Cloud and Fog Computing: A Survey to the Concept and Challenges

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***Abstract*—Cloud Computing is one of the most emerging technologies that has transformed the macro world. The advent of cloud computing is not less than an evolution and miracle to the technology. It has made the on-demand availability of various scalable software resources possible over the internet. Although its extraordinary services and advantages like reduction of computing and storage resources as well as reducing cost, there are some barriers that limits and challenges the usability of cloud computing. On the other hand, Fog Computing, another computing paradigm, is an extended and advanced version of cloud computing. Having distributed nature, Fog Computing tries to address the limitations faced by cloud computing. The paper provides a general study of the challenges faced by cloud computing and how fog computing infrastructure serves to be an emerging technology to those limitations.**

Keywords—computing paradigms, cloud, fog, cloud computing, fog computing, IOT.

I. Introduction

Today, cloud computing has emerged out very quickly and the increasing penetration of smart devices transformed the internet utilization and allowed the users to have a rewarding cloud experience. Cloud computing allows its user to rent on demand hardware as well as software [1]. But sometimes sharing resources in this way presents some security risks. These risks can be minimized depending on the type of technology wanted to include in the cloud computing concept. Since 2007, Cloud Computing has aroused as a hot research area in scientific, technical as well as industrial fields. The world have much transformed with the usage of cloud computing. Furthermore, other computing paradigms like Mobile Cloud Computing (MCC), Edge Computing and Mobile Edge Computing (MEC) have extended the cloud computing. But due to certain limitations in them, Fog Computing came into being [2].

Mobility, a famous word is appreciated much quickly in the era of computers today. An unbelievable increase has aroused in the evolution of mobile devices such as, Smartphone, PDA and laptops as well as different mobile computing, networks and security paradigms. At the same time, smartphones are acting as ambassadors for numerous mobile devices while have connection with the incredibly increasing usage of wireless technology such as WiMAX and WIFI etc. [3].

The fundamental concept of cloud computing was to connect various electronic devices connected to the Internet with the wireless network technology to the cloud server. Due to large number of connected devices and their connection with the same cloud server, the network congestion and large end-to-end delays caused much problems in the cloud computing services [4]. In addition, MCC and MEC paradigms help much to solve the problems but due to the absence of IAAS, PAAS and SAAS platforms, Fog computing is designed to satisfy that need too.

Fog computing comes up with numerous advantages to the paradigm like end-to-end delay is reduced, traffic congestion is minimized, devices are provided facilities of computation at the fog nodes, less computational pressure at the main cloud server and many more facilities. Thus, fog computing has made the cloud computing paradigm much easier to be handled [5].

The contribution of this paper is to have a general analysis of how the cloud computing served the purpose, due to which reasons the idea of fog computing was introduced, what are the properties of both computing paradigms and their architecture. The remaining paper is structured as follows: Section 2 includes some literature review related to Cloud Computing and Fog Computing. Section 3 explains about the cloud computing, its properties, architecture and challenges. Section 4 provides a general information of Fog Computing, the concept and its characteristics. Section 5 comprises of the conclusion.

II. Literature Review

In the papers [1], the authors made a comprehensive survey of the state-of-the-art and challenges faced by cloud computing. The cloud architecture along with the business models are clearly explained. Authors [2] gave a brief description regarding the characteristics of cloud within the cloud environment. Papers [3, 4] indicates towards the networking, elastic applications and whole infrastructure of the cloud framework.

Corresponding to the challenges faced by the cloud, possible solutions are presented in [5, 6]. The authors addressed towards the security and privacy issues as well as resource provisioning and processing demand problems are stated. As well as, a comparison between the cloud, fog and

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edge computing is made to identify their strengths and weaknesses. Paper [7] gives us knowledge about the fault tolerance in cloud environment corresponding to the vulnerabilities and poor performance observed in cloud.

Han Qi and Abdullah Gani [8] proposed the context and principles of MCC, as well as the modern characteristics and trends of MCC. They considered that cloud computing was a paradigm of large-scale business and economic computing whose core technology was virtualization. When reading in the background, they presented a brief description of mobile computing and cloud computing, as well as their characteristics and challenges. They had written the description on MCC, including its concepts, principles, challenges and solutions: limitations, quality of communication and division of the application service. In addition, open research questions.

Mandeep Kaur Saggi and Amandeep Singh Bhatia [9] described the architecture, principles and features, limitations of mobile computing and challenges as well as proposed solutions. They proposed that, with respect to the top 10 trends in technology [10] provided by Gartner (a renowned analyst and consulting firm), cloud computing is at the top of the list, which means that cloud computing will have an impact increased on the business and most organizations in 2012.

Victor C. M. Leung [11] and his three colleagues presented the four main challenges of mobile cloud computing, which are included but not limited. With the full investigation into the different ways of combining cloud computing and mobile platforms into a new computing / communication paradigm. In "Mobile Gear Gears Without Resources and Powerful Clouds: Architecture, Challenges, and Applications," Luteal. Provide a complete taxonomy of mobile cloud offload architectures and a new kind of real-world business applications. The article presents a comprehensive review of the technical challenges and existing solutions for exploiting mobile cloud computing in rich multimedia applications.

Huerta-Canepa [12] presents the guidelines for a framework mimicking a traditional cloud provider using mobile devices near users. The structure detects neighboring nodes that are in stable mode and provides the means to save resources such as power and processing power. Manaswini Pradhan [13] has written a study on mobile cloud computing including: features, architecture, challenges, solutions, benefits, applications, research themes and elements of MCC. Pragya Gupta and Sudha Gupta [14] have written the cloud service model with three service layers and deployment models with four different clouds. And the detailed presentation on MCC architecture with some challenges and proposed solutions, including strategies that can be adopted by service providers to solve problems [15, 16, 17, 18, 19, 20………..].

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III. Cloud Computing

Cloud computing is a technology which enhances agility, feasibility of user, elasticity and availability of data in much more optimistic and inexpensive cost [6]. Cloud computing is a computing paradigm which enables its users to store, process and access their valuable data in a secure way. The idea is actually derived from the word 'cloud' which keeps on moving and serves a common medium. Thus, cloud computing directs us towards the outsourcing of valuable information and its processing. Through cloud computing, a user from a remote area can easily access the data stored in the cloud and doesn't require him/her to use any hardware source for the data storage and computation [7].

According to the NIST definition, "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (for example servers, networks, storage, services, and applications) that can be quickly provisioned and released with least management effort or service provider interaction" [8].

Thus, our data stored in the cloud is safe and secure, acquires less storage space and can be accessed faster from anywhere over the internet. However, a comparison is often made between cloud computing and other similar technologies like Grid Computing, Utility Computing, Autonomic Computing etc. [1, 6].

A. *Characteristics*

There are some characteristics of cloud computing which differentiates it from the traditional service computing [1, 6]. These are as follows:

- **Resource Pooling:** It is a term used in cloud computing which indicates that a provider can serve multiple consumers at a time with a variety of services. These services include storage, memory, computation, network etc. Thus, infrastructure provider provides a pool of shared computing resources to a number of resource consumers.
- **Ubiquitous network:** The clouds are accessible through the Internet and they use internet for service providing. But to increase the network performance and enhance service delivery, there are datacenters placed at different places around the world. Due to which, the service providers are available and accessible all the time.
- **Service-oriented computing:** Cloud computing focuses on the service management. The different cloud service providers i.e. IAAS, PAAS and SAAS providers provide services based on the Service Level Agreement (SLA) which is an agreement between the service provider and consumer.
- **Dynamic resource allocation:** Cloud service providers offer resources to the customers based on their current demands which decreases the operational cost as compared to that in traditional service

computing that provide resources based on the peak demand.

- **Self-organizing and self-servicing:** Based on thee resource allocation on-demand, the service provider has the capability to manage the consumption of resources by itself. On the other hand, without the interaction of a human with the service provider, a consumer can provide computing resources like server-time etc. to itself as needed.

- **Service measurement:** The cloud system monitors and controls the resource usage automatically by using some sort of metering capability according to the resources utilized. This provides transparency for both the service provider and consumer.

B. Service models

Cloud computing provides services to the customers on-demand. These services can be categorized into 3 groups: Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS).

- **Infrastructure-as-a-Service:** In IaaS system, the service provider, also known as IaaS provider, performs the on-demand distribution of computing resources regarding the hardware virtualization. The hosts can use hardware resources like CPU, disk, memory etc. as virtual machines for processing, perform networking and keeping the data [1, 7]. Examples of IaaS include AWS (Amazon Web Services), Microsoft Azure, Oracle, GCE (Google Compute Engine) etc.

- **Platform-as-a-Service:** In PaaS system, the user is provided a platform with software and hardware tools for the creation, running, testing and managing the applications in cloud. The PaaS provider also provides base operating system and software development frameworks. Examples include Windows Azure, Google App Engine and AWS etc.

- **Software-as-a-Service:** In SaaS system, the service provider provides the OS and all the software applications to the users. The user can access those services over the web and thus provides on-demand services on the internet. Examples include Google apps, Dropbox, Cloud Stack and Salesforce.com etc.

C. Issues and challanges

Despite of all the advantages and services provided by the cloud computing to its users, the paradigm is facing a number of problems and challenges which need to be discussed.

1. *Privacy issues:* Privacy refers to the quality of appropriate use of the customer's data, data protection and customer satisfaction with the data usage. Some data that are used to collect, process, store and transfer etc. needs privacy controls on it, and thus have chances of privacy risks. However, extreme type of personal data like personal location, social networks, personal data etc. have high potential risk. For that purpose, some tracking or embedded profiling steps are taken to normalize the environment. Within a public cloud, where the services are offered to the general public, a number of privacy issues occur. These include dynamic data distribution, unauthorized resource usage, lacked user control, data retention and dynamic data growth [17]. All these factors have affected so much that public cloud is now avoided due to these reasons.

2. *Security issues:* In the security perspective, the cloud environment should be protected from unauthorized access and data redundancy [8]. But a number of security attacks occur to the cloud environment. Some of the popular attacks include the Denial-of-Service attack (IP spoofing, SYN flood attack, Buffer overflow attack etc.) as well as the cloud malware injection attack which tries to inject some vulnerability inside the cloud system. The other security issues comprises pf the abusive use of cloud computing, data leakage, infected interfaces and insecure APIs, account hijacking and malicious insiders. The unauthorized access to the cloud causes data theft and breakage of cloud system. Thus, the cloud computing faces more danger from malicious behavior than from the processing risks occurring inside. As far the data backup issues are concerned, the remote data hosting in cloud is more critical. The multitenancy feature of cloud also arises some security issues. Since cloud providers maximize hardware utilization through virtualization. These virtual machines are isolated i.e. sandboxed and thus benefits for the users using same hardware. But sometimes, these obstacles are broken and an attacker can easily take over the host, causing cross-VM side-channel attacks [17].

3. *Trust issues:* For a stable and successful cloud environment, there must exist a trustful relationship between the service provider and consumer. This trust matter a lot in terms of resource distribution. Service Level Agreement (SLA) is the key document between the provider and consumer which binds them for a certain time period with the commitment of defined services. Quality of Service (QoS) is one of the SLA's key parameters that enables in building a trusted relationship. However, in a cloud environment, there are sometimes weak trust relationships. A customer may trust some of the providers but not the others [17]. When the customers are asked for their personal data, they are not sure whether they will have their data secured and for what reason they are being asked. This creates lack of customer trust.

Due to all these factors and issues, cloud computing is affected even in today's world. Furthermore, the congested networks and the long distances between the cloud data center and the clients which caused significant data transmission delays. As well as the cloud's centralized nature in cloud computing are the main factors which gave rise to the birth of Fog Computing.

IV. Fog Computing

Another computing paradigm i.e. Fog Computing is presented to solve the challenges faced by cloud computing. 'Fog', as the name suggests, is a cloud near to the ground, extending the cloud computing architecture to the network's edge [18]. Actually, the fog acting as a medium layer between the IOT devices and the cloud data centers, distributes the load by performing most of the application processing itself while the rest is directed towards the cloud data center [19]. These operations include data storage, networking and data computing etc. so that the cloud-based services are offered near the devices as compared to that performed by the cloud data center at the far-off places. Since cloud computing follows the centralization of data i.e. the cloud data centers are physically centralized, the cloud is unable to fulfill the storage as well as processing needs of millions of connected IOT devices. Thus, results in the failure of the cloud system [19]. Additionally, the data congestion, large end-to-end delays of data transmissions due to the large physical gaps between the cloud data center and the connected end users, massive data processing and communication makes the cloud computing paradigm much complicated to perform its task [20].

A. Architecture

To have an alternative solution to all these cloud computing problems, Fog Computing is emerged. **F**rom c**O**re to ed**G**e computing is a distributed architecture between cloud and different grounds. The 3-tier architecture consist of the cloud data center layer, the fog layer and the layer of end users. IOT devices from the end user layer are firstly connected to the fog layer through LAN, unlike the cloud computing case where the end users connect with the cloud server through WAN [18]. In the fog layer, the fog nodes, also known as fog servers, micro servers or micro data centers, provide data storage and processing services like the cloud data servers. They are often located at common locations like shopping centers, parks, bus stop terminals etc. [19]. The nodes may include networking devices like routers, switches PCs, mobile phones etc. performing data networking operations.

Many researchers have defined Fog Computing according to their research and knowledge. According to the definition of Fog Computing by OpenFog Consortium [20], "a system-level horizontal architecture that distributes resources and services of computing, storage, control and networking anywhere along the continuum from cloud to Things." However some believe Fog Computing as; "a scenario where a huge number of heterogeneous (wireless and sometimes autonomous) ubiquitous and decentralized devices communicate and potentially cooperate among them and with the network to perform storage and processing tasks without the intervention of third parties. These tasks can be for supporting basic network functions or new services and applications that run in a sandboxed environment. Users leasing part of their devices to host these services get incentives for doing so" [21].

B. Properties

Fog Computing comprises of a number of characteristics that differentiates it from other computing paradigms. Some of its characteristics include the following [20, 21]:

- **Reduced latency:** Since in a fog computing architecture, the fog nodes are placed near the end users, thus the data processing has low latency rate. Fog Computing is favorable for latency-sensitive applications.
- **Decentralization:** Unlike cloud computing, Fog Computing has a decentralized architecture. They are geographically distributed and provisioned services.
- **Intermediate layer:** The fog layer in fog architecture acts as an intermediate layer between the end user and cloud server, facilitating both the entities.
- **Low energy consumption:** Due to the dispersed nature of fog nodes, less heat energy is produced and thus less cooling arrangements are required [24].
- **Mobility:** Fog nodes can directly get connected with mobile devices and thus enables end device mobility methods.
- **Location Awareness:** Fog nodes are located at different locations throughout the globe. This indicates the location awareness of Fog Computing.
- **Interoperability:** Fog nodes are capable of working on different platforms with different domains and service providers.
- **Real-time applications:** Fog Computing enables real-time interaction between the end users and fog nodes.
- **Scalability:** The fog layer contains scalable sensor networks controlling the whole environment. There exists large-scale end devices connected in a network.
- **Heterogeneity:** The heterogeneous nature of fog nodes and end devices make them enable to work together on different platforms.

C. Issues and Challenges

Despite of all the characteristics and properties, Fog Computing still faces a number of challenges.

- **Device Authentication:** A number of heterogeneous devices make attempts to get connected with the fog nodes. These devices should be firstly authenticated to avail the network services. Through this step, the unauthorized devices are prevented. Traditional computing paradigms used to circulate Primary key Infrastructure (PKI) and certificates for authentication purposes. But it is becoming more critical in the case of Fog Computing. Some authentication protocols have been proposed to serve the purpose but authentication should be offered as a service to guarantee a secure computing environment. Moreover, dynamic nature of fog nodes may cause interruptions for authenticated end user devices [23]. Devices face complexities while registering and in re-authentication steps.

- **Resource Management:** Fog nodes have limited storage and computing capabilities as compared to the cloud servers. Thus, the resource management remains a critical issue for the micro centers to decide which end users require the resource urgently.

- **Security:** Since the fog nodes are deployed around the globe with less protection steps, Fog Computing are subjected to malicious security attacks [22]. Sometimes, some malicious fog nodes become a threat for the data security. However, sometimes, data security is compromised due to malicious edge devices. In both the cases, the identification of the fault is difficult. Man-in-the-middle attack is one of the common attacks while data transmission from user device to fog nodes [22]. Denial-of-Service attack occurs when a number of devices demand for unlimited storage and processing services. One of the serious attacks include the data theft attack which is due to the malicious member inside the cloud provider. Lack of authenticated cloud providers results in the occurrence of data theft attack [23].

- **Scalability:** One of the real challenges for Fog Computing is handling millions of end user devices and providing storage and processing services to billions of data generated by those connected devices. The number of devices are increasing day by day and so does the produced data [21].

- **Privacy:** In fog computing, the fog nodes lie near the end user devices and contains private data that needs privacy controls. However, due to decentralized infrastructure, the centralized control of the cloud server doesn't exist and the privacy check of data is now up to the fog nodes [22]. An attacker in a critical situation may enter the network and steal the data from the nodes. Furthermore, location privacy issue also arises when end users offload data to the nearest fog nodes and transmit their personal location along. Due to frequent communications between the fog nodes and clients as well as the inter-communications between the fog nodes, private data is leaked and thus causes privacy issues within the system [23].

- **Trust:** A stable fog environment can be maintained by having a trust factor in between its layer components. They should observe trust in 2 main scenarios: 1st when the end devices request services from the fog nodes, the nodes should identify and trust the devices whose resource needs are genuine. 2nd when the IOT devices offload their private data to an authorized fog node that needs to be verified. This model ensures security, trust and reliability within the fog environment [22-24].

V. CONCLUSION

Traditional cloud computing is being replaced by the new developed computing paradigms like Fog Computing, Edge Computing etc. With the increase in IOT devices within the network, researchers are trying to reduce the latency rate and enhance the network performance keeping the security perspective into consideration. Fog computing has significant applications due to its distributed nature and efficient storage and processing services. However, technology should introduce new computing paradigms keeping in view the security, privacy and trust issues of data.

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