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Fog Computing: A Boost For Cloud Computing And IoT

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Abstract
IoT has become an integral part of our lives today. Right from the morning alarm to reminders of all day activities till the bedtime reminders we have IoT devices to help us. Alexa, Health tracking devices to name few, have become an intrinsic part of many human lives. There are millions of such devices on the network which are connected to the Internet, all collecting and exchanging data with other devices and systems over the Internet. All these data coming from IoT devices goes to cloud storage for future analysis. This gave rise to a concept called "Cloud Computing".
In cloud computing, remote servers hosted on the internet are used to store, manage and process data which has come from various IoT devices. Data generated through these devices is send to the cloud over the internet, instead of storing them in in-house storage devices. Thus, cloud computing has brought a huge change for both individuals and businesses. The most important benefit of cloud is, it eliminates the need of in-house data storage and thereby it helps to decrease the storage and operational cost. Since its inception, Cloud computing has increasingly became popular in the business world. As we can see, technology is evolving at a very fast pace and many businesses, small or large are slowly turned/turning to the Cloud. Organizations recognized the impact of cloud computing on their revenue, productivity, and security. Today, most of our daily activities are based on cloud without us even knowing that!
You are using cloud:

- When you are taking backup of your mobile data online,
- When you are listening music or watching videos online,
- When you are performing Data Analysis, and
- When you use On-demand services from banks or websites etc.

According to Domo's ninth annual 'Data Never Sleeps' infographic, 65% of the world's population — around 5.17 billion people — had access to the internet in 2021. The amount of data consumed globally was 79 zettabytes, and this is projected to grow to over 180 zettabytes by 2025. The rapid growth of wireless technology has given mobile device users tremendous computing power [1]. With so many users at the edge network using cloud services, give rise to congestion and significant response latency of data. This left organizations questioning the quality and quantity of data that they store in the cloud as they are paying huge sum for using cloud services. As the data flow to cloud is going up every day, it is making real-time response difficult at times for edge network users.
As a solution Fog Computing is introduced in cloud environment; it is an extension of cloud placed closer to each area of end users. This solution provides low response latency for devices that request data from cloud. It also provides processing and storage features to IoT/sensors which do not adopt them. With Fog services we are able to enhance the cloud experience by isolating user's data that need to live on the edge.

Keywords: Cloud computing, edge network, IoT, fog computing, latency, real time response

Introduction
Recently fog computing has emerged as a promising new paradigm for offering computation and storage services in a distributed way over cloud. Fog computing architecture makes use of edge devices to perform a significant portion of computation, storage, and communication locally before routing it over the cloud.
In 2012, Cisco's, Product line manager, Ginny Nichols has originally coined the term fog computing. It also refers as fogging. This term, fog, has a connection with the real world weather phenomenon, a

cloud formed close to the ground. Later in November 19, 2015, Cisco Systems, Dell, Intel, Microsoft, and Princeton University, founded the OpenFog Consortium to promote interests and development in fog computing[2].

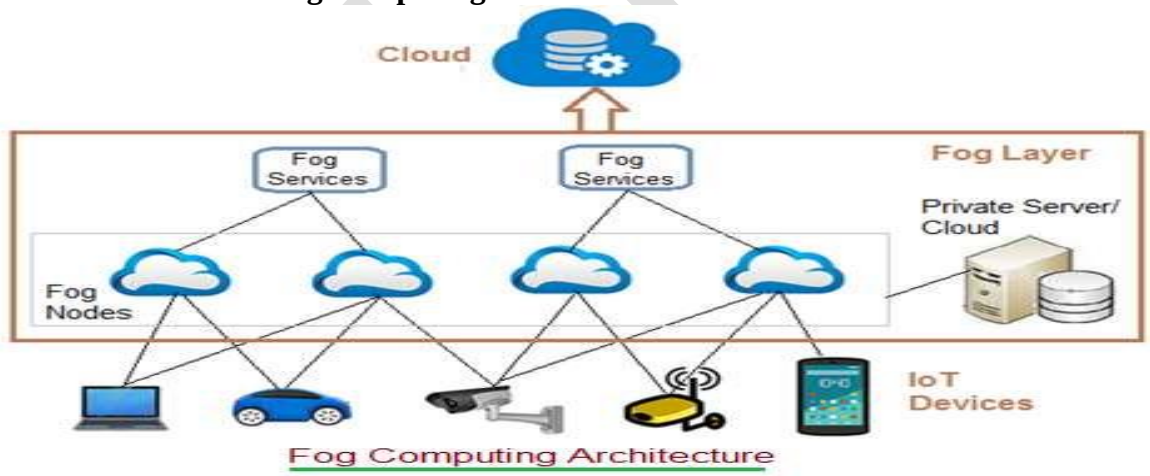
Fog computing aim for processing maximum possible data using computing units that are co-located with edge network devices so that processed data is sent to the cloud instead of raw data with much less bandwidth. Many times the processed data is required or requested repeatedly by the same devices that created the data. Thus, processing the data locally at fog nodes rather than at cloud reduces response time in such situations. Data that does not need immediate action can be sent to the cloud for long-term storage and analysis.

Fog computing has fog nodes which are located closer to IoT devices and have high storage and processing ability. The fog nodes being closer to the data generating devices, data is processed faster than cloud processing. As an example, if I have a CCTV camera without storage capacity installed at my home and I want to review the latest footage, I need to request the cloud as my CCTV camera do not have storage. This could take some time. With fog computing in place, this delay can be eliminated by requesting data to local fog node rather than cloud directly. Depending on need, this data may or may not be sent to further to the cloud saving storage and time.

Fog Computing Architecture

Location of fog node, topology implemented for connecting the devices and protocols used for transmission of data plays an important role to decide features of fog computing architecture. It involves the distribution of functions at different layers, and decision making about what the types of and how many protocols should be used at various layers. The fog computing architecture is divided into 2 types:

1. **Hierarchical Fog Computing Architecture**



[3]

The hierarchical fog architecture comprises of following three layers:

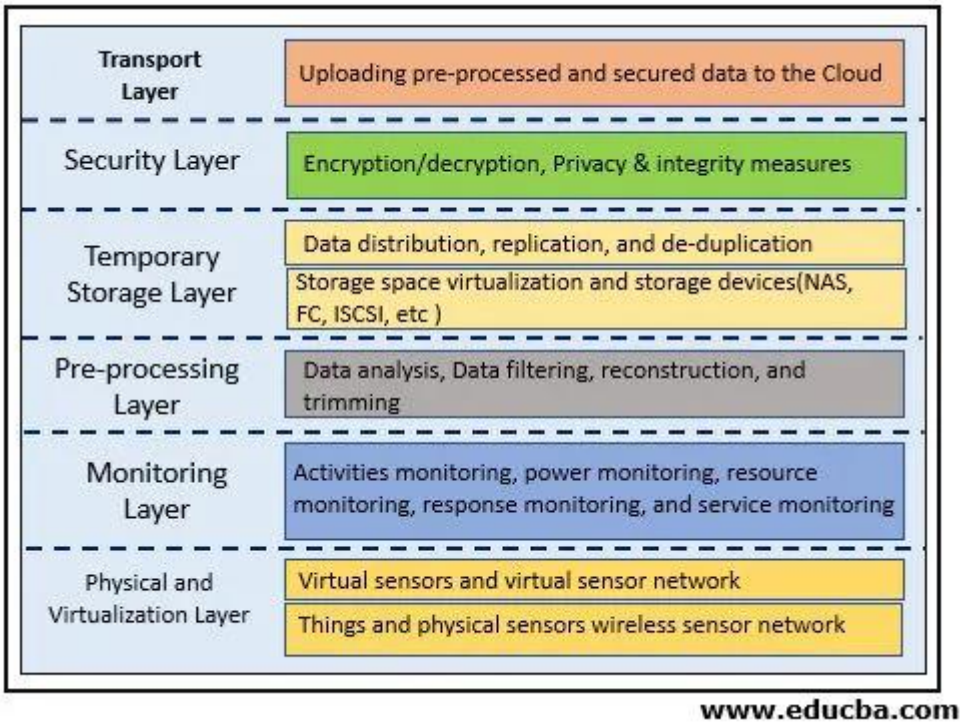
I. **The edge layer:** It consists of numerous different IoT devices like sensors, vehicles, security cameras, smart wearable devices, smart machines and smart home appliances etc which are connected to fog nodes. These devices which are from different places and uses different applications are data generators.

II. **The fog layer:** This layer works as a middle layer between the edge and cloud layer. It consists of many inter-connected domains. The domain has virtualized fog servers connected to each other and the centralized cloud server. These units work together for real time data processing.

III. **The cloud layer:** This is the uppermost layer of the architecture. It consists of high performance servers and storage devices for all the edge network devices.

Fog computing architecture works based on type of data it receives. Nearest fog nodes takes data input from the IoT devices. After the received data is analyzed, decision or action is transmitted to the device. After this, fog node sends and stores summary to the cloud for future analysis.
Time sensitivity of data is considered to decide which fog node will handle the data request. Only the time insensitive data is sent directly to cloud for storage and future analysis.

2. Layered Fog Computing Architecture



[4]

I. Physical and Virtualization Layer

This layer consists of nodes which send data and are located at different locations. At these nodes, sensors collect data from edge devices and it is sent to upper layers via gateways for further processing.

II. Monitoring Layer

At this layer, nodes are monitored for their performance based on factors like the amount of time they work, the temperature and other physical properties they are possessing, their present state etc. The amount of power consumed by fog nodes is monitored at regular intervals.

III. Pre-processing Layer

This layer is responsible for cleaning of the data by removing useless data. Data is thoroughly checked for its meaningfulness before using it to further analysis.

IV. Temporary Storage

This layer provides temporary storage for the data. Once processed, it is forwarded to cloud and is removed from storage.

V. Security Layer

This layer takes care of security and privacy of data that is forwarded to fog nodes. In fog computing privacy can be use-based, data-based and/or location-based privacy. It also handles encryption and decryption of data to preserve data integrity.

VI. Transport Layer

Uploading of processed (partially/fully), cleaned and safe data to the cloud layer for permanent storage is the responsibility of this layer. This uploading is done in chunks so as to maintain the latency ratio.

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Characteristics of Fog computing

- **Low Latency**

Because of the connectivity of the fog nodes with efficient and smart end devices, the analysis and generation of data by these devices are quicker. This results in lower latency of data.

- **Heterogeneity**

Fog computing is quite a heterogeneous infrastructure as it can collect data from multiple sources. Being virtualized platform providing end-user storage and other services like networking, it acts as a bridge between end devices and traditional cloud computing centers.

- **Mobility**

Many fog computing applications have to communicate with mobile devices. This makes them conducive to mobility techniques like LISP (Locator/ID Separation Protocol). The main task of LISP is to decouple the location and identity.

- **Scalability and Agility of Fog-Node Clusters**

Being adaptive in nature at the cluster level, it is able to support the majority of functions like elastic compute, data -load changes, and network variations.

- **The dominance of Wireless Access**

Although fog computing is widely used in wired environments. But the wireless sensors spread on vast areas associated with IoT devices demand different requirements related to analytics. For this also, fog computing is suitable for wireless IoT access networks.
[5]

Fog Computing and Wellness

During COVID-19, the healthcare sector faced many challenges a major one being shortage of staff or nurses to assist the doctors. This lead to delayed treatments or wrong diagnosis for patients and the stress of workload had a severe impact on healthcare workers' health. IoT devices worked like a magical wand to solve this problem to a great extent. Internet of medical Things and linked network components provide data exchange, report recording, patient recording, knowledge processing and interpretation, hygiene medical treatment, etc. Various healthcare agencies are adopting fog-installed cloud computing in the field of healthcare to use all the above information efficiently to treat their patients. Fog-installed cloud computing is the most effective and suitable method to provide the improved quality of healthcare services, because of abundant storage and speedy handling of the huge patients' data at lesser bandwidth and reduced response time in case of emergencies. Fog Computing provides a real-time solution for the healthcare system where even a delay of few minutes can risk the patients' life. Fog computing could be used to monitor and control possibility of spreading of infection in patient post surgery or treatment in a cost-effective and time-saving manner.
Following diagram shows the use and working of fog computing in healthcare services.

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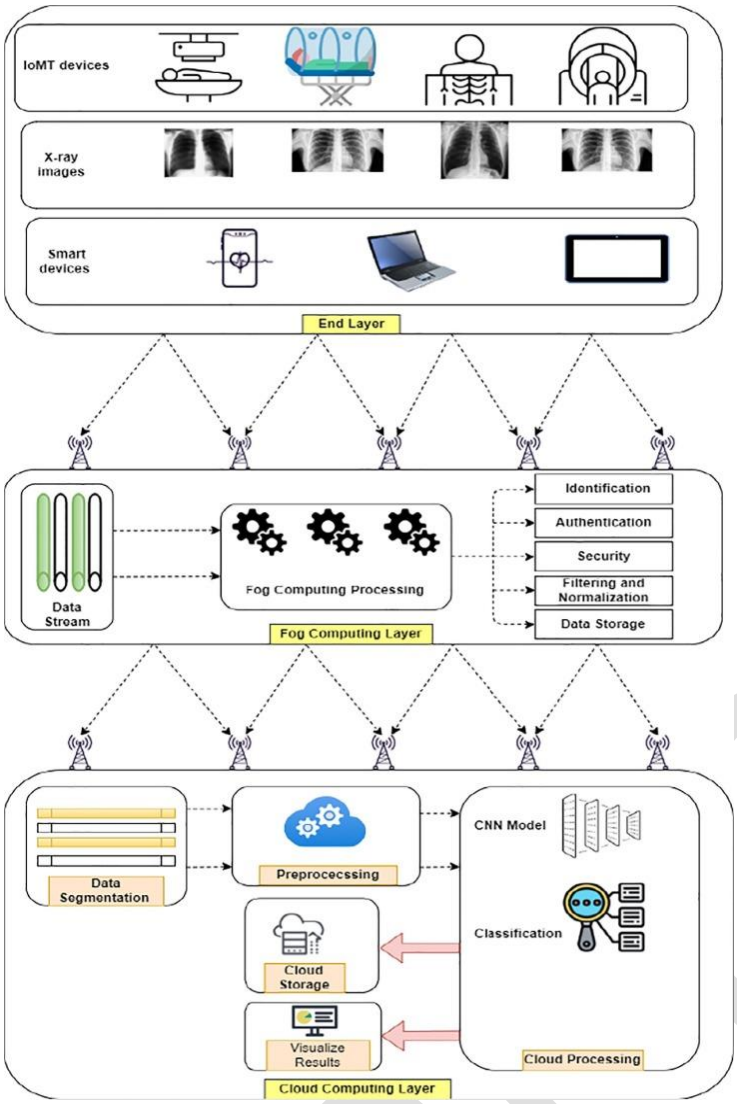

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Conclusion

In this paper, fog computing, its application and architecture is discussed. The architecture provides an overview of different functionalities that are performed by respective layers. Fog computing provides an excellent platform to manage the distributed and real-time nature of emerging IoT infrastructures. Post COVID-19, online consultations from doctors have become a new normal. Patient-related data is one of the most overwhelming aspects of healthcare sector today. The storage and retrieval of the patients' data in real time as and when required, is a challenge that the hospitals and individual healthcare professionals are facing with the increasing use of IoTM devices. Data overload and mismanagement may lead to wrong diagnoses, improper treatment, lapsed appointments, failure to keep up with the changes in progress or regression of the patient's condition and even the patient's data can be compromised. Considering its applications, fog computing is as an appropriate solution for all these problems. First, it reduces the cost of memory usage, computational costs, and sensors power consumption. It also helps to balance cloud data load and reduce the response time to edge devices. Fog computing offers a lower latency by increasing the number of fog nodes or using various edge mining techniques to reduce the data transmission time. Fog computing is compatible with edge computing applications which provide a high degree of protection and authentication thereby ensure data security. Advancement in fog computing in 5G Era will definitely take the IoT services to next level in coming future which will help to lessen the workload of health professionals and unwind them.

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