White Paper

AWS at the Edge: A Cloud Without Boundaries

Sponsored by: Amazon Web Services

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December 2020

IN THIS WHITE PAPER

As organizations chart their path toward digital transformation, they are incorporating more edge technology into their business operations to help improve application performance and reduce costs. Edge computing moves data processing and analysis close to endpoints where data is generated, to deliver real-time responsiveness and reduce the cost associated with transferring large amounts of data.

Across a wide range of industries, there are a diverse set of use cases driving requirements for improved performance at the edge of the cloud. Autonomous vehicles ingest and process data from in-vehicle sensors in real time, without the time lag of connecting back to the cloud. Smart home devices interpret and act on voice commands, using responsive processing located right on the device. Many industrial machines in smart factories detect and adjust automatically to variations in the quality of materials on assembly lines. These use cases have common characteristics: ultra-low latency, limited or no internet connectivity, and large volumes of data generated and processed locally. These examples combine both cloud and edge infrastructure to unlock new capabilities for organizations more effectively than a centralized approach alone.

The challenge is that edge solutions cover such a wide range of scenarios that cloud service providers need to develop and support technologies, services, and devices that operate in a variety of different environments. Technology has become embedded everywhere in today's world, and edge services are deployed in locations ranging from branch offices to factories to oil fields, and even into the connected devices themselves. Some of these systems and services are large, resembling traditional server racks, while others are small enough to carry in a backpack and some are even embedded software that enables the smallest, low-power devices to connect to the cloud, quickly and securely.

Regardless of where the technology is deployed, organizations are discovering a few important considerations. First, it is critical to implement and audit security best practices that ensure device identity, authenticate and authorize devices, and encrypt device data. Second, developers want to be able to use the same methods of building and distributing code, both on devices and in the cloud. Third, CIOs want these systems managed in a homogeneous manner, with flexibility to scale resources to meet changing needs.

IDC predicts that over 75% of infrastructure in edge locations will be consumed and operated via an as-a-service model, as will more than half of datacenter infrastructure. This supports the sentiment that enterprises want all the benefits of the cloud with the ability to deploy virtually anywhere.

December 2020, IDC #US46512020

This White Paper explores current edge market trends and highlights industry-specific use cases. It also describes how Amazon Web Services (AWS) and its partners are enabling customer success through its portfolio of edge services and solutions.

SITUATION OVERVIEW

Cloud services have transformed the way information technology (IT) is developed, deployed, and managed. Organizations of every type, size, and industry are using the cloud for a wide variety of use cases such as data backup, disaster recovery, email, virtual desktops, software development and testing, big data and analytics, business applications, and machine learning (ML).

By removing the burden of owning and managing physical infrastructure, cloud computing unlocks several benefits:

- **Agility:** The cloud provides easy access to a broad range of technologies, enabling faster innovation with the ability to build nearly anything imaginable. It is possible to spin up resources as needed – from infrastructure services, such as compute, storage, and databases, to Internet of Things (IoT), robotics, machine learning, data lakes, and advanced analytics.
- **Elasticity:** With cloud computing, it is not necessary to over-provision resources up front to handle peak levels of business activity in the future. Instead, provision the amount of resources that is currently needed. These resources can scale up or down to instantly grow or shrink capacity as business needs change.
- **Cost savings:** The cloud trades capital expenses (such as datacenters and physical servers) for variable expenses, and charges are based on actual consumption. And the variable expenses are much lower because of the economies of scale.
- **Global deployment in minutes:** With the cloud, expanding to new geographic regions and deploying globally happen in minutes. Putting applications in closer proximity to end users improves response times and overall availability.

As cloud solutions have matured, use cases have emerged across various industries that need to combine cloud resources with local processing and storage of data under certain conditions:

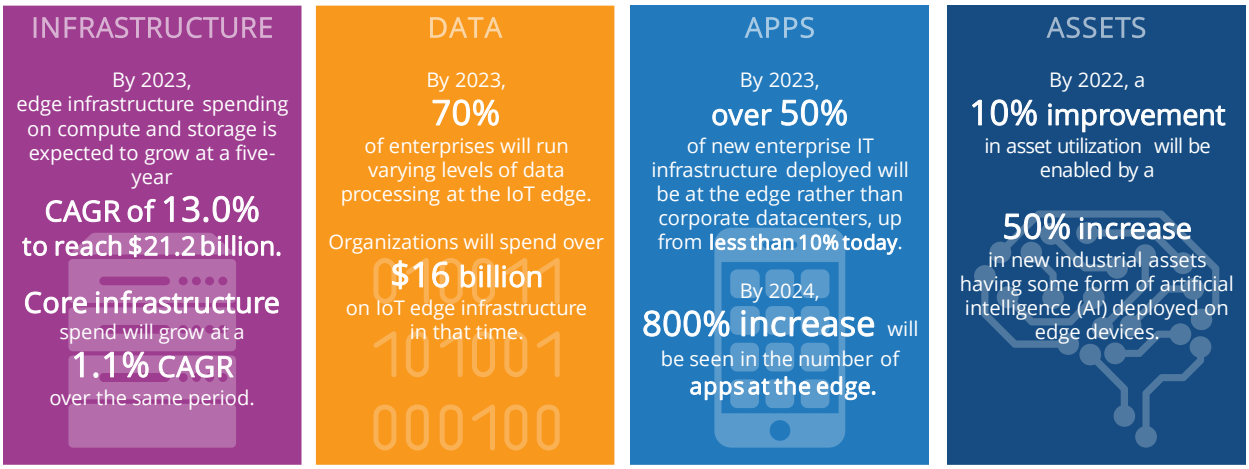
- **Latency-sensitive applications:** Latency refers to the time it takes between a request and a response. Whether introduced by the network itself or the number of hops between an endpoint and a server, latency represents a delay. There are many use cases where quick response times are critical. For example, autonomous vehicles require a near-real-time response to sensor data to make a decision. The same is true in smart manufacturing where artificial intelligence (AI) is used to improve quality or yield.
- **Assets with limited connectivity:** IoT devices or other connected equipment can be mobile in nature, meaning they are not tied to a fixed location. In these situations, the assets may move in and out of coverage areas or have limited bandwidth. For example, mining equipment can travel miles underground yet requires the analysis of telemetry data for maintenance and safety conditions. Shipping and logistics companies track cargo that moves between different modes of transportation but must still ensure data can be collected and reported.
- **Significant data volumes:** As the amount of data generated in remote locations increases, the costs associated with transmitting the information to a central data store also grow. In the case of wireless, this could result in extra charges for the amount of data transferred or having to

opt for more expensive connections over low-bandwidth alternatives. The same is true for wired connections that must be upgraded to handle the additional flow of data.

To meet this need, IDC research indicates that CIOs are planning significant investments in edge technology (see Figure 1). By 2023, edge infrastructure spending on compute and storage systems is expected to grow at a five-year CAGR of 13.0% to reach $21.2 billion. In contrast, on-premises core infrastructure spend will grow at just 1.1%.

FIGURE 1

IDC Future Outlook for Edge



Source: IDC, 2020

Growth is also projected for both data and applications that will run on this distributed infrastructure. 70% of enterprises will run varying levels of data processing on IoT devices, and there will be an 800% increase in the number of applications at the edge. The potential benefits of these trends to organizations are apparent when considering the actual use cases. For example, in the industrial sector, as an increasing amount of industrial assets have some form of artificial intelligence deployed either near or on the equipment, it will lead to a projected 10% improvement in asset utilization. At scale, this is a meaningful improvement in business operations.

INDUSTRY PERSPECTIVES

Best practices for designing technology solutions always start with understanding the business objective – this is no different when it comes to the edge. The benefits of distributing applications across cloud and edge infrastructure apply to almost every vertical market including manufacturing, retail, and financial services.

Each industry has unique needs in terms of the problems it is solving and its approach to implementing edge technologies. Here are four examples of organizations realizing the benefits of edge computing, representing a subset of the edge services and solutions deployed today.

Government and Emergency Response

Citizen safety is a chief responsibility of federal and local governments. During times of emergency, first responders rely heavily on whatever information is available to inform their disaster response plan. This involves creating temporary command centers that must collect and analyze multiple real-time data feeds. Knowing the location of personnel, vehicles, and equipment is critical to maximizing the effectiveness of the operation.

These scenarios are anything but ideal for deploying technology. Network connections are rarely reliable, which makes cloud-based applications prohibitive. There is also the issue of tying together video, sensor, and public data sources into a single view that provides consolidated situational awareness.

Novetta, an AWS Advanced Consulting Partner, is an advanced analytics company that provides solutions for defense, intelligence, and other government entities. It views disaster response as the perfect use case for the tactical edge, where real-time decision making is paramount. Novetta relies on AWS Snowball Edge, a rugged, shippable edge computing device with Amazon EC2 and storage on board, to help support disaster response efforts in the field.

"We are able to use an AWS Snowball Edge device to successfully track the location of various personnel and assets, like emergency vehicles, critical to a disaster response effort," said Rob Sheen, SVP of Client Operations at Novetta. "Leveraging advanced video processing software running on the AWS Snowball Edge, we post-process video surveillance feeds to operate under reduced bandwidth, a typical condition during response operations."

Governments set a high bar for security and the physical nature of an edge device can require a long certification process. Novetta has been able to alleviate those concerns by standardizing on the AWS Snow Family of products, including AWS Snowball Edge and AWS Snowcone, that are highly secure, portable devices to collect and process data at the edge and migrate data into and out of AWS. "AWS Snowball Edge provides a slice of your cloud environment in a rugged box that can function without being connected to the cloud," added Sheen.

Having local compute and cloud resources allows the software to work while disconnected from the cloud. Novetta trains machine learning models in the cloud using Amazon SageMaker, which is a fully managed service that provides developers and data scientists with the ability to build, train, and deploy machine learning models quickly. Novetta then deploys the models directly to AWS Snowball Edge to complete image analysis in the field, with no lag in object detection.

Novetta also uses AWS IoT to deploy ML models locally. Its own specialized sensor equipment is embedded with AWS IoT Greengrass, a device software enabling local compute, messaging, management, sync, and ML inference capabilities. AWS IoT Greengrass provides a containerized AWS Lambda runtime environment for user-defined code authored in AWS Lambda, a serverless computing service. This code, known as an AWS Lambda function, is then deployed to AWS IoT Greengrass devices and run in its local AWS Lambda runtime. Local AWS Lambda functions can be triggered by local events, messages from the cloud, and other sources, which bring local compute functionality to connected devices. Novetta's sensor equipment uses AWS Lambda functions for event triggers, making them responsive in near real time.

"There is no other cloud service provider that allows me to achieve parity between what I have in the cloud and what I can integrate on edge devices," said Sheen. "AWS is leading in the development of

practical, mission-ready edge computing technology that we use to build solutions to help our public sector clients save lives. AWS Snowcone is a great example of AWS innovation for the edge. Snowcone gives us a rugged, secure, and portable edge computing platform that we can use in disaster zones and austere edge locations. In our recent field exercises, AWS Snowcone performed admirably as a sensor hub at the edge to track people and assets in a disaster zone."

Telecommunications

Communications service providers are actively deploying edge technology as they implement virtual network functions (VNFs) in support of 5G networks and multi-access edge compute (MEC) solutions. These new capabilities are instrumental to shifts in the industry from traditional network connectivity to value-added services, including content delivery and new customer experiences. These changes are occurring across multiple types of access methods including wireless, fiber, and satellite.

Inmarsat, a mobile satellite communications provider specializing in broadband and voice services, is currently using AWS both in the cloud and at the edge. For IT operations, the company has been on a migration journey to the cloud, standardizing on the AWS technology stack. However, like many companies, Inmarsat has several custom and third-party applications that do not adhere to a cloud-native architecture and are sensitive to network latency.

"15% of our workloads must remain on premises for various reasons," said Tim Brown, senior director, Cloud and Operations at Inmarsat. This is mainly centered around applications that require a high volume of transactional operations against databases that are hosted on local physical servers. "As we moved applications to the cloud and left databases on premises, we were noticing up to 20–30ms of latency, which was causing performance problems with major queries and large reports."

Inmarsat is using AWS Outposts to address this need. "We still wanted to have a single pane of glass for management with all of the benefits of the cloud including elasticity but have the compute next to those databases and other systems onsite," said Brown. "AWS Outposts gives us the ability to be cloud native while integrating with these existing systems."

The solution helped Inmarsat maintain consistency with its intention to purchase infrastructure as a managed service, regardless of whether it is in the cloud or at the edge. During the implementation process, AWS was deeply involved in the details of the deployment, including the architecture and site planning phases to ensure a successful installation. In addition, the ability to failover from an edge location to a cloud region provides a cost-effective method of achieving high availability and business continuity.

Media and Entertainment

Edge technology in the form of content delivery networks (CDNs) is critical for media and entertainment companies, especially as the industry shifts to streaming services. Three to four years ago, streaming was considered an optional companion to traditional television service. Currently, it is becoming the primary way consumers interact with media.

It can take upward of a year to develop and launch a new streaming service. If the initial impression is poor, the consumer will look elsewhere. This puts an incredible amount of importance on the quality of the experience. Media companies expect CDNs to provide a high level of visibility into how the platform is operating as well as user behavior.

Kaltura, an Amazon Web Services customer, knows this well. The company's mission is to power video experiences through the company's video platform, video player, and wide array of video solutions that are deployed at thousands of enterprises, media companies, and service providers.

"Edge services are an essential part of my business," said Zohar Babin, EVP, Platform and Growth at Kaltura. "I don't see how Kaltura is possible without edge services." Kaltura uses Amazon CloudFront to serve playback closest to the end user. "In an enterprise application, you may not notice latency or response time lag, but with video there is a lot of data going back and forth, so unless you are deploying a CDN, your experience will suffer."

The company uses data analytics to develop benchmarks and best practices. This is relevant not only for distributing video but also for uploading new content from the user back to the origin servers in the fastest way possible with the least potential problems. According to Babin, this becomes 10 times more important for live broadcasts and 100 times more important for a real-time video.

"One thing we've been doing at Kaltura and pioneering in this industry segment is something we call cloud TV," said Gideon Gilboa, EVP, Product, Marketing, and Solutions Engineering at Kaltura. The company uses AWS IoT services to perform software updates and collect data from set-top boxes that reduce the load on the network with a combination of push notifications and job scheduling features.

In addition, leading media companies such as Amazon Prime Video, Hulu, and Fox are also using Amazon CloudFront to deliver services to their customers.

Healthcare and Pharmaceuticals

Developing a new medicine or therapy is not a trivial task. It can be a 10- to 15-year process that consists of designing and conducting experiments, determining and optimizing molecules, and performing toxicology studies — all before the first clinical trial with actual patients begins.

The research phase of this process can involve thousands of scientists, which creates a tremendous amount of data from lab equipment spread across multiple locations. The development of cloud-based edge computing capabilities presents an opportunity for companies to accelerate their research by leveraging high-performance computing (HPC) and artificial intelligence to run simulations.

The biggest challenge companies must overcome to utilize these capabilities is to move data generated by legacy instruments into the cloud. These instruments are dispersed geographically in a company's global network of labs and are not designed to natively connect to the cloud. The microscopes and genomic sequencers they use can range in cost from $100,000 to over $1 million per instrument, and have an average life span of a decade; so replacing them with modern, internet-connected equipment is not always feasible. Further, large pharmaceutical companies can have tens of thousands of these devices scattered across the world.

To address these issues, Celgene (a subsidiary of Bristol-Myers Squibb) decided on AWS Storage Gateway and AWS DataSync as a solution. AWS Storage Gateway is a hybrid cloud storage service that provides on-premises access to virtually unlimited cloud storage. AWS DataSync is a data transfer service that uses a purpose-built protocol to securely transfer data at speeds up to 10 times faster than open source tools. These services enable the company to seamlessly transfer research data from legacy instruments into the cloud while applying security and data management policies.

"A big challenge that we face is the integration of labs, where we conduct physical experiments generating data, with the computational aspect of our research," said Lance Smith, associate director

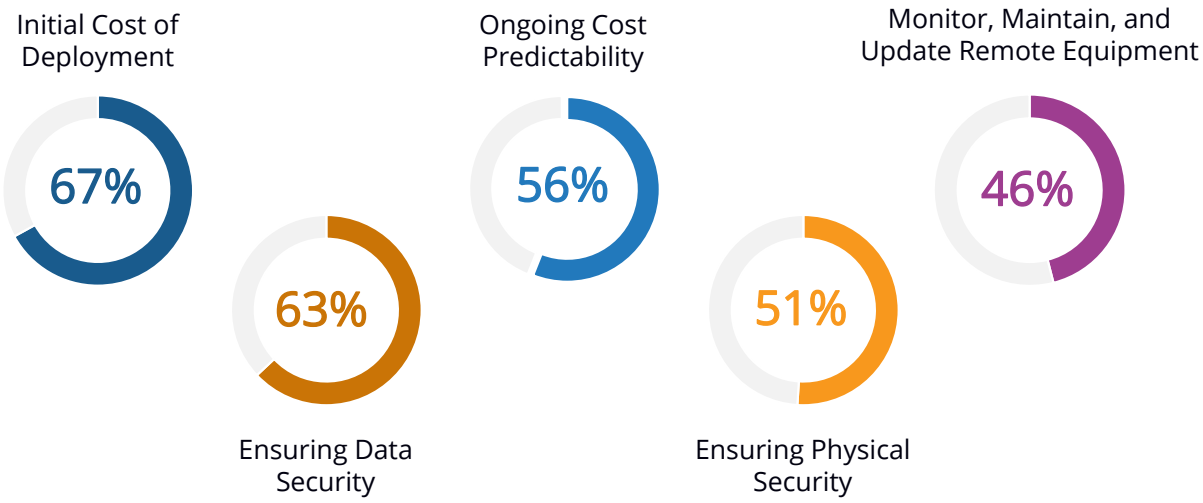
at Celgene. "We use AWS Storage Gateway and AWS DataSync to synchronize our on-premises labs with our AWS storage. By having our scientists immediately be able to save their files directly to the cloud, they can go on with the next experiment without having to wait for the transfer times and they never run out of space."

CHALLENGES/OPPORTUNITIES

As CIOs plan for edge deployments, there are several concerns on their minds. Figure 2 illustrates response data from an IDC survey regarding edge.

FIGURE 2

Top IT Concerns for Edge Deployments



Source: IDC, 2020

It is no surprise that areas such as cost, security, and remote management rank high on the list. These are top reasons why many enterprises have migrated their workloads to the cloud. For some, the thought of deploying infrastructure and applications in the field can feel like a step backward.

Organizations that have realized the benefits of cloud-native application design and the ability to scale up and down in response to demand want those same characteristics in their edge solutions as well. The edge should feel like an extension of their existing cloud environment and not a bolted-on appendage.

AWS Edge to Cloud Solutions

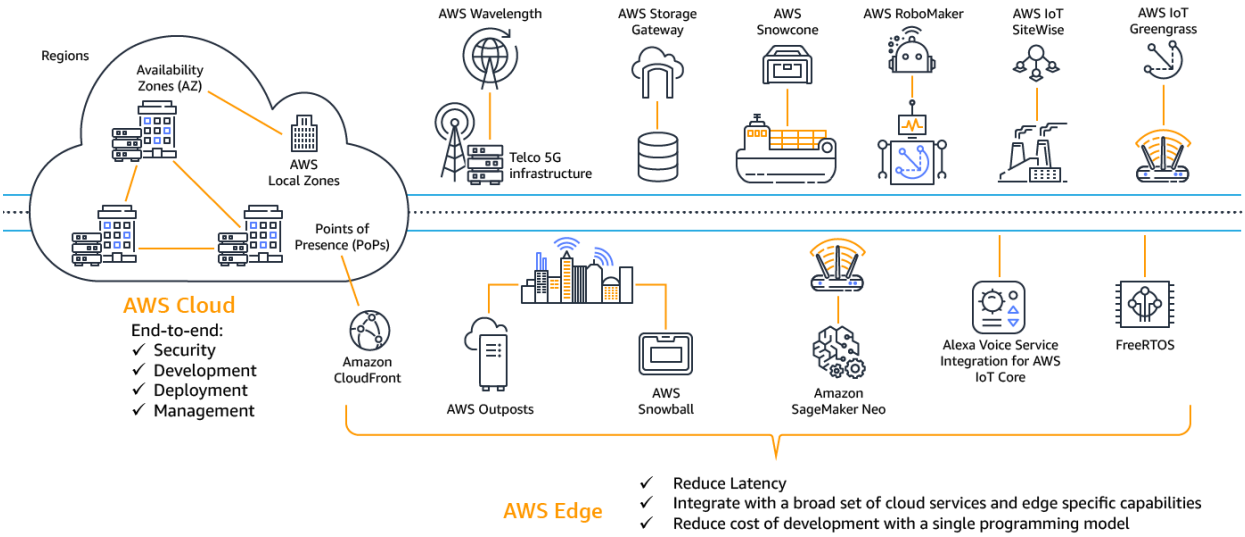
AWS has responded to the demand for edge computing and the aforementioned common concerns by developing a broad range of integrated edge-to-cloud services and solutions, combined with global cloud infrastructure, that provides data processing and analysis capability as close as necessary to where data is generated.

This comprehensive edge portfolio enables customers to pick the right solution for their needs while leveraging cloud investments. AWS edge services enable the use of a single programming model in the cloud and across devices, allowing for end-to-end security, development, deployment, and management. These services address scenarios that require reduced latency for time-sensitive applications, unreliable network connections, and high volumes of locally generated data.

Figure 3 illustrates the AWS edge portfolio.

FIGURE 3

AWS Edge Computing Portfolio



Source: AWS, 2020

Infrastructure Solutions

AWS Wavelength is designed to deliver applications that require ultra-low latency for 5G devices by extending AWS infrastructure, services, APIs, and tools to 5G networks. AWS Wavelength embeds storage and compute inside telco providers' 5G networks to help developers build new applications for 5G end users that require single-digit millisecond latency, including IoT devices, game streaming, autonomous vehicles, and live media production.

AWS Outposts is designed for workloads that need to remain on premises due to low-latency or local data processing requirements, where customers want that workload to run seamlessly with the rest of their other workloads in AWS. AWS Outposts is a fully managed and configurable compute and storage rack built with AWS-designed infrastructure. It allows customers to run AWS compute, storage, database, and analytics services on premises and seamlessly connect to AWS' broad array of services in the cloud.

AWS Local Zones are a new type of AWS infrastructure designed to run workloads that require single-digit millisecond latency, such as video rendering and graphics-intensive virtual desktop applications. Not every customer wants to operate its own on-premises datacenter, while others may be interested in getting rid of their local datacenter entirely. AWS Local Zones allow customers to gain all the benefits of having compute and storage resources closer to end users, without the need to own and operate their own datacenter infrastructure.

Storage

AWS Storage Gateway is a hybrid cloud storage service that provides on-premises applications access to virtually unlimited cloud storage using NFS, SMB, iSCSI, and iSCSI-VTL interfaces through file, tape, and volume gateways. You can use AWS Storage Gateway for backing up and archiving data to AWS, using on-premises file shares backed by cloud storage, and providing low-latency access to in-cloud data for on-premises applications.

Content Delivery Network

Amazon CloudFront is a global content delivery network service that securely delivers data, videos, applications, and APIs to your viewers with low latency and high-transfer speeds. You can get started with Amazon CloudFront in minutes using APIs, AWS Management Console, AWS CloudFormation, CLIs, and SDKs. Amazon CloudFront offers a simple, pay-as-you-go pricing model with no up-front fees or long-term contracts.

Rugged Edge

AWS Snow Family helps customers that need to run operations in austere, non-datacenter environments and in locations where there's lack of consistent network connectivity. The Snow Family, made up of AWS Snowcone, AWS Snowball Edge, and AWS Snowmobile, offers a number of physical devices and capacity points, most with built-in computing capabilities. These services help physically transport up to exabytes of data into and out of AWS. Snow Family devices are owned and managed by AWS and integrate with AWS security, monitoring, storage management, and computing capabilities.

AWS Snowcone is the smallest member of the AWS Snow Family of edge computing, edge storage, and data transfer devices, weighing 4.5lb (2.1kg) with 8TB of usable storage. Snowcone is small, portable, rugged, secure, and purpose built for use outside of a traditional datacenter. Its small form factor makes it a perfect fit for tight spaces or where portability is a necessity. You can use Snowcone in backpacks on first responders or for IoT, vehicular, and even drone use cases. You can execute compute applications at the edge, and you can ship the device with data to AWS for offline data transfer, or you can transfer data online with AWS DataSync from edge locations.

AWS Snowball Edge, a part of the AWS Snow Family, is a data migration and edge computing device that comes in two options. Snowball Edge Storage Optimized devices provide both block storage and Amazon S3-compatible object storage and 40 vCPUs. They are well suited for local storage and large-scale data transfer. Snowball Edge Compute Optimized devices provide 52 vCPUs, block and object storage, and an optional GPU for use cases such as advanced machine learning and full-motion video analysis in disconnected environments. You can use these devices for data collection, machine learning and processing, and storage in environments with intermittent connectivity.

Machine Learning

Amazon SageMaker Neo enables developers to train machine learning models once and run them anywhere in the cloud and at the edge. Amazon SageMaker Neo automatically optimizes machine learning models to perform at a higher speed, with no loss in accuracy. Using deep learning, SageMaker Neo discovers and applies code optimizations for your specific model and the hardware you intend to deploy the model on. You get the performance benefits of manual tuning without the weeks of effort.

AWS IoT

AWS IoT offers a set of managed cloud services that secure, control, and manage connected devices from the cloud, and it provides data management and rich analytics services designed for noisy IoT data. AWS IoT Core can support billions of devices and trillions of messages and can process and route those messages to AWS endpoints and to other devices. AWS IoT Core provides automated configuration and authentication upon a device's first connection, as well as end-to-end encryption throughout all points of connection. With AWS IoT Core, IoT applications can keep track of and communicate with all connected devices, all the time, even when they aren't connected.

Alexa Voice Service (AVS) Integration is a feature of AWS IoT Core that enables Alexa Voice to be produced on any type of connected device. AVS Integration for IoT Core reduces the cost of producing Alexa built-in devices by up to 50% by offloading compute- and memory-intensive audio workloads to the cloud. With this reduction in production cost, customers can now cost-effectively build new categories of differentiated voice-enabled products such as light switches, thermostats, and small appliances.

In addition to these cloud services, AWS also offers IoT device software that is deployed on edge devices.

AWS IoT Greengrass seamlessly extends AWS to edge devices, so they can act locally on the data they generate while still use the cloud for management, analytics, and durable storage. With AWS IoT Greengrass, connected devices can run AWS Lambda functions, Docker containers, or both; execute predictions based on machine learning models; keep device data in sync; and communicate with other devices securely – even when not connected to the internet.

FreeRTOS is an open source, real-time operating system for microcontrollers that makes small, low-power edge devices easy to program, deploy, secure, connect, and manage. Distributed freely under the MIT open source license, FreeRTOS includes a kernel and a growing set of software libraries suitable for use across industry sectors and applications. FreeRTOS is built with an emphasis on reliability and ease of use.

AWS IoT SiteWise is a managed service that makes it easy to collect, store, organize, and monitor data from industrial equipment at scale. You can easily monitor equipment across your industrial facilities to identify waste, such as breakdown of equipment and processes, production inefficiencies, and defects in products.

Robotics

AWS RoboMaker enables robotics developers to build, test, and simulate robotics applications and then deploy them to the edge in production robot fleets. With AWS RoboMaker simulation, you can easily simulate and virtually test robotics applications in various environments faster and at a higher

scale than you can with only physical devices, enabling higher-quality software and better performing, safer robots. Using AWS RoboMaker's fleet management, built on AWS IoT Greengrass, you can deploy an application to a fleet of robots. Using Amazon CloudWatch metrics and logs extension for robot operating system (ROS), a set of software libraries and tools that help you build robot applications, you can monitor these robots throughout their life cycle to understand CPU, speed, memory, battery, and more.

AWS Partner Network

The AWS Partner Network (APN) is the global partner program for technology and consulting businesses that leverage Amazon Web Services to build solutions and services for customers. The APN helps companies build, market, and sell their AWS offerings by providing valuable business, technical, and marketing support. The APN consists of two categories:

- APN Consulting Partners are professional services firms that help customers of all types and sizes design, architect, build, migrate, and manage their workloads and applications on AWS, accelerating their journey to the cloud. APN Consulting Partners often implement Technology Partner solutions in addition to the professional services they offer. APN Consulting Partners include systems integrators, strategic consultancies, agencies, managed service providers, and value-added resellers.
- APN Technology Partners provide hardware, connectivity services, or software solutions that are either hosted on or integrated with the AWS Cloud. Technology Partner products are often delivered as components to broader AWS customer solutions and can be delivered globally by Consulting Partners through AWS Marketplace, bundled solutions, or directly from APN Technology Partners. APN Technology Partners include original equipment manufacturers (OEMs), semiconductor manufacturers, network carriers, SaaS providers, and independent software vendors (ISVs).

In addition, the AWS Partner Device Catalog consists of devices and hardware to help explore, build, and go to market with IoT solutions. Search for and find hardware that works with AWS including development kits and embedded systems to build new devices, as well as off-the-shelf-devices such as gateways, edge servers, sensors, and cameras for immediate IoT project integration. The choice of AWS-enabled hardware from our curated catalog of devices from APN partners can help make the rollout of IoT projects easier. All devices listed in the AWS Partner Device Catalog are also available for purchase from partners to get you started quickly.

CONCLUSION

The world is continuing to become more connected, with more and more data being generated by billions of devices being pushed to the cloud, enabling new intelligent, responsive applications. These applications increasingly depend on reduced latency, improved security, and increased bandwidth at the edge.

With Amazon Web Services edge solutions, it is truly possible to have a cloud without boundaries.

Essential guidance includes the following:

- Identify situations where edge can improve business outcomes by reducing latency, mitigating unreliable networks, and managing large local data sets.

- Demand consistent security, development, deployment, and management across both edge and cloud resources.
- Choose the right set of products and services for your industry and use case.

About IDC

International Data Corporation (IDC) is the premier global provider of market intelligence, advisory services, and events for the information technology, telecommunications and consumer technology markets. IDC helps IT professionals, business executives, and the investment community make fact-based decisions on technology purchases and business strategy. More than 1,100 IDC analysts provide global, regional, and local expertise on technology and industry opportunities and trends in over 110 countries worldwide. For 50 years, IDC has provided strategic insights to help our clients achieve their key business objectives. IDC is a subsidiary of IDG, the world's leading technology media, research, and events company.

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