Fog Computing V/S Cloud Computing: A Survey

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Abstract: With the rapid growth of Internet of Things (IoT) applications, the classic centralized cloud computing paradigm faces several challenges such as high latency, low capacity and network failure. To address these challenges, fog computing brings the cloud closer to IoT devices. The fog provides IoT data processing and storage locally at IoT devices instead of sending them to the cloud. In contrast to the cloud, the fog provides services with faster response and greater quality. Therefore, fog computing may be considered the best choice to enable the IoT to provide efficient and secure services for many IoT users. This paper presents the state-of-the-art of fog computing and its integration with the IoT by highlighting the benefits and implementation challenges. This review will also focus on the architecture of the fog and emerging IoT applications that will be improved by using the fog model. Finally, open issues and future research directions regarding fog computing and the IoT are discussed.

***IndexTerms*- Internet of Things; cloud of things; fog computing; fog as a service; IoT with fog computing; cloud computing**

I. Introduction: The Internet of Things (IoT) is one of the spotlight innovations which have the potential to provide unlimited benefits to our society. The development of the IoT is about to reach a stage at which many of the objects around us will have the ability to connect to the Internet to communicate with each other without human intervention [1]. Originally, the IoT was intended to reduce human data entry efforts and use different types of sensors to collect data from the environment and permit automatic storage and processing of all these data [2,3]. Today's state-of-the-art applications are typically deployed on top of cloud services, thus, leveraging cost benefits, ease-of-use, elastic scalability, and the illusion of infinite resources [5].While cloud services come with these obvious benefits, they also have a major disadvantage: cloud data centers are centralized and, thus, typically far from the end user resulting in high access latencies. This is sufficient for many application domains such as enterprise or web applications but not for more modern application domains such as autonomous driving, Internet of Things (IoT)-based platforms, or 5G mobile applications. Therefore, these applications are typically deployed on edge devices.

In this situation, an obvious approach is to use both cloud services and edge nodes at the same time to achieve low latency while having access to scalable, infinite resources. This paradigm, which has recently emerged as a natural extension of Cloud Computing, is typically referred to as Fog Computing.

The term fog computing was coined by Cisco [6]. It is a new technology that provides many benefits to different fields, especially the IoT. Similar to the cloud, fog computing provides services to IoT users such as data processing and storage. Fog computing is based on providing data processing capabilities and storage locally to fog devices instead of sending them to the cloud. Both the cloud and fog provide storage, computing and networking resources.

The purpose of fog computing in the IoT is to improve efficiency, performance and reduce the amount of data transferred to the cloud for processing, analysis and storage. Therefore, the data collected by sensors will be sent to network edge devices for processing and temporary storage, instead of sending them into the cloud, thus reducing network traffic and latency [7].

This paper provides an overview of the comparison of fog computing with the Cloud computing; this involves an investigation of the fog state-of-the-art, characteristics and benefits. The integration and differences of the cloud computing with fog computing is also discussed by highlighting the integration benefits, emerging cloud computing challenges encountered. Related models and articles that discuss the integration of the cloud computing with the fog are described.

II. Cloud Computing to Fog Computing

Fog computing has been initially introduced in the telecommunication sector [4] when researchers and practitioners realized how the role of the final users changed from consumers of information to prosumers. Prosumers with mobile devices or IoT sensors, however, generate immense data quantities at the edge of the network. Edge Computing is exclusively about computation at the edge of the network without any notion of cloud services. Depending on the source, Fog Computing is either the same as Edge Computing [2] or is defined as the amalgam of cloud, edge, and any intermediary nodes in between. In addition, the centralized cloud approach is not appropriate for IoT applications where operations are time-sensitive, or Internet connectivity is poor. There are many scenarios where milliseconds can have serious significance, such as telemedicine and patient care. This is the same scenario for vehicle-to-vehicle communications, where avoiding collisions or accidents cannot tolerate the latency caused by the centralized cloud approach. Therefore, an advanced cloud computing paradigm that improves the capacity and latency constraints is required to handle these challenges. With the advent of Fog Computing, applications based on this paradigm can exploit the advantages of both the edge and cloud environments.

To realize its full potential, Fog Computing must be more than creating a data center in the box, i.e., Cloudlets. Instead, Fog Computing must be seen as a “resource layer that fits between the edge devices and the cloud data centers. For this, Fog Computing technologies especially need to enable fluid data movement between cloud services and edge, in both directions, while satisfying application constraints in terms of quality of service (QoS). With specifically tailored frameworks, e.g., [7], developers can leave it to the Fog Computing layer to automatically handle data and computation placement. While Cloud Computing is largely centered on a service concept, this is not (yet) the case for the edge. Already today, cloud service providers offer access to cloud infrastructure services. Fog service providers, in contrast, offer service-based access to fog infrastructure resources – in this capacity, fog service providers may act as resellers. Fog application providers rent resources through fog infrastructure services to offer their application to clients. We explicitly use the broad term “client” as this may include IoT devices, mobile phones, or any other end user.

However, there are several obstacles and yet unsolved research challenges that need to be faced in order to actually pave the way for a broad adoption of Fog Computing. For instance, even if it does not mention Fog Computing, [6] analyses the challenges when considering the integration of IoT and cloud services, thus, in a scenario close to Fog Computing.

III. Fog Computing

Fog computing is a paradigm with limited capabilities such as computing, storing and networking services in a distributed manner between different end devices and classic cloud computing. It provides a good solution for IoT applications that are latency-sensitive [3]. Although the term was originally coined by Cisco [6], fog computing has been defined by many researchers and organizations from a number of different perspectives. Yi et al. [4] have provided a general definition of fog computing. It is stated as; “Fog Computing is a geographically distributed computing architecture with a resource pool which consists of one or more ubiquitously connected heterogeneous devices (including edge devices) at the edge of network and not exclusively seamlessly backed by Cloud services, to collaboratively provide elastic computation, storage and communication (and many other new services and tasks) in isolated environments to a large scale of clients in proximity”. Fog computing is also defined by the Open Fog Consortium [8] as; “a system-level horizontal architecture that distributes resources and services of computing, storage, control and networking anywhere along the continuum from Cloud to Things”.

3.1 Features of Fog Computing

Fog computing is considered to be the building blocks of the cloud. According to Ai et al. [5] and Yi et al. [4], the characteristics of fog computing can be summarized as follows:

a. Location awareness and low latency
b. Geographical distribution
c. Scalability
d. Support for mobility
e. Real-time interactions
f. Interoperability

3.2 Main obstacles in adopting Fog Computing

a. No Edge Services
b. Lack of Standardized Hardware
c. Management Effort
d. No Network-Transparency
e. Physical Security

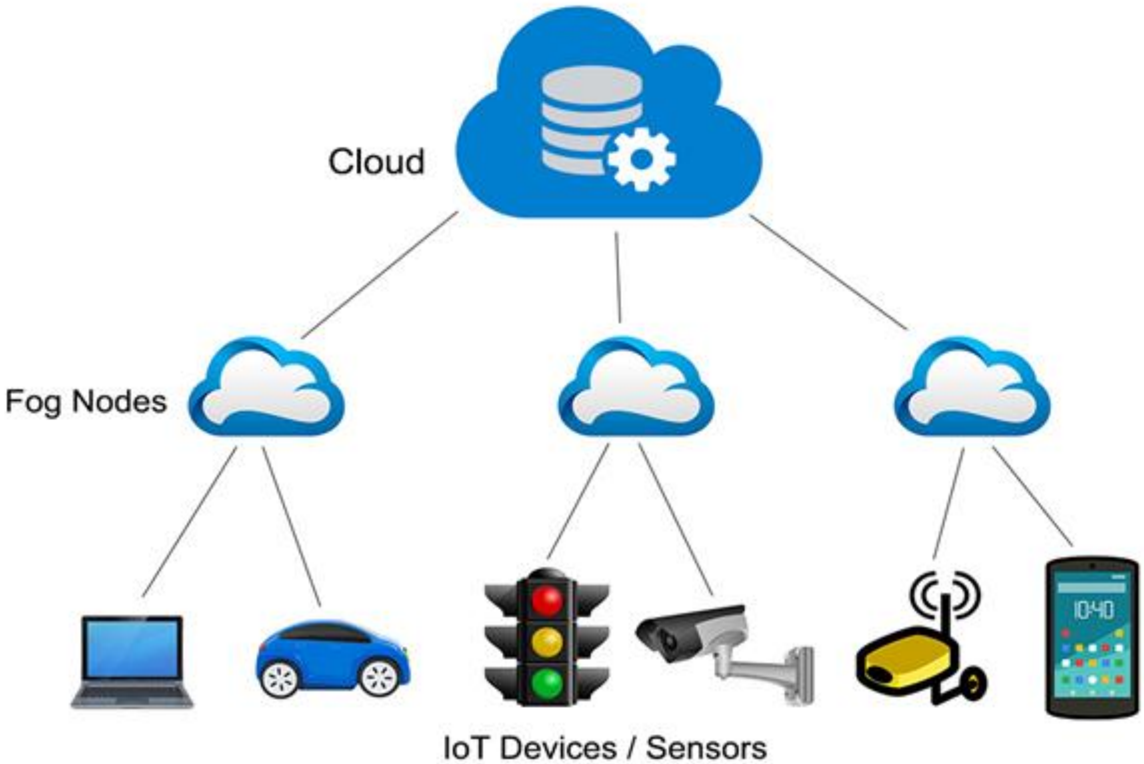

Fig1: Fog Computing with Cloud computing using IOT

IV. Comparison between Cloud Computing and Fog Computing

Parameters	Cloud	Fog
Architecture	Centralized	Distributed
Communication with devices	From a distance	Directly from the edge
Data Processing	Far from the source of information	Close to the source of information
Computing Capabilities	Higher	Lower
Number of nodes	Few	Very Large
Analysis	Long-term	Short-term
Latency	High	Low
Connectivity	Internet	Various protocols and standards
Security	Lower	Higher

Conclusion:

While Cloud Computing can today be considered well established, modern application domains such as IoT, autonomous driving, or even mobile applications trying to tap the full potential of future 5G networks require an extension of the cloud towards the edge, thus, naturally leading to the new Fog computing paradigm. In Fog Computing, application services run on both edge nodes (with low latency access but very limited resource capabilities) and in the cloud (with higher access latency but practically unlimited resources) as well as on possible intermediary nodes. Fog computing as a new paradigm is a yet virtually unexplored field that offers a number of open research challenges.

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