smart homes, smart industries and smart cities as well. Despite the fact the cloud computing gives several advantages to both users and service providers compared to traditional computing paradigms, it has certain impediments too.[11] The conspicuous constraints of cloud computing include the necessity of high-speed reliable internet availability, high latency, undefined security, and so on.[12][13] A massive amount of data is delivered by the sensors and applications in IOT, the cloud, as a centralized server, may confront issues like high latency, network failure, inadequate storage, high computational power, and so forth.[14] The emerging trends in networking such as large distributed internet-connected sensor networks, Internet-of-Things, mobile data network and real-time applications have qualities that can't be fulfilled by cloud computing. Therefore, an advanced cloud computing paradigm that improves the limit and latency imperatives is required to deal with these difficulties.[15] Cisco recommended new innovation called fog computing to address the greater part of these difficulties. [16]

III. FOG COMPUTING

It is a new technology that gives numerous advantages to various fields, especially the IoT. This new innovation called Fog computing focuses around conveying the cloud closer to end devices. Fog computing is an intermediate layer among cloud and IoT devices.[17] The fog nodes will communicate with terminal nodes at one side and cloud on the other side shown in figure 3. The fog nodes are designed in such way where the data is managed and processed at the edge of the network, instead of routing it through a central data center in the cloud, hence reducing network traffic and latency,[18] which is a critical issue while dealing with real-time applications such as navigation, in cloud-of-things.

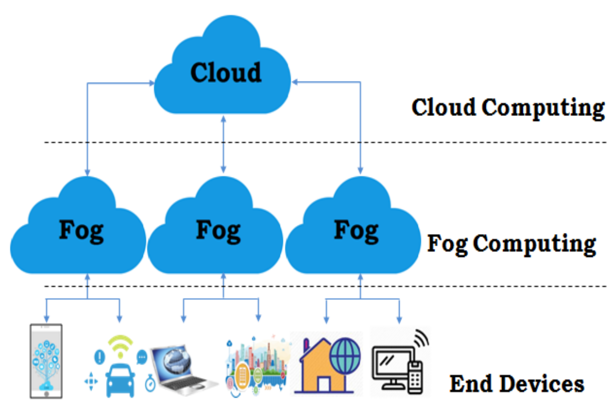

Figure 3. Fog computing is an extension of the cloud but closer to end devices.

The reason behind fog computing in the IoT is to improve efficiency and reduce the amount of data that needs to be transported to the cloud. Rather than utilizing the cloud as a single server, the distributed approach of fog computing is used to diminish the computational power and storage limit. The fog nodes have significant storage and computational abilities to deal with the devices in their region. The fog computing stage has an expansive scope of uses. Bonomi et al. have presented fog computing scenarios in the connected vehicle, smart grid, smart cities, and in general remote sensors and Actuators Networks.

Pros of Fog Computing
Fog computing has numerous advantages for IoT applications as summarized below.[19][20] Here are the main advantages of fog computing over cloud computing.
Low Latency: There are certain latency sensitive real-time applications where emergency responses are required. With compare to cloud computing, Fog computing assures low latency.
Scalability: As fog node is nearer to the end devices, it can enable to scale the number of connected devices and services.
Real-time: Fog has the potential to provide better performance for real-time interactive services.
Interoperability: IoT brings distinctive devices having a diverse set of rules. Fog nodes are fit for interoperating with different rules.
Distributed Approach: The distributed approach of fog computing help to decrease the overall storage and computational resources required.

Challenges of Fog Computing with the IoT
Despite the fact that there are numerous amazing benefits to adopting fog computing, there are several noteworthy barriers that stand in the way of its successful deployment. Figure 4 shows some of the research challenges confronted while implementing fog computing with IoT.[21][22][23][24]

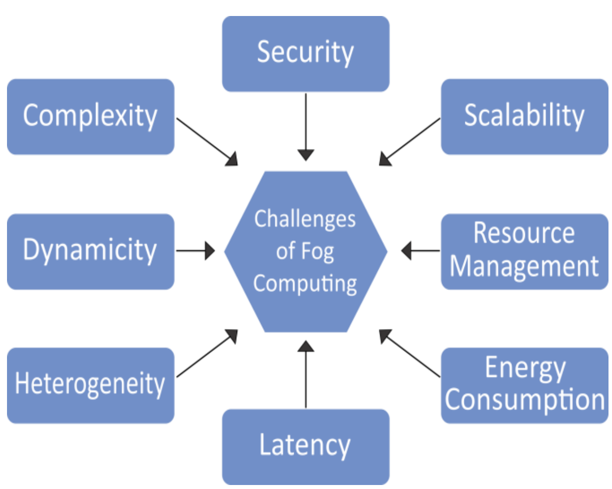

Figure 4. Challenges in Fog Computing with the IoT

Scalability: The number of IoT devices in the order of billions, which creates a massive amount of data and requires an immense measure of resources such as processing power and storage. Therefore, fog servers ought to have the capacity to help all of these devices with sufficient resources. The real challenges will be the capability to react to the quick development of IoT devices and applications.

Resource Management: Fog computing requires fog servers and data storage facilities at the edge of the system to accelerate the processing. The administration of extra computing and storage resources presents management and maintenance costs. In this manner, research should concentrate on a fog-based framework to be legitimately dissected for viable management of fog servers.

Energy Consumption: The fog environment includes an extensive number of fog end devices; the computation is distributed and can be less vitality proficient than the centralized cloud model of computation. In this way, diminishing vitality consumed in fog computing is an imperative challenging that should be tended to.

Latency: Latency is an imperative parameter to view. Low Latency was the principle motivation to convey cloud server closer to the end device through the fog. Henceforth, if latency necessity isn't fulfilled, the execution would be degraded resulting in user disappointment.

Heterogeneity: There are a variety of IoT devices and sensors communicating with fog servers. They may have distinctive conventions, storage capabilities, sensor characteristics, and so on. The coordination between these devices and fog server as well as correspondence between geographically distributed fog servers is a big challenge.

Dynamicity: One of the important highlights of the IoT device is the capacity to evolve and dynamically change their work process arrangement. This challenge will change the internal properties and execution of IoT devices. In addition, handheld devices suffer from hardware and software ageing, which will bring about changing work process conduct and device properties. Consequently, fog nodes will require programmed and intelligent reconfiguration of the topological structure and assigned resources.

Complexity: Since there are numerous IoT devices and sensors planned by different manufacturers, choosing the optimal components is becoming very entangled, particularly with various hardware and software setups and individual necessities. Moreover, in some cases, applications with high-security requirements require explicit hardware and protocols to work, which builds the trouble of the task.

Security: Since fog nodes are at the edge of the system, these are increasingly included in the cyber assault. The procedures that are used in cloud computing for security purpose are not suitable for fog computing in light of various formats, portability and heterogeneity. Along these lines, more research is required to guarantee security in fog-based frameworks.

IV. OPEN ISSUES OF FOG WITH THE IOT

It is clear that fog computing is a new innovation that needs more research to address all the challenges mentioned in this paper. This section provides an outline of the open issue as well as future research directions related to fog computing and its reconciliation with the IoT.

Communications between the Fog and the Cloud

Fog computing is an extension of the cloud, which is a central controller of fog servers that are deployed at different locations. The cloud manages the applications and contents of the whole framework. In a fog, just particular confined applications are provisioned and synchronized with the cloud.[25] With the dual functions of the cloud, the data delivery and update from the cloud to fog face issues identified with communications sessions created during the processing of fog nodes. Choosing the best possible communication between the fog and the cloud that guarantees high performance and low latency of fog nodes is a key challenge.[26]

Communications between Fog Servers

Each fog server deals with a pool of resources at various locations. Correspondence and coordinated effort between fog severs are important to keep up administration arrangement and content delivery between them. In the event that the correspondence effectiveness is expanded, the execution of the whole framework will be improved. The data transmission between fog servers faces numerous provokes that ought to be tended to. For instance, there is a requirement for administration strategies where fog servers are deployed at various locations with different entities to empower them to adjust various approaches characterized by proprietors.[27] Furthermore, the data transmission between fog servers needs to consider association highlights. As such, fog servers should most likely interface with one another using either wired or a remote connection over the Internet.[28]

Fog Computing Deployment

Fog computing places additional computing and storage resources at the edge of the system to process local service requires rapidly using local resources. As fog servers are deployed at various locations, they have to adjust their services in regards to the management and upkeep costs. Moreover, the system administrator of fog computing systems needs to address the prerequisites of each IoT application and fog server collaboration.

Parallel Computation Algorithm

Optimization algorithms are typically time and resource-consuming when connected on a vast scale. Consequently, parallel methodologies will be expected to accelerate the optimization procedure. Since fog computing provides computing resources to billions of IoT devices, using an effective calculation will be important to work with vast scale IoT applications.[29] Some present work gives potential outcomes to use an in-memory computing framework to perform activities in a cloud framework. However, building a system with dynamic graph generation and partitioning at runtime still needs more research, particularly where the system needs to adjust to dynamically and countless IoT components. [30]

Security

There are well-examined security issues for cloud computing that required significant security measures to ensure the cloud. However, these measures are not appropriate for fog computing because of their diverse characteristics, outstandingly portability, heterogeneity and large-scale geo-distribution.[31] In addition, the fog is an appealing target for cyber-attackers since the fog contains huge volumes of sensitive data from both the cloud and IoT devices. In this manner, more research is required to improve fog security.

End User Privacy

Privacy-Preserving the end user's privacy is a significant issue that faces fog computing as fog nodes are closer to end users, which enable them to collect more sensitive data including financial records, identity, location and other. Moreover, as fog nodes are distributed in large regions, keeping up concentrated control is exceptionally troublesome. Unsecured fog nodes can be an entry point for an adversary who can get into the system and steal user data that are transferred among fog devices. Ensuring the security of fog nodes is a challenging issue that requires more research. [32][33]

V. EVALUATION

For practical evaluation, fog computing platform, consisting of two fog sub-systems and install OpenStack on each of them. To be more specific, installed four OpenStack modules: Keystone, Glance, Nova, and Cinder. Keystone is for authentication and authorization; Glance is for VM image management; Nova is a registered module with simple network functionality, and Cinder is the block-level storage module. Here two fog sub-systems are two separate OpenStack frameworks, with a system interface between them. To support service continuity, implement a VM offloading scheme which can migrate one VM to another fog cluster. As illustrated in Figure 4, each of the fog sub-systems possesses one router and three servers. The routers are connected to the Amazon EC2 cloud through WAN, as well as connected with each other through LAN. The routers are also integrated with Wireless AP function so that mobile devices can access the fog as well as the Amazon EC2 cloud through them. In the following, we present some fundamental outcomes dependent on significant execution measurements. First, compare the latency and bandwidth provided by fog and cloud using RTT (Round Trip Time) as the metric of latency, and measure both uplink and downlink transmission capacity.

VI. RESULTS AND DISCUSSION

The outcomes are shown in Table 1. The outcomes show that fog computing has strong advantages regarding low latency and high data transfer capacity for clients.

Table 1. Latency and Bandwidth Comparison

	RTT (ms)	**Up/Downlink Bandwidth (Mbps)**
Fog	1.416	83.723/101.918
Cloud	17.989	1.785/1/746

VII. CONCLUSION AND FUTURE SCOPE

Fog computing is an emerging area for IoT applications. Fog computing is a transitional layer between the cloud and end users. In fog computing systems, a major part of computing and processing of IoT data is performed at the fog nodes which decrease the value of response time in case of latency-sensitive apps. In this research paper, our goal was to review open challenges in fog computing in the world so that the functionality and parameters used by these cases could be used for future research directions. This review talked about the improvement in the execution of these use cases considering various parameters. We additionally displayed the difficulties faced by fog computing and the exploration commitments to deal with challenges of fog computing. Based on the survey, we have highlighted some serious issues which are should have been tended while integrating fog computing with IoT.

REFERENCES

[1] L. Coetzee, J. Eksteen, The Internet of Things- Promise for the Future? An Introduction, IST Africa 2011, http://www.ISTafrica.org/Conference 2011

[2] L. Atzori et al., The Internet of Things: A survey, Comput. Netw.(2010), doi:10.1016/j.comnet.2010.05.010.

[3] Bolivar Torres et.al., Integration of an RFID reader to a wireless sensor network and its use to identify an individual carrying RFID tags, International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC) Vol.1, No.4, December 2010

[4] B. B. P. Rao, P. Saluia, N. Sharma, A. Mittal and S. V. Sharma, "*Cloud computing for the Internet of Things & sensing based applications,*" 2012Sixth International Conference on Sensing Technology (ICST), Kolkata, pp. 374-380, 2012.

[5] G. Joshi and S. Kim, “Survey, Nomenclature and Comparison of ReaderAnti-Collision Protocols in RFID,” IETE Tech. Rev.,Vol. 25, no. 5,

[6] R. Jason Weiss, Development Dimensions International. J. Philip Craiger, University of Nebraska–Omaha

[7] S. Maharajothi, Dr S. Adaekalavan: Deadline Based Resource Provisioning and Scheduling Algorithm for Scientific Workflows on Clouds, International Journal of Advance Research in Computer Science and Management Studies, Vol 4, Issue. 8, pp 60-66, August 2016, ISSN: 2321-7782 (Online)

[8] NIST, (2009). *“Presentation on Effectively and Securely Using the Cloud Computing Paradigm v25,”* http://csrc.nist.gov/groups/SNS/cloudcomputing/cloud-computing-v25.ppt, on August 29, 2009

[9] P. Mell and T. Grance: *“The NIST definition of cloud computing (v15),”* National Institute of Standards and Technology, Version 15, 10-7-09.

[10] Aazam, M., Huh, E.-N.: Fog computing and smart gateway based communication for a cloud of things. In: The Proceedings of IEEE Future Internet of Things and Cloud (FiCloud), Barcelona, Spain, pp. 27–29, 2014

[11] M.M. Islam, S.Morshed, and P.Goswami, *"Cloud computing: A survey on its limitations and potential solutions," International Journal of Computer Science Issues*, Vol.10, no.4, pp. 159--163, 2013.

[12] E.O. Yeboah-Boateng and K.A. Essandoh, *"Factors influencing the adoption of cloud computing by small and medium enterprises in developing economies," International Journal of Emerging Science and Engineering*, Vol.2, no.4, pp. 13--20, 2014.

[13] R.P. Padhy and M.R. Patra, *"Managing IT operations in a cloud-driven enterprise: Case studies," American Journal of Cloud Computing*, Vol.1, no.1, pp. 1--18, 2013.

[14] 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 (SmartData), Exeter, UK, 21–23, pp. 655–661, June 2017;

[15] Ai, Y.; Peng, M.; Zhang, K. Edge cloud computing technologies for the internet of things: A primer. Digit.Commun. Netw. 2017, in press.

[16] 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 pp. 13–16, August 2012

[17] \Manzalini and N. Crespi, *“An Edge Operating System Enabling Anything-as-a-Service,”* IEEE Commun. Mag., Vol. 54, no. 3, pp. 62–67, Mar. 2016.

[18] Wen, Z.; Yang, R.; Garraghan, P.; Lin, T.; Xu, J.; Rovatsos, M. Fog orchestration for internet of things services.IEEE Internet Comput., 21, 16–24, 2017

[19] Liu, Y.; Fieldsend, J.E.; Min, G. A Framework of Fog Computing: Architecture, Challenges and Optimization. IEEE Access, 4, 1–10, 2017.

[20] Peralta, G.; Iglesias-Urkia, M.; Barcelo, M.; Gomez, R.; Moran, A.; Bilbao, J. Fog computing based efficient IoT scheme for the Industry 4.0. In Proceedings of the2017 IEEE International Workshop of Electronics, Control, Measurement, Signals and

their application to Mechatronics, San Sebastian, Spain,; pp.1–6, 24–26 May 2017
[21] 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.
[22] 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.
[23] Mukherjee, M.; Matam, R.; Shu, L.; Maglaras, L.; Ferrag, M.A.; Choudhury, N. Security and Privacy in Fog Computing: Challenges. IEEE Access **2017**, 5, 19293–19304.
[24] 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, HotWeb 2015, Washington, DC, USA, pp. 73–78, 24–25 October 2016
[25] 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, pp. 155–162, 26–28 October 2015
[26] Ketel, M. Fog-Cloud Services for IoT. In Proceedings of the Southeast Conference, Kennesaw, GA, USA, pp. 262–264, 13–15 April 2017
[27] 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, pp. 511–517, 24–26 April 2017
[28] Lee, K.; Kim, D.; Ha, D.; Rajput, U.; Oh, H. On security and privacy issues of fog computing supported the Internet of Things environment. In Proceedings of the 6th International Conference on the Network of the future (NOF), Montreal, QC, USA; 2015; pp. 1–3.
[29] Yin, B.; Shen, W.; Cheng, Y.; Cai, L.X.; Li, Q. Distributed resource sharing in fog-assisted big data streaming. In Proceedings of the 2017 IEEE International Conference on Communications, Chengdu, China, pp. 1–6, 27–30 October 2017
[30] Hung, C.L.; Yan, R.Y.; Wang, H.H. Parallel image dehazing algorithm based on GPU using fuzzy system and hybrid evolution algorithm. In Proceedings of the 2016 IEEE/ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD), Shanghai, China, pp. 581–583, 30 May–1 June 2016
[31] 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.
[32] Wang, L.; Liu, G.; Sun, L.A secure and privacy-preserving navigation scheme using spatial crowdsourcing in fog-based VANETs.Sensors 2017, 17, 668.
[33] 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.

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