International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 7 Issue 2, February - 2023, Pages: 79-83

A Comparison Study of Cloud Computing and Fog Computing

Saif Y. Almahalawi[1] amd Dr.Mohammad A. Mikki[2]

[1]College of Engineering,Islamic University of Gaza
Gaza Strip, Palestine smahalawe@gedco.ps
[2]College of Engineering,Islamic University of Gaza
Gaza Strip, Palestine mmikki@iugaza.edu.ps

Abstract— *Fog computing is a decentralized computing architecture that brings computing resources and services closer to the edge of the network. It is situated between data-generating devices and the cloud, and is capable of performing functions such as computing, storing, and networking. Fog computing is distinguished from cloud computing by its decentralized nature and flexibility, and offers benefits such as reduced latency, increased reliability, reduced operational costs, increased security, and improved business responsiveness. Some potential applications of fog computing include smart cities, smart grids, and smart homes. In order to evaluate the performance of fog computing, a group of simulators will be selected based on technical features and training resources.*

Keywords— Fog, decentralized, cloud, edge, data-generating, latency, reliability, costs, security, smart cities, grids, simulators.

I. Introduction

Fog computing is a decentralized computing paradigm that aims to bring computing resources and services closer to the edge of the network, where they can be more efficiently accessed and utilized by devices and applications. It is similar to cloud computing, but aims to reduce latency and improve performance by bringing resources and services closer to the devices and users that need them. One of the main challenges faced by cloud computing is the large volume of data generated by resources, especially with the rise of the Internet of Things. Fog computing can address this challenge by distributing resources and data closer to the source, improving efficiency and reducing the need for high bandwidth. However, privacy and security concerns remain an issue in fog computing..

II. Related Work

A. Cloud Computing

Cloud computing is widely recognized for its ability to provide both hosted services and high-performance computing resources. "These services can be divided into three categories: software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS)" [5]. Cloud computing can be deployed in four different ways: public, private, community, and hybrid .

B. The Four Models of Cloud Computing:

Public cloud: This type of cloud is owned and managed by companies, academic institutions, or government organizations, or a combination of them, and is available to anyone. [1].Private cloud: This type of cloud is owned and managed by one or more organizations for the exclusive use of their customers, such as educational institutions, businesses, or government agencies. [2].Community cloud: This type of cloud is owned and managed by a specific community for use in business or security, and is typically managed by one or two organizations. [3].Hybrid cloud: This type of cloud combines elements of public, community, and private clouds in order to improve the flexibility and mobility of computing resources, data, and applications. [4] .

C. Advantages of Fog computing:

Real-time processing is crucial for many important applications. "Cloud computing is able to provide real-time service to critical applications through its control system, which is located close to the devices it serves"[6]. This helps to minimize latency and ensure efficient service. In addition to improving real-time processing, fog computing also offers a number of other benefits, including the ability to conserve network bandwidth, reduce costs, enhance security, and increase reliability.

D. Challenges of Fog computing:

Privacy and security are important considerations in fog computing. The decentralized nature of fog computing can make it easier to gather sensitive and private information from dispersed nodes. This can be especially challenging in wireless fog computing networks. Encryption may be used to address this issue. "In addition, the increased complexity of device authentication in fog computing, with multiple levels, gates, and nodes, can make it easier for outsiders with fraudulent IDs to access the network"[7]. These factors must be carefully considered in order to ensure the privacy and security of fog computing systems.

E. The applications of Fog computing:

Fog computing has numerous applications, including in smart cities and healthcare systems. In smart cities, the vast amount of data generated requires effective operating systems, which can be provided by fog computing. Its decentralized structure allows for quick resolution of issues and requirements at the point of origin. In healthcare systems, fog computing enables care providers to make timely decisions in emergency situations by accessing records, while also maintaining the confidentiality of data and reducing delays compared to cloud computing.

III. CLOUD COMPUTING VERSUS FOG COMPUTING

Cloud computing and fog computing differ in several ways. Cloud architecture is centralized, with large data centers located far from client devices, while fog design is decentralized, with numerous small nodes placed close to client devices. Fog acts as a connection between data centers and hardware, and is therefore closer to end users. Without a fog layer, direct connection between the cloud and devices can be slow. In cloud computing, data processing is handled by remote data centers, while in fog computing, processing and storage are performed at the network edge, close to the source of information, enabling real-time control.

TABLE I. CLOUD COMPUTING VERSUS FOG COMPUTING

Requirement	**Computing**	
	Cloud	***Fog***
Architecture	Centralized	Distributed
Data compromise	High probability	Low probability
Capacity	No data reduction when transmitting or transforming data	Reduces amount of data transferred to the cloud
Interaction with devices	From a distance	Directly from the edge
Computing capabilities	Higher	Lower
Connectivity	Internet	Various protocols
Data processing	Far	Close
Distance between server and client	Multiple hops	Single/multiple hops
Geo distribution	Centralized	Distributed
Latency	High	Low
Mobility	Limited	Supported
Number of server nodes	Few	Very large
Security	Less secure, undefined	More secure, can be defined
Transmission	Device to device	Device to cloud
Number of users	Unlimited	Unlimited
Resource	Unlimited	Unlimited
Type of service	IaaS, PaaS, SaaS, Everything as a service	CPU, network, memory, bandwidth, device, storage
Ownership	Single	Multiple
Future	Next generation of Internet and computing	Fog computing

IV. CLOUD/FOG SIMULATORS

After There are several simulation tools available for modeling cloud and fog environments, each with their own features and capabilities. In order to accurately simulate complex environments, especially at the level of Internet of Things (IoT) devices, it is important to consider various factors. When selecting a simulation tool, it is also useful to consider the availability of community support, such as tutorials, documentation, examples, and discussion forums. Three popular simulation tools are iFogSim, YAFS, and EdgeCloudSim. iFogSim is a Java-based tool that allows for the simulation of IoT applications in cloud/fog environments and the analysis of resource management techniques on network congestion, energy consumption, delay, and cost. YAFS, which is open-source and uses Python as its programming language, allows for the evaluation of placement, scheduling, and routing algorithms, and provides results in the form of CSV-based logs. EdgeCloudSim, which is based on CloudSim and focuses on edge computing, allows for the simulation of computational, network, and fog-specific modeling themes and provides results in CSV format. YAFS was chosen for this discussion due to its use of Python and its inclusion of various graphics libraries.

TABLE II. CHARACTERISTICS OF SIMULATORS

Characteristics \Simulators Language	**Computing**		
	iFogSim	***YAFS***	***EdgeCloudsim***
Community support	Java	Python	Java
Characteristics \Simulators	Low	Moderate	Moderate

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Fig. 1. Latest Release & Date of publication

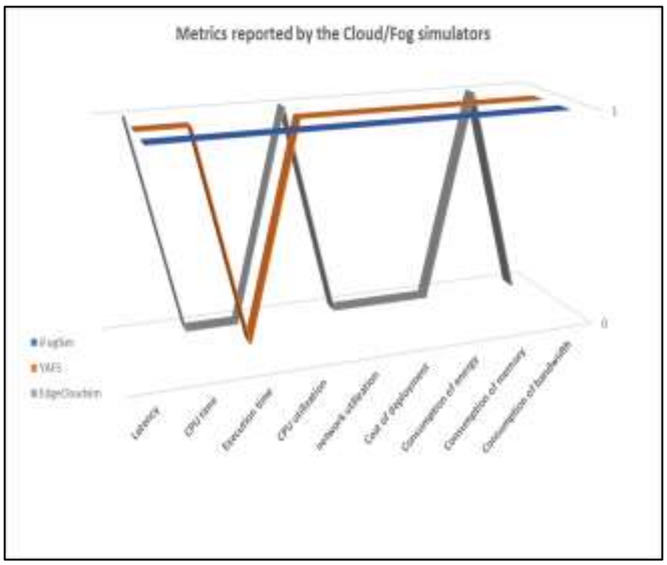

Fig. 2. Matrix reported by the Cloud/Fog simulators.

A. Comparative evaluation

A comprehensive analysis of the results of the YAFS test is presented in this paper. The experiments were conducted on a computer with 8 GB of DDR3 RAM operating at a frequency of 1333 MHz, as well as an Intel Core i7-3770HQ CPU with a clock speed of 3.40 GHz and a total of 4 cores and 8 threads. The computer was running the Ubuntu 18.04.2 LTS operating system. The programming language chosen for the implementation of YAFS was Python 2.7.15. Out of the various applications that were considered, we have focused on the health application as an example of fog computing applications in this analysis.

B. Applications modeled

The eHealth application is a simple system where data collected by a sensor attached to a patient unit is processed and sent to a diagnostic unit for further analysis. The patient unit then receives the diagnostic unit's findings for display.

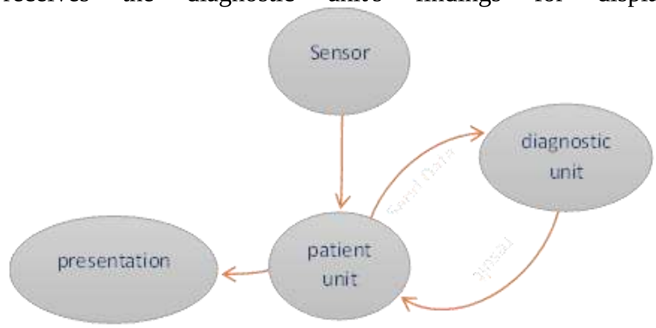

Fig. 3. eHealth application units

C. Simulation Results for Fog Computing Systems

The simulation scenario involves a variable number of Fog nodes (Fogs) and devices per Fog node (Devs). As the number of Fogs and Devs increases, the execution time for the simulation also increases. Additionally, the predicted pattern for CPU utilization and memory usage data shows that these metrics tend to increase as the scenario becomes more complex. This suggests that the simulation becomes more resource-intensive as the number of Fogs and Devs increases.

TABLE III. SIMULATIONS' EXECUTION TIME IN YAFS PER EHEALTH APPLICATION IN SECONDS

eHealth					
YAFS	**type**	**#Fogs \#Devs**	**4**	**8**	**12**
	Cloud	*4*	1.00	2.53	4.79
		8	2.50	7.92	16.63
		12	4.70	16.46	35.68
		16	7.64	27.94	61.81
		20	11.28	42.29	94.00
	Fog	*4*	1.91	6.24	13.21
		8	6.19	22.83	50.72
		12	12.89	50.05	112.43
		16	22.05	86.99	199.15
		20	33.06	133.77	305.15

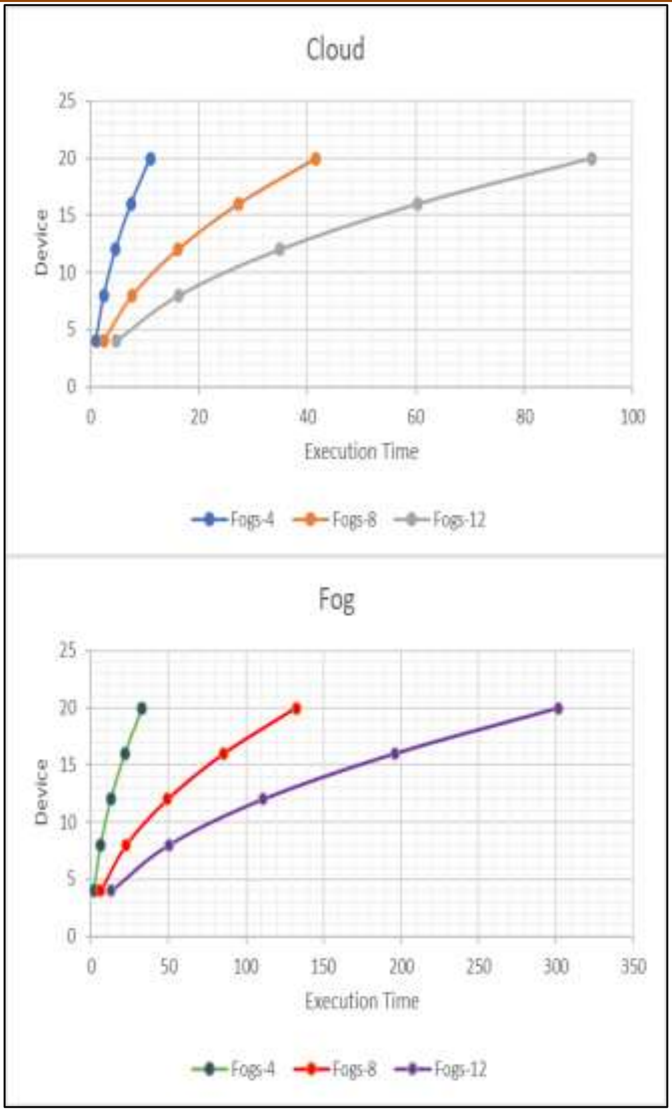

Fig. 4. EXECUTION TIME

TABLE IV. SIMULATIONS' CPU CONSUMPTION IN YAFS PER EHEALTH APPLICATION IN %

eHealth					
YAFS	type	#Fogs \#Devs	4	8	12
	Cloud	4	96.25	98.01	98.42
		8	97.92	98.46	98.58
		12	98.14	98.39	98.46
		16	98.10	98.32	98.34
		20	98.69	98.80	98.85
	Fog	4	98.22	98.90	98.99
		8	98.84	99.06	99.09
		12	98.92	98.97	99.00
		16	98.83	98.90	98.90
		20	99.16	99.24	99.24

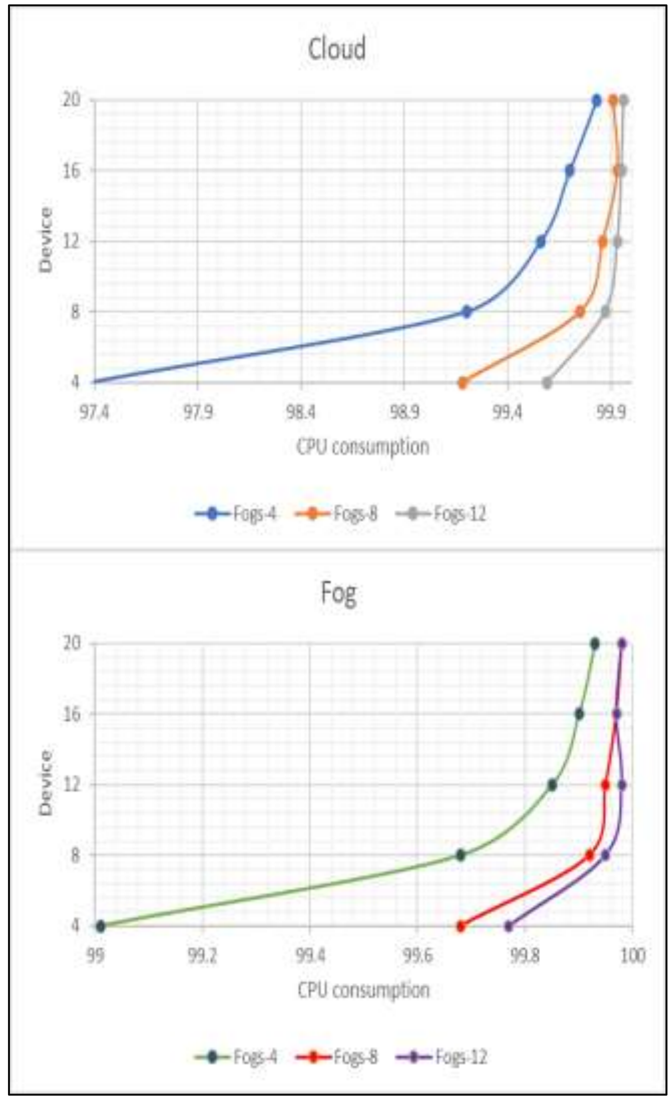

Fig. 5. CPU consumption

TABLE V. SIMULATIONS' MEMORY CONSUMPTION IN YAFS PER EHEALTH APPLICATION IN MB

eHealth					
YAFS	type	#Fogs \#Devs	4	8	12
	Cloud	4	232.02	281.28	345.39
		8	283.40	415.41	535.70
		12	357.72	550.58	686.31
		16	435.25	650.42	760.00

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	20	500.19	702.71	845.14
Fog	4	217.53	269.03	330.85
	8	256.27	396.47	545.27
	12	333.84	548.65	730.28
	16	408.46	663.60	873.52
	20	479.26	782.19	932.13

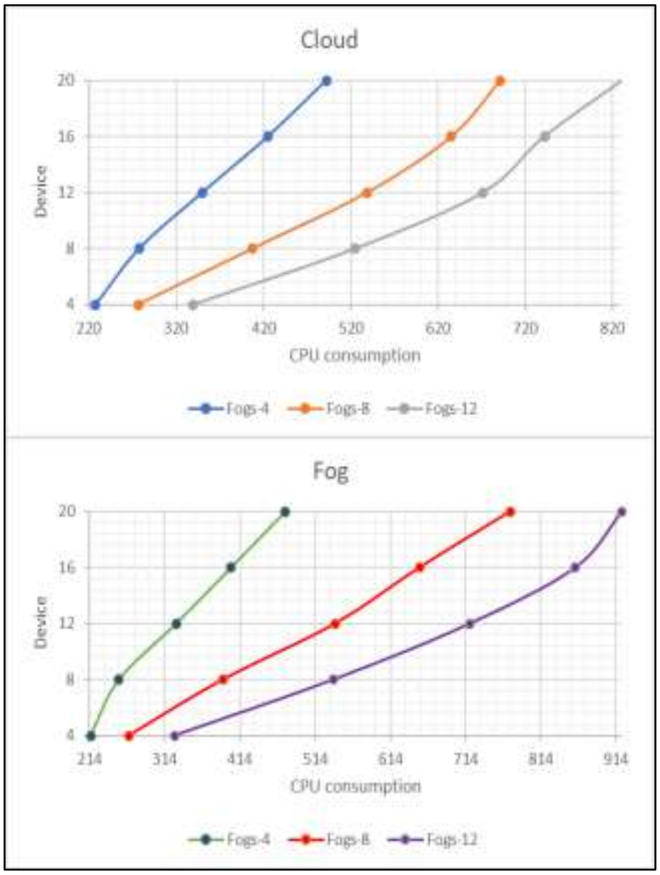

Fig. 6. Memory consumption

CONCLUTION AND RECOMMENDATION

The Fog computing has the potential to enhance the speed, latency, and reliability of IoT applications while also improving security and reducing costs. When real-time processing or a large amount of data are needed, it is recommended to carefully consider the use of fog computing. It is also suggested to carefully compare the available simulation tools to determine the best fit for the project's goals. In implementing a fog computing system, it is important to consider the privacy and security implications and to implement the necessary security measures to protect sensitive data..

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