Fog Computing: An Extension to the Cloud or the Future!

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Abstract-- Fog computing is a decentralized computing platform, which is an extension to cloud, computing. [2]The main aim of fog computing or fogging is to erase the difficulties in earlier platforms and guide the computation nearer to its data sources and data centers. A Reduction is noticed in latency and costs of delivering the data. This can be highlighted as a major advantage of this distributed platform.[1]This novel platform provides reliability, fault tolerance and security. With off-loading data centers and reducing service latency, this technology is very well suited for IoT applications. [1]The security and privacy have always been a major challenge to cloud computing and related technologies which are handled by Fogging. [2]By bringing computation close to data sources there are many field of aspects that are improved with help of Fog Computing. The paper presents the comparison of fog computing with other computing technologies.

Keywords-*Cloud Computing, Fog Computing, Edge Computing, IoT, Smart Applications.*

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I. INTRODUCTION

Fog Computing, popularly referred to as fogging is a newly emerged paradigm in the current technical era.[2] Fogging is basically considered as an extension to the widely used “The cloud” technology. To understand the working and architecture of fog technology, we need to understand how the cloud works. Considering the recent behavior, it can be vividly inferred that the technology has drifted towards “The Cloud”. The current decade is a proof of collaboration of cloud computing worldwide via mobile devices. The cloud computing provides information technology (IT) services. The traditional technicalities had limitations which cloud has overcome and proved useful. It uses remote servers and imparts services like to store, manage and process the data.[1] The remote servers are hosted over the internet instead of the conventional sources such as local servers or personal computers.

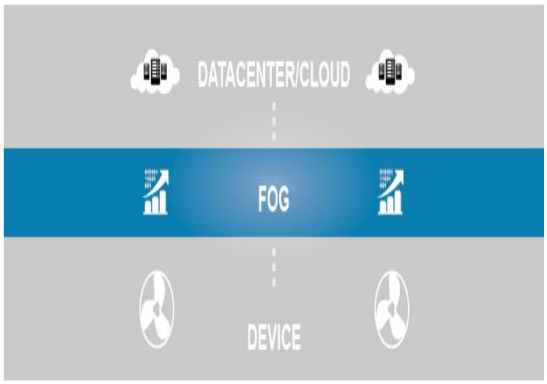

Figure 1. Fog extending cloud services

Cloud computing supplies an omnipresent access to data and control to the end users so that they can have their data whenever and wherever they want. Computing services such as storage, networking, security, privacy, software, extraction, analysis, etc. are available within this technology. It has simplified the problems by putting everything over the internet but the new designs have new flaws and shortcomings. Cloud computing too had a few.[3] The concept of fog computing or also known as fog networking was introduced by Cisco in January 2014 with an aim to enrich the technology and make it better. Fog

brings cloud computing or the cloud itself, closer to the ground that is the end devices in a faster and a cheaper way. Looking over a past few years, the cloud was the storage and access unit for mobile devices that helped the devices to become smart before which there was not an ample amount of space for applications and services. Using cloud the data was stored over the Internet and transferred back and forth as per the requirements. The system had a major flaw, the bandwidth was limited, due to which the data transmission was inefficient. Launching fog technology helped to overcome this physical limitation and bring the data closer. As per the growing trends of Internet of Things (IoT), the end devices goes on increasing among the networks. The Forbes has projected 19.92% of annual compound growth rate in IoT, the use and amount of edge devices will increase in a massive way. Ericcson predicts that the number of IoT devices will exceed the number of mobile phones soon enough. With this large statistics, we need the more efficient computing technology. Fog Computing brings it down. The process and services are provided at network edge with the help of fog computing. Currently, though the IoT generated data is considered the Big data, certain sources such as video surveillance is a big contributor to Big data. With the rise in big data, the IoT is promoted to a new level of business creating certain major technical concerns. Latency sensitivity, time allocation, cost and expenses, performance and lack of high efficiency come into account while considering this business. Using the traditional ways, there is a high probability of traffic overload at the data centers. In addition, the time and cost of long-distance transmission based on the cloud architecture is highly inefficient. In recent IoT models and big data domain, data redundancy play a vital role to achieve accuracy and precision.[2] In popular projects on self-driving automated cars the data created while studying the environmental features using detection, recognition methods. Sensors and similar devices are very complicated and largely discreet. These devices have to fulfill their work and provide orders to the steering etc. in about milliseconds. For such efficient performance, the technique must be speedy and accurate. Nevertheless, if the data is not processed in time by the cloud because of delaying or device malfunction or connection failure, the entire concept and device may lose its function and can cause major disastrous issues. Following gives a brief idea of diverse platforms related to the concept:

Pervasive Computing:

The main goal of pervasive or ubiquitous computing is to be omnipresent and provide everywhere access. Smart products were designed to fulfill the purpose. These smart products were connected making the data communication easier and faster. This technology considered storage of data and providing local, global, social as well as private features. One to one relationship was replaced by many to many relationship. Increasing efficiency along with removing complexity was the central idea of this platform.

Cloudlet:

Cloudlet, a new paradigm emerged from the concurrence of mobile computing and IoT based cloud computing. Cloudlet is nothing but a data transmitting data center residing over the internet. [2]The aim of cloudlet nothing but drifting the cloud closer. Using the cloudlet approach, two architectures: adhoc cloudlet and elastic cloudlet. Computation offloading was performed using these two architectures. Cloudlet can be regarded as the overlap between cloud computing and edge computing.

Mobile Cloud Computing:

On the nominal basis, we can infer that the term mobile cloud computing has emerged from two other definitive terms: (1) Mobile computing (2) Cloud Computing. Mobile Cloud Computing is a topic of interest currently, for its high performance. Mobile Cloud Computing technique is placing the process of a mobile computing over the cloud data centers to make it more efficient and productive.

Fog Computing:

Fog Computing is the hot topic of the networking world. [3]First launched by Cisco, Fog Computing is rapidly taking over the computing world providing complex but efficient and high performance based results. Fog computing does not use remote cloud data centers for processing. The data processing is carried out with the help of the local resources. Wireless services for data access and processing and distribution management are a few key features of Fog computing. However, these features are also provided by the Ubiquitous Computing techniques. Although coming to the complexity of problems, Ubiquitous computing cannot handle complexity whereas, Fog computing provides key features and is widely applicable in varied fields. Fog computing is formed by nothing but overlaps of classic computing platforms.

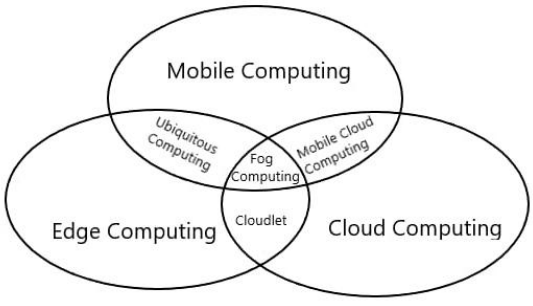

Figure 2. Overlap pf Classic computing platforms

According to the geo-distributed view, fog should be arranged at the gateway level. This position benefits with

better computing power. Fog Computing is a wireless distributed computing platform in which complex latency sensitivity tasks can be processed via a group of sharing resources at IoT gateway level in a locality.

II. FOGGING AND ITS ARCHITECTURE

Fogging or fog networking is implemented at various levels within the topology. [4]Fog computing architecture is nothing but the ordering up of network components and IoT devices. The central idea of the fog computing architecture is positioning of the fog nodes.[3]Fog is named a mini cloud working at the edge of the network by Cisco. Fog nodes are the building blocks of the network infrastructure. However, a different application will give rise to a different definition for fog nodes. So far, there is no accepted definition of fog nodes which specifically identifies the functions and concepts of fog computing. [4]The working of fog computing service for data processing is described as stepwise as follows:

- The data is divided into blocks
- The blocks are then allotted to the designated nodes
- The blocks are lined up prior to transmission.
- After the blocks are queued, the channels are allotted. Some blocks occupy the idle channels and the others wait for the next released channel.
- The blocks are then processed. Processed blocks will then be sorted according to their finishing time.
- In a similar manner, the blocks are carried back to the hosts.
- When the blocks arrive, the host reunites them.

The transmission of the data starts from the electronic indicators connected to the I/O points of the controller (PAC or PLC)[4]. A control system program is then put down so that the automation can start. The data obtained as the system starts is sent to Open Platform Communication (OPC) server where it is converted to the protocol format. This data is placed at the fog nodes. Here, the data is stored for further processing and analysis. The system then processes the data and analyzes it. [7]The data is stored for the later purpose such as transmission to the cloud. From all the mentioned information, we can conclude that fog computing is a highly complicated technology. [8]The architecture links the data from the physical world to the digital side of information technology.

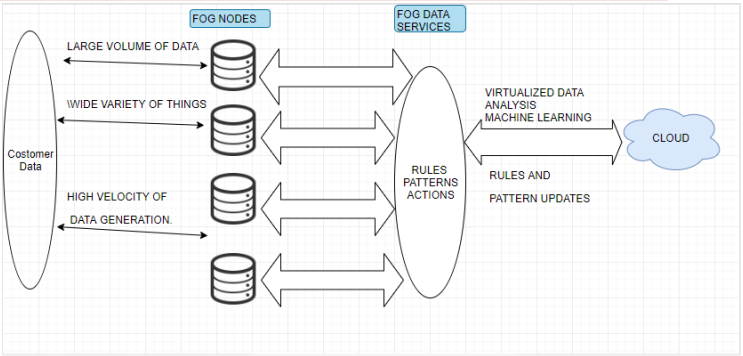

Figure 3. Fog architecture

III. IS FOG AND EDGE COMPUTING IDENTICAL?

Edge computing from the name itself suggests processing over the edge. The main function of Edge computing is to optimize the services provided by the cloud. Edge computing deals with the data at the edge of the network i.e. the application layer. Big data domain and increasing IoT applications have given rise to infinite endpoints to the economic networks. Edge computing performs data storage, analysis, andprocessing of data closer to where they are created. Cost of computing the end devices such as sensors, actuators etc. continues to increase quickly. Gateways or hubs consume more computing power comparatively. Continuously, evolving machine learning and analytical techniques give rise to a large volume of data.

It is wrongly believed that fog computing is not liable for marketing. [10]The role of fog computing is alike edge computing. Fogging or fog networking supplies computing power closer to the edge of the network. This technology positions the storage, access, analysis, and processing of data over the most logical, efficient and productive place. [7]Fog nodes come into the picture this way. The motives of both fog and edge computing are identical. [8]These include data redundancy at a great amount transmitted from and to the cloud. Reduced latency both of the network and the internet is required. Cost reduction is also one of the important goals. Refine system response time will help the technology get better and make it more efficient.

IV. COMPARISON: EDGE VS FOG COMPUTING

Though serving the same motives, the concepts are quite different. Fog and edge computing both aim to bring the data storage, access, analysis and processing to the creation of the data that is at the network edge. The difference between the concepts come at the place where the computing power is shifted by both the methods. [8]In the case of Fog computing, the computer power is drifted towards the local area network (LAN) level of the network architecture. Here, the data processing takes place over the IoT gateway. This place is termed as a fog node. As for edge

computing, the computing power for data processing and communication is transferred to the edge gateway. If not, the power is directly pushed to the edge devices such as actuators.

V. COMPARISON: CLOUD VS FOG COMPUTING

As we have learned so far, Fogging complements cloud computing in a way to higher performance and greater efficiency. Dissimilarities are found among both cloud and fog computing. These are vividly mentioned below[10]:

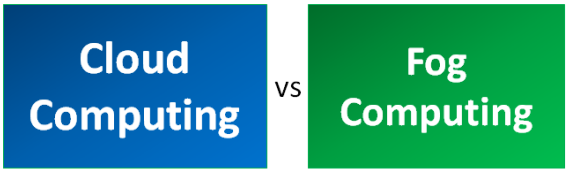

Figure 4: Cloud VS Fog

- Latency: Cloud provides lower latency compared to the traditional methodologies, but Fogging gives even lower latency considering the network.
- Capacity: Cloud computing benefits with various plus points but data redundancy is not one of them. Fogging gives an advantage of data redundancy. It decreases the data that is transmitted to the cloud.
- Bandwidth: Cloud computing does not preserve as much bandwidth as compared to fog computing. Fog computing conserves a good amount of bandwidth.
- Time Response: In cloud computing, data processing occurs at cloud and due to transmission, time response is very low. However, in the case of cloud computing, the processing takes place at the edge of the network that makes responsive time very high.
- Security: Security has always been an issue in cloud computing technology. As for fogging, security is pretty high and sustainable.
- Speed: Data access and processing speed are high in cloud computing. Comparatively, fog computing provides a better speed.
- Data Integration: Multiple data centers are integrated as per the requirements in cloud computing. Fogging allows integration of multiple data sources along with the end devices.
- Cloud computing is parted into two sections i.e. front end and back end as a whole network. Fog computing extends these services by helping out at the edge of the network.
- Cloud computing services have access from any devices around from anywhere whereas in the case of fog computing, it is carried by large open group consortium well known as Open Fog Consortium. The Open Fog Consortium was created in November 2015 by a bunch of companies including Microsoft, Intel, ARM and, Princeton University.
- Cloud computing uses servers for the data storage and backend purpose. Fog computing performs data analysis and processing at the central server after fetching the data from data centers and devices.

TABLE 1. COMPARISON AMONG PLATFORMS

Platform	Cloud	Mobile	Fog
Cost	Medium	High	Low
Computational Power	High	High	Medium
Latency	Medium	High	Low
Node Devices	Data Center	Server	Routers, Switches, Access Points, Gateways
Data awareness	Low	High	Medium
Access tools	Wi-Fi	Mobile Networks	Bluetooth, Wi-Fi, Mobile networks
Power consumption	Low	High	Low

VI. SECURITY ISSUES AND CHALLENGES

The technology discussed in the paper deals with a large amount of sensitive data. The data we are working with here comprises of video surveillance, important business data, sensitive and confidential data in different formats. The major security goals that are confidentiality, Authentication, and Integrity must be achieved for any technology used in dealing with such sensitive data. The security and privacy become the most important issues while dealing with such data. [5]Fog computing applied in IoT, by which it connects a large number of devices over a vast network. Validation and Verification of users and devices are some important issues. IoT based end devices that transmit data to the based on the data requests and processing requests should be able to verify whether or not the fog nodes are unadulterated as well as original. Meanwhile, the fog nodes should be able to validate the end devices, which are seeking the fog computing services, are authenticated or not. The major issues are discussed as follows:

i. Trust issues:

In IoT applications, trust for devices and service request plays a vital role using fog computing for data processing and analysis. [5]The trust issue is hard to elaborate in terms of technology. Here, trust can be considered as the whether the device on the other side is trustworthy or not. Trust is build based on the previous observations and the trusted and known organization associated. Trust is not an abstract entity. It can be calculated considering various parameters as mentioned above. Suggestions given by various trusted entities can also be considered within trust parameters. [4]There are certain **Trust Models** for solving the trust

issues. **Reputation-based trust model** has been applied and used. They have successfully, served the purpose by giving a solution to the trust issues. The trust model designed a few areas that create the issues. First of all, the accurate identification has to be achieved. Secondly, the device malfunction should not occur and if in case, it should be detected and repaired. In addition, consequential steps should be taken whenever the identity or trust is compromised. [4]Thus, reputation-based trust model was precise and successful too. Besides, a few others trust models were also effective such as [4]**Trusted Platform Module (TPM) and Trusted Execution Environment (TEE). Secure Element (SE) model** also solved trust issues for application of fog computing.

ii. Rogue Fog Node

As we know that fog computing parts the data into chunks and then passes it to the middle-way pre-determined area called as the fog node. Security comes into the picture if we consider a rogue i.e. a fake fog node which impersonates to be a genuine one comes in alignment with the other fog nodes. [5]Data leak and loss can occur in such conditions. While objectifying the fog nodes, the aligned fake fog node also gets instantiated and thus can cause a security breach. Once the node is linked with the end devices, the requests can be manipulated resulting in complete data loss. This type of attack can be considered an insider attack. Since, the generation and deletion process of the fog nodes is via a virtual machine, differentiating the rogue fog nodes becomes a convoluted task. Han et al have researched a way out of it. It will keep the access point area of the fake fog nodes away through a measurement-based proposal.

iii. Lightweight Encryption:

The main reason for security is to protect the data from leaking out. There is another way to solve this issue. We can encrypt our data that is to be transferred using the lightweight algorithms available. [6]The data is encrypted at the device edge from the beginning only. The algorithms used for the cryptography purpose are as follows:

- Lightweight block cipher
- Lightweight hash function
- High-performance function
- Lightweight stream cipher
- Low resource device

The algorithm for encryption depends on the data to be encrypted, time of execution, response time, pace, efficiency, performance and, throughput. Using this solution for securing the data, is beneficial and relevant.

iv. Authentication:

Authentication is the main security issue whenever communication and data transfer is included. While [6]Fog Computing technology is used for IoT based application, authentication of the devices, request, and services are most crucial. As fog computing use fog nodes at every level of data communication and processing, the authentication of fog nodes becomes an issue. Similar issues when raised in mobile and cloud-based computing, biometric authentication was introduced. Even in the case of Fog Computing, biometric authentication process that uses fingerprint and facial detection for authentication purpose are useful and applicable.

VII. PRIVACY ISSUES AND CHALLENGES

The issue of compromising private information is one of the major issues when we use the technology such as Fog computing, Cloud computing, Mobile computing, and Pervasive computing. Here, the data and the user's private identification information is stored over the internet. As the cloud connects to the other clouds, the privacy can be easily compromised. Issues:

1. **Data Privacy**: Fog computing enables the connection of the users with the cloud storing their personal information. Privacy-preserving algorithms such as [5]Top-k Query Processing and Hiding Data Access Patterns are utilized so that the privacy is not settled over the channels from fog nodes to the cloud. At the end devices and the nodes, privacy is at stake. Non-disclosure of privacy is used to solve the issue.
2. **Location Privacy**: The location privacy in fog computing can be termed as the location of the end users or the clients. On the normal basis, the clients tend to choose the server near them for the computational purpose. Hence, the fog nodes linked to them will have the information about their location. [5]To overcome this issue, the authors can create dummy IDs with different locations creating multiple locations for the user. In this way, the location becomes vague and the private information about the client's location will not be compromised.
3. **Usage Privacy**: As the data is transmitted and processed via fog nodes, they store the information about the data, amount of usage, purpose, basic ideas etc. [5]The usage patterns and such information is private and cannot be known to the outer entities. As a solution to this, the data of the application can be stored by the clients in an unordered manner dividing it in chunks.

VIII. APPLICATIONS OF FOG COMPUTING

Smart Transportation: [9]Projects on Automated vehicles are already being designed. **Smart Driverless Cars** will probably be installed in the near future. Automated steering

wheels and thoughtful gears will be the characteristics that are to be achieved. These cars will reduce the number of accidents according to the expectations.

Smart Parking System: Smart parking system is designed with the help of actuators and sensors. They will sense the key cards installed on the vehicles for the parking allowance. They can provide notifications about the empty spaces at the parking and other information. This will lead to a safe parking system

Smart building: This application comes with various features such as [9]**smoke and gaseous detection, alarm system, heat and motion sensors, video surveillance for security purposes, parking system, Intrusion Detection system** etc. The sensors and systems will be connected via fog nodes to the clients, here users. In case of noticeable and abnormal activities, the connected users will be notified. Similar applications when applied everywhere lead in the formation of a **Smart City** and to a **Smart World**.

Smart Traffic Lights: With the help of the Road cameras, the traffic lights will be able to sense the traffic and vehicles, thus performing an intelligent analysis.

Smart Driverless Railway: This application includes features such as rail study, [9]speed control, temperature/heat sensors. This may lead to safer rail rides and better experiences.There are a large number of applications of Fog Computing all over the technical world. Overall, Fog Computing aims to make the world smarter and better.

IX. CONCLUSION

From the briefly discussed terms and paradigms in the paper, we can say that Fog as a Service Technology (FA2ST) extends the services provided by cloud computing and mobile computing technologies and overcomes their limitations for good. [10]Fog Computing is the rising, optimistic and favorable solution to the major issues and challenges faced by the Cloud over the IoT applications. The comparison of Fog Networking with the other prevailing technologies prove how highly efficient and useful, the technology is. The architecture explains how the technology works. Issues and challenges are briefly described along with the solutions researched over them. [3]Fog Computing is scalable and flexible and applicable to various domains such as Big data analytics and Internet of Things (IoT). The technology has innumerable, world-changing applications that are applied and the technology is on the verge of building a new and smart technical era. Fog Computing is the future for the data processing and maintenance.

X. ACKNOWLEDGMENTS:

The paper was thorough and studious work and would not be a success without the support of the intellectuals. We are grateful to Assistant. Professor **Mohammed Bohara, Department of computer engineering, DEPSTAR**, CHARUSAT. I am very thankful to my **educator Jesal Desai, Assistant Professor, Department of Computer Engineering, DEPSTAR**, CHARUSAT for helping and supporting us in need. I would like to thank my family members for supporting us in chasing our aims.

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