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Passer Journal

Passer 4 (2022) 37- 44

http://passer.garmian.edu.krd/

A Survey of Simulation Tools for Modelling Internet of Thing

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Received 05 November 2021; revised 01 January 2022;
accepted 15 January 2022; available online 01 February 2022

doi:10.24271/psr.39

ABSTRACT

The Internet of Things (IoT) is a revolutionary technology that has shifted lifestyle from traditional to high-tech. Many critical research studies and investigations have been conducted to improve technology through IoT. IoT has a vast range of applications in many fields such as the military, healthcare, agriculture, and education. The physical and virtual resources used by the IoT applications include: processor, memory, power consumption, storage usage, network bandwidth, sensor nodes, protocols, or algorithms used in processing and encryption. IoT Simulation tools are the base stone for developing, designing, and evaluating new IoT products before deployment in their target area or environment. It needs good testing and evaluation, which can be done through various simulation tools. This paper explains some of the most popular simulators for IoT research that are currently available. The article is mainly concerned with different simulation tools used in other IoT areas and compared nine simulation tools based on scope, type, programming language, IoT architecture layers, the scale of operation, API integration, cyber resilience simulation, target space, and security measures. Furthermore, the paper provides an excellent discussion; based on the operability of the IoT environment and application simulations and the many other issues, such as selecting a viable simulation for a specific context. In addition, the paper will analyze and compare existing simulation tools, focusing on the most important standard for evaluating IoT simulation tools. By the end, the review simulation tools were discussed.

Keywords: IoT, Smart environment, Simulation tools, SimIoT, NS-Series.

1. Introduction

The Internet-of-Things (IoT) is a model in which objects are turned into components, within a convergence of services and knowledge, of the Internet itself, which uniquely identifies. It makes each entity available and recognizes its location and status, resulting in the physical and digital worlds fusing, significantly impacting professional, personal, and social settings[1]. Introducing a high-quality computerization ecosystem, creative and efficient services, and enhanced efficiency has gained growing attention in the Internet of Things (IoT). Consequently, IoT encompasses a variety of applications in schooling, healthcare, agriculture, military, and manufacturing. In these applications, the IoT resources available are heterogeneous, such as storing, processor, network, sensor nodes, and electricity[2]. Each IoT entity has a unique ID, such as a protocol Internet (IP) in the actual Internet accessible through the IoT networking architecture, which can link to and interact with other entities. Users can access sensors directly and offer controls to sensors, whereas before IoT, users could only get data from the service provider. This capability would use IoT data to provide a unique service to businesses, academics, and the community at large. Virtual and physical components make up a typical IoT research process cycle[3], which starts with creating an idea and ends with real-world implementation. A proof of concept is usually done in the virtual realm using simulation and an existing prototype design in a testbed experiment[4]. IoT simulation tools are critical to designing, creating, and evaluating new IoT products and protocols before implementing the targeted system. They involve adequate testing and assessment with a broad range of devices. Large-scale prototyping with many hardware nodes during the initial exploratory design and evaluation process may be impractical due to financial and operational constraints, especially if the protocol under consideration has not yet demonstrated its reliability and utility. In addition, establishing reliability and reproducibility experiments with real hardware can

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Peer-reviewed under the responsibility of the University of Garmian.

be complex[5]. Generally, IoT simulators have to provide high reliability for heterogeneous-compatibility scenarios, help the scalability, provide energy and device efficiencies[6]. This article compares nine simulation tools based on scope, type, programming language, IoT architecture layers, the scale of operation, API integration, cyber resilience simulation, target space, and security measures. I am primarily concerned with the various simulation tools used in other IoT areas. In addition, the paper includes an excellent debate based on the operability of the IoT environment and application simulations, as well as a variety of other challenges, such as selecting a suitable simulation for a specific context. In addition, the study will analyze and compare existing simulation tools, focusing on the most crucial standard for evaluating IoT simulation tools.

2. Methodology for Paper Selection

This section explains how research question and problem definition formulation have been conducted together with a search query and selection phases during the research stage of this paper.

A. Research Question

The following are some of the questions that this paper should answer:

- What are those prominent simulators currently available and used for IoT reksearch? (Section 9)
- What is the IoT simulation concept (Section 5)
- How simulations are adopted and used for IoT environment (section 8)

How the Simulators are assessed and evaluated and what criteria are used in comparing simulators (section 10).

B. Search Query

This paper collects the majority of IoT simulations. Hence, those keywords have been used. ("Simulation for Internet of things") AND ("Internet of thing simulators") OR "(Internet of thing simulation tools") OR ("simulation for the smart environment in IoT").

C. Selection of Sources

Google Scholar and ResearchGate have been used for applying the search queries. The databases that have been considered were (IEEE Xplore Digital Library, SpringerLink Journal, Elsevier, ICM Library, AIS e-library, and Science Direct).

D. Selection Phases

Each article that has been chosen to be included in this paper went through the following procedures:

- Putting the search queries into action.
- Only include papers that were written between 2012 and 2020 in your quest.
- Look at the paper's title and see if it contains the words "security awareness training, Gamification based Training, training methods.
- We read the summary and conclusion of the article and chose the paper based on its abstract and conclusion and the relative position of its body to them.

They took the journals' indexing and the number of reviews they received into account.

3. Literature Review

The Internet of Things (IoT) paradigm is a multidisciplinary one that encompasses technological and societal concerns. As a result, it's critical to create an application that meets the IoT concept's requirements and specifications. IoT technology integration could be complex. As a result, simulation is required throughout the development of an IoT application to evaluate the system's components and ensure that it fits the design requirements. However, finding a suitable tool for modeling and testing IoT systems before deployment is difficult for researchers and developers[5]. The Internet of Things is based on a network of connected physical devices with the computational power of many smart devices. This problem necessitates the creation of a comprehensive simulation modeling framework for the implementation of IoT applications. As a result, the authors emphasize the necessity for research into an effective modeling environment that can capture IoT applications' physical layer (sensor), actuators, and computational logic aspects[14]. The study[15] focuses on the difficulties during the simulation procedure. This includes a simulation tool's capacity to replicate intelligent objects in a 3D real-time environment accurately. Another study demonstrates the importance of using simulators tools in the study of distributed systems, which has been at the core of the implementation of computer systems in giving a supportive environment for evaluating diverse applications' initial deployment[16]. The study also shows that more study is required to conduct realistic simulation research to accomplish various operations and test IoT functions at a lower administrative cost[16]. According to[12], the article compares existing simulators with graphical technologies to help analyze real-time input activities for IoT embedded systems. Prominent algorithms such as Rate Monotonic and EDF are discussed in the study. According to[14], an evaluation of the state-of-the-art in testbeds for Wireless Sensor Networks (WSNs) and Internet of Things (IoT) applications is presented. Furthermore, the report conducted a comparative examination of the selected testbeds' technical characteristics, highlighting their potential. This study provides a thorough analysis of current IoT simulators. The study describes their essential characteristics, weighs their benefits and drawbacks, and discusses present and future advancements. This survey was primarily conducted to serve as a valuable resource for people who have trouble finding relevant IoT simulators for their research or practical needs.

4. IoT Application and Architecture

The Internet's expansion spurs IoT to include physical objects and the ABI better environmental services as more data becomes available. This structure has the ability parts of our environment into a single functional entity. This concept has been effectively integrated into many industries, including health care, transportation, smart cities, and other areas of human endeavor, to make humanity's existence better and easier. The criticality and size of each application have a significant impact on the usability and functionality of IoT. Thus, it is essential to understand those architectural models utilized to implement the notion of IoT. As a result, the architecture of IoT applications was examined in this article. Nevertheless, the reviewed paper presents a generic IoT architecture with four essential components in Fig 1[7].

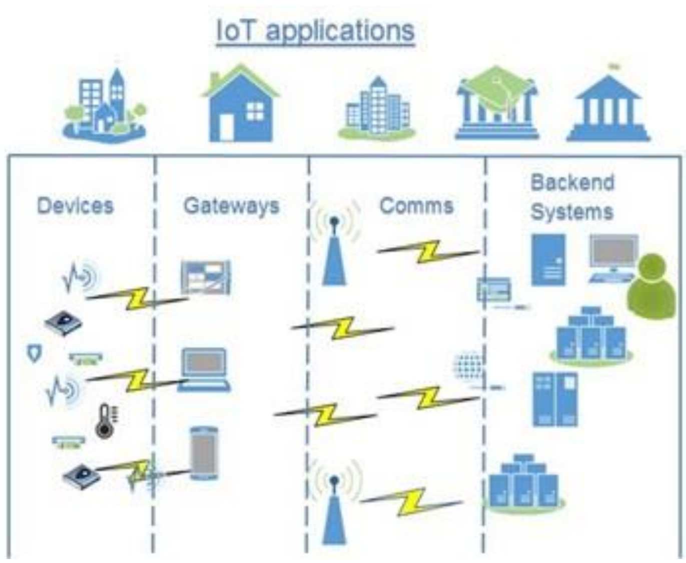

Figure 1: The Main Components of IoT Architecture [7].

5. Internet of Things (IoT) simulation

Simulations allow real-life scenarios to be built and validated before being employed in the working world. Simulations are commonly used to evaluate the cost-effectiveness and product complexity. The use of simulation tools in IoT is required for various reasons, including ensuring the Apps' performance, efficiency, and reliability. Large-scale testbeds or scalable simulation instruments are also included in the layout of intricate IoT installations. Furthermore, the scenario convenes and the level of detail needed for node-to-node communication are essential components for simulation optimization. The authors of[8] outline criteria for the next generation of IoT testing equipment, discuss some of the drawbacks of simulation methodologies and conduct a study of present experimental equipment (some of they also support Co-simulation.). In[9], the authors suggested an intelligent home IoT-based framework in which performance assessment is carried out using various methods for simulation. DPWSim[10] is a toolkit to endorse the OASIS "Devices Profile for Web Services" modeling standard (DPWS). The simulator's primary purpose is to evaluate DPWS devices and protocols to be cross-platform and straightforward to utilize. It is not built for very massive settings, in other terms. Finally, the author suggested incorporating Cooja-centered simulations into a network simulator for a certain domain in a hybrid simulation framework. (i.e., OMNeT++).

6. Requirments of the IoT Simulations

The IoT concept's main strength is the significant impact on various aspects of daily life and potential users' behavior. The IoT provides value-added services to people and things linked to anyone and everyone, every time, anywhere via the communication and information infrastructure[13]. In a general way, IoT is formed by three layers[15].

1. Physical Layer:
    1) **Perception layer:** the lower layers collect and convert data with RFID, sensors, wireless, 3G, LAN, Bluetooth, and NFC, into readable, digital signals. This layer includes all data collection and sensing components.
    2) **Network layer:** a middle layer gathers perception layer data and transmits digital signals to the appropriate platforms. The coating can only contain a gateway with one network and one internet interface.
2. Virtual layer: It reflects the cyber representation of natural world objects. The virtual layer is typically utilized in cloud infrastructure, eliminating the requirement for computer resource ownership, housing, and maintenance.
3. Application layer: The final data presentation is completed on the upper layer. The application layer collects data from the bottom layer and gives detailed data to global application management.

7. Categories of IOT Simulations

Three simulator types can be used for IoT study depending on the architectural layer level. The first group is the complete stack simulators built to react to the IoT paradigm. These simulation models help all IoT components end-to-end. The second group includes simulators that concentrate on broad data processing elements of IoT applications. Network simulators are the third type. It should be noted that several of these simulators were not designed with the IoT paradigm in mind at the outset but evolved to include IoT-specific implementations for the parts[16].

A. Full-stack simulators

This type of simulator intends to accommodate all IoT elements from start to finish. For example, DPWSim[17], and iFogSim[18]. Researchers can give the desired IoT application and any template needed to interface with DPWS by employing a highly sophisticated simulator that incorporates standard-based standardized information standards, a perfect combination of the appliance, room, event, and action. DPWSim's main purpose is to generate virtual DPWS devices that may be found on a network and communicate with other devices or clients using DPWS protocols. It also can simulate the conditions in which DPWS devices are found. It also includes a management tool for creating, managing, storing, and loading simulations, allowing users to render their simulations with a great deal of freedom[17]. Moreover, the iFogSim simulator embraces cloud computing, and Fog computing, expanding the CloudSim toolkit, incorporates several components, including sensors, actuators, application processing that create practical network topologies and application depictions. The simulator monitors the latency of the loop, bandwidth, and energy usage of various service models. Multiple apps can run concurrently on the infrastructure with iFogSim. According to the module deployment criteria, each software would need to develop its sensors/actuators and application model deployed in the fog infrastructure. The deployment policy can record distinct behavior for various applications, enabling application-specific module placement guidelines[18].

B. Big data processing simulators

These simulators will focus more on cloud performance and big data processing. IOTSim[19] and SimIoT[20] are two example tools for this simulator. The application layer is the center of the IOTSim. It will establish a space where significant data processing power in IoT applications may be evaluated using the Map Reduce programming methodology and cloud computing. In addition, instead of sensor network interactions, this simulator recreates data center mechanics such as computing requirements and Virtual Machine(VM) Configuration with Cost. In addition, SIMIoT is a good choice if we want to evaluate job processing times in a particular configuration of a cloud-based system based on the data sent by the sensor and actuators. Also, this simulator is mainly focusing on data center performance and how to evaluate it.

C. Network simulators

The majority of available simulators are found in this section. Network protocol research precedes the paradigm of other simulators that are functional tools for wireless sensor networks (WSN), or basic networking research adapts to incorporate parts of IoT Specific. More than 30 WSN simulators were included in the review[20] that can be extensively utilized for IoT study. For instance, CupCarbon, OMNeT++, and NS-3 initially intended to support the geographic node in real-world cases as a simulator. Though it is not mature, it has grown to produce IoT simulation for smart cities with the assistance of a mobile agent capable of representing unidentified airborne cars and a comprehensive highway topology that everything makes of a real-world map. OMNeT++ is another simulator, a standard system used tremendously in investigations. This simulator can provide urban mobility with urban mobility simulation[22].

8. IoT Simulation Application

Several intelligent applications, including smart climate, health, and agriculture, have been integrated with Internet of Things (IoT) technology. Simulations provide a cost-effective verification method for an end-to-end implementation to build these applications. Furthermore, by simulation, we can also test the possible use of such techniques in the target IoT applications that guide potential future execution. The following subsections will explain several smart application fields that simulation tools could play a vital role in testing and evaluating the requirements for implementation before setting up in the natural environment.

A. Smart environment

Many kinds of research have been carried out to analyze and evaluate IoT simulation tools in this field. In the intelligent environment, Sensors and actuators may attach to household appliances such as refrigerators, electricity, and conversation devices to track the process indoors. For example, the lighting system of a smart building can alter. In the evening, most lights have to be on, while at dawn, they are off. A precautionary fire measure can be set by its design based on detecting a sensor or a smoke-finding temperature since such an application is no longer required. Based on the older person's motion on the spot, multiple devices like a door in the room can be unlocked, provided that a sensor senses a moving light in the present space. The air cooler, fridges, and washing machines are IoT-enabled and web-controlled to save energy and vitality. Soon, an intelligent failing fridge would then transmit a message without the intercession of the customer to a service person. By sharing RFID labels with goods, mechanical mechanization is pushed forward. A generation process is monitored to ensure product quality by obtaining conclusive sensor parameter values[23]. The OMNeT++ simulation framework system is used to demonstrate an IoT network infrastructure that includes sensors, actuators, and CPUs. Based on a space-specific simulator, this approach allows for the simulation or restoration of components (that are not but are accessible) in the presence of equipment in the loop[22].

B. Health care

Another area of impact is health care, in which IoT can be used in tracking and gathering information for patients and staff[24]. In patient-flow observation, real-time tracking of individuals or moving objects is done. It offers a hand to handle staff conveying. Proper authorization can ensure that patients are safe and help to prevent an error such as giving the wrong medicine/dose/time. The configured set of clinical information is to be improved to allow for medical inventory; attaching differentiating sensors to the body temperature allows for real-time checks or tracking health patents activities such as blood weight, cardiac reactions. These IoT-enabled sensors can quickly detect irregularities in their immediate surroundings. The piece of information can be sent to doctors. However, there are significant hurdles in implementing IoT in that location. The m-IoT ecosystem and deciphering meaning are two distinct difficulties[25].

C. Smart cities

Refers to a cyber-physical ecosystem in which modern information and communication technology (ICT) provides services to city residents[26]. IoT maximizes physical assets such as a power grid, water, and stopping space in smart cities in Glasgow, Barcelona, Masdar, and others. In cities, activity observation is possible, and activity redirection makes it necessary to keep a safe distance from the bottleneck. Smart car parking is made possible by RFID and sensor technologies, which allow smart automobiles to find nearby parking spaces[27]. CupCarbon began as a simulator with a strong emphasis on supporting real-world geographical node movement. With the support of mobile agents who talk to uncrewed aerial vehicles and a thorough road-level topology based on actual-world maps, it has steadily grown into a built-up IoT simulation network for innovative city ecosystems[28].

D. Agriculture

Many kinds of research have been carried out to analyze and evaluate IoT simulation tools in agriculture. Sensors such as moisture, nutrients, and knowledge collected from farmers will save their energy. The human initiative in these communities can be used to industrialize (developing country). The influence of IoT in agriculture can be optimized by minimizing the waste of resources such as water. Deferent sensors for detecting moisture, temperature, and soil supplements are being sent in the field. The total water, fertilizer, or bug spray will be determined based on data from these sensors. This procedure decreases the fetched of development. In any event, using IoT in agriculture is difficult due to the high upfront costs. The sensors are susceptible to physical aggression in the body region. Again, reckless sensor arrangement produces unnecessary field data that do not belong to the farmer. IoTSim is one of the most frequent simulations used in this field[29].

9. IoT Simulation Tools

The simulator may be a particular device or computer programming design that reimagines in real-time the effects of findings of various hypotheses or theories without demonstrating a vulnerability risk to the experimentalist. Underneath is the detail of each simulation tool displayed in this survey paper.

IOTSim: It was developed on top CloudSim, an IoT cloud-based simulator. It is supplied with the MapReduce framework to support the control and address of big data processing. It reconfigures the identification and analysis of the IoT-based target via observers and the profitable business industries by genetically supporting individual data policies[29].

CupCarbon: It may be a 2D/3D modeling multiple-actor device, a discrete Remote Sensor Network (WSN). It accepts the distributed algorithm for industrial applications and the automation of certain rehashed activities. It can support coaches to demonstrate the critical steps and how intelligent sensor systems operate. In addition, it will help the researcher to test his wireless topology, connectivity, protocols, driving, and more[28].

SimIoT is a toolkit used in an IoT environment to simulate the static/dynamic or multi-user acquiescence feature and failure. The SimIC's cross hybrid integration is the foundation of the kit. It is a software compensation scheme in which a person or multiple estimated endowment demand, computer program sources, and virtual machine persistence must be sent by the preferred number of consumers[30].

OMNeT++: based on a C++ simulation framework and library, this could be a non-commercial simulation and discrete-event simulator model. Therefore, OMNeT++ can use at no cost in instructive education. Furthermore, OMNeT++ collects more extensive components and strategies employing a High-Level Language (HLL)[22].

***NS-Series*:** The NS-1, NS-2, NS-3, and NS-4 are distinct-event computer-based network simulators that support a variety of protocols such as FTP, TCP, UDP, DSR, and DSR. The NS-Series simulators are a free computer program licensed under the "GNU GPLv2" license and are open to the public[31].

Babywise IoT Simulator: IoT Simulator by Babywise: This IoT simulator allows users to test functionalities on the cloud and enables actual applications in fog computing. This simulator is a complete product that supports IoT and industrial IoT applications from start to finish. For example, it might be utilized as a prototype and tested in a real-time IoT Aria or environment.

IoTIFY: It might not be an embedded location for an IoT program expansion setting, according to IoTIFY. Switching to the Virtualization device and Smart system simulator results in an automated laboratory for analytical modeling, implanted prototypes, load testing, and a Group Simulation for informative scaling[32].

DPWSim: DPWSim is a toolset for simulating IoT devices and applications. DPWS defines a stable web-based measurement service, detection and interpretation, and resource-diminished devices, as well as a model for systems that provide two types of services: hosted and hosting[17].

iFogSim: is a cloud-based Edge and Fog computing simulator that can simulate IoT, Fog Device class(FDC)s, e-boards, network ties, cloud analysis. It is a cloud simulator. It provides research and comparison of system administration techniques/tactics based on quality management principles among these features[18].

10. Comparative Analysis of Simulation Tools

The previous sections also addressed the significance of the simulator method for performing a functional study of IoT tasks. To this end, researchers have made several attempts. A survey of some popular simulators and display systems is shown and discussed in this section. The selected IoT simulators are summarized as seen in Table 1. The reasons for the comparison chosen criteria are given for the efficiency of a simulation system.

- **IoT architectural layers:** It specifies the amount of IoT architectural layers protected by IoT, which means maximum coverage.
  1. ***Type***: A simulation paradigm represents the assumptions underlying the entities and relationships.
  2. ***Programming Language:*** It demonstrates basic simulated use portability levels for subsequent hardware prototyping (usually only when using C).
  3. ***The scale of operation***: It demonstrates the scale of the assessment of a recorded simulator.
  4. ***Cyber Resilience Simulation***: Cyber resilience is the ability to plan, react to, and restore cyber-attacks. Due to the lack of conventional cyber security intervention to defend organizations against persistent attacks.
- **API integration** enables processes to be automated and data sharing and incorporation across different applications to be enhanced.
  1. ***Target Domain***: study aid in the face of an existential adverse threat linked to one of IoT's main challenges.
  2. ***Security measure***—it indicates the degree of specialization Low (L), Medium (M), High (H).

Also, many available features were used to evaluate the overall simulation tools. Table 2 compares the selected simulation tools based on the general criteria significant to consider IoT simulation. Tools. According to the reviewed papers, the security measures for the simulation mainly focused on the data security and privacy protection for the application.
The requirements are presented as follows.

Live simulation: Is the simulator is online or offline

Multicore support: Is simulator have the ability to work on various task in parallel

Open source: Is simulator creation code is available

Visualization: Support chart and other types of Visual imagery

Sporadic task: Is the simulator can overcome an unwanted obstacle if execs

Shared resource: Is simulator calculate and dived the resource among the tasks

Table 1: Comparison of Selected IoT Simulators.

Simulators	Type	Programming Language	IoT Architecture Layers	Scale of Operation	API Integration	Cyber Resilience Simulation	Target Domain	Security Measures
IOTSim	Big Data Processing Simulators	Java	Application	Large scale	REST	No	Agriculture	M
CupCarbon	Network Simulators	Java Custom scripting	Perceptual Network	Small scale	UDX	No	Smart City	H
SimIoT	Big Data Processing Simulators	Java	Application	Small scale	REST	No	Health care	H
OMNeT++	Network Simulators	C++	Perceptual Network	Large scale	SOAP	Custom extensions	Smart environment	M
NS-Series	Network Simulators	C++	Perceptual Network	Large scale	REST	No	Smart environment	H
DPWSim	Full-stack simulators	java	Perceptual Network application	Small Scale	SOAP	No	Generic	M
iFogSim	Full-stack simulators	java	Network application	Not known	SOAP	No	Generic	M
IoTIFY	Big Data Processing Simulators	Python Java	Application Network	Large scale	REST	Yes	Smart environment	H
Babywise-IoT	Network Simulators	Python Java	Network	Large scale	REST	No	Smart City	M

Table 2: Comparison of Selected IoT Simulators Based on General Criteria.

Tool Name	Live Simulation	Multicore support	Open Source	Visualization	Sporadic task	Shared resources
IOTSim	Yes	Yes	Yes	Yes	No	Medium
CupCarbon	Yes	Yes	Yes	Yes	Yes	LOW
SimIoT	Yes	Yes	Yes	Yes	No	HIGH
OMNeT++	Yes	Yes	Yes	Yes	Yes	Medium
NS-Series	Yes	Yes	Yes	Yes	Yes	Low
DPWSim	Yes	No	Yes	Yes	Yes	High
iFogSim	Yes	No	Yes	Yes	No	Low
IoTIFY	Yes	No	No	Yes	Yes	High
Babywise-IoT	Yes	No	No	Yes	Yes	High

11. Discussions

This section will discuss the comparison related to those simulators mentioned in the previous parts. Alongside the reviewed papers, our discussions come based on some criteria shown in Tables 1 and 2. Hence, we will provide a discussion about recapped simulators. From the beginning, IOTSim is one of the good simulators used in Agriculture applications. The application has many good features for its field. However, IoTSim does not support sporadic tasks, which might affect its performance. Second of the queue, CupCarbon is a smart city-based simulator. CupCarbon has served many smart design features, but it lacks resources, decreasing its performance. Also, OMNET++ is one of its kind for network designing and has many good features. Nevertheless, eventually, OMNeT++ has the limitation of built-in support for IoT-specific radio models. In addition, NS Series is a generic IoT Simulator used in many fields, as other simulators also lack bandwidth and power consumption, which can be measured as a disadvantage. On the other hand, SimIoT is another simulator used to analyze and process a vast amount of data used in the healthcare field. However, the lack of Sporadic tasks and Shared resources are the problems with SimIoT. Furthermore, IoTIFY is a modern simulator, and as it is discussed, it has a high-rank score. Nevertheless, it has some disadvantages. For example, it does not support multicore, which caused it not to support parallel tasks. Also, it is not an open-source simulator. Finally, BevyWise-IoT is another simulator that has served a lot in the E-learning process, but alongside this great feature, it has a problem of multicore support. Also, DPWSim and iFogSim simulator is not supporting multicore, which can mean that we cannot do parallel tasks in time. However, DPWSim has a high rate for sharing resources than iFogSim, which has a low rate.

12. Conclusion

IoT Simulation tools are necessary to design, develop, and process evaluation of any product before installing it in their target area and environment. This paper has explained some prominent simulators currently available and used for IoT research. The paper presented a comparison of nine different simulation tools based on some parameters such as scope, type, programming language, IoT architecture layers, the scale of operation, API integration, cyber resilience simulation, target space, and security measures. Also, the paper offers an excellent discussion based on their operability of the IoT environment and application simulations, alongside the other many challenges such as finding good simulation for a particular environment. Nevertheless, more in-depth research is needed to assess the accuracy of each tool, Finlay all the simulations discussed in this paper are all suitable for IoT scenarios.

Conflict of interests

None.

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