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Comparative Analysis of Network Architecture: Client-Server Versus Peer-to-Peer

Analisis Perbandingan Arsitektur Jaringan: Client-Server Versus Peer-to-Peer

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Abstract

Network architecture is the foundation of all modern digital communication, with the client-server and peer-to-peer (P2P) models being two dominant paradigms. This study aims to present an in-depth comparative analysis of these two architectures. Using a qualitative literature study method with sources from fundamental textbooks, international journals, and conference proceedings from the last ten years, this article examines the fundamental differences in topology, resource management, scalability, performance, and security. The main findings indicate that the client-server model excels in environments that demand centralized control, data consistency, and manageable security, making it ideal for business and financial applications. In contrast, the P2P architecture offers superior scalability, resilience, and cost-efficiency for large-scale decentralized applications such as file-sharing platforms and blockchain technology. The security analysis reveals that while P2P is vulnerable to specific attacks like Sybil and poisoning, the client-server model faces the risk of a single point of failure and a concentrated target for DDoS attacks. In conclusion, neither architecture is universally superior; the optimal choice is highly dependent on the specific goals, technical requirements, and threat model of the application being developed.

Abstract

Arsitektur jaringan adalah fondasi dari semua komunikasi digital modern, dengan model client-server dan peer-to-peer (P2P) sebagai dua paradigma dominan. Penelitian ini bertujuan untuk menyajikan analisis komparatif yang mendalam antara kedua arsitektur tersebut. Menggunakan metode studi literatur kualitatif dengan sumber dari buku teks dasar, jurnal internasional, dan prosiding konferensi dalam sepuluh tahun terakhir, artikel ini mengkaji perbedaan mendasar dalam topologi, manajemen sumber daya, skalabilitas, kinerja, dan keamanan. Temuan utama menunjukkan bahwa model klien-server unggul dalam lingkungan yang menuntut kontrol terpusat, konsistensi data, dan keamanan terkelola, menjadikannya ideal untuk aplikasi bisnis dan keuangan. Sebaliknya, arsitektur P2P menawarkan skalabilitas, ketahanan, dan efisiensi biaya yang unggul untuk aplikasi terdesentralisasi skala besar seperti platform berbagi file dan teknologi blockchain. Analisis keamanan mengungkapkan bahwa sementara P2P rentan terhadap serangan tertentu seperti Sybil dan keracunan, model klien-server menghadapi risiko titik kegagalan tunggal dan target serangan DDoS yang terkonsentrasi. Kesimpulannya, tidak ada arsitektur yang lebih unggul secara universal; Pilihan optimal sangat tergantung pada tujuan spesifik, persyaratan teknis, dan model ancaman dari aplikasi yang dikembangkan.

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1. Introduction

The development of information and communication technology in recent decades has brought about major changes in the way humans manage, process, and distribute information. These advances have encouraged the increasing use of computer networks in various fields such as education, business, government, and industry. Computer networks allow different devices to connect to each other so that they can share resources, exchange data, and support communication faster and more efficiently (On, n.d.).

In the context of modern organizations, computer networks are very important infrastructure because they can improve operational efficiency and work productivity. Through a computer network, various devices such as computers, printers, and servers can be connected to each other, allowing the process of sharing data and information centrally or distributed. The use of computer networks also allows for more structured management of information systems and simplifies the process of data processing on a large scale (Maha Putra et al., 2018).

One of the important aspects of computer network design is the selection of the right network architecture. Network architecture determines how devices connected in a network interact with each other, how data is transmitted, and how resources are managed in a network system. In general, there are two models of network architecture that are widely used in modern computer systems: client-server architecture and peer-to-peer architecture (Tanenbaum & Wetherall, 2003).

Client-server architecture is a network model that uses a server as the center for managing network services and resources. In this architecture, the server is in charge of providing services or data that can be accessed by a number of client computers over the network. The client computer sends the request to the server and the server will process the request and then respond to the client. This model is widely used in various network services such as web servers, database servers, and enterprise information systems because it allows for centralized data management as well as more structured security controls (Nurjaman, 2017).

On the other hand, peer-to-peer (P2P) architecture has a different approach because it does not rely on a single central server. In a peer-to-peer network, each connected computer has the same position and can function as both a client and a server at the same time. This allows each node to share resources such as files, storage capacity, and network bandwidth directly with other nodes without having to go through a central server (Saputra, 2018).

The peer-to-peer model is widely used in various data sharing applications such as file sharing, distributed communication, and various internet-based systems. One of the main advantages of this architecture is its ability to distribute workloads evenly across all connected nodes, thereby improving system scalability. However, peer-to-peer architectures also have some drawbacks such as a lack of centralized control as well as potential security and data reliability issues in the network (Leibnitz et al., 2007).

In addition, other research shows that peer-to-peer systems have decentralized characteristics that allow for the direct exchange of resources between network users without requiring coordination from a central server. However, some peer-to-peer network implementations still face various challenges such as security management, trust between nodes, and protection against network attacks (Alharbi & Aljaedi, 2020). The difference in characteristics between client-server and peer-to-peer architectures causes both models to have their own advantages and limitations in their application to computer network systems. Therefore, a comprehensive analysis is needed to understand

the differences, advantages, and disadvantages of the two architectures in order to determine the network model that best suits the needs of the system. Based on this background, this study aims to conduct a comparative analysis of client-server and peer-to-peer network architectures by reviewing various aspects such as system structure, working mechanisms, advantages, and limitations of each architecture.

2. Literature Review

2.1 Computer network concept

A computer network is a set of computing devices that are interconnected through communication media so that it allows data exchange and resource utilization together. Through computer networks, devices such as computers, servers, printers, and other network devices can communicate with each other and share information efficiently without being limited by the user's physical location(Tanenbaum & Wetherall, 2003).

The utilization of computer networks is not only limited to data communication, but also includes various services such as file sharing, database access, web services, and various other network-based applications. In modern organizational environments, computer networks are used to improve operational efficiency by allowing various work units to access information quickly and integrated. (On, n.d.).

In addition, computer networks also play an important role in supporting the process of collaboration between users in an information system. With a computer network, users can exchange data, share hardware, and access the same applications at the same time. This makes computer networks an important infrastructure in various modern information systems(Maha Putra et al., 2018).

The development of network technology has also led to the emergence of various network architecture models designed to efficiently manage communication and distribution of resources. The two most commonly used network architecture models are client-server architecture and peer-to-peer architecture, each of which has different characteristics and working mechanisms in network system management(Faodiansyah et al., 2018).

2.2 Client-server architecture

The client-server architecture is one of the network models that is widely used in various modern information systems. In this model, there is a separation of roles between the computer that provides the service (server) and the computer that uses the service (the client). The server is in charge of storing data, managing resources, and processing requests sent by the client's computer over the network(Tanenbaum & Wetherall, 2003).

In this architecture, the network communication process takes place through a request and response mechanism. The client computer sends the service request to the server, and then the server processes the request and sends the results back to the client. This communication pattern allows for more structured management of the system as all major services are controlled by a central server (Nurjaman, 2017).

A key advantage of client-server architecture is its ability to centrally manage data and services. With a server as a management center, network administrators can control user access, set up security, and manage network resources more easily. This makes client-server architectures widely used in enterprise networking systems, web services, and database-based applications (Suhanda, 2020).

In addition, the client-server model also allows for improved system performance through more organized resource management. Servers can be designed with larger computing capacity so that they can handle multiple requests from clients at the same time. Thus, the network system can provide more stable and efficient services for users (Leibnitz et al., 2007).

Nonetheless, the client-server architecture also has some limitations. Reliance on a central server can make the system vulnerable to failure if the server is down. If the server cannot operate properly, then all network services that depend on the server can also be disrupted (Faodiansyah et al., 2018.

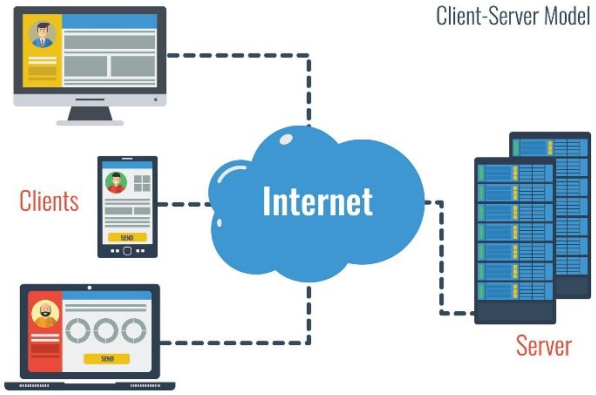

Figure 1. Client-Server Network Architecture

2.3 Architecture peer-to-peer

A peer-to-peer (P2P) architecture is a network model that does not rely on a single central server in system management. In this architecture, each computer connected to the network has the same position and can function as both a service provider and a service user at the same time(Saputra, 2018).

In a peer-to-peer network, each node in the network can share resources such as files, storage capacity, and network bandwidth directly with other nodes. This allows for a more even distribution of resources because there is no single central point that controls all network activities (Schollmeier, 2001).

One of the key advantages of peer-to-peer architecture is its ability to distribute workloads more efficiently. In this system, each node can contribute to the service provisioning process so that the network load does not depend solely on a single server device. This approach allows the system to have a higher level of scalability compared to a fully centralized system (Leibnitz et al., 2007).

In addition, peer-to-peer architecture is also widely used in various internet-based applications such as file-sharing systems, distributed communications, and various collaborative applications. The concept of decentralization in a peer-to-peer system allows for the direct exchange of data between network users without having to go through a central server(Ghatnatti, 2016).

While it has several advantages, peer-to-peer architecture also faces various challenges especially in terms of security and system reliability. Due to the absence of centralized control, peer-to-peer systems are more vulnerable to various threats such as the spread of invalid files, network attacks, and difficulties in managing identity and trust between nodes in the network (Alharbi & Aljaedi, 2020).

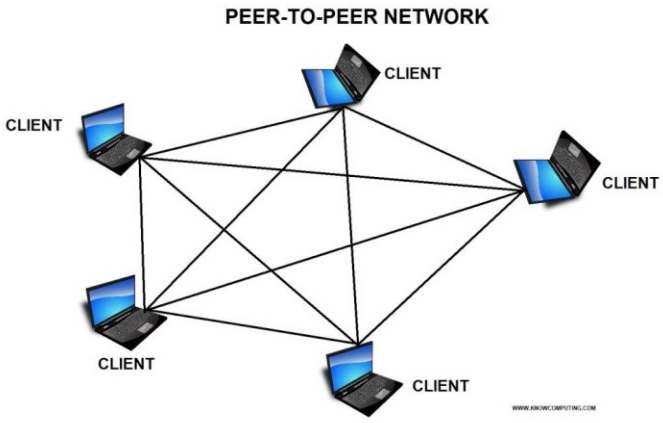

Figure 2. Peer-to-Peer Network Architecture

2.4 Comparison of Client-Server and Peer-to-Peer Architectures

The main difference between client-server and peer-to-peer architectures lies in the way resources are managed as well as the control structure in the network. In a client-server architecture, all services and data management are controlled by a central server, whereas in a peer-to-peer architecture all nodes in the network have an equal role in providing services(Tanenbaum & Wetherall, 2003).

In terms of system management, the client-server architecture offers more centralized control, making it easier for administrators to manage security and data management. In contrast, peer-to-peer architecture offers greater flexibility because each node can function independently without relying on a central server (Faodiansyah et al., 2018).

In terms of scalability, peer-to-peer architecture has an advantage due to the system's ability to evolve as the number of nodes in the network increases. Each new node that joins the network can contribute to the provision of resources so as to increase the overall capacity of the system (Leibnitz et al., 2007). However, the client-server architecture has advantages in terms of security and data management because all network activities can be controlled through a central server. With a more structured control mechanism, a client-server system can provide a better level of security compared to a decentralized peer-to-peer system(Suhanda, 2020).

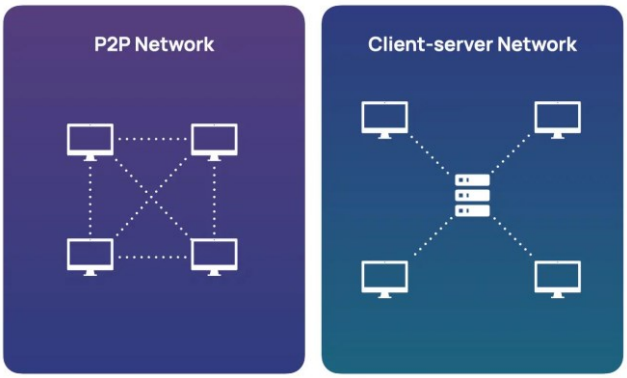

Figure 3. Comparison of Client-Server and Peer-to-Peer Architectures

Based on various previous studies, the two network architectures have different characteristics so that their application needs to be adjusted to the needs of the system. Therefore, a comparative analysis of these two architectures is

important to understand the advantages and limitations of each model in supporting the performance of modern computer network systems.

3. Research Methods

3.1 Research Design

This study uses a qualitative approach with a literature study method to analyze and compare the characteristics of client-server and peer-to-peer network architectures. The literature study approach was chosen because it allows researchers to examine in depth various concepts, theories, and results of previous research related to computer networks and distributed systems. This method is also widely used in research in the field of information technology to understand the development of network architecture concepts and their implementation in various modern computing systems (Tanenbaum & Wetherall, 2003).

Through this approach, the research is focused on a comparative analysis of two network architecture models that are widely used in computer network systems. The analysis was carried out by comparing various aspects such as the architecture structure, network communication mechanism, resource distribution, system scalability, and security level of each network architecture. This comparative approach aims to provide a clearer picture of the advantages and limitations of the two network architectures (Leibnitz et al., 2007).

3.2 Research Data Sources

The data used in this study was obtained from various sources of scientific literature that are relevant to the research topic. Sources of literature include scientific journal articles, conference proceedings, computer network reference books, and other scientific publications that discuss computer network architecture, distributed systems, and peer-to-peer and client-server technologies.

Computer networking textbooks are also used as a primary reference for understanding the basic concepts of computer networks as well as communication mechanisms in client-server architectures. The book explains that computer networks allow various devices to communicate with each other and share resources through a structured data communication system (Tanenbaum & Wetherall, 2003).

In addition, some previous research has also been used as a reference to understand the implementation of peer-to-peer architecture in various modern network systems. The research shows that peer-to-peer networks allow for the direct distribution of resources between nodes without relying on a central server, thus providing flexibility in network management (Schollmeier, 2001).

Other literature is also used to understand the various problems that arise in the implementation of peer-to-peer networks, particularly in the aspects of security and trust between nodes. Some studies show that peer-to-peer systems have a potential vulnerability to various security threats due to the absence of centralized control in the network (Alharbi & Aljaedi, 2020).

3.3 Data collection techniques

The data collection technique in this study is carried out through documentation studies, namely by collecting and examining various literature sources related to the research topic. The data collection process is carried out by browsing various databases of scientific publications such as academic journals, research repositories, and reference books that discuss computer networks and distributed systems.

The collected literature was then selected based on several criteria, such as relevance to the research topic, quality of publication sources, and research contribution to the development of computer network architecture concepts. This

selection process was carried out to ensure that the literature sources used really supported the comparative analysis conducted in this study (Faodiansyah et al., 2018).

In addition, research that discusses the implementation of client-server networks in computer networking systems is also analyzed to understand how the architecture is used in various modern information systems environments. Previous research has shown that client-server systems are widely used in organizational information systems because they are able to provide centralized data management and make it easier to control user access in the network (Nurjaman, 2017).

3.4 Data Analysis Techniques

The data analysis in this study was carried out using a comparative descriptive analysis method. This method is used to compare the various characteristics of client-server and peer-to-peer architectures based on information obtained from the literature that has been collected.

The analysis process begins by identifying the basic concepts of each network architecture, then continues by analyzing the communication mechanisms, resource distribution, and advantages and limitations of the two architectures. The results of the analysis from various literature were then compared to find patterns of differences and similarities between the two network architecture models (Ghatnatti, 2016).

In addition, analysis was also carried out on various important aspects of the computer network system such as system performance, network scalability, and the level of security in the implementation of the two network architectures. This comparative analysis approach is expected to provide a more comprehensive understanding of the characteristics of each network architecture in supporting modern computing systems (Leibnitz et al., 2007).

4. Results and Discussion

4.1 Client-server architecture analysis

The client-server architecture is one of the most widely used network models in modern information systems. In this architecture, the server serves as the center for managing network services and resources, while the client computer is in charge of accessing the services provided by the server through a communication network. This model allows for centralized data management, making it easier to manage user access as well as overall network system management (Tanenbaum & Wetherall, 2003).

In implementation, servers typically have higher hardware specifications than client computers because they need to be able to handle multiple requests from multiple users simultaneously. The server also serves to manage various network services such as data storage, web services, and database management that can be accessed by users in the network (Suhanda, 2020).

One of the main advantages of client-server architecture is its ability to provide a structured and centralized management system. With a server as the central management of the system, network administrators can easily manage user access rights, secure data, and monitor network activity more effectively. This makes client-server architecture widely used in corporate networking systems and internet-based service systems (Nurjaman, 2017).

In addition, the client-server architecture also provides a relatively better level of security because the entire data management process is done through a central server that can be controlled by the network administrator. With this

mechanism, the data security process can be carried out in a more organized manner so that it can minimize the risk of data misuse in the network (On, n.d.).

However, the client-server architecture also has some drawbacks. Reliance on a central server can make the system vulnerable to disruption if the server experiences a system malfunction or failure. If the server cannot operate properly, then all network services that depend on the server can also be disrupted (Faodiansyah et al., 2018).

4.2 Peer-to-peer architecture analysis

A peer-to-peer (P2P) architecture is a network model that allows every device connected in the network to have an equal role. In this architecture, each computer can function as both a client and a server at the same time, so there is no fully centralized system management as in a client-server architecture (Saputra, 2018).

In a peer-to-peer network, each node in the network can directly share resources such as files, storage capacity, and network bandwidth with other nodes. This allows for a more even distribution of resources because no one device is the central control center of all network activity (Schollmeier, 2001).

The main advantage of peer-to-peer architecture is its ability to distribute workloads more efficiently among all nodes in the network. As the number of users in the network increases, the capacity of the system can also increase.as each new node that joins the network can contribute to the provision of network resources(Leibnitz et al., 2007).

In addition, the peer-to-peer architecture also has high flexibility because each node in the network can operate independently without having to rely on a central server. This makes peer-to-peer systems more resilient to the failure of one particular node because the network can still remain operational as long as the other nodes are still active in the network(Ghatnatti, 2016).

Nonetheless, peer-to-peer systems also have some drawbacks, especially in terms of security and system management. Due to the absence of centralized controls, security management in peer-to-peer networks has become more complex. In addition, the system is also more vulnerable to various security threats such as the spread of malicious files or data manipulation by untrusted nodes(Alharbi & Aljaedi, 2020).

4.3 Comparative Analysis of Client-Server and Peer-to-Peer Architectures

Based on the results of the analysis of various literature that has been studied, there are some fundamental differences between client-server architecture and Peer-to-peer architecture. The difference lies mainly in the structure systems, resource management, network communication mechanisms, as well as the level of system security.

In the client-server architecture, all services and data management controlled by a central server so that the system has a more structured Organized and easy to manage by network administrators. Instead, In a peer-to-peer architecture, there is no central server that Handle all network activity because each node has an equal role in providing network services (Tanenbaum & Wetherall, 2003).

In terms of resource management, the client-server architecture has more entralized management mechanism, making it easier to access rights and securing data in the network. Meanwhile, Peer-to-peer architecture enables Direct distribution of resources between nodes so that it can increase efficiency Resource Usage network power (Leibnitz et al., 2007).

When it comes to system scalability, peer-to-peer architecture has an advantage because of the system's ability to evolve along with increase number of nodes in

network. Every new node that joins the network can contribute against the capacity of the system by so that the system can develop more flexible (Ghatnatti, 2016).

Nevertheless, client-server architectures have advantages in terms of security and management of the system due to the presence of centralized control that allows network administrators to supervise the entire activity network more effectively. This makes it possible for Client-server architecture More widely used in corporate information systems and services web-based that requires centralized data management (Suhanda, 2020).

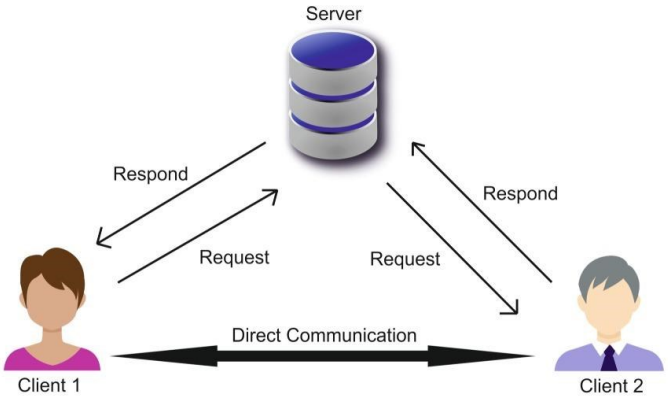

Figure 4. Network Communication Mechanism

5. Conclusion

Based on the results of the analysis of various literature that has been studied, it can be concluded that network architecture **client-server** and **peer-to-peer** have different characteristics, advantages, and limitations in the implementation of computer network systems. The client-server architecture implements a centralized management system, where the server serves as the primary service provider serving the requests of various client computers in the network. This model provides convenience in system management, security settings, and user access control because all network data and services can be controlled through a central server (Tanenbaum & Wetherall, 2003).

On the other hand, architecture **peer-to-peer** It offers a more decentralized approach because every device connected in the network has an equal role as a client as well as a server. This approach allows for a more even distribution of resources and increases the flexibility of the system in handling data exchange between users. In addition, peer-to-peer systems also have advantages in terms of scalability because network capacity can increase as the number of nodes in the network increases(Leibnitz et al., 2007). However, both architectures also have some limitations. The client-server architecture has a high dependence on a central server so if the server is disrupted, the entire network service can be affected. In contrast, peer-to-peer architectures have challenges in terms of security management as well as system control due to the absence of centralized control in the network (Alharbi & Aljaedi, 2020).

Thus, the selection of network architecture needs to be adjusted to the needs of the system to be built. Client-server architectures are best suited for use in systems that require centralized data management and tighter security controls, such as organizational information systems and web-based services. Meanwhile, peer-to-peer architectures are more suitable for use in systems that require high flexibility and direct distribution of resources between users in the network

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