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Comparative Analysis of Simulators for IoT Applications in Fog/Cloud Computing

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***Abstract*— In order to make people's life easier, a significant number of Internet of Things (IoT) applications have become a part of a global world. The internet of things is strongly intertwined to cloud computing, and sensor data handling is one of the most urgent issues with cloud computing. Sensors and other cloud-connected smart devices are frequently used to operate IoT-Cloud systems; as a result, these devices generate a large volume of data that must be preserved and processed efficiently. Simulators have the advantage of allowing complex systems to be explored without the requirement to purchase and install physical resources. The purpose of this article is to look at several cloud implementation simulators and see which ones are best for today's IoT demands. With the moving of the trend and computing needs, this paper provides a brief examination of the different most widely used simulators in the research field by categorising the simulators into three categories: cloud, edge, and fog simulators. Finally, various future research direction in accordance with the simulator's evolution is given.**

***Keywords*— IoT, Simulators, Cloud Computing, Edge Computing, Fog Computing, Edge Computing**

I. Objective

A simulator is a program or computer that creates a virtual replica of a real-life environment, usually for the purpose of training or experimentation. Simulators allow users to study and execute such tasks without risking their lives. Simulators are used to evaluate processes and designs in great detail. Because they can simulate numerous process configurations and adjust design parameters, they can make decisions and progress towards an ideal process based on an objective function. In the field of emerging IoT technologies and applications these simulators can play a big role for industries, smart city, medical and several other IoT implementation scenarios by replicating the imitation of actual implementation.

Simulators are particularly useful in IoT-based application scenarios where actual experimentation is expensive and simulators are preferable for demo deployment. The IoT concept connects sensors and intelligent objects to the Internet, allowing for a variety of cloud and IoT service combinations [1]. As more devices connect to the network to create IoT systems, the data flow and capability of supportive facilities increases, creating new difficulties like as resource utilisation, cost reduction, and compliance with regulations. It can be costly to employ physical computers from virtual server parks to fulfill a variety of IoT situations, and it is not always practical to investigate IoT-enabled cloud service compositions with actual cloud providers. As an outcome, cloud simulators are increasingly being used to assess such complicated ecosystems [2]. There are several issues with the IoT applications as sensor-generated data lead to the issue of congestion among the network [3], several congestion control protocols exist and simulators play a big role to handle such kind of issues as they allow the simulation before the deployment in actual scenario [4]. Authors in [5] have demonstrated the use of different simulators in one of the data offloading IoT application scenarios which reflects the importance of simulation tools for the deployment. Fig 1 presents the basic architecture structure for IoT applications that simulators are considered to support, with the objective of data storage, processing, and analysis.

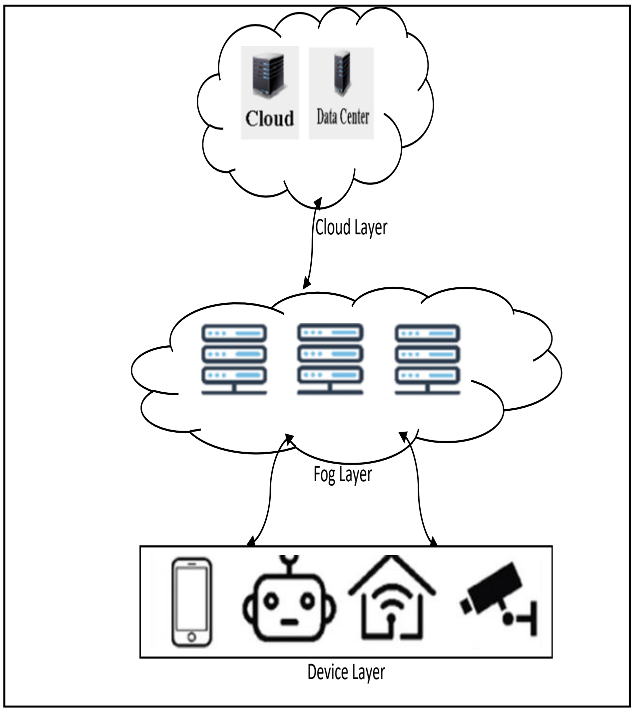

Fig.1. Architecture representation of cloud and fog layer.

Some of the widely used simulators supporting these different layers are mentioned, like CloudSim [6] is one of the most extensively used clouds and IoT simulation tools. In order to represent the components of a cloud computing system, data centres and virtual machines, as well as cloud resource provisioning, are all being investigated and these methods are supported by CloudSim. When the IoT became popular, CloudSim was expanded to deliver demonstrating abilities for IoT structure mechanisms. The iFogSim [7] covers CloudSim to model IoT and fog settings through assessing reserve administration approach, latency, network congestion, energy usage, and cost are some of the metrics used. Zeng et al. [8] presented IOTSim, a tool that allows huge data processing to be replicated and used the MapReduce framework as well as a real-life example. SimIoT [9] is a SimIC [10]-based simulation framework. The MobIoTSim [11] scenario is a semi-simulated platform for testing IoT cloud architecture. It uses a mobile simulation environment to replicate the behaviour of IoT sensors and devices. The Yet Another Fog Simulator (YAFS) [12] is offered for simulating the deployment of applications on a fog infrastructure. The world of cloud, IoT, and fog computing simulators are very big and they are used according to the requirement of implementation of application scenario. The simulator's key capabilities are as follows: (i) user mobility, (ii) network problems, and (iii) dynamic application module allocation.

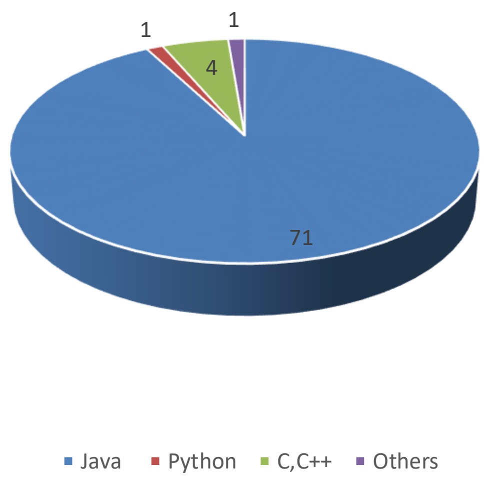

Fig. 2. The approximate usage ratio of the programming languages

From the study, it has been identified that more than 70 % of simulators are Java-based and it also has been identified that python is an emerging future due to its rich set of libraries. Fig 2 shows the approximate average percentage of programming languages used in the simulation tool [2].

A. *Motivation of the Study*

With the growth of IoT and cloud in different fields of society like agriculture, medical, smart city, home, and even the army there is a need of a simulation environment to save cost, infrastructure and identify the implementation issues beforehand of the actual deployment.

The large number of the simulators already exist in the research field having a different bases and working scenarios, there is a need for study for the users so that they will be able to identify the finest working model in terms of simulators according to their implementation scenario.

The remainder of the paper is organised as follows: Section 2 reviews the specification of some of the most popular cloud and IoT simulators, with their repository and base type information. Section 3 highlights the features of main fog simulators followed by section 4 of comparative analysis and discussion and after giving the future research direction in section 5 a conclusion has been made in section 6.

II. Approaches Under Cloud and IoT Simulants

This section provides an overview as well as a quick assessment of the cloud, fog, and Internet of Things simulators currently available. Tables I and II show the basis for these simulators implementation.

A. *Cloud Simulators*

This section introduces and compares contemporary cloud, fog, and IoT simulators. Table I and Table II have been drawn to show the basis of implementation of these simulators. There are various cloud simulators but most of them are Cloud Sim based only, and share common properties and working scenarios. Some of the scenarios having different working properties based on the parameters are:

- Cloud Sim: In terms of popularity and use, the CloudSim modeling toolset [13], which is a widely used solution for simulating cloud environments, is one of the most popular and widely used simulators. CloudSim allows users to build tasks by producing cloudlets, which are then processed by virtualized computers that are connected to cloud services and run on clouds.

- GreenCloud: Energy consumption is an important performance parameter among the simulators, and GreenCloud is having the main focus on this. An energy-aware cloud data center analysis using system component energy use measurements is the simulator's main goal.

- ICanCloud: It includes a virtualization component for controlling cloud brokerage rules, it distinguishes itself from other similar products. Its investigation is focused on the economic and efficiency tradeoffs associated with a particular application that can only be executed on Amazon VM instance categories.

B. *IoT Simulators*

Several new IoT trends inspired these cloud simulators. Sensors and other tiny devices that may connect to the internet and monitor surroundings or gather data are examples. Cloud services are rarely used on their own, although they are frequently used to store and process data. We get at the latest trend of Fog Computing is a kind of cloud computing in which data monitoring is carried out at the cloud network edge or near to the consumers. As a result of this approach, we decided to include IoT simulators in our study. The goal of the updated cloud simulators was to simulate entities from the IoT environment, which lead to an addition in terms of fog elements in some situations. Some of the most used simulators for IoT scenarios are:

- SimIoT: This addon for CloudSim allows you to simulate the IoT and Big Data. It is represented by three layers in the CloudSim model that are perceptual, network, and application layers, as follows: These are the four main components of CloudSim. This study's goal was to model a MapReduce technique for large-scale information processing.

- SmartSim is a tool for energy metering in the IoT smart homes, with a focus on energy conservation. On the basis of power consumption models including frequency, length, time, and action, this Python-based simulation tool can generate smart device energy traces.

- MobIoTSim: IoT device simulation and management software based on Android. It was created with the goal of avoiding the procurement of expensive devices and sensors when building and assessing IoT applications. By running simulations, the duplicated devices may join to real cloud workers (such as IBM Bluemix) and interact across the network using the MQTT and HTTP protocols. Sensor, device, application, and cloud are the levels of MobIoTSim.
- DISSECT-CF-IoT: The cloud simulator DISSECT-CF has been updated to the latest version. The sensors architecture involves comprehensive configurations (e.g., measuring latency, gathering and analysis rate, and produced data size factors), network design setups for IoT systems, and multiple multiple cloud management techniques for Internet of Things systems, is a unique feature of this extension.

III. Upcoming Approach of Fog Simulants

Lastly, most current class is achieved for fog simulations, which was created in reaction to the recent Fog Computing trend. In this section, the important properties essential to prototype a Fog Computing ecology are explained. In evolution, notice of strong link to clouds can be seen: maximum out of them are expansions to clouds otherwise IoT simulants. However, they trail diverse architectural models: few are more centralised than others, and they use peer-to-peer communication protocols. Some of the important and widely used fog simulators are:

- FogNetSim++: It is a simulator that allows users to configure any fog network (e.g. Scheduler techniques for fog devices, as well as device hand-over) The notable characteristics of the simulation includes compatibility for network topologies like MQTT and CoAP, and also supports for multiple simulations including LinearMobility and TractorMobility.
- Edge-Fog: It can build grid of Edge and Fog resources as well as a work dependency diagram based on a variety of operator defined factors. This tool is used by the authors to show how their LPCF (Least Processing Cost First) algorithm prioritises jobs based on processing time and network costs.
- Yet Another Fog Simulator (YAFS): It's a simulator that has been presented for simulating application disposition in fog network. Simulator's key features include dynamic component for the applications assignment, faults in the networking, as well as scalability.
- iFogSim: Because the components are divided into three groups, the sensor, processing, and actuation model is used to simulate real systems. The basic physical components are: Actuators with a geographic position and reference to the gateway connection; and sensors that generate data in the form of a tuple expressing information.
- EdgeCloudSim: It’s a CloudSim extension that can be found on GitHub. The network modeling continuation for WLAN, WAN, and device agility is the simulator's key features. Researchers wanted to address the flaw in iFogSim simplistic network prototype, which overlooks network weight and lacks content flexibility.
- DockerSim: The goal of this project is to aid in the study of container-based SaaS systems in virtual environments. It makes use of the OMNET++ and iCanCloud networking simulations to mimic containers behaviour, as well as network, protocols, and operating system scheduler actions.
- DISSECT-CF-Fog: To depict fog devices and nodes, as well as IoT-Fog-Cloud systems, this simulator extension draws on the base DISSECT-CF simulant and DISSECT-CF-IoT and delay services. The key advantage of this fog addon is that it allows for precise tuning situations through XML conformation, it requires basic understanding of simulator programming to create new scenarios.

IV. Result Analysis and Findings

Different simulators study have been done and it has been identified that most of the simulators are java based whereas python libraries are also evolving to provide simulation support, Two comparison tables are given in the result where, Table I gives the specifications related to some of the important and frequently used simulators with their language and access-based specifications, in the label tag it can be figured out Java is the most used language and open access is provided by these simulators and can be easily accessed on Github, built on types are also specified in the table I. Here NA means here that information is not available for these simulators in some particular categories.

Table II on the same parameters gives the description of fog-based simulators with the language and platform details. Java can again be seen as the most used language among simulators and also most of the simulators are actually extended version of the cloud simulators. The resource availability is also specified with base information.

In the case of cloud solutions, the majority of cloud simulators use a generic, event-driven paradigm. As seen in tables I and II, it can also be concluded that CloudSim is used by the majority of the simulators. Java is the dominating programming language, based on the most recent studies, we can say that fog computing models are evolving more quickly than IoT models, that is supported through the statistics that has been identified double as many solutions in fog category. Some CloudSim solution is on the way due to a rise in mobile-based applications in IoT. Python extended library support is becoming the new vision as the preferred structure development for these simulators.

V. Conclusion

The simulators are divided into three categories: cloud, edge, and fog simulators, which are compared, with the changing trend and computing requirements. Two tables containing cloud, IoT simulators, and edge simulators have been designed as comparative tables built over the nomenclature to show their variances and how they model the features of IoT-Fog-Cloud systems, with a clear division of language used, built type, and access availability. We can deduce that a complete fog computing model is still missing, and that complex fog settings are difficult to simulate with a sole simulator. In conclusion, it can be said that there exist several challenges with the existing simulators in terms of parameters they consider and their built type and there is a future research scope to keep expanding simulator model extensions to better understand fog capabilities, with the constraint of the scalability requirements of applications.

VI. FUTURE RESEARCH CHALLENGES

In the cloud, IoT and fog we were able to witness the cutting-edge of technology for the simulations. The earliest field is cloud computing solution modeling, and the CloudSim simulator and its family leads research in this zone. Due to the implementation constraints, there are several research challenges among these simulators like:

- CloudSim is one of the most used simulator having lot of extensions and acting as a base for many simulators but It is simply limited to the amount of energy consumed by the CPU. Lot of extensions are available due to missing and insufficient features and still a research challenge and future scope of study.
- iFogSim one of the popular extension of CloudSim that is widely used, but lack of source code and extensive learning results in to the implementation problems.
- YAFS simulator is new and popular simulator having base of python, many improvements are still required to cope with the emerging needs of the applications.
- Vulnerabilities and bugs among the simulators are quite common, lead to security and accuracy issues among the simulators.
- IoT applications for providing smart medical and health services are the evolving need of society and, these simulators can play a large part in the field of medical image analysis [40-41].
- In order to accomplish efficient data management and energy saving in Internet of Things sensing applications, cloud services can be combined with an efficient web architecture for this objective fog/cloud simulators can play big role [42].
- In health monitoring IoT can play a big role, where patient's ECG data can be analysed to provide intelligent monitoring. In smart monitoring systems, IoT module makes it possible to manage and communicate data in telemetry, and the data obtained is saved in the cloud to improve the overall quality of services [43-44].
- When it comes to Internet of Things and image registration, the effectiveness of the deep learning method has already been analyzed in terms of improving the applicability of image identification while maintaining high testing accuracy in such scenarios mentioned simulators can provide cost effective approach to test the implementation scenarios [45].

Though they are still being used to create and verify new cloud management methods. Fog Computing modeling is the most recent trend, and it aims to improve on prior cloud and IoT system simulators, as the name implies. This is an ongoing study area, and fog modeling is still in its infancy, since real-world fog applications are still developing. The future of fog modeling will most likely be defined by the extension of present simulators.

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TABLE I. CLOUD & IOT SIMULATORS WITH SPECIFICATIONS

Simulator	**Access**	**Language Supported**	**Availability**	**BuiltOn**	**Type**
CloudSim	OpenSource	Java	Github [14]	SimJava [15]	Cloud Simulator
GreenCloud [16]	extension of NS-2 [17]	TCL scripts and C++	NA		
ICanCloud [18]	NA	NA	NA	OMNET++ based simulator [19]	
IOTSim [20]	OpenSource	Java	NA	CloudSim	IoT Simulator
SmartSim tool [21]	OpenSource	Python	Github [22]	NA	
MobIoTSim [23]	OpenSource	Java,XML	Github [24]	Android-based	
DISSECT-CF-IoT [25]	OpenSource	Java,XML	Github [26]	DISSECT-CF	

TABLE II. FOG SIMULATORS WITH SPECIFICATIONS

Simulator	**Access**	**Language Supported**	**Availability**	**BuiltOn**	**Type**
FogNetSim++ [27]	OpenSource	C++	Github [28]	OMNeT++	Fog Simulator
Edge-Fog [29]	OpenSource	Python	Github [30]		
Yet Another Fog Simulator (YAFS) [31]	OpenSource	Python	GitHub [32]	JSON	
iFogSim [33]	OpenSource	Java	GitHub [34]	CloudSim	
EdgeCloudSim [35]	OpenSource	Java	GitHub [36]	CloudSim	
DockerSim [37]	OpenSource	NA	GitHub [38]	OMNET++ and iCanCloud	
DISSECT-CF-Fog [39]	OpenSource	Java	GitHub	DISSECT-CF-IoT [26]	