intellias

Cloud+Edge:

A Powerful Combo for Next-Gen Ecosystems

www.intellias.com

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01 Executive summary

The exponential growth of data generated by Internet of Things (IoT) devices has led to the development of innovative new technologies to process it.

Cloud platforms, which have been the default IoT data processing solution for decades, are no longer enough. Cloud-related issues with latency, connectivity, and data processing have made developers consider edge computing as an alternative in some cases.

This white paper explores these issues and how combining cloud computing with edge computing can help solve them.

02 The evolution of cloud computing

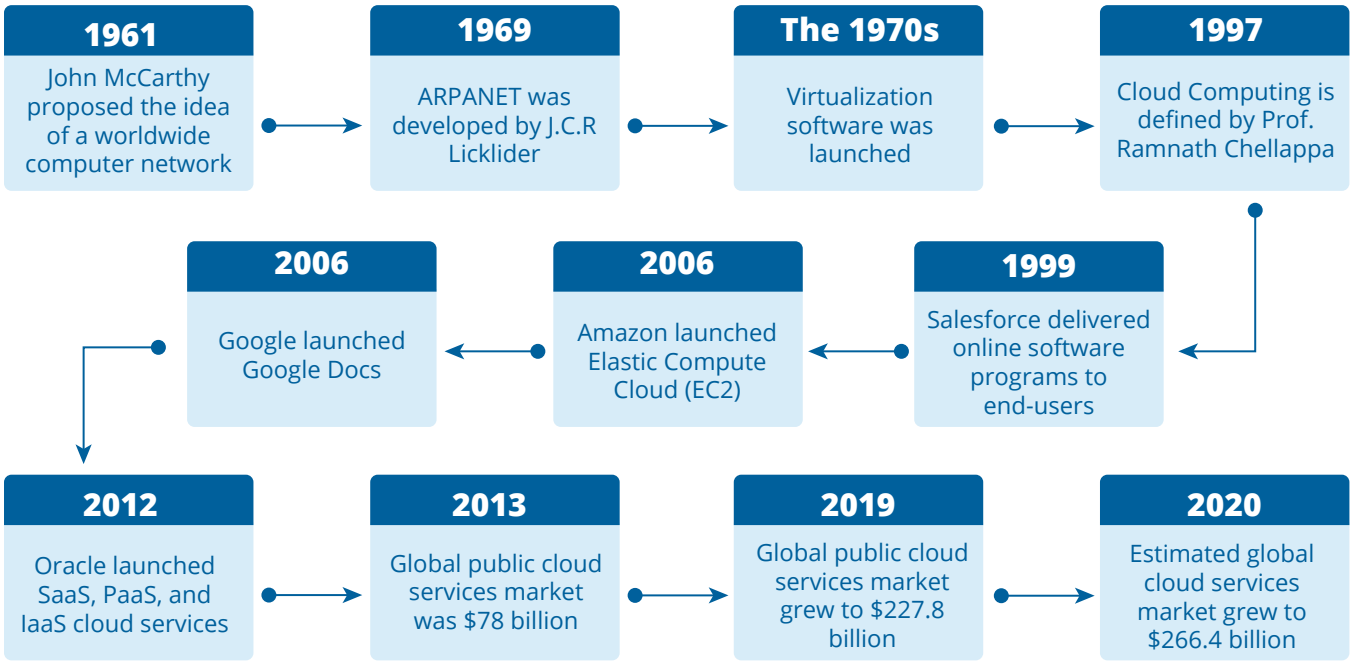


Figure 1. The evolution of cloud technology

Cloud computing is at the core of digital transformation. By allowing users to store and use data on remote servers instead of local data centers, it paved the way for the Internet of Things. Back in 1961, John McCarthy, known as the father of artificial intelligence (AI), proposed the idea of sharing resources through a worldwide computer network. He also suggested that computing could one day be sold as a public utility. [1][2][3]

J. C. R. Licklider, one of America's leading computer scientists, had a similar idea in 1963. He envisioned an "Intergalactic Computer Network" in which users could access programs and data from any computer in the world. In 1969, this vision was implemented in the Advanced Research Projects Agency Network (ARPANET). As a predecessor of the internet, it allowed users to access files remotely. [4]

> "Computing may someday be organized as a public utility, just as the telephone system is a public utility."
>
> Professor John McCarthy, 1961

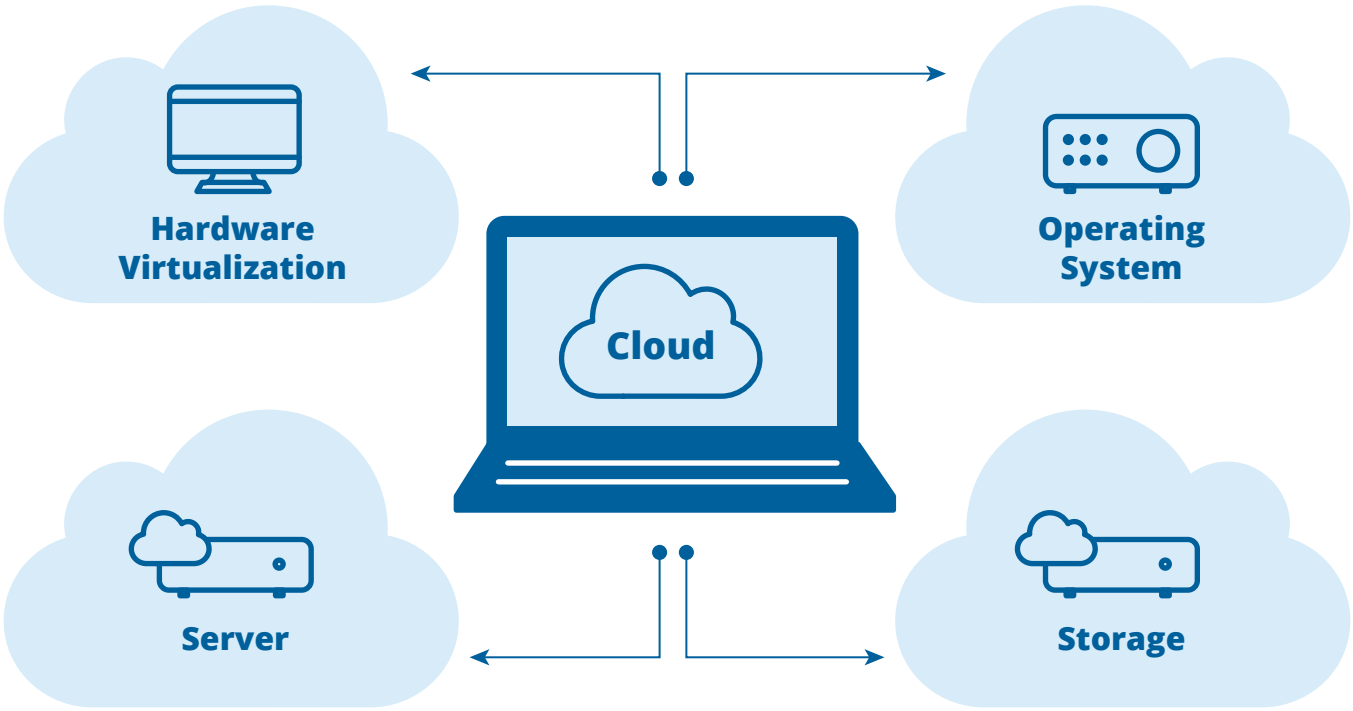


Figure 2. Virtualization in cloud computing

Virtualization as a concept came about in the 1970s with the emergence of virtual machines that functioned like physical computers. The concept gained momentum in the 1990s, following the rapid development of the internet.
Once users could rent virtual private networks, cloud infrastructure as we know it today began to take shape. [6] But it wasn't until 1997 that the term "cloud computing" was defined by Ramnath Chellapa:

> "[Cloud computing is] A new computing paradigm, where the boundaries of computing will be determined by economic rationale, rather than technical limits alone."
>
> Professor Ramnath Chellapa, Emory University

Salesforce

Around the turn of the twenty-first century, cloud computing began to really pick up steam. In 1999, Salesforce pioneered the idea of using cloud computing to deliver software programs to end users. [7] With this new paradigm, software could be purchased and accessed by anyone with an internet connection.

AWS

In 2006, Amazon started to offer online services with the launch of Amazon Web Services (AWS). With AWS, Amazon customers could access data storage, computational resources, and even human intelligence services through the Amazon Mechanical Turk platform. They could also rent individual virtual computers to run programs and applications through Elastic Compute Cloud (EC2). [8]

Google Docs

In the same year, Google launched its Google Docs services. Google Docs enabled users to create, edit, save, and share word processing documents and spreadsheets online, making cloud technology useful for everyone. At the Search Engine Strategies Conference in San Jose in 2006, Google CEO Eric Schmidt used the term "cloud computing" to describe these services. The term caught on and became part of the vernacular. [9]

Oracle Cloud

As the years passed, cloud technology was standardized, and Oracle played a part in that. Introduced in 2012, Oracle Cloud provided Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) cloud solutions. [11]

"It starts with the premise that the data services and architecture should be on servers. We call it cloud computing – they should be in a 'cloud' somewhere."

Eric Schmidt, CEO of Google [10]

Gartner provides the following snapshot of the cloud technology market:

- **In 2013, the global public cloud services market was worth $78 billion.**
- **As of November 2019, its value was $227.8 billion.**
- **The cloud services market is expected to reach $266.4 billion in 2020. [12]**

03 Three types of cloud computing

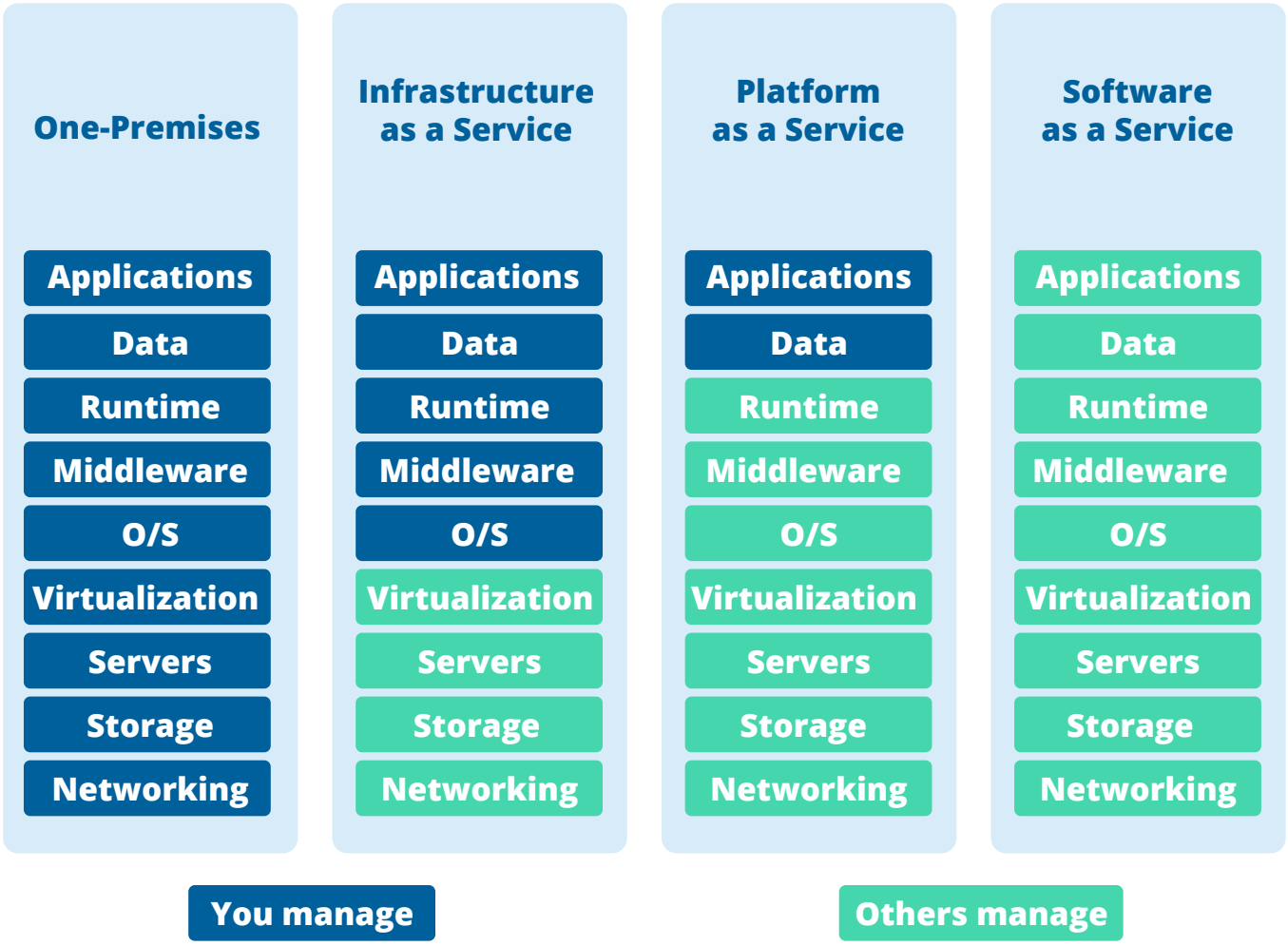


Figure 3. Types of cloud computing

As the demand for cloud development services grew, various solutions were developed to suit specific user needs. According to IBM [13], these three main cloud computing models are used in developing business software today:

- Software as a Service (SaaS)
- Platform as a Service (PaaS)
- Infrastructure as a Service (IaaS)

Software as a Service (SaaS)

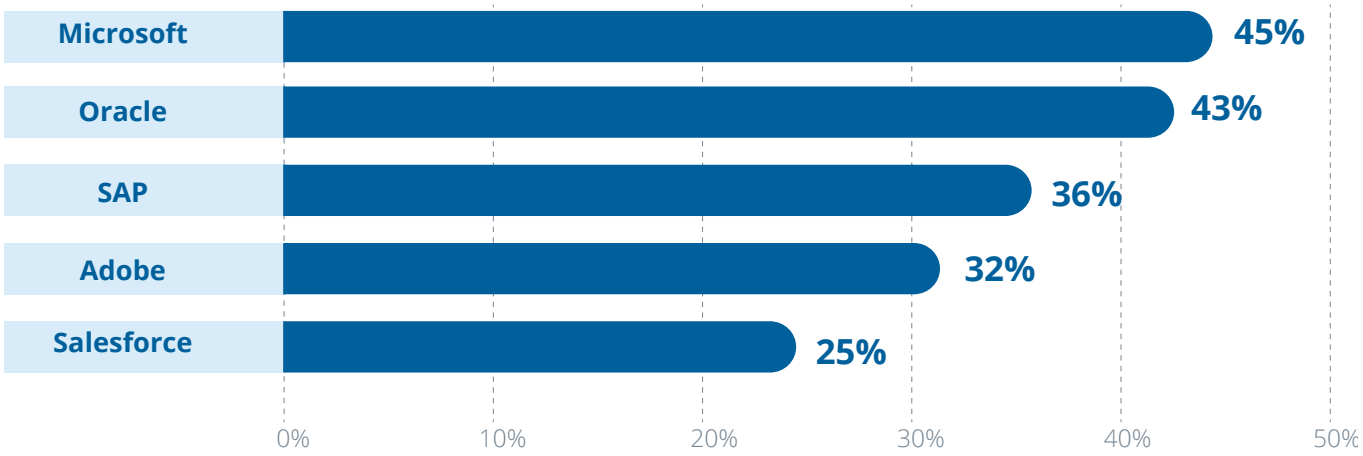


Figure 4. Software as a Service (SaaS)
Source: Synergy Research Group

The SaaS cloud computing model allows users to run programs in a web browser. This reduces the cost of starting and running a business, as you don't need to invest in hardware or on-premises software. SaaS vendors provide you with infrastructure, an operating system, and data management so your customers can use your services anytime and from any place.

Cutting out the initial investment in software allows you to get up and running fast, and with pay-per-use services, you can scale operations as required.

Platform as a Service (PaaS)

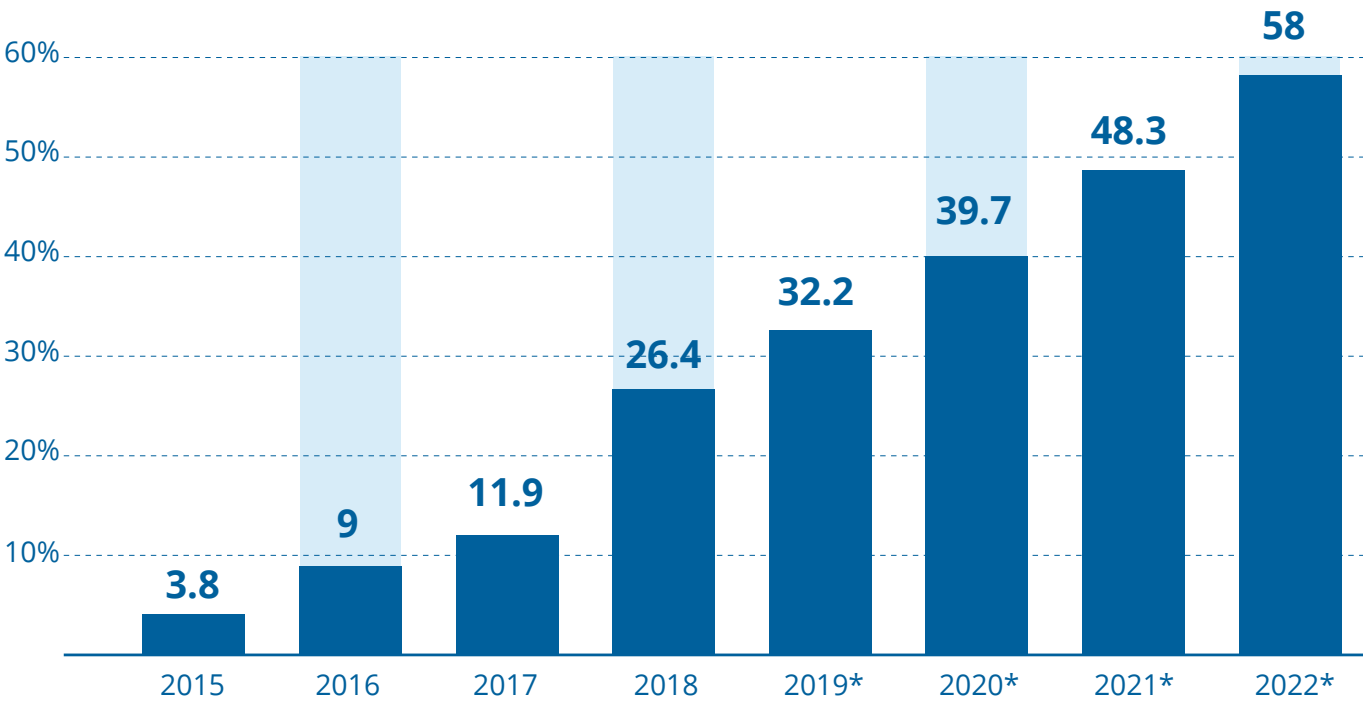


Figure 5. Platform as a Service (PaaS)
Source: Statista, Size of the Public PaaS Market Worldwide from 2015 to 2022 (U.S. Billion Dollars)

PaaS products provide the framework needed to build, test, and deliver web-based applications. With PaaS, you don't need to pay to deploy and maintain hardware and software, as PaaS solutions provide you with all the infrastructure, operating systems, development tools, and management systems you need.

Infrastructure as a Service (IaaS)

According to Gartner, the IaaS market is dominated by five vendors who account for nearly 80% of the global IaaS cloud market share: Amazon (47.8%), Microsoft (15.5%), Alibaba (7.7%), Google (4.0%), and IBM (1.8%).

IaaS is the most comprehensive type of cloud service. You can use your IaaS vendor's virtual services as is; or you can customize them to meet your business needs. You're in full control of your infrastructure and can install, configure, and manage any software, operating systems, analytics, and development tools. Pay-per-use subscriptions make IaaS a highly scalable model.

04 Cloud computing deployment models

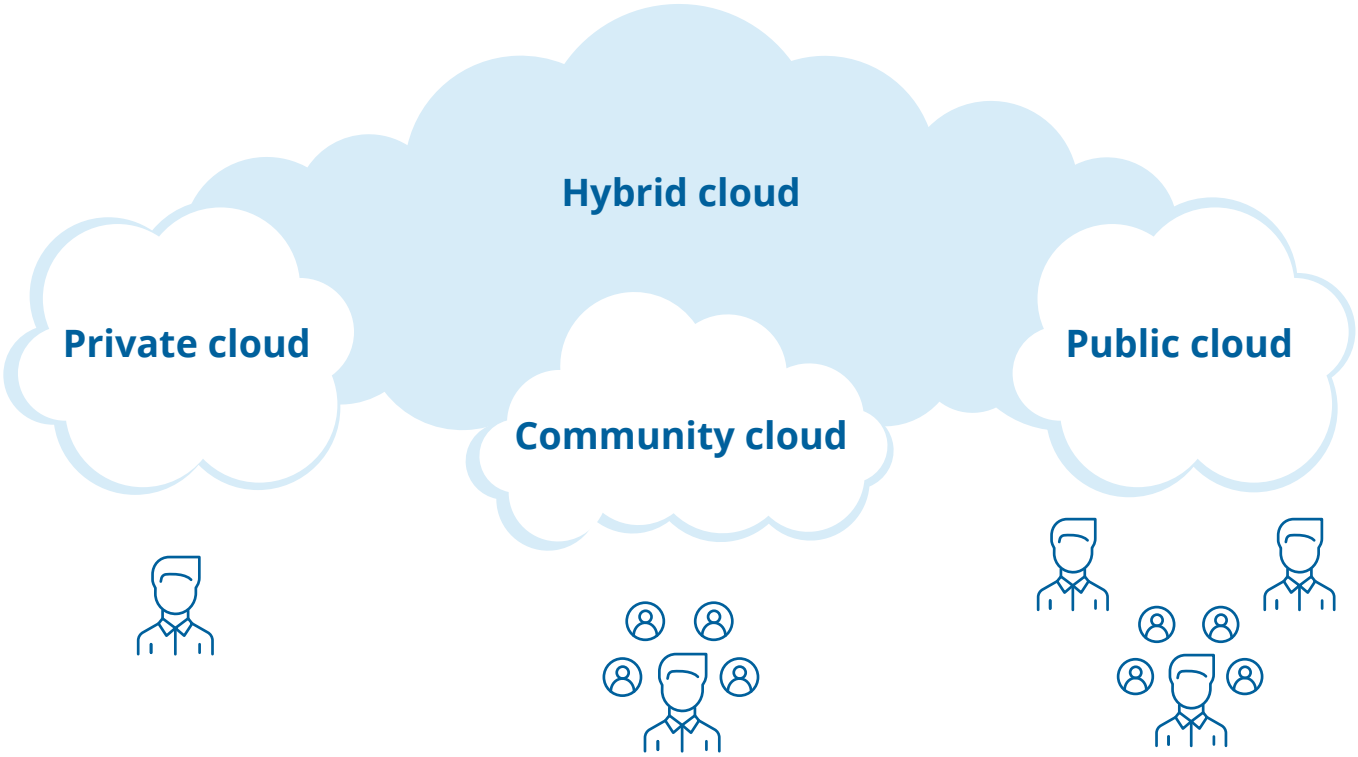


Figure 6. Cloud deployment models
Source: Cloud Computing Deployment Models (Mell and Grance, 2011)

The SaaS, PaaS, and IaaS models can be deployed in different ways to address specific business needs. [14] The most common deployment types are:

- Public cloud
- Private cloud
- Hybrid cloud
- Community cloud

Public cloud

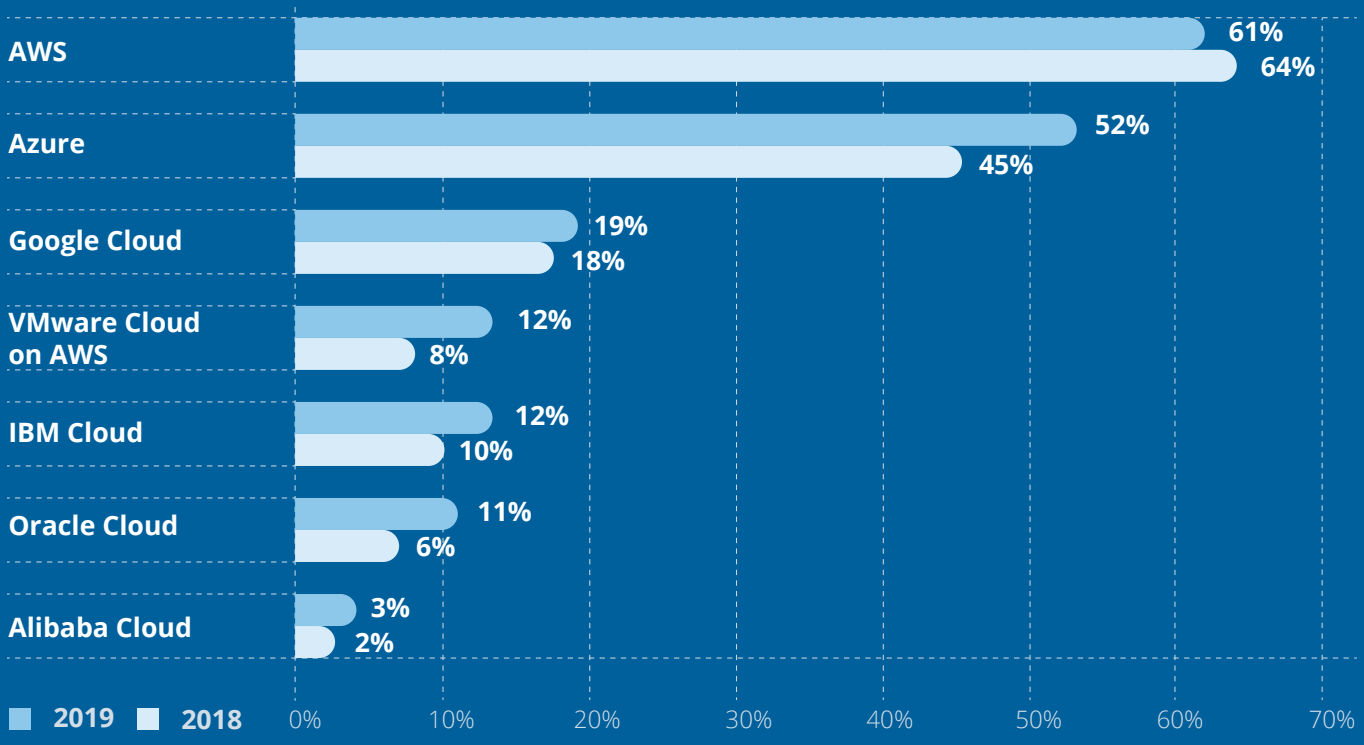


Figure 7. Public cloud adoption
Source: RightScale 2019 State of the Cloud Report from Flexera

Public clouds are, as the name suggests, available to the general public. In a public cloud, both software and hardware run on third-party servers and can be accessed through a subscription service.
Public clouds are increasingly used for file sharing and email services, though that's just a small part of what they can do. They can allow you to access hardware and operating systems, store data, run software, use servers, manage databases, and more.

Private cloud

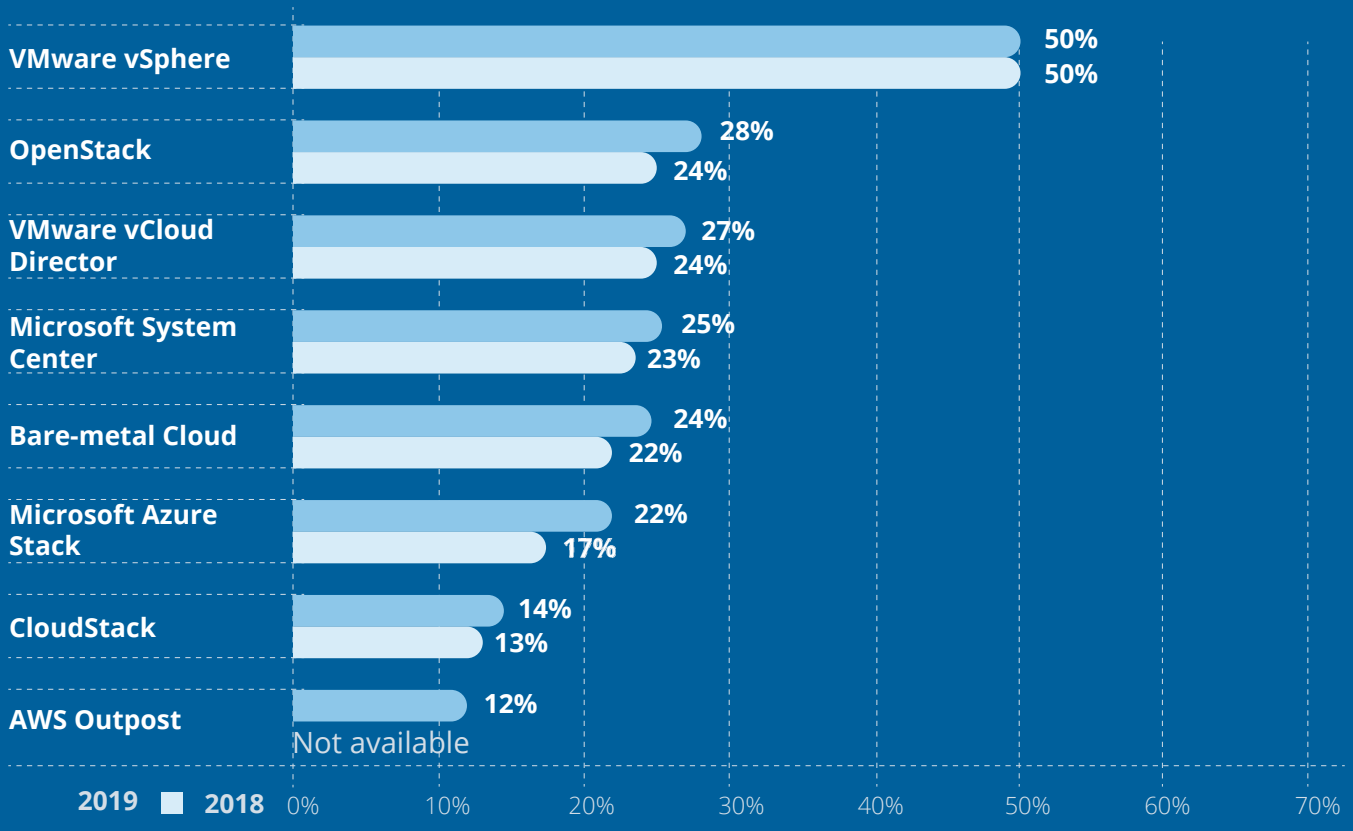


Figure 8. Private cloud adoption
Source: RightScale 2019 State of the Cloud Report from Flexera

Private clouds are strictly accessible by a single organization for the sake of privacy and security. In general, private clouds are the most secure, though that security comes at the cost of expensive deployment and maintenance.

Hybrid cloud

62% of public cloud adopters are using 2+ unique public cloud environments/platforms...

74% of enterprises describe their strategy as hybrid/multi-cloud today...

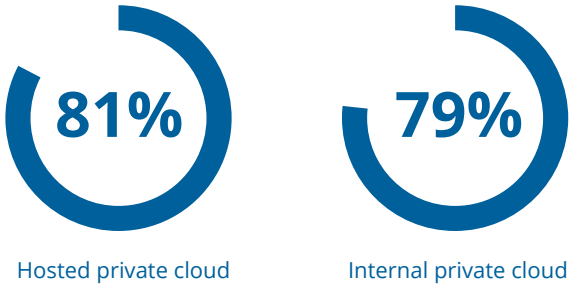
But only

42% regularly optimize cloud spending

41% maintain an approved service catalog

37% enforce capacity limits or expirations

Percentage of puplic cloud users that also use the following other cloud platform deployment types



Hosted private cloud

Internal private cloud

Implementations/environments of unique vendors

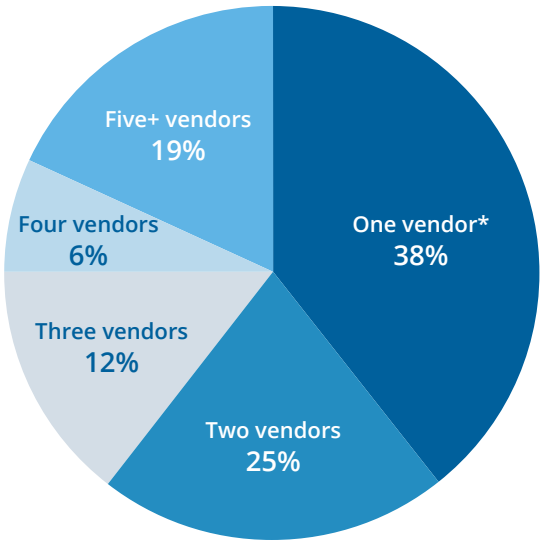


Figure 9. Multi-cloud & hybrid cloud by the numbers
Source: Dave Bartoletti, VP & Principal Analyst, Forrester Research

A hybrid cloud links private and public clouds, which is especially useful when you need to rapidly scale your IT infrastructure. A hybrid cloud allows you to benefit from the capacity of a private cloud while providing public access.

In addition, a hybrid cloud allows you to distribute your data storage. You can keep critical, sensitive data in a private cloud and store non-sensitive data in a less expensive public cloud. [15]

Community cloud

“Community clouds feature infrastructure that is shared by several organizations and meets the needs of a specific community of users.”

Source: McKinsey, Protecting information in the Cloud

Community clouds are similar to private clouds in the level of security and privacy they provide. The main difference is that a community cloud can be used by several organizations as opposed to a single organization with a private cloud.
Companies with similar backgrounds use community clouds to reap the benefits of private clouds while paying less. These companies share infrastructure and resources with each other along with the price of the services.
The community cloud model is best suited for collaborative projects within a group of organizations. For product development, management, and implementation, using a centralized cloud facility can be efficient.

05 Role of the cloud in the IoT ecosystem

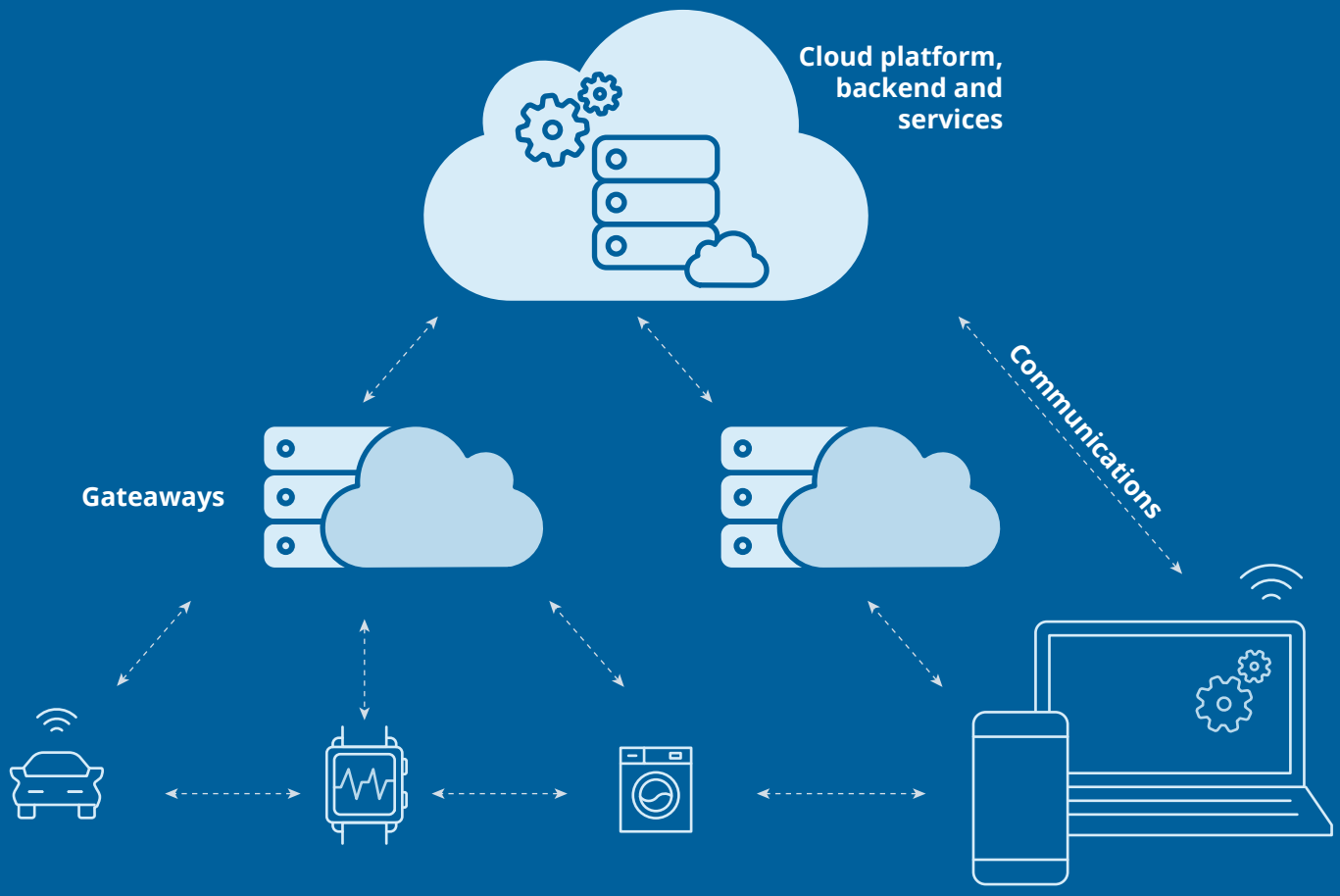


Figure 10. IoT and the cloud
Source: ENISA Towards Secure Convergence of Cloud and IoT

The Internet of Things is an ever-evolving network connecting physical objects to the internet. Across industries, devices from heart monitors to automobiles are designed with built-in sensors and IP addresses so they can transfer data over a network.

Devices powered with software, electronics, sensors, and data transfer technology allow businesses to sell additional services. These services are enabled by generating and exchanging data with developers, manufacturers, operators, and connected devices. [16]

IoT technology is redefining business as we know it. Not only does it change what your company does; it also changes how it does it. With IoT devices, the opportunities for growth are endless, and these opportunities are already being realized by companies in various industries including: [17]

- Healthcare
- Automotive
- Manufacturing
- Agriculture
- Transportation
- Energy
- Construction
- Hospitality
- Retail
- Finance

IoT and the cloud working as one

IoT devices generate enormous amounts of data. Immense computing power is required to store, process, and transfer this data, and onboard electronics alone cannot provide this power. It takes powerful servers and other equipment to facilitate this data processing, and the costs and storage requirements can quickly escalate. Cloud computing solves this problem.

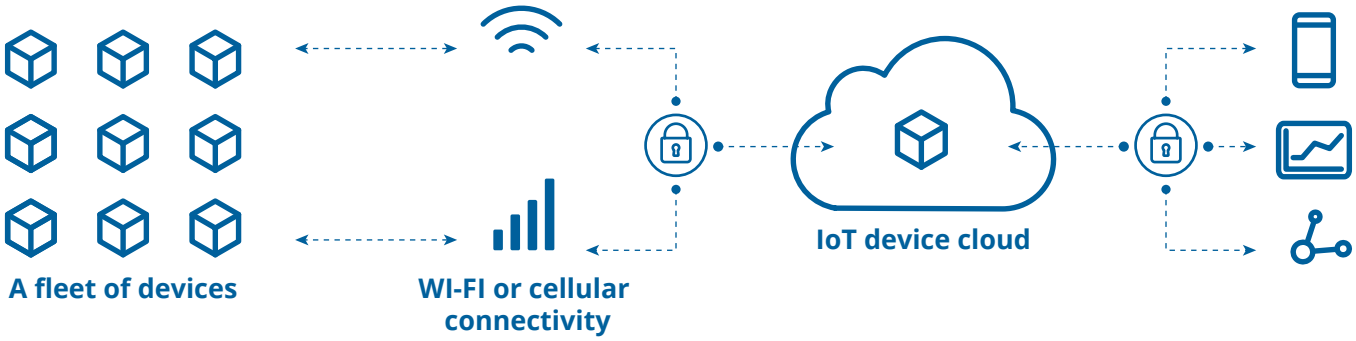


Figure 11. IoT data processing via the cloud
Source: ENISA Towards Secure Convergence of Cloud and IoT

Cloud computing enables companies to run IoT applications without the spiraling costs of on-premises infrastructure and data processing equipment. Processing data in the cloud allows you to be flexible and scale as needed.

The cloud as the key to successful IoT applications

Moving your core business software to the cloud will allow you to make the most of the Internet of Things. [18] When you run applications and software on servers within a secure online environment, you can effectively use data collected by your IoT system in real time. Using the cloud for real-time data processing provides these benefits:

- No upfront or capital investment in infrastructure
- Pay-per-use subscriptions
- Ability to scale up or down when necessary
- Real-time monitoring and management of connected devices
- Customizable applications and software
- Easy automation of storage, networking, servers, and processing power

Besides the obvious benefits of running an IoT system in the cloud, there are also challenges with this model.

06

Cloud-related IoT challenges

As IoT technology develops, the challenges associated with cloud computing become increasingly apparent. IoT operators using cloud technology face four categories of issues:

- Security
- Latency
- Bandwidth
- Quality of service

Security

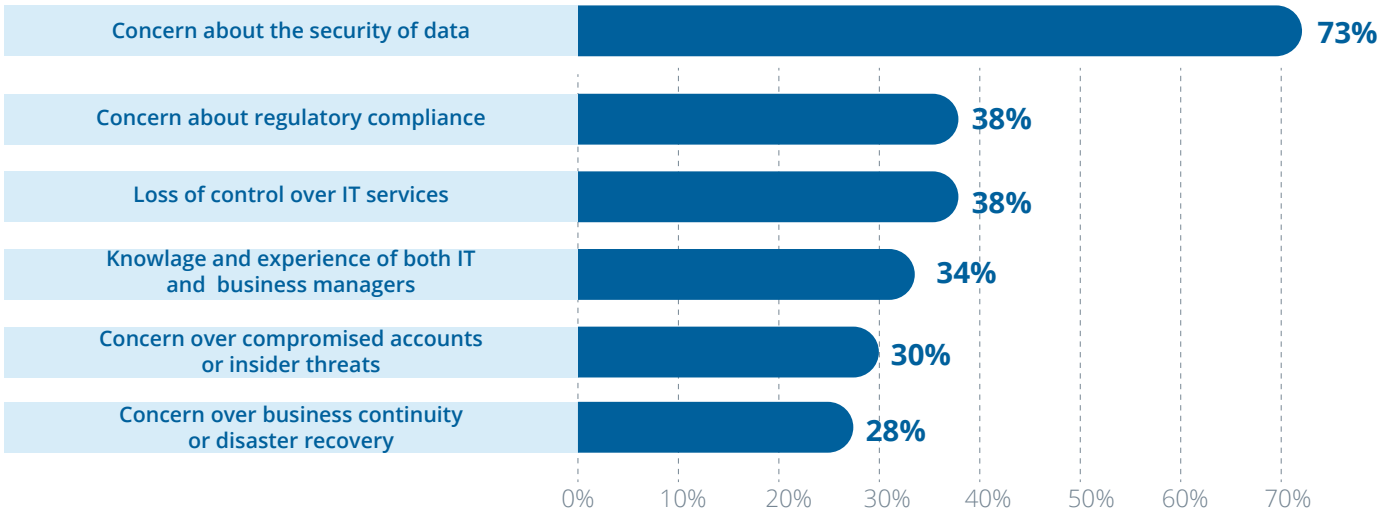


Figure 12. Top challenges holding back cloud projects
Source: Cloud Security Alliance "Cloud Adoption Practices & Priorities Survey Report"

A study by the Cloud Security Alliance has shown that data security concerns are the number one factor holding back cloud projects. As the idea of connected devices is relatively new, security has not always been the focus of product design.
Protecting data stored in the cloud is one of today's top cybersecurity challenges, as this data can be extremely valuable for hackers. [19] Some IoT devices are sold with software and operating systems that haven't been patched. Software that isn't patched in a timely manner allows unauthorized parties to access data processed by such devices, violating its privacy.
Thankfully, you can solve the most common security issues by selecting the right type of cloud.

Latency

IoT devices are subject to unpredictable latency when connected to cloud servers. Even though the cloud is designed to provide real-time connectivity between smart devices, data transfer delays occur frequently.
Connection speeds can drop at any point while processing, transmitting, or streaming data or while connecting to the server, which impairs the user experience. More importantly, latencies in industrial or medical IoT applications can disrupt real-time decision-making and potentially lead to life-threatening situations.

Bandwidth

There are two types of bandwidth: downstream (when data flows from the server to the IoT device) and upstream (when the IoT device sends data to the server). While current networks typically have more downstream than upstream bandwidth, IoT devices move a lot of data upstream. As a result, upstream links can become overloaded.

Quality of service

Many things that rely on IoT technologies, such as heart monitors and traffic systems, are critical to people's safety and wellbeing. For such applications, latency fluctuations and unstable connections are not acceptable. Disconnecting a sensor, even for a few seconds, can cost lives. Therefore, cloud providers need to make sure IoT devices continue working even offline.
Distributed denial of service (DDoS) attacks, software bugs, and operator errors can also affect the quality of service.

07

Edge computing

Managing millions of IoT devices via a cloud can be problematic due to issues with security, latency, bandwidth, and quality of service. This has pushed developers to source alternative solutions where data processing is executed closer to IoT sensors, at the edge of the network.

For instance, autonomous vehicles are equipped with a variety of sensors to connect with the internet, infrastructure, and other vehicles. [21] The quality of these sensors' connections with the internet or cloud affects real-time driving decisions. These connections, though, have to be completely reliable so that not to cause danger of car accidents.

> "We need to expand our thinking beyond centralization and cloud, and toward location and distributed processing for low-latency and real-time processing."
>
> Tom Bittman, VP at Gartner

> "As the volume and velocity of data increases, so too does the inefficiency of streaming all this information to a cloud or data center for processing."
>
> Santhosh Rao, Senior Research Director at Gartner

How edge computing fixes cloud issues

Edge computing facilitates real-time data processing at or near the point of data generation. Instead of sending device-generated data directly to the cloud, edge computing processes this data within the local network. Only less critical data is conveniently bundled and sent to the cloud to reduce latency issues. [22]

> Gartner estimates that by 2025, 75% of data will be processed outside the traditional data center or cloud. [23]

In fact, edge computing directly solves all of the abovementioned cloud-related IoT issues.

Security

With edge computing, devices keep most of their sensitive data locally, filtering it before uploading it. As a result, you don't need to connect as many devices to the internet as you do when using cloud computing.

Latency

In edge computing, key computing decisions are made locally, reducing delays in response.

Bandwidth

Edge computing alleviates network bandwidth requirements by processing data locally.

Quality of service

Interruptions in cloud connectivity can cause life-threatening situations, especially when IoT devices are used in driverless cars or heart monitors. Edge computing can keep systems running even when devices are offline. [24]

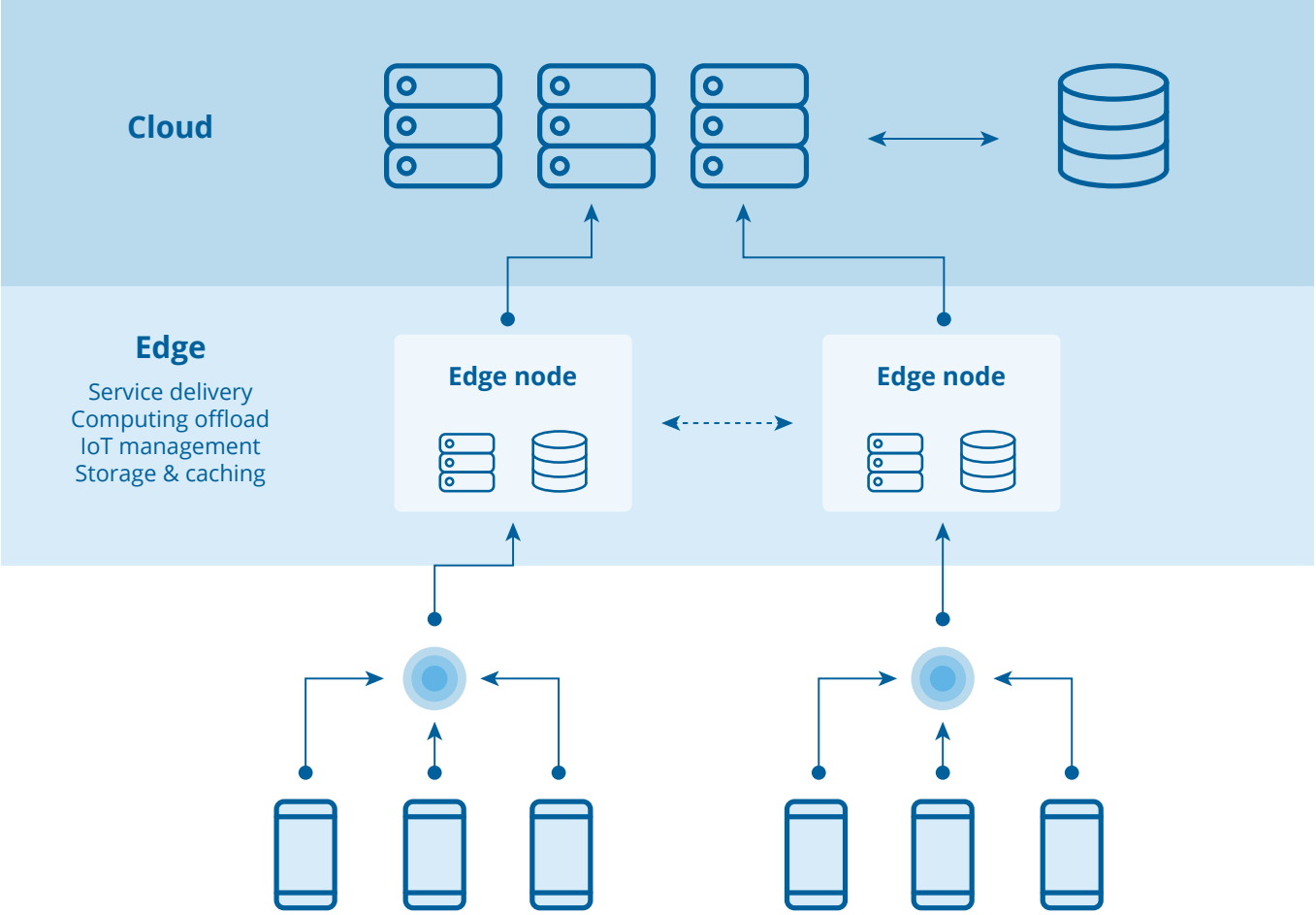


Figure 13. Cloud + edge combination for the best results
Source: Wikipedia Edge Computing Infrastructure

IoT projects benefit from combining the cloud and edge computing, no matter how different those approaches are. [25]

Edge devices cannot process or store large volumes of data and struggle to deal with complex analytics. But edge computing can compensate for cloud-related IoT issues, allowing for low latency, local autonomous actions, reduced backend traffic, and data confidentiality.

Edge computing is now a core element of these services:

- Amazon Web Services (AWS) [26]
- Microsoft Azure [27]
- Google Cloud [28]

IoT devices powered with edge computing spend less time communicating with the cloud, operate more efficiently, and can respond to local changes in real time.

One step ahead

While IaaS providers are developing new ways to bridge cloud and edge computing environments, Microsoft is taking a step ahead.
Microsoft has introduced Azure Arc with the goal of ending the era of proprietary software. Arc allows companies to use Azure cloud tools alongside other providers' software. [29] Companies can use Azure Arc to get the best of both worlds, taking advantage of cloud innovations paired with the benefits of edge computing.

08

Cloud + edge use cases

Powering cloud-based devices with edge computing enables local processing and the exchange of data between devices and the cloud, all in real time. Data in the cloud can be analyzed on the back end to improve functionality for all IoT applications. Across industries, the synergy of cloud and edge computing has solved latency, connectivity, and other issues for IoT deployments.

Retail

Problem

Comprehensive usage statistics and data on consumption patterns are vital for retailers in order to outcompete rivals and provide a superior customer experience. Additionally, retailers are striving to improve the efficiency of their stores and warehouse facilities to prevent goods from spoiling. For this purpose, they need to constantly monitor and log the temperature and humidity levels of cooling systems to prove that products have been safely stored. Typically, this is done manually by checking the systems once per day. But this workflow has some pitfalls. For one thing, as stores can be closed on certain days of the week or on public holidays, it's possible that no one will notice a system outage, leading to spoiled goods that need to be discarded.

Solution

Leveraging the power of IoT, the cloud, and edge computing, retailers can remotely monitor the temperature, humidity, and air pressure in cooling systems.
As we showed in a case study, the right mix of these technologies can enable supermarkets and retail stores to meet food storage safety requirements as well as save around 20% on energy consumption.
Read more about how IoT connectivity can serve as a solid tech backbone for building an advanced customer engagement platform that has the potential to help retailers revolutionize the customer experience and make it more dynamic.

Industrial automation

Problem

Industrial IoT use cases require quick response times that cannot always be ensured by the cloud. For example, with safety-critical systems in which a super fast response time is necessary to avoid physical injury to people, even 99.99% reliability is not good enough. Or consider predictive maintenance applications, which often require local processing of sensitive data to improve the overall privacy and security of industrial environments.

Solution

The ability to make fast decisions at the edge is critical for industrial IoT projects, especially in terms of human safety. For predictive asset maintenance and remote monitoring applications, data processing can be performed locally on edge devices to reduce the amount of sensitive data sent outside industrial facilities. Additionally, predictive maintenance solutions can be bundled with inventory management systems. In this case, both real-time data from edge devices and historical data stored in the cloud are critical to predict possible failures and ensure that spare parts are in stock in case of a malfunction.

Robotics

Problem

Data interactions between robots and cloud platforms is one of the biggest challenges of industrial robotics. Real-time execution of tasks requires local processing and sophisticated data analysis along with high memory capacity and low latency, which cannot be fully guaranteed by the cloud due to lengthy delays. Additionally, regulations can prohibit transferring data to cloud servers outside a country or outside a company's IT infrastructure.

Solution

Combining cloud and edge computing allows companies to create flexible robotics platforms capable of both improving real-time operations and providing powerful infrastructure for data processing and analysis. This approach eliminates the need to move all data, enabling intelligent real-time applications. For more on this topic, read about how the Intellias team leveraged cloud and edge computing to build a full-stack, on-premises IoT platform for managing and maintaining a fleet of high-tech industrial robots.

Automotive

Problem

As vehicles generate and exchange massive amounts of data about their locations, temperature, traffic conditions, and more, it's becoming a big challenge to process this data efficiently. For instance, safety-related functions need to be constantly available and cannot rely on wireless connectivity to distant data centers, as these connections may be unstable. Real-time decision-making is vital for real-world use cases like autonomous driving or remote vehicle monitoring and diagnostics.

Solution

A synergy of cloud and edge computing is the best approach to ensuring the safety, functionality, and effectiveness of critical autonomous systems. Cloud-based over-the-air updates lay the groundwork for regular preventive maintenance, while edge gateways can be used to locally process essential real-time data for safety-critical systems. In this case, edge software can act as the communication client to enable the exchange of information for device management and telemetry data.

Telecommunications

Problem

Communication Service Providers (CSPs) are looking for new revenue sources to grow their businesses, specifically in the B2B segment. With the introduction of 5G, they're now in a better position to diversify their service offerings, leveraging advanced connectivity as the backbone of their value propositions. The majority of new revenue potential for CSPs is expected to come from purpose-built IoT applications for different market verticals, many of which require enhanced security, ultra-high reliability, and real-time analysis of critical data.

Solution

As part of a distributed cloud system, edge computing will become a fundamental component of 5G infrastructure, enabling CSPs to host non-telco workloads and provide distributed computing and storage resources close to where they're needed. In the context of the wider enterprise opportunity, such an approach is paving the way for new use cases like smart manufacturing, connected healthcare, and augmented/virtual reality (AR/VR), reducing latency, network congestion, and the risk of data loss.

Cloud-native microservices

Problem

Cloud computing is a powerful technology. However, it takes time to set up the cloud environment required for developing microservices. The shorter the setup time, the faster companies can scale their infrastructure.

Solution

Intellias developed the CQRS framework to speed up the setup of cloud environments many times over. This framework draws on the Azure Cloud, Microsoft's flagship cloud service. It features cloud connectors and libraries for Azure CQRS services, such as Service Bus, Storage Queue, and Table Storage. It also provides tools for deployment, monitoring, real-time streaming (using GraphQL), messaging, and automated testing. Today, the CQRS framework boasts a system capacity of 500 terabytes and a transaction throughput of about four billion transactions per second. Businesses across industries are using it to speed up their time to market, cutting development time by up to 50% and infrastructure costs by up to 80%.

09

About Intellias

Intellias is a software development company based in Ukraine. We're experts in IoT, cloud, edge computing, and other technologies critical for the success of modern organizations.
With our help, organizations:

- get the most out of private, public, and hybrid clouds
- streamline your digital transformation
- shift to SaaS, PaaS, and IaaS service delivery models

In building solutions for our clients, we rely on major cloud services including Amazon Web Services, Microsoft Azure, and the Google Cloud Platform.

Intellias cloud services

Intellias provides a full range of cloud software services:

- **Application re-architecting**

Boost software performance by migrating applications from a monolithic to microservices architecture and exposing their functionality via APIs.

- **Cloud discovery and optimization**

Audit your cloud infrastructure to find out how you can reduce inefficiencies that cost you hundreds of thousands of dollars annually.

- **Cloud migration**

Move your IT infrastructure and business processes to the cloud using the most suitable migration strategy.

- **Cloud-native development**

Develop serverless, cloud-based applications using fully managed services like AWS Lambda and Azure Functions and databases like Amazon DynamoDB and Azure Cosmos DB.

Get the most of your cloud with Intellias

Intellias works with enterprises and tech innovators in different sectors including manufacturing, automotive, finance, retail, telecom, agriculture, transportation, and beyond, enabling them to achieve business agility and optimize their technology infrastructure. Our cross-industry experience allows us to come up with creative technical solutions to nontrivial problems, providing the desired level of cost efficiency and ensuring that all the business-critical requirements are met.

Learn more about our cloud development and consulting services to uncover how cloud technology can bring a truly transformative impact to your business.

Contact us

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