

# THE ROLE OF CLOUD PROVIDERS IN IOT SERVICES

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## ABSTRACT

*Cloud providers play a key role in IoT services, as they provide the necessary infrastructure, platforms, and services to connect and manage IoT devices and applications. Simply Cloud providers offer These Cloud providers a scalable and flexible computing environment that allows IoT devices to communicate with each other, process data and securely store information. There are several Cloud providers in the market that offer IoT-specific solutions and services such as Amazon Web Services, Microsoft Azure, Google Cloud Platform, IBM Cloud, and Alibaba Cloud. These Cloud Providers offer a range of services specific to IoT, data analytics, and security. This paper compares four Cloud providers, and their advantages and disadvantages. The development of the four Cloud providers and their trends in historical development are also presented with the help of graphs. Finally, a model was created based on three criteria: services, security and big data processing.*

## KEYWORDS

*Cloud, IoT, Amazon Web Services, Microsoft Azure, Google Cloud Platform, IBM Cloud, Alibaba Cloud.*

## 1. INTRODUCTION

The number of Internet of Things (IoT) devices is doubling every five years reaching 8.7 billion connected devices worldwide by the end of 2022. (Source: <https://www.statista.com/statistics/1183457/iot-connected-devices-worldwide/>). Due to the rapid increase in the number of IoT devices, it is imperative to look for new complete solutions for secure storage, processing, and modelling of Big Data. It is important that these solutions also give support to clean energy transition. Cloud Services make this possible.

IoT services refer to various offerings and solutions that enable businesses and individuals to connect and manage a network of interconnected devices and systems. These services typically include a combination of hardware, software, and cloud-based platforms that enable seamless integration and management of IoT devices.

Cloud's various concepts for the USA ecological future can reduce CO2 emissions by 59 million tons per year which equates to taking 22 million cars off the road [1].

All these lead to the exploding use of cloud services with enterprise applications migrating to the Cloud and organizations becoming more cloud-native in their deployments. Furthermore, Gartner's study shows that it expects more than 15 billion IoT devices will connect to Cloud services by 2029. The rapid pace of innovation in the cloud makes it a platform for new digital services and existing traditional workloads alike, which is why 40% of all enterprise workloads will be deployed in Cloud Services Platforms by 2023, up from only 20% in 2020 [2].

On the other hand, the market of Cloud services providers is constantly growing, and participants offer almost similar kinds of services that can provide a solution to meet customer needs and requirements. Key requirements when designing high- performance real-time IoT big data solutions are Operational Excellence, Security, Reliability, Performance Efficiency, and Cost Optimisation. These requirements are covered to varying degrees by different Cloud providers. Therefore, it is important to analyse them and find the most suitable CSP (Cloud Service Providers) for building or migrating an IoT system generating real-time Big Data, which stores, processes, models and visualizes the collected data [3].

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The model presented in this study will facilitate the process and save users time and resources in choosing a Cloud Service Providers. This is done by guiding the process and presenting criteria to be considered in their decision. The purpose of using the model presented in the study is to find the best option for designing high- performance, real-time IoT Big Data solutions in a Cloud environment.

## **2. BASIC COMPARISON OF CLOUD PROVIDERS**

There are several main cloud providers available in the market: AWS IoT, Azure IoT Hub, IBM IoT Solution, and Alibaba Cloud IoT. Each provider has its strengths and weaknesses and choosing the right one depends on your specific needs and requirements.

Alibaba provides a special service for IoT systems, namely Alibaba cloud IoT platform [4]. 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.

Web services Amazon web services (AWS) is one of the popular cloud computing service providers, AWS provides several services for IoT system development [5], [6] 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 Lamda, 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.

One of the cloud computing service providers that are gaining popularity is Google cloud platform (GCP) [7]. 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.

Microsoft Azure is a cloud computing service developed by Microsoft [8]. Microsoft Azure has several service products that implement Big Data and can be used for IoT systems [9]. 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.

Table 1. Comparison of cloud providers

Cloud Provider	Pros	Cons
Azure IoT Hub	<ul style="list-style-type: none"> <li>- <b>Scalability:</b> Azure IoT Hub can work with millions of devices and dynamically meet your needs.</li> <li>- <b>Security:</b> Azure IoT Hub provides strong security features such as device authentication, access control, and data encryption to keep your data and devices safe.</li> <li>- <b>Easy integration:</b> Azure IoT Hub integrates seamlessly with other Azure services such as Azure Stream Analytics, Azure Functions, and Azure Event Grid.</li> <li>- <b>Flexible management:</b> Azure IoT Hub provides a device management interface that makes it easy to configure, monitor, and manage your IoT devices.</li> <li>- <b>Real-time data analytics:</b> Azure IoT Hub lets you analyze and visualize your IoT data in real-time, enabling you to make faster data-driven decisions.</li> <li>- <b>Cost-effective:</b> Azure IoT Hub offers a pay-as-you-go pricing a comparative overview , allowing you to pay only for the services you use.</li> <li>- <b>Language platform:</b> C#, Java, Python, Node.js.</li> </ul>	<ul style="list-style-type: none"> <li>- <b>Cost:</b> Depending on the size and scope of the IoT project, the cost of using Azure IoT Hub can quickly add up. You will have to pay for the data sent to and from the center, as well as for all additional services.</li> <li>- <b>Complexity:</b> Azure IoT Hub is a powerful tool, but it can also be quite complex to set up and manage.</li> <li>- <b>Support:</b> Microsoft offers extensive documentation and support for Azure IoT Hub, but it can still be challenging to troubleshoot more complex issues. For non-Microsoft devices it is limited.</li> </ul>

Cloud Provider	Pros	Cons
AWS IoT	<ul style="list-style-type: none"> <li>- <b>Scalability:</b> AWS IoT enables scalable IoT applications with the ability to connect billions of devices and process trillions of messages.</li> <li>- <b>Security:</b> AWS IoT provides robust security features to ensure secure communication between devices and the cloud, including encryption, device authentication, and access control.</li> <li>- <b>Integration:</b> AWS IoT can be easily integrated with other AWS services, such as Lambda, Kinesis, and DynamoDB, to enable developers to build and manage complete IoT solutions.</li> <li>- <b>Real-time data analytics:</b> AWS IoT enables real-time analytics of IoT data, which can be used to derive insights and make data-driven decisions.</li> <li>- <b>Efficient:</b> AWS IoT offers a pay-as-you-go pricing a comparative overview making it cost-effective for organizations of all sizes to build and manage IoT applications.</li> <li>- <b>Language platform:</b> Java, C#, Node.js, Ruby, Python.</li> </ul>	<ul style="list-style-type: none"> <li>- <b>Complexity:</b> AWS IoT is a complex system that can require significant time and expertise to set up and use effectively. Users may need to have a good understanding of IoT concepts, programming languages, and cloud infrastructure.</li> <li>- <b>Cost:</b> The cost of using AWS IoT can grow up quickly. Although there is a free tier available, as usage increases, charges for messaging, storage, and other resources can become significant.</li> <li>- <b>Dependency on AWS:</b> AWS IoT is a proprietary system, which means users depend on Amazon Web Services (AWS) to maintain and update the system. If AWS experiences an outage or other problems, it could affect the reliability of IoT devices and applications that support the platform.</li> <li>- <b>Limited connection options:</b> While AWS IoT supports many different connection options, such as MQTT, HTTPS, and WebSockets, it may not work with all IoT devices or platforms. Users may need to customize their devices or applications to work with AWS IoT.</li> </ul>
IBM IoT Solution	<ul style="list-style-type: none"> <li>- <b>Scalability:</b> IBM IoT Solution is designed to improve as the business grows. It can interface with a large number of devices, sensors, and data points, making it suitable for high - level applications.</li> <li>- <b>Security:</b> This provider provides strong security features to protect your data and devices from cyber attacks. It has built-in security protocols that ensure secure communication between devices and cloud services.</li> <li>- <b>Analytics:</b> This provider offers advanced analytics capabilities that help you understand the data generated by your IoT devices. You can use this data to gain insight into your business operations, optimize processes, and make data-driven decisions.</li> <li>- <b>Integration:</b> IBM IoT Solution integrates with other IBM products and services, such as Watson AI and IBM Cloud, making it easy to manage your entire IoT ecosystem from a single platform.</li> <li>- <b>Customization:</b> The IBM IoT Solution is highly customizable, allowing you to adjust it to your specific needs and requirements. You can choose the components you need and configure them to work together seamlessly.</li> <li>- <b>Language platform:</b> Java, C#, Node.js, Ruby, Python.</li> </ul>	<ul style="list-style-type: none"> <li>- <b>Complexity:</b> Implementing an IBM IoT solution can be complex, requiring both hardware and software expertise. This may require significant investment in time, resources, and training.</li> <li>- <b>Cost:</b> IBM IoT solutions can be expensive, especially for smaller businesses or organizations with limited budgets.</li> <li>- <b>Integration:</b> Integration with existing systems can be challenging, especially if the organization has a mix of legacy and modern systems.</li> <li>- <b>Security:</b> IoT devices can be vulnerable to cyber attacks, and ensuring the security of an IoT solution requires significant effort and constant attention.</li> </ul>

Cloud Provider	Pros	Cons
Alibaba Cloud IoT	<p>- <b>Scalability:</b> Alibaba Cloud IoT provides a highly scalable infrastructure that can handle a huge number of devices. Whether you have thousands or millions of devices, you can easily connect and manage them on the Alibaba Cloud platform.</p> <p>- <b>Device Management:</b> The platform offers comprehensive device management capabilities, allowing you to efficiently register, monitor and control your IoT devices. You can easily onboard and provision devices, remotely update firmware, manage device permissions, and monitor device status.</p> <p>- <b>Data collection and analytics:</b> Alibaba Cloud IoT allows you to collect data from your connected devices in real-time. It provides a variety of data input and storage options, including time series data storage to efficiently handle IoT data streams. You can leverage Alibaba Cloud's powerful analytics services to gain valuable insights from your IoT data, enabling you to make data-driven decisions and optimize your operations.</p> <p>- <b>Security:</b> Security is a critical aspect of IoT and Alibaba Cloud IoT offers strong security features to protect your devices and data. It provides secure device authentication, data encryption, access control, and threat detection capabilities to protect your IoT infrastructure.</p> <p>- <b>Integration with Alibaba Cloud Services:</b> Alibaba Cloud IoT seamlessly integrates with other services offered by Alibaba Cloud. You can leverage Alibaba Cloud's broader ecosystem, including services such as data analytics, machine learning, computing and storage to build comprehensive IoT solutions.</p> <p>- <b>IoT Platform as a Service (PaaS):</b> Alibaba Cloud IoT provides a PaaS a comparative overview, which means you can focus on developing your IoT applications without worrying about the underlying infrastructure. The platform takes care of scalability, security and maintenance, allowing you to accelerate your time to market.</p> <p>- <b>Global footprint:</b> Alibaba Cloud has a strong global presence, with data centers located in different regions around the world. This allows you to deploy your IoT solutions closer to your target markets, reducing latency and improving overall performance for your users.</p> <p>- <b>Competitive pricing:</b> Alibaba Cloud offers competitive pricing a comparative overview</p>	<p>- <b>Learning curve:</b> Alibaba Cloud IoT has a steep learning curve, especially for users who are new to the Alibaba Cloud ecosystem. It may take time and effort to understand the platform's features, APIs, and integration methods.</p> <p>- <b>Documentation and Support:</b> While Alibaba Cloud provides documentation and support for their IoT platform, the quality and availability of these resources may vary. Some users have reported challenges in finding comprehensive documentation or timely support for specific use cases.</p> <p>- <b>Pricing:</b> Alibaba Cloud IoT services have a cost, and pricing structures can be complex. It is crucial that you carefully review the pricing a comparative overview and understand the costs of various services, including device connectivity, data transfer, and additional features.</p> <p>- <b>Integration with other cloud services:</b> Alibaba Cloud IoT is part of the broader Alibaba Cloud ecosystem and offers seamless integration with other Alibaba Cloud services, integrating with external services or platforms may require additional effort and customization.</p> <p>- <b>Limited geographic coverage:</b> Although Alibaba Cloud is expanding its global presence, its data centers and IoT services may have limited geographic coverage compared to some other cloud providers. This can be important if your IoT deployment requires specific regions or data residency requirements.</p>

Cloud Provider	Pros	Cons
	<p>for its IoT services. You can choose from different pricing options based on your specific requirements, such as the number of devices, data storage, and data transfer. This flexibility helps you optimize costs as you scale your IoT deployments.</p> <ul style="list-style-type: none"> <li>- <b>Developer-friendly environment:</b> Alibaba Cloud IoT provides comprehensive documentation, SDKs (software development kits), and developer tools to facilitate the development of IoT applications. The platform supports multiple programming languages, making it accessible to developers with different skill sets.</li> <li>- <b>Language platform:</b> Java, C#, Node.js, Ruby, Python.</li> </ul>	

However, the comparison of Cloud providers is constantly being improved with services and functions and includes new ones. By tracking the historical development of Cloud providers, new trends can be formed that represent the ability of Cloud providers to grow and consistently provide high-quality, premium services.

### 3. DEVELOPMENT OF CLOUD PROVIDERS

The development of Cloud providers is based on their trends which are documentation of their progress and evolution over time. Trend analysis helps connect all their the dots and identify operational and functional consistencies they may have in the coming years. Four cloud providers are considered in our paper: IBM IoT Solution, AWS IoT, Azure IoT Hub, and Alibaba Cloud. We will consider their three - year trend and development (2021, 2022, 2023) in three categories: financial, data management, internet, and all categories (Source://trends.google.com/trends/explore). During the considered period these providers were used by various institutions. During the period under review, Alibaba Cloud was the market leader. However, AWS IoT in late January 2023 is starting to increase its market shares and move closer to Alibaba Cloud's values. Figure 1 shows developments in the "Finance" category. It shows that Alibaba Cloud and AWS IoT are highly competitive leaders. Towards the end of 2022 IoT Solution started growing in the finance category.

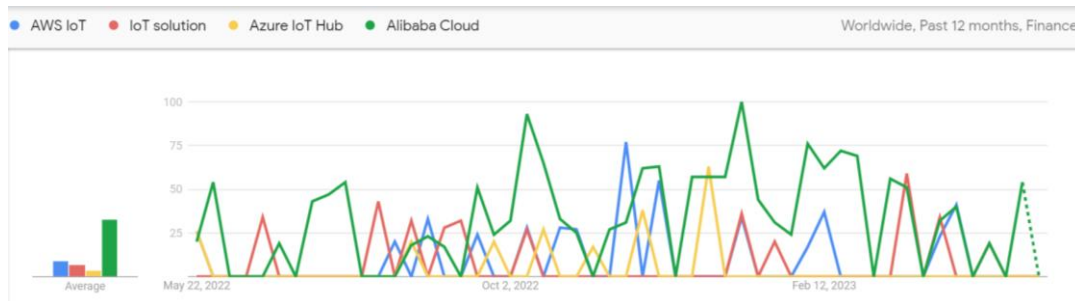


Figure 1. Development of Cloud providers in the finance category

Figure 2 shows the development in the "Data Management" category. It shows that all four cloud providers had close growth in this category over the last three years. At the end of October 2022,

an explosive growth in the value of IoT solution is seen, then that growth declines at the end of 2022.

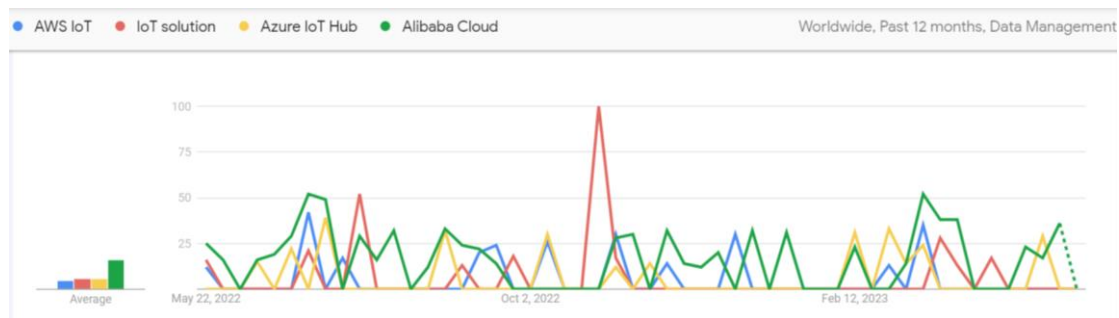


Figure 2. Development of Cloud providers in the data management category

Figure 3 shows the development in the "Internet and Telecom" category. It shows that Alibaba Cloud is the market leader during the period under review. Others keep their positions.

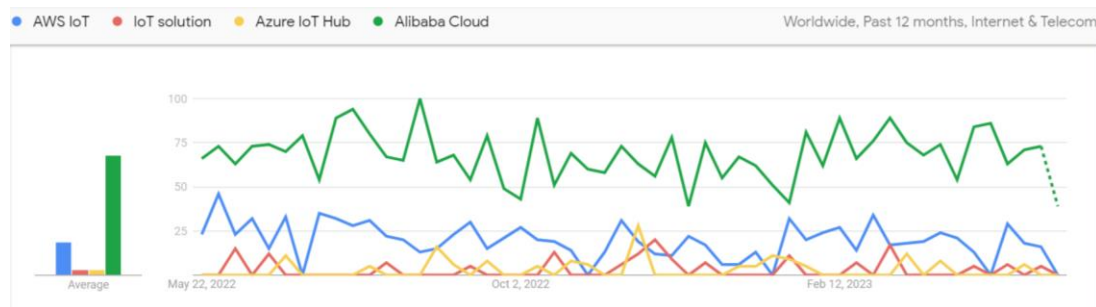


Figure 3. Development of Cloud providers in the Internet and Telecom category

Figure 4 shows the development of three Cloud providers for all categories. During the period under review, Alibaba Cloud was the market leader, continuing to maintain its market position. AWS IoT maintains some constant position.

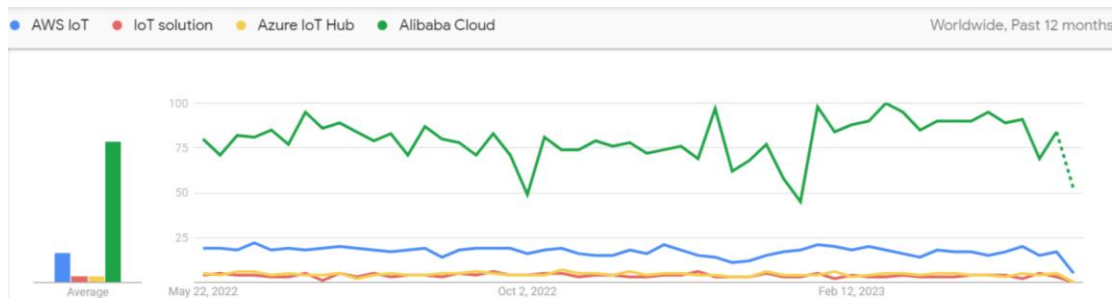


Figure 4. Development of Cloud providers in all categories

Despite trends during this time, the market is very dynamic. Each Cloud Service Providers improves the services offered and develops new ones. Several large companies and startups are migrating to the Cloud or starting to build completely new projects in the Cloud environment [10,11]. Each Cloud Service Providers has a category where it shines brighter than the other Cloud Service Providers. For this reason, choosing the right Cloud Service Providers is not easy

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process. The formation of an evaluation a comparative overview will support the overall decision - making process.

#### **4. COMPARATIVE OVERVIEW OF CLOUD PROVIDERS**

In this part of the paper, we will compare four Cloud providers based on three criteria for designing high-performance, real-time IoT big data solutions.

*Criterion 1 – Services.* There are multiple Cloud providers offering services for IoT applications. In our paper, we analysed four Cloud providers namely: AWS IoT, IoT Solution, Azure IoT Hub, and Alibaba Cloud IoT.

- **Azure IoT Hub:** This provider has a fully managed service provided by Microsoft Azure. It enables secure two-way communication between IoT devices and cloud applications. Azure IoT Hub supports various protocols and provides features such as device management, device- to- cloud and cloud – to - device messaging, device provisioning, security, and analytics. This cloud provider integrates well with other Azure services, allowing IoT solutions to be built.
- **AWS IoT:** This provider is an Amazon Web Services IoT platform designed to help users connect, manage, and provision IoT devices and data. This provider offers features such as device connection and activation, messaging, a rules engine for data processing and transformation, and secure device management. It also provides integration with other AWS services, such as Lambda, DynamoDB, and S3, to build scalable IoT applications.
- **IBM IoT Solution:** This provider provides a range of IoT capabilities and services to help organizations design, build and deploy IoT solutions. IBM offers various IoT platforms, such as IBM Watson IoT Platform and IBM Maximo Asset Monitor.
- **Alibaba Cloud IoT:** This provider is Alibaba Cloud's IoT platform that offers a range of services to connect and manage IoT devices. It provides device management, data collection, and data processing capabilities. Alibaba Cloud IoT integrates with other Alibaba Cloud services such as Alibaba Cloud Function Compute and Alibaba Cloud DataWorks for data processing and analysis.

*Criterion 2 - Big Data Processing.* Cloud providers Azure IoT, AWS IoT, IBM IoT Solution, and Alibaba Cloud IoT provide options for processing big data generated by IoT devices.

- **Azure IoT Hub:** this provider offers several services and tools for processing and analyzing big data generated by IoT devices. Azure Stream Analytics - this service enables real- time processing and analysis of streaming data from IoT devices. It supports SQL requirements and integrates with other Azure services such as Azure Blob Storage, Azure Data Lake Storage, and Azure Event Hubs. Azure IoT Hub integration with Azure services - this provider can integrate with various Azure services like Azure Functions, Azure Machine Learning, Azure Data Lake Analytics, and Azure Synapse Analytics. These services provide options for further processing and analysis of IoT data.
- **AWS IoT:** this provider provides several big data processing services. AWS IoT Analytics - this is a fully managed service that enables the collection, processing, and analysis of IoT data. It supports batch and real- time processing and integrates with other AWS services such as Amazon S3, AWS Lambda, and Amazon QuickSight. Amazon Kinesis - AWS IoT devices can transmit data to Amazon Kinesis, which is a real -time data transmission and



processing platform. Kinesis Data Streams and Kinesis Data Analytics are services within this platform that provide real-time analytics capabilities on streaming data. Amazon Elastic MapReduce - it is a managed big data processing service that can be used to process large volumes of IoT data. It supports popular big data frameworks like Apache Spark, Apache Hadoop, and Apache Hive.

- IBM IoT Solution: this provider provides an IoT platform that includes services for processing big data. IBM Watson IoT Platform - this platform offers tools for collecting, managing, and analyzing IoT data. It integrates with IBM Watson services, such as Watson Analytics and Watson Studio, which provide advanced analytics, machine learning, and data visualization capabilities. IBM Streams - it is a real-time streaming analytics platform. It enables processing and analysis of high-speed data streams from IoT devices and integrates with other IBM analytics and data management services.
- Alibaba Cloud IoT: this platform provides a range of services to manage and connect IoT devices. The Alibaba Cloud IoT platform offers device management, real-time data processing and integration with other Alibaba Cloud services. For big data processing, Alibaba Cloud provides services such as Alibaba Cloud DataWorks, MaxCompute, and E-MapReduce. These services enable the ingestion, storage, processing, and analysis of data at scale, making it possible to handle large amounts of IoT data.

*Criterion 3 – Security.* It is a critical aspect of any IoT solution. Azure IoT, AWS IoT, and IBM IoT solutions offer a variety of security features and capabilities to help protect IoT devices and data. Here's an overview of their security offerings.

- Azure IoT: Device Security - Azure IoT provides secure device connectivity using industry-standard protocols such as MQTT, AMQP, and HTTPS. Supports X.509 certificate for device identity and authentication. Azure IoT Device Provisioning Service enables secure provisioning of IoT devices at scale. Network security - Azure IoT offers virtual network (VNet) integration to isolate IoT devices in a private network. Traffic can be restricted by using network security groups and virtual private networks (VPNs) to improve network security.
- AWS IoT: Device Security - AWS IoT offers mutual authentication between devices and the cloud using X.509 certificates. Supports device security policies to control device actions and permissions. AWS IoT Device Defender provides continuous monitoring of device behavior and detects anomalies.
- IBM IoT Solution: Device Security - IBM IoT solutions support device identity and authentication using X.509 certificates. They provide functions to safely secure and turn on devices. IBM Watson IoT platform offers secure device connectivity using MQTT and HTTPS protocols.
- Alibaba Cloud IoT: It offers security solutions to protect IoT devices, data, and networks. Includes features such as device identity authentication, secure communication protocols, and threat detection and response mechanisms. Alibaba Cloud IoT Security also provides integration with other Alibaba Cloud services, enabling seamless data management and analytics.

Each platform has its own set of security features and integrations. It is essential to assess the specific security requirements of each IoT solution and assess how each platform fits those requirements. Additionally, following best practices such as regular software updates, secure

device configurations , and strong access controls can further improve the overall security of each IoT solution.

## 5. CONCLUSIONS

IBM IoT Solution, AWS IoT, Azure IoT Hub, and Alibaba Cloud IoT are four significant platforms in the field of the Internet of Things (IoT). Each platform offers a range of features and capabilities to help organizations connect, manage and analyse their IoT devices and data.

IBM IoT Solution provides a comprehensive IoT solution called the IBM Watson IoT Platform. It offers device management, data ingestion and analytics, real- time insights and integration with other IBM services like Watson AI. The IBM platform is known for its robustness, scalability and security features. It also provides tools for building IoT applications and supports a wide range of protocols and devices.

Amazon Web Services IoT provides device management, data processing and storage capabilities. It integrates well with other AWS services, enabling users to build complex IoT solutions using a range of AWS tools and services. AWS IoT supports various protocols and offers strong security features. It also provides machine learning capabilities through AWS IoT Analytics and integration with Amazon SageMaker.

Microsoft's Azure IoT Hub is another prominent IoT platform. It provides device management, data entry and processing capabilities. Azure IoT Hub integrates well with other Azure services, enabling users to leverage services such as Azure Stream Analytics, Azure Functions and Azure Machine Learning to build end- to - end IoT solutions. Azure IoT Hub supports a wide range of protocols and offers strong security features. It also provides advanced features such as dual device and direct device management methods.

Alibaba Cloud IoT is an Internet of Things (IoT) platform provided by Alibaba Cloud. It is designed to help businesses and developers connect and manage their IoT devices, collect and analyse data and build IoT applications.

All four platforms offer robust IoT deployment features and capabilities. The choice among IBM IoT Solution, AWS IoT, Azure IoT Hub and Alibaba Cloud IoT depends on the specific requirements, and integration preferences of the organization. IBM IoT Solution is known for its advanced analytics and artificial intelligence capabilities, AWS IoT is well integrated with the broader AWS ecosystem, and Azure IoT Hub provides tight integration with the Azure cloud ecosystem. Alibaba Cloud IoT is designed to cater to various industry verticals, including manufacturing, transportation, healthcare, agriculture, and smart cities. It provides a comprehensive suite of tools and services to address the challenges of IoT device management, data processing, and application development, helping businesses unlock the full potential of the Internet of Things. Organizations should assess their specific needs and consider factors such as scalability, security, analytics capabilities and existing technology investments to determine the most appropriate IoT platform for their use.

A comparison of the pros and cons for four cloud providers, along with the trends in their historical development in different categories, shows that choosing a cloud provider is a difficult and complex task. The proposed comparative overview of several criteria based on the requirements for designing solutions for IoT, allows companies and users to have a complete picture of the operation of the cloud provider. By comparing their positive and negative sides, analysing their trends, and comparing them according to three criteria, we get a overview for each of the three cloud providers. The knowledge base in this area can be improved through thorough

detailed research. 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.

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