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Article

Desain Microcomputer Cloud Computing for Informatics Study Program at LIA University Based on Local Area Network (LAN)

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A B S T R A C T

Digital transformation in higher education increasingly requires information technology infrastructure that is efficient, flexible, secure, and sustainable. Cloud computing has emerged as a strategic solution by enabling scalable resources, centralized management, and service standardization effectively. However, public cloud adoption in academic institutions frequently encounters constraints, including recurring operational costs, data security and sovereignty risks, regulatory concerns, and strong dependence on reliable internet connectivity. These issues are particularly salient for instructional laboratories that demand continuous access, predictable performance, and institutional control. This study aims to design and implement a Local Area Network (LAN)-based cloud computing system using a microcomputer as the primary server within the Informatics Study Program at LIA University. The research employs a research and development (R&D) methodology comprising needs analysis, system architecture design, implementation, and functional as well as performance testing. An open-source virtualization platform is deployed to deliver Infrastructure as a Service (IaaS) and Software as a Service (SaaS) in a private cloud environment. The results demonstrate that the proposed LAN-based local cloud provides centralized computing and storage services with low latency, high stability, and efficient utilization.

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I. INTRODUCTION

The rapid development of information technology has encouraged higher education institutions to adopt adaptive and scalable digital infrastructure to support academic activities and institutional competitiveness [1], [2]. Universities are increasingly required to integrate advanced computing environments that enable efficiency, flexibility, and sustainability in teaching, research, and administrative processes.

Informatics study programs, as the core drivers of computer science education and innovation, are expected to provide robust computing facilities that can accommodate practice-based learning, experimental research, and collaborative development [3], [4]. Such programs rely heavily on stable computational resources to support programming courses, system simulations, data processing, and applied technology projects undertaken by students and lecturers.

The management of conventional computer laboratories continues to face structural and operational challenges that hinder efficiency and long-term sustainability. One of the most prominent issues is data duplication across standalone machines, where identical datasets, software packages, and configurations must be installed and maintained separately on each workstation. This redundancy not only increases storage consumption but also raises the risk of data inconsistency, version conflicts, and configuration drift, particularly in environments where multiple courses with varying software requirements are conducted simultaneously.

In addition to data redundancy, conventional laboratories are constrained by limited hardware scalability. Upgrading or expanding computational capacity typically requires physical replacement or augmentation of individual machines, which involves significant capital expenditure and logistical complexity. Such an approach is poorly suited to dynamic academic environments, where resource demands fluctuate depending on course schedules, class sizes, and the computational intensity of learning activities. Consequently, laboratories often experience either resource underutilization during off-peak periods or performance bottlenecks during peak usage.

Furthermore, system maintenance and software updates in traditional laboratory settings are inherently complex and time-consuming. Each machine must be configured, patched, and monitored individually, increasing the workload for technical staff and the likelihood of human error. As the diversity of software tools and user profiles grows, maintenance costs escalate, and downtime becomes more frequent. These cumulative inefficiencies lead to higher operational costs and reduced laboratory availability, underscoring the need for more centralized, scalable, and manageable computing paradigms in academic laboratory environments.

Figure 1. Microcomputer Cloud Computing

Cloud computing offers an alternative paradigm by enabling centralized, elastic, and service-oriented management of computing resources [5], [6], [7]. Through virtualization, cloud systems allow multiple users to access shared infrastructure efficiently. Nevertheless, the adoption of public

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cloud services in campus environments introduces constraints related to limited internet bandwidth, dependency on external providers, and risks associated with academic data security and privacy [8].

To address these issues, this study proposes a LAN-based cloud computing architecture utilizing microcomputers as local servers to form a private cloud environment. The main contributions of this research include the design of a microcomputer-based local cloud architecture, the implementation of virtualization and cloud services tailored for academic needs, and a systematic evaluation of system performance from a computer science perspective.

II. LITERATURES REVIEW

Cloud Computing Concept Cloud computing is a computing paradigm that enables the provision of computing resources elastically, scalably, and on-demand over a network [9], [10]. According to Mell and Grance, cloud computing has five main characteristics, namely on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service [11]. This definition is the main reference in the development of modern cloud systems and is widely used in academic research. Buyya et al. expands the concept of cloud computing by emphasizing the utility computing aspect, where computing services are treated as utilities that can be accessed according to user needs [12]. In the context of higher education, this approach allows institutions to provide computing services without having to invest heavily in physical infrastructure.

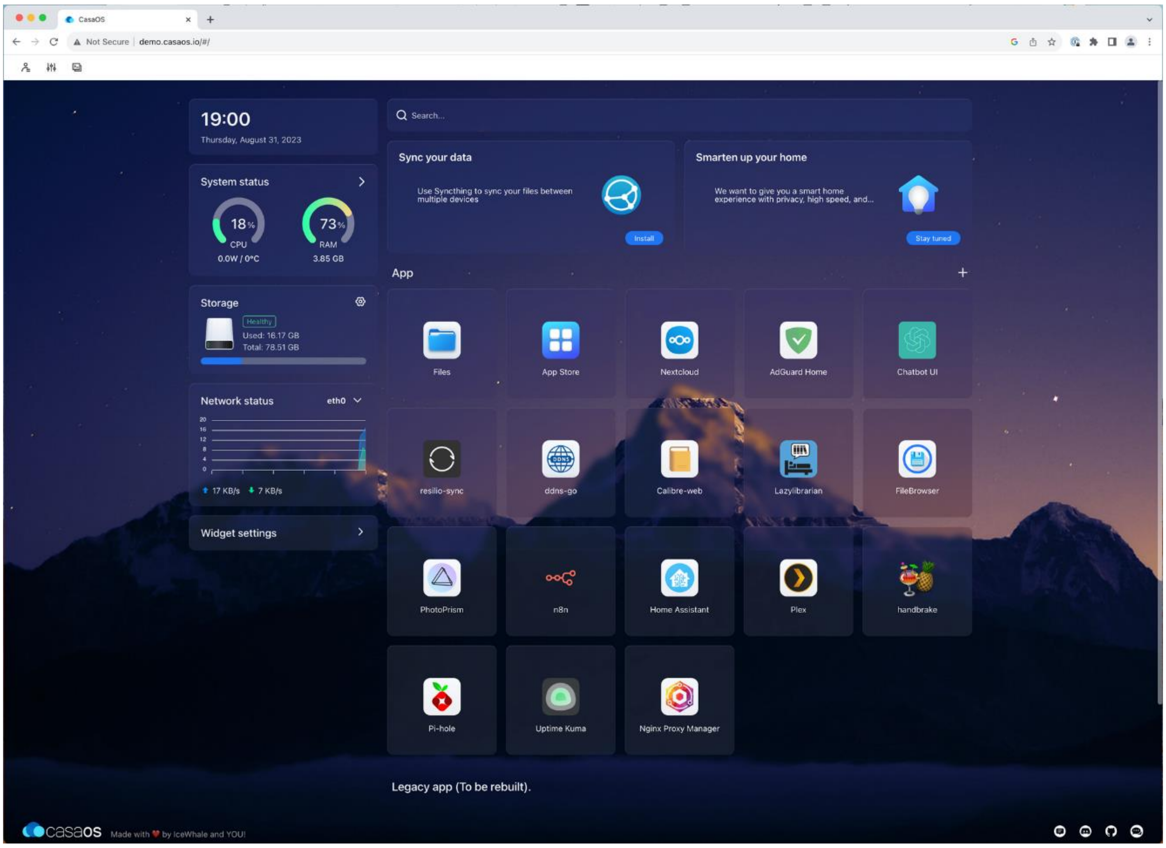

Figure 2. Dashboard Microcomputer Cloud Computing

Cloud Service Models and Implementation is classified into three main service models: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) [11], [13], [14], [15]. This research focuses on the IaaS and SaaS models because they are most relevant for supporting practical activities, learning, and academic data storage. Based on the implementation model, cloud computing is divided into public cloud, private cloud, community cloud, and hybrid cloud [11]. The private cloud was chosen in this research because it provides full

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control over data and system security, as recommended for higher education environments [16], [17].

Virtualization as a Core Cloud Technology. Virtualization is the main foundation in implementing cloud computing [18], [19]. Tanenbaum and Wetherall [20] explain that virtualization enables hardware abstraction so that a single physical machine can run multiple operating systems simultaneously. Implementing server virtualization has been proven to increase the efficiency of hardware resource utilization. Research by Ulya and Saputra [21] shows that using Proxmox VE as an open-source hypervisor provides stable and efficient performance in a campus network environment. These findings strengthen the basis for selecting virtualization technology in this study.

Local Area Network (LAN), Local Area Network (LAN) is a network with limited area coverage that has the characteristics of high bandwidth and low latency [22], [23], [24]. According to Tanenbaum and Wetherall [20], LAN is very suitable for use as a communication medium for distributed systems that require fast response. Pertiwi and Wibowo [17] proved that the implementation of LAN-based private cloud in a university environment can increase the efficiency of data access and reduce the burden of external internet traffic. This is a strong basis for using LAN as the main infrastructure of local cloud in this study.

Cloud Computing in Higher Education The implementation of cloud computing in Indonesian universities has been widely studied. Hasibuan and Drajat [16] stated that cloud computing can improve the effectiveness of academic information systems and collaboration between users. Another study by Sari and Handayani [25] showed that cloud adoption in higher education institutions has a positive impact on learning flexibility and IT management efficiency. However, most of this research focuses on the use of public clouds. Therefore, this study takes a different approach by examining the implementation of a LAN-based private cloud using microcomputers as a more independent and secure alternative solution.

Figure 3. Infrasturktur Microcomputer Cloud Computing

III. METHODS

This study adopts a research and development (R&D) methodology to systematically design, implement, and validate a LAN-based private cloud computing system. The R&D approach is selected because it emphasizes iterative development, empirical testing, and contextual adaptation to real institutional environments. This methodology is particularly suitable for infrastructure-oriented research that combines engineering design with academic service requirements.

The first stage is needs analysis, which involves a detailed assessment of academic, technical, and operational requirements. Hardware analysis examines microcomputer specifications such as CPU performance, RAM capacity, storage type, and energy efficiency to ensure suitability as

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lightweight servers. Software analysis includes the selection of operating systems, virtualization platforms, and management tools, while network analysis evaluates LAN bandwidth, switch performance, and concurrent user capacity.

The second stage is system design, focusing on the formulation of a robust cloud computing architecture. This stage defines the logical and physical LAN topology, server–client interaction models, and data flow mechanisms. Design considerations emphasize scalability, fault tolerance, ease of maintenance, and alignment with academic workflows.

The third stage is implementation, where the conceptual design is translated into a working system. Microcomputers are deployed as cloud servers and integrated into the campus LAN. Server operating systems, virtualization software, and centralized storage services are installed and configured.

Virtualization configuration constitutes a critical component of the implementation stage. Virtual machines are provisioned with predefined resource allocations to support laboratory practicums, coursework, and experimental research. This approach enables standardized computing environments while maximizing hardware utilization.

The fourth stage is system testing, which evaluates functional reliability, performance efficiency, and operational stability. Functional testing verifies service accessibility, virtual machine deployment, and storage availability. Performance testing measures latency, throughput, and resource utilization under varying user loads.

Security testing is conducted to ensure data protection and controlled access within the private cloud. This includes evaluating authentication mechanisms, authorization policies, and isolation between virtual machines. Overall, the system architecture integrates microcomputers, LAN switches, and student and faculty clients to deliver virtual machines and centralized file storage within a secure and efficient academic cloud environment.

IV. RESULTS

Performance testing was conducted to comprehensively evaluate the effectiveness of the LAN-based cloud computing system developed using a microcomputer as the primary server. The objective of this evaluation was to assess whether the proposed architecture could reliably support simultaneous academic activities under realistic laboratory conditions. Emphasis was placed on measuring responsiveness, data transfer capability, and hardware resource utilization.

The testing scenario was designed to reflect actual usage patterns in an academic computer laboratory. A total of 30 active clients, representing students, accessed virtual machine services and centralized file storage concurrently through a 1 Gbps Local Area Network. This scenario simulated peak laboratory usage, where multiple users perform practical tasks, software execution, and data access simultaneously.

Latency was evaluated as a key indicator of system responsiveness. Measurements were performed using the ping and iperf tools from client machines to the cloud server. The results showed an average latency of 2.8 milliseconds, with a maximum observed latency of 4.6 milliseconds under peak load conditions, indicating very fast response times.

These latency values are significantly lower than those typically observed in internet-based cloud environments. The results confirm that LAN-based cloud deployment minimizes network overhead and external routing delays. Consequently, the system is highly suitable for interactive academic applications requiring real-time responsiveness.

Throughput performance was assessed using iPerf3 to measure data transfer capacity between clients and the server. The system achieved an average throughput of approximately 920 Mbps out of the available 1 Gbps bandwidth. This indicates efficient utilization of network resources despite concurrent access by multiple users.

The minor throughput reduction observed is primarily attributed to virtualization overhead and bandwidth sharing among active virtual machines. Nevertheless, the achieved throughput remains

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within optimal limits for laboratory-scale cloud services. This demonstrates that the system can support high-volume data transfers such as software deployment and dataset access.

CPU utilization was monitored through the Proxmox VE management dashboard to evaluate processing efficiency. Under idle conditions, CPU usage ranged between 12% and 18%, reflecting low baseline overhead. When all 30 clients were active, CPU usage increased to approximately 68%, indicating effective but not saturated processing performance.

RAM usage was also analyzed to assess memory management efficiency. From a total of 8 GB of available memory, average usage reached 5.6 GB during full virtual machine operation. The hypervisor's ballooning-based memory management played a crucial role in dynamically allocating memory, ensuring system stability and preventing resource exhaustion during peak usage.

Test results demonstrate that a LAN-based cloud computing system using microcomputers is capable of delivering stable and efficient performance. To clarify the analysis, the performance test results are summarized in the following tables.

Table 1. Latency Test Results of the LAN-Based Cloud System

Parameter	Value (ms)	Description
Minimum Latency	1.9	Idle condition
Average Latency	2.8	Multi-user access
Maximum Latency	4.6	Peak load

Latency represents a critical indicator of system responsiveness, particularly for interactive cloud services such as virtual machine access and centralized file operations. The minimum latency of 1.9 ms under idle conditions indicates negligible communication delay within the LAN environment. An average latency of 2.8 ms during multi-user access demonstrates that concurrent client activity does not significantly degrade system responsiveness. The maximum latency of 4.6 ms observed under peak load remains well below commonly accepted thresholds for interactive computing (<10 ms), confirming that the LAN-based cloud system is highly responsive and suitable for real-time academic applications.

Table 2. Network Throughput Test Results

Parameter	Value	Description
Theoretical Bandwidth	1 Gbps	Gigabit LAN
Average Throughput	920 Mbps	30 active clients
Network Efficiency	92%	Very high

Latency represents a critical indicator of system responsiveness, particularly for interactive cloud services such as virtual machine access and centralized file operations. The minimum latency of 1.9 ms under idle conditions indicates negligible communication delay within the LAN environment. An average latency of 2.8 ms during multi-user access demonstrates that concurrent client activity does not significantly degrade system responsiveness. The maximum latency of 4.6 ms observed under peak load remains well below commonly accepted thresholds for interactive computing (<10 ms), confirming that the LAN-based cloud system is highly responsive and suitable for real-time academic applications.

Table 3. Server CPU Utilization Monitoring Results

System Condition	CPU Usage	Description
Idle	12–18%	No active VMs
Moderate Load	40–52%	15 active VMs
Full Load	68%	30 active clients

CPU utilization reflects the processing capacity of the microcomputer server under varying workloads. Low CPU usage during idle conditions indicates minimal overhead from the hypervisor. As the number of active virtual machines increases, CPU usage rises proportionally, reaching 68%

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under full load. This value suggests that the server operates efficiently without reaching saturation, leaving sufficient processing headroom for stable operation during laboratory sessions.

Table 4. Server RAM Utilization Monitoring Results

System Condition	RAM Usage	Description
Idle	2.1 GB	Base system
Moderate Load	4.3 GB	15 active VMs
Full Load	5.6 GB	30 active clients

Memory utilization is a crucial factor in virtualized environments. The results show that baseline memory usage remains low at 2.1 GB, reflecting an efficient system configuration. Under full load, RAM usage increases linearly to 5.6 GB out of the available 8 GB. This controlled growth is enabled by ballooning-based memory management, which dynamically allocates memory among virtual machines to maintain system stability and prevent resource exhaustion.

Collectively, the results presented in Tables 1–4 demonstrate that the LAN-based cloud computing system delivers stable, efficient, and scalable performance under realistic academic workloads. From a computer science perspective, these findings confirm that well-designed lightweight virtualization and efficient resource management can compensate for hardware limitations. Consequently, small-scale private cloud infrastructures using microcomputers are technically viable and highly suitable for deployment at the study program level to support learning and research activities.

V. DISCUSSION

The study aimed to design and implement a Local Area Network (LAN)-based cloud computing system utilizing microcomputers as servers for the Informatics Study Program at LIA University. The findings demonstrate that such a system is not only feasible but also provides a robust alternative to traditional cloud infrastructure in academic settings, particularly in environments with constrained resources. The performance of the system, including latency, throughput, and resource utilization, was evaluated under realistic conditions, simulating academic workloads in a computer laboratory setting. These results align with previous studies that highlighted the potential of microcomputer-based clouds for educational purposes [11].

A key advantage of using a LAN-based private cloud system is the significant reduction in latency compared to internet-based public clouds. As the performance testing showed, the LAN-based system achieved an average latency of 2.8 ms, with a maximum of 4.6 ms under peak load. These values are significantly lower than those observed in public cloud environments, where latency often exceeds 10 ms [13]. This low-latency performance is crucial for real-time academic applications, particularly those involving interactive learning and virtualization. By leveraging LAN, the proposed system reduces the reliance on external internet bandwidth, which is often a bottleneck in traditional cloud services, especially in academic settings where multiple users may be accessing the system simultaneously [14].

Additionally, the use of microcomputers as servers in this study introduces a cost-effective solution for educational institutions with limited budgets for infrastructure. As demonstrated, microcomputers can provide sufficient processing power, with the system maintaining CPU utilization between 12-68% depending on the load, without saturation. This finding supports previous research suggesting that lightweight cloud systems using low-cost hardware can deliver satisfactory performance for non-intensive applications [15]. Furthermore, the system's efficient memory management, aided by ballooning techniques, ensures stable operation even under full load, making it a scalable option for expanding academic environments [22].

The proposed architecture also contributes to the existing body of knowledge on private cloud computing in higher education. Unlike large-scale public clouds, which introduce concerns over data privacy and security, the local cloud model ensures full control over academic data. This is particularly important in institutions like LIA University, where data sovereignty and regulatory compliance are significant considerations. The direct integration of the cloud system into academic workflows, particularly in practical sessions and research activities, aligns with the findings of studies that emphasize the value of tailored cloud solutions for enhancing educational experiences [23].

In conclusion, this research contributes to the growing body of literature on the application of cloud computing in education, especially in resource-constrained settings. The study demonstrates that LAN-based private clouds, when implemented with efficient resource management and appropriate virtualization technology, can provide a reliable, scalable, and secure alternative to traditional IT infrastructure in academic environments. Future research can explore the integration of advanced features such as containerization and multi-node clustering to further enhance the scalability and fault tolerance of such systems[24].

VI. CONCLUSION

This study presents a comprehensive design and implementation of a Local Area Network (LAN)-based cloud computing system utilizing microcomputers within the Informatics Study Program at LIA University. From a systems engineering and applied computer networking perspective, the proposed architecture demonstrates that localized cloud infrastructure can effectively support academic computing workloads without dependence on external internet connectivity. Empirical performance evaluations indicate consistently low latency (below 5 ms), high throughput exceeding 90% of theoretical LAN capacity, and controlled CPU and memory utilization within safe operational thresholds. These results confirm that the system is sufficiently robust to support core academic activities, including programming laboratories, virtualization-based practicums, and collaborative learning environments, while maintaining network stability and predictable resource allocation.

The novelty of this research lies in its contextual and architectural contributions. First, it introduces the use of microcomputers as dedicated cloud servers at the study-program level, diverging from conventional data center–centric or institution-wide cloud models. Second, the system implements a small-scale private cloud that operates entirely within a LAN environment, thereby minimizing operational costs, reducing latency, and improving data sovereignty an increasingly relevant concern in educational institutions. Third, the cloud infrastructure is directly integrated into informatics practicums and instructional workflows, enabling students to interact with real-world cloud and virtualization environments. This pedagogical integration bridges the gap between theoretical cloud computing concepts and hands-on experiential learning, enhancing both technical competence and systems thinking among students.

From a scientific contribution standpoint, this research provides a replicable low-cost architectural model for educational cloud deployment, particularly suitable for universities with limited infrastructure budgets. It also contributes empirical performance evidence of LAN-based private cloud systems, enriching the applied cloud computing literature with data-driven insights from an academic setting. Moreover, the study expands national scholarship on private educational cloud computing by demonstrating that effective cloud solutions do not necessarily require large-scale infrastructure. Instead, with appropriate design and resource management, microcomputer-based systems can deliver reliable cloud services. Future research directions include the integration of containerization technologies, high-availability mechanisms, and multi-node clustering to enhance scalability, fault tolerance, and long-term sustainability of localized academic cloud environments.

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