Cloud Automation for 5G Network

June 16, 2021

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Contents

Abstract

This whitepaper introduces Cloud Automation for Cloud Native 5G Networks and how different AWS tools and services can be used by digital services providers (DSPs). This allows DSPs to fully automate the deployment and testing of 5G networks; enable orchestration, closed loop use cases, Predictive Automation and edge analytics for 5G networks; and enable 5G use cases to unlock 5G revenue potential. The paper explains how you can use AWS tools and services to meet the requirements of these 5G network automation use cases.

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Introduction

Telecommunications software vendors traditionally delivered custom hardware and custom software to deliver real-time process delivery for traditional 2G, 3G, and 4G networks. This lead digital service providers (DSPs) to experience relatively long cycles of development, lab and field integration testing, and production deployment of new network nodes or new features to ensure the stability of mission and business critical telecom services. The inherited long cycle of deployment was due to the monolithic architecture of traditional network nodes, a typical multi-vendor environment, and many point-to-point interfaces among network entities in the 2G, 3G, and 4G mobile networks.

As introduced in 5G Network Evolution with AWS, 5G mobile networks, as standardized by 3rd Generation Partnership Project (3GPP), now support a cloud-native architecture enabled by virtualization and containerization. 5G network technology uses a cloud-native approach with microservice stateless service-based architecture, programable with network APIs and network slicing.

About 5G Network Architecture

This 5G network architecture means that different network functions can work as loosely coupled independent services that are communicating with each other through well-defined interfaces and APIs. Most important, each network function can be updated independently. This architecture shift in 5G enables DSPs to achieve more agility and operational efficiency by making it easier to roll out updates for network functions more frequently while maintaining the vesting and security requirements and standards through automation.

5G brings major technology enhancements through these characteristics:

- **eMBB:** Enhanced Mobile Broadband that supports a 100 Mbps average user data rate and peak data rates of 10 Gbps.
- **URLLC:** Ultra Reliable Low latency that provides a latency as low as 1 msec with six 9s of reliability.
- **mMTC:** Massive machine type communication that power up to 100,000 devices per km2. These 3 technology enablers in 5G will revolutionize and power a whole range of use cases.

The complexity of the traditional method of going digital comes with a heavy lift in the form of planning, resources, capital investment and configuration before you get to the value of developing the application that really matters to the customer.

AWS enables DSPs to go cloud-native. This approach allows for abstracting away many layers of infrastructure that would otherwise be required, such as networks, servers, operating systems etc. A cloud native environment allows DSPs to define their requirements in code and use the AWS development environment to rapidly ideate, build, and deploy, saving a tremendous amount of overhead. ISVs can focus on their specific requirements needed for their particular application rather than being concerned with the environment setup and maintenance. AWS provides the infrastructure to jumpstart the deployment of the network and a deep set of existing services to configure as needed. With an added extension of our partners and professional services team we can provide the automation, orchestration, and monetization of the network in record time (up to 4 to 6 times faster is common in many environments.)

Reinventing Cloud 5G Networks

There are five distinct value drives when building a cloud-native networks with AWS:

- Velocity of build out and deployment by leveraging AWS infrastructure and security already in place. Impacting TCO (Capex)
- Operating Efficiency: Adaptability and High Availability to scale on demand
- Automation: Intent based network orchestration and ubiquitous cloud programming model
- Monetize the network faster with MEC application ecosystem enabled by AWS edge service portfolio and unique business models
- Access to a deep eco-system of partners to accelerate business and operational support system transformations

There are 4 key areas of potential benefits for Cloud Native 5G network builds.

- Networks moved to the cloud to orchestrate a secure, scalable, software-driven network
- Simplified operations- transform and automate for a future-ready business
- Reimagined Customer Experience to anticipate usage pattern changes with AI, discover new use cases and offerings with data, to deliver excellence of services

- Unlock growth to accelerate innovation to monetize 5G, Edge and enterprise transformation

By leveraging the innovative culture of Amazon and introducing the 4 areas above it allows DSPs to continually provide business value to their customers.

Cloud automation areas

The following table details the specific functions of Cloud Automation that unlock the potential for Cloud Native 5G.

Table 1: Cloud Automation for 5G – Use cases

Cloud Automation Area	Capability
CICD	Full 5G network CI/CD code pipeline
Observability	Integration of Amazon CloudWatch and AWS CloudTrail with Prometheus and Fluentd.
Closed Loop Automation	Closed loop automation by integration of cloud infrastructure, cloud-native network functions (CNF) and test logs
Network Slicing	Integration of Orchestrator with AWS continuous integration/continuous delivery (CI/CD) pipeline to enable network slicing.
Hybrid Cloud Deployment	Same code pipeline to deploy CNF in both Region and Edge locations of cloud.
Edge Analytics	Inference at the Edge using Amazon EMR
Predictive Automation	Forecast-based scaling and predictive maintenance using AI/ML
Test as a Service	Zero touch automated 5G testing with full integration with CICD pipeline
CNCF Projects Integration	Integration of AWS Cloud infrastructure with other third-party and open source projects.

E2E 5G CICD Pipeline

Challenge

Traditionally, DSPs deploy networks manually and with a range of scripts. This approach includes vendor specific methods with little to no automation. Every network deployment is unique and the repeatability of the deployment procedures is limited. This approach also involves heavy planning, resources burdened deployment, and other lifecycle management procedures.

Solution

AWS has pioneered the development of new CI/CD tools for software delivery to help a broad spectrum of industries to develop and rollout software changes rapidly while maintaining systems stability and security. These tools include a set of DevOps (Software Development and Operations) services such as AWS CodeStar, AWS CodeCommit, AWS CodePipeline, AWS CodeBuild, and AWS CodeDeploy. Moreover, AWS also has been evangelizing the idea of IaC (Infrastructure as a Code) using AWS Cloud Development Kit (CDK), AWS CloudFormation, and API-based third-party tools (e.g. Terraform). Using these tools you can automate the development processes of a network function in AWS as source code, and you can maintain this IaC source code in the CI/CD pipeline to realize continuous delivery.

AWS worked with ISVs to deploy CNFs following full cloud native principles, with full CI/CD, observability and configuration through cloud native tools like Helm, Config maps among other features. In addition, AWS also implemented resiliency to the network, that would avoid traffic interruptions and can recover flawlessly in spite of Point of Delivery Kubernetes Pods). AWS developed and implemented a full 5G Network CI/CD Code pipeline for rapid deployment and lifecycle management (LCM) of 5G Network architecture.

The CI/CD process for the 5G network build includes the following steps:

1. Network setup – Cloud Development Kit (CDK) and AWS CloudFormation create templates that initiate the creation of the network prerequisites
    - Networking Stack (Amazon VPC, subnets, NAT gateway, Route table and internet gateway)
2. Infrastructure deployment – CDK and AWS CloudFormation initiate the creation of the following resource stacks

- Compute stack (Amazon EKS cluster creation, EKS worker nodes, Lambda)
- Storage stack (Amazon S3 Buckets, Amazon EBS volumes and Amazon EFS)
- Monitoring stack (Amazon CloudWatch, Amazon Elasticsearch Service)
- Security stack (IAM roles, IAM policies, Amazon EC2 security groups, VPC network access control lists (ACLs)

3. Cloud Network Function (CNF) deployment – In this stage CNF is deployed onto Amazon EKS clusters using Kubectl and Helm charts tools. This stage also deploys any specific application/tools which are needed by the CNFs to work efficiently (e.g. Prometheous, Fluentd). The CNFs can be either deployed via AWS Lambda functions or AWS CodeBuild, which can be part of the AWS CodePipeline stages.
4. Continuous Updates and deployment – These will be a sequence of steps that will be carried out iteratively to deploy changes coming as part of container/configuration changes resulting in upgrades. Similar to the CNF deployment case, this can be automated using AWS services with the trigger from AWS CodeCommit, Amazon ECR or third-party source systems such as GitLab Webhook.

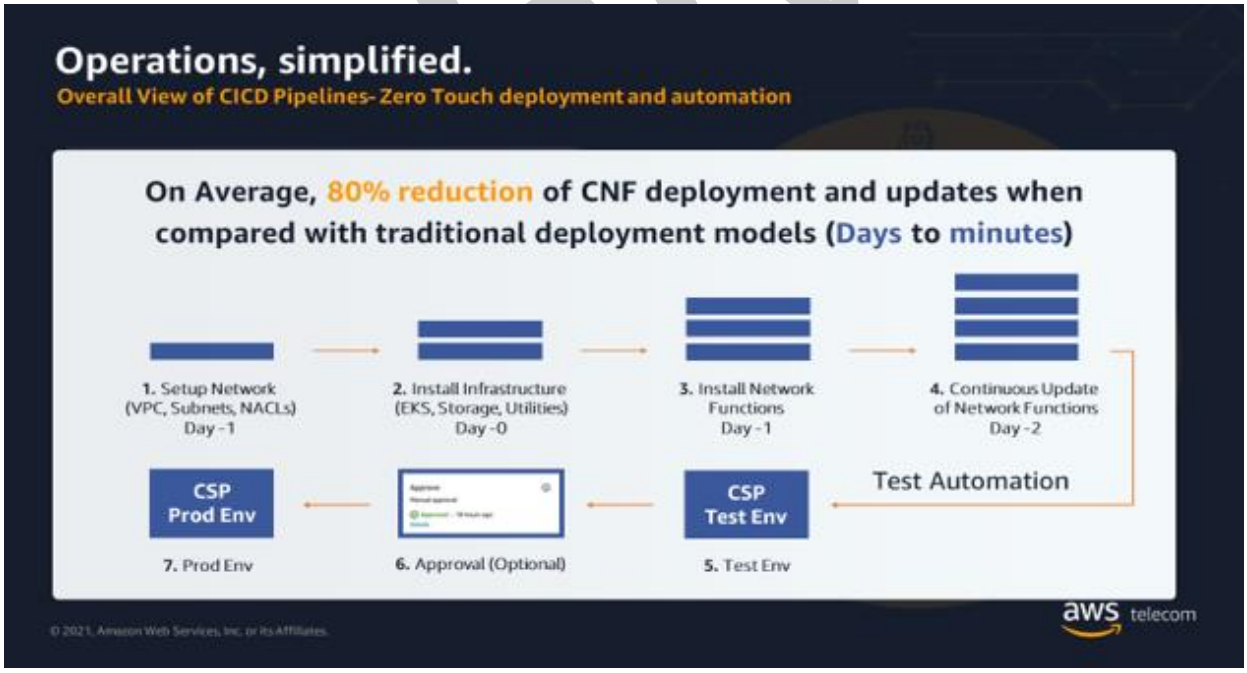

Figure 1: AWS CI/CD pipeline flow diagram

The CICD pipeline is built using AWS CodePipeline and utilizes a continuous delivery service that models, visualizes, and automates the steps required to release software. By defining stages in a pipeline, you can retrieve code from a source code repository, build that source code into a releasable artifact, test the artifact, and deploy it to production. Only code that successfully passes through all these stages will be deployed. In addition, you can optionally add other requirements to your pipeline, such as manual approvals, to help ensure that only approved changes are deployed to production.

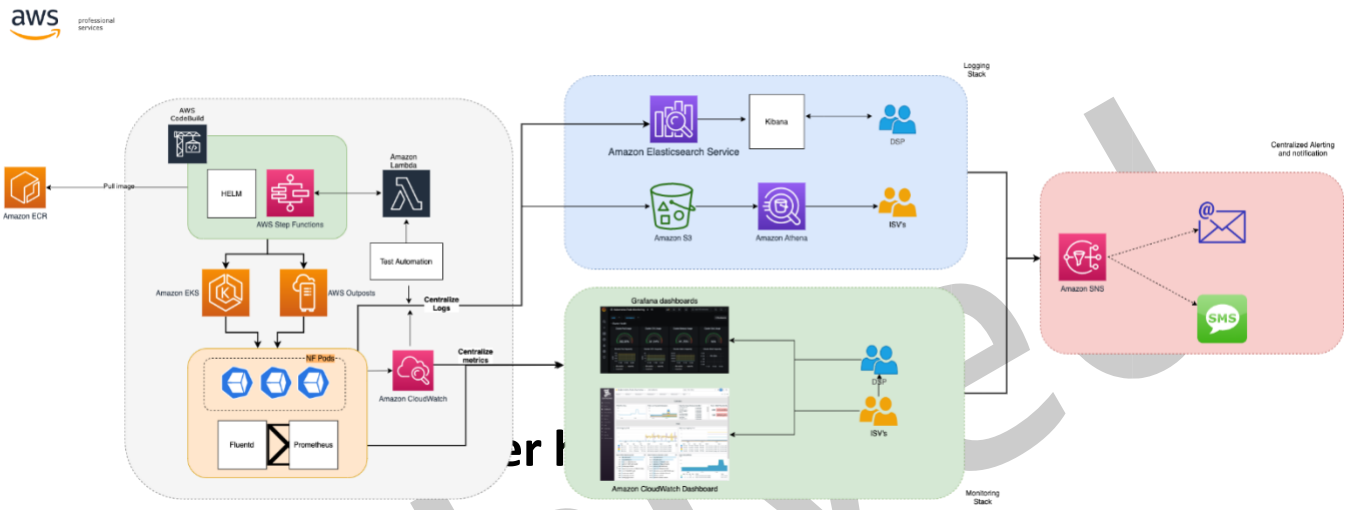

Figure 2: AWS CICD pipeline Architecture Diagram

Implementing 5G Cloud solutions

Operations Simplified- By using infrastructure as code, DSPs can automate the creation (and decommissioning) of environments, increasing the pace of innovation, reducing human errors, and ensuring compliance with DSPs security postures through automated CI/CD pipeline checkpoints and constant monitoring tools like Guard Duty (threat protection) and Macie (sensitive data identification and protection).

Observability

Challenge

DSPs must also manually deploy, enable, and integrate observability solutions. DSPs need to collect the logs and metrics in a common repository to triage the logs and metrics to identify the networks errors and enable actions to autocorrect the network. These logs and metrics include infrastructure, network function (application), and test logs. Often, these solutions are a collection of third-party tools or vendor specific

implementation tools that needed to be incorporated mostly manually after the network function is deployed.

The lengthy process of implementing multiple tools and capturing logs added more time to network readiness and the ability for the DSP to monitor and observe their network.

Solution

When you deploy the AWS CI/CD solution and enable the Observability utilities like Promethus and Fluentd during infrastructure deployment phase you are able to reduce the number of tools required. The AWS solution includes observability utilities for infrastructure, network function (application), and test automation.

Along with the Observability utilities that are needed for CNS, AWS IaC (infrastructure as a Code) enables by default the CloudWatch to enable the infrastructure monitoring for the infrastructure resources deployed for the network function.

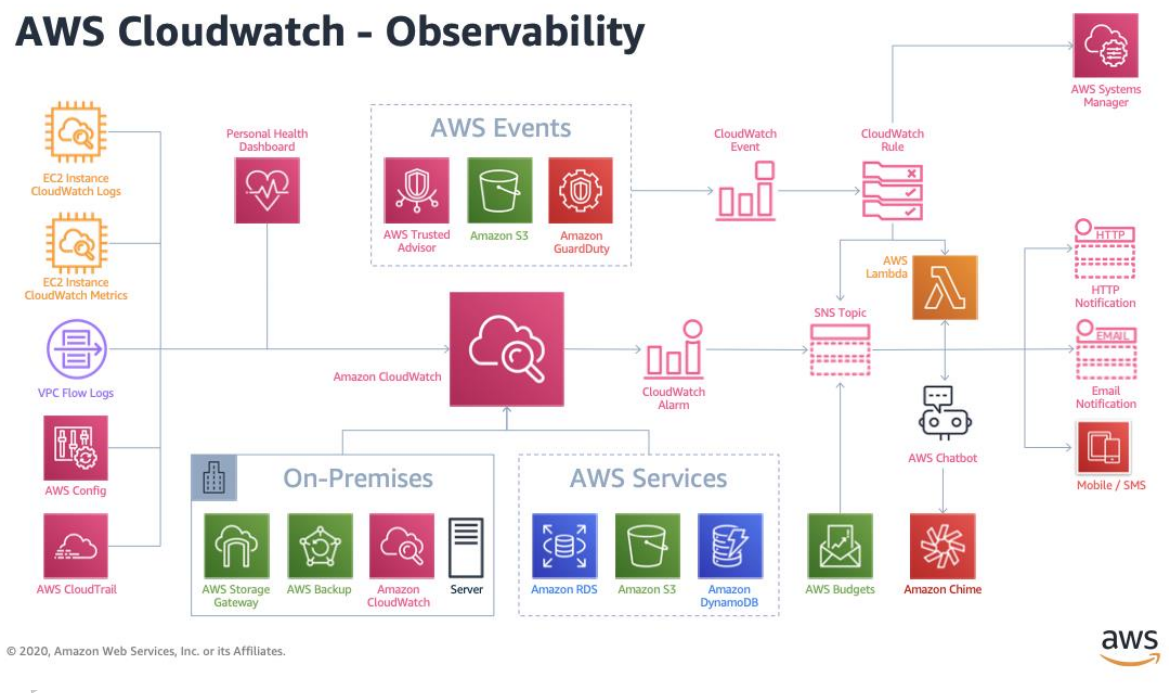

Figure 3: AWS CloudWatch – Observability Architecture

The AWS Observability solution includes a common log collection with Amazon Elasticsearch Service. This enables the DSPs to aggregate the application, test automation, and cloud infrastructure logs to Amazon Elasticsearch Service forming a common log collection. Triaging these logs enable you to create root cause analysis (RCA) reports by identifying network anomalies and triggers. These network anomalies

and triggers can be ingested into a high level of orchestration that can invoke CI/CD for further LCM policies to autocorrect the network.

The logs can also be ingested into a common data lake, for long term retention and data processing for data analytics and intelligence. These data insights can be fed to service assurance and orchestration for network function lifecycle management.

Unlocking the Potential of Cloud Native 5G

Deploying the observability capabilities while deploying the network allows DSPs to quickly turn up the monitoring and management components of their network infrastructure. This approach allows for faster time to revenue and eliminates the lengthy trial and error testing sessions to confirm elements are working as planned. The ability to capture the logs and metrics in an automated process and feed them into a data lake allows DSPs to make intelligent decisions using AWS AI/ML services based on the real-time data flowing into the system. The observability enables closed loop use cases by using logs and metric alarms to trigger an auto-healing action. This action is input to orchestration to complete LCM for network healing and also enable new 5G use cases with network slicing.

Closed Loop Automation

Challenge

In 5G network, there is a massive need to deploy new services and operationalize them in in real time. Often the time to respond to network key performance indicator (KPI) degradation involves many steps which involves semimanual operations by the network operations team. The semi manual operations typically results in poor customer service, poor service performance, and customer churn. DSPs would benefit from a “self-healing network” wherein automated actions would auto correct the network issues.

Solution

AWS developed closed loop automation that enables rapid dynamic autocorrection of the network., allowing for improved customer service. In the following diagram, Amazon CloudWatch is monitoring the cloud infrastructure logs and metrics. In Amazon CloudWatch, CloudWatch alarms are defined based on the cloud metrics like CPU utilization. After a defined threshold is reached, CloudWatch generates an alarm. This CloudWatch alarm triggers an AWS Lambda function that increases the worker node

group by updating the AWS Auto Scaling group. This CloudWatch alarm is also sent to the customer via Amazon Simple Notification Service (Amazon SNS) to customer email.

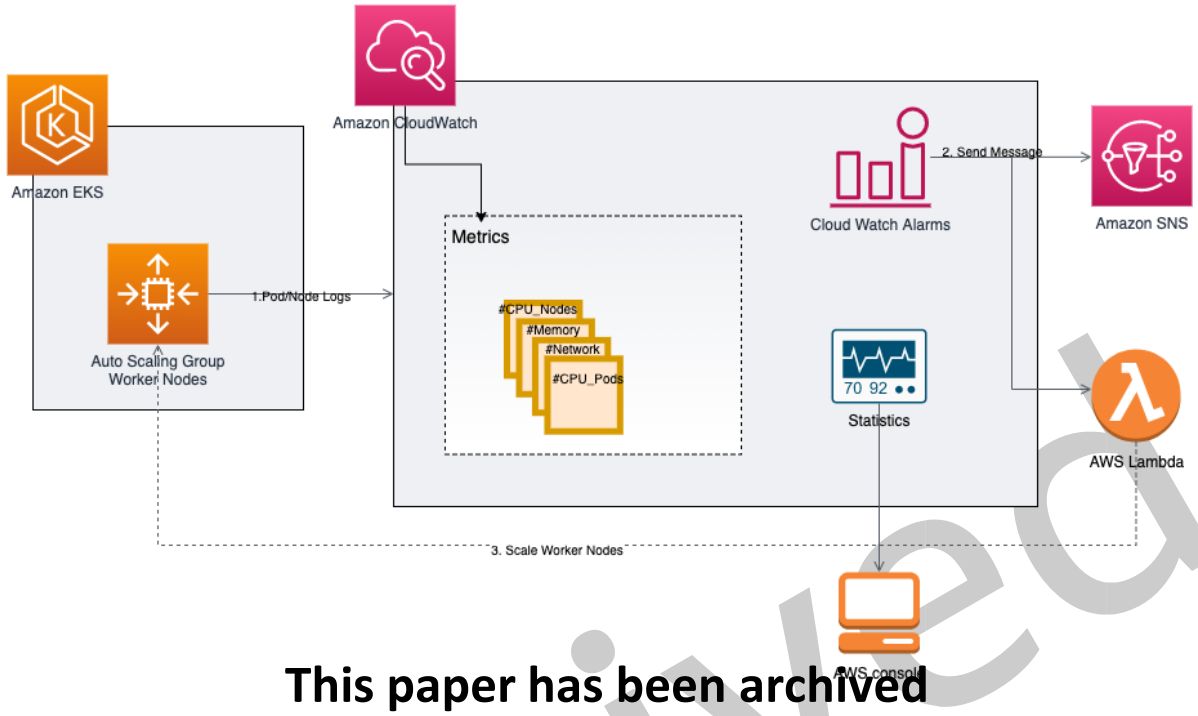

Figure 4: Closed loop automation

This closed loop is dynamically responding to increase the compute nodes and thereby normalize the compute load. This approach enables the end services to function normally in adverse load conditions. This self-healing network is enabled using AWS services and allows customers to build an automated network and launch new services.

AWS Closed Loop Use case

The closed Loop automation use cases are exposed via API and can be integrated with higher level service assurance platforms that can then call the closed loop use cases to enable network auto healing.

Unlocking the Potential of Cloud Native 5G

Closed loop automation allows you to automate operations and help launch new services in rapid time.

This approach reduces operations costs and enables new revenue potentials. This approach also helps DSPs to retain and gain new customers by enabling a stable 5G

network. Ultimately closed loop automation should help customers move one step further toward the goal of a self-healing network.

Network Slicing

Challenge

As DSPs launch the 5G network, one of major promise of the 5G network is to enable 5G network slices to cater to enterprises to power industrial use cases that need specific network characters like latency, quality of service, and bandwidth among others. Enabling 5G network slices has it challenges, including deploying network slices dynamically.

Solution

AWS CI/CD was integrated with higher level Orchestrator, in European Telecommunication Standards Institute (ETSI) terms network function virtual orchestrator (NFVO), to enable network slicing on a 5G Network built on AWS. AWS CICD fulfills the role of Virtual Infrastructure Manager (VIM) and Virtual Network Function Manager (VNFM). This is integrated with NFVO using the ETSI SOL003 interfaces. The integration with NFVO happens via Amazon API Gateway and AWS Lambda functions. The NFVO dynamically sends the SOL003 API call to AWS CI/CD via Amazon API Gateway and AWS CI/CD completes the lifecycle management (LCM). The NFVO in turn is integrated with higher level service order management, which takes the input from network conditions or through enablement of new network service via customer order management. The Service Orchestrator will publish the Service that will send to NFVO, which communicate to CI/CD via SOL003, to execute the LCM policy for network slicing.

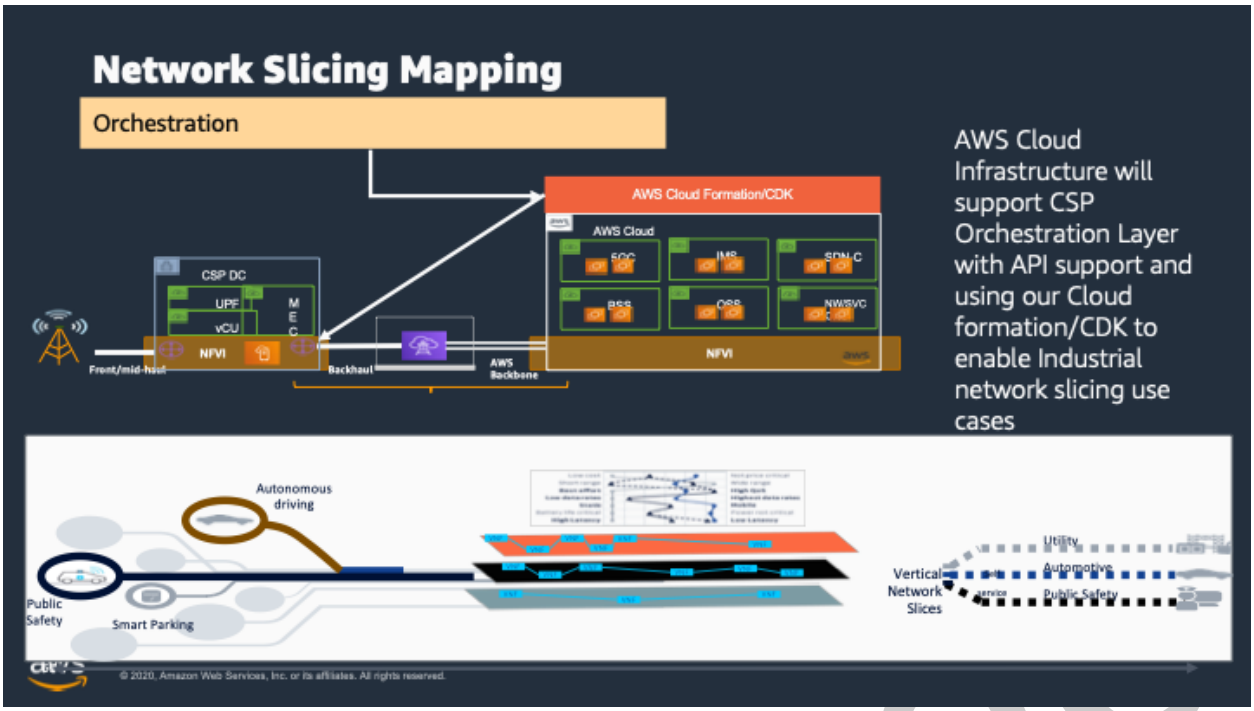

Figure 5: Network slicing of 5G network on AWS

Unlocking the Potential of Cloud Native 5G

Network slicing is a dedicated virtual network matched to individual use case, this defines specific network characteristics like QOS, latency, bandwidth, and so on. Network slicing will power enablement of vast range of 5G use cases increasing the revenue potential to DSPs.

DSPs can realize the potential of 5G network industrial use cases by deploying 5G Network slices as needed by their end enterprise customers. This approach unlocks a full new revenue potential for 5G DSPs.

Hybrid Cloud Deployment

Challenge

DSPs have a good amount of private cloud mostly on Openstack that is currently running the 4G network. DSPs are commonly looking at hybrid cloud vision and to have a common automation framework for both private and public cloud. DSPs want an automation framework that works both for private and public cloud. Having separate automations tools is not optimal for capital and operational costs, moreover it reduces the optimum use of a DSPs existing resources.

Solution

AWS extended the AWS CI/CD services to deploy on a private cloud. In addition, we extended the AWS CICD pipeline to deploy on third-party Kubernetes frameworks. The AWS CICD pipeline is integrated with Kubernetes, extending the Helm client to run on third-party Kubernetes. In addition, AWS extended the AWS CI/CD pipeline to VMware TANZU on AWS Outposts. AWS Outpost is an example of a CNF, 5G Network Resource Function (NRF) was deployed using the 5G Network CI/CD.

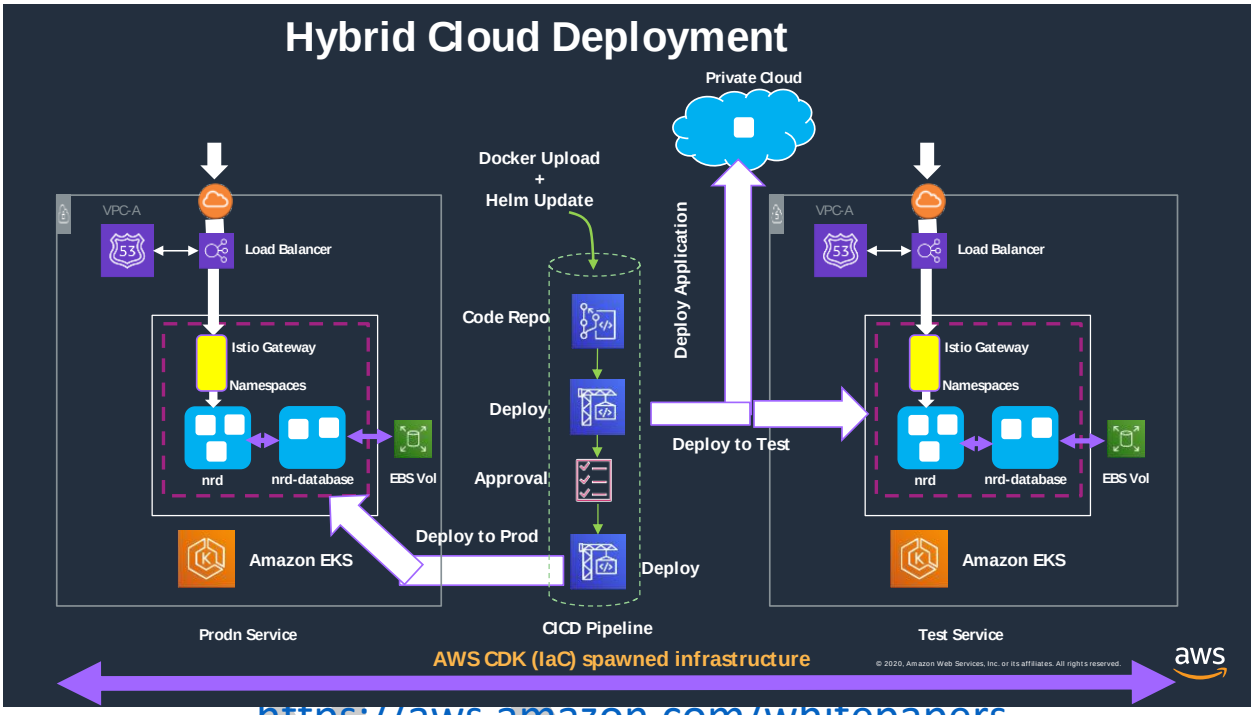

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Figure 6: AWS Cloud Deployment

Unlocking the Potential of Cloud Native 5G

Using AWS common automation frameworks like AWS CI/CD pipeline, DSPs can rapidly deploy their 5G networks. DSPs can optimize their resources using both their on-premises private cloud and AWS Cloud, including AWS Outpost Edge offerings. This approach allows you to optimize capital and operational costs. In turn, helps DSPs to launch additional 5G network use cases and add to their revenue potential.

Edge Analytics

Challenge

5G networks will bring together networks that are currently distributed. This will include bringing user plane functions (UPF) closer to the radio access network (RAN) to enable low latency and high bandwidth use cases for end customers. There is a significant amount of data at these edge cloud locations. This data, in the form of logs and metrics, is useful for network and service assurance. The data can also be used to monetize and enable many use cases such as leveraging end user data to develop new services. The transfer of this edge data to a central data lake uses a large portion of network bandwidth and slows the network reaction time. Moreover, the hauling of data from edge incurs cost and does not serve as an optimal use of network bandwidth.

Solution

AWS provides inference at the edge using Amazon EMR. This service enables Edge data analytics. The solution deploys Amazon EMR on AWS Outposts (edge offering). The data is analyzed at the AWS Outpost and only the appropriate data is sent to the central data lake. This approach reduces the amount of data that must be transferred to the central data lake, thereby optimizing cost and network bandwidth. The raw data is stored locally in Amazon Simple Storage Service (Amazon S3) for additional use. This raw data is typically stored for a set period of time, such as 30 days. The intelligent data that is sent to central data lake is used to create additional machine learning (ML) models and will be fed into AWS Outpost for a continuous refinement of edge data analytics.

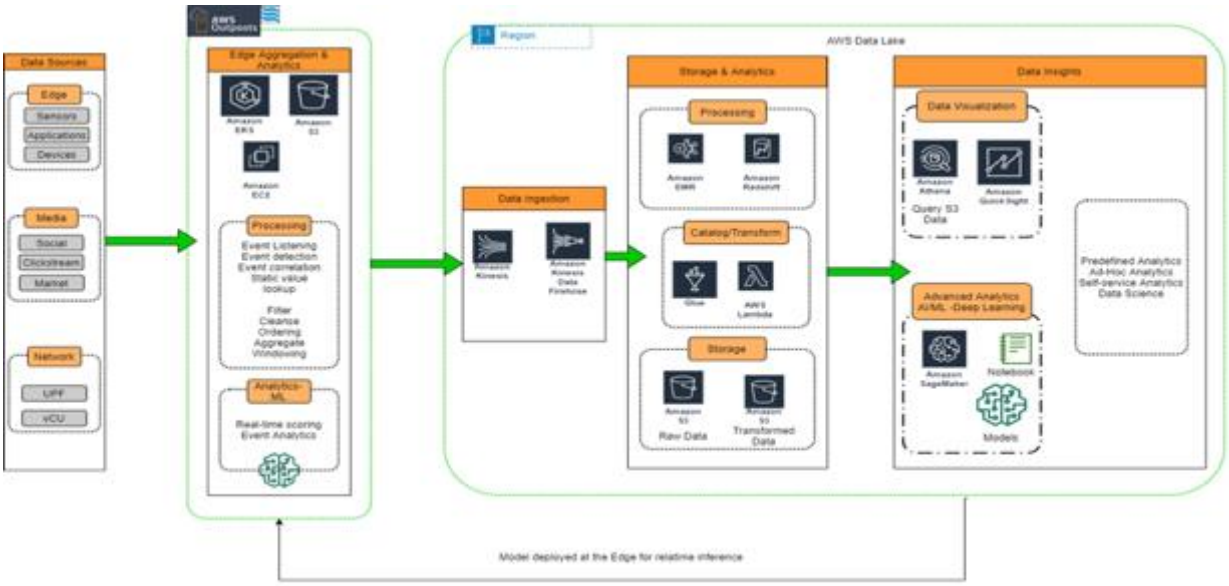

Figure 7: Amazon EMR on AWS Outposts architecture

Unlocking the Potential of Cloud Native 5G

DSPs have a good amount of cost optimization using AWS edge data analytics by data inference right at the edge. The application will help reduce the network bandwidth burden and network data transfer costs. The edge data analytics will help monetize data for additional use cases like the following:

Use Case 1: Location services and content awareness

- Monitor and predict traffic and obtain insights to make necessary changes
- Leverage the Edge as a Service by utilizing the location mapping available from marketing promotions

Use Case 2: Social behavior

- Analyze data to obtain social behavior insights
- Monetize the data with third parties and applications

Use Case 3: Anomaly detection

- Use AI/ML algorithms from Amazon SageMaker to predict anomaly scores to identify risks and take proactive actions.

Predictive Automation

Challenge

5G Networks require the ability to rapidly deploy use cases in constantly changing environments. Networks needs the ability to predict network anomalies and potentially blocking scenarios during growth and large-scale events. The ability to adapt and respond dynamically to conditions before events occur and potentially block customers is needed to deliver the appropriate service levels.

Solution

AWS development predictive automation using native AWS AI/ML tools.

One of the solutions is predictive scaling. Predictive scaling from AWS uses ML models that train on network conditions for the prior 48 hours and then forecast the network loads for next 48 hours. The forecast can be enforced to automatically scale the worker node group before the network load condition is met. This prevents any network blocking. The worker node group return to normal operating conditions after the network load condition normalizes. DSPs operations will have a seamless experience in network operations completely through automation.

Unlocking the Potential of Cloud Native 5G

The predictive automation assists DSPs to optimize for their network sizes and optimize 5G Network that covers network load spikes. This approach is especially useful during network load events with unusually heavy traffic. DSPs can plan deploy for the normal network load conditions and let predictive automation respond to network spikes.

Test as a Service

Challenge

With 5G Network deployments moving in a rapid pace, there is a significant need to automate the deployment, integration, and testing of 5G use cases such as enhanced Massive Broadband (eMBB), massive Machine Type Communication (mMTC) and Ultra Reliable Low Latency (URLCC). The traditional legacy testing process normally takes several months to a year. DSP testing costs are significant with the traditional approach, which can lead to a cost burden when deploying 5G Networks.

Solution

AWS developed Test as a Service with Test Automation framework like Spirent. AWS CI/CD is integrated into the Test Automation framework via an API integration. The AWS CI/CD pipeline initiates an API call to the Test Automation framework to check the available tests, launches the testing via an API call with a payload indicating the test id and the system under test, ie., the CNF that was deployed with CICD.

The Test as a Service will check and parse the results based on predetermined inputs from Test Automation frameworks.

The results are fed into the AWS CI/CD pipeline for approval to deploy the CNF into the production network. The test logs are further stored in Amazon Elastic File System (Amazon EFS) or additional RCA use cases.

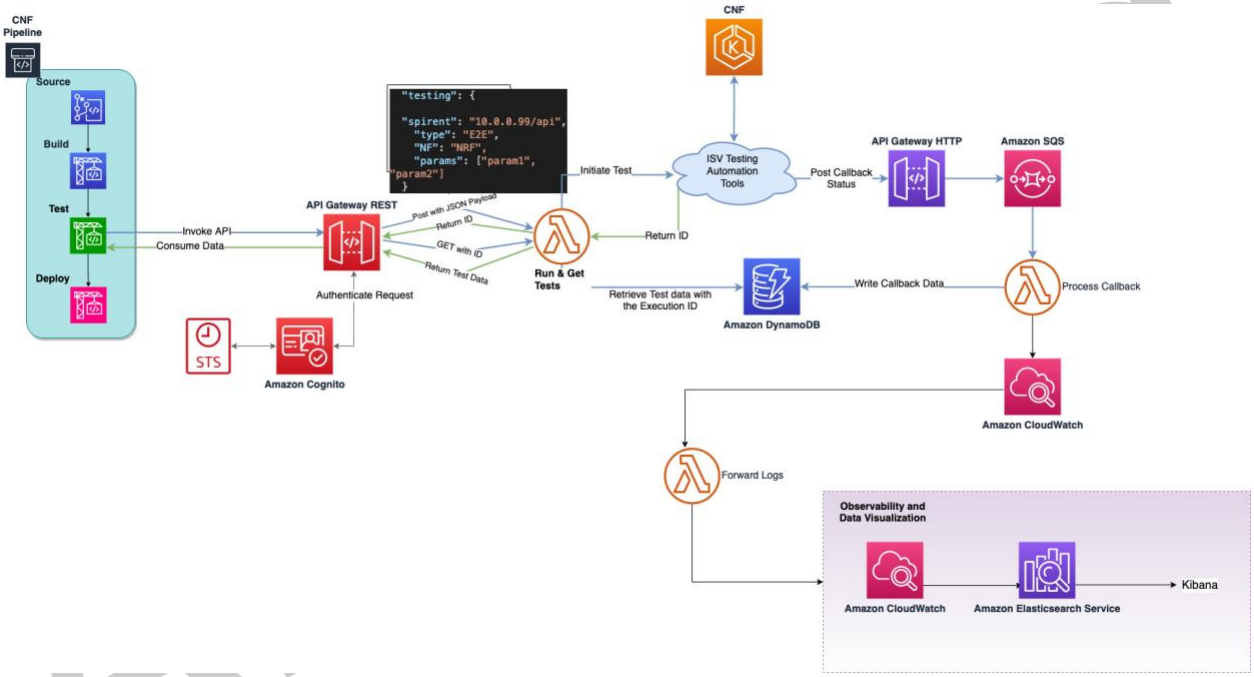

Figure 8: AWS Testing

The Potential of Cloud Native 5G

AWS is enabling DSPs to remove the barrier of lengthy testing cycles with their test as a service capabilities. This allows DSPs to test more frequently, on-demand, and rapidly in an automated cycle. Test results are analyzed with the results stored for triaging with infrastructure logs and application logs. Test as a Service allows DSPs the ability to more quickly turn up services without requiring or deploying additional resources.

Conclusion

AWS believes this methodology for deploying 5G will allow Digital Service Providers (DSPs) to harness the power of a cloud native network. This will enable DSPs to operate with speed, efficiency and automation not yet seen in the industry today. This one of a kind 5G Network build allows for monetization opportunities as well as allowing DSPs the ability to provide their customers the reliability and flexibility required in today's market.

Deploying a cloud native network allows DSPs the ability to respond on-demand to customers wireless needs and growth. This provides business agility and a significant competitive advantage from a time to market perspective by deploying 4-6X faster than traditional deployment.

This cloud native network will simplify the process for developers to create new 5G applications. This will allow developers, customers as well as partners to create innovative 5G solutions for customers by leveraging AWS APIs.

AWS is unlocking the potential of 5G and powering business outcome by co-innovating and enabling cloud-based, end-to-end 5G networks that deliver consistent, cost-effective performance from core to the edge, offering their customers on-demand control of their wireless needs.

This methodology promotes faster development cycles and a short time to value for end customers to deploy new Virtualized Network Functions (VNFs).

Contributors

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Further Reading

For additional information, see:

- Practicing Continuous Integration and Continuous Delivery on AWS

- Carrier-Grade Mobile Packet Core Network on AWS
- 5G Network Evolution with AWS

Document history

Date	Description
June 16, 2021	First publication