

Security and Performance Challenges, Solutions and Future of Cloud-based IoT Systems: A brief review

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Abstract. Integrating the Internet of Things (IoT) with cloud computing has presented a groundbreaking worldview, rethinking communications and data sharing among the connected devices. This paper thoroughly investigates cloud-based IoT, including its architecture, advantages, challenges, and future possibilities. Cloud technologies enhance IoT capabilities, such as, data processing, storage, and analysis. As the current technology trends mature and their popularity increase in terms of providing novel applications, there is an observance of a deluge of connected gadgets, and hence cloud computing becomes a strategic partner in fulfilling the diverse requirements of efficient data management. In general, the research focuses on security and performance considerations for Cloud-based IoT systems. More, specifically, it delves into the critical aspects of data security, system performance optimization and interoperability among existing platform and novel applications. The solutions to the issues identified are proposed so as to address the limitations of Cloud-based IoT and provide insights on how to improve the state-of-the-art solutions to cater for the future diverse needs of the ever-evolving cloud-based IoT landscape.

Keywords: Internet of Things · Cloud Computing · IoT Challenges · Data Management · Scalability · Data Security · Edge Computing

1 Introduction

In the 21st century, the expansion of connected devices has led to the Internet of Things (IoT), where regular objects are outfitted with sensors and communication capabilities. This explosive growth is aptly captured by Fig. 1, which projects the count of IoT devices to more than 100 billions by the year 2050. However, this interconnected ecosystem produces immense amounts of information, requiring advanced, effective administration and use of technologies. With its versatile and adaptable infrastructure, cloud computing has become a natural partner for IoT, giving data processing and storage a concentrated stage. This cooperative relationship has reclassified how devices communicate and share information, offering uncommon open doors for development and efficiency.

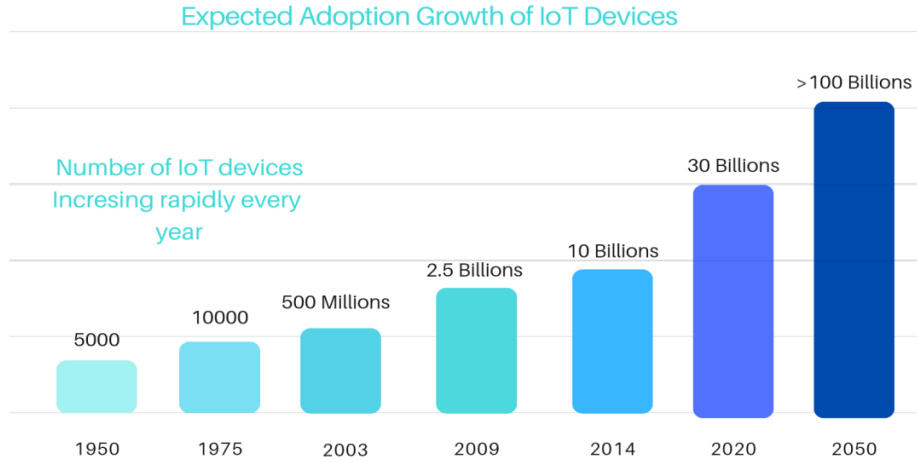


Fig. 1. Projected growth of IoT devices [1]

As we explore this powerful scene, this report extensively investigates Cloud-Based IoT, digging into its complicated design, clarifying the complex advantages it offers, tending to the unpredictable difficulties, and graphing the promising vistas for what's in store. We won't just inspect the specialized viewpoints but also consider the more extensive ramifications for ventures and society, as this collaboration among IoT and cloud computing keeps reshaping the technological and economic landscape. This exploration means to give a comprehensive comprehension of how Cloud-Based IoT improves the capabilities of IoT, enabling efficient data processing, secure storage, and robust analysis.

The design of cloud-based IoT fills in as the foundation of our research. It includes a powerful framework that interconnects a variety of gadgets and sensors, which, by and large, create a considerable volume of information. This information is then consistently sent to remote cloud servers, which are processed, stored, and made accessible for analysis. Our investigation digs into the complexities of this design, clarifying how it empowers real-time data trade and engages the consistent connection of a different scope of IoT gadgets.

2 Review of Cloud-based IoT Research

Many researchers have researched this subject, which has led to massive improvement in the cloud-based IoT, but there is still enormous room for improvement. Some of this research points to one aspect, like validity or scalability, and some to challenges, like security or connectivity. Therefore, in this section, we summarize and discuss some of these related works in integrating cloud-based IoT. The findings of this review work is summarised in Table 1.

Authors in [2] is about how IoT and Cloud Computing work together, making something they call 'CloudIoT.' It combines the finest parts to investigate

unused conceivable outcomes and handle modern issues. The thesis also explores various CloudIoT frameworks, covering those you can have secretly and others open to all. At last, it underscores CloudIoT's key role in forming the Internet's future and focuses on the questions we still ought to reply to, implying future investigative bearings.

Table 1. Summary of literature in the domain of Cloud-based IoT systems

No.	Ref	Year	Approach	Comments
1	[2]	2016	Writing overview on CloudIoT integration, IoT and Cloud Computing, investigation of applications and challenges	Recognizable proof of the complementary nature of Cloud and IoT, a diagram of applications picking up energy beneath CloudIoT, and an audit of existing stages and ventures.
2	[3]	2017	Writing study on CloudIoT integration, looking at the collaboration between IoT and Cloud Computing, and investigating applications and challenges	Point-by-point understanding of Cloud and IoT integration, knowledge of applications and challenges, and an outline of existing stages
3	[4]	2020	Survey of CloudIoT innovation, examination of its effect on intelligent grids and control markets, and discourse of openings and challenges	Understanding how IoT and cloud integration can modernize vitality administration, transitioning to a more decentralized and independent framework
4	[5]	2018	Outline of Cloud and IoT integration, examination of benefits and challenges, and talk on the architecture and applications of Cloud-based IoT	Upgraded understanding of how Cloud assets can advantage IoT and vice versa, and bits of knowledge into the architecture and applications of Cloud-based IoT
5	[6]	2018	Conducting a writing overview on CloudIoT integration and analyzing the cooperative energy between IoT and Cloud Computing	Insight into the complementary nature of Cloud and IoT, Exploration of applications and a review of current platforms and projects
6	[7]	2021	Overview of IoT and Cloud of Computing centered on security issues, analyzing both innovations' integration and standard highlights	Distinguish proof of the synergies between IoT and cloud computing and how cloud computing upgrades IoT usefulness
7	[8]	2014	Introduction of a Cloud-based IoT stage, centering on its communication, handling, capacity properties, and representation of actualized ventures	Improve a stage that utilizes Cloud assets to overcome IoT restrictions, improving information dealing with and handling capabilities
8	[9]	2020	Investigate IoT and cloud computing, tending to integration challenges and cloud-compatible computing methods for IoT	Distinguishing proof of cloud computing as a practical arrangement for information administration in IoT, accentuating security and integration challenges
9	[10]	2016	Investigation of IoT and cloud computing integration, centering on gadget integration, arrangement, communication, security, and QoS administration in IoT WSNs	Experiences into the challenges and potential arrangements in coordinating IoT with cloud computing and improving secure, adaptable, and productive IoT cloud frameworks
10	[11]	2019	Examination of IoT innovation and cloud integration, comparison of items from major innovation companies, and model improvement for savvy domestic items	Experiences into IoT convention efficiencies, a comparative investigation of items from driving tech, and many domestic item characteristics

Another work in [3] investigates the integration of Cloud Computing with the Internet of Things (IoT), a crucial step towards overcoming the challenges confronted by both advances. It emphasizes how Cloud Computing's endless assets can improve the IoT and, alternately, how IoT can offer assistance to Cloud Computing interface more successfully with real-world objects in an energetic and dispersed way (see Fig. 2 for the Cloud-based IoT architecture). The consider

gives a list of the benefits and challenges of this integration and discusses the design of the coming Cloud-based IoT worldview and its modern application scenarios. It concludes with proposals for open issues and future investigations in this quickly advancing field.

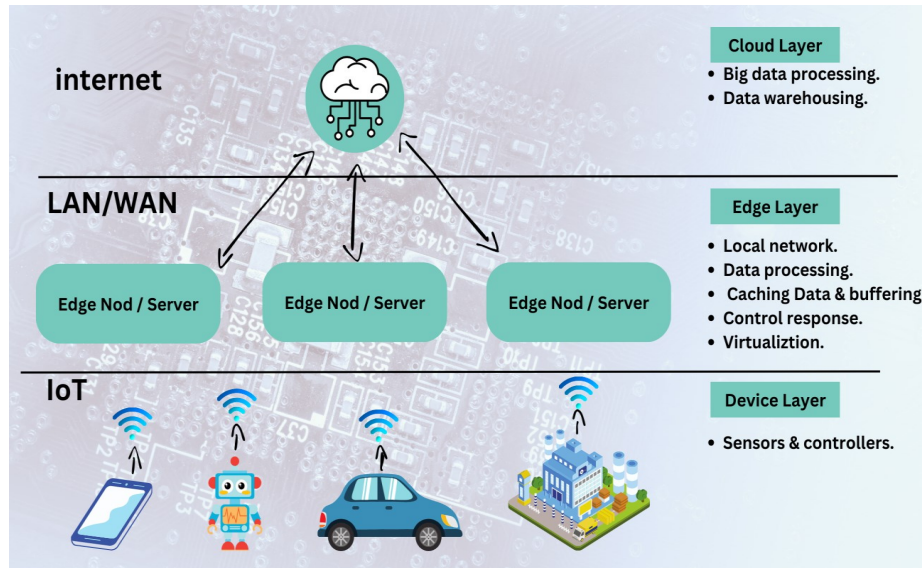


Fig. 2. Architecture of Cloud-based IoT Systems.

Authors in [4] discuss the noteworthy part of the Internet of Things (IoT) in changing conventional vitality administration frameworks in keen networks and control markets. It highlights how IoT when coordinated with cloud innovation (Cloud IoT), can revolutionize these frameworks by presenting a decentralized, peer-to-peer structure with tall independence. The consideration starts with an expound survey of Cloud IoT, looking at its benefits for savvy networks. At that point, it dives into the openings and challenges displayed by this integration, advertising comprehensive dialogs on potential arrangements to address these challenges. This integration is seen as a critical factor in modernizing power systems and improving the effectiveness of control frameworks.

Further research [5] investigates the meeting of Portable Cloud Computing and the Internet of Things (IoT), with an extraordinary center on security issues. It dives into how these two quickly creating-advances in remote communications can complement each other. They consider overviews of IoT and Cloud Computing, analyzing their typical highlights and the benefits of their integration (see Fig. 3 for the integration of IoT and cloud with use cases). The investigation especially highlights how Cloud Computing can improve the usefulness of IoT frameworks. The paper concludes by focusing on the security challenges that

emerge from integrating IoT and cloud computing, underscoring the significance of vigorous security measures in this combined innovative space.

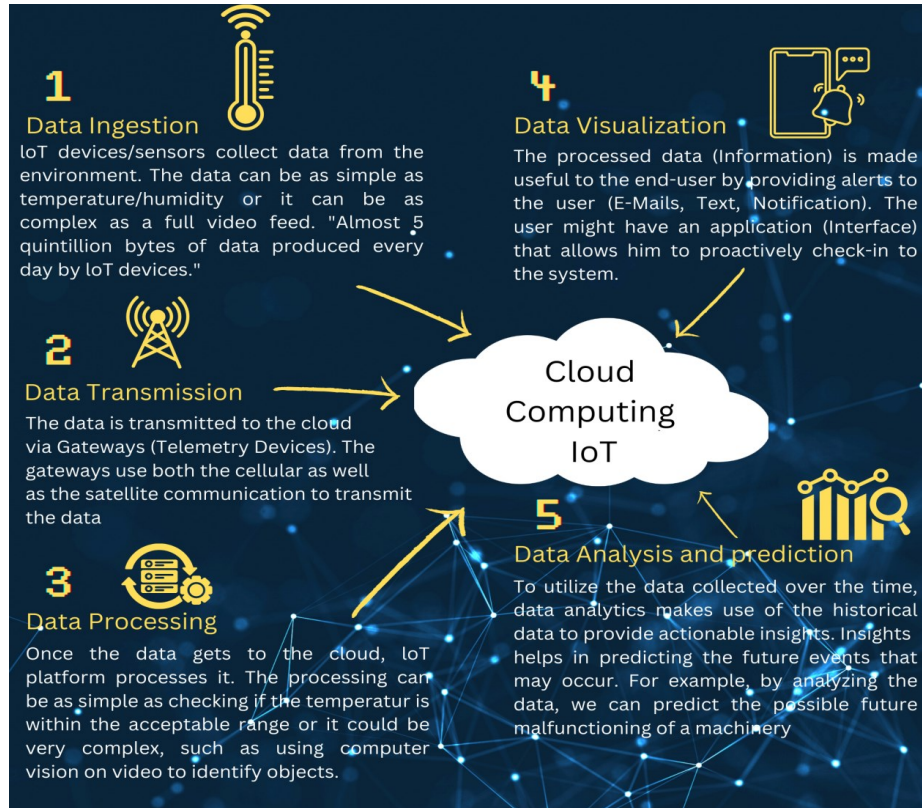


Fig. 3. Integration of IoT and Cloud with use cases.

Another research [6] analyzes the integration of Cloud Computing with Internet of Things (IoT) innovation to address the restrictions of IoT, such as constrained capacity, vitality, and handling capacities. It presents a Cloud-based IoT stage, portraying its communication, handling, and capacity capabilities. This stage leverages cloud assets and administrations to manage information from differing IoT gadgets productively. The think about exhibits different ventures that have effectively executed this Cloud-based IoT stage, highlighting its down-to-earth applications and adequacy in upgrading IoT functionalities.

Authors in [7] examine the challenges faced by the Mechanical Web of Things (IIoT) in overseeing the tremendous volume of information created, especially considering IoT gadgets' restricted vitality and capacity capacities. It investigates how cloud computing can be a proficient arrangement for outsourcing information capacity and preparing, in this manner, overcoming the inborn im-

peratives of IoT gadgets. The ponder dives into the one-of-a-kind security concerns and integration issues between IoT and cloud computing. Moreover, it looks at cloud-compatible computing strategies and methodologies to encourage a smooth move of IoT applications to the cloud, guaranteeing proficient information taking care of and handling in IoT situations.

Here the research in [8] focuses on the rapid growth trend of computing globally and the need to coordinate IoT with cloud computing, referred to as the cloud of things. It emphasizes that the tremendous sum of information produced by IoT gadgets requires significant capacity and virtual asset utilization, which cloud computing can give. This integration is crucial for changing simple information into valuable data, information, and, indeed, shrewdness, encouraging the advancement of intelligent applications. The paper recognizes that this integration is complex and presents critical issues and potential arrangements, highlighting the challenges and openings in making a consistent Cloud of Things environment.

Authors in [9] dig into the progressed innovation of the Internet of Things (IoT) and its integration with cloud computing, centering on how IoT conventions optimize organized transfer speed and code space. It audits the adaptability of IoT with other stages and talks about significant innovation companies like Apple, Google, and Amazon, comparing their IoT items based on parameters like cost, gushing choices, and associations.

The main aim of [10], centers on integrating cloud computing and the Internet of Things (IoT), tending to different perspectives such as IoT gadget integration, arrangement, communication, and security over the cloud. It emphasizes the part of sensor-cloud arrangement and the challenges in quality of service (QoS) administration in IoT Wireless Sensor Networks (WSNs) (see Fig. 4 for challenges and benefits of cloud-based IoT systems). The paper also digs into the security concerns in IoT and cloud computing, highlighting the requirement for strong security conventions and strategies. Additionally, it talks about the potential and challenges of IoT in different spaces like frameworks, e-Health, and large-scale IoT ventures. The objective is to form a bound together, decentralized computing environment that effectively oversees IoT gadgets and information through the cloud, overcoming interoperability, versatility, and security issues.

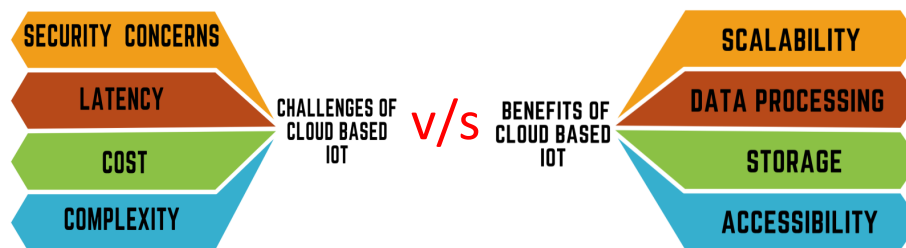


Fig. 4. Benefits versus Challenges in the Cloud-based IoT systems.

Finally, in [11] gives an in-depth survey of the integration of Cloud Computing and the Web of Things, commonly called cloud WoT. It addresses the challenge of overseeing the enormous amounts of information produced by the expanding utilization of sensor gadgets and RFID communication, surpassing these gadgets' capabilities. The chapter presents a comprehensive vision of the Cloud IoT integration components, discussing the consistent applications empowered by this stage and the components driving its integration. Moreover, it digs into security issues inside the IoT layered engineering, counting vulnerabilities within the cloud and recommending potential countermeasures. Furthermore, the chapter investigates different CloudIoT stages outlined to resolve the differences between Cloud and IoT gadgets. It concludes by recognizing and exploring open issues and challenges in cloud and IoT integration.

3 Findings and Recommendations

The discussion delves into the identified benefits and challenges of Cloud-Based IoT, emphasizing the need for a holistic approach to address security concerns and optimize system performance. Future recommendations include exploring innovative hybrid cloud architectures, implementing advanced encryption techniques, and fostering collaboration among industry stakeholders to establish standardized security protocols.

- **Security** is paramount in Cloud-Based IoT, given the interconnected nature of devices. Robust security measures, including advanced protocols, encryption methods, and intrusion detection systems, are imperative to safeguard user data and system integrity. Ongoing research should focus on evolving security measures to counter emerging threats effectively [12].
- **System Performance Optimization** Ensuring perfect system execution is imperative for the reliable movement of Cloud-Based IoT. Methods to move forward adaptability, diminish idleness, and optimize asset utilization to be at the front line of future turns of occasions. Executing profitable data dealing with and stockpiling courses of action will include a common advancement in system execution.
- **Interoperability** could be an essential perspective of Cloud-Based IoT, as different devices and platforms have to consistently communicate and collaborate. Future endeavors must prioritize improving standardized communication protocols, middleware solutions, and compatibility measures to improve interoperability.
- **Data Privacy and Governance** Protecting the security of client information and setting up robust information governance practices are essential for building strength in the Cloud-Based IoT frameworks. Future proposals

incorporate using privacy-preserving techniques, straightforward data governance systems, and compliance with advancing data security directions [13].

One of the interesting findings was how different Cloud Service Providers (CSPs) are providing IoT services for the customers. Prominent CSPs (AWS [14], Microsoft Azure [15] and Google Cloud Platform [16]) were compared with each other in terms of the criteria of scalability, data processing, storage options and accessibility. The results are summarized in Table 2.

Table 2. Comparative Analysis of Cloud Service Providers for IoT-based services

Criteria	Amazon Web Services	Microsoft Azure	Google Cloud Platform
Scalability	High	Medium	High
Data processing	Real-time	Batch	Real-time
Storage options	Flexible	Limited	Scalable
Accessibility	Global	Regional	Global

4 Future Directions

Progressing research in Cloud-Based IoT is committed to beating existing difficulties and enhancing the cooperation between IoT and cloud computing. As the technology landscape develops, there is an emphasis on resolving issues connected with security, reducing latency, and implementing cost-effective solutions.

Moreover, the incorporation of edge processing and the investigation of cross-breed cloud methodologies are regions that require further examination. In this specific situation, a similar analysis of edge registering arrangements gives meaningful experiences into their handling capacities and combination with the cloud. One significant area that requires attention is security. As our reliance on interconnected systems grows, ensuring the robustness of security measures within operating systems becomes paramount. Future operating systems should be outfitted with cutting-edge security conventions, encryption strategies, and interruption location frameworks to shield client information and keep up with the respectability of the framework.

The concept of real-time collaboration and seamless integration of applications across diverse platforms is gaining prominence. The future operating systems need to focus on providing an ecosystem that facilitates effortless collaboration, file sharing, and communication between users regardless of the devices and platforms they use. Due to the advancement of technology, more IoT devices are available, and they continue to grow. There is a concern about their environmental impact and energy consumption. Future researchers should focus on designing energy-efficient solutions that reduce the carbon footprint of Cloud-Based IoT systems. This may involve developing low-power IoT devices,

optimizing transmission protocols, and finding renewable energy resources to power these systems.

5 Conclusions

This paper presents a detailed analysis of integrating the Internet of Things (IoT) and cloud computing, emphasizing its revolutionary vast impact on technology and our lives. The research dives into various aspects, such as architecture design, information management, flexibility, and challenges associated with Cloud-Based IoT implementation. It highlights its potential to transform and how connected devices operate and interact.

Significant benefits from this integration are covered in detail in the study; these include optimizing IoT capabilities by employing advanced data processing techniques for enhanced storage solutions using cloud computing, leading to increased overall efficiency and effectiveness. Potential issues, among others, relate primarily to security concerns requiring structured protocols coupled with encryption technologies safeguarding vulnerable information effectively.

The research also proposes future studies investigating reduced latency-enabled edge computing alongside other hybrid models comprehensively addressing crucial sectors necessary for sustained growth in an effort towards continued improvements within industry applications powered through innovative advancements facilitated via cloud-based IoT platforms.

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