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A Survey on Issues and Challenges in Fog Computing

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Abstract:* Fog computing is a term introduced by CISCO which is a fog layer between cloud and mobile services. Cloud computing has provided many enterprises with opportunities by offering various computing services. It frees end users from specification such as computation limitation, network bandwidth cost, storage resources, etc. Fog computing is an extension to cloud computing that complements cloud computing towards low-latency high-rate services to mobile users. This intermediate fog layer calls for an efficient management of resource. The prime goal this paper is to identify the advantages of fog computing over cloud computing, the issues associated with the introduction of fog layer and existing technique of resource allocation in fog computing.

***Keywords:* Cloud computing, Fog computing Resource Allocation, Virtual machine, Virtualizations**

1. Introduction

Cloud computing has proved to be a boon to enterprises and end-users by offering them on-demand services remotely, high scalability as well as resource allocation as per the usage. It has number of advantages such as reduced cost, increased storage, flexibility, reduced time for implementation and shortened life cycle [1]. Though, it has many benefits, there are some issues that have made it necessary to look out for more advanced form of computing.

Fog computing is one of the potential approach to deal with today's increasing demand of Internet of Things. In this model, the data and its processing is concentrated in devices at the edge of the network. This infrastructure allows applications to run as close to sensed actionable and massive data, coming out of people, processes and things [1].

Fog Computing is a three layer architecture as shown in Figure 1. The fog layer is present between the end devices and the cloud layer. The end fog devices may be interconnected to each other as well as to the Cloud.

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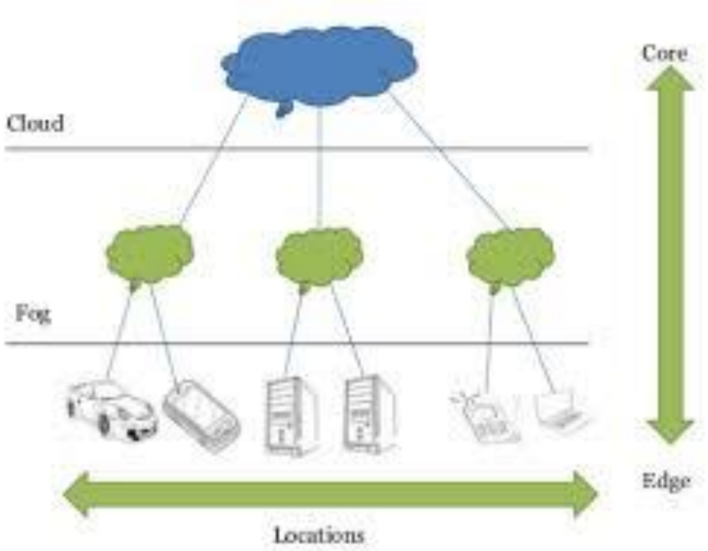

Figure 1: Fog Computing Architecture [1]

2. Cloud vs Fog

Though cloud computing offers so many advantages, it has some of the limitations too. Fog Computing is similar to cloud computing but as it is nearer to the edge devices, it offers some benefits over cloud computing.

With IoT, there is an IP Address for each of the participating device. For example, in vehicular networks, low latency, mobility, real time interactions, fast processing, good wireless connectivity are important criteria. Vehicles communicate with each other and to the access point, the access points communicate with one another for transferring of the important data. Thus, fog proves to be more beneficial than cloud as transfer of data might cause a delay which is harmful for real time interactions.

Internet applications require data integrity and security. If the data is stored at one place for a longer period of time, it is prone to attacks as compared to storage at multiple hops. Fog computing supports multiple hops as compared to single hop of cloud.

Fog computing characterizes low bandwidth, low power, geographically distributed processing nodes. Wireless sensor networks, that are nowadays widely implemented, require low latency, location awareness and geographically distributed systems for data processing and distribution. These characteristics are not met by cloud.

As cloud computing is present inside a network, it is prone to various Denial of Service (DoS) attacks. Whereas, in fog computing, the devices are distributed over a large area. So, in order to disrupt the services, the attacker would require more resources as compared to the cloud. Fog has an edge over cloud when it comes to DoS attacks.

It can be seen that fog has an edge over cloud, but there are some factors where cloud becomes more reliable over fog. For example, geographically distributed nodes cannot process a large amount of data due to less resources. Computations such as batch jobs require large amount of resources and does not depend on latency. This can be handled with cloud computing.

Hence, it can be seen that both fog and cloud computing have their own merits and demerits. Fog may extend cloud to a certain limit, as in case of delay sensitive applications but it cannot completely replace cloud computing in near future. The comparison between fog and cloud is summarized below in the given table.

Requirement	Cloud Computing	Fog Computing
Latency	High	Low
Delay Jitter	High	Very low
Location of server nodes	Within the Internet	At the edge of the local network
Distance between the client and server	Multiple hops	One hop
Security	Undefined	Can be defined
Attack on data enroute	High probability	Very low probability
Location awareness	No	Yes
Geographical distribution	Centralized	Distributed
No. of server nodes	Few	Very large
Support for Mobility	Limited	Supported
Real time interactions	Supported	Supported
Type of last mile connectivity	Leased line	Wireless

Table 1: Cloud Vs Fog [1]

3. Fog Computing Challenges and Opportunities

We have seen that fog computing has an advantage over cloud computing when it comes to delay sensitive, geographically distributed applications. As fog layer is an intermediate between cloud and edge devices, it requires additional resources and different data processing techniques in addition to existing cloud computing techniques. These issues include programmability, Data Abstraction, Resource Management, Privacy and Security.

3.1 Programmability

In cloud computing, user program their own code and then deploy it on the cloud. The cloud provider decided the place of computing and users have no knowledge of how their application runs. In fog computing, the computation does not take place in the cloud and is done on the heterogeneous edge devices. Their runtime may also differ creating a problem for the programmer to write an application to be deployed in fog environment.

3.2 Data Abstraction

With IoT, a lot of data is generated each moment but only the sensitive and important is sent to the cloud for further assessment. For example, a security camera in the home which might keep recording and sending the video to the gateway, but the data will just be stored in the database for a certain time with nobody actually consuming it, and then be flushed by the latest video [2]. It becomes difficult to identify the data that has to be filtered out. Sometime the data reported at edge is not reliable. In this case, how to abstract useful information from unreliable data sources is still a challenge for IoT application and system developers [2].

3.3 Resource Management

Fog computing involves a layer of heterogeneous resources spread across geographically. A lot of edge devices would be interacting with the fog resources for computation. So, it becomes essential to manage resources at the intermediate layer for efficient and effective use for high performance. Also, as fog layer is an essential component of delay sensitive applications, it becomes necessary to manage the fog resources and allocate them efficiently among the edge devices.

3.4 Privacy and Security

Fog computing involves a separate layer between end users and cloud layer. One potential threat is attack on the middle layer or its replacement by a fake one. Sometimes, it becomes difficult to protect the fog layer with encryption method as it may amount to large consumption of battery on mobile devices. Various intrusion detection methods are available in cloud computing such as port scanning and insider attack. As fog computing has limited resources and computing, it becomes difficult to detect rootkit. Also, it costs much if behavior based detection techniques are used as IoT devices have low computing power.

4. Resource Management

Resource Management is the effective and efficient use of the available resources. The main characteristics of fog computing include low latency, geographical distribution, location awareness, mobility and real time interactions. Thus, the resources are heterogeneous and spread across geographically. This presents a big challenge in managing fog resources.

4.1 Resource Allocation Significance

Resource Allocation is the efficient and systematic way to allocate available resources to the end users or the fog clients. Its benefit is that the user does not have to expand their software or the hardware systems to meet the growing demands. Virtualization is one such technique that utilizes resources with high performance.

4.2 Resource Allocation Issues

The primary issue in resource allocation is to know "how efficiently resources are utilized in the system". It is also needed to devise an algorithm that can deal with any number of clients in the system, i.e., the issue of scalability. While allocating resources, energy consumption must be kept in mind along with the system performance. Job Scheduling plays an important role in yielding maximum profit in minimum execution time. Load Balancing methods are needed to minimize the associated overhead.

5. Related Work

This section is about the study and review other authors work. Several techniques and methodologies have been proposed for resource allocation in fog computing environment. One such technique involves virtualization of the fog layer. Server virtualization increases utilization of resources by dividing one physical server into multiple virtual servers. Each of the multiple virtual servers multiply the capacity a single machine.

5.1 Existing Architecture

The existing fog layer virtualization technique divides the Fog computing environment into three layer architecture as shown in the figure. The model consists of three layers namely the cloud layer, the fog layer and the client layer. The computing first takes place in the client-fog layer. If the resource is not available in the fog layer, the computation takes place in the client-cloud layer.

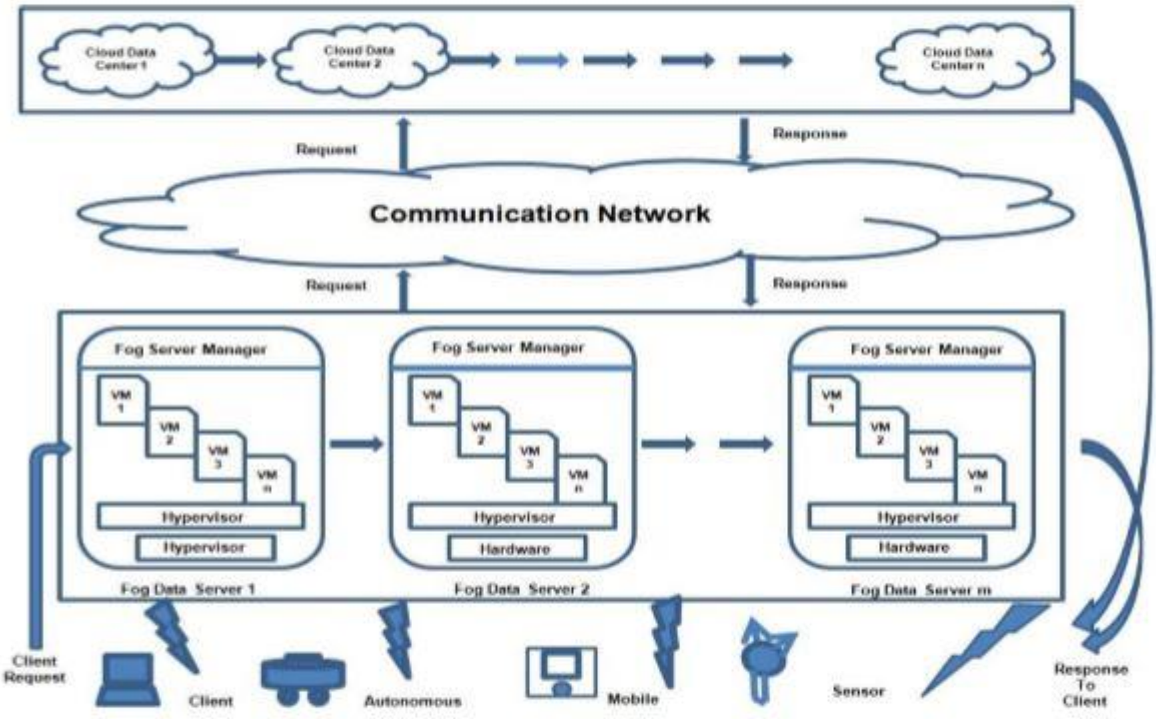

Figure 2: Fog- Cloud Three Layer Architecture [3]

All the data centers are arranged in the fog and the cloud layer. A request from the client is submitted to the fog data server (FS) which is then requested to the fog server manager (FSM). The fog data server processes the client request directed to it by the fog server manager. In case of non-availability of fog data server in the middle layer, the server manager directs the request to the cloud data server (CS).

6. Simulation Tools

Fog computing techniques and algorithms can be implemented and tested on following tools.

6.1 CloudAnalyst

CloudAnalyst is a CloudSim-based Visual Modeler for analyzing cloud computing environments and applications. The main feature of CloudAnalyst are [4]:

- Easy to use graphical user interface (GUI).
- It defines a configuration with high flexibility and configurability.
- Experiments can be easily repeated.
- It has a graphical output.
- The ease of extension.

6.2 iFog Simulator

iFog Simulator is a toolkit for modeling and simulation of resource management techniques in the Fog computing environments. It evaluates resource management and scheduling policies across fog and cloud resources under different scenarios. It focuses on impact of latency, network congestion, energy consumption and cost of operation.

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7. Conclusion and Future Work

Fog computing is an extension to cloud computing and can be seen as a promising future to the delay sensitive and real time applications. Just like cloud computing, fog too has its own merits and demerits. This paper gives an idea of challenges and opportunities available in fog computing and various tools that can be used in implementing various methods and algorithms devised for fog environment. It also focuses on resource allocation and its one of the existing techniques in fog computing.

The existing algorithm surveyed in this paper allocates only those resources that are requested by the clients before processing. The future work may be extended to include resource allocation during run time of requests. This work may also be extended to include job scheduling and load balancing techniques to improve the efficiency and performance of the system.

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