ISSN 2278-3091
Volume 10, No.3, May - June 2021
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse751032021.pdf
https://doi.org/10.30534/ijatcse/2021/761032021

Fog Networks: A Prospective Technology for IoT

Urooj Yousuf Khan[1], Tariq Rahim Soomro[2]
[1]Institute of Business Management, Pakistan, urooj.yousuf@iobm.edu.pk
[2]Institute of Business Management, Pakistan, tariq.soomro@iobm.edu.pk

ABSTRACT

Cloud computing is currently the most sought-after solution for almost all of enterprise problems. Distinguishing features of the Cloud are ease of service and lesser hassle on the client end. These services come with a hefty price. Cloud services face issues of delay, slower connectivity and security. Fog Computing answers these downsides by providing nearer-to-ground and ever available Internet connection to nodes. Fog Computing relies on multiple, smaller clouds, nearer to ground.
Internet of Things is the next logical leap for Internet. It envisions creating an environment wherein various heterogeneous devices can communicate with each other via internet. Enabling Internet of Things requires uninterrupted Internet connection and an interpreter.
Both these features are intrinsically present in Fog Computing. Hence, this paper proposes Fog as the expected ground for enabling Internet of Things.

Key words: Fog Computing, Cloud Computing, Internet of Things.

1.INTRODUCTION

It is estimated that by 2030, 50 billion devices will be connected to the internet. The IoT is well-thought-out future of the internet. Internet of Things (IoT) is a networking concept that focuses on enabling devices to be connected to the internet and having a valid communication path. Several enabling technologies are currently in market. One of the path is to assign a valid IPV6 address to each node to act as identifier. Other defining paths include Low Energy Blue Tooth and Radio Frequency Infrared Detection (RFID). None of these technologies, however is robust enough to materialize IoT to its full potential. Internet of Things can revolutionize several fields such as health, education and development of smart cities.
A novel approach to visualizing IoT is the Fog Computing. Fog is an enhancement of the Cloud.Fog or haze computing implies multiple smaller clouds nearer to ground. There are multiple application areas of Fog. It includes connected devices, smart computing and wireless sensor /actuator networks. Enabling Internet of Things using Fog as a platform is a relatively newer concept. This implementation has several obvious advantages over other similar technologies. This paper discusses the possible implementation of IoT using Fog Computing. The paper is organized as follows: Section 2 covers the literature review. Section 3 explains Fog computing in greater detail. Section 4 concludes the paper by addressing the IoT challenges that can be answered by a Fog network. Section 5includes the references used.

2.LITERATURE REVIEW

Cloud computing is the trend of today. It encompasses a wide spectrum, ranging from centralized management to cellular core networks. Lately, however, there are some challenges. These challenges have emerged as Internet of Things takes a key place in tomorrow's technology. Future developments include information transmitting light bulbs, computers on the stick and button sized radio frequency tuners[1].

A.Fog Networks In The Past

Fog is "a cloud near to ground". It is a newer concept that aims at providing a layer between Cloud and nodes. Key features of the Fog are location sensitivity and lower latency as compared to Cloud[2]. There are many advantages if Fog networks are deployed properly[3]. Fog networks ensure that devices that require services locally are not transferred to the Cloud. Rather, they are entertained at the edge of the network[4].
The term Fog Computing or Haze is a networking idea that transports the Cloud to the edge of the network[5]. It implies creating a platform wherein device requests that require least services can be entertained at the edge instead of being transported to the Cloud. It is an intermediate network between the smart devices and the Cloud[4]. As already mentioned, distinguishing features of the Fog are lesser transmission delay, location sensing, extensive physical coverage and mobility [5].Fog devices are located between cloud and smart devices. Their swift backbone link to the cloud and location proximity to nodes enable real time applications to be processed in no time.[6]. Fog computing is an extension of the Cloud. In the Fog, a group of routers and nodes act as cloudlets[6]. Thus, Fog emulates an environment where in applications no longer need to access centralized data servers[4]. This corresponds to faster response and higher user rights to control their own data/applications. Applications can be visualized as small pieces of code that execute securely at the edge of the network[7].The presence of large number of sensors is only one of the many views of the Fog.

B.Internet Of Things(IoT)

Internet of Things: this term was devised by Kevin Ashton in 1999 [8]. Internet of Things aims at a rich interconnection and interaction of smart devices through a network of sensors and actuators[8].It can provide long lasting solutions in domains such as smart grids, security, education and consumer electronics[9].

For IoT to take its true form there are three proposed layers: hardware, middleware and presentation layer[8]. Hardware comprises of sensors and actuators. These devices are deployed at user level to ensure data collection. They can be heterogeneous in nature. The hardware part of the IoT can also comprise of embedded communication systems[8].The major emerging technologies at this layer include RFID and WSN[8].RFID acts as electronic barcode, thereby sending identity signals for any device attached [8].Wireless sensor networks or WSN are low power, cheap, small devices used for remote sensing and identification of the objects[8]. Other promising fields are those of optical tagging and Bluetooth Low Energy Devices[9].

The middle ware is generally considered a cloud server[8],[9].Cloud servers act as a translator layer between the lower layer heterogonous devices and higher homogenous presentation layer. Cloud servers provide ease of management, economic solutions; automatic backup and assured physical security[9]. Another popular middle ware realization is WSN-Middleware[8].It implies creating a middle ware that is platform independent[8].

In terms of presentation layer, there might be apps for every task[9].It also demands that our Web Services be extended so that each device may broadcast its URL[9].

Another option could be software identifiers for every device. These identifiers can also be IPV6 addresses that can be given to any device on the network[9].

C.IoT And Fog Networks

Fog computing extends the cloud computing paradigm and takes it to the edge of the network[5].

Cloud services face latency and intermittent connectivity issues[5]. As discussed earlier, Internet of Things is a concept that focuses on real time application processing originating from several heterogeneous nodes. For applications to be processed there is an ever-growing and uncompromising need for seamless internet backbone. Internet of Things, in fact, is the next generation of internet. Fog computing can be a valid platform for Internet of Things[5]. Fog computing ensures that nodes are always connected to a server for application processing. This embedded system of device-to-sensor or device-to-router can act as a Fog unit wherein requests sent by "things" that require interaction with in the same unit are entertained locally.

Besides, the requests to the server on the Cloud can be forwarded to the presentation layer. This proposed solution of deploying a Fog receiver can be a groundbreaking approach for implementing the Internet of Things in its full potential[5].

3.INSIDE A FOG NETWORK

This section explores the basic and detailed architecture of the Fog network. Key features of the Fog include large scale geographical coverage and interconnectivity to the cloud.Wide scale geographical coverage comprises of varied resources that require dispersed management.The figure 1 below shows one approach to the layered structure of Fog network.

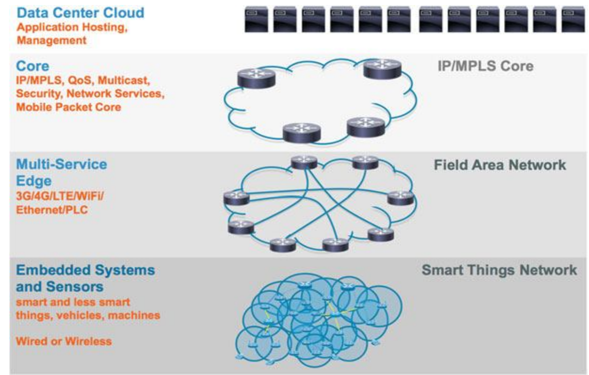

Figure 1: Layered Architecture of Fog Network[10]

The above figure clearly demonstrates the vast and varied nature of the Fog networks.The layered approach clearly comprises of four distinct layers ,beginning from the smart things at the bottom all the way to the Cloud at the top. The servies provided by this architecture include localized computations,processing,storage and network connections.This connectivity is vertical and horiozontal at the same time.Each service offered by this organization comprises of distinguished sub services.For instance,computing implies choice of optiml hypervisors;storage implies online and virtual space allocation whereas networking means selecting ideal support or the underlying structure[10].

An alternate,three layered approach is shown in Figure 2 below.

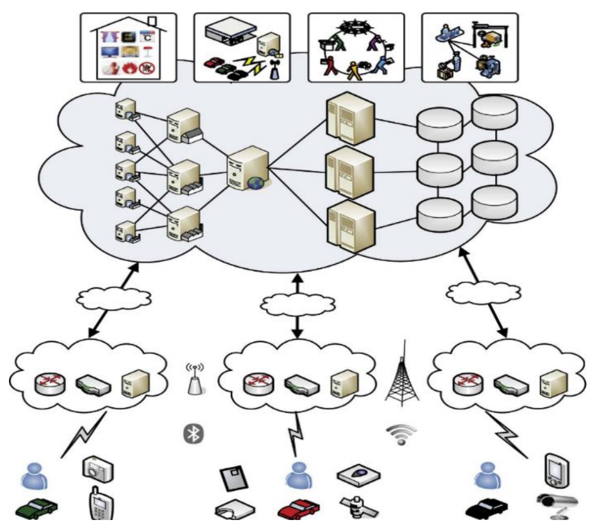

Figure 2: Three Layered Approach to Fog Architecture[11]

As can be seen clearly,there is no common,agreed upon layered architecture of the Fog.This is an alternate approach to demonstrate the way an ideal Fog architecture might be designed.

Figure 2 is also a hierarchical model that follows the Top-down approach.The defining feature of the Fog is clearly demonstrated:extendingthe user required services to the Edge of the network.These three layers are explained in detail below.

Terminal Layer:This layer is closest to the end user and majorly comprises of heterogenous devices and smart sensors. At this layer,the major challenge is data acquisition from varied sources.These sources range from embedded,IoT based devices to intelligent systems.These input components are geographically distributed. Moreover,these Fog nodes can be interlinked by a wired or a wireless network.Key wireless technologies in this layer include Wireless Local Area Network(WLAN),WiFi,4G,ZigBee etc.An underlying IP network links the Fog nodes to the Cloud.

*Fog Layer:*This is the distinguishing layer that sits between the End devices and the Cloud.This layer includes local routers,gateways,switches,access points,base stations etc.

Large scale geographical coverage include their placement in cafes,shopping centres,bus terminals etc.These nodes can be fixed at a predefined location or could be mobile.These nodes can provide localized storage,computation and real time analysis.Additionally,these nodes can obtain higher order services by connecting to the Cloud.

*Cloud Layer:*This layer is the backbone layer or the infra structure layer. It comprises of core routers,high performance servers and redundant storage systems. It is at this layer that powerful and computationally intensive jobs are performed.There is scheduling and sequencing and the jobs are not performed randomly[11]**.**

A detailed five layered architecture of Fog is also described below in figure 3[12].

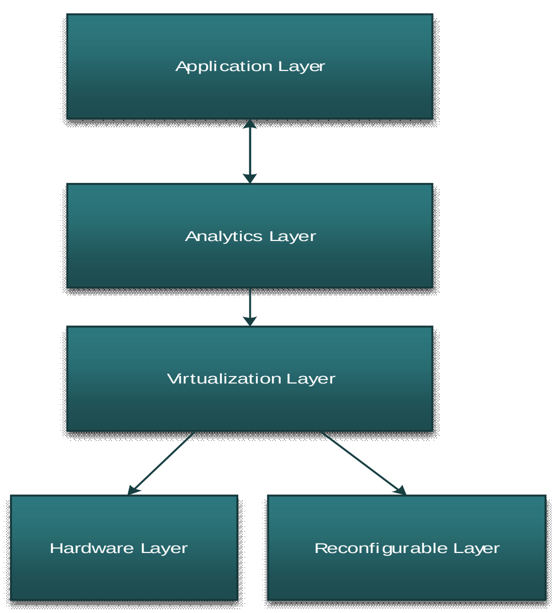

Figure 3: Five Layered Architecture of Fog[12]

The five distinct layers of the Fog architecture are application layer,analytics layer,virtualization layer,reconfiguration layer and hardware layer.These layers are described below.

*Application Layer:*This is the top most layer of the architecture. It consists of various application servers that provide numerous services. These services include computational offloading,data storage and management and other usercentred services.It is at this that smart devices connect to the Fog network.Effectively speaking,this is an abstraction layer that provides a standard platform for IoT users and developers.

*Analytics Layer:*This layer is further divided into three smaller modules:statistics module,machine learning module and power manager module.

The statisticsmodule is used by the aplication layer to moniter the utilization of software services.Machine learning module determines the required computational and hardware resources.Utilization of Edge server in terms of frequency and voltage is determined by the power manager module**..**

*Virtualization Layer:*The main purpose of this layer is abstraction and information hiding.This abstraction is between hardware resources and applications running on the network. In other words,virtualization layer acts as an IaaS.

*Reconfiguration Layer:*The main purpose of this layer is resource reconfiguration**.** It consists ofa manager and its controllable modules.This reconfiguration helps to better understand the dynanmic workloads under different demands.

*Hardware Layer:*This layer majorly works on the hardware management,operational voltages, frequencies and controllers.It includes various modules such as dynamic voltage and frequency scaling,storage controllers etc.Another significant module is for network management and connectivity.Thisconnectivity can be vertical connection between Cloud and Fog or a horizontal connectivity between Fog peers[12]**.**

Another alternate representation of Fog architecture is represented below in figure 4[13].

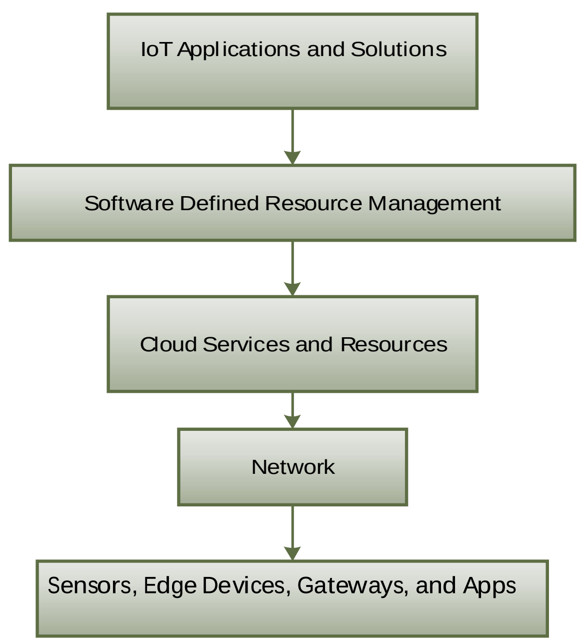

Figure 4: Alternate five layered Fog architecture[13]

The above figure shows the highlevel architectural diagram of Fog network.The bottom most layer comprises of smart devices,nearer to ground.It is imperative to note here that this layer also comprises of gateways.This layer uses the communication services of the next layer.The communication services are among themselves and between these devices and the Cloud.

The layer that sits above comprises of the Cloud services .These services include resourcemanagement and processing.The resource management ensures the quality of service to applications.

The software defined resource management module is worth mentionaing in detail.This layer comprises of multiple smaller modules such as work placement,knowledge base,performance prediction and security.This layer is essentially the middleware.The major purpose of this layer is to minimize the routing to the Cloud.Majority of these services reduce processing latency.

To conclude,the topmost layer is made up of applications that provide support and backup to Fog computing framework[13]**.**

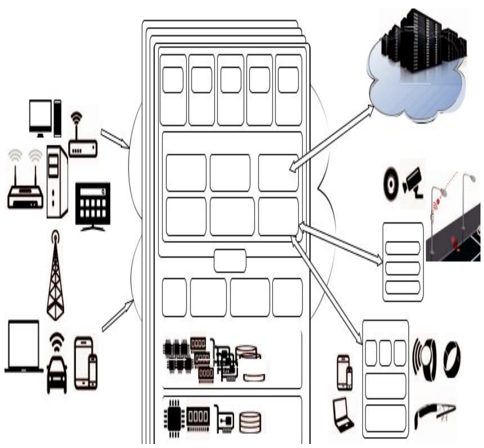

Figure 5: Components in a Fog Network[14]

Figure 5 sums up the architecture for Fog networks. It describes the various components that can be utilized to envision a Fog network.

*Authentication and Authorization:*To connect to a Fog network,various heterogenous devices must be authenticated for purposes of security and reliability.

*Offloading Management:*Offloading implies types of information needed to carry out the specific task.This information may ebe on multiple layers such as physical layer,network layer or application layer.

*Location Services:*These services are needed for ubiquitous connectivity. The connectivity is among the various Fog peers and from Fog to Cloud.

*System Monitor:*This component manages the overall performance and contains significant information such as energy demand,workload management etc.

*Resource Management:*This component is chiefly responsible for resource administration,allocation and provisioning.The required resources are varied in nature.

*VM Scheduling:*The design of this component needs update as there is still no common,agreed upon scheduling mechanisms or pooling algorithm to provide optimal solution[14].

A. *Implementing Data Fusion on Fog Computing for Analysis of Big Data*

There can be many ways to envision Internet of Things. One of the ways is to introduce Fog devices at the infrastructure boundry. An efficient tailoring of the data fusion algorithm for Fog computing can enhance effective implementation of IoT.

The idea stems from the concept that Fog devices are placed at the edge of the network. If data fusion algorithm is implemented at the Edge /Fog device, data from heterogeneous nodes can be gathered efficiently. It will reduce the time required to process the data as well. Fusion algorithm works on data blocks. Level 1 data preprocessing can be done at the client end.Level 2 partitioning can be done at the localized datacentre within the Fog nodes.Core attributes for level 3 can be calculated at the local gateway and authenticated at the Fog. Level 4 reduction algorithms can be applied on the data sets thus obtained to produce efficient data mining output. Once the data is gathered, it can be transported to the core cloud in case if it is destined for higher end services, say packet transfer to another network or rule definitation ,as depicted in layer 5. In case of request within the same network, smart node/edge device can entertain the query, thereby significantly reducing the communication overhead.Figure 7 describes a possible implementation of the data fusion algorithm utilizing the availble hardware.

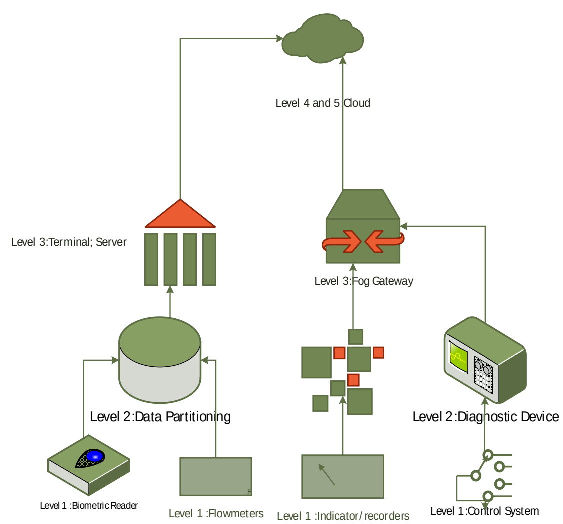

Figure 7: Physical implementation of Data Fusion Algorithm

4..IoT CHALLENGES ADDRESSABLE BY FOG

Fog can serve as an effective platform for enabling Internet of Things.This paltform has the capability to address multiple challenges faced during IoT implementation.Few of these are given below.

*Network Bandwidth Constraints:*Limited bandwidth is a major constraint in envisioning IoTapplications.Fog network works along the continum and provides optimal bandwith for varied applications.

*Resource Constrained Devices:*Energy consumption in various constrained applications can be reduced by addressing their questions locally instead of routing them all the way to the Cloud.

*Uninterrupted Services:*Uninterrupted services are provided by a constant twoway link to the Cloud.This permits both faster uploading and downloading of applications.

*Addressable Security Challenges:*A proxy system comprising of multiple Fog devices can offer a variety of security functions.These functions can be heterogenous in nature depending on the nature of devices[1]**.**

5. CONCLUSION

Fog networks offer great advantages and is still an emerging field. It has great potential in envisioning Internet of Things as the next leap of Internet. Many challenges are on the way. However, Fog networks can successfully tackle major hurdles that are inhibiting the complete implementation of Internet of Things[15],[16].

REFERENCES

[1] M. Chiang and . T. Zhang, "Fog and IoT: An Overview of Research Opportunities," *IEEE Internet of Things Journal*, vol. 3, no. 6, pp. 854 - 864, 2016.

[2] . F. Bonomi, R. Milito, J. Zhu and . S. Addepalli , "Fog computing and its role in the internet of things," in *MCC '12 Proceedings of the first edition of the MCC workshop on Mobile cloud computing,* Helsinki, Finland, 2012.

[3] I. Stojmenovic, "Fog computing: A cloud to the ground support for smart things and machine-to-machine networks," *Australasian Telecommunication Networks and Applications Conference (ATNAC),* p. 6, 20 November 2014.

[4] E.-N. H. Mohammad Aazam, "Fog Computing and Smart Gateway Based," in *International Conference on Future Internet of Things and Cloud*, Suwon, South Korea., 2014.

[5] R. M. J. Z. S. A. Flavio Bonomi, "Fog Computing and Its Role in the Internet of Things," in *ACM SIGCOMM 2012*, Helsinki, Finland , 2012.

[6] I. Stojmenovic, "Fog computing: A cloud to the ground support for smart things and machine-to-machine networks," in *Australasian Telecommunication Networks and Applications Conference (ATNAC)*, Sydney, 26-28 Nov. 2014.

[7] L. R.-M. Luis M. Vaquero, "Finding your Way in the Fog: Towards a Comprehensive Definition of Fog Computing," in *ACM SIGCOMM Computer Communication Review,* Vigo,Sain, 2014.

[8] R. B. S. M. ,. M. P. Jayavardhana Gubbia, "Internet of Things (IoT): A vision, architectural elements, and future directions," *Future Generation Computer Systems 29 (2013) 1645–1660,* no. 29, pp. 1645-1660, 2013.

[9] B. N. S. a. S. J. Roy Want, "Enabling the Internet of Things," IEEE COMPUTER SOCI ET Y, 2015.

[10] F. Bonomi, R. Milito, . P. Natarajan and J. Zhu, "Fog Computing: A Platform for Internet of Things and Analytics," in *Big Data and Internet of Things: A Roadmap for Smart Environments*, Springer International Publishing Switzerland 2014, 12 March 2014, pp. pp 169-186.

[11] P. H. Hu, S. Dhelim, H. Ning and T. Qiu, "Survey on fog computing: architecture, key technologies, applications and open issues," *Journal of Network and Computer Applications,* vol. 98, pp. 27-42, 15 November 2017.

[12] A. Munir, P. Kansakar and S. U. Khan, "IFCIoT: Integrated Fog Cloud IoT: A novel architectural paradigm for the future Internet of Things.," *IEEE Consumer Electronics Magazine* , vol. 6, no. 3, pp. 74 - 82, July 2017.

[13] A. V. Dastjerdi, H. Gupta, R. N. Calheiros, S. K. Ghosh and R. Buyya , "Chapter 4 - Fog Computing: principles, architectures, and applications," in *Internet of Things:Principles and Paradigms*, Elsevier, 2016, pp. 61-75.

[14] "Fog Computing: Platform and Applications," in *Third IEEE Workshop on Hot Topics in Web Systems and Technologies*, 2015 .

[15] U. Y. Khan and T. R. Soomro, "Envisioning Internet of Things using Fog Computing," *IJACSA: International Journal of Advanced Computer Science and Applications,* vol. 1, no. 9, pp. 441-448, 1 2 2018.

[16] U. Y. Khan and T. R. Soomro, "Applications of IoT: Mobile Edge Computing Perspectives," Karachi, 2018.