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Using the Strategy of Multi-Cloud Solutions for Environmental Protection

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Abstract: This paper discusses several extremely promising applications of multi-cloud solutions that can help achieve environmental protection and sustainability goals, provide ecological benefits, and aid wildlife research, conservation and protection. The widespread adoption of multi-cloud strategies helps illustrate the range of initiatives and approaches to reduce environmental burdens employed by government agencies, non-governmental organizations, and private companies.

Keywords: environmental protection; multi-cloud computing; multi-cloud platforms.

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1. The concept of multi-cloud environment

Cloud computing (CC) is a paradigm for providing customers with networked access capabilities to a scalable and elastic pool of shared physical or virtual resources on a self-service and on-demand administration basis [*Dovgal and Dovgal*, 2019a]. Through the network, the customer obtains from more than one cloud service provider the cloud computing services they need to process and analyze datasets. According to GOST ISO/IEC 17788-2016 [*GOST ISO/IEC 17788-2016*, 2016] cloud computing services are categorized into seven cloud computing services called categories: Communications as a Service (CaaS), Compute as a Service (CompaaS), Data Storage as a Service (DSaaS), Infrastructure as a Service (IaaS), Software as a Service (SaaS), Platform as a Service (PaaS) and Network as a Service (NaaS). The main purpose of such categories is to provide services via the Internet to cloud clients on a paid basis.

A multi–cloud solution is the execution of cloud computing, allowing the client to deploy applications and services in multiple cloud infrastructures regardless of the provider. The multi-cloud paradigm for most businesses and organizations means using solutions from multiple cloud providers such as Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP). Multi-cloud solutions are usually built on the basis of open-source cloud technologies (for example, Kubernetes), which allow you to run workloads in any cloud without being tied to a specific platform.

Organizations choosing a multi-cloud architecture can use any combination of public clouds along with private cloud deployments and traditional on-premises infrastructure – and these environments do not necessarily need to be integrated [*Dovgal and Dovgal*, 2019b].

With a multi-cloud strategy, customers can choose their preferred services from each cloud provider based on cost, technical requirements, geographic availability, and other factors. For example, a company may use GCP for development/testing environments, AWS for disaster recovery, and Microsoft Azure for business intelligence workloads.

Traditionally, experts distinguish between a multi-cloud solution and a hybrid cloud. The primary difference between the two is that a hybrid cloud approach utilizes a combination of public cloud, private cloud and/or on-premises platforms with some form

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of integration or orchestration between these environments. In contrast, a multi-cloud approach involves deploying systems on cloud platforms delivered by several different vendors. This does not necessarily require coordinated operations or integration between different cloud environments.

Figure 1 shows a diagram of a multi-cloud technology.

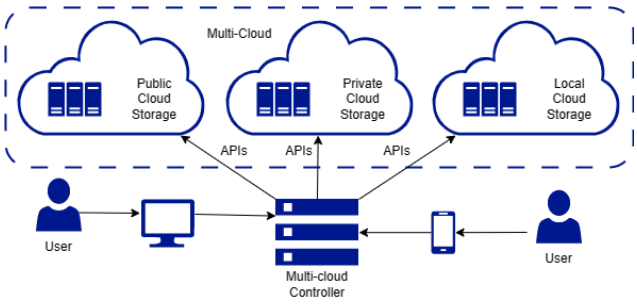

Figure 1. Schematic diagram of multi-cloud technology.

2. Prospective advantages of using multi-cloud environment

Let's consider the advantages of using multiple clouds by clients, which have an impact, among other things, on the level of environmental protection [*Al-Bdairi*, 2022].

1. The greater flexibility of multi-cloud strategy gives environmental protection companies the freedom to choose where and how to deploy workloads, which prevents the client from being tied to a monopoly vendor. Thus, the customer reduces the risk or unnecessary costs that may result from using only one vendor. In addition, the customer is not limited to the offerings or functionality offered by a single cloud provider at the current point in time. Instead, the customer, by going to different providers, can choose only the services they need based on specific pricing preferences, required levels of performance, security and compliance.
2. Increased information security protection resulting from deploying customer business services across multiple clouds and reducing the likelihood of being hit by distributed denial of service (DDoS) and single point of failure (SPoF) attacks, and therefore increasing the continuity and availability of data. Many enterprises also utilize distributed and redundant deployments across multiple clouds to provide seamless failover and disaster recovery. Distributing workloads across multiple clouds avoids the risk of key applications and data being unavailable in the event of a failure in one of the clouds.
3. Better performance of multi-cloud strategy due to the ability to choose a cloud service provider with data centers geographically close to their business users or customers. By doing so, latency and other performance issues can be minimized.

However, multi-cloud also has some drawbacks, especially from an identity management perspective. Potential problems include:

1. More clouds, more complexity – increased complexity in managing access to applications and environments, and security as the number of service and application providers expands. The use of a single cloud platform allows you to solve these problems quite safely and consistently.
2. The need for several groups of highly skilled professionals maintaining services deployed in multiple clouds. In addition, the use of multiple cloud service providers requires the use of overlapping teams with specialized skills at these providers. Given the ongoing shortage of IT professionals, recruiting and retaining professionals with the required level of cloud security expertise can be challenging.
3. Difficulty managing costs. The primary reason many companies choose to move to the cloud in the first place is to reduce costs, but without careful planning and management, dealing with multiple clouds can be costly. Flexible charging models

can make it difficult to predict costs, especially the customer does not have a clear idea of which users will access which systems and resources.

4. Increased concerns about the secure use of data residing in multi-cloud architectures due to the need to enforce multiple access control policies. Any deviations in security mechanisms, strict adherence to a centralized approach to identity management opens up a wider range of security vulnerabilities, leading to an increased risk of data protection issues and security breaches.

3. Examples of the use of multi-cloud architecture in conservation and sustainable development

It is clear that multi-cloud environments can be useful in the field of environmental research, enabling conservation organizations to efficiently and cost-effectively identify key conditions and trends in the environmental state of specific regions, countries, and the planet as a whole. The application of multi-cloud architecture has the potential to bring great benefits when backed by ongoing sustainability efforts.

Multicloud technologies can also play a significant role in protecting natural resources. The use of multiple cloud providers by environmental organizations can reduce the risk of data loss or downtime in the event of a disaster or cyberattack, which can be especially important for those environmental organizations that rely on data to monitor and protect natural resources.

There are many examples of proactive use of a multi-cloud strategy to protect the environment. Let us consider those that are most significant and popular on the Internet.

3.1. Cloud environment for the Advanced Multi-risk Management (SIGMA) sensor-integrated environmental information processing system

Such a system utilizes multi-cloud technologies to store data provided by sensors monitoring water quality or air pollution levels [*Stecca et al.*, 2016]. By using multiple cloud providers, organizations can ensure that their critical data is always available, even if one provider experiences an outage. In addition, multi-cloud architectures can be designed with built-in redundancy and failover mechanisms to further reduce the risk of data loss.

A similar data processing scheme is used, for example, by the Italian National Operative Program project (PON), aimed at collecting, integrating and calculating heterogeneous data from different sensor networks (weather, seismic, volcanic, water, rain, road and sea traffic, environment, etc.), and allows the management of hazardous situations both in the industrial production process and in the national territory [*PON Ricerca*, 2021].

3.2. Specialized services provided by various cloud providers.

Their use is one of the advantages of companies that use multi-cloud technologies to protect natural resources. For example, a company that monitors water quality may use one cloud provider to store raw sensor data, another provider that offers advanced analytics capabilities to process and analyze large amounts of environmental data and visualize it, and yet another provider for data backup and disaster recovery. That way, if one cloud provider experiences downtime or data loss, a cloud client company could still access its data from the other provider. In addition, these companies could use specialized services provided by different cloud providers, such as machine learning algorithms to identify patterns in environmental data or geospatial tools to visualize and analyze data from remote sensors.

Examples of companies that monitor water quality and utilize cloud-based solutions include:

- The company Aquatic Informatics (Vancouver, Canada), which provides water management software solutions for government agencies, utilities and consulting firms [*Aquatic Informatics ULC*, 2023]. The software, which uses multi-cloud solutions, helps analyze water quality data and water management decisions;

- The analytical company for the water market Bluefield Research (Boston) provides data, analysis, and analytical information to water companies and investors [*Bluefield*, 2023]. The company uses cloud-based platforms to monitor water quality, helping customers make informed decisions about water investments;
- The company Echologics, which has offices not only in Toronto, Canada, but also in the Free Zone of Dubai Airport (United Arab Emirates), London, Singapore, and Atlanta (Georgia, USA), provides acoustic leak detection and pipe condition assessment services to water utilities around the world [*Echologics a Mueller brand*, 2023]. Several cloud-based platforms used by the company allow real-time monitoring of water quality and distribution networks.

3.3. Disaster forecasting using multi-cloud technologies

This is another example of using multiple providers to store and analyze data from different sources (such as satellite imagery, weather reports, and seismic activity). Using machine learning algorithms and predictive analytics, organizations can identify patterns and predict natural disasters such as volcanic eruptions, earthquakes, hurricanes, floods, avalanches, tsunamis, and fires.

Examples of companies using multi-cloud technology to predict natural disasters include both large and smaller companies. Among the former are:

- The company IBM, which provides various cloud-based disaster management solutions. The IBM Weather for Emergency Management artificial intelligence platform includes cloud-based industry packages that can analyze data from various sources including social media, news feeds, and sensors to provide real-time information and forecasts [*IBM*, 2015]. IBM cloud solutions can also help first responders in resource allocation and logistics planning;
- The company Google, which provides its Google Cloud solution with tools for disaster response, including Earth Engine [*Google Earth Engine*, 2023] and Google Maps satellite imagery analysis platforms that can be used to visualize disaster data and create custom maps. Google Cloud services also offer machine learning tools for predictive modeling and data analysis.

Similar solutions are offered by other large companies, such as Amazon (Amazon Web Services solution, AWS) [*Amazon Web Services*, 2023] or Microsoft (Microsoft Azure solution) [*Descartes Labs*, 2023], which offer various cloud-based tools for disaster response, including real-time data analytics, machine learning, and geographic information systems (GIS).

Some of the less well-known companies that use multi-cloud technologies for disaster forecasting include:

- Everstream analytics, a software company that provides predictive analytics solutions for supply chain risk management [*Everstream Analytics*, 2023]. Their cloud-based platform uses machine learning algorithms to analyze data from multiple sources such as weather forecasts, traffic patterns, and operator throughput to help businesses anticipate and mitigate supply chain disruptions caused by natural disasters such as hurricanes, floods, and wildfires;
- The Planetary Computer project is a Microsoft initiative that provides cloud-based tools and infrastructure for environmental science and conservation [*Microsoft*, 2023]. The platform integrates data from various sources such as satellite imagery, climate models, and ground observations to help researchers and governments monitor and respond to natural disasters such as droughts, floods, and wildfires;
- One Concern startup offers a digital twin of the world around us that uses artificial intelligence and machine learning to predict and prevent hidden risks in artificial and natural environments associated with natural disasters, extreme weather and climate change by analyzing data from various sources, including satellite imagery, social media and historical records [*Climate FieldView*, 2023]. The project provides cloud

technologies to help emergency managers and municipal officials make data-driven decisions and allocate resources more efficiently during disasters.

3.4. Environmental organizations utilizing multi-cloud technologies

Examples of companies using multiple clouds to store and analyze data from remote sensors, cameras to monitor wildlife and animal habitats [*Dovgal and Kuizheva*, 2022]:

- WildTrack is a non-profit organization that uses artificial intelligence and machine learning to monitor endangered species and their habitats [*WildTrack*, 2023]. The company uses multi-cloud technology to monitor wildlife non-invasively, analyzing data from remote sensors and camera traps, as well as local communities and indigenous knowledge. The platform used by the company can help conservationists identify individual animals, track their movements and assess the health of their populations;
- TrailGuard AI is a tool to facilitate wildlife protection and monitoring, the result of a collaboration between Intel and the nonprofit organization Resolve [*Resolve TrailGuard AI*, 2023]. The artificial intelligence platform, using multi-cloud technology to analyze data from camera traps and motion sensors to monitor endangered species such as elephants and tigers, can detect poachers in real time and alert rangers or law enforcement officers to prevent illegal hunting and wildlife trafficking;
- Wildlife Insights is a platform developed by the non-profit organization Conservation International that uses multi-cloud technology to monitor wildlife and their habitats, helping researchers and conservationists identify and track endangered species, assess ecosystem health, and develop conservation strategies [*Wildlife Insights*, 2023].

Climate change research can also utilize multi-cloud technologies. Here are examples of companies using machine learning algorithms and predictive analytics to identify patterns and make predictions about the future of the environment:

- Climate Corporation is a subsidiary of the Bayer concern, has developed a multi-cloud technology platform to help farmers optimize their crop yields, reduce water consumption, and mitigate climate change on their farms [*Climate FieldView*, 2023];
- Climate Group is an international non-profit organization that uses multi-cloud technologies as well as data from various sources such as energy consumption models, emissions data and policy frameworks to advise businesses and governments on the transition to a low-carbon economy [*Climate Group*, 2023]. To do so, the platform sets emission reduction targets, tracks their progress and shares best practices with other stakeholders;
- Jupiter Intelligence is a multi-cloud startup that assesses risks associated with climate change [*Jupiter*, 2023]. The platform offers businesses and governments to identify areas vulnerable to flooding, extreme heat or other climate-related hazards and develop strategies to adapt to these risks.

3.5. Wildfire prevention

This type of human activity to protect the environment can also utilize multi-cloud technologies. Some examples are:

- Descartes Labs is a startup that identifies areas at risk of wildfires based on processing satellite data, forest health and wildfire risk information using artificial intelligence and machine learning. The platform can help foresters to take preventive measures to reduce the risk of forest fires [*GOST ISO/IEC 17788-2016*, 2016];
- Exci is a company that offers multi-cloud platforms for early emergency response, effective coordination of efforts, and better allocation of resources in real time [*EXCI*, 2023];
- Descartes Laboratories is a project that uses artificial intelligence and machine learning techniques to analyze data related to wildfires based on vegetation density, temperature, and humidity [*ESRI*, 2023];

- Forest Fire Analyst is a software that provides real-time analysis of wildfire behavior and simulates the spread of wildfires to enable timely and effective decision making [*Descartes Labs*, 2023].

Thus, we are on the threshold of widespread implementation of multi-cloud architecture technologies in the protection of the world around us, conservation and sustainable development of nature. Currently, the services provided by the tools described in this article can be used for environmental forecasting of decision-making processes in both public and private sectors. It should be emphasized that, in order to solve sustainable development problems, it is important to maintain close links between decision makers and those affected by them. The application of artificial intelligence tools and machine learning techniques can only provide environmental authorities with detailed evidence of the rapid changes in nature, from documenting the greenness of our planet to identifying where resources are being illegally extracted. Ultimately, there must be a strong link between the data collected and processed by cloud platforms and the sustainability agenda to ensure that humanity still has the time and space to save not only our environment, but humanity itself.

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