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IoT-Fog-Edge-Cloud Computing Simulation Tools, A Systematic Review

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Abstract:

The Internet of Things (IoT) perspective promises substantial advancements in sectors such as smart homes and infrastructure, smart health, smart environmental conditions, smart cities, energy, transportation and mobility, manufacturing and retail, farming, and so on. Cloud computing (CC) offers appealing computational and storage options; nevertheless, cloud-based explanations are frequently conveyed by downsides and constraints, such as energy consumption, latency, privacy, and bandwidth. To address the shortcomings related to CC, the advancements like Fog Computing (FC) and Edge Computing (EC) are introduced later on.FC is a novel and developing technology that connects the cloud to the network edges, allowing for decentralized computation. EC, in which processing and storage are performed nearer to where data is created, may be able to assist address these issues by satisfying particular needs such as low latency or lower energy use. This study provides a comprehensive overview and analysis of IoT-Fog-Edge-Cloud Computing simulation tools to assist researchers and developers in selecting the appropriate device for research studies while working through various scenarios and addressing current reality challenges. This study also takes a close look at various modeling tools, which are examined and contrasted to improve the future.

Keywords: Simulators, Internet of Things, Cloud Computing, Fog Computing, Edge Computing

1. Introduction

The Internet of Things (IoT) is crucial in creating a decent society and a healthy economy, and it necessitates rigorous standards for various applications to ensure that ideas are recognized with the most important criteria [1]. IoT contains wonderful visions that are moulded into various measures that are used to employ smart things, sensors, and technologies with certifiable knowledge and a communication system [2]. As a result, the critical requirement for a sophisticated simulation instrument that can be used in realistic formative and exploratory contexts is critical before implementing IoT applications in real-world scenarios, as illustrated in figure 1[3].The architecture of an IoT system includes the hardware infrastructure (servers, gateways, communication networks, sensors, and actuators), the application software, and the decision of where to arrange the application software components inside the hardware infrastructure.

The most common strategy for developing efficient IoT systems is to perform as much computation and storage as possible in the cloud [4]. However, edge computing (EC) architectures that blend edge and cloud computing give new opportunities for designing effective IoT systems.Cloud computing offers enticing computational and storage choices to solve these issues; nevertheless, cloud-based solutions usually come with drawbacks and limits, such as energy consumption, latency, privacy, and bandwidth [5, 6].EC, in which computation and storage are performed closer to the source of the data, may be able to assist address these issues by satisfying particular needs such as low latency or lower energy usage [7]. Moving data and computing from the edges to the cloud may be inefficient and costly, as well as raising privacy and security concerns. Furthermore, the cloud's centralized character, geographical reliance in terms of distance, and the cost of cloud-provided services are all significant flaws in cloud-IoT integration [8]. Fog computing (FC) is a way to get around these limits. In terms of bandwidth savings,latency reduction, mobility assistance, geographically dispersed and decentralized deployment, interoperability, heterogeneity, data security,and energy consumption, and privacy protection, it complements cloud computing and improves on it [9,10].

1.1. Motivation and Objective of the Survey

Simulations are frequently used to show the behaviour of a framework over a period of time. Reproduction tools circumstances enable a true situation to be appraised before frameworks are built or transported in operational state. Simulation is commonly used to evaluate rate adequacy and the execution of complex frameworks. The use of IoT simulation devices is becoming increasingly important for a variety of reasons, including confirmation of execution, productivity, and application dependability. Various rebuilding devices are developed and tested for suitable and portable applications.These approaches are used in Windows and Linux operating systems, and the design contents are used to rebuild models. Every device has its own set of design requirements, as well as the ability to replicate different elements of a framework.

1.2. Contributions

We give a thorough and systematic review of simulation tools for IoT-Fog-Edge-Cloud computing in this research. This work's major contributions include:

1. Identified the key research issues in the field and how simulation may aid in their resolution.
2. Gave a comprehensive review of cutting-edge IoT-Fog-Edge-Cloud computing simulation tools, highlighting their unique qualities and how they solve a variety of crucial challenges such as latency, energy usage, and so on.
3. Emphasised the benefits and drawbacks of available simulation tools.
4. When evaluating the tools, numerous values that may be employed as metrics or system parameters were highlighted.

1.3. Paper Structure

The following is how the rest of the paper is planned: Contextual studies are presented in Section 2; simulation tools are labeled in Section 3; an analysis of various simulators is offered in Section 4 concerning the identified qualities;

we deliberate the advantages and disadvantages of present simulators in Section 5, and we accomplish and summarise this research in Section 6.

2. IoT-Fog-Edge-Cloud Computing Integration: The Background Study

There is no usual design for IoT-Fog-Edge-Cloud computing, and diverse architectures are frequently used in research. Figure 1 depicts the IoT-Fog-Edge-Cloud computing topology at a high level. It comprises four major layers in the most frequent scenario: cloud, fog, edge,and IoT layers as depicted in Fig. 1:

- Cloud Layer: This layer contains physical data center nodes. Every node is equipped with a CPU, main memory, and network bandwidth, and it is utilized to fulfill resource demands from users. Control techniques allow cloud resources to be managed and scheduled based on their load needs [11].
- Fog Layer: This layer is the layer that sits on top of the edge device layer. Any device that can store, process, and connect to the network, can be regarded as a fog processing device. In this way, certain gadgets may be classified as both IoT and fog devices; cellphones are a good example. Between network edges and clouds, the fog layer is made up of processing gateways, devices, and networked devices (switches and routers) [12].
- Edge Layer: The edge devices such as mobile cellphones and tablets, smart meters, aircraft, and smart vehicles, desktop PCs, and laptop computers with applications are represented in this base layer. Edge devices are human-operated resources that provide a wide variety of computer capabilities [13].
- IoT Layer: This bottom layer represents end devices such as sensors, actuators, and objects. This is the bottom layer, also referred to as the IoT health sensors layer.

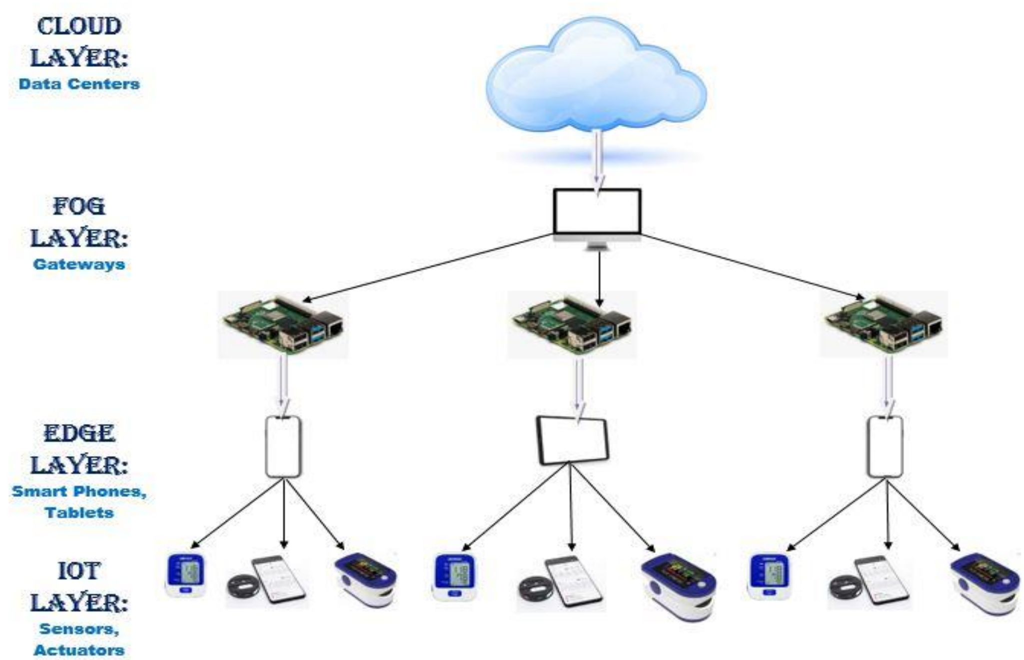

Fig. 1. IoT-Fog-Edge-Cloud Computing Integration

3. Review on Simulation Tools

The improvement of simulation tools might be investigated using a variety of ways to assist researchers in making innovative discoveries in their study.As a result, the researcher concentrates on the simulation needs and underlines the key points involving the physical layer (detecting), actuators, and computational reasoning [14].

3.1. IoT Simulation Tools

There are various simulation tools available for IoT applications. Some of them are discussed as IoTIFY is the first cloud-based performance testing tool for contemporary corporate IoT applications, designed to help you create, validate, and continually monitor them.COOJA is a system test system that enables the simulation of real-world equipment stages.Clients may use NetSim Emulator to connect their NetSim test system to real-world equipment and connect it to live applications.The NS-3 test system is a discrete event arrange test system that may be used to replicate ordered frameworks.The TOSSIM tool recognizes the real-world motives for behavior.BEVYWISE IoT Simulator is an unexpected and simple to use MQTT simulation gear that allows you to simulate a large number of IoT devices.ANSYS IoT simulation tools can help you design and test tomorrow's IoT gadgets and systems.MATLAB has an exciting IoT module that allows you to develop and test smart devices as well as collect and analyze IoT data on the cloud.The J-Sim test system gadget delivers a part-based replica condition a consistent reproduction structure.The majority of the time, OMNET++ is used to reproduce correspondence systems [15-25].

3.2. Cloud Computing Simulation Tools

Several cloud simulators are being built nowadays using mathematical formulae to simulate the actual world. We provide a brief overview of 21 simulators.Resource provisioning strategies data centers, service brokers, and virtual machines are all modeled in CloudSim.NetworkCloudSim allows you to simulate data center resources like networks and computers, as well as a variety of application types including parallel applications. The CloudAnalyst distinguishes between simulation experimentation and a programming exercise. EMUSIM employs emulation to automatically extract information from application activity, which it then uses to create a simulation model. The MIPIPS, i.e.,mega integer plus instructions per the second unit is used in CDOSim to compute a new statistic for data center computing performance. TeachCloud is a handy and simple cloud computing simulation and modeling application that fills in the gaps left by the absence of cloud computing teaching resources.ElasticSim has a GUI to show the execution state in real-time.DartCSim has a user-friendly interface, so users may utilize a visual interface to select simulation settings including cloudlets, network architecture, and management algorithm. DartCSim+ adds a resend function to provide a more realistic network model for resolving transmission failures. FederatedCloudSim's main purpose is to simulate various forms of cloud federations. The FTCloudSim toolbox is used to simulate various techniques for improving service dependability. The WorkflowSim is a cloud-based tool for simulating scientific workflows. The CloudReports simulator is a programmable energy-aware cloud environment simulator. The CEPSim toolkit is designed for complicated event processing in the cloud.CloudSim is enhanced by DynamicCloudSim, which handles heterogeneity, failure, and dynamic changes in real-time. In a cloud system, the CloudExp simulator is used to handle virtualization and business process management. The CM Cloud can create any cost approachvia XML and can dynamically retrieve information from existing cloud service providers such as Microsoft Azure, Google, and Amazon's websites. The MapReduce computing paradigm is the subject of the MR-CloudSim on CloudSim. The UCloud management oversees the cloud management system (CMS), which comprises services such as security management, university activities, and performance monitoring, among others.In a cloud setting, the CloudNetSim simulator is used to manage resource and scheduling algorithms. CloudNetSim++ is the initialCC simulator to mimic dispersed data centers using actual network physical features [26-48].

3.3. Fog and Edge Computing Simulation Tools

As the next development of cloud computing, fog and edge computing is gaining popularity. Although there are many simulators for CC, they cannot be utilized as-is for research in the area of FC and EC; as a result, they have been modified to match the new requirements. At the same time, new simulation tools, particularly for the FC and EC, have been suggested and built. This section examines all of the tools used in the FC and EC fields.The Python-based Edge-Fog-Cloud simulation toolsare made up of 2-layers: the outer layer, which contains edge devices, and the inner layer, which contains fog devices. FogTorch is a Java program that allows designers to design the fog infrastructure (in terms of RAM, CPU cores, and storage per node), establish latency and bandwidth QoS criteria, and specify application needs. FogTorchPi is a FogTorch plugin that can determine IoT application installations via fog computing systems.One of the most popular tools for modeling and simulating IoT and fog settings areiFogSim, which is developed in Java and uses the JSON file format.FogNetSim++ is an event-driven simulator based on OMNET++ with the primary goal of providing a static or dynamic environment that includes sensors, fog nodes, remote data centers, and a broker node. Cloud/fog simulations are possible with the Yet Another Fog Simulator (YAFS), which is developed in Python and supports the JSON file format. The goal of FogDirMine, a Python-based simulation program, is to simulate the behavior of the CISCO FogDirector, a tool for controlling IoT-based fog frameworks. FogBus allows a wide range of infrastructure devices, application execution, and interactions across nodes thanks to RESTful technologies and a grouping of programming and scripting programming languages.To represent user movement and migration methods, ModFogSim, an extension of iFogSim, necessitates a large amount of work. FogWorkFlowSim is a Java-based user interface for evaluating resource and task management techniques. The Fog Security Service method is evaluated using an OPNET-based network simulator with overall processing time as the performance parameter [49-63].

4. Pros and Cons

The advantages and disadvantages of using various simulation tools are discussed in this section.

4.1. Pros

1. Simulation allows you to investigate 'what if' scenarios and problems without having to test the system.
2. It aids in the detection of material, information, and product flow bottlenecks.
3. It assists you in determining which factors are most critical to system performance.
4. It has the ability to prevent danger and loss of life.
5. Variable conditions and results can be explored.
6. Risk-free investigation of critical circumstances is possible.
7. It is inexpensive.
8. Simulations can be sped up to allow for a more in-depth analysis of behavior over time.
9. Simulation tools may be slowed down to investigate behavior in greater detail.

4.2. Cons

1. The quality of the analysis is determined by the model's quality and the modeler's abilities, which need specialized training.
2. Because it is a time-consuming and costly technique, it should not be employed if an analytical method may yield faster findings.
3. Measuring how one item impacts another, taking the first measurements, and creating the model may be costly.
4. To mimic something, you must have a complete grasp of all the variables involved. A simulation cannot be produced without this.

5. Conclusion

We address modeling and simulation exertions and offer the latest methodologies in the works in this study, and the simulation tools were chosen based on the measurements of discovering appropriate devices. Furthermore, the benefits and drawbacks of utilizing various simulation tools are highlighted, which may assist researchers in considering the tools, not only by the academic community but also by industry.

This is a difficult task since no tool can mimic all conceivable system configurations; instead, they focus on specific problems and give specialized and restricted solutions.

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