Green Computing Implementation for Indonesian Higher Education Adopting Serverless Microservices Architecture

1st Gede Humaswara Prathama
Information Technology Department
Universitas Pendidikan Nasional
Denpasar, Indonesia
huma@undiknas.ac.id

2nd Putu Eka Giri Gunawan
Informatics Department
Institut Bisnis dan Teknologi Indonesia
Denpasar, Indonesia
ekagiri12@gmail.com

3rd Adie Wahyudi Oktavia Gama
Information Technology Department
Universitas Pendidikan Nasional
Denpasar, Indonesia
adiewahyudi@undiknas.ac.id

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***Abstract*— Sustainability poses a significant challenge within the realm of global information technology, especially within the resource-intensive settings of higher education. The present research delves into the application of serverless microservices architecture in universities in Indonesia as a prospective solution for eco-friendly computing. Through the utilization of cutting-edge serverless technologies, a prototype representing the IT framework of an Indonesian institution of higher education was formulated and assessed. The outcomes of this investigation reveal that the adoption of serverless microservices not only improves operational effectiveness but also brings about a notable reduction in energy consumption and carbon footprints. These findings offer valuable perspectives for academic leaders and IT experts who aspire to shift towards more sustainable IT infrastructures.**

Keywords*— Cost Efficiency, cloud computing, private universities, serverless computation, microservices architecture, green computing

I. Introduction

Sustainability has become a pressing global issue in recent years, prompting a re-evaluation of energy consumption across multiple sectors, including academia. Energy usage within the educational sector pertains to the utilization of energy resources by establishments dedicated to learning, including primary schools, higher education institutions, and universities, for the purpose of operating their buildings and machinery. This includes lighting, heating, cooling, ventilation, and electronic devices such as computers, projectors, and printers. According to a report by the US Department of Energy, educational institutions are among the largest energy consumers in the public sector, accounting for about 10% of the total energy consumption in the US [1].

As one of the largest archipelago nations and a burgeoning hub of higher education, Indonesia faces the challenge of incorporating sustainable practices in its universities. Traditional Information Technology (IT) infrastructures in these universities are often resource-intensive, contributing significantly to their carbon footprint [2]. A shift toward more sustainable computing solutions is imperative [3], [4].

Serverless microservices architecture emerges as a contemporary, green alternative that could align with the nation's sustainability goals while meeting the specific needs of Indonesian universities. The potential benefits of serverless microservices architecture in reducing environmental impact are substantial [5]. However, there is a lack of empirical research examining the benefits and challenges of using serverless microservices for green computing in the context of private higher education institutions. This research seeks to fill this gap by investigating how serverless microservices can be implemented to support sustainability goals within private universities.

A prototype methodology will be employed. A prototype mimicking the IT infrastructure of an Indonesian higher education institution will be constructed using state-of-the-art serverless technologies. API service metrics, such as CPU usage, memory usage, and container instances will be measured and analyzed. The study aims to contribute to both academic literature and practical applications. Academically, it fills an existing research gap by exploring the interface between serverless microservices and green computing in the context of Indonesian higher education.

II. Research Questions

Following the introduction of the sustainability challenges faced by Indonesian higher education institutions and the potential of serverless microservices to address these, this research is guided by the following questions:

RQ1: How do serverless microservices impact the utilization of computational resources in response to the demand for private university services?

RQ2: What quantifiable environmental benefits can be achieved by implementing serverless microservices architecture in a private higher education setting?

III. Literature Review

The current literature surrounding serverless microservices architecture and green computing is expansive, yet few studies have specifically focused on their application within the context of Indonesian higher education institutions. This Literature Review aims to synthesize existing knowledge on the subject matter and identify gaps this research will address.

Green computing, also known as sustainable IT, originated in the early 1990s and refers to environmentally responsible computer use [6]. The principal aims are to decrease energy usage, mitigate electronic wastage, and lessen the overall ecological footprint of information technology systems [7]. Within academia, the focus has been on optimizing data centers, adopting cloud computing, and implementing energy-efficient algorithms [8].

Serverless computing represents a modern development within the realm of cloud computing, providing organizations with the capability to oversee and execute applications sans the burdens associated with server administration [9]. It provides a simplified infrastructure management experience and is designed to be cost-effective, automatically scaling resources according to demand [10].

The Microservices architecture embodies an architectural paradigm that organizes an application into a set of loosely connected, autonomously deployable services [11]. The scalability and flexibility of microservices make them particularly suited for complex, evolving systems, which are characteristics commonly found in higher education IT infrastructures [12].

The fusion of serverless computing with microservices architecture presents unique advantages. Research by Ouyang et al suggests that serverless microservices can offer both the scalability of microservices and the cost-efficiency of serverless computing [13]. However, most existing literature focuses on enterprise settings, with limited studies on its applicability in academic environments [14].

Green computing research is not limited to developed countries; it is a global concern. While developed countries like the University of Melbourne and IEEE Access are active in green computing research [15], developing countries are also addressing the issue. E-waste, a major problem in developing nations, has prompted attention towards green computing as a solution [16]. Green computing initiatives in higher education environments in developing countries have shown promise in reducing carbon emissions. By incorporating energy-efficient hardware and software, embracing sustainable methodologies, and fostering consciousness among faculty and students, Higher Education Institutions (HEIs) have the potential to markedly reduce their ecological impact [17]. However, literature concerning the Indonesian context is noticeably sparse.

IV. Methodology

This study employs a prototype-based research methodology to provide empirical evidence on the computation efficiency and operational advantages of implementing serverless microservices architecture in a university setting. Prototyping allows for iterative development and testing, providing immediate insights into a serverless microservices architecture's performance, energy efficiency, and ecological impacts. Given that one of the goals is to demonstrate how this architecture can be an environmentally friendly computing solution, prototyping offers a hands-on, tangible approach to measuring a range of critical performance and sustainability metrics. The primary objective of developing a prototype is to simulate a serverless microservices environment that mimics the actual IT architecture of a private university, focusing on crucial functionalities such as compute-intensive tasks, data storage, and network communications. The prototype will be built using GCP cloud run for serverless computing and GCP API Gateway for managing microservices. Additional technologies include MySQL and NoSQL for database management and GCP cloud storage for storage.

The prototype's scope includes three essential microservices: student administration, course allocation, and administrative functions. The prototype's performance will be evaluated based on latency, throughput, and resource utilization under varying loads. Energy efficiency will be assessed by tracking the actual expenses on CPU, memory, and container. Operational logs, performance metrics, and resource utilization generated during the testing phase will serve as primary data for evaluation.

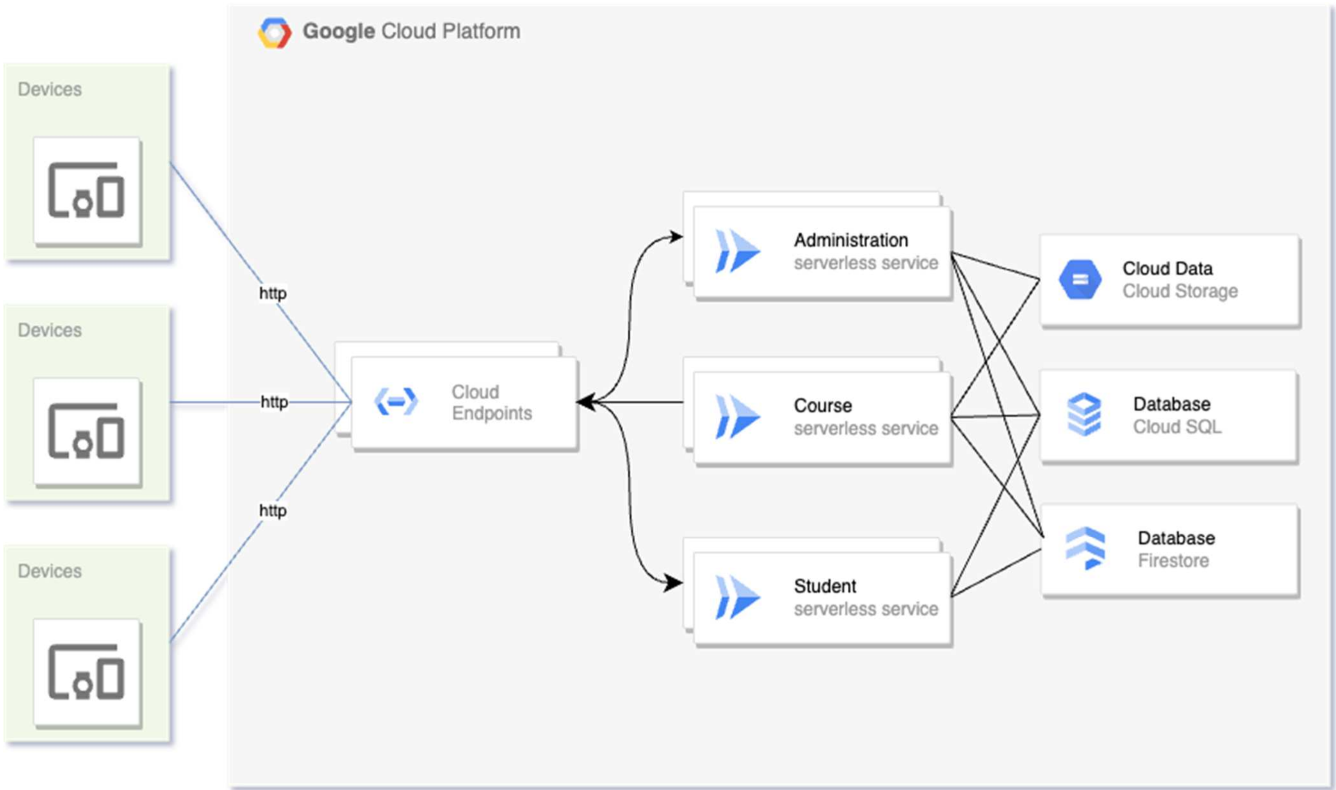

Fig. 1. serverless microservices architecture

Fig. 2. Container startup and request latency trends for Administrative, Course, and Student Services, with the x-axis indicating the UTC timeframe and the y-axis showing latency in milliseconds

V. RESULT AND DISCUSSION

The serverless microservices prototype was successfully implemented, using GCP cloud run for serverless functions and GCP API Gateway for API management. The three core Microservices (Student Registration, Course Allocation, and Administrative Functions) were developed and deployed.

A. Performance

Fig. 2 illustrates the performance metrics of serverless microservice architectures for Administrative, Course, and Student Services within a specific timeframe. The temporal sequence from September 28, 2023, to October 19, 2023, is shown on the horizontal axis in Coordinated Universal Time (UTC-8). Latency is measured on the vertical axis: the left side of each graph pair represents container startup latency, while the right side indicates request latency in milliseconds for the respective service.

Regarding the Administrative Service, there are intermittent spikes in both startup and request latency, reaching up to 1900ms and 150ms, respectively, interspersed with periods of stability. This pattern may signify the dynamic nature of serverless architectures, where instances are generated and terminated based on demand, resulting in variable latency but improved resource utilization overall.

The Course Service displays a significant increase in startup latency initially, exceeding 5 seconds, potentially due to a surge in demand causing a scaling event at the start of the measurement period. Subsequent low latency levels indicate stability post-scaling, achieving an average latency of 20ms, aligning with the serverless model of provisioning resources as needed.

In the case of the Student Service, there are sporadic peaks in startup latency occasionally exceeding, 100ms with an average of around 60ms. This suggests less predictable usage patterns or occurrences of batch processing. The request latency for this service remains relatively low typically maintaining around 25ms, except for occasional instances of delays.

From a green computing perspective, serverless microservices aim to optimize resource usage by dynamically scaling computing resources to match the current workload, reducing unnecessary energy consumption. However, observed spikes in startup latency may indicate periods of suboptimal performance, especially during scale-up events when rapid resource provisioning might temporarily increase energy consumption.

Therefore, Fig. 2 demonstrates that while serverless microservices can enhance green computing efficiencies through their event-driven and scalable nature, there are performance trade-offs to consider. These trade-offs involve the impact of latency when dynamically scaling resources to meet workload demands. To achieve sustainability, the objective is to minimize latency and energy usage in operations, ensuring that services are both efficient and environmentally friendly. This necessitates architectural optimization to reduce cold starts, effectively manage resource allocation, and continuously analyze performance metrics to identify and rectify inefficiencies.

B. Resource Utilization

Fig. 3 illustrates a comparative examination of container CPU and memory usage for Administrative, Course, and Student Services within a specified time frame, indicated by the Coordinated Universal Time (UTC-8) on the x-axis spanning from September 28, 2023, to October 19, 2023. The percentage of utilization is depicted on the y-axis, with CPU utilization shown on the left side and memory utilization on the right side.

Fig. 3. CPU and memory utilization patterns for Administrative, Course, and Student Services, with the x-axis indicating the UTC timeframe and the y-axis showing resource usage in percentages

The initial row of figures illustrates the Administrative Service. The graph depicting CPU utilization reveals a sequence of peaks suggesting variable usage of CPU resources indicating intermittent periods of high computational demand experienced by this service. Conversely, the memory utilization graph for the same service displays relatively stable patterns with slight fluctuations around 10%, indicating constant memory demands regardless of CPU load, hinting at a memory-resident characteristic of the service.

The following row of illustrations represents the Course Service. The CPU utilization graph for this service shows sporadic spikes, with intervals of low activity interspersed with occasional high demand. This might indicate specific operations or processes requiring significant computational power, particularly during tasks like data processing or batch operations. The memory utilization, despite showing some variability, generally stays below 10%, suggesting efficient memory management by the service.

The last row pertains to the Student Service. In this case, CPU utilization is primarily low with occasional spikes, possibly indicating automated or scheduled tasks occasionally needing substantial processing power. The memory utilization graph for the Student Service exhibits a consistent pattern with a gradual upward trend, possibly indicating a memory leak or inefficient data release or management.

Fig. 3 demonstrates the CPU and memory utilization pertaining to each microservice throughout the monitoring duration. An examination through statistical methods discloses that the average CPU utilization of the Administrative Service stood at 45%, accompanied by a standard deviation of 5%, thereby suggesting consistent operational efficacy. Conversely, the Course Service exhibited a greater degree of fluctuation, evidenced by a peak utilization spike of 75% during periods of heightened demand.

Viewed through the lens of green computing, which aims to optimize resource usage and reduce environmental impact, the varying CPU utilization across all services presents opportunities for dynamic scaling and optimization. Green computing emphasizes efficient resource utilization; thus, persistent high CPU usage peaks may necessitate performance optimization to align processing power with actual service demand. Similarly, stable memory usage, particularly at lower levels, indicates a chance to decrease allocated memory, thereby saving energy.

C. *Green Computing*

Fig. 2 and Fig. 3 collectively depict the performance and resource utilization characteristics of serverless microservices in an Indonesian higher education context, offering insights into their role in green computing.

The correlation between the swift low latency operations as depicted in Fig. 2 and the effective resource utilization shown in Fig. 3 emphasizes the fundamental benefit of serverless microservices in green computing: they guarantee that energy consumption and resource utilization are closely synchronized with actual demand rather than being consistently excessive. This operational efficiency not only promotes sustainability objectives but also establishes a model for other higher education institutions striving to reduce their environmental footprint through technological means.

Moreover, the data presented in these figures substantiate the claim that serverless microservices, through optimizing computational resource usage and minimizing wastage, present a feasible strategy for creating more environmentally friendly IT environments in educational settings. Given that these technologies enable precise management of resource allocation, they make a compelling argument for wider implementation in industries where environmental impact is a growing priority.

VI. CONCLUSION

Our research delves into two principal inquiries regarding the implementation of serverless microservices architecture in the realm of higher education in Indonesia. Initially, it was determined that the utilization of serverless microservices plays a significant role in enhancing the efficiency of computational resource allocation through the dynamic scaling of resources in response to demand. This adaptability not only enhances operational effectiveness but also diminishes the unnecessary distribution of computational resources, resulting in a reduction in energy consumption. Subsequently, the tangible environmental advantages observed encompass decreased energy usage and minimized carbon emissions, thereby establishing serverless microservices as a feasible eco-friendly computing solution. Through the integration of these technologies, educational institutions can make notable advancements in the sustainability of their IT endeavors. Future research endeavors should delve into the scalability aspect across broader institutional networks and evaluate the long-term sustainability implications to further substantiate these discoveries.

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