

The Development of Distributed Systems in Supporting Scalability and Availability of Modern Cloud Computing-Based Digital Services

Perkembangan Sistem Terdistribusi dalam Mendukung Skalabilitas dan Ketersediaan Layanan Digital Modern Berbasis Cloud Computing

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Abstract

This study aims to examine the development of distributed systems in supporting the scalability and availability of modern digital services. The rapid growth of digital services across various sectors requires information systems that can handle increasing workloads while maintaining continuous service availability. Distributed systems have emerged as a key architectural approach to address these demands through workload distribution, efficient resource management, and system resilience. This research employs a qualitative method using a literature review approach. Data were collected from textbooks, indexed national and international journal articles, and scientific conference proceedings related to distributed systems, cloud computing, and microservices architecture. The collected literature was analyzed descriptively and comparatively to identify key concepts, architectural models, and research findings related to scalability and service availability. The results indicate that distributed systems have evolved significantly with the adoption of cloud computing and microservices architecture. These technologies support horizontal scalability, enhance system flexibility, and improve service availability through redundancy and data replication mechanisms. The study concludes that distributed systems play a crucial role as the foundation of modern digital services by enabling scalable, reliable, and sustainable digital infrastructures.

Abstrak

Penelitian ini bertujuan untuk mengkaji perkembangan sistem terdistribusi dalam mendukung skalabilitas dan ketersediaan layanan digital modern. Meningkatnya penggunaan layanan digital di berbagai sektor menuntut sistem informasi yang mampu menangani beban kerja yang besar serta tetap menyediakan layanan secara berkelanjutan. Sistem terdistribusi menjadi pendekatan utama untuk menjawab kebutuhan tersebut melalui pembagian beban kerja, pengelolaan sumber daya, dan peningkatan ketahanan sistem. Penelitian ini menggunakan metode kualitatif dengan pendekatan studi literatur. Data diperoleh dari buku teks, artikel jurnal nasional dan internasional terindeks, serta prosiding konferensi ilmiah yang relevan dengan sistem terdistribusi, cloud computing, dan arsitektur microservices. Data yang terkumpul dianalisis secara deskriptif dan komparatif untuk mengidentifikasi konsep, model arsitektur, serta temuan penelitian yang berkaitan dengan skalabilitas dan ketersediaan layanan. Hasil kajian menunjukkan bahwa sistem terdistribusi mengalami perkembangan signifikan seiring dengan adopsi cloud computing dan arsitektur microservices. Teknologi tersebut memungkinkan penerapan skalabilitas horizontal, meningkatkan fleksibilitas sistem, serta menjaga ketersediaan layanan melalui mekanisme redundansi dan replikasi data. Penelitian ini menyimpulkan bahwa sistem terdistribusi merupakan fondasi penting dalam pengembangan layanan digital modern yang andal dan berkelanjutan.

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1. Introduction

The development of information technology has driven a major transformation in service delivery across various sectors, including government, education, industry, and business. This transformation is marked by the increasing use of modern digital services, namely information technology-based services provided through digital platforms such as the web, mobile, and cloud computing, which serve multiple users simultaneously, operate in real time, and require continuous, uninterrupted availability (Buyya et al., 2023).

Examples of modern digital services include e-government, e-commerce, e-learning, and cloud-based enterprise systems. These services must be able to handle dynamically increasing user numbers and data volumes while maintaining continuous service availability (Zhou & Chen, 2022).

The increasing number of users and data volumes demands information systems that offer scalability and reliable service availability. Distributed systems are the primary solution because they enable data processing to be performed by multiple nodes connected through a network, allowing for efficient workload management (Steen & Tanenbaum, 2017). Several studies show that the implementation of distributed systems can increase service efficiency and system resilience to failure (Ilham et al., 2025; Triyono et al., 2025).

As technology advances, distributed systems have undergone significant evolution, particularly with the advent of cloud computing and microservices architecture. Cloud computing provides elastic, service-based computing resources, allowing systems to dynamically adjust their capacity based on user needs (Saputra et al., 2025). Meanwhile, microservices architecture allows applications to be developed in the form of small, independent services, thus simplifying the management, maintenance, and continuous development of the system (Ilham et al., 2025; Triyono et al., 2025).

In addition to scalability, service availability is a crucial factor in modern distributed systems. System disruptions, network failures, and cyber threats can directly impact the quality of digital services. Therefore, various mechanisms such as data replication, redundancy, and *failover* automatic, and data recovery strategies are implemented to ensure the system continues to operate optimally (Muhammad Zufahrizi Zubair et al., 2024; Silvi Fara Dita et al., 2025). Cybersecurity awareness is also an important part of maintaining service continuity, especially in institutional and enterprise environments (Jonathan Hobbs, 2023).

While numerous studies have explored distributed systems, most studies still focus on specific technologies, such as cloud computing or microservices. Therefore, studies are needed that more comprehensively examine the development of distributed systems to support the scalability and availability of modern digital services.

Based on this background, this study aims to examine the development of distributed systems and their role in supporting modern digital services through a literature review approach. The results are expected to provide a comprehensive overview of the concept, evolution, and application of distributed systems as the primary foundation for developing scalable and reliable digital services.

This research also provides a conceptual contribution in understanding the evolution of distributed systems and their role in supporting the scalability and availability of modern cloud computing-based digital services.

2. Literature Review

2.1 Basic Concepts of Distributed Systems

A distributed system is a collection of computers connected to each other through a network and working cooperatively to achieve a common goal, as if they were a single system. This concept emphasizes transparency, communication between nodes, and workload sharing (Alshuqayran, 2022).

Some studies such as (Triyono et al., 2025) And (Ilham et al., 2025) explains that distributed systems are built to improve service efficiency, particularly in organizational and public service environments. The use of communication protocols such as TCP/IP enables reliable data exchange between system components.

In the enterprise context, distributed systems are the main foundation for the development of modern digital services that require high performance, flexibility, and system resilience.

2.2 Distributed System Evolution

The evolution of distributed systems is marked by a shift from centralized (monolithic) architectures to network-based architectures and cloud computing. Research by Ishaq et al. (2025) confirms that post-2020, distributed enterprise systems will undergo significant transformation due to the increasing need for scalability, cross-platform integration, and the adoption of cloud technologies.

(Saputra et al., 2025) shows that cloud computing accelerates the evolution of distributed systems by providing elastic, service-based computing resources. Meanwhile, (Silvi Fara Dita et al., 2025) highlights the role of cloud operating systems in managing distributed resources to keep them optimal and stable.

In addition, recent research shows that the evolution of distributed systems is also supported by the implementation of containerization and orchestrators such as Kubernetes which enable automated, flexible, and scalable service management in cloud-native environments. (Pahl & Jamshidi, 2022).

2.3 Scalability in Distributed Systems

Scalability describes a system's ability to adjust its capacity as the workload increases without compromising service performance. In distributed systems, scalability is achieved through horizontal scaling, which is the addition of new nodes or services. (Dave, 2024).

Study (Julia et al., 2024) demonstrated that distributed databases in a cloud environment can improve system performance as data volume and user numbers increase. (Dipraja & Rahman, 2025) confirmed that implementing Redis Cluster on a microservices architecture significantly improves caching efficiency and speeds up service response times.

Several recent studies also show that implementing autoscaling mechanisms on microservices in a cloud computing environment can increase resource efficiency and maintain service stability when there is an increase in user demand. (Gupta, 2025; Matineh Zargar Azad & Mehrdad Ashtiani, 2023; Minxian Xu et al., 2022)

Recent research also emphasizes that cloud-based microservice architecture significantly improves scalability through elasticity and auto-scaling mechanisms. (Al-Dhuraibi et al., 2022; Sharma, 2024; Zhang et al., 2022). Thus, distributed systems provide a strong foundation for modern digital services that demand high scalability.

2.4 Service Availability (*Availability*)

Service availability is a key indicator of digital system quality. Modern distributed systems enhance availability through redundancy mechanisms, data replication, and automatic failover. Fault-tolerant approaches such as circuit breakers, bulkhead isolation,

and chaos engineering have become standard practice to maintain system resilience against component failures.(Silvi Fara Dita et al., 2025).

Research by(Muhammad Zulfahrizi Zubair et al., 2024)emphasizes the importance of data recovery strategies in distributed systems to address cyber threats. In addition,(Jonathan Hobbs, 2023)shows that cybersecurity awareness plays an important role in maintaining the continuity of services, especially in educational institutions.

In the context of enterprise and public services, high availability is a critical factor in maintaining user trust and operational continuity.

In addition, high availability in distributed systems is supported by cloud-native architecture through redundancy and fault tolerance mechanisms.(Santos, 2024).

2.5 Microservices Architecture in Digital Services

The microservices architecture is a modern approach to distributed system development, where applications are divided into small, independent services that communicate with each other via APIs.

(Ilham et al., 2025) and (Ahmeth Maulana Ishaq et al., 2025), microservices enable the development of more flexible, easy to maintain and scalable systems. Research (Dipraja & Rahman, 2025) adding that distributed caching integration like Redis is very performance support *microservices* in a cloud environment. This architecture is the backbone of modern digital services such as *e-government*, *e-commerce*, and enterprise based systems *cloud*.

Other research also shows that architecture *microservices* able to improve *maintainability*, system scalability, and supports more adaptive digital service management in the environment *cloud computing* (Thatikonda, 2023; Vudayagiri & Vaibhav, 2024).

3. Research Method

This research uses a qualitative method with a literature review approach. Data were collected through textbook searches, indexed national and international journal articles, and scientific conference proceedings discussing distributed systems, cloud computing, and microservices architecture. Literature was selected based on topic relevance, source credibility, and year of publication to ensure the information is up-to-date. The collected data were analyzed descriptively and comparatively to identify concepts, models, and research findings related to the scalability and availability of digital services. The results of the analysis are used as a basis for discussing the development of distributed systems in supporting modern cloud computing-based digital services.

4. Results and Discussion

4.1 Research Results

Based on the analysis of various literature reviewed, several key findings were obtained regarding the development of distributed systems. Previous research indicates that distributed systems have undergone significant evolution, particularly following the adoption of cloud computing technology and microservices architecture. These changes have had a direct impact on improving system scalability, service availability, and flexibility.

Much of the literature suggests that implementing distributed systems allows organizations to manage workloads more efficiently through horizontal scaling, data replication, and service segmentation into independent components. Furthermore, the use of supporting technologies such as distributed caching (e.g., Redis Cluster) and

distributed databases has been shown to improve system performance in environments with large user bases and large data volumes.

To provide a conceptual overview of the implementation of distributed systems in a cloud computing environment, Figure 4.1 shows an illustration of a distributed system architecture that supports the scalability and availability of digital services.

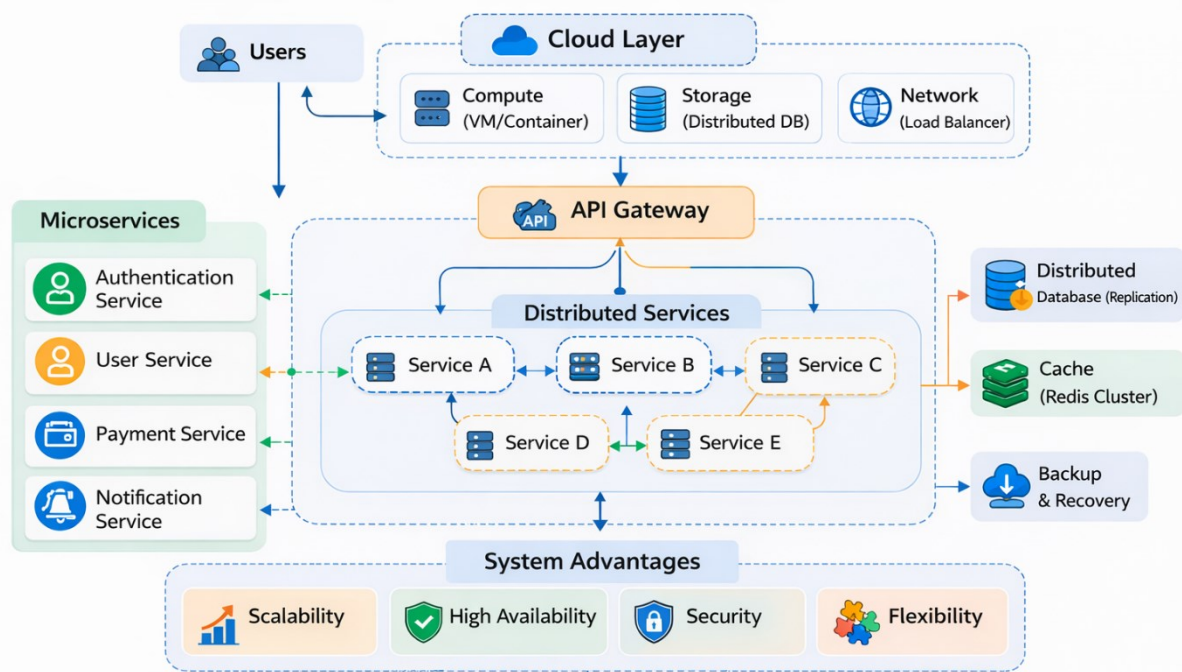


Figure 1. Cloud Computing Based Distributed Systems Architecture

Based on the architectural illustration in Figure 1, distributed systems utilize several key components, such as microservices, distributed databases, and caching mechanisms, to improve service performance. To reinforce these findings, Table 1 summarizes several previous studies that discuss the application of distributed systems to improve the scalability and availability of digital services.

Table 1. Summary of Previous Research on Distributed Systems

Writer	Year	Research Focus	Contribution
Xu et al.	2022	Scaling microservices in the cloud	Optimizing autoscaling to improve resource efficiency
Zhang et al.	2022	Microservices architecture in the cloud	Increase system scalability and flexibility
Al-Dhuraibi et al.	2022	The elasticity of cloud computing	Scalability improvement strategies in the cloud
Pahl & Jamshidi	2022	A systematic study of microservices	Comprehensive mapping of microservices concepts
Zhou & Chen	2022	Edge computing & AI	Supports distributed real-time systems
Jonathan Hobbs	2023	Cybersecurity awareness	The role of security in safeguarding digital services

ZargarAzad & Ashtiani	2023	Autoscaling microservices	Improve the stability and performance of cloud services
Thatikonda	2023	Microservices architecture	Improve system maintainability and scalability
Santos	2024	Cloud-native high availability	Fault tolerance & redundancy strategy
Sharma	2024	Cloud-native auto-scaling	Optimizing resource usage
Julia et al.	2024	Distributed database	Improving data processing performance in cloud computing
Vudayagiri Vaibhav	2024	AI-driven microservices	AI integration in distributed systems
Muhammad Zubair et al.	2024	Distributed system data recovery	Strategies to deal with cyber threats
Georg-Daniel Schwarz et al.	2025	Microservices integration	Taxonomy of inter-service communication
Gupta	2025	Stateless microservices	Supports horizontal scaling on distributed systems

Based on Table 1, most studies show that the implementation of cloud computing-based distributed systems and microservices architectures significantly contributes to increasing the scalability and availability of digital services. Approaches such as autoscaling, distributed databases, and stateless microservices allow systems to handle increased workloads more efficiently.

The findings are further analysed in the discussion section to understand the role of distributed systems in increasing the scalability and availability of modern digital services.

4.2 Discussion

The literature review shows that the development of distributed systems plays a strategic role in supporting modern digital services. Distributed architectures enable systems to maintain optimal operation despite increased access load or disruptions to some system components. This aligns with the primary objectives of modern digital services, which demand high availability and responsiveness.

The adoption of cloud computing has become a key factor in the evolution of distributed systems. With its service-based computing model, the cloud enables elastic resource provision that can be dynamically adjusted to meet system needs. This offers significant advantages in terms of scalability, particularly for enterprise systems and digital-based public services.

Furthermore, the microservices architecture is considered capable of increasing flexibility in system development and maintenance. Each service can be developed, tested, and deployed independently without impacting the overall system. This approach also

supports the integration of additional technologies such as distributed caching and load balancing mechanisms, which contribute to increased service availability.

From a security and reliability perspective, several literatures emphasize the importance of data recovery strategies and cybersecurity awareness in distributed systems. Cyber threats and system failures can be minimized through the implementation of data replication, distributed backup, and adequate security policies. Thus, distributed systems focus not only on performance but also on the sustainability of digital services.

Overall, the results and discussion demonstrate that distributed systems are a key foundation for developing modern digital services. The combination of cloud computing, microservices, and other supporting technologies can significantly improve service scalability and availability, while addressing the challenges of system complexity in the digital age.

This shows that the integration between cloud computing and microservices architecture is an important factor in increasing the flexibility, scalability, and resilience of distributed systems in supporting modern digital services.

5. Conclusion

Based on the results of the literature review that has been carried out, it can be concluded that distributed systems have a very important role in supporting the scalability and availability of modern digital services. The development of distributed systems, particularly through the implementation of cloud computing and microservices architectures, enables systems to manage increased workloads efficiently without compromising service performance.

Results showed that scalability in distributed systems can be achieved through horizontal scaling mechanisms, the use of distributed databases, as well as the implementation of distributed caching. That approach allows digital services to dynamically adjust system capacity according to the growth in the number of users and the volume of data. In addition, the availability of services is improved through the implementation of redundancy mechanisms, data replication, automatic failover, as well as fault tolerance strategies that are able to keep the system operational despite interference with some components.

Theoretically, this research contributes to enriching understanding of the evolution of distributed systems and their role as the foundation of modern digital services. Practically speaking, the results of this research can serve as a reference for system developers and organizations in designing scalable, reliable and sustainable digital services. Subsequent research is suggested to conduct empirical testing of distributed systems implementation as well as explore the integration of new technologies, such as artificial intelligence and blockchain, in order to improve the performance and reliability of future systems.

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