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Fog Computing: A Conceptual and Practical Overview

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ABSTRACT- Electronic gadgets, appliances, medical equipment, cameras, sensors, and cars are all part of the Internet of Things (IoT), which enables smart cities and infrastructure. It is predicted based on evidences that a minimum of forty nine billion IoT devices shall definitely be linked or connected with the Internet by or before 2020. Those devices will generate a huge and unprecedented amount of information, which conventional systems and cloud systems may find challenging to handle. Fog computing was created to address the shortcomings of existing technologies. Fog offers storage, computation, data, and application services at the network's edge, comparable to cloud computing. This article discusses the features that generally makes fog or edge computing a good stage for the recently evolved technology "IoT", as well as application, characterization and interrelated research in the trending fields including IoT and Fog. Edge computing is a suitable platform for IoT because of its heterogeneous nature, mobility support, very low latency, and huge number of nodes. Rather of transmitting data to the cloud, data will be processed at the network edge.

KEYWORDS- Cloud Computing, Edge computing, Fog, Fog computing, Internet of Things.

I. INTRODUCTION

The cloud computing paradigm is a cost-effective way to host and manage private data centers, and it will benefit customers dealing with Web-based applications and batch processing. It frees the company and its clients from having to provide a lot of specifics, which might be an issue for latency-sensitive applications that need a lot of nodes to satisfy the delay requirements. In addition to location awareness and low latency characteristics, the Internet of Things (IoT) is an emerging wave of internet technology that requires mobility support and a wide range of geo-distribution. As a result, a new platform is required to satisfy all of these criteria. Fog computing, often known as fogging, is a platform that extends cloud platforms to provide a new set of online apps and services to end-users. Fog computing was coined by Cisco's Ginny Nichols [1].

Fog computing is one of the trending and new technology development in IoT, a network architecture that outspreads the predecessor cloud computing (CC) and facilities to the network's end point known as edge. Fog computing, like cloud computing, offers end-users with data, processing, storage, and applications. Nearness to an end-user, mobility assistance, as well as a impenetrable topographical dispersion separate Fog computing from Cloud computing. Cloud computing is a cost-effective and efficient alternative to operating private data centers (DCs) or centralized server systems for clients that need to host mobile applications and website pages along with batch processing. Customers benefit from processing power, storing capacity, as well as a "pay-as-you-go" cloud computing model, which might assist fulfill and scale IoT requirements. However, the time it takes to transmit data from the cloud to end-devices, particularly in health-monitoring of the patients in the hospitals, latency-sensitive applications, and emergency services will be intolerable. End-devices require geographical dispersion and mobility support in addition to low latency.

According to Aazam et al., quantity of linked devices has already surpassed global population, with an anticipated 50 billion IoT devices connected to the Internet by 2020 [2]. These end-devices will generate a significant amount of data, transmit it to the cloud for storage and processing, and then get the data after it has been processed. Substantial traffic amid the end-devices and cloud will occur, lowering service quality and overloading network capacity. Fog is able to satisfy the needs of fixing these difficulties since it's a kind of a cloud near the field or at network's edge shown in Figure1.

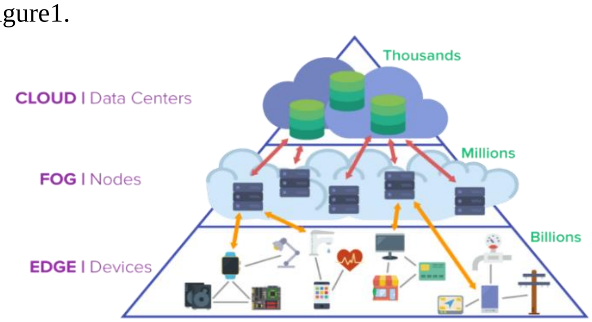

Figure 1: Illustrates the comparison of Cloud, Fog and Edge Computing [1]

The following is a breakdown of the structure of this publication. Following that is a section on the edge computing prototype and the working of the same, subsequently followed by a segment on edge computation features. Further, another segment goes through more or less of the most important facilities and uses that employ the latest technology of fog computing, as well as why the technology is a good fit for them. Thereafter, in subsequent part, various prior relevant studies are reviewed and analyzed, proving the case for the technology and why it is essential in IoT, as well as highlighting the holes in the discussed technology paradigm. As a final point, last portion of the article closes with observations on the current phase of fog based technology and its importance in IoT, as well as suggestions for further research.

II. LITRATURE REVIEW

A number of writers have examined and analyzed idea and function of IoT in association with the fog computing in recent years. Bnomi et al. articulated the concept for Fog computing and identified its features, which might be utilized to provide latest applications along with its services [3]. In his primary or initial work, the author identified four situations in which Fog computing may be used (smart grids and connected cars). He feels that Fog computing's features make it ideal for the scenarios. Fog computing is ideal for those scenarios because of its instantaneous interactions and global spread. This is a legitimate point; instantaneous interactions and low-latency may be realized in the situations using fog computing. In the case of linked cars, if there is a delay in processing of data in real-time, an accident may occur.

Fog computing, according to Bonomi et al., may also be used as a base for IoT analysis [4]. The author argues that data has varying necessities and is consumed at varying durations, and that the topographical dispersion of server may help with this. Data flow will rise as a result of the unprecedented volume and diversity of data collected. Instead of transmitting all data to a single point for processing, just the data that is necessary is sent to many points or servers for processing, which reduces network and bandwidth usage. The author also feels that it is very much difficult to discourse how suppliers would be aligned with the users at this early stage of Fog computing. Subscriber models, he believes, will play a significant role in applications including smart automobiles, intelligent metropolises, smart grids, and so on.

The fog model is ideally suited for data analytics and scattered data collecting sites, as well as for applications in entertainment, advertising, computing, and other fields. Fogging can readily host end services like as access points and set-top boxes. Fogging differs from cloud computing in terms of proximity to end users, mobility support, and a wide range of geo-distribution options. It also boosts QoS and cuts down on latency. Fogging's main goal is to bring information closer to a user by placing it at the network edge.

Misra and Sarkar created a hypothetical prototype to quantitatively depict the design of Fog computing [5]. Because this is their first try in this field, they based their work on a few simple but reasonable assumptions. The authors presumed that the network's edge nodes including smart mobile phones and automobiles most of the time are conscious of their position and can communicate information through GPS, GIS, or GNSS in their mathematical model. The second assumption was that the Fog computing layer is made up of very much sensible devices most of the time capable of performing routing and sending the packets of information to higher level or tiers as well as calculating, processing, and storing data. Further next hypothesis considered by the author was regarding networking devices that can do resource sharing, and the fourth supposition regarding fog computing devices was that they can provide a great level of support for the end nodes. In case all of the considerations are taken into account, the researchers mathematically modeled fog computing and assessed its performance with respect to energy consumption and service dormancy in a setup where almost twenty four percentage of IoT apps required non-delayed services with very little latency. When compared to a typical cloud computing environment, computation in fog environment reduced mean energy usage by thirty eight percent. When comparing the computation in cloud based environment, dormancy similarly was reduced; nevertheless, transmission delay rose as the sum or count of all node in a bunch of fog server grew at a very high rate. The researchers or the authors of the paper concluded that combining IoT with fog computation will result in a better platform for computation, which their experimental findings appear to support.

Khan feels Fog computing is a superior option for IoT, similar to Bonomi et al's work [4,6]. As per to Khan, using computation in fog along with the IoT will almost eradicate main computer environs, minimizing significant blocks besides a single points of failure, and lowering the transmission capacity use. Fog guarantees that the manipulation most of the time takes place at network's edge, decreasing the amount of data that needs to be transported. There is a case to be made that this will reduce transmission costs, latency, and improve service quality (QoS). The authoress also says that the computation in Fog often offers extra level of safety by encrypting the data and sending it to the network's edge, although there is no evidence to support this claim.

III. DISCUSSION

A. A Base For Computation in Fog

Fog computing may essentially be thought or considered as a kind of a progression of the model or exemplar of cloud computing from the network's core to the periphery. Fog computing is a highly virtualized platform that provides compute, storage, and networking services between users and cloud servers or data centers. Fog computing brings together the ideas of mobile cloud computing (MCC) and mobile-edge computing (MEC). MEC is a cloud server situated at the edge of a mobile network that performs specific activities that cannot be accomplished through regular networks, whereas MCC is an infrastructure that performs both data computation and storage outside of mobile devices.

The function of fog computation along with its usage in IoT apps is depicted in Figure 1. Fog mostly is distributed between the servers on cloud and the devices being used by the users, as indicated in the diagram. Fog platforms are dispersed worldwide & also placed at locations locally available including such Children Park, retail or wholesale markets and malls, and airport passenger terminal. The devices used by the users may attain lesser latency than usual, superior and enhanced QoS for instantaneous applications including streaming, thanks to this system design, which puts computing, storage, and communication resources closer to them. Unlike Cloud servers situated in a central datacenter, the topographical spread of servers performing fog computation allows for localization and position awareness. As illustrated in Figure 2, each layer in the Fog architecture will have distinct features in terms of network bandwidth, storage, and so on. It has the potential to build a linked network since the devices being used the general public exist at multiple layers with interrelated topologies among each of them. Fog does not necessarily supplant the existing technology of cloud; rather, the fog complements or acts as a middleman between the existing computations performed on cloud and the fog nodes that includes end layer devices in order to offer crucial services to those devices.

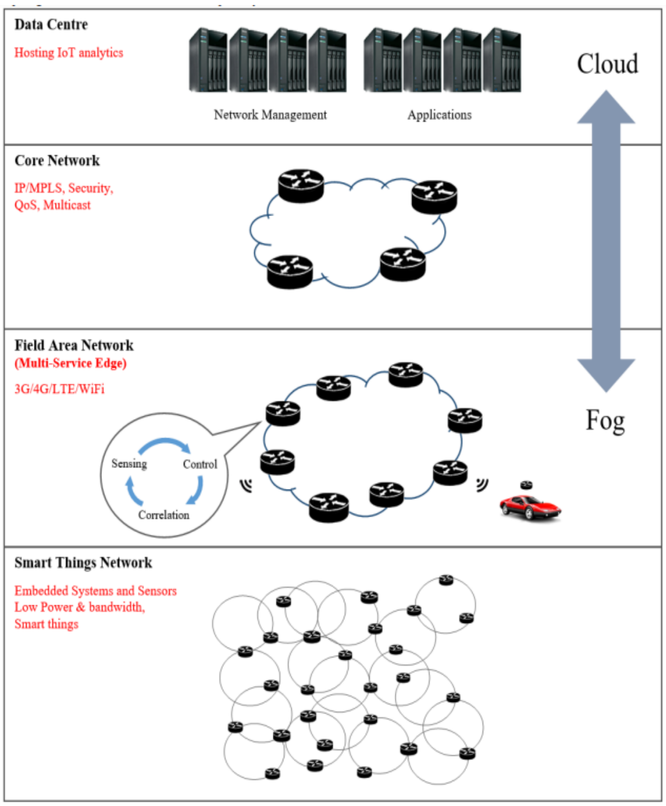

Figure 2: The Architecture involving the Internet of Things and Fog Computing [3].

Figure 3 shows how to download a file using Cloud technology and the same file using Fog technology. Figure 3 (a) demonstrates a file getting downloaded from a server in cloud architecture devoid of a Fog server. The business owner will have to submit the localized flyer or file to the cloud server first in this case. Even though the user is physically close to the shop, she has to connect to the internet in order to download the file i.e., the flier of the shop straight from the server hosted by the shop in cloud through a link that goes through a long distance. As an alternative of getting connected to the cloud server, the user in Figure 3 (b) receives the localized file directly from the Fog server that makes the download faster. The to-and-forth communication in the middle of the cloud and the user aids to conserve the bandwidth that is the backbone of the internet, boost transferring rate of data, and minimize dormancy and time of response since the file is downloaded from the Fog server. Instead of people, the IoT end-devices deployed in this scenario are generally different kinds of sensors and IoT friendly digital tools interacting between the Fog servers. Single-hop wireless connections allow the end-devices to communicate.

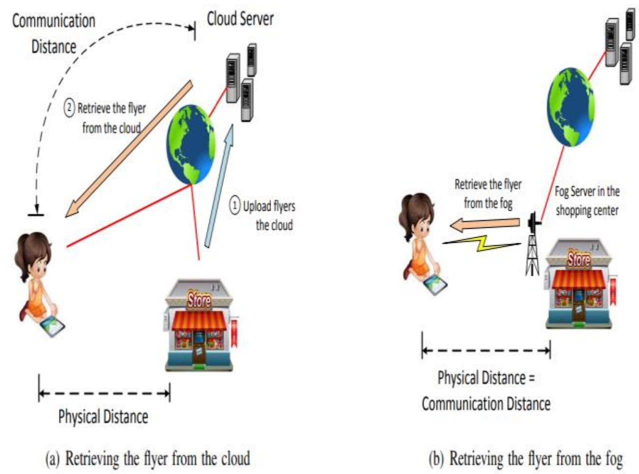

Figure 3: Obtaining a copy of a neighboring store's flier [7]

B. *Fog Computing Characteristics*

According to Bonomi et al., compute power, storage, and networking components are the building elements of both Fog and Cloud [3,4]. Fog computing differs from Cloud computing, according to Luan et al, since it supports location awareness. In contrast to the Fog based computation, which usually has a very inadequate level of storage, calculation supremacy, and a non-wired interface, he says that cloud computing is typically characterized by location awareness since it is centralized and has scalable storage capacity and computational power. In order to perform computing accomplishments, storing activities, communicating actions, controlling activities, managing and configuring undertakings of IoT devices use and rely on the Fog server or layer [8,9]. The Fog server will minimize latency and jitter since the node devices used in IoT are very much near to the information foundation. It may also reduce latency and jitter to millisecond levels, allowing end-devices to reach millisecond latency. IoT tools might generally be knowing own position depending on the set up locality of Fog servers due to the variety in geographical dispersion of Fog servers. Data may also be kept or held at an ideal profundity within the connected devices due to the geographic spread of Fog servers, allowing caching structures to be improved. IoT devices, according to Cisco, will create massive amounts of data and traffic, overloading interconnect networks. The data connected with networking nodes may usually be controlled near origin of information with the Fog layer or servers installed, conserving bandwidth on backbone lines and decreasing network traffic. Fog computing also supports user mobility, resource heterogeneity, and interface heterogeneity. According to CISCO, the computation in Fog environ offers on the spot communications and analysis of scattered information or data to meet needs of globally spread apps that demand lesser dormancy and greater security. Fog also offers interoperability, allowing for the smooth acclimatization of a catholic facilities.

C. Usage of Computation in Fog Environment

Fog is a viable platform and applications for many critical IoT services. The following are a few examples of IoT services

D. Smart Grid

IoT and Fog may be used to provide an effective control and management system for energy distribution. Fog collectors i.e., the devices used to collect data at end point use data generated by instruments including grid sensors and tools to change among other types of natural energy like energy from sun, wind, and so on. All of such data will be processed at the end point or edge, and the necessary action will be taken. The effective operation of the protection and control loops is one of the most important tasks in the smart grid. This necessitates real-time data processing, which the Fog platform can offer. An array of IoT device in a grid capable of working intelligently may essentially be connected in a smooth & efficient manner using Fog.

E. Connected Vehicle

Companies such as Tesla, Google, GM, Uber, and others are now testing and deploying self-driving autonomous vehicles. According to Datta et al., linked vehicles and IoT can reduce traffic congestion and improve road safety, as well as improve vehicle movement management and safely keeping of the vehicles [10]. Connected vehicles capable of inter-communication bring up a new connectivity developments, such as connecting vehicles of self to someone else or own other vehicles and vehicles to the surrounding IOT devices including contact points available on roadside, such as smart traffic signals and place indicators, utilizing internet conventions like TCP/IP, HTTP, WAP, and others. Fog is a good platform for communication between linked cars or in smart mobility due to its location awareness and on the spot communication provision with several heterogeneity features. Vehicle to Infrastructure (V2I) is a new feature from Audi USA that connects with public stream of traffic to notify the drivers when the color of lights change from one color to other. The driver are now acquainted with exact time of changing color of lights and accordingly manages the speed of traveling to escape the red light when traffic lights and cars are connected. Road collisions can be prevented with this technology, since vehicle controlling lights arranged on the road can transmit indications to oncoming cars or takes prompt action of altering the default sequence of changing color to avoid a likely probable accident and hence saves several lives at risk. Because the action of changing default sequence must be completed in real-time, Fog is one of the best or the only platform for the job. Vehicle to Vehicle (V2V) communication is also being investigated by automobile giants such as Mercedes and Volvo Corporation. V2V allows automobiles to automatically interact with one another and avoid collisions.

F. Wireless Sensor and Actuator Networks (WSAN)

To improve battery life, WSAN are designed to require relatively little power. Almost all of the node takes part in info or doc transfer to another node within the range or a main node that is also within range. The data is subsequently processed by the base station, which then takes appropriate accomplishment, such as activating a WSAN device. Considering an instance for illustration, in applications requiring real-time measurements of hotness, humidity, and different gasiform constituents in the environment are utilized to make choices about temperature management and vent opening and shutting. When the sensor detects any aberrant readings, it should be submitted to be processed and quick action taken. Fog is the platform to support WSNs and WSANs because of its geo-distribution, location awareness, closeness, low-latency, and hierarchical organization.

G. IoT in Association with Big Data

Because it solves disadvantages of computation in cloud environment, such as excessive dormancy and interruption, the computation in Fog environment is better suited for IoT in association with big data. The set of information will be transferred to and forth amongst the cloud and data-transmitting edge level or end-devices. This takes time and has an impact on bandwidth and quality of service. The set of info may be pooled and extracted at the servers of fog architecture, delivering fast feedback or response to the devices used by the end user and the servers available in the cloud when the Fog platform is used. The cloud server can then perform detailed analytics and computationally expensive activities.

H. Medical Services

Services relating to health and medical applications are time-sensitive, and they produce personal information about patients. In some circumstances, location data may be sensitive, and the data collected comprises sensitive and personal information. Higher jitter and latency may cause a slew of issues in telehealth and telemedicine applications, thus Fog computing is a good fit for these scenarios. Stantchev et al. suggested a Fog computing-based architecture for healthcare and elderly-care applications, claiming that the architecture may offer overabundance and automatic backup of the system in the event of any disaster with the cloud server (11). The movement of data from and to the cloud can be better managed using fog computing. They have created an interface for the computation in the fog environment to simplify data and add a level of intellect at nodes, illustrating how Fog may be utilized in healthcare applications to triumph computational intelligence, stretchy configuration, and interpretability.

IV. CONCLUSION

The data created by IoT devices generates an unprecedented volume of data, which Fog Computing can handle. Although computation in cloud environment can help IoT by offering a multitude of expanding services to match the needs, applications which usually requires a very short level of dormancy and high QoS will struggle due to network congestion. Fog computing extends cloud computing to the network's edge to address the issues highlighted, as well as the other features. The features minimize network load, lower latency, and increase performance. Despite the fact that Fog is a good platform for devices implementing or using the IoT technologies, most of the times it lacks in implementing a standard protocol, and all of the above there are numerous concerns that need to be resolved or at least investigated. The concerns includes security issues, monetization and privacy issues, provisioning issues, and finally the issues related to resource management.

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