

## Comparison of cloud computing providers for development of big data and internet of things application

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### ABSTRACT

The improved technology of big data and the internet of things (IoT) increases the number of developments in the application of smart city and Industry 4.0. Thus, the need for high-performance cloud computing is increasing. However, the increase in cloud computing service providers causes difficulties in determining the chosen service provider. Therefore, the purpose of this study is to make comparisons to determine the criteria for selecting cloud computing services following the system architecture and services needed to develop IoT and big data applications. We have analyzed several parameters such as technology specifications, model services, data center location, big data service, internet of things, microservices architecture, cloud computing management, and machine learning. We use these parameters to compare several cloud computing service providers. The results present that the parameters able to use as a reference for choosing cloud computing for the implementation of IoT and big data technology.

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## 1. INTRODUCTION

With current technological advancements, such as the internet of things (IoT), cyber-physical systems (CPS), and blockchain that are applied to industry era 4.0 [1], in the field of internet of things, various studies are showing that the IoT market will grow rapidly. It is estimated that the development of the number of IoT devices used in 2025 will reach 64 billion [2]. In other research by Cisco appraised that the quantity of embedded systems device associated with the Internet in 2020 will arrive at 50 billion [3]. The ability of IoT systems to integrate with various fields is the reason why the number of IoT technology implementations is increasing rapidly [4], [5].

Because of that, the need for cloud computing is increasing [6]. Cloud computing is a computing model that makes it possible to access information or data through the internet network comfortably and on-demand to a collection of computing resources that can be configured together [7]. In general, the types of cloud computing services consist of infrastructure as a service (IaaS), platform as a service (PaaS) and software as a service (SaaS). Several studies that estimate the development of the size of the global cloud computing market, such as research published by TC 1228 showing that from USD 272.0 billion in 2018 it is estimated to be USD 623.3 billion in 2023 [8], [9]. With this large market, many cloud computing providers provide services that facilitate development, both in functional and non-functional needs.

There are research on the comparison of cloud computing, such as research conducted by Maurizio Naldi and the team shows a comparison method of cloud computing providers based on the price of the services provided [10]. Meanwhile, research published by Filiopoulou [11] presents an approach that focuses on calculating service efficiencies such as computation optimized instances, memory optimized instances, and storage optimized instances [11]. Other publications conducted by Junjie Peng use the functional requirements of the cloud computing services provided [12]. But there are no other comparison parameters such as server location, this is related to the rules of data center usage that must exist in the country, such as the rules in Indonesia. Therefore, the need a comparison parameter is needed by the developer or user in choosing the provider and optimal cloud computing services, according to the needs and existing rules for build an IoT application that is integrated with big data services.

This journal is divided into several sections. Section 1 describes the need for cloud computing for IoT systems which is the background problem of this research. In section 2, we show a comparison method for cloud computing service providers that have been worked on by previous researchers. In section 3, we describe the comparison method of cloud computing service providers proposed in this study. The results of the comparison process are described and discussed in section 4. Finally, in section 5 we explain the conclusions of this research and the future works that we plan to do.

## 2. RELATED WORKS

There are several studies about the comparison of cloud computing providers that proposed some parameters or criteria used to discuss the performance of cloud service for cloud computing providers selection. The most commonly shown approach is the price parameter [10], [13], [14], research by Maurizio Naldi and Groups [10] about reviewed and analyzed the estimating plans of a determination cloud service utilizing the unit cost with two strategy approaches, the first technique utilized a pointwise examination for each estimation of capacity volume, by distinguishing the least expensive cloud supplier for every limit section. The second strategy utilizing a two-part tariff approximation and Pareto-predominance criteria for all the evaluating plans considered and utilize that guess to arrange them. As research conducted by Li *et al.* [15] shows the relationship between the cost of cloud computing with the performance obtained using two metrics, namely cluster computing, and storage services. This method first uses monetary costs to complete benchmarking tasks to capture the effectiveness of virtual instance costs. Then, use the costs of each storage operation to compare the cost-effectiveness of different storage services.

Other researchers, Brebner and Liu [16] showed the parameters that cloud computing services should have in more detail than previous research. The parameters used in the study are Server performance variability, local area network (LAN) latency and bandwidth, and WAN latency and bandwidth. Research conducted by Pierleoni *et al.* [17] and the team had compared 3 popular cloud computing providers such as Amazon Web Services, Google Cloud Platform and Microsoft Azure regarding IoT services provided by each provider. Therefore, in this research, we conduct analysis and compilation using several parameters that able to affect the development of IoT and Big Data systems, especially in cloud computing services provided by several providers.

## 3. RESEARCH METHOD

In the current IoT technology development, many cloud computing service providers appear both on an international scale such as Amazon Web services (AWS) and Google cloud platform (GCP), as well as local Indonesian cloud computing service providers such as CloudKilat. Each cloud computing service provider has different technology, features, and data center locations. Therefore, in this study, we aim to compare the features provided by each cloud computing service provider to be used as a cloud computing medium in developing an IoT system that is integrated with big data services to support the needs of computing services such as smart city, or industry 4.0. Therefore, we propose several parameters that able to used for cloud computing services comparison which consist of:

### 3.1. Technology specifications

Each cloud computing provider uses a physical device engine that functions as a data center for the storage and distribution of the server [18]. Typically, cloud computing providers offer different node flavors to optimize computing performance, input/output (I/O), or amount of memory. Therefore, in this study, we consider the server technology specifications used by cloud computing providers.

### 3.2. Model services

The use of pay-per-usage methods in cloud computing services has led to the emergence of several types of service types provided by cloud computing providers [19]. The modeling used includes

infrastructure as a service (IaaS), software as a service (SaaS), and platform as a service (PaaS). So, in this study, we use the service model as a comparison parameter.

### 3.3. Data center location

Each cloud computing service provider provides data center locations in various places, but not all provide data center locations in every country, the location of the data center affects network latency [20]. There are 2 things to consider when choosing a cloud computing service provider based on the location of the data center. If the system requires very low latency, it is necessary to choose a data center location that is in the same country or closest to the location of the device or user of the IoT system that has been developed. The second reason is about the strict policy of the local government which must choose the location of the data center which is located in the same country as the device location device or IoT system user that has been developed.

### 3.4. Big data service

IoT system is a system that retrieves device data continuously at a certain time and produces a lot of data with various data content. Thus, the IoT system requires big data services to accommodate this data, this is because of the ability of big data services to store large amounts of data, vary and able to analyze data more efficiently [21]. Currently, big data services are developing into a more complex architecture to be used in various requirements, such as real-time analysis processes that are often used by IoT system developers. Big data frameworks that are often used by developers such as Apache Spark and Hadoop.

### 3.5. Internet of things

IoT platforms are currently developing in the market [22], causing several cloud computing services to provide special services for IoT systems. Thus, in this research, we use the internet of things parameters to compare services related to IoT technology such as device management, connectivity management for message management, interfaces for data visualization to services for analytical IoT data obtained.

### 3.6. Microservices architecture

The microservice system in cloud computing services functions as a computational service architecture that divides and groups the services used by users in the form of interconnected microservices. This architecture aims to simplify the complex large-scale system development process and improve the performance of the system. This is because the IoT system development process is dynamic and requires real-time data processing.

### 3.7. Cloud computing management

In the development of the IoT application system, it allows for many situations where the development hires one or more server computers, both in the form of containers or virtual machines. So that cloud computing services generally provide at least a management-related service that allows users to create, monitor, and control cloud computing sessions [23]. Therefore, the parameters about the services used by cloud computing providers in helping users to server management need to be considered. Besides, the existence of the microservice concept applied to an IoT application caused a delay in the role of cloud computing management services. Beside cloud computing, IoT also depend on edge computing. The benefits of edge computing mean that application can move their infrastructure from centralized location to the edge and run application closer to the end user.

### 3.8. Machine learning

In developing an IoT application that is integrated with big data, the implementation of machine learning services is increasing. Therefore, we use machine learning service parameters in this study to compare services used by cloud computing providers, namely how cloud computing providers provide machine learning services as analytic services both in real-time or offline (batch) form. This includes the types of algorithms that can be used such as unsupervised learning, supervised learning and reinforced learning [24]. In addition to using the comparison method based on the parameters mentioned earlier, in this research, we also present an overview of some popular cloud computing providers. Following is an overview and analysis of the specifications, types of services and features provided by cloud computing providers as follows.

## 4. RESULTS AND DISCUSSION

In this section, we present the experimental results and analysis of the cloud computing service provider comparison process using the parameters proposed in this study. Cloud service providers that have been compared include Alibaba, AWS, GCP, Microsoft Azure, and CloudKilat.

### 4.1. Alibaba cloud

Alibaba provides a special service for IoT systems, namely Alibaba cloud IoT platform [25]. This service provides communication services between the IoT platform and the device nodes of users with low latency and security services to ensure the security of data communications with various measures to ensure the security of communications carried out by users. The advantage offered by the Alibaba Cloud IoT Platform service is the system's ability to integrate with other Alibaba cloud services or application programming interface (API) systems that have previously been developed by users. Besides, this service provides regulatory features to make it easier for users to develop faster computing service systems, such as in the process of collecting and processing user IoT data. Until this paper was written, IoT and data visualization services servers from Alibaba cloud still in Singapore.

### 4.2. Web services

Amazon web services (AWS) is one of the popular cloud computing service providers, AWS provides several services for IoT system development [26], [27] such as communication, processing and storage services integrated with big data technology. The Big Data service that AWS provides consists of several types of big data services such as Amazon Kinesis, AWS Lambda, Amazon EMR, Amazon QuickSight, Amazon Athena and Amazon Elasticsearch Service. Therefore, users can choose the type of Big Data service according to the needs of the system to be developed. In communication and data flow processing, AWS provides several services for streaming data, where on these services users can build an analysis system on the data stream process (data stream analytics). Thus, users can create real-time data processing and analysis systems such as data prediction systems, application logs or IoT telemetry data that run without waiting for all data to be collected. Data that has been processed can be distributed to data lake services, Big Data or other applications developed by users.

AWS provides storage services with other methods such as AWS S3, which is data storage services distributed across several nodes in cloud computing. In addition to the services for implementing MapReduce, users can take advantage of the elastic map reduce (EMR) service. Amazon EMR is a distributed computing service for processing and storing data using Apache Hadoop, an EMR service enabling systems to distribute and process data across user clusters on AWS. Through the EMR service, users able to use Hadoop tools like Spark and Hive to perform big data analytics. S3 and EMR services can be used as alternative services for users who are unable to develop a Big Data and Hadoop service system in a cluster. However, users must consider bandwidth usage. There is an extract, transformation and load (ETL) service that can make it easier for users to process data such as moving or combining data between data stores.

### 4.3. Google cloud platform

One of the cloud computing service providers that are gaining popularity is Google cloud platform (GCP) [28]. GCP offers cloud computing services that provide integrated data analytics services at scale for greater performance and more efficiency costs. The GCP architecture allows users to develop analytical applications using several popular programming languages such as Python, Java, C #, Node.js, Ruby or PHP.

Big data services provided by GCP consist of BigQuery, cloud Pub/Sub, data studio, cloud composer, cloud storage, cloud dataproc, cloud dataprep, cloud data fusion, cloud dataflow. The advantages offered by GCP are the speed in analyzing data using ANSI SQL and providing an API to integrate the system with other applications that have been developed by users. The system stability offered by GCP allows the distribution and processing of data to be carried out faster without reducing the accuracy and functionality of the data. Besides, GCP provides Business Intelligence tools in the form of a dashboard. The infrastructure on the GCP service is developed with security and system workload in mind so that users can develop a wider range of data analysis applications.

### 4.4. Microsoft Azure

Microsoft Azure is a cloud computing service developed by Microsoft [29]. Microsoft Azure has several service products that implement Big Data and can be used for IoT systems [30]. Microsoft Azure IoT Suite is a special service provided by Azure as a cloud computing solution for IoT system development. With this service, users able to integrate IoT device data sent to the Azure server with data analytics and machine learning systems. Azure HDInsight service is a data distribution service solution using the Hadoop tool offered by Azure with the advantages offered such as cost-effective and fast processing of massive amounts

of data. This service is supported by several commonly used data processing tools such as Spark, Hadoop, Kafka, LLAP, R, HiveStorm and others. Besides, the Azure HDInsight service allows users to develop various data processing scenarios such as the extract, transform, and load (ETL) method which able to process data from various types of data sources and store them in structured data storages. The data streaming service on Azure HDInsight allows users to receive data from various types of devices.

Microsoft Azure provides Azure data share services for the process of sharing data between users safely and easily, where users can share new data, invite other users or partners to share data. However, data owners can easily control and supervise other users who access the data. With these advantages, users can collaborate with other parties so that they can enrich the analytical process on the system being developed.

#### 4.5. CloudKilat

CloudKilat [31] is a cloud computing service aimed at Indonesian consumers. CloudKilat was launched in September 2013 by PT Infinys System Indonesia. CloudKilat services are divided into two types, CloudKilat and Infinyscloud. CloudKilat is specifically for web developers, individual businesses, startups, and MSMEs, while Infinyscloud (managed services) is aimed at enterprise-class businesses.

Infinyscloud has advantages in terms of fully managed services, flexible billing and in-depth technical consultations so that users get peace of mind with Infinyscloud's cloud infrastructure. Infinyscloud users will be able to enjoy world-class cloud services owned by AWS, Google and Microsoft which will be bundled with services managed by Infinyscloud's expert team so that users get a total solution. With fully managed services, 24-hour customer service support, and data centers located in Indonesia. Besides, the presence of Infinyscloud's local data center guarantees data sovereignty that meets PP No.82 of 2012.

#### 4.6. Table result

We have made a comparison using this parameter which is shown in Table 1 which is in the first appendix. Table 1 shows that almost all cloud providers provide high computing resources. GCP has the highest specifications among the five cloud providers, where GCP provides up to 11 TB RAM and is equipped with the latest GPU resource, NVIDIA Tesla T4, which has the highest GPU Counting Ability than any other GPU. In terms of services, all cloud providers provide almost all types of cloud computing services (IaaS, PaaS, and SaaS) except CloudKilat. For cloud management, Azure, AWS, and Alibaba provide specific cloud management products like microservice and dedicated servers. GCP offers products that are simpler than others to serve the needs of cloud services and CloudKilat has Kilat VM 2.0 to provide VPS. Alibaba, AWS, GCP, and Azure have also implemented microservices in their services. Most of them use Kubernetes to regulate the use of infrastructure through the efficient distribution of computing resources in various processes in microservices. In terms of IoT and big data services, Azure and AWS have products that provide more specific functions compared to GCP and Alibaba, from data collection to data analysis. GCP and Alibaba wrap their services in one complete package. To serve machine learning needs, Amazon and GCP provide more case options than Alibaba and Azure. From price comparison, GCP offers lower prices compared to other cloud providers with the same specifications. One important point from cloud providers is the location of data centers. Of all the cloud providers being compared, only Alibaba and CloudKilat have data centers located in Indonesia. This can increase the confidence of cloud users to entrust their data to the cloud provider.

### 5. CONCLUSION

Based on the results and analysis conducted to compare several cloud computing providers that are often used by developers, both global providers, and local Indonesian providers, namely Alibaba, AWS, GCP, Microsoft Azure and CloudKilat using several parameters such as technology specifications, service models, data center locations, big data services, the internet of things, micro service architecture, cloud computing management, and machine learning. The results of cloud computing providers comparison describe that almost all cloud providers provide high computing resources. All cloud providers provide almost all types of cloud computing services (IaaS, PaaS, and SaaS), except CloudKilat. Alibaba, AWS, GCP, and Azure have implemented a microservice architecture use Kubernetes to regulate infrastructure and resource. But overall features and specifications, Azure and AWS have products and features that are more specific in implementing IoT and big data technology when compared to other providers. However, based on server location, to increase user confidence, Alibaba Cloud and CloudKilat have the advantage of being located in Indonesia. Therefore, based on the previous statement, it can be said that the parameters developed in this study can be used as a reference for selecting cloud computing providers by developers in developing IoT and big data applications. In future work, we will compare cloud computing service providers by testing the IoT and big data systems using the services and features outlined in this research.

## APPENDIX

Table 1. Comparison result

Parameters	Alibaba Cloud	AWS	GCP	Azure	CloudKilat
Technology Specifications	Intel Xeon Scalable Processor (Cascade Lake), Up to 768GB Memory, SSD Storage, Network Bandwidth: 25 Gb/s, NVIDIA Tesla V100	Intel Xeon Scalable Processor (Cascade Lake), Up to 768GB Memory, SSD Storage, Network Bandwidth: 25 Gb/s, NVIDIA Tesla V100	Intel Xeon Scalable Processor (Cascade Lake), Up to 11,776TB Memory, SSD Storage, Network Bandwidth: 20 Gb/s, NVIDIA Tesla T4	Intel Xeon Scalable Processor (Cascade Lake), Up to 4TB Memory, SSD Storage, NVIDIA Tesla V100	Intel Xeon Scalable Processor (Cascade Lake), Up to 32GB Memory, SSD Storage
Services Internet of Things	IaaS, PaaS, SaaS IoT Platform, Link Kit SDK	IaaS, PaaS, SaaS AWS IoT Greengrass, FreeRTOS, AWS IoT Core, AWS IoT Device Defender, AWS IoT Device Management, AWS IoT Analytics	IaaS, PaaS, SaaS Cloud IoT Core	IaaS, PaaS, SaaS Azure IoT Central, Azure IoT solution accelerators, Azure IoT Edge, Azure IoT Hub, Azure Digital Twins, Azure Time Series Insights, Azure Sphere, Azure Maps	IaaS, PaaS -
Big Data	MaxCompute, E-MapReduce, DataWorks, Realtime Compute, Elasticsearch, Data Lake Analytics, DataV, Quick BI	Amazon Athena, Amazon CloudSearch, Amazon Elasticsearch Service, Amazon EMR, Amazon Kinesis, Amazon Managed Streaming for Apache Kafka, Amazon Redshift Formation	BigQuery, Cloud Dataflow, Cloud Dataproc, Cloud Pub/Sub, Cloud Data Fusion, Cloud Composer, Data Catalog, Google Data Studio, Google Sheets, Cloud Dataprep, Cloud Data Transfer	Azure Databricks, Azure Stream Analytics, Azure Synapse Analytics, HDInsight, Data Factory, Data Lake Analytics, Azure Analysis Services, Azure Data Lake Storage, Azure Data Explorer, Azure Data Share	-
Cloud Management	Elastic Compute Service, Simple Application Server, Elastic GPU Service, Auto Scaling, Server Load Balancer, Container Service for Kubernetes, Elastic Container Instance, Container Registry, ECS Bare Metal Instance, Super Computing Cluster, Web App Service, Function Compute, Batch Compute, Dedicated Host	Amazon Elastic Compute Cloud (EC2), Amazon Lightsail, Amazon Elastic Container Service (ECS) Amazon Elastic Kubernetes Service (EKS), AWS Lambda, VMware Cloud on AWS, AWS Local Zones, Amazon EC2 Spot Instances, Amazon EC2 Autoscaling, AWS Batch, , Elastic Load Balancing (ELB)	Compute Engine, App Engine, Cloud GPUs, Migrate for Compute Engine, Preemptible VMs, Shielded VMs, Sole-tenant nodes	Virtual Machines, Azure Kubernetes Service (AKS), Service Fabric, App Service, Container Instances, Batch, SQL Server on Virtual Machines, Cloud Services, SAP HANA on Azure Large Instances, Azure Functions, Virtual Machine Scale Sets, Linux Virtual Machines, Windows Virtual Desktop	Kilat VM 2.0, Kilat Storage, Kilat Plesk, Kilat Backup, Kilat Hosting, Kilat Iron
Machine Learning	Image Search, Machine Translation, Machine Learning Platform For AI, Intelligent Speech InteractionBeta  GCP	Amazon SageMaker, Amazon Augmented AI, Amazon CodeGuru (Preview), Amazon Comprehend, Amazon Lex, AWS Deep Learning AMIs, AWS Deep Learning Containers, AWS DeepComposer, AWS TensorFlow on AWS	AI building blocks, AutoML, Vision AI, Video AI, Cloud Natural Language, Dialogflow, AutoML Tables (beta), AI Platform Deep Learning VM Image, AI Platform Deep Learning Containers (beta), AI Hub (beta), Cloud GPUs, Cloud TPU, TensorFlow Enterprise	Cognitive Services, Azure Bot Service, Machine Learning, Azure Databricks, Azure Cognitive Search	-
Microservices Architecture	Kubernetes Cluster	AWS ALB, Amazon ECS, Amazon EKS, Azure Lambda	Google Kubernetes Engine	Azure Kubernetes Service	-

Table 1. Comparison result (continue)

Parameters	Alibaba Cloud	AWS	GCP	Azure	CloudKilat
Data Center	Global, Local	Global, Local (Jakarta,	Global, Local (Jakarta,	Global	Local (Jakarta)
Location	(Jakarta)	est 2021)	est 2021)		
Price (USD)	\$1,554.9 /month	\$1,701.51 /month	\$856.98 /month	\$1,332.46 /month	\$180.93 /month*

\*Specification: 32 vCPUs, 32GB RAM and 320GB SSD

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