Fog computing: A review and conceptual architecture, issues, applications and its challenges

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ABSTRACT

Fog computing, an extension of cloud computing services to the edge of the network to decrease latency and network congestion, is a relatively recent research trend. Although both cloud and fog offer similar resources and services, the latter is characterized by low latency with a wider spread and geographically distributed nodes to support mobility and real-time interaction. In this paper, we describe the fog computing architecture and review its different services and applications. We then discuss security and privacy issues in fog computing, focusing on service and resource availability. Virtualization is a vital technology in both fog and cloud computing that enables virtual machines (VMs) to coexist in a physical server (host) to share resources. Indeed, the Fog, which does not replace the centralized Cloud but cooperates with it[5].

Keyword : -*Cloud computing, fog computing, IoT*

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1. INTRODUCTION

Cloud computing can be an efficient alternative to owning and maintaining computer resources and applications for many organizations, particularly small- and medium sized organizations, due to the pay-as-you-go model and other characteristics (e.g., on-demand, self-service, resource pooling and rapid elasticity). The continued interest in cloud computing has also resulted in other emerging cloud paradigms, such as fog computing. In fog computing, cloud elastic resources are extended to the edge of the network, such as portable devices, smart objects, wireless sensors and other Internet of Things (IoT) devices to decrease latency and network congestion. IoT devices use interconnected technologies like Radio Frequency Identify (RFID) and Wireless Sensor and Actor Networks (WSAN) to exchange information over the Internet, and are more integrated in our daily life. Smart-home, smart-city and smart-grid are examples of IoT applications, where sets of sensors are used to obtain information to improve the quality of life and quality of experiences. IoT is characterized by widely distributed objects known as ‘things’ with limited storage and processing capacity to guarantee efficiency, reliability and privacy. However, its applications require geo-distribution, mobility support, location-awareness and low latency to efficiently collect and process data from IoT devices. This information is then used to perform detection and prediction for optimization and timely decision-making process. Cloud and fog computing share overlapping features, but fog computing has additional attributes such as location awareness, edge deployment and a large number of geographically distributed nodes in order to offer a mobile, low latency and real-time interaction. The deployment of both cloud and fog computing is primarily driven by virtualization technology, which introduces a software abstraction between the computer hardware and the operating system (OS) and application running on the hardware. This abstraction layer is also known as a Virtual Machine Monitor (VMM) or hypervisor. The VMM acts as a controller of hardware resources and enables multi-tenancy by allowing multiple OS to co-exist on the same physical hardware and share resources[5].

2. ISSUES IN CLOUD

IoT environments generate unprecedented amounts of data that can be useful in many ways, particularly if analyzed for insights. However, the data volume can overwhelm today's storage systems and analytics applications.

Cloud computing could help by offering on-demand and scalable storage, as well as processing services that can scale to IoT requirements. However, for health-monitoring, emergency-response, and other latency-sensitive applications, the delay caused by transferring data to the cloud and back to the application is unacceptable. In addition, it isn't efficient to send so much data to the cloud for storage and processing, as it would saturate network bandwidth and not be scalable.

Recent analysis of a healthcare-related IoT application with 30 million users showed data flows up to 25,000 tuples per second And real-time data flows in smart cities with many more data sources could easily reach millions of tuples per second. To address these issues, edge computing was proposed to use computing resources near IoT sensors for local storage and preliminary data processing. This would decrease network congestion, as well as accelerate analysis and the resulting decision making. However, edge devices can't handle multiple IoT applications competing for their limited resources, which results in resource contention and increases processing latency.

3. FOG COMPUTING

CISCO recently delivered the vision of fog computing to enable applications on billions of connected devices, already connected in the Internet of Things (IoT). IoT combines information and computing processes to control very large collections of different objects.

Fog computing is a distributed paradigm that provides cloud-like services to the network edge. It leverages cloud and edge resources along with its own infrastructure, as Figure 1 shows. In essence, the technology deals with IoT data locally by utilizing clients or edge devices near users to carry out a substantial amount of storage, communication, control, configuration, and management.

Fog computing involves the components of data-processing or analytics applications running in distributed cloud and edge devices. It also facilitates the management and programming of computing, networking, and storage services between datacenters and end devices. In addition, it supports user mobility, resource and interface heterogeneity, and distributed data analytics to address the requirements of widely distributed applications that need low latency.

4. FOG COMPUTING ARCHITECTURE

Fog computing is well suited for the geographical distribution of resources instead of having a centralized one, meaning Fog computing is the extension of Cloud computing. The difference is Fog provides proximity to its end users through dense geographical distribution and it also supports mobility. Access points or set-up boxes are used as end devices to host services at the network. In Fog computing platform multi-tier architecture is used. In first tier there is machine to machine communication and the higher tiers deals with visualization and reporting. See in Figure 1[2].

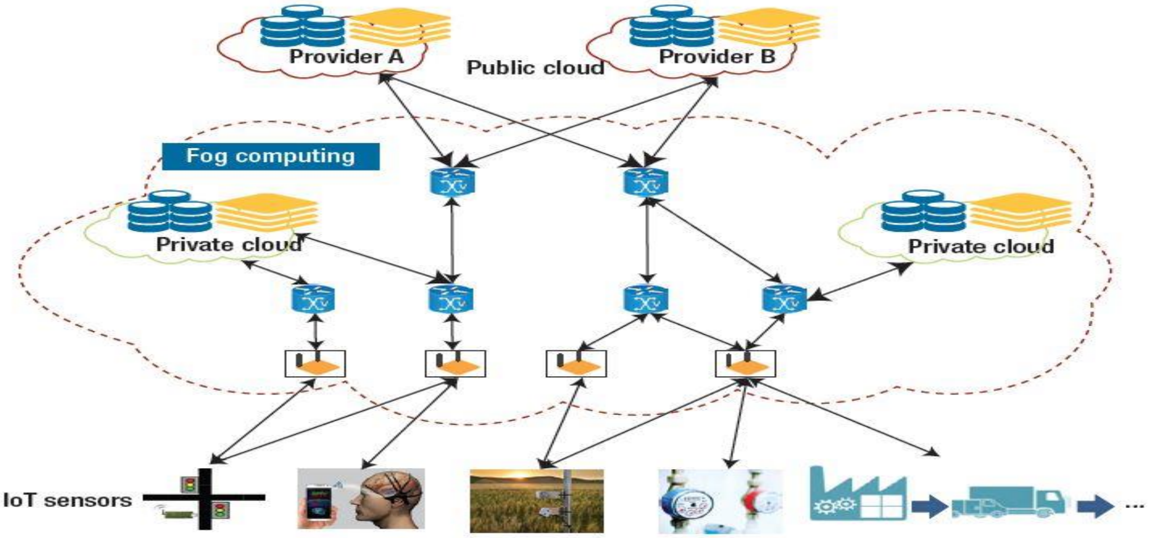

Fig -1: Fog computing Architecture

5. KEY FEATURES

- Heterogeneity: Fog computing is a virtualized platform that offers computational, networking and storage services between cloud computing and end devices. Its heterogeneity feature serves as a building block as it exists in different forms and can be deployed in wide ranging environments.

- Geographical distribution: Fog computing has a widely distributed deployment in order to deliver high-quality services to both mobile and stationary end devices.

- Edge location, location awareness and low latency: The emergence of fog computing is partly due to the lack of support for endpoints with quality services at the edge of the network. Examples of applications with low latency requirements are video streaming in real-time closed circuit television monitoring and gaming.

- Real-time interaction: Various fog applications, such as real-time traffic monitoring systems, demand real-time processing capabilities rather than batch processing.

- Support for mobility: Mobility support is essential for many fog computing applications to enable direct communication with mobile devices using protocols such as Cisco's Locator/ID Separation Protocol that decouples host identity from location identity using a distributed directory system.

- Large-scale sensor networks: This is applicable when monitoring the environment or in smart grid using inherently distributed systems that require distributed computing and storage resources.

- Prevalent to wireless access: Wireless access points and cellular mobile gateway are typical examples of a fog network node.

- Interoperability: Fog components must be able to interoperate to ensure support for wide range of services like data streaming.

5. SUMMARY OF FOG COMPUTING, CLOUD COMPUTING AND IOT FEATURES.

Table -1: Summary of Fog computing, cloud computing and IoT feature[4]

Features	Fog computing	Cloud computing	Internet of things
Target User	Mobile users	General Internet user	Stationary and mobile devices
Number of server nodes	Large	Few	Large
Architecture	Distributed	Centralized	Dense and distributed
Service Type	Localized information service limited to specific deployment location	Global information collected worldwide	Information specific to the end device
Working environment	Outdoors(i.e., streets fields tracks) or Indoor (i.e., home, malls, restaurants)	Indoors with massive space and ventilation	Outdoor and Indoor
Location awareness	Yes	No	Yes
Real-time interactions	Supported	Supported	Supported
Mobility	Supported	Limited supported	Supported
Big data and duration of storage	Short duration as it transmits big data	Months and years as it manages big data	Transient as it is the source of big data
Major service provider	Cisco IOx	Amazon, Microsoft, IBM	ARM, Atmel, Bosch

6. ADVANTAGES

- Gets the data close to the user. Instead of housing information at data center sites far from the end-point, the Fog aims to place the data close to the end-user.
- Creates dense geographical distribution. First of all, big data and analytics can be done faster with better results. Second, administrators will be able to support location-based mobility demands and not have to traverse the entire network. Third, these edge (Fog) systems would be created in simplest way that real-time data analytics become a reality on a truly massive scale.
- True support for mobility and the Internet of Everything. By controlling data at various edge points, Fog computing integrates core cloud services with those of a really distributed data center platform. As more services are created to benefit the end-user, edge and Fog networks will become more prevalent.
- Many verticals are ready to adopt. Many organizations are already adopting the concept of the Fog. Many different kinds of services aim to deliver rich content to the end-user. This spans IT shops, vendors, and entertainment companies as well.
- Seamless integration with the cloud and other services. With Fog services, we‘re able to enhance the cloud experience by isolating user data that needs to live on the edge. From there, administrators are able to tie-in analytics, security, or other services directly into their cloud model[3].

7. APPLICATION

- Healthcare and activity tracking: Fog computing could be useful in healthcare, in which real-time processing and event response are critical. One proposed system utilizes fog computing to detect, predict, and prevent falls by stroke patients[2].

- Smart utility services: Fog computing can be used with smart utility services whose focus is improving energy generation, delivery, and billing. In such environments, edge devices can report more fine grained energy-consumption details (for example, hourly and daily, rather than monthly, readings) to users’ mobile devices than traditional smart utility services. These edge devices can also calculate the cost of power consumption throughout the day and suggest which energy source is most economical at any given time or when home appliances should be turned on to minimize utility use[2].

- Augmented reality, cognitive systems, and gaming : Fog computing plays a major role in augmented-reality applications, which are latency sensitive. For example, online brain–computer interaction game performs continuous real-time brain-state classification on fog devices and then tunes classification models on cloud servers, based on electroencephalogram readings that sensors collect. A wearable cognitive-assistance system that uses Google Glass devices helps people with reduced mental acuity perform various tasks, including telling them the names of people they meet but don't remember. In this application, devices communicate with the cloud for delay-tolerant jobs such as error reporting and logging. For time-sensitive tasks, the system streams video from the Glass camera to the fog devices for processing. The system demonstrates how using nearby fog devices greatly decreases end-to-end latency[2].

8. ISSUES AND CHALLENGES IN FOG COMPUTING

Realizing fog computing full potential presents several challenges including balancing load distribution between edge and cloud resources, API and service management and sharing. There are several other important examples.

- Enabling real-time analytics: In fog environments, resource management systems should be able to dynamically determine which analytics tasks are being pushed to which cloud or edge-based resource to minimize latency and maximize throughput. These systems also must consider other criteria such as various countries' data privacy laws involving, for example, medical and financial information.

- Programming models and architectures: Most stream- and data-processing frameworks, including Apache Storm and S4, don't provide enough scalability and flexibility for fog and IoT environments because their architecture is based on static configurations. Fog environments require the ability to add and remove resources dynamically because processing nodes are generally mobile devices that frequently join and leave networks.

- Security, reliability, and fault tolerance: Enforcing security in fog environments which have multiple service providers and users, as well as distributed resources is a key challenge. Designing and implementing authentication and authorization techniques that can work with multiple fog nodes that have different computing capacities is difficult. Public-key infrastructures and trusted execution environments are potential solutions. Users of fog deployments also must plan for the failure of individual sensors, networks, service platforms, and applications. To help with this, they could apply standards, such as the Stream Control Transmission Protocol, that deal with packet and event reliability in wireless sensor networks.

- Privacy: The fog will allow applications to process user‘s data in third party‘s hardware/software. This of course introduces strong concerns about data privacy and its visibility to those third parties.

- Power consumption: Fog environments consist of many nodes. Thus, the computation is distributed and can be less energy efficient than in centralized cloud systems. Using efficient communications protocols such as CoAP, effective filtering and sampling techniques, and joint computing and network resource optimization can minimize energy consumption in fog environments.

9. CONCLUSIONS

Fog Computing is not a replacement for Cloud Computing. Fog Computing is a big step to a distributed cloud by controlling data in all node points, fog computing allows turning data centre into a distributed cloud platform for users. Fog is an addition which develops the concept of cloud services. It is possible to isolate data in the cloud systems and keep them close to users. Fog computing is proposed to enable computing directly at the edge of the network, which can deliver new applications and services especially for the future of Internet. Fog computing extends the Cloud Computing paradigm to the edge of the network, thus enabling a new breed of applications and services. Defining characteristics of the Fog are: low latency and location awareness; wide-spread geographical distribution; mobility; very large number of nodes, predominant role of wireless access, strong presence of streaming and real time applications, heterogeneity. In this paper, the authors argue that the above characteristics make the Fog the appropriate platform for a number of critical Internet of Things (IoT) services and applications, namely, Connected Vehicle, Smart Grid, Smart Cities, and, in general, Wireless Sensors and Actuators Networks (WSANs)[3].

10. REFERENCES

[1]. Carlo Puliafito, EnzoMingozzi, Giuseppe Anastasi,”Fog computing for the Internet of Mobile Things: issues and challenges”. In 2017 IEEE.

[2]. Amir Vahid Dastjerdi and Rajkumar Buyya,“Fog Computing: Helping the Internet of Things Realize its Potential” in IEEE 2016.

[3]. Niranjanamurthy M, Kavitha P B, Priyanka Kasana, Vishnu S N,”research study on fog computing for secure data security”.In International journal of science Technology and management 2016.

[4]. Opeyemi osanaiye, shuo chen, zheng yan, rongxing lu, kim-kwang raymond chooand mqhele dlodlo, ”From Cloud to Fog Computing: A Review and a Conceptual Live VM Migration Framework” in IEEE 2017.

[5]. Y. Cao et al., “FAST: A Fog Computing Assisted Distributed Analytics System to Monitor Fall for Stroke Mitigation,” Proc. 10th IEEE Int’l Conf. Networking, Architecture and Storage (NAS 15), 2015, pp. 2–11.

[6]. Sonali khairnar, dhanashree borkar, "fog computing: a new concept to minimize the attacks and to provide security in cloud computing environment"ijret: international journal of research in engineering and technology volume: 03 issue: 06 | jun-2014

[7]. Kshamata Shenoy, Prachi Bhokare, Unnathi Pai "FOG Computing Future of Cloud Computing"International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Volume 4 Issue 6, June 2015.