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**Research Article**

# Harnessing the Power of Hybrid Integration: A Comparative Study of Azure and SAG Middleware Platforms

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**ABSTRACT**

The Industrial Internet of Things' (IIoT) rapid adoption in industrial sectors has produced unparalleled advantages in terms of performance, production, and efficiency. Despite providing a good degree of protection today, the security frameworks in place are insufficiently scalable to the increasing variety and quantity of devices that are included into the Industrial Internet of Things. Without active administration, the cloud-based deployment offers on-demand availability. In order to enable businesses, create software more quickly and update it more regularly and achieve significant commercial results, the idea of cloud-native applications has been put out more recently. Due to the recent expansion of the cloud computing sector, several cloud organisations are now providing their customers with an extensive array of options. The fact that those cloud companies have developed new services with distinct APIs suggests that cloud-oriented apps may be instantiated inside a single cloud provider, which is terrible. Since the IT industry's applications will grow provider-dependent, this situation is undesirable. We provide a platform in this work that enables applications to communicate with the services of many cloud providers using a standardised interface. A common API is provided by the suggested method, which reduces the current deficiency in cloud API standardisation and offers redundant and secure service allocation. Additionally, services from other cloud providers may be added to and coupled with other features, such as real-time ciphering and redundancy.

**Keywords:** Industrial Internet of Things (IIot), Growing Diversity, APIs, Consumers, Cloud Players, Dramatic Business, Services Allocation.

## 1. INTRODUCTION

Over the last ten years, companies of all sizes and in all sectors have been using cloud services to meet their computing requirements [1]. Adopting cloud services at the corporate level has several advantages, including the potential to lower the cost of managing and maintaining IT systems and the ability of cloud infrastructures to be swiftly scaled up or down in response to storage and computation requirements, providing flexibility as needs evolve.

The introduction of cloud computing has completely changed the IT landscape by enabling businesses to use enormous amounts of processing power without having to make large capital expenditures in physical infrastructure. Hybrid cloud models, which mix the advantages of public and private clouds to provide a flexible and dynamic IT environment, are becoming more and more popular as organisations move to the cloud [1, 2]. Businesses may use the scalability and flexibility of public cloud platforms while maintaining vital data and apps on-premises thanks to hybrid cloud architectures [2, 3]. Numerous benefits come with this strategy, such as increased agility, cost savings, [3, 4], and the capacity to react quickly to changing company needs.

The IIoT is a network of networked smart devices used in many different sectors to carry out more effective operations. Data on the process is gathered by a variety of devices, including sensors, actuators, and other equipment, and then sent to other devices. Following its analysis by other devices, the Big Data is used in a number of ways [3, 4], ranging from process optimisation to the identification of an element that is below the required level. IIoT may therefore be defined as the application of IoT technologies to manufacturing and other industrial sectors.

IoT equipment and other devices in industries like manufacturing, agriculture, and oil and gas enable device-to-device interaction via data exchange. Because it transforms conventional linear production into dynamic, networked systems, the Industrial Internet of Things technology is significant. This change may help businesses become more

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efficient, reduce operating expenses, and increase safety [3, 5]. This implies businesses may now get insights they were previously unable to access from the data collected by IIoT devices.

The smart grid, also known as the intelligent grid, is a modernised electrical network that can efficiently offer sustainable, affordable, [6], and secure power supplies to customers by intelligently integrating various digital computers and sophisticated communication technologies. Numerous obstacles stand in the way of the development and deployment of smart grid technologies, but these obstacles continue to spur stakeholders in the electric power sector, including utilities, manufacturers, suppliers, regulators, governments, and consumers, to acknowledge and resolve the difficult problems.

As the current grid system trend, the smart grid may be defined as a contemporary power generating and distribution infrastructure that can automate and handle the 21st century's growing complexity and demands for energy. Distributed energy resources (DER), energy storage, power electronics, administration (control, technology, monitoring, and protection), and communication are some of the technologies and components that must be developed in order to transition conventional power networks to smart grids [6, 7]. To assess the dependability of their electricity distribution, the majority of electric power utilities use common reliability measures such the System Average Interruption Duration Index (SAIDI) or System Average Interruption Frequency Index (SAIFI) [4, 9].

The majority of cloud providers, however, have been developing unique APIs for their services in spite of this development, which suggests that cloud applications are tied to each vendor and can only be instantiated in a single provider [9, 10]. It is obvious that shareholders, or the user community and the marketplace, must embrace a standard architecture in order to achieve portability and interoperability. To enable interoperability across the different cloud providers, several attempts have been made to develop standards, such as SNIA and CDMI. The ideal situation would include developing interfaces and standards that all cloud service providers could use.

These standards still have little practical influence since they are drafts. Furthermore, whereas Platform-as-a-Service (PaaS) currently lacks a uniform, consistent API, Infrastructure-as-a-Service (IaaS) has undergone many attempts to standardise [10]. To address this problem, a number of groups, like j-clouds, lib-cloud, and simple-cloud, have made a significant effort to provide a special programmatic API to handle various cloud solutions. They only support a few numbers of providers, which is unfortunate, and adding more is not easy. IaaS remains the primary emphasis of the majority of them, while other services like database, storage, and notification services are still not fully standardised.

Applications may interface with any cloud, even those from various providers, at the same time thanks to the transparent mixing of many cloud resources, which gives rise to the idea of "sky computing." Despite the fact that this paradigm was first only used to IaaS, there have been recent attempts to expand it to PaaS. But sky computing for PaaS is still in its infancy, and up until now, only a few potential architectures have been mentioned.

A standard software unit that bundles applications and all of their dependencies together is called a container. An application's dependability across many contexts is ensured via containers, which separate it from its surroundings [11]. On the contrary, cloud-native apps are a group of separate services that are bundled into small, portable containers. In contrast to virtual machines, containers are more portable, effective, and scalable since they virtualise operating systems rather than hardware. Application layers are abstracted by containers, which allow numerous containers to operate as separate processes on the same computer. The container pictures are composed of layers.

An example image for operating an Apache Spark container is shown in Fig. 1. The Ubuntu Operating System (L1) is the first thing we get from Docker Hub. Maven (L2) for Java-related programs is loaded on top of the OS layer [11,12], and Hadoop HDFS (L3) is then constructed on top of L2. For data processing, we lastly get Spark (L4) [12]. Containers take up less space and use less hardware to run more programs than simulated machines.

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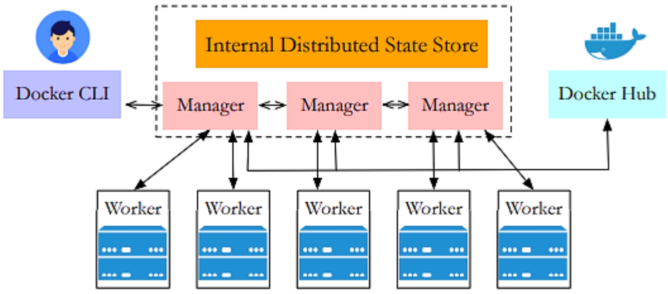


Fig. 1 Swarm Mode for Docker. [5]

There is constant resource competition in a busy cloud computing platform. From the perspective of the operating system, active containers are no different from normal processes, in which the system controls resource allocation. There are two tiers of resource management systems for cloud-native applications that are driven by a cluster of containers: worker-level and container placement-level [7, 9].

### 1.1 AWS, Azure, and GCP: A Comparative Overview

Amazon Web Services (AWS) is well known for being the top supplier of cloud services, with a broad range of goods to meet various corporate requirements. Businesses looking to create and manage hybrid cloud systems find AWS to be a compelling option because to its vast global infrastructure and strong ecosystem of tools and services. AWS's virtual private cloud (VPC) capabilities, which allow for safe and easy connection with on-premises data centres, and its wide range of analytics, machine learning, and storage solutions are among its key characteristics [8]. A strong competitor in the cloud industry, Microsoft Azure stands out for its extensive integration with Microsoft's corporate suite of products and services. Azure's hybrid cloud products, such Azure Stack and Azure Arc, are designed to seamlessly integrate on-premises and cloud settings.

Azure's strengths include its extensive compliance frameworks, strong support for hybrid IT solutions, and sophisticated data analytics and artificial intelligence (AI) capabilities. A prominent cloud provider, Google Cloud Platform (GCP) is well-known for its proficiency with open-source technologies, machine learning, and data analytics [4, 8]. Businesses may easily manage workloads across on-premises and cloud environments with the help of GCP's hybrid cloud solutions, such as Anthos and hybrid networking services [8].

A sophisticated grasp of the particular possibilities and difficulties connected to each platform is necessary for optimising hybrid cloud settings. Businesses must strike a balance between the variable costs of cloud services and the cost of on-premises infrastructure; thus, cost management is essential. Each of AWS, Azure, and GCP provides cost management tools and price structures that accommodate various financial needs, allowing businesses to maximise their cloud expenditures [8, 9]. Another major issue with hybrid cloud installations is security. A thorough security plan that includes identity and access management, encryption, threat detection, and compliance is required to guarantee the safety of data and apps in both on-premises and cloud settings [9, 10]. Although AWS, Azure, and GCP all provide strong security features and services to protect hybrid cloud infrastructures, businesses must customise these products to fit their own security requirements.

When a real-time monitoring system isn't in place, it might cause major malfunctions, such damage to the connections of the underlying equipment because unexpected circumstances aren't identified and recognised in time, endangering people in the vicinity [11]. Therefore, the author suggested a GSM-based signalling system that will identify variations in the voltage-current parameters of distribution transformers. If the current threshold is surpassed, the microcontroller will immediately send a message to the responsible party via a GSM modem in order to predict the type and location of the fault based on the parameters. A low tension (LT) pillar fault detection system can facilitate automation on the low-voltage side of distribution networks. The LT pillars will communicate via ZigBee to an intermediary, which will then use a GSM technique to send the fault information (fuse blown status) to the main control centre [11].

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For applications that don't need a lot of data transmission, including defect detection and monitoring, cellular technologies like GSM are often used in conjunction with GPRS (general packet radio service) to create the Internet of Things. The IoT, which consists of sensor equipment, communication networks, internet technology, and intelligent technology for computing to achieve real-time collection of things, reliable transmission, and intelligent computation and control of things, can be referred to as the third wave of the information industry (after the computer, internet, and mobile communication network) [12].

At the core of smart grid optimisation is data, which powers more effective and efficient energy management [13]. Utilities can estimate energy demand, identify defects, optimise energy distribution, and monitor the condition of the infrastructure by gathering enormous volumes of real-time data from different grid components. Making better choices about energy efficiency, load balancing, and the integration of renewable energy sources is made possible by having access to high-quality, real-time data. Additionally, sophisticated features that improve operational efficiency and service dependability, like as demand response programs, predictive maintenance, and grid automation, depend on precise data [14].

Sensors, smart meters, and IoT devices are the cornerstones of a smart grid's data-driven capabilities. By continually gathering and sending data from the grid and customer locations, these sensors provide vital information on a range of grid characteristics, including voltage, current, frequency, and energy use. Sensors inserted into the grid keep an eye on electrical conditions and provide operators real-time data. At the customer level, smart meters record comprehensive data on power use [12], allowing utilities to provide dynamic pricing models and individualised services. By providing smooth two-way communication, IoT devices expand the grid's capabilities and make it possible for more sophisticated features like automated control, fault detection, and load forecasting [11]. By strengthening grid performance, efficiency, and resilience, these technologies together serve as the foundation of the smart grid's real-time data ecosystem.

## 2. CLOUD COMPUTING SERVICES

On-premise software, which is housed in private company datacentres, has historically supported IT solutions. Off-premise software has become more applicable with the rise of cloud computing, and these days, cloud providers provide programs as services. As a result, cloud providers now have different development strategies as cloud computing was modified to meet client needs [12]. It is evident that these businesses provide self-services, where clients may access resources at any time and from any location.

For every operating system and application, Storage-as-a-Service (SaaS) provides remote storage in a local virtualised manner. The Blobstore idea is not new in and of itself, but it is being used by cloud providers to supply storage these days [13]. These ideas were previously used to the storage and transfer of big data blocks in Database Management Systems (DBMS). Blobstores are key-value storage providers, or associative memory, in which a text key is used to conduct a search on an unstructured data (value) blob that is stored in a container. The blobs' namespace or domain is called a container [13]. Every time, a blob is uploaded to a container.

DaaS, or database-as-a-service, is a new paradigm that shifts the workload to the cloud provider. As a result, the database is housed in a distant data center and is transparently shareable across users. For example, consumers may pay for the database as a service provided by Rackspace (2011), Windows Azure, and Amazon AWS. Key-value structures are used to organise a new kind of database known as columnar data [10]. Unlike the conventional databases that store data by row, these databases store data by column. These databases are now available from cloud providers, and they have several benefits when it comes to processing vast volumes of data. These services facilitate all database activities, including the creation of tables and the loading and retrieval information from databases.

### 2.1 Interoperability and standardization

These days, the industry is fiercely competitive to provide more and better cloud services. The services offered by several players, however, are usually incompatible. Interoperability and portability are undoubtedly necessary to facilitate the easier transfer of applications across various cloud providers [13]. To develop common interfaces and standards that might enable interoperability across various cloud platforms, a number of organisations have recently

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been established. For instance, the Storage Network Industry Association (SNIA) has been developing a cloud storage data standard.

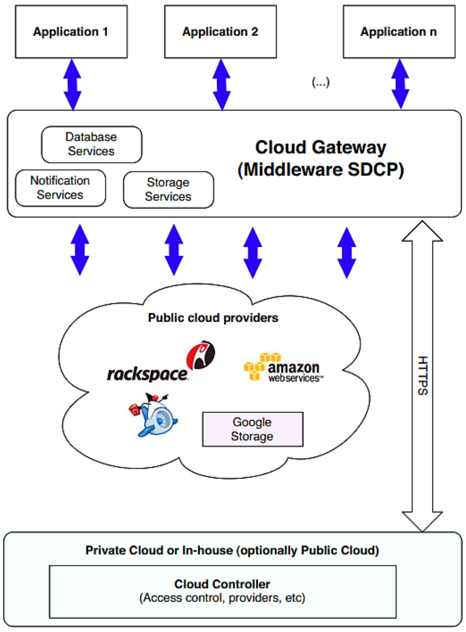


Fig. 2 Overview of SDCP in general. [16]

## 3. A SERVICE DELIVERY CLOUD PLATFORM

We have created the Service Delivery Cloud Platform (SDCP), a single API for providing services across cloud resources from many vendors. This platform's three primary objectives are: (1) establish an abstract layer for three cloud services to enable interoperability across various cloud providers; (2) provide services utilising a variety of cloud resources, such as database management, storage, and notification systems; and (3) offer service orchestration, decoration, and combination [14, 15].

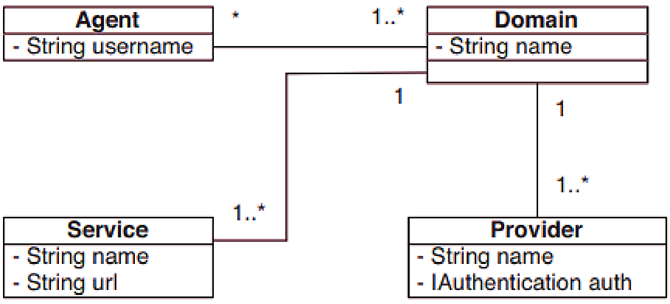


Fig. 3 Cloud Platform Service Delivery Entities. [12]

### 3.1 Entities

The platform has its own entities that model the system architecture and describe how it is structured. The fundamental entities and associations of the infrastructure are described in Fig. 3

- **Agent –** An agent account must be used to log in to each gateway. In essence, agents are the inside organisation units that transmit data to the cloud [15].
- **Domain –** a collection of agents who are part of the same business or reputable organisation [11]. As a result, only agents within the same domain are able to interact or access data inside that domain.

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### 3.2 Cloud services

This section explains the Cloud services that have been put into place. We will outline the three cloud services that have been put into use as well as how the abstraction for these services was used [13].

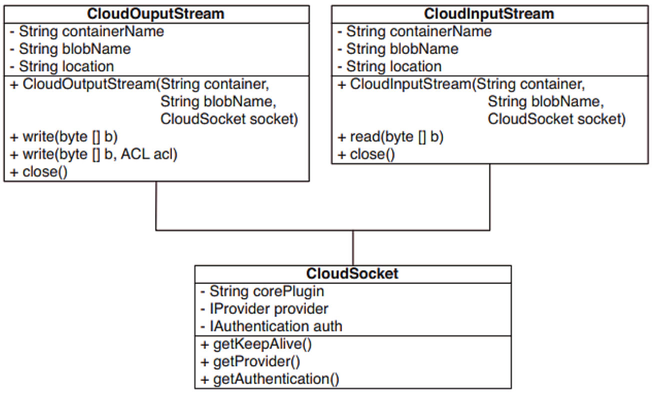


Fig. 4 Cloud input/output. [11]

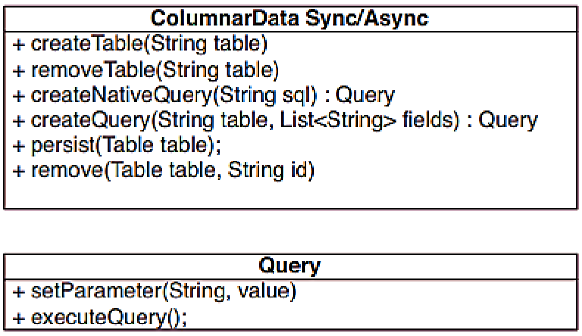


Fig. 5 Abstraction columnar data. [12]

### 3.3 Cloud Controller

A key element of our design, the Cloud Controller is in charge of tasks including coordinating authentication procedures with Cloud Gateways, regulating access to cloud resources, aggregating provider credentials, and adding new services [16, 17].

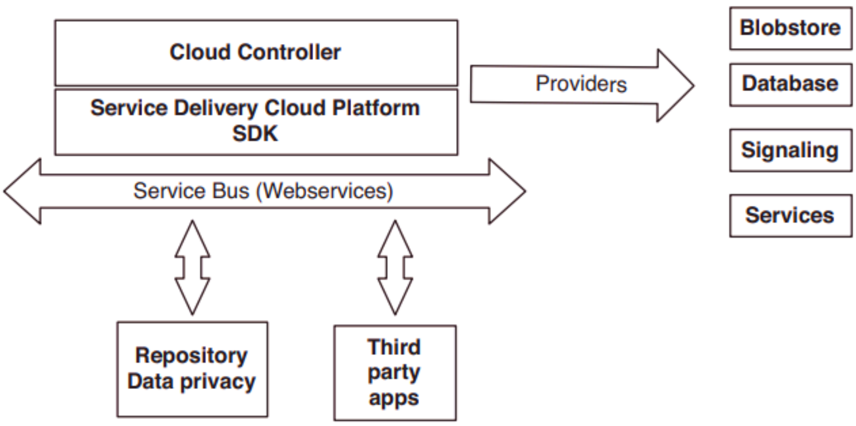


Fig. 6 Cloud controller – architecture. [18]

### 3.4 Cloud Gateway

One crucial element of the architecture is the Cloud Gateway. In essence, it is an application that dynamically loads new services [19]. It immediately loads the services that the user uploads and authenticates the user with the Cloud Controller. It is possible to run Cloud Gateway as a daemon. Additionally, it has an optional external GUI that lets the user see the operation log or load additional plugins or programs [20].

### 3.5 SDCP-SDK

Applications that use cloud resources and new plugins for new cloud providers may be developed by SDCP end users [21, 22]. The apps may thus benefit from additional cloud providers that the developer wishes to support. The SDCP-SDK will be used by the developer to produce these new apps.

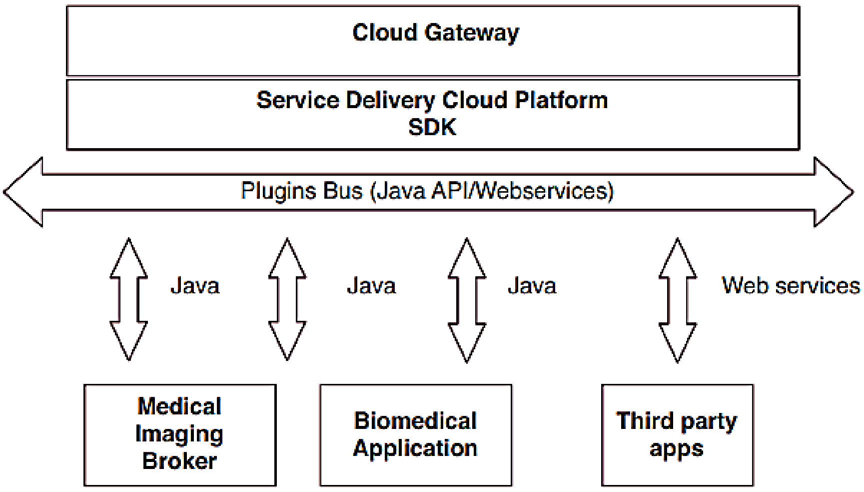


Fig. 7 Cloud gateway architecture. [23]

### 3.6 Privacy and confidentiality model

Unquestionably, cloud computing offers businesses a number of benefits, but there are two main concerns that must be addressed: the solution's cost and benefits as well as the privacy and security of the data kept on the cloud [22].

## 4. CASE STUDIES

### 4.1 Medical imaging repository

The suggested method will be advantageous in a number of use case situations. Medical imaging repositories are one such example that we shall discuss in this article [23]. In order to facilitate diagnosis, treatment, and patient care, the healthcare industry has embraced ICT more and more during the last 20 years. For example, medical imaging [24] generates vast amounts of data and uses these technologies in routine diagnostic processes.

### 4.2 Sharing medical images "anytime and anywhere"

Dropbox and Gmail are only two of the numerous instances of cloud computing's widespread usage for file sharing via the Internet. Additionally, cloud companies provide scalable and highly available services [25]. The medical repositories in this case study are not cloud-based. The objective is to provide external and/or inter-institutional access across organisational barriers, but we retain them in the healthcare companies. Utilising the SDCP platform, our DICOM relay architecture enables the seamless transfer of imageology data across several sites.

## 5. CONCLUSION

Despite the development of several cloud service applications, interoperability and portability of cloud resources remain significant obstacles, and multi-vendor integration requires common specifications and standards. We have offered a solution in this work that aims to achieve this objective. Utilising resources from many cloud providers, the proposed Service Delivery Cloud Platform (SDCP) is a cloud middleware platform that offers a wide range of services. The architecture that has been given makes it possible to separate the particulars of each cloud provider API into a distinct abstraction. The system architecture has been covered in great length throughout the essay, along with the benefits and limitations of the suggested solution. Three standard services—blobstore, columnar data, and notification service—were used to test the platform in both private and public clouds. The platform has also been effectively used in a number of medical picture situations that take advantage of storage redundancy by using two databases, private and public clouds, and the notification service to facilitate communication between several data access points.

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