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Navigating the Landscape of IoT, Distributed Cloud Computing: A Comprehensive Review

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ABSTRACT: This comprehensive academic exploration delves into the revolutionary convergence of the Internet of Things (IoT) with distributed cloud computing, redefining the realms of data processing, storage, and communication. The paper critically analyzes scholarly work from reputable journals, providing profound insights into this integration's multifaceted applications and underlying technological frameworks. The relevance of IoT, a network of interconnected devices and sensors, is emphasized through its significant impact on diverse sectors, including healthcare, education, agriculture, and smart cities. This impact is magnified by its extensive data collection, processing, and analysis capabilities, enabled through cloud computing platforms. The objective of the paper is to methodically compare and contrast contemporary scholarly contributions, shedding light on the diverse applications and technological infrastructures of IoT in conjunction with distributed cloud computing. This endeavor encompasses an examination of IoT-based cloud infrastructure, detailed analysis of specific needs, implementations, and applications of IoT-based cloud computing, and a review of various IoT cloud platforms. The paper also highlights the benefits of integrating IoT with cloud computing, elucidating significant advantages and potential future directions of this technology. Through this scholarly inquiry, the paper aims to offer an in-depth perspective on the state-of-the-art developments in IoT and distributed cloud computing. It underscores their significance and potential in shaping the future of digital technology and its applications across various domains.

Keywords: IoT, Distributed Systems, Cloud Systems, Distributed Computing, Cloud Computing

1. Introduction

The convergence of the Internet of Things (IoT) and distributed cloud computing marks a significant evolution in the digital landscape, offering unprecedented opportunities for innovation and efficiency (Lakhan et al., 2024; M Zeebaree et al., 2019a). IoT, characterized by a vast network of interconnected devices generating a wealth of data, brings forth challenges and potentials that distributed cloud computing aims to address. This comprehensive review explores the intricate interplay between these two technological realms, delving into their synergies, architectural frameworks, and the emerging trends shaping their integration(M. Zeebaree et al., 2019; Mohammed et al., 2023).

The concept of IoT revolves around the idea of embedding internet connectivity into everyday objects, enabling them to send and receive data(Hikmat Ibrahem & Zeebaree, 2024). This network of physical devices extends internet connectivity beyond traditional devices like computers and smartphones to a diverse range of devices and everyday things yer works in tandem with the central cloud, which offers more substantial computing power and storage capabilities (Sami et al., 2023c; Taha et al., 2020). This hybrid model optimizes performance, enhances data management, and ensures security and privacy in IoT applications.

Emerging trends in IoT and distributed cloud computing include the adoption of advanced analytics, artificial intelligence, and machine learning algorithms(Salih Abdullah & M Zeebaree, 2024). These technologies enable intelligent decision-making and automate various processes within the IoT ecosystem. For instance, predictive maintenance in industrial IoT, powered by machine learning algorithms, can foresee equipment failures before they occur, thus reducing downtime and maintenance costs (Tabrizi et al., 2017; Zeebaree, 2020).

Moreover, the integration of IoT and distributed cloud computing is not without its challenges. Key among these is ensuring the security and privacy of the data transmitted across the network. The distributed nature of IoT devices, often with varying levels of security, presents a complex landscape for cybersecurity. Addressing these security concerns is paramount, as vulnerabilities can lead to significant risks, including data breaches and unauthorized access (Ageed et al., 2022; Taha et al., 2020).

The integration of IoT with distributed cloud computing is a dynamic and evolving field, presenting both challenges and opportunities(Majeed Zangana & Zeebaree, 2024). This review aims to provide a comprehensive understanding of the current state of this integration, exploring the technological advancements, architectural frameworks, and emerging trends that are shaping the future of IoT and distributed cloud computing. By addressing the challenges head-on and leveraging the synergies between these two technologies, which can unlock the full potential of this integration, paving the way for a more connected and efficient future (Malallah et al., 2021; Mohammed, 2023).

Through this scholarly inquiry, the paper aims to offer an in-depth perspective on the state-of-the-art developments in IoT and distributed cloud computing, underlining their significance and potential in shaping the future of digital technology and its applications across diverse domains(Khalid et al., 2024).

2. Background Theory

The integration of Distributed Cloud Computing and the Internet of Things (IoT) represents a significant advancement in the digital era, reshaping how data is processed, stored, and utilized. Distributed Cloud Computing extends the traditional cloud model by decentralizing data processing and storage, bringing these services closer to the data source, and thereby reducing latency, enhancing data processing speeds, and improving system resilience (Mohammed Sadeeq et al., 2021; Mohammed et al., 2023).

IoT, on the other hand, involves the interconnection of everyday objects equipped with computing devices, enabling them to send and receive data. This creates a massive network of data-generating devices, necessitating robust, scalable, and efficient computing solutions (Ahmed, 2023; Mohammed et al., 2024). The intersection of these technologies is revolutionizing various sectors by enabling real-time data processing, advanced analytics, and improved operational efficiencies(Hasan et al., 2021).

2.1 Cloud Computing

Cloud computing represents a transformative shift in the way computing resources are managed, offering scalable, flexible, and efficient solutions for data storage and processing. The essence of cloud computing lies in its ability to provide on-demand access to a shared pool of configurable computing resources, which can be rapidly provisioned and released with minimal management effort or service provider interaction (Mohammed Sadeeq et al., 2021; Sami et al., 2023b). The evolution of cloud computing can be traced back to the 1960s, with the development of the concept of time-sharing, which laid the foundation for the shared resource model. Over the years, significant advancements in virtualization, broadband internet, and fast, reliable online services have catalyzed the growth of cloud computing (Mohammed et al., 2023; Zebari et al., 2019). Three primary service models define cloud computing: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Each model offers varying degrees of control, flexibility, and management, tailored to meet diverse needs. IaaS provides basic infrastructure services, PaaS offers a platform for the development and deployment of applications, and SaaS delivers software applications over the internet (M. Sadeeq & Zeebaree, 2023; Van Schuppen et al., 2011).

The deployment models of cloud computing are another vital aspect, including public, private, community, and hybrid clouds. Public clouds are operated by third-party cloud service providers, offering services over the internet(Ageed & Zeebaree, 2024). Private clouds are exclusively used by a single organization, offering enhanced security and control. Community clouds are shared by several organizations with common concerns, and hybrid clouds combine public and private clouds, offering a balance of control, scalability, and cost-effectiveness (Mohammed Sadeeq et al., 2021; Sami et al., 2023a). Cloud computing also faces challenges, particularly in security, privacy, and data management. The distributed nature of the cloud poses unique security threats, and ensuring data privacy and compliance with regulations is crucial. Moreover, managing the vast amount of data in cloud environments necessitates robust data management and analytic tools (Mohammed et al., 2023).

Cloud computing has revolutionized the IT industry, offering scalable, efficient, and cost-effective solutions. Its evolution from a shared resource model to a comprehensive framework encompassing various service and deployment models highlights its adaptability and potential for growth. As cloud computing continues to evolve, addressing its challenges will be crucial for maximizing its benefits and potential (Muhammed et al., 2022; Van Schuppen et al., 2011).

2.2 Internet of Things

The Internet of Things (IoT) represents a paradigm shift in the digital world, characterized by the interconnectedness of physical devices capable of collecting and exchanging data. The inception of IoT can be traced back to the early 1980s with the development of interconnected, sensor-based technologies. However, it was not until the early 2000s that the term "Internet of Things" was coined, symbolizing the expansion of internet connectivity beyond traditional devices like computers to everyday objects (Shukur, Zeebaree, et al., 2020; Mohammed et al., 2024). IoT is built on a complex architecture comprising various layers: perception, network, middleware, application, and business layers. The perception layer involves sensors and actuators, playing a pivotal role in data collection and interaction with the physical environment(M Zeebaree et al., 2019b). The network layer ensures connectivity, typically using technologies like RFID, NFC, and Bluetooth. Middleware acts as a bridge, providing data management and processing services. The application layer delivers IoT services to users, and the business layer oversees the overall IoT system operation, addressing concerns like business models and user privacy (Ageed et al., 2021; Ahmed, 2023).

Key technologies that have fueled the growth of IoT include Radio-Frequency Identification (RFID) and Wireless Sensor Networks (WSN). RFID technology, used for automatic identification and tracking, is integral in IoT for tagging and identifying objects. WSNs, consisting of spatially distributed autonomous sensors, facilitate environmental monitoring and data gathering (Ahmed, 2023; Jghef et al., 2022).

IoT applications span various domains, such as smart homes, healthcare, agriculture, and industrial automation. In smart homes, IoT devices contribute to energy management and home security. In healthcare, IoT technologies enable remote monitoring and patient care. In agriculture, IoT assists in precision farming techniques, and in the industrial sector, IoT enhances efficiency through automation and predictive maintenance (Ibrahim et al., 2021; Jino Ramson et al., 2020).

However, IoT also faces significant challenges, particularly in terms of security, privacy, and scalability. The diverse and distributed nature of IoT devices presents a complex landscape for cybersecurity. Ensuring data privacy and managing the vast amounts of data generated by IoT devices require robust security protocols and efficient data processing techniques (Abdullah et al., 2020; Mohammed et al., 2024). IoT is a rapidly evolving field, significantly impacting various sectors by enhancing connectivity and data-driven decision-making. Its architecture, key technologies, applications, and challenges highlight the multifaceted nature of IoT and the need for continued innovation and security enhancements to realize its full potential (Ahmed, 2023; Shukur, Jubair, et al., 2022).

3. Methodology

This section delineates the systematic approach employed in this comprehensive review to explore the integration of the Internet of Things (IoT) and distributed cloud computing. The methodology is designed to critically analyze, synthesize, and present findings from an array of scholarly articles, thereby offering a profound understanding of this domain.

The primary step involved an exhaustive search of relevant literature, focusing on studies published in high-impact journals post-2019. Multiple databases, including IEEE Xplore, Springer, ScienceDirect, and MDPI, were meticulously scoured using keywords such as "IoT," "Distributed Cloud Computing," and related terms. The inclusion criteria were stringent, prioritizing peer-reviewed articles that specifically addressed the integration of IoT with distributed cloud computing, their applications, challenges, and future prospects.

Once the relevant articles were identified, a detailed extraction of data followed. Key information regarding the methodologies, findings, and conclusions of each study was systematically recorded. Further, information related to system architecture and design, performance and efficiency of the cloud system were gathered. Additionally, details about security, privacy, and reliability of the system, along with user experience, application, evaluation and impact of the distributed cloud system were recorded. This process was critical to understand the depth of the research conducted in this field and to identify any gaps in the existing literature.

The extracted data were further analyzed, where common themes and patterns across the literature were identified and grouped. This approach facilitated a comprehensive understanding of the current trends, challenges, and advancements in the integration of IoT with distributed cloud computing.

Each selected study was subjected to a critical review, evaluating the strength, validity, and relevance of the research. This evaluation was instrumental in ensuring that the review was based on robust and high-quality studies, thereby enhancing the credibility of the findings.

Finally, the findings from the analysis and critical review were synthesized to provide a coherent narrative. This narrative encapsulates the current state, challenges, and future directions of IoT and distributed cloud computing integration, offering valuable insights for researchers, practitioners, and policymakers in this field.

4. Literature review

This literature review meticulously examines an array of scholarly articles that elucidate the synergistic integration of the Internet of Things (IoT) and distributed cloud computing. These selected studies offer a comprehensive insight into the multifaceted applications and challenges within this burgeoning domain, spanning eco-agriculture to smart home architectures, while critically addressing issues of efficiency, security, and environmental sustainability.

(Liu et al., 2019) This paper delved into the development of an IoT monitoring system for modern eco-agriculture, integrated cloud computing to address challenges in China's agricultural sector like product quality, environmental pollution, and management efficiency. The proposed platform combined IoT, cloud computing, data mining, and other technologies, featured an intelligent gateway, multi-protocol data transmission, cloud data storage, real-time monitoring, big data analysis, and decision-making tools. The study highlighted the system's feasibility as a cost-effective and reliable approach to enhancing agricultural efficiency and security.

(Rao & Dave, 2019) The paper discussed developed practical laboratory exercises to teach STEM students about IoT, cloud computing, and blockchain. Highlighting the importance of hands-on learning, the authors used the Raspberry Pi platform to create engaging exercises, including image acquisition, cryptographic hash functions, and cloud storage. The approach was shown to enhance student understanding and engagement, effectively bridging the gap between traditional educational content and evolving tech trends, demonstrating its adaptability to other emerging technologies.

(Darwish et al., 2019) Addressed a comprehensive review that discussed the integration of Cloud Computing and IoT in healthcare, introduced the CloudIoT paradigm. It examined how CloudIoT could enhance healthcare services, discussed its application in smart hospitals, medicine control, and remote medical services. The paper highlighted how Cloud Computing and IoT, as complementary technologies, could solve IoT-related issues like data access, processing, analysis, security, and privacy. The discussion included challenges and opportunities presented by this integration, emphasizing communication, storage, and computation aspects.

(Singh et al., 2019) This paper introduced SH-BlockCC, a smart home architecture that leveraged IoT, cloud computing, and blockchain technology. It aimed to address scalability, efficiency, and security concerns in smart home systems through a decentralized blockchain approach for secure transaction processing and data handling. The architecture also incorporated multivariate correlation analysis for network traffic analysis. Performance evaluations focusing on throughput demonstrated blockchain's efficiency as a security solution, marking a significant development for secure and efficient smart home environments.

(Naregal & Kalmani, 2020) Authored by Keerti Naregal, the paper explored the development of a lightweight Attribute-Based Encryption (ABE) tailored for cloud-based IoT systems. It critically addressed the limitations of conventional ABE methods, proposing an innovative elliptic curve cryptography-based lightweight ABE. This solution was particularly suited for resource-constrained IoT devices. The paper underscored the crucial need for secure and efficient data encryption in IoT applications across a spectrum of domains, highlighting the significance of enhancing data security in the rapidly evolving IoT landscape.

(Aceto et al., 2020) The paper surveyed the impact of Industry 4.0 technologies (IoT, Cloud and Fog Computing, Big Data) on healthcare, leading to the evolution of eHealth into Healthcare 4.0. It systematically reviewed these technologies' integration in healthcare, changing the delivery of services and products. The paper discussed the benefits, challenges, and necessary mindset changes in the healthcare sector due to these new technologies, emphasizing the importance of understanding and effectively integrating these methods in healthcare processes.

(Aburukba et al., 2020) Addressed the need for real-time and predictable latency in IoT applications, this paper integrated Cloud and Fog computing paradigms to improve service latency. It modeled IoT service request scheduling as an optimization problem, using Integer Linear Programming and a customized Genetic Algorithm for scheduling. The paper showed that the Genetic Algorithm significantly improved overall latency, outperforming other scheduling techniques, thereby enhancing the timeliness of IoT service delivery.

(Wu et al., 2020) This paper introduced a novel approach to optimizing task offloading in smart city IoT applications, combining mobile cloud computing, mobile-edge computing, and distributed deep learning. The proposed Distributed Deep Learning-driven Task Offloading (DDTO) algorithm aimed to minimize task completion delay and energy consumption while maintaining QoS for mobile devices. The algorithm, using parallel deep neural networks, efficiently made offloading decisions across various computing environments. The results demonstrated improved computational performance compared to traditional offloading schemes, addressing challenges like high latency in city IoT applications.

(Jahantigh et al., 2020) This systematic survey meticulously explored the fusion of IoT and cloud computing, providing an in-depth analysis of challenges and metrics associated with their integration. The survey reviewed 38 recent papers to comprehensively understand the current state of this integration. It emphasized the current challenges, detailed proposed platforms, and evaluated applications in this field. Furthermore, the paper illuminated potential areas for future enhancement, thereby contributing to the evolving understanding of cloud and IoT technologies' integration.

(Ahmed et al., 2020) The paper delved into the concept of a Distributed Fog Layer, an innovative approach designed to optimize ambient data processing in IoT systems. It detailed a comprehensive methodology for implementing this distributed fog computing framework. Central to this methodology was the preprocessing of datasets at the fog layer, a critical step in enhancing data processing efficiency and system performance. The results and subsequent discussion provided in the paper highlighted the effectiveness of this approach. By preprocessing data at the fog layer, the study demonstrated significant improvements in reducing latency and enhancing overall system performance. This approach effectively addressed the limitations inherent in traditional cloud computing models, offering a scalable and efficient solution for IoT data processing. The paper's findings, supported by an extensive list of references, contributed significantly to the field, proposing a practical and efficient method for integrating fog computing into IoT systems.

(Aleisa et al., 2020) In this empirical study, two cloud-based IoT implementations using Amazon Web Services (AWS) were meticulously analyzed, contrasting an implementation with a fog layer against a direct cloud connection. The research extensively utilized AWS CloudWatch metrics to evaluate performance disparities over prolonged durations. This study significantly contributed to the comprehension of fog computing's impact on cloud-based IoT systems, offering in-depth insights into performance variations, thereby enriching the understanding of fog computing's role in IoT infrastructures.

(Wang & Zhang, 2020) This paper tackled the inefficiencies and low fault tolerance in cloud computing data access storage algorithms, proposing an optimized solution using the Hadoop Distributed File System (HDFS). It emphasized enhancing cloud storage system performance by optimizing data access storage architecture, distribution strategy, IoT network topology, and data block size. The paper's significant contributions lay in improving file read-write speed, memory usage, and fault tolerance in large-scale IoT data management within distributed cloud environments.

(Ben Hassen et al., 2020) This paper proposed a home hospitalization system that integrated IoT, Fog computing, and Cloud computing, particularly relevant during the COVID-19 pandemic. It supported elderly and chronic disease patients by enabling in-home treatment and recovery. The system architecture included environmental sensing units and mobile applications as Fog servers for real-time monitoring. The inclusion of cloud hosting offered secure storage of medical data for analysis. The system was well-received by patients and doctors, indicating its effectiveness and potential benefits.

(Ke et al., 2020) This paper investigated grant-free massive access in a cell-free massive MIMO-based IoT environment using OFDM for uplink transmission. It proposed a new frame structure for massive access and assessed cloud and edge computing paradigms for processing active user detection and channel estimation. The study developed algorithms for compressed sensing recovery and interference cancellation, considering signal quantization. It presented two processing paradigms: centralized cooperation via cloud computing and distributed cooperation via edge computing, providing insights into their technical components and implementation.

(D. Jiang, 2020) Focused on smart city systems, this study developed and applied IoT and cloud computing technologies to address traditional urban system inefficiencies. It proposed a smart city system architecture supported by IoT and cloud computing, integrating various sensors and technologies for data acquisition. The paper also introduced a data aggregation algorithm based on Markov chains to optimize data transmission, aiming to improve data aggregation quality under time and energy constraints, thus enhancing the efficiency of smart city systems.

(Muniswamaiah et al., 2020) This paper explored integrating green computing within the IoT realm, highlighting the need to address the environmental impacts of expanding IoT infrastructure. It discussed the roles of cloud computing, edge computing, and IoT devices in promoting eco-friendly computing environments. The paper emphasized reducing energy consumption through practices like hardware virtualization and energy-efficient data centers. It explored green computing applications in various scenarios, such as autonomous vehicles and smart cities, underlining the importance of sustainability in the digital age and proposing solutions for challenges like public awareness and equipment costs.

(Ghosh & Grolinger, 2021) Investigated the integration of edge and cloud computing for IoT data analytics, this paper focused on reducing network traffic and latencies. It employed edge computing to minimize data transfer to the cloud and utilized deep learning for feature learning. The study demonstrated that data could be reduced by up to 80% at the edge using sliding windows in data preparation, without significant accuracy loss. It explored scenarios based on IoT device locations and sensor similarities, showing that these approaches-maintained accuracy while enabling data reduction at different edge nodes.

(Pérez & Salvachúa, 2021) This research investigated the usage of Wireless Sensor and Actuator Networks (WSAN) in the context of Internet of Things (IoT) applications, focusing particularly on overcoming the challenges related to scalability in smart city settings. This research paper introduced a novel approach to model and simulate Internet of Things (IoT) systems. The proposed methodology leveraged a simulator for Wireless Sensor and Actuator Networks (WSAN) along with cloud computing technologies. The study demonstrated the effectiveness of simulation methods in evaluating scalability and presented a pragmatic framework for the advancement of Internet of Things (IoT) applications in urban areas.

(Martikkala et al., 2021) The paper, focused on interoperability challenges in IoT, particularly between data collection and storage services, delved into the past development of a classification system. This system was meticulously designed to enhance both performance and flexibility in IoT systems. The study further proposed a conceptual middleware framework, emphasizing its pivotal role in addressing interoperability issues. Additionally, the paper highlighted the sustained necessity for research and development in IoT system classification and robust multi-platform support, stressing these elements as crucial for the future evolution and efficiency of IoT technologies.

(Javed et al., 2021) This comprehensive review, set in the backdrop of IoT's rapid expansion, thoroughly examined the integration challenges posed by traditional cloud computing, particularly issues like latency, space constraints, and network failures. Fog computing emerged as a strategic solution, bridging the gap with its proximity to data sources, thus facilitating faster and superior-quality outcomes. The study delved into the intricate architecture of fog computing, its harmonization with IoT, and prospective applications. It scrutinized the structural design and security hurdles, highlighting the tangible benefits for IoT devices. Future potential and advancements in the field were also explored, underscoring the critical role of fog computing in enhancing IoT's efficacy.

(Muniswamaiah et al., 2021) This scholarly paper intricately detailed the integration of fog computing within the Internet of Things (IoT) landscape, focusing on its pivotal role in local processing and storage of massive data, thereby reducing the dependence on cloud data centers. It explored the evolution of IoT and elaborated on the advantages of fog computing, including its low latency and real-time application capabilities. Additionally, the paper outlined the architecture of fog computing and its potential to optimize IoT implementations, shedding light on the architectural nuances and the transformative impact of fog computing in the IoT domain.

(Kumar et al., 2021) Expanding upon the initial summary, this paper intricately investigated the paradigm shift from cloud to fog computing. It scrutinized their respective applications, limitations, and emerging research areas, placing particular emphasis on the Cloud of Things (CoT) concept. The limitations of traditional cloud models were rigorously analyzed, showcasing fog computing as a robust solution for real-time applications. This scholarly work offered a detailed review of fog and edge computing, serving as a seminal guide for future research directions, thereby marking a significant contribution to the field's evolving landscape.

(Huang et al., 2021) This paper introduced a novel authentication and key agreement protocol for IoT devices within distributed cloud computing environments. It featured a lightweight pseudonym identity-based approach using smart cards, aiming to enhance both security and efficiency. The protocol's robustness against various cyber-attacks was demonstrated using security analysis tools like AVISPA and Scyther. This protocol represented a significant advancement in securing IoT device authentication, especially in distributed cloud computing architectures.

(Nwogbaga et al., 2021)'s paper explored data reduction techniques in distributed IoT-fog-cloud environments. It proposed two strategies: IoT Canonical Polyadic Decomposition for Deep Learning Algorithm (IoTCP_DL) and Rank Accuracy Estimation Model (RAEM), aimed at reducing data size and minimizing delays in data offloading. This study is particularly relevant for smart city, vehicular networks, and telemedicine applications, significantly reducing data size and improving network performance in IoT environments.

(Al Masarweh et al., 2022) This paper explored a Dynamic Congestion Management Brokering (DCMB) system within the IoT environment, inspired by Cisco queuing models. The system was designed to manage cloud and fog service requests, improving IoT Quality of Service (QoS) and ensuring compliance with service-level agreements. It demonstrated effectiveness in enhancing IoT QoS compliance and avoiding cloud SLA violations, providing significant insights into managing congestion and resource allocation in IoT environments.

(Mahmood et al., 2022) The study presented a multicriteria optimization approach for resource allocation using a distributed edge computing framework in IoT-based smart cities. It introduced a three-layer network architecture, incorporating an innovative edge resource allocation scheme aimed at delay-sensitive tasks. This scheme proved efficient in optimizing resource allocation, significantly reducing energy consumption and computational delay. Through rigorous testing, including simulations, the study demonstrated the protocol's effectiveness in enhancing resource allocation efficiency in IoT environments, particularly in smart city contexts.

(Qiu et al., 2022) This study explored the integration of blockchain technology within IoT, augmented by cloud computing. It primarily focused on overcoming the resource constraints of IoT nodes crucial for blockchain operations. The paper introduced a unique combination of agent mining and cloud mining to facilitate blockchain processes in IoT. A deep reinforcement learning approach was proposed for optimizing user access, computing, and networking resource allocation. The effectiveness of this scheme was validated numerically, showcasing its potential to substantially improve blockchain-IoT integration in terms of resource management and efficiency.

(Albouq et al., 2022) The reviewed paper provided a historical perspective on interoperability within the Internet of Things (IoT), with a focus on its critical role in the development of smart cities. It retrospectively categorized various solutions to address interoperability challenges, advocating for a hybrid approach tailored for smart city applications. The study dissected the hierarchical structure of IoT, examining interoperability across different types, data sources, levels, and contexts within the smart city framework. Looking back, the paper anticipated future directions in IoT interoperability, including the emergence of open data platforms and the adoption of semantic web and ontology concepts to enhance system integration and functionality.

(K. Jiang & Zhou, 2022) Focused on athlete health, this paper presented a detailed study on designing an intelligent acquisition system for monitoring athletes' physiological signals, utilizing cloud computing and IoT. The system integrated various physiological signals (e.g., ECG, EEG, EMG) into a cloud-based platform, employing the TDMA protocol for efficient data transmission and energy usage. Security measures were also addressed. Experimental results confirmed the system's high data acquisition accuracy and low power consumption, emphasizing its potential in aiding athletes' training and recovery processes.

(Vijarania et al., 2023) This study introduced a new load-balancing algorithm that aimed to optimize energy efficiency in combined IoT-Fog-Cloud settings. The paper discussed the difficulties associated with the substantial increase in data traffic generated by Internet of Things (IoT) devices. It proposed the utilization of fog computing as an intermediary layer to facilitate efficient allocation of workloads. The paper compared different IoT–fog–cloud models and proposed a fog computing-based strategy for efficient load balancing. The results indicated significant improvements in system performance, energy consumption, throughput, and resource utilization, while reducing response times. This research was pivotal in addressing IoT network complexities, focusing on energy efficiency and resource optimization.

(Golightly et al., 2023) The paper presented a comprehensive survey that evaluated various access control methods like ACLs, RBAC, and ABAC in distributed environments including Cloud, Blockchain, IoT, and SDN. The paper discussed how these methods addressed modern cybersecurity challenges and legal compliance in data privacy, emphasizing the importance of effective access control in maintaining system integrity and preventing unauthorized access. It also explored strategies for organizational adoption and future research directions, providing valuable insights into the evolution of access control techniques for securing distributed systems.

(Rajagopal et al., 2023) This study introduced "FedSDM," a federated learning-based framework for smart decision-making in healthcare IoT applications, particularly ECG data analysis. By integrating federated learning with edge and fog computing, it addressed privacy and latency challenges. The framework was shown to be more efficient in edge-based deployments compared to fog and cloud implementations, significantly advancing IoT applications in healthcare by optimizing privacy, reducing latency, and enhancing decision-making processes.

(Moparthi et al., 2023) This paper presented an improved energy-efficient cloud-optimized load-balancing algorithm for IoT, focusing on the Hadoop Distributed File System (HDFS). It aimed to enhance cloud storage system performance by optimizing aspects like data access storage architecture, distribution strategy, and IoT network topology. The research demonstrated significant improvements in file read-write speed, memory usage, and fault tolerance, offering insights into optimizing IoT data management in distributed cloud environments.

(Furstenau et al., 2023) This paper conducted a Bibliometric Performance and Network Analysis (BPNA) and a Systematic Literature Review (SLR) to investigate the Internet of Things (IoT). It utilized SciMAT software for BPNA, classifying 31 strategic clusters in IoT, covering themes like cloud computing and smart cities. The research traced the thematic evolution of IoT from 2002 to 2019 and identified challenges such as security, privacy, and the need for specialized IoT skills. It underscored IoT's role in the fourth Industrial Revolution and its potential impacts across various sectors.

Each of the papers discussed in the literature review contributes uniquely to the field of IoT and cloud computing, exploring innovative solutions and methodologies to enhance system efficiency, security, and performance.

5. Discussion and Comparison

This section highlights the differences amongst the practical papers discussed in the literature review. The comparison is based on different themes where each theme includes a related detailed comparison for the discussed work.

5.1 System Architecture and Design

This section highlights the pivotal areas of discussion encompassing innovative architectural frameworks for IoT systems and their integration with cloud computing, emphasizing the evolution of system design for enhanced functionality. A significant focus is on scalability, addressing the adaptation of IoT systems to escalating demands, a critical factor for managing the influx of data and devices. The section also delves into efficient strategies for data management and processing, central to IoT's functionality where vast data generation is a norm. Further, it touches upon the geographic distribution of IoT systems, underscoring the challenges and solutions in managing data across varied locations, which is vital for global IoT applications. The complexity of IoT and cloud computing systems is another key aspect, where discussions revolve around managing or simplifying this complexity for improved performance. Lastly, the integration of IoT with cloud platforms is explored, a significant area given the need for robust data processing and storage capabilities. This table 1 provides a comprehensive overview of the critical factors shaping the effectiveness and future potential of IoT systems in diverse applications.

Table 1: System Architecture and Design.

Reference	Architecture and Design	Scalability	Data Management and Processing	Geographic Distribution	Complexity	IoT Cloud Platform
(Aleisa et al., 2020)	Two implementations: with and without a fog layer		Focus on data transmission between IoT and cloud layers			AWS IoT used for cloud-based IoT implementations
(Naregal & Kalmani, 2020)	Lightweight ABE for cloud-based IoT	IoT applications	Secure data storage and encryption		ABE design	Integration with cloud platforms for IoT
(Huang et al., 2021)	New authentication and key agreement protocol design	Protocol's applicability in IoT	Efficient protocol operations	Wide distribution	design of the protocol	Applicable in distributed cloud environments
(Nwogbaga et al., 2021)	IoT-fog-cloud computing	data reduction techniques	Data reduction for offloadable tasks		Managed through proposed algorithms	Application in distributed IoT-fog-cloud environments
(Wang & Zhang, 2020)	Optimized data storage architecture for IoT	Enhanced data storage techniques	Optimizing data access and storage	Distributed cloud systems	Managed through the optimization process	Application in distributed cloud environments
(Rajagopal et al., 2023)	Integration of IoT with edge, fog, and cloud computing	Federated learning across different layers	ECG data processing in healthcare IoT applications		Managed through the system's architecture	Integrated IoT, cloud, edge, and fog platforms
(Mopparthi et al., 2023)	Cloud-optimized load balancing in IoT	Data storage optimization techniques	Central to the improved load balancing algorithm		Algorithm design	Application in distributed cloud environments
(Hennebelle et al., 2023)	Integrated IoT-edge-cloud system for	Integration of IoT, edge, and cloud computing	Diabetes data processing using ML algorithms		The framework design	Integration of IoT with edge and cloud computing

Reference	Architecture and Design	Scalability	Data Management and Processing	Geographic Distribution	Complexity	IoT Cloud Platform
	diabetes prediction					
(Al Masarweh et al., 2022)	Advanced broker magement system for fog and cloud computing	DCMB system for cloud and fog requests	Focus on managing cloud requests and IoT data		The DCMB system design	Integration of IoT with fog and cloud platforms
(Ahmed et al., 2020)	distributed fog computing in IoT	Distributed fog computing			The system design	Integration with IoT for enhanced data processing
(Mahmood et al., 2022)	Three-layer network structure: IoT, edge, cloud layers	Smart city implementations	Efficient Management in IoT systems		The network architecture and allocation scheme	Integration of IoT with edge and cloud platforms
(Pérez & Salvachúa, 2021)	WSAN simulator and cloud computing technologies for IoT		IoT system simulation		The simulation approach	Use of cloud computing for IoT system deployment
(Vijarania et al., 2023)	Integration of IoT, fog, and cloud computing	Load balancing in IoT–fog–cloud	Efficient data handling and processing		The proposed mechanism	Integrated IoT–fog–cloud environment
(Qiu et al., 2022)	Agent and cloud mining in blockchain-ebled IoT	Dynamic resource allocation	Cloud computing servers		Proposed model and learning framework	Focus on blockchain-ebled IoT with cloud assistance
(Ke et al., 2020)	Cell-free massive MIMO-based IoT with cloud and edge	Cell-free massive MIMO and two computing paradigms	Cloud and edge computing frameworks	The cell-free massive MIMO system design	The proposed algorithms and system structure	Cloud and edge computing paradigms

Reference	Architecture and Design	Scalability	Data Management and Processing	Geographic Distribution	Complexity	IoT Cloud Platform
	computing paradigms					
(Darwish et al., 2019)	Integration of CC and IoT in healthcare systems	Integration of CC and IoT	CloudIoT integration, focusing on communication, storage, and computation		CloudIoT integration, providing simplified solutions	Integration of CC and IoT in healthcare, known as CloudIoT
(D. Jiang, 2020)	IoT and cloud computing-based smart city system architecture	A three-tier system architecture	Cloud computing and IoT technologies	Smart city system covering various urban aspects	Structured system architecture and data aggregation algorithm	Integration of IoT and cloud computing in smart city information systems
(Ben Hassen et al., 2020)	IoT, Fog computing, and Cloud computing-based home hospitalization system		IoT and mobile applications with Fog and Cloud computing integration	Designed for home hospitalization	An integrated system of IoT, Fog, and Cloud computing	Integration of IoT with Fog and Cloud computing platforms for healthcare data
(Aceto et al., 2020)	Integration of IoT, Cloud/Fog Computing, and Big Data in healthcare	Addressed through Cloud and Fog Computing solutions	Big Data technologies and Cloud Computing	Implementation across various healthcare settings	integration of technologies into healthcare systems	Integration of IoT with Cloud and Fog Computing platforms for healthcare data
(Aburukba et al., 2020)	Hybrid Fog-Cloud computing architecture integrating IoT		Managed through IoT, Fog, and Cloud integration		The integration of Fog and Cloud computing and GA scheduling	Integration of IoT with Fog and Cloud computing platforms
(Ghosh &	Edge-cloud computing		Edge nodes and deep		The integration of	Integration of edge and

Reference	Architecture and Design	Scalability	Data Management and Processing	Geographic Distribution	Complexity	IoT Cloud Platform
Grolinger, 2021)	integration for IoT data analytics		learning feature learning		edge and cloud computing	cloud computing for IoT data management
(Liu et al., 2019)	Intelligent gateway design, multi-protocol data transmission	High scalability through cloud computing platform	Cloud data storage and real-time monitoring, big data analysis		Complex integration of various technologies	Amazon Web Services (AWS) used for cloud computing
(K. Jiang & Zhou, 2022)	Integrated system for multiple physiological signals, use of TDMA protocol, cloud-based platform		Cloud computing, real-time data processing		High due to integration of various technologies and signals	Cloud computing platform
(Wu et al., 2020)	Combination of MCC, MEC, and distributed deep learning	High scalability in edge and cloud computing environments	Efficient task offloading and processing using DDTO algorithm		High due to the integration of multiple computing paradigms	Utilizes a Combination of edge and central cloud platforms
(Rao & Dave, 2019)	Use of Raspberry Pi for IoT applications, integration with cloud and blockchain technologies		Data acquisition, cryptographic hashing, cloud storage		Integration of multiple technologies in a teaching context	Use of cloud platforms for storage and processing of data

Reference	Architecture and Design	Scalability	Data Management and Processing	Geographic Distribution	Complexity	IoT Cloud Platform
(Singh et al., 2019)	IoT smart home architecture with cloud computing and blockchain technology	High scalability through decentralized blockchain	Efficient data handling via blockchain and cloud computing		Complex integration of IoT, cloud computing, and blockchain	Utilization of cloud computing platforms
(Muniswamaiah et al., 2020)	Integration of cloud computing, edge computing, and IoT devices in green computing		Efficient data processing with hardware virtualization and energy-efficient data centers		Integration of green computing with existing IoT infrastructure	

5.2 Performance and Efficiency

This section critically examines key attributes essential to the operational excellence of IoT and distributed cloud computing systems. It encapsulates discussions on system responsiveness, data processing capabilities, and throughput, pivotal for assessing the efficiency of IoT applications. it also delves into energy efficiency, a cornerstone in sustainable technology deployment, and explores data storage strategies, crucial for managing the extensive data generated by IoT systems. This compilation serves as a succinct overview, highlighting the engineering and optimization facets vital for the high performance and sustainability of these systems as illustrated in table 2.

Table 2: Performance and Efficiency

Reference	Latency and Performance	Real-time Processing	Data Throughput	Data Storage	Energy Efficiency
(Aleisa et al., 2020)	Experimental results for two models	Central to the study's focus		Cloud-based storage in AWS IoT	
(Naregal & Kalmani, 2020)				Secure cloud storage for IoT	Requirement for IoT devices
(Huang et al., 2021)				Distributed cloud computing	

Reference	Latency and Performance	Real-time Processing	Data Throughput	Data Storage	Energy Efficiency
(Nwogbaga et al., 2021)	Reducing offloading delay	Central to the study's focus	Improved Indirectly improved by data reduction methods	Impacted by data reduction techniques	
(Wang & Zhang, 2020)	Improved through optimized storage algorithms		Improved through optimized algorithms	Optimized IoT data storage	
(Rajagopal et al., 2023)	Key benefit of the proposed framework	Central to the system's design for ECG data processing		IoT integrated edge–fog–cloud architecture	
(Moparthi et al., 2023)	Improved through the proposed algorithm		Improved through the algorithm	Optimized IoT data storage	Enhanced through the algorithm's efficiency
(Hennebelle et al., 2023)	Improved diabetes prediction accuracy	Essential for timely diabetes prediction		Managed through the integrated system	
(Al Masarweh et al., 2022)	Enhanced QoS and reduced latency through DCMB system	Central to the system's design for managing cloud requests		Cloud and fog computing infrastructure	
(Ahmed et al., 2020)	Enhanced through distributed fog computing	Central to the proposed system's effectiveness	Enhanced through the proposed approach	Fog computing architecture	
(Mahmood et al., 2022)	Minimized delay for edge computing tasks	Essential for delay-sensitive tasks		Managed within the three-layer architecture	Minimizing energy consumption
(Pérez & Salvachúa, 2021)		Essential for the IoT parking system model		Managed within the simulation framework	
(Vijarania et al., 2023)	Reduced latency through	Central to the proposed solution	Enhanced through the		Highly Energy Efficient

Reference	Latency and Performance	Real-time Processing	Data Throughput	Data Storage	Energy Efficiency
	efficient load balancing		proposed mechanism		
(Qiu et al., 2022)	Improved through dynamic networking resource allocation		Blockchain and IoT integration	Managed through cloud computing servers	the optimization problem
(Ke et al., 2020)	Enhanced through proposed algorithms and system design	Supported by both cloud and edge computing paradigms	Enhanced by the proposed frame structure and processing paradigms		
(Darwish et al., 2019)	Enhanced through CloudIoT integration	Enabled by CloudIoT integration, especially for IoT sensor data	Enhanced by CloudIoT integration	Large-scale and long-lived storage provided by cloud, addressing IoT's limitations	
(D. Jiang, 2020)	Improved through efficient data aggregation and transmission methods	Supported by IoT and cloud computing technologies	Enhanced by efficient data aggregation and IoT network technologies	Utilizes cloud storage for data management	Considered in the data aggregation algorithm for IoT sensor networks
(Ben Hassen et al., 2020)	Real-time environmental monitoring and health status updates	Supported through Fog computing and IoT integration	Efficient data transfer between IoT devices, Fog servers, and the Cloud	Utilizes Cloud computing for secure and permanent data storage	
(Aceto et al., 2020)	Improved by Fog Computing architecture and IoT applications	Enabled by IoT and Fog Computing technologies	Cloud and Fog Computing infrastructure	Utilizing Cloud Computing for large-scale data storage	

Reference	Latency and Performance	Real-time Processing	Data Throughput	Data Storage	Energy Efficiency
(Aburukba et al., 2020)	Significantly improved by using a Genetic Algorithm for scheduling	Enhanced real-time processing through Fog computing		Utilizes Cloud computing for data storage	
(Ghosh & Grolinger, 2021)	Improved by reducing data transfer to the cloud	Supported by edge computing infrastructure	Enhanced by efficient data processing at the edge	Cloud computing used for processing and storage	
(Liu et al., 2019)	Real-time data processing and monitoring	Real-time data processing and decision-making capabilities	High throughput with real-time data collection and processing	Hybrid storage using Amazon DymoDB and RDS (Oracle)	
(K. Jiang & Zhou, 2022)	High data acquisition accuracy, efficient performance	Real-time data collection and processing	Efficient data transmission using TDMA protocol	Cloud-based storage	Energy-efficient data transmission, low-power operation
(Wu et al., 2020)	Optimization of task completion delay and energy consumption	Real-time task offloading and decision-making	Efficient data handling through optimized offloading	Utilizes edge and central cloud servers for data storage	Focus on reducing energy consumption in task offloading
(Rao & Dave, 2019)		Real-time data acquisition and processing in lab exercises		Use of cloud storage for data	
(Singh et al., 2019)			Efficient data throughput via blockchain and cloud-based architecture	Utilization of cloud storage, secure data management with blockchain	
(Muniswamaiah et al., 2020)				Energy-efficient data storage solutions	Focus on reducing energy consumption through green

Reference	Latency and Performance	Real-time Processing	Data Throughput	Data Storage	Energy Efficiency
					computing practices

5.3 Security, Privacy, and Reliability

In the realm of Security, Privacy, and Reliability within IoT and distributed cloud computing systems, the section offers an in-depth scholarly examination of the methodologies and technological implementations pivotal for data protection and system dependability. This analytical overview encapsulates the nuanced strategies employed to bolster security and privacy, addressing a fundamental concern in contemporary digital ecosystems. Additionally, the discourse extends to the reliability and uptime of these systems, a critical determinant for ensuring their uninterrupted and efficient functionality. Overall, this academic compendium serves to highlight the integral challenges and solutions pertinent to the maintenance of secure and resilient IoT and cloud computing architectures. see table 3.

Table 3: Security, Privacy, and Reliability.

Reference	Security and Privacy	Reliability and Uptime	Technique	Hardware Diversity
(Aleisa et al., 2020)			Fog computing and direct cloud connection	Use of Raspberry Pi and sensors
(Naregal & Kalmani, 2020)	Development of secure ABE		Lightweight ABE using elliptic curve cryptography	Resource-limited IoT devices
(Huang et al., 2021)	Enhanced security mechanisms	The robustness of the protocol	Utilizes smart cards for authentication	
(Nwogbaga et al., 2021)		Improved network performance	IoTCP_DL algorithm, RAEM	
(Wang & Zhang, 2020)		Enhanced through improved storage solutions	Use of HDFS and novel optimization methods	
(Rajagopal et al., 2023)	Enhanced through federated learning and localized processing	The robustness of the system	Federated learning and edge-fog-cloud integration	Utilization of IoT devices, edge, fog, and cloud resources
(Moparthi et al., 2023)		Improved through the algorithm's robust design	Use of HDFS and novel optimization methods	
(Hennebelle et al., 2023)		Implied in improved prediction accuracy	Use of ML algorithms for data alysis	Use of IoT devices and medical sensors

Reference	Security and Privacy	Reliability and Uptime	Technique	Hardware Diversity
(Al Masarweh et al., 2022)		Enhanced through DCMB system's effective management	DCMB system based on Cisco queuing models	
(Ahmed et al., 2020)		Improved system performance	Distributed fog computing for IoT data processing	
(Mahmood et al., 2022)		Efficient resource allocation and performance	Multicriteria optimization and auction-based allocation	Deployment of controllers at UAVs for resource allocation
(Pérez & Salvachúa, 2021)			WSAN simulation and cloud computing	
(Vijarania et al., 2023)		Efficient load management	Load balancing in IoT–fog–cloud	Involves IoT devices and fog computing nodes
(Qiu et al., 2022)			Dueling deep reinforcement learning, Cloud Mining	Simulation settings include diverse hardware configurations
(Ke et al., 2020)			SS-GAMP algorithm, SIC-based AUD and CE	Mention of various APs and processing units, but no specific hardware details
(Darwish et al., 2019)	Improved security and privacy through CloudIoT integration		Integration of Cloud and IoT technologies	
(D. Jiang, 2020)			Markov chain-based data aggregation algorithm	Use of various sensors, RFID, GPS/Beidou technologies
(Ben Hassen et al., 2020)	Encryption and secure cloud storage of medical data	Continuous monitoring ensures reliability and uptime	Use of IoT for data collection, Fog computing for real-time processing, and Cloud computing for data storage and analysis	Use of environmental sensors and mobile devices

Reference	Security and Privacy	Reliability and Uptime	Technique	Hardware Diversity
(Aceto et al., 2020)	Challenges in data privacy and security due to Cloud Computing and IoT		Utilization of IoT for data collection, Fog Computing for processing, and Cloud Computing for data storage and analysis	IoT devices, sensors, and Cloud infrastructure
(Aburukba et al., 2020)			Integer Linear Programming and Genetic Algorithm for scheduling	Incorporates a variety of IoT devices, routers, gateways, and cloud data centers
(Ghosh & Grolinger, 2021)			Employing autoencoders for feature learning and reduction	
(Liu et al., 2019)	Secured data transmission, encrypted data exchange	High reliability and system stability	IoT, cloud computing, big data, machine learning	Use of Raspberry Pi, Zigbee wireless sensor networks
(K. Jiang & Zhou, 2022)	Secure data transmission, privacy protection mechanisms	High reliability indicated by experiment results	Use of EEG, ECG, EMG, skin, respiratory sigls	
(Wu et al., 2020)		Enhanced through optimal offloading decisions	Distributed deep learning, MCC, MEC	
(Rao & Dave, 2019)	Cryptographic hashing for data integrity		Hands-on teaching methods with real-world applications	Use of Raspberry Pi, various sensors and camera modules
(Singh et al., 2019)	Strong security using blockchain, multivariate correlation analysis for network traffic	Enhanced through blockchain and secure network architecture	Blockchain technology, cloud computing, multivariate correlation analysis	
(Muniswamaiah et al., 2020)			Use of hardware virtualization, energy-efficient data centers	

5.4 User Experience and Application

In this section, the context of "User Experience and Application" within IoT and distributed cloud computing systems is presented with a scholarly analysis of how these technologies are applied and perceived from a user-centric perspective. It explores the cost-effectiveness and resource utilization of these systems, an important consideration for their practical deployment. Moreover, the interoperability of IoT systems with existing standards and other technological platforms is discussed as a key factor for seamless integration. Furthermore, the diverse applications of IoT and cloud computing, illustrating their versatility and impact across various sectors is discussed. The user interface and experience, along with the innovation and advanced features of these systems, are highlighted, underscoring their significance in enhancing user engagement and satisfaction. Table 4, thus provides a comprehensive insight into the application, usability, and technological advancements of IoT and cloud computing from the user's perspective.

Table 4: User Experience and Application

Reference	Cost and Resource Utilization	Interoperability and Standards Compliance	Use Cases and Applications	User Interface and Experience	Innovation and Advanced Features
(Aleisa et al., 2020)			IoT environments using AWS IoT		Innovation in fog computing application
(Naregal & Kalmani, 2020)			IoT in various sectors like healthcare, agriculture		Lightweight ABE technique as an innovation
(Huang et al., 2021)			Smart city applications with IoT devices		Pseudonym identity-based approach with smart cards
(Nwogbaga et al., 2021)	Indirectly related to data reduction		Smart city vehicular networks, telemedicine		IoTCP_DL and RAEM strategies
(Wang & Zhang, 2020)	Indirectly related to optimized storage		IoT applications in distributed cloud systems		Novel optimization techniques for IoT storage
(Rajagopal et al., 2023)	Included in the performance evaluation		Healthcare IoT, particularly ECG data analysis		Federated learning for smart decision making in healthcare
(Moparthi et al., 2023)	Related to improved algorithm efficiency		IoT applications in distributed cloud systems		New energy-efficient load balancing algorithm

Reference	Cost and Resource Utilization	Interoperability and Standards Compliance	Use Cases and Applications	User Interface and Experience	Innovation and Advanced Features
(Hennebelle et al., 2023)			Diabetes prediction in healthcare		Innovative approach to diabetes prediction
(Al Masarweh et al., 2022)	Indirectly related to system efficiency		IoT environments integrating fog and cloud computing		Introduction of the DCMB system
(Ahmed et al., 2020)	,		IoT-based ambient data processing		Distributed fog computing as an innovative approach
(Mahmood et al., 2022)	,		Smart city services relying on IoT		Auction-based approach for resource allocation
(Pérez & Salvachúa, 2021)			Monitoring and control of city parks, IoT parking systems		Novel simulation approach for IoT systems
(Vijarania et al., 2023)	Energy efficiency and load balancing		Applicable to various IoT scenarios		Novel load-balancing mechanism in IoT–fog–cloud
(Qiu et al., 2022)	Addressed in the joint optimization problem		Blockchain-enabled IoT applications		Dueling deep reinforcement learning approach
(Ke et al., 2020)	In terms of AP deployment and processing paradigms		Cell-free massive MIMO-based IoT applications		SS-GAMP and SIC-based AUD and CE algorithms
(Darwish et al., 2019)	Improved through CloudIoT integration, providing cost-effective solutions		Healthcare applications like smart hospitals, medicine control, remote medical services		CloudIoT paradigm integration in healthcare

Reference	Cost and Resource Utilization	Interoperability and Standards Compliance	Use Cases and Applications	User Interface and Experience	Innovation and Advanced Features
(D. Jiang, 2020)			Smart city applications like environmental monitoring, traffic management, and security	GIS-based comprehensive management platform for user interaction	Data aggregation algorithm based on Markov chains
(Ben Hassen et al., 2020)	Cloud hosting offers a cost-effective solution compared to traditional hosting		Home hospitalization for elderly and chronic disease patients	Mobile applications for real-time monitoring and analysis, user-friendly interfaces	Integration of IoT with Fog and Cloud computing for home healthcare
(Aceto et al., 2020)	Cloud Computing enables resource leasing with pay-per-use billing	IoT paradigms in healthcare focus on interoperability and integration	Ranging from remote monitoring to personalized healthcare, telemedicine, and smart pharmaceuticals		Advanced technologies enabling new healthcare practices and solutions
(Aburukba et al., 2020)			IoT applications requiring real-time and predictable latency		Implementation of Genetic Algorithm for scheduling IoT requests
(Ghosh & Grolinger, 2021)			Human activity recognition from sensor data		Implementation of deep learning for data reduction at the edge
(Liu et al., 2019)	Cost-effective due to cloud computing and IoT integration	Multi-protocol support for device and data communication	Modern eco-agriculture monitoring and management	Web-based interface for real-time monitoring and control	Integration of IoT, cloud computing, and big data
(K. Jiang & Zhou, 2022)			Monitoring athletes' physiological		Integration of IoT and cloud computing for

Reference	Cost and Resource Utilization	Interoperability and Standards Compliance	Use Cases and Applications	User Interface and Experience	Innovation and Advanced Features
			states for training and recovery		athlete monitoring
(Wu et al., 2020)			Smart city IoT applications		Distributed deep learning for task offloading
(Rao & Dave, 2019)	Use of low-cost Raspberry Pi for laboratory exercises		Teaching IoT, cloud computing, and blockchain applications	Hands-on laboratory exercises with Raspberry Pi and cloud platforms	Application of IoT in educational settings
(Singh et al., 2019)			Smart home applications		Integration of IoT, cloud computing, and blockchain
(Muniswamaiah et al., 2020)	Equipment costs and solutions for green computing		Applications in autonomous vehicles, smart cities, and industrial processes		Adoption of green computing in IoT infrastructure

5.5 Evaluation and Impact

The Evaluation and Impact part within the context of Internet of Things (IoT) and distributed cloud computing provides a scholarly examination of the benefits and drawbacks associated with these technologies, as well as their overall significance in the respective sector. This analysis encompasses an evaluation of the advantages, such as increased operational effectiveness, expandability, or higher user satisfaction, that the integration of IoT and cloud computing offers across diverse applications. On the other hand, it is imperative to acknowledge the prospective limitations, encompassing concerns pertaining to security, privacy, and intricacy. Table 5 offers valuable information regarding the comprehensive influence of these technologies, encompassing their present applications as well as their prospective capabilities. This comprehensive assessment facilitates comprehension of the intricate ramifications and contributions of Internet of Things (IoT) and cloud computing within the wider framework of technical progress and social implementation.

Table 5: Evaluation and Impact

Reference	Advantages	Disadvantages	Contribution
(Aleisa et al., 2020)	Advantages of fog layer in IoT		Performance analysis of IoT implementations with/without fog layer
(Naregal & Kalmani, 2020)	Enhanced security and suitability for IoT		Advancement in ABE for cloud-based IoT systems
(Huang et al., 2021)	Improved security in IoT environments		Novel authentication and key agreement protocol
(Nwogbaga et al., 2021)	Reduced data offloading delay, improved network performance		Novel data reduction methods in IoT-fog-cloud computing
(Wang & Zhang, 2020)	Enhanced efficiency and fault tolerance		Novel data storage algorithm for IoT in cloud computing
(Rajagopal et al., 2023)	Enhanced privacy, reduced latency, and efficient processing		Novel integration of federated learning in IoT healthcare
(Moparthi et al., 2023)	Enhanced efficiency and fault tolerance		Novel algorithm for cloud-optimized IoT load balancing
(Hennebelle et al., 2023)	Improved accuracy in diabetes prediction		Novel healthcare framework for diabetes prediction
(Al Masarweh et al., 2022)	Improved QoS, efficient resource allocation		Novel approach in congestion management for cloud services
(Ahmed et al., 2020)	Improved efficiency and reduced latency		Introduction of distributed fog computing for IoT data processing
(Mahmood et al., 2022)	Efficient resource allocation and reduced delays		Novel approach for resource allocation in IoT-based smart cities
(Pérez & Salvachúa, 2021)	Scalability analysis, rapid development and deployment		Novel approach to analyze scalability in IoT systems
(Vijarania et al., 2023)	Improved performance, energy efficiency		Novel energy-efficient load-balancing mechanism
(Qiu et al., 2022)	Improved resource management and efficiency in blockchain-IoT integration		Novel approach for integrating blockchain in IoT with cloud computing support

Reference	Advantages	Disadvantages	Contribution
(Ke et al., 2020)	Enhanced massive access performance, reduced latency		Novel algorithms and comparison of cloud and edge computing in massive MIMO-based IoT
(Darwish et al., 2019)	Improved healthcare services, enhanced security and privacy, cost-effective solutions		Comprehensive review and analysis of CloudIoT integration in healthcare systems
(D. Jiang, 2020)	Enhanced urban management, efficient data processing, and interconnectivity		Proposal of a novel smart city system architecture and data aggregation algorithm
(Ben Hassen et al., 2020)	Enables remote healthcare, reduces hospital congestion, secure data management		Innovative home hospitalization system integrating IoT, Fog, and Cloud computing for improved healthcare delivery
(Aceto et al., 2020)	Improved healthcare delivery, efficiency, and innovation	Challenges in data privacy, security, and infrastructure complexity	Systematic survey of the integration of Industry 4.0 technologies in healthcare
(Aburukba et al., 2020)	Improved service latency and efficient meeting of deadlines		Novel approach for scheduling IoT requests in hybrid Fog-Cloud architecture
(Ghosh & Grolinger, 2021)	Reduced network traffic and latency, maintained data analytics accuracy		Novel approach for merging edge and cloud computing for IoT data analytics
(Liu et al., 2019)	Enhanced agricultural efficiency, reduced costs, real-time monitoring		Novel integration of IoT and cloud computing for agriculture
(K. Jiang & Zhou, 2022)	High accuracy, low power consumption, real-time monitoring		Novel approach to athlete monitoring using IoT and cloud computing
(Wu et al., 2020)	Improved performance, reduced energy consumption, and latency		Novel integration of distributed deep learning in MCC and MEC
(Rao & Dave, 2019)	Enhanced student engagement and understanding of emerging technologies		Innovative approach to STEM education using hands-on IoT, cloud computing, and blockchain exercises

Reference	Advantages	Disadvantages	Contribution
(Singh et al., 2019)	Enhanced security, scalability, and efficient data management		Novel approach integrating blockchain with IoT smart home systems
(Muniswamaiah et al., 2020)	Environmental sustainability, reduced energy consumption	Challenges in implementation and awareness of green computing	Emphasizing the need for sustainable practices in IoT

6. Semaphores of Compared Metrics

The scholarly analysis of metrics pertaining to the Internet of Things (IoT) and distributed cloud computing reveals critical insights into the multifaceted nature of these technologies. The metrics related to architecture and design elucidate the evolving complexities and innovative approaches in IoT systems, reflecting a paradigm shift in accommodating modern technological demands. Scalability, integral to understanding the adaptability of IoT frameworks, underscore the systems' ability to handle expanding networks of data and devices. This aspect is pivotal in gauging the robustness and flexibility inherent in contemporary IoT architectures. Concurrently, metrics centered on data management and processing, as well as latency and performance, offer a lens through which the efficiency and responsiveness of IoT systems in processing voluminous data streams are evaluated.

In the realm of security and privacy, the metrics proffered provide an assessment of the current state of protective measures against burgeoning cybersecurity threats, a paramount concern in the digital era. Complementarily, energy efficiency and cost/resource utilization metrics shed light on the sustainability and economic impact of IoT implementations, critical factors in their long-term viability and ecological footprint. Metrics that address interoperability and standards compliance are indicative of the ease with which IoT systems coalesce with established technological infrastructures, a determinant in their broader adoption. Metrics evaluating use cases, applications, and user interfaces offer a user-centric perspective, essential in appraising the practicality and accessibility of IoT solutions.

Furthermore, the exploration of innovation and advanced features through relevant metrics highlights the frontier developments and distinguishing attributes of modern IoT systems. Reliability and uptime metrics, conversely, provide insights into the operational consistency of these systems, an aspect crucial for applications where uninterrupted functionality is requisite.

In assessing technique and hardware diversity, the metrics illuminate the range of methodologies and hardware configurations employed, reflecting the field's innovation capacity and adaptability. Metrics concerning data throughput and storage emphasize the capability of IoT systems to manage extensive data efficiently, integral to their core functionality.

Real-time processing metrics are particularly telling, underscoring the capability of IoT systems to offer timely and actionable insights, a requisite in a myriad of IoT applications. Geographic distribution and complexity metrics further elucidate the challenges and scalability considerations in deploying IoT solutions across diverse and expansive environments.

Finally, the comprehensive evaluation of advantages, disadvantages, and overall contributions offers a balanced perspective, acknowledging both the merits and the areas necessitating refinement in IoT and distributed cloud computing. The inclusion of IoT cloud platform metrics accentuates the role of cloud computing in augmenting the capabilities and reach of IoT solutions. In essence, the discussion of compared metrics furnishes a detailed portrait of the capabilities, challenges, and prospective trajectories of IoT and distributed cloud computing, serving as an invaluable guide for researchers, practitioners, and policymakers in navigating and fostering advancements in these dynamic and ever-evolving fields.

7. Recommendations

In light of the comprehensive review and findings delineated in this paper, several key recommendations emerge for future research, policy formulation, and practical implementation in the field of IoT and distributed cloud computing. These recommendations are aimed at harnessing the full potential of IoT in synergy with distributed cloud computing, addressing existing challenges, and guiding the future trajectory of these technologies.

1. Enhancing Interoperability and Standardization: Future research should focus on developing universal standards and protocols to enhance interoperability among diverse IoT devices and cloud computing platforms. This endeavor is critical for facilitating seamless communication and data exchange, thereby bolstering the efficiency and effectiveness of IoT systems.

2. Fostering Scalable and Flexible Architectures: Given the importance of scalability in IoT frameworks, it is imperative to design architectures that can effortlessly adapt to expanding networks of data and devices. Research should delve into innovative architectural solutions that offer both robustness and flexibility, accommodating the dynamic nature of IoT deployments.

3. Prioritizing Security and Privacy: As IoT systems become increasingly prevalent, ensuring the security and privacy of data is paramount. Future research must explore advanced cybersecurity measures and privacy-preserving techniques to safeguard against potential breaches and unauthorized access.

4. Advancing Data Management and Processing: Efficient management and processing of the vast amounts of data generated by IoT devices is a critical area for research. Exploring novel data analytics algorithms and real-time processing techniques will enhance the capability of IoT systems to provide actionable insights.

5. Promoting Energy Efficiency: In the realm of sustainable technology, the energy efficiency of IoT and cloud computing systems should be a key research area. Developing energy-efficient algorithms and low-power hardware designs will contribute to the environmental sustainability of these technologies.

6. Encouraging Policy Development and Regulatory Frameworks: Policymakers should work in tandem with technologists to develop comprehensive regulatory frameworks that address the ethical, legal, and social implications of IoT and cloud computing. This includes formulating policies that foster innovation while ensuring data security and user privacy.

These recommendations aim to steer the future research and development in IoT and distributed cloud computing towards addressing the current challenges, leveraging untapped potentials, and realizing the transformative impact of these technologies on society and industry.

8. Conclusion

The reviewed research in this study reveals significant insights into the complex and dynamic nature of IoT and distributed cloud computing. Key findings include the evolving architecture and design of IoT systems, reflecting a paradigm shift to accommodate modern technological demands. Scalability is crucial in managing expanding networks of data and devices, highlighting the robustness and flexibility inherent in contemporary IoT architectures. Additionally, data management and processing, as well as latency and performance, provide a comprehensive view of the efficiency and responsiveness of IoT systems in processing large volumes of data. These findings emphasize the pivotal role of IoT and cloud computing in various applications, underlining their potential to revolutionize data handling and analysis in diverse sectors. Future research directions should continue to explore and address the evolving challenges and opportunities in this integrative technological domain, with a focus on enhancing efficiency, scalability, and security in IoT and cloud computing applications.

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