IMPROVING IOT APPLICATIONS USING FOG COMPUTING ENVIRONMENT

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Abstract - With the fast growth of Internet of Things (IoT) applications, the cloud computing can solve an important issue IoT represented by the availability of limited resources. However, cloud computing faces several challenges such as high latency, low capacity and network failure. To overcome these challenges, fog computing brings the cloud down to IoT devices. The fog delivers IoT data processing and storage locally at IoT devices rather than sending them to the cloud. Unlike the cloud, the fog offers services with greater quality and faster response. Furthermore, fog computing can be considered the best option to provide efficient and secure services for IoT users.

Keywords - Internet of Things; Cloud of Things; CoT; Fog computing; IoT with Fog Computing; Cloud Computing.

I. INTRODUCTION

Due to the fast developments in technology, IoT is one of the important innovations which has the possibility to provide great benefits to society. The day when objects around us communicate with each other without user intervention is as close as ever. However, there are still many issues including (performance, security, privacy and reliability, limited resources in terms of processing power and storage) that need to be addressed. On the other hand, Cloud of Things (CoT) represents the integration of the IoT with the cloud and has the potential to overcome most of these issues [1]. However, as there are a substantial number of IoT devices with heterogeneous platforms, the development of new IoT applications is a difficult procedure. The CoT makes the flow of IoT data collection and processing easier. In addition, it provides quick low-cost installation and integration for complex data processing and deployment. This large amount of data is subsequently analyzed to determine decisions regarding various actions. Sending all these data to the cloud requires significantly higher network bandwidth. In this case, fog computing (a horizontal paradigm that lies between the smart devices and the data centers [2]) might provide a solution to help with these issues.

The goal of fog computing in IoT is to enhance efficiency, performance and to reduce the amount of data transferred to and from the cloud for processing, analysis and storage. Therefore, the data collected by sensors, instead of being sent to the cloud are sent to network edge devices for processing and temporary storage, thus reducing network traffic and latency.

This paper reviews the state of the art in the field of fog and IoT. In addition, it presents empirical results using the iFogSim simulator focusing on latency. network usage and energy.

II. LITERATURE REVIEW

The concept of IoT was first mentioned in 1999 by Kevin Ashton, when he said that “The Internet of Things has the potential to change the world, just as the Internet did. Maybe even more so”. In 2005, the International Telecommunication Union (ITU) formally presented the IoT. According to the ITU (2012), the IoT is “a global infrastructure for the Information Society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies” [1].

IoT is a new paradigm that adds a new dimension to the modern wireless telecommunications by enabling communications with and among smart objects, thus leading to the dimension of „„anytime, anywhere, any media, anything” communications. The idea of this concept is a network of physical "things" or objects (embedded with electronics, operating system (OS) and network sensors) enabled to change information and services by interacting (with each other, the manufacturer, devices and other connected operators) through Internet with advanced communication protocols without human involvement. IoT devices have a high impact on several aspects of daily-life, behavior of potential users and the next generation networks.
The word „things“ in IoT term refers to any object in world with an embedded network sensor, whether it is a smart communication device or an idle object. The backbone of IoT can be considered the Machine-to-Machine (M2M) communication. In M2M, communication between two machines takes place without any human interaction. For examples like smart home and e-Health applications. Huge amounts of data can be generated by billions of connected devices and transferred through the networks to the Internet[6].
Cloud computing has been defined by the National Institute of Standards and Technology (NIST) as “a

model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction"[1].

Fog computing is an idea first introduced by CISCO in 2012 and it is an extension of cloud computing from the core to the edge of the network. It enables computing at the edge of the network, closer to IoT and/or the end-user devices. It also supports virtualization [2].

Fog computing in computer science is a new distributed computing infrastructure model that extends the services offered by the cloud such as computation, communication, and storage facilities to edge devices. Although both paradigms (cloud computing and cloud computing) provide a similar set of services in terms of processing, storage etc., fog provides an additional advantage because of it closeness to the user and its dense geographic coverage. The fundamental element of the fog computing architecture is called a „fog node", which is an extra layer added between an IoT device/data generating node and a remote cloud server. The aim of these fog nodes are to speed up time-sensitive applications. Services are hosted, away from the cloud [6].

The fog is a highly virtualized platform that acts as an intermediary between the cloud and end devices. It brings basic analytic services, storage and networking services to the network edge, increasing performance by positioning computing resources closer to where they need to be. Each resource-poor device with computing, storage and network connectivity can be a fog node, such as set-top-boxes, access points, routers, industrial controllers, switches and embedded servers. Fog computing does not replace cloud; it empowers the cloud computing. The fog nodes can be deployed anywhere with a network connection [2] [7]

Fog computing characteristics:

- Lower operating expense: it improves network bandwidth by working with data locally instead of sending it to the cloud for analysis.
- Minimize latency: many applications need low latency, which can be offered by fog. Analyzing data close to the device that collected it can represent the difference between averting disaster and a cascading system failure [9]
- Edge location: the fog node is positioned at the edge of the network
- Geographical distribution: unlike the centralized cloud, the fog services demand widely distributed deployments. For instance, the fog plays an active role in delivering high quality streaming to moving vehicles, through proxies and access points positioned along highways and tracks [8]
- Large-scale sensor: inherently distributed system like environment monitoring networks and the Smart Grid, require distributed computing and storage resources [8]
- Very large number of nodes: this is a consequence of the wide geo-distribution [8]
- Support for mobility [8]. It is essential for many Fog applications to communicate directly with mobile devices, and therefore support mobility techniques. Such as the LISP protocol, that decouple host identity from location identity. And require a distributed directory system
- Heterogeneity [8]: fog nodes come in different forms and are deployed in a wide variety of environments
- Real time interactions [8]: fog computing requires real time interactions for speedy service.
- Interoperability and federation: fog components must be able to interoperate, and services must be federated across domains.to support of certain services, fact that requires the cooperation of different providers [8]
- Location and context awareness [10] [8]: fog computing spreads present cloud services by spanning an edge network with many dispersed endpoints
- -Reduces amount of data sent to the cloud
- Improves system response time
- Availability: fog device provides services locally; thus, the availability of services increases [10]
- Better and faster decision making: one can analyses data locally, the way he wants. Hence, can have deeper insight into data analytics for better decision making [10]
- Privacy increases: sensitive data can be processes and stored locally. Hence the privacy and the safety of data increases [10]
- Better security: the same policy, controls, and procedures of own IT environment can be implemented for Fog devices. Thus, in addition to physical security, it increases the information/ network security [10]
- Energy efficiency: a comparison study between the energy efficacy of cloud and fog was performed and the results showed that the cloud consumed a large amount of energy compared to the fog servers [11].

Fog applications

In addition to supporting the deployment of IoT applications (such as smart cities, smart traffic lights, smart factories, smart homes, retail stores, cruise lines, airlines, vehicular, smart building control ,telematics, ICT green communications, industrial internet and industry monitoring), fog computing can be suitable for latency-critical applications [12]. Scenarios that can benefit from the fog computing concept include:

- Smart cities: fog computing suits the need of future smart cities where ubiquitous deployment of various kind of sensors requires a fog advantage [13] [6]
- Smart transportation: due to the increase number of connected vehicles, the collected data is huge; this indicates the need for big data analysis adoption [16]
- Health care: a geographically distributed intermediary layer of fog nodes between sensory nodes and cloud data centers in health monitoring systems can provide local data processing, analysis, filtering, compression before sending it to the cloud, thus ensuring high response and energy efficient communication [14] [15]
- Manufacturing: reduces time, secure machines and data, authorize access to machines, increases agility, continually confirming that safety systems are intact etc. [8]
- Utilities: restores power more quickly, detects potential physical security breaches, detects potential cyber security breaches, reduces maintenance costs and increases system reliability [8]
- Smart Grids: smart grid is another application where fog computing is being used. The filtered data are consumed locally [8]
- Self-maintaining train: Another application of fog computing is self-maintaining trains. A train ball-bearing monitoring sensor senses the changes in the temperature level and any disorder will automatically alert the train operator. Thus, major disasters can be avoided [8]
- The real Wireless Sensor Node (WSN) were operating by battery and They are also often distributed over a large geographic area Making it suitable for fog computing. Actuators serves as Fog devices [8]

Fog computing architecture as shown in Figure 1, the fog computing structure consists of three layers. The first layer is the Internet objects (IoT) devices that generated the data. The second layer is fog devices that process data. The third layer is the cloud that handles data that is not processed in the fog layer. The authors in this paper [1] provides an overview of the integration of the cloud with the IoT to overcome the challenges of IoT, such as data storage, scalability, energy efficiency. Furthermore, they mentioned that the huge amount of resources available on cloud can help the limited capabilities of IoT. For example, it helps in term of processing power, storage performance, security, privacy, reliability. In addition, it provides quick low-cost installation and integration for complex data processing.

They are aware of the relation of their work to existing literature and future work. For example, they mentioned fog computing as an extension of cloud computing and how it helps in latency.

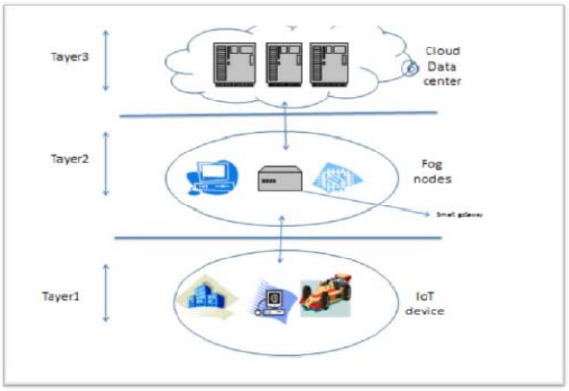


Figure 1: Fog Computing Architecture

It is true that CoT solves some of IoT issues but also, it has some challenges such as, security and privacy. Finally, the authors [1] discussed the architecture of CoT, where it has three layers: application, perception and network layer please refer to Figure 2. The network layer is the cloud layer is the cloud-based IoT architecture. The perception layer is used to identify objects and gather data, from the surrounding environment . The application layer provides the interface to different services.

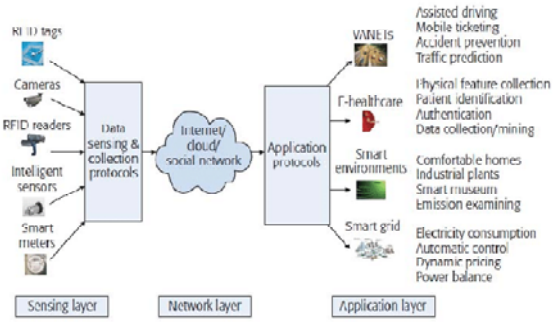


Figure 2: Cloud based IoT Architecture [1]

The authors of in [3] mentioned that fog computing complements the cloud paradigm by seeking to reduce the unnecessary internet data traffic and latency through the use of geographically distributed resources closer to the source, such as sensor [8] . However, fog computing cannot work in isolation, it operates closely with the cloud. Because its low latency and its location at the edge of local networks – with less bandwidth demand –, fog computing is just a bridge that connects the gap between the computational capabilities provided by the cloud and the demand of IoT infrastructure. The author [3] focused on understanding fog computing with IoT. They mentioned that they will discuss fog Computing and its challenges, application and its comparison with the cloud. However, they did not discuss the

challenges of fog computing with IoT. Table 1, shows comparison of cloud and fog computing.

Table 1: Cloud and Fog comparison

Areas	Cloud	Fog
Location and model of computing	Centralized in a small number of data centers.	Distributed along large geo-graphical areas and it is closer to the user. Fog nodes and systems can be controlled by a centralized node or in distributed manner.
Size	Each cloud data center is very large in size consisting of at least thousands of servers.	Each fog node can be equivalent to a single server machine. It's designed to meet the user demands.
Deployment	Requires sophisticated deployment planning	Depends on the environment. Majority of them don't require intense planning.
Operation	Operated in a fully controlled environment with technical expert teams by large companies.	Operated in environment where it primarily depends on user demands. They are not operated directly by a person. It can be operated by any size of company.
Applications	It can support predominantly cyber-domain applications. The applications mainly suffer high latency.	Can support cyber-domain, cyber-physical applications. It suffers very less latency and hence useful for time critical applications.
Network requirements	Require clients to have network connectivity until the user wants to access its services. Bandwidth requirement grows with the increase in total amount of data generated by all the clients.	Can operate autonomously to provide uninterrupted network services even with no or intermittent network connectivity. Bandwidth requirement depends on the total amount of data need to be sent to cloud after filtered by fog.

In their paper [4], the authors propose a simulator, called iFogSim, to simulate and model IoT, fog and edge environments. It measures the impact of resource management technique based on Quality of Service (QoS) criteria such as latency under different workloads. Two case studies were used to demonstrate the effectiveness of iFogSim for evaluating resource management techniques: a latency sensitive online game and the other case is an intelligent surveillance through distributed camera networks.

III. THE METHODOLOGY

In our paper, we aim to minimize delay to speed up response time leading to improvement QoS for time sensitive application by executed it at the edge of network. To prove the idea, we will implement VRGame as example of time sensitive application. We are going to implement time sensitive application model VRGame one time at cloud computing and next time at fog computing. Then compare the result and determine which is the best paradigm to implement time sensitive application in term delay, network usage and energy conception. The EEG tractor beam game application is being tested using iFogSim. iFogSim tests the application with cloud computing and fog computing.

From the existing simulators, iFogSim was selected because fog provides effective ways to overcome many limitations of existing computing architectures that rely only on computing in the cloud and on end-user devices that are related to IoT devices.

iFogSim Simulator
This paper discusses a simulator named iFogSim as a toolkit. It addresses a well-known problem which is modeling IoT and Fog environments and measure the impact of resource management techniques in terms of latency, network congestion, energy consumption, and cost .Downloaded iFogSim source zip file on Windows 10 x64 from https://github.com/Cloudslab/iFogSim or http://cloudbus.org/cloudsim/

A. EEG Tractor Beam Game (VRGame)

EEG tractor beam game is a human-vs-human game that involves an augmented brain-computer interaction. As we know about augmented reality games that it is highly latency-intolerant in which a very small delay in response can damage the user experience. Therefore, (Zao et al) built the EEG Tractor Beam game based on fog computing and linked data. When a user plays the game, he or she needs to wear an EEG headset that is connected to his smartphone. The application performs real time processing of the EEG signals to calculate the brain state of the user, which the EEG headset senses it. The application employs both fog and cloud servers, real-time processing should be performed in fog servers like the smartphone itself. On the other hand, the classification models are tuned regularly in the cloud servers based on the EEG readings [4]

IV. EXPERIMENT

The EEG tractor beam game application is being tested using ifogsim. Ifogsim tests the application with cloud computing and fog computing. In order to test the performance of fog computing on time sensitive applications. We simulated five different size physical topology. Configuration 1, Configuration 2, Configuration 3, Configuration 4, Configuration 5. Where the application is tested on fog computing and cloud computing. Each smartphone connects to headset by a Bluetooth. Each smartphone connects to the Internet via the Wi-Fi gateway connected to the ISP gateway. With Wi-Fi gateways 1, 2, 4, 8 and 16. Each gateway is connected to four smart phones playing the EEG tractor beam game. Performance of an application on the fog depends on latencies of the links connecting the fog devices. In the simulation topology, different kinds of devices have different latencies between them [4]

A. Physical Network

VR game network topology is shown in Figure 3Table 2 illustrates the fog devices used in this

topology. The links between the devices are shown in Table 3.

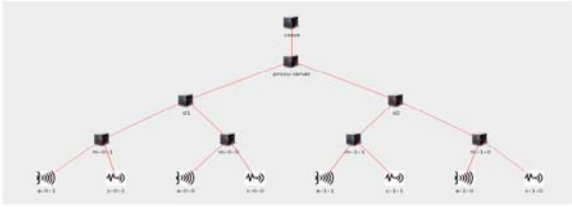


Figure 3: VR game network topology[4]

Table2 : Fog Configuration in Network Topology

Name	Rate/MIPS	Down Bw	UpBw	Ram	Level	MIPS
Cloud	0.001	10000	100	40000	0	20000
Proxy Server	0.0	10000	10000	4000	1	2000
Deployment	0.0	10000	10000	4000	2	2000
Mobile	0.0	270	10000	1000	3	1400

Table3 : Links details

Source	Destination	Latency
Proxy server	Cloud	200
Deployment	Proxy server	2
Mobile	Deployment	2
Senor	Mobile	6
Actuator	Mobile	1

V. RESULT

The results are scheduled to be readable.

A. Latency:

Table 4

Configuration	Number of rooms	Users/room	Cloud	Fog
Config1	2	4	231.285744	24.3299828
Config 2	3	4	231.185044	24.1969555
Config 3	4	4	231.212304	24.2009397
Config 4	4	8	902.684509	23.6479489
Config 5	4	12	3240.82751	22.6374573
Config 6	4	16	4055.55845	22.0306148

Chart is drown depending on results mentioned previously.

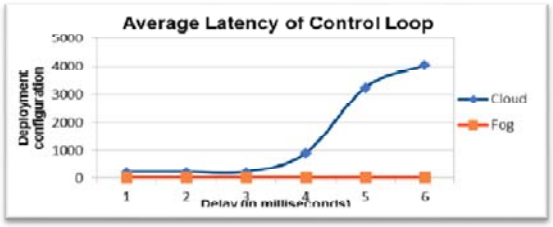


Figure 4: Average latency of control loop

Figure 4, illustrates the average latency in execution of this control loop. It shows that control loop execution delay dramatically increases for cloud device. Moreover, it shows that with the same number of rooms and users the delay for fog is much decreased compared to the cloud. So the executed time sensitive application at edge of network lead to improve the delay because fog computing provides the possibility of data processing near the source of generate data. In contrast to a cloud computing that provides sources for data processing at remote data centers. We find that fog computing reduces the delay where it reduces time for send and receive data from far data center of cloud computing

In Figure 5, we compare network usage on fog-based and cloud-based. The network usage data is shown in table 5. The increase of number of users significantly increases the load on the network. Figure 5 clearly shows that the result of network usage in fog-based applications is very low compared to the cloud-based application. This proves that fog decreases the network usage and the efficiency increases because the data will be processed at fog nodes rather than transported and processed at the cloud.

B. Network usage:

Table 5 Network Usages with Cloud computing and Fog computing

	Dept.	Mobile/Dept.	Cloud	Fog
Config1	2	4	58346.82	17947.2
Config2	3	4	89113.06	15940.8
Config3	4	4	122227.78	33934.4
Config4	4	8	230406.54	65908.8
Config5	4	12	336674.24	97883.2
Config6	4	16	440946.86	129857.6

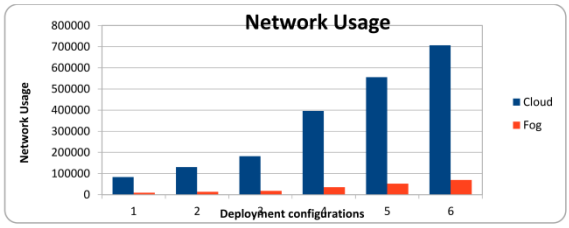


Figure 5 Comparison between Cloud and Fog in network usage

C. Average Energy Conception (mobile Energy, cloud Energy)

Table 6: Average energy conception between fog and cloud

	Number of rooms	Users/room	Mobile Energy		Datacenter Energy	
			Cloud	Fog	Cloud	Fog
Config1	2	4	874435.416	873134.552	1.56E+07	1.33E+07
Config2	3	4	874386.119	873256.052	1.61E+07	1.33E+07
Config3	4	4	874381.658	873101.633	1.62E+07	1.34E+07
Config4	4	8	873504.397	872616.414	1.63E+07	13385452.6
Config5	4	12	873112.789	871934.179	16395332.7	13415757
Config6	4	16	871327.464	871337.207	16425004.9	13446061.4

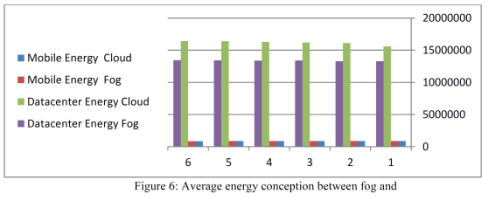


Figure 6: Average energy conception between fog and

As shown in the Figure 6, the use of fog devices in the Edge-Edge mode strategy (fog computing) lead to reduces energy consumption in cloud data centers while the power consumption of edge devices increases slightly. Unlike cloud computing, power consumption increases in cloud data centers and reduces power consumption for edge devices

CONCLUSION

In recent years, the IoT has attracted the attention of both academia and commercial organizations. Although it provides to society a great benefit, IoT devices have limited storage and processing capabilities.

The integration of the cloud with IoT might provide a solution to help with these issues. However, the cloud

has many issues, such as high latency and network traffic. To overcome these issues, fog computing has been developed as an extension of the cloud to reduce latency, especially for time-sensitive applications.

To sum up, the purpose of this paper was to provide a review of several research papers in the field of cloud and fog computing with IoT. In addition, evaluation to each of these papers was given . Then compare between cloud computing and fog computing And at this paper we are improve QoS for time sensitive application in term of latency , networks usage and energy of cloud data center by execute the time sensitive application at fog computing (edge network)

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