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Review article

A Review of Cloud Computing-Internet of Things: Issues and Solutions, Open Challenges, and Research Directions

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Abstract
The integration of both technologies, the Internet of Things (IoT) and the Cloud, is bringing many advantages. These two technologies can be used in different domains and applications such as smart cities, environmental monitoring, healthcare, education, E-commerce, and others. However, Cloud-IoT technologies are facing various issues and challenges which are needed to be studied and highlighted. In this paper, we present an overview of the concept of Cloud and IoT together. In addition, this paper shows the issues and solutions that are addressed in Cloud-IoT. Besides, in this paper, we highlight the major challenges in Cloud and IoT, which are recommended to be solved in future work. Finally, we present the future directions and trends for using Cloud and IoT jointly.
Keywords: IoT, Cloud, Issues and Challenges, and Future Trends

Introduction

The Internet of Things (IoT) permits users to connect many Intelligent Machines (IM) and share data, monitoring, and control for services. For instance, home automation, agriculture, security surveillance, management of the energy grid, and control of critical infrastructure. In addition, the IoT is the latest technology [1], in which the boundaries between real and artificial environments are constantly blurring as physical systems are dynamically digitalized and ready to give value-added services to mobile devices [2]. Furthermore, the IoT is powered by purpose-built software that can sense, control, and change the status of things [3]. This life-saving technology must evolve into a network of networked devices in an interconnected society, enabling doctors to perform remote treatments and assess people's houses and power sources. Lead a decent infrastructure and a key national situation (i.e., security program) [4, 5]. The proliferation of smart devices linked to the IoT has increased dramatically as a result of the diversity of IoT utilization technologies and is predicted to reach more than 20.4 billion by the end of 2020 [6, 7]. With the growing number of heterogeneous devices connected to the IoT and data creation, the autonomous IoT will find it more challenging to use power and bandwidth effectively for tasks [8].

In this regard, the convergence of cloud computing with the IoT was conceptualized [9]. When the Cloud is connected to the Internet of Things, a scenario emerges that generates multimedia material [10]. Because the content of multimedia uses additional processing energy, storage space, and resource scheduling, it will be vital to efficiently manage multimedia content and conduct cloud resource management. In addition, the IoT services that perform vital activities need great responsiveness and processing [11]. In this situation, the user is unable to communicate via the Internet using the Cloud range [12]. Besides, the public Cloud and the Internet of Things are two distinct, but in the situation when they are interconnected in one platform, these two technologies will play a significant role in the Internet's future [13]. These mergers are seen as a massive disruptive process with significant future advantages [14]. The Internet of Things and the Cloud are undergoing rapid transformation. The difficulties encountered during the inquiry into merging IoT and Cloud Computing yielded unsatisfactory findings [15]. Using both technologies of IoT and Cloud are coming up with several services. These services of IoT Cloud applications can be summarized as follows:

1. **Development of IoT Sensor Network and Cloud Interfaces:** Developing a safe and stable communication link between IoT devices and the cloud, such as the IoT Cloud Application, continually monitors the connectivity of IoT devices. Additionally, it notifies end-users of connection concerns and recommends fixes.
2. **Development of IoT applications for end-users:** The identification of IoT devices is formed and maintained in the cloud and is then mapped to the appropriate users to prevent unauthorized access.
3. **Design and management of databases:** The database can be populated using the IoT devices. Subsequently, this gathered data can be managed and processed in the Cloud.
4. **Analytical and reporting capabilities:** Development and combination of Machine Learning (ML) methods with IoT cloud application in accordance with business objectives. For instance, providing an IoT Cloud Application with the ability to evaluate historical data for predicting device behavior and determine patterns for predictive maintenance, asset usage, and other applications.

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Report Organization

This paper is organized as follows: Section 3 gives the background of the Cloud-IoT concept. Section 4 discusses the issues with provided solutions in Cloud-IoT. Furthermore, the Cloud-IoT challenges are presented in Section 5. Besides, the future trends and directions of Cloud-IoT are delivered in Section 6. Ultimately, Section 7 presents the summary of this paper.

Background of Cloud-IoT Concept

Services of Cloud Computing have been carried out in numerous fields which are related to the iot technology. For example, manufacturing, genomics data processing, e-learning, emergency recovery, hospitality business, teaching, Internet of Cars (IoC), augmented reality, smart cities, services for businesses, remote forensics, E-Learning approaches, and other fields [16, 17]. There are distinct challenges in cloud computing and the Internet of Things, as well as in environmental applications [18]. Critical challenges in determining how cloud computing and IoT may be linked have resulted in inconclusive outcomes. Cloud computing and the Internet of Things have proliferated rapidly around the world in recent years [19]. When combined, the features they exhibit may be rather remarkable. They are each really unique and necessary for the other [20]. The researchers planned a variety of cloud and IoT-related apps to develop and amass data with the support of cloud storage and processing capabilities. Then, in this section, the Cloud-IoT (Cloud and Internet of Things) architecture. Furthermore, the architecture of Cloud-IoT and the knowledge layers are illustrated in Figure 1. There are interconnections between the network, the application, and sensor layers.

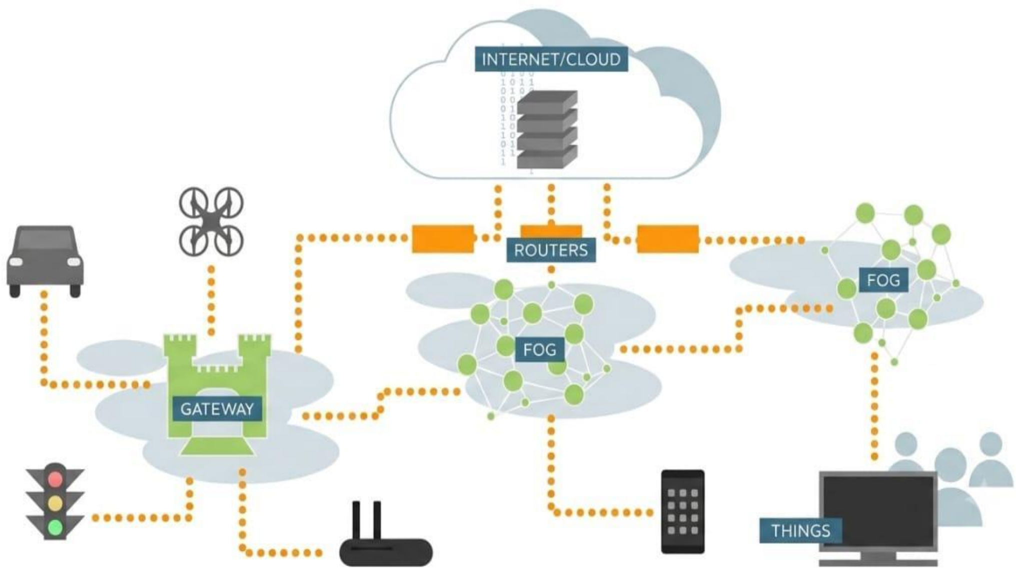

Figure 1. The architecture of Cloud-IoT

Through IoT visualization protocols, the objects have the ability to read and gather data through different IoT models. This knowledge may be processed on the Cloud in order to make the processing stage easier [21]. The application layer can detect the environment and concurrently transmit requests to the Cloud to analyze and acquire the results of sensor data [22]. Additionally, information must be re-posted to the IoT and other IoT devices, as well as data collected from the sensor layer and data analysis for further processing [23]. The environment of Cloud-IoT is illustrated in Figure 2.

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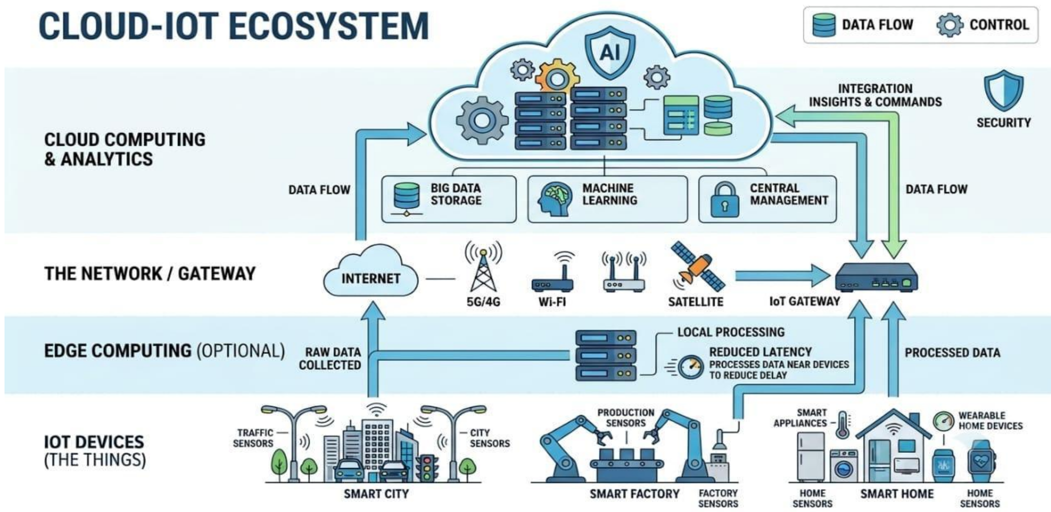

Figure 2. The environment of Cloud-IoT

Overview of Issues and Solutions in Cloud-IoT

The cloud-IoT expands economic prospects in the electrical sector; it also increases the attacker's danger. Furthermore, security, privacy, and, most importantly, identity protection are becoming critical aspects in the intermittent and rapidly varying cloud environments that serve as the foundation for public and private clouds used in commercial operations. Cloud-IoT may incorporate and link heterogeneous networks and systems to enable various data and services. The network must be adaptable and flexible enough to accommodate different sorts of data, depending on their requirements, while maintaining a high level of service quality. While the combination of IoT and cloud partners may answer some of the current concerns between these two technologies that must be dealt with bilaterally, new obstacles may be formed in such a collaborative and synergistic connection [24]. These issues of cloud-IoT will be summarized in the following subsection, and solutions will be provided for each issue.

Heterogeneity in the cloud and IoT and the shortage of appropriate standards for services and data

Existing solutions are very diverse and fundamentally dissimilar in terms of IoT and cloud computing convergence. This disparity is mostly due to the absence of industry-standard tools to assist in the creation of these solutions, which increases their complexity and requires substantial work for their design and style. This difficulty is worsened by a lack of appropriate guidelines and structure for meeting functional and non-functional requirements since these solutions are implementation- and deployment-dependent. Additionally, data created by various IoT devices do not adhere to any standard. In other words, it is regularly represented in disparate formats, units, and so on [25]. Presently, there are no tools or widespread platforms for uniformly and consistently characterizing IoT devices and their specific capabilities, preventing software agents from doing routine activities such as coordination of devices, services, and data, as well as automated detection. Besides, the reference architecture is considered one method for mitigating these issues. Reference architectures may be essential in defining the building blocks required to construct architectural solutions that contain IoT and cloud computing ideas.

The contextual information

Not only should sophisticated sensor data be managed sensitively in IoT, but their context, which contains any type of information necessary to determine a person's identity, location, or status, also demands an extended management method. Contextual data, for instance, metrics, position, component condition, and data correctness may be evaluated in conjunction with raw data that has been gathered from sensor devices for further processing and retrieval. Including contextual information increases the amount of sensed data. Besides, it increases its variability with respect to the format used as well. Indeed, including several display models creates a barrier to information sharing and retrieval. To solve this difficulty, data created by millions of IoT-enabled devices must be gathered and processed for the purpose of extracting insight, with the goal of granting access and authorization for exploration and extraction to a broad range of end-users and applications [26].

Analytics of big data

Given that 50 billion devices will be linked to the network by 2020, particular consideration must be paid to the conveyance, access, storage, and processing of the massive amount of data created. Due to current technical advancements, IoT technology will undoubtedly be a critical component of big data analytics, while the cloud will enable long-term storage and advanced analyses. Indeed, the widespread use of mobile devices is a signal and a need for a scalable computing stage (i.e.,

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approximately 2.5 quadrillion bytes of data are created daily). Managing this volume of data is a significant problem since the application's overall performance is greatly dependent on the data management services' characteristics. For instance, cloud-based ways of summarizing massive data based on semantic feature selection algorithms are evolving and improving. As a result of the NoSQL trend, both available online and private database solutions for dealing with large data have been implemented [27].

Supporting the protocol

There are several protocols for linking disparate things to the Internet, even though their natures are similar. For instance, an IoT sensor might support many protocols, including IEEE 1451, ZigBee, 6LOWPAN, and Wireless HART [28]. Certain protocols are supported by the gateway device, while others are not. This is dependent on the gateway and the sensor type utilized. From the user's and subscriber's standpoint, a sensor that is less expensive or simpler to access takes precedence over the others. As a result, no assurance can be made about the successful setting of the newly introduced sensor. The map of normal gateway protocols is considered the solution to this issue.

The issue of communication delay and network congestion

Devices and components that are connected to the Internet in smart grids create and transmit a massive amount of data that must be categorized, organized, and processed in the cloud. If all data produced by all equipment is transferred to the cloud, this large data stream over the networks is the main reason for causing congestion. As a result, communication delays occur, which may be particularly infuriating for real-time applications. One strategy for addressing this issue is to use the technology of fog computing, which extends the cloud to the network's edges to offer different services (e.g., data processing and analysis), as well as network services among linked devices and the cloud platform [29].

Cloud-IoT Challenges

Currently, there are numerous different challenges that are facing the technologies of both Cloud and IoT. The consideration of these challenges in future research and work is highly significant in order to elevate the performance of a system that uses such technologies. We will discuss the challenges of Cloud-IoT in the subsequent subsections.

Security

The cloud is used to store and analyze IoT data. This includes data encryption before it is transferred to or stored in cloud-based repositories, as well as data security during cloud access and usage [30]. The degree to which cloud computing information is lacking is such that data owners are unaware of their own data's actual location. Because data is now ubiquitous, data security is considered a primary challenge in the paradigm of Cloud-IoT [31].

Computational Performance and Storage

Plans that involve cloud-based IoT device usage need a high-performance objective specification. Such criteria may be challenging to achieve in all circumstances since cloud-based IoT devices are in use for a variety of applications [32].

Reliability

IoT devices are reliant on the Cloud to function as service providers for time-critical applications, and the impact would be proportional to the program's output directly. For instance, in surgical instruments, car applications, and in the security domain [33].

Service Quality

By increasing the number of databases and diversifying the kinds, ambiguity, and unpredictability of data in the system, the quality of service is considered debatable. Any kind and quantity of data may be used at any time. Certain data are also considered emergency data. As a result, dynamic request prioritization on the cloud-side is required. Frequently, the quality of service is quantified in terms of percentage of missed packages, noise, delay time, and bandwidth. The quality of service must be determined by the kind of data and the urgency with which it is sent to the sync node [34].

Future Trends of Cloud-IoT

In this section, we will briefly present some future trends of Cloud-IoT technologies. These future trends of Cloud-IoT can be summarized as follows:

- **Focusing on the Security of Cloud-IoT:** Organizations and companies are adding IoT devices into their networks. However, bad actors are on the lookout for vulnerabilities that these new endpoints may reveal. A growing trend is for security teams to prioritize cloud data encryption, where guaranteeing that data and information are encrypted both at rest and in transit is critical.

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- **Using 5G Technology in Cloud-IoT:** At the end of 2021, according to the business called "Omdia", there will be 692 million worldwide 5G connections. This rise is being fueled in part by increased IoT adoption. As enterprises implement cloud-based IoT services, rapid connection speeds are critical. Furthermore, 5G technology is bridging the connection divide in rural areas, enabling new businesses to use IoT to improve their performance and operations.
- **Edge Computing and IoT:** Similar to the adoption of 5G, organizations and enterprises are increasingly relying on edge computing to manage IoT data owing to the promise of greater connection speed and reliability. Particularly for applications using big data analytics. While IoT devices collect huge amounts of data, firms that lack big data processing skills lose out on the many advantages of data analytics. In addition, edge computing is considered a distributed network that may be used in conjunction with cloud data repositories to minimize data processing latency. Industry observers anticipate that edge computing will continue to grow in popularity as enterprises and consumers alike embrace IoT devices.
- **AI and IoT in Cloud Computing:** Cloud computing is regarded as very important in the domain of AI (Artificial Intelligence), where it delivers general access to effective and efficient ML (Machine Learning) platforms that need data bandwidth and massive processing capability. For instance, ML algorithms are being employed to learn from the collected data by IoT devices for automating operational methods and facilitating supply chains. With the evolution of cloud resources, nearly any AI application can now be accessed and utilized via the cloud, significantly improving the usefulness of data that has been produced by IoT devices, which is often in real-time.

Conclusion

The technologies of Cloud and Internet of Things (IoT) have obtained high significance by many researchers due to the massive benefits that can be gained using these technologies together. Nevertheless, there are several issues and open challenges that need to be highlighted and studied. In this paper, we have presented the concept of Cloud and IoT when they are used together. Further, we presented the issues that have been faced by the cloud and IoT and provided solutions for each issue. The open challenges for such technologies are provided as well in order to avoid or solve them in future work. Ultimately, we have delivered the future trends and directions for utilizing Cloud and IoT concurrently.

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