WHITEPAPER

Cloud-native 5G – Management of Constant Change

How CI/CD can enable operators to realise the full potential of 5G networks

Hewlett Packard Enterprise

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Executive summary

A 5G core network controls the end-to-end delivery of services and the creation of network slices to support a specific application or customer. Designed to be more versatile and flexible than its predecessors, a 5G core will evolve continuously to support many different use cases with many different requirements.

Developed in conjunction with HPE, this paper explains how CI/CD (continuous integration and delivery) methods can enable a 5G core network to change in line with the needs of a mobile operator and its customers. By helping development and operations teams to work together in an agile way, CI/CD can streamline integration in a complex technology environment, such as a 5G core network. Once automated tests have been written upfront, CI/CD can dramatically reduce operating costs and enable agile and fast-moving software development. CI/CD practices can also reduce risk, as an app is updated one step at a time, rather than all at once, reducing the likelihood of a major fault going undiscovered.

A rich environment requires rigorous testing

Typically comprised of 20 or more main network functions and more than 50 interfaces, a 5G core network is far more complex and much richer than its 4G equivalent. As the network functions are composed of microservices, 5G operators can perform very granular changes, enabling the network's capabilities to evolve over time. But each software upgrade needs to be tested with all the related infrastructure, with all the other network functions, and the environment that it's going to interwork with. Similarly, a new connectivity slice should also go through a rigorous process to validate that it will work properly.

HPE uses CI/CD throughout the development and change lifecycle of its HPE 5G core stack - a complete 5G core solution that is cloud-native from the ground up. Using CI/CD, HPE can frequently integrate and test software from multiple sources. "Continuous integration allows us to take frequent deliveries as inputs and produce multiple kits a day," says Sebastien Klahr, 5G Core Stack Product Manager at HPE. By using the same testing tools across multiple environments, HPE also seeks to reduce costs and complexity.

Modelling new network functions and services

Once a new solution is in production, operators can use HPE's continuous deployment pipeline to initiate network changes. When the operator wants to define a new slice (or a new instance of an existing slice), it will need to provide a set of parameters representing the topology, the IP addresses and other characteristics. HPE can use this information to model the slice and underlying network functions in templates and descriptors. "The difference between the telecom world and the IT world, in which CI/CD was born, is the network and service modelling," explains Pierre Lavillat, 5G Core Stack & 5G Global Practice Manager at HPE.

If an operator needs to upgrade a slice, a cloud-native architecture can run two versions of a slice within its live network simultaneously, with the traffic being progressively diverted away from the initial version to the newer one.

In summary, the modular and dynamic nature of 5G means change management is a key capability for mobile operators that want to fully harness the advantages afforded by 5G. CI/CD can help operators realise the full potential of the flexible and versatile architecture that underpins 5G: It provides the automation required to enable operators to introduce changes much more frequently and with much faster testing than was possible with previous generations of cellular technology.

Introduction

As the telecoms industry begins to deploy standalone 5G networks, operators are realising that constant change is a basic characteristic of the open and flexible design of 5G. This paper explores how telcos can plan for continuous change management in a cloud-native 5G core environment. In particular, it considers how CI/CD (continuous integration and delivery) methods can enable a 5G core network to evolve in line with the needs of a mobile operator and its customers.

Developed by Mobile World Live in partnership with Hewlett-Packard Enterprise, the paper begins by defining CI/CD and the potential benefits. It then explores why CI/CD is relevant to the rollout of 5G, before explaining how these techniques can be applied to a core network by outlining HPE's approach to software upgrades and the deployment of slices. The paper concludes with some recommendations for mobile operators preparing to deploy 5G standalone networks.

Defining CI/CD

Now common practice in the IT sector, CI/CD is a specific approach to the automation and monitoring of app development, delivery and deployment.

The "CI" in CI/CD refers to continuous integration: It requires all code and configuration updates to be implemented in smaller chunks, rather than in larger batches. That allows new code changes to an app to be regularly tested, and merged to a shared repository. This could happen on a daily basis.

Once a developer's changes to an application are merged, those changes are validated by automatically building the application and running different levels of automated testing to ensure the changes haven't broken the app. If the testing discovers a conflict between new and existing code, CI makes it easier to fix those bugs quickly and often.

The "CD" in CI/CD refers to continuous delivery and/or continuous deployment, which are related concepts that sometimes get used interchangeably. Both are about automating further stages of the pipeline.

Continuous delivery usually means a developer's changes to an application are automatically bug tested and uploaded to a repository, from where they can be deployed to a live production environment by the operations team. The goal of continuous delivery is to have a codebase that is always ready for deployment to a production environment.

In continuous delivery, every stage—from the merger of code changes to the delivery of production-ready builds—is automated. At the end of that process, the operations team should be able to deploy an app to production quickly and easily.

The benefits of CI/CD

In colloquial terms, CI/CD is designed to avoid "integration hell" by helping development and operations teams to work together in an integrated and agile way. As automated tests need to be written upfront, CI/CD essentially calls for an investment in automation (capital spending) that can then dramatically reduce operating costs and enable software development to become agile and fast-moving.

By removing repetitive, labour-intensive and error-prone operations, CI/CD is designed to allow IT staff to concentrate on more valuable work. At the same time, CI/CD practices can make the deployment of an application less risky, as the app is updated one step at a time, rather than all at once, reducing the likelihood of a major fault going undiscovered. In practice, CI/CD should make the software delivery life cycle more predictable and manageable.

In the telecoms sector, CI/CD promises to enable 5G operators to develop, deploy and upgrade new network functions in a fast, predictable and reliable manner. "My team today produces software completely CI/CD," Sireen Malik, Director of Automation Systems for the architecture division at T-Mobile, told the TM Forum in October 2020. "If the communication between the end user, the developer and ops is taking weeks and months, that's not going to work. If the frequency of interaction is hourly or daily, that's DevOps right there."

At the same event, Sana Tariq, senior architect for E2 Service Orchestration at TELUS, explained the importance of implementing changes in small chunks, rather than taking a big bang approach. "[In DevOps], we are trying to limit the impact zone. We are trying to think small on each piece of the problem," she said. "We are thinking about doing something with one thing without impacting the other."

5G networks are designed to be dynamic and versatile

Unlike previous generations of cellular technologies, 5G networks will make extensive use of cloud-native technologies and IT development and management methods, such as CI/CD. Rather than employing rigid preconfigured computer systems, 5G networks can decouple software from the computing hardware. That allows for a much more dynamic environment in which the network can be modified and upgraded quickly.

This dynamism is important because 5G has been designed to support a much broader range of use cases than its predecessors. As the connectivity requirements of these use cases can differ immensely, 5G infrastructure needs to be versatile, malleable and resilient.

By comparison, a 4G network plays a relatively narrow role, primarily focused on delivering mobile broadband connectivity to smartphones. Typically a 4G core network is comprised of five main network functions or network elements and about 12 interfaces, according to HPE, which describes 4G network elements as typically "monolithic black boxes" where their hardware and software comes from the same vendor and are tightly-coupled.

This architecture means most 4G core networks are not able to accommodate frequent changes. "Whenever you want to do a hardware expansion, you have to go through a very lengthy sourcing process in order to bring your hardware from the manufacturer and have it installed and delivered in your data centres," says Eduardo Ruano, 5G Core Stack, Outbound Product Manager, HPE Communications Technology Group (CTG). As a result "major software upgrades were maybe done once per year, or if you were very active, twice per year, but not more."

By contrast, a 5G core network is much more complex and much richer. HPE says it will typically be comprised of 20 or more main network functions and more than 50 interfaces (see Figure 1). The network functions are cloud native: they are containerized applications, built up of stateless microservices running in a common shared data environment to allow automatic scaling in and scaling out. The architecture of the core itself is service-based. This cloud native and modular approach should allow an operator to make frequent and agile changes to a 5G core network.

Figure 1: 5G core networks are more complex and dynamic than their predecessors

Source: HPE

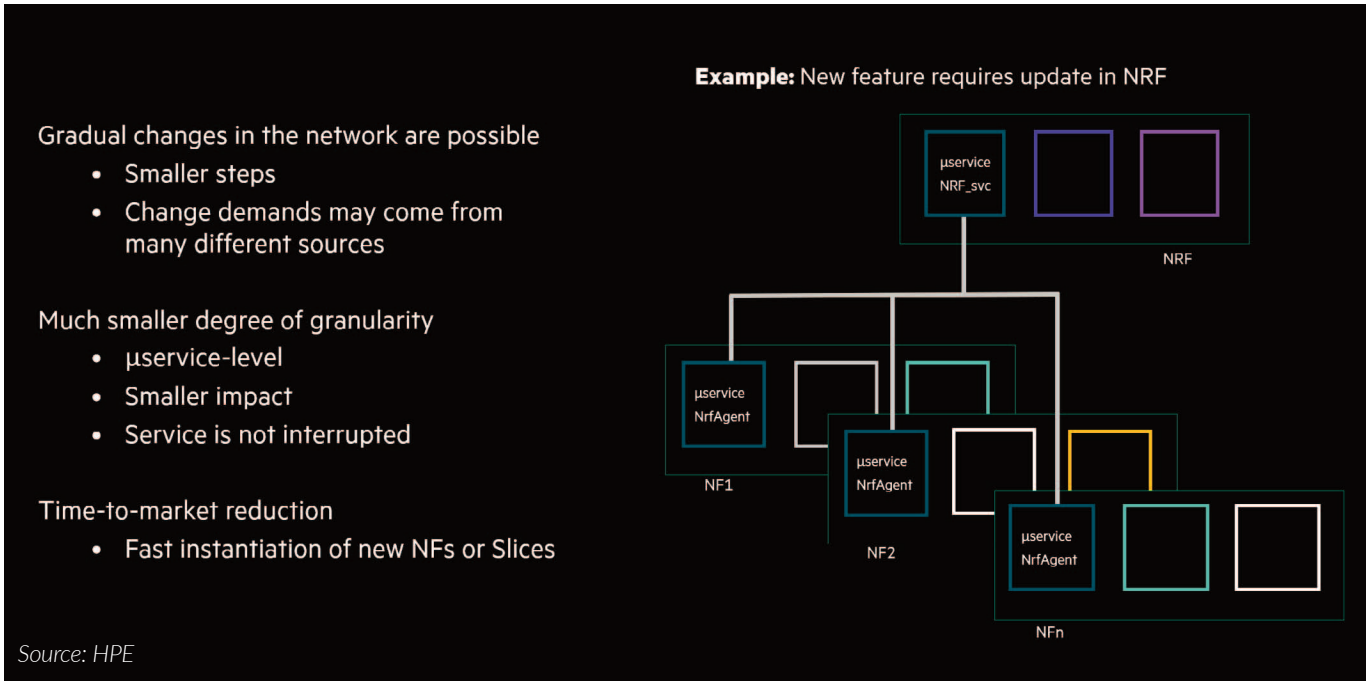
The advantages of a granular architecture

For operators, a cloud native core network offers several benefits, such as the ability to deploy slices of connectivity dedicated to specific services, and the automatic scaling in and scaling out of instances in line with changes in demand. HPE says there is also important upside when it comes to network operations: The modular and dynamic nature of the 5G core allows for small software release patches, small fixes and small minor releases at a much faster pace than was possible in previous generations of mobile networks.

As the network functions are composed of microservices, 5G operators can perform very granular changes, enabling the network's capabilities to evolve over time. As a microservice is only one part of a network function, upgrading a microservice is not as disruptive as upgrading the entire network function.

This modularity makes it easier, for example, to update the NRF (network repository function), which maintains an updated repository of all the 5G network elements available in the network along with the services provided by them. HPE notes all the network functions in the core network can use an NRF 'agent' microservice to communicate with the NRF. If the operator wants to deploy new features that require a software upgrade, it will only need to update and restart this specific agent microservice in each one of the network functions, not the network functions as a whole. That will make changes much less disruptive to the overall service (see Figure 2).

Figure 2: Updates to specific microservices rather than entire network functions



Validating changes to the network

A 5G operator will need a systematic and rigorous change management process to enable its network to quickly adapt to changes in demand or customers' requirements. Without such a process, an operator won't be able to take advantage of the full flexibility of 5G.

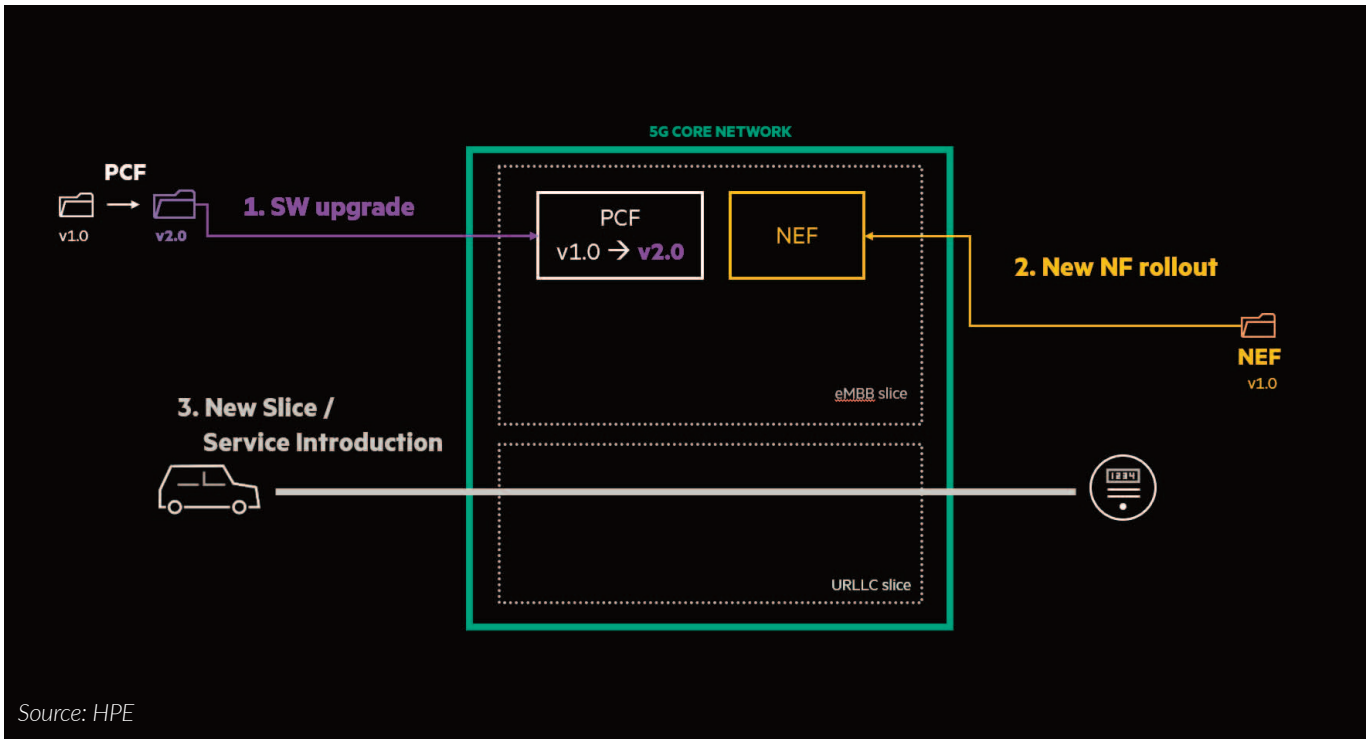
Ideally, the operator will employ automatic tools that can be used to validate software changes before uploading them to production. Whatever the source and reason for the change, the telco needs to include a validation step, as even a small software patch could jeopardize the service they are providing.

"Imagine that you want to support new policy use cases and because of that you realize that you need to upgrade your PCF," says Eduardo Ruano. "So you bring a new release of your PCF, your PCF version 2.0, and before deploying this new version to your network, you need to run and test this version with your whole environment, with your infrastructure, with your containers, with the rest of the network functions in your slice, with your observability and KPI tools to properly validate that this new release is going to adapt to your network."

Another common scenario for a 5G operator will be the roll out of a new network function, such as an NEF to expose the capabilities residing in the network to an external entity (see Figure 3). Again, the operator needs to test this new network function with all the related infrastructure, with all the other network functions, the network slice where the NEF is going to be deployed and with the environment that it's going to interwork with.

Similarly, a new connectivity slice should also go through a rigorous change management process to validate that it will work properly.

Figure 3: Typical changes to a 5G core network



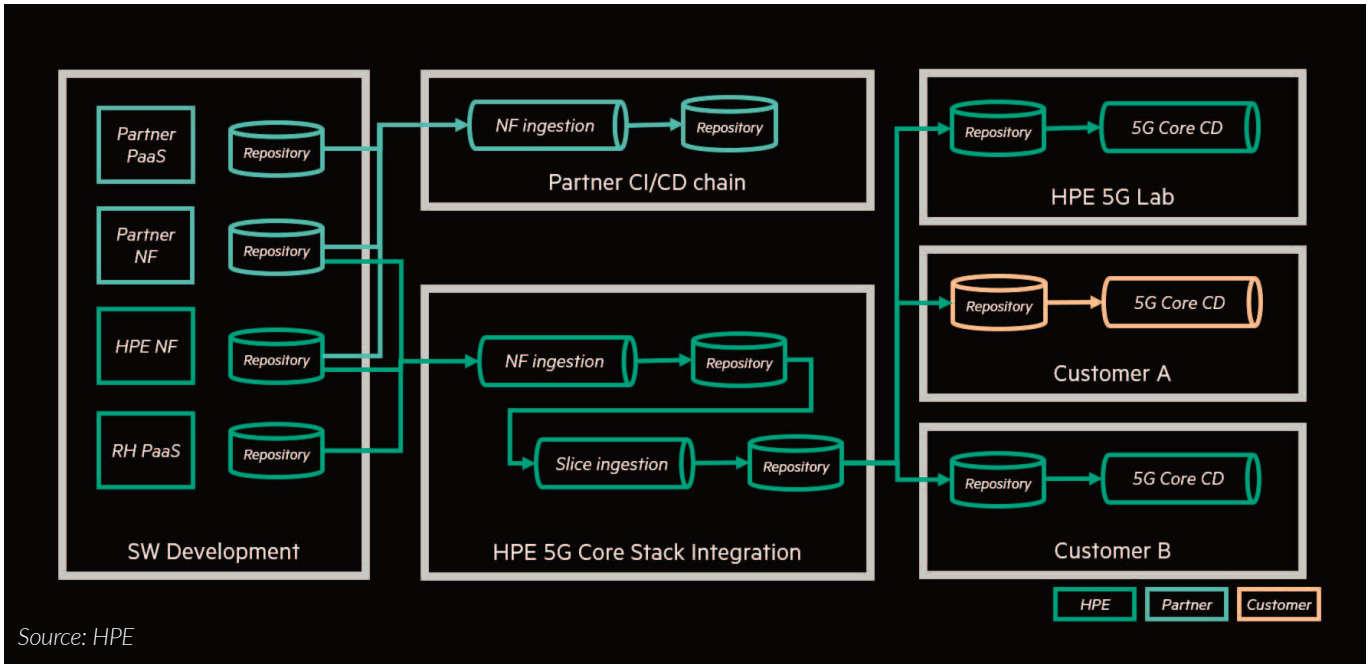
Source: HPE

How HPE's 5G core stack employs CI/CD

HPE uses CI/CD throughout the development and change lifecycle of its HPE 5G core stack - a complete 5G core solution that is cloud-native from the ground up. The left hand side of Figure 4 shows the network function products, each typically developed by a different engineering team – a single engineering team might specialize in policy charging or subscriber data management, for example. HPE says the teams use agile development processes to produce smaller increments of the network functions on a frequent basis.

The modularity within the 5G core stack enables the CI/CD process to manage multiple updates or changes in parallel. Figure 4 shows how each network function can be developed to its own schedule (left pane of the diagram), and then ingested into the core stack (central pane) , followed by the customer-specific deployment (the right pane).

Figure 4: CI/CD pipelines used with HPE's 5G core stack



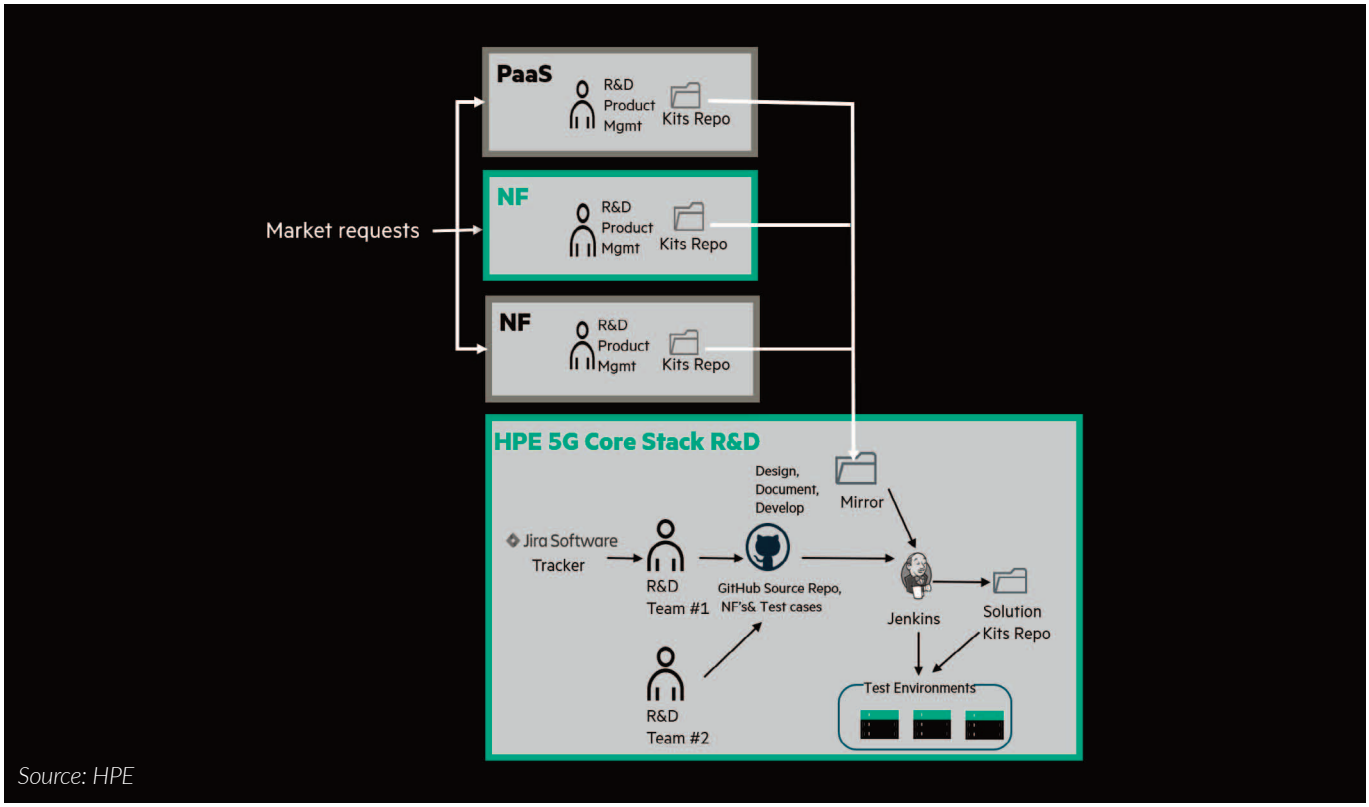
Source: HPE

Continuous integration for 5G

HPE's R&D labs rely on a continuous integration process to build and refine its 5G core solution. As HPE receives requests for changes from the market, it prioritizes them in its solution backlog. When a change is selected for implementation, the R&D engineers build the relevant software modules. Each release goes through automated testing to validate the performance of the whole system incorporating the updated modules (see Figure 5).

Using a CI/CD approach, HPE is able to frequently integrate and test software from multiple sources. "Continuous integration allows us to take frequent deliveries as inputs and produce multiple kits a day," says Sebastien Klahr, 5G Core Stack Product Manager at HPE. "This flexibility allows us to accept an early version of a module for evaluation or testing. The process is based on a layered integration approach mixing the PaaS (platform-as-a-service), the network functions and the slices as well."

Figure 5: HPE's engineers using continuous integration to implement market requests



Source: HPE

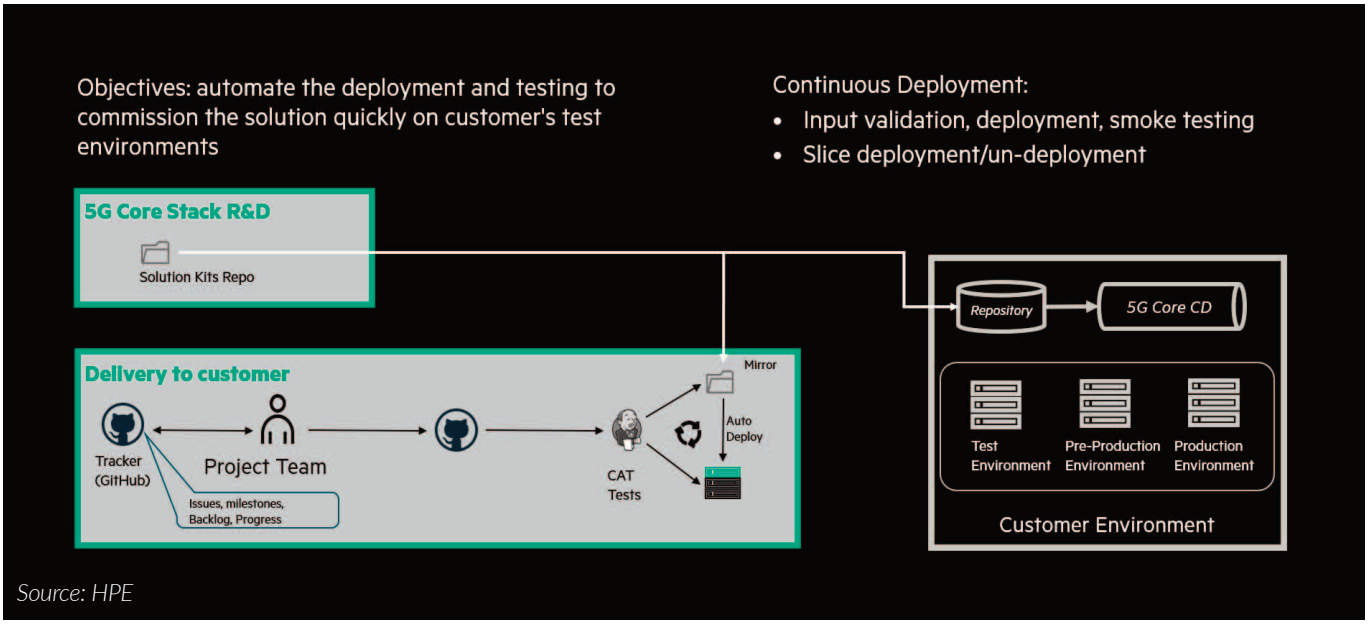
One of the key development principles for HPE is that if a system breaks it should "fail fast." Applying this principle will help maximise usage of resources and enable any software bug to be discovered as early as possible during the integration phase and before being released to the customer. "It should also provide an immediate feedback loop to notify the author of the module that is preventing the work from being successfully run," adds Sebastien Klahr. "They can quickly fix it, and commit the fix, and trigger the next cycle."

Continuous delivery/deployment for 5G

By automating the delivery and deployment stage of the process, HPE aims to quickly "sanity check" the software before it moves to the final acceptance testing. By using the same testing tools across multiple environments, HPE also seeks to reduce costs and complexity.

By accessing the repository hosting qualified HPE software, the delivery team will deploy a new solution, together with the continuous deployment framework, which is part of the product itself. This framework is used to deploy network functions and slices, perform testing in each environment (see Figure 6) and also to decommission slices when needed.

Figure 6: Automated testing tools validate the solution during the delivery process



Source: HPE

An operator will usually have its own engine to drive continuous deployment and testing, which can be integrated with the HPE continuous deployment pipeline, typically via a REST API . HPE says this is one of the many validation steps that the customer is likely to conduct in its own qualification process.

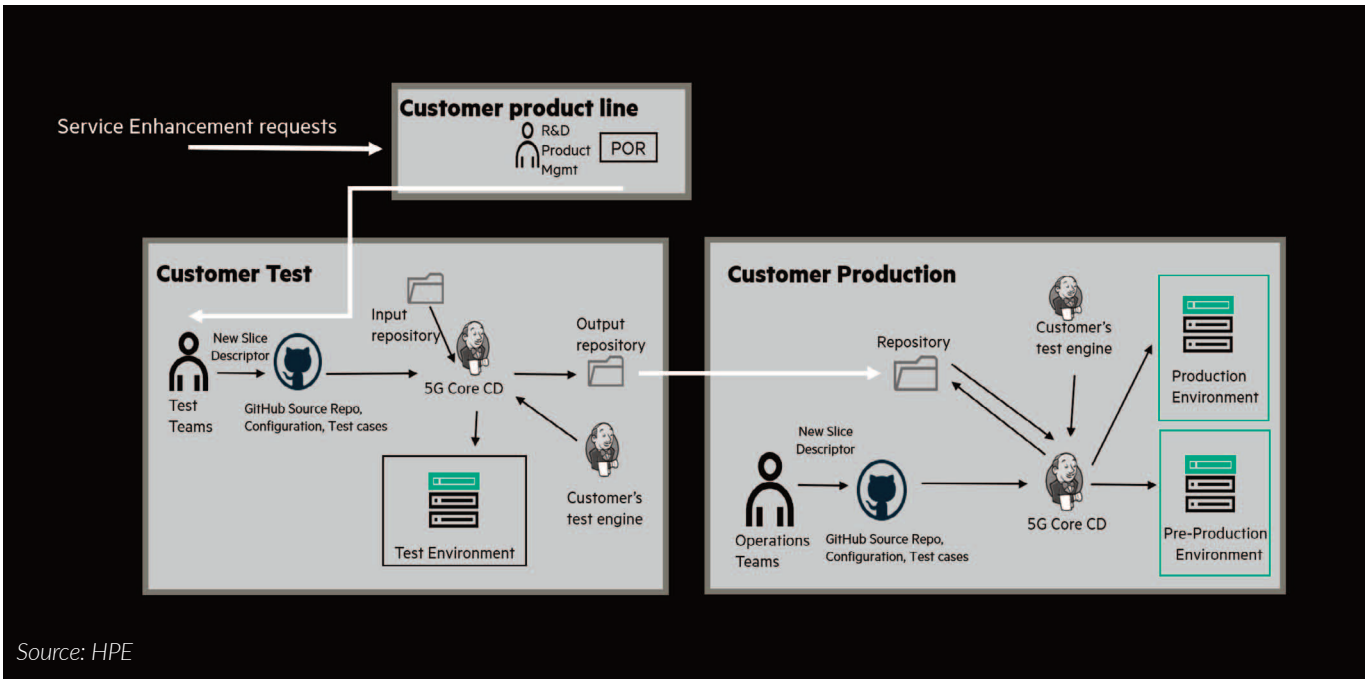
Customer-initiated changes

Once a new solution is in production, HPE's continuous deployment pipeline can deploy changes initiated by its operator customers. The customer can define a new slice (or a new instance of an existing slice) by specifying a slice descriptor, which may, for example, refer to a new set of quality of service (QoS) parameters.

This new slice descriptor can be committed to the local versioning system for configuration management. The workflow engine will then trigger the deployment of that new slice into the test environment. Once software is deemed ready for production, it is pulled into the production environment in line with the customer's deployment strategy (see Figure 7).

Within its live network, the operator can have two versions of the slices running at the same time with the traffic being progressively diverted away from the initial version to the newer one.

Figure 7: Deploying and testing a new slice version



Source: HPE

Again, HPE aims to reduce costs and complexity by employing the same tools to implement changes initiated by customers as it uses to deliver fixes and new versions of its network functions.

How to model 5G slices

Although CI/CD is a well-established and proven methodology in the IT sector, it needs to be adapted for use in telecoms networks. "The difference between the telecom world and the IT world, in which CI/CD was born, is the network and service modelling," explains Pierre Lavillat, 5G Core Stack & 5G Global Practice Manager at HPE. "A slice is made of a slice subnet. It has some characteristics, some SLAs, some quality of service and the slice subnet is made of network functions."

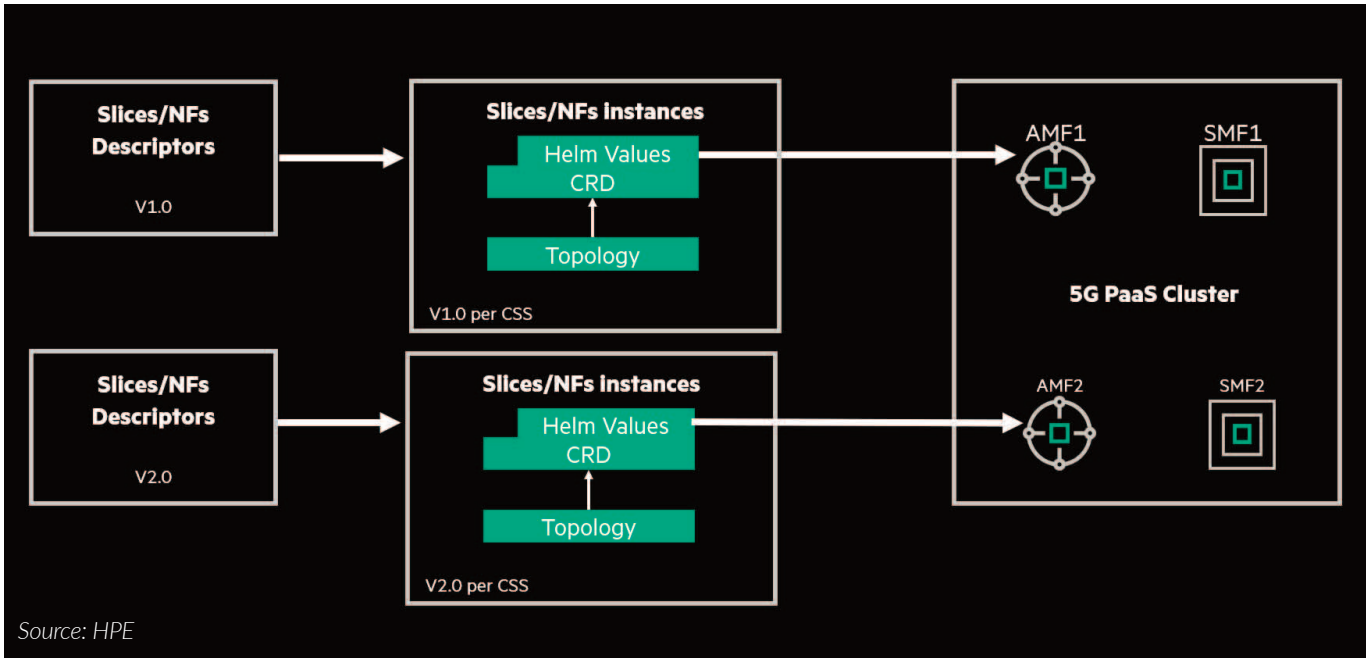
To take this into account, HPE implements CI/CD in its 5G core via the following steps:

- The slices and underlying network functions are modelled in templates and descriptors
- The templates and descriptors are used for deployment
- Versioning of templates and descriptors are then used to implement lifecycle management

When an operator wants to deploy a new slice, it needs to provide a set of parameters representing the topology, the IP addresses and other characteristics. Once these parameters are populated in the software, the operator can then instantiate the slice in its cluster (see Figure 8), enabling it to automate the deployment.

"As 5G is fully cloud-native and fully software-based, you have the capability to deploy different instances of different slices for a different purpose in the same environment," explains Pierre Lavillat. "When you are happy with the new version or the slice of course, you can decommission the previous slice and keep on using the new version in your environment."

Figure 8: The process of implementing a new version of a slice or network function



Source: HPE

Conclusions and recommendations

The cloud-native architecture of 5G networks opens up new opportunities for mobile operators: the decomposition of network functions and microservices allows for frequent software updates and the rapid deployment of dedicated slices of connectivity.

Given the modular and dynamic nature of 5G, change management becomes a key capability for mobile operators that want to fully harness the advantages afforded by 5G.

To that end, CI/CD can help operators realise the full potential of the flexible and versatile architecture that underpins 5G. It provides the automation required to enable operators to introduce changes much more frequently than was possible with previous generations of cellular technology.

“But we strongly recommend adapting CI/CD techniques to the 5G environment,” cautions Pierre Lavillat of HPE. “If you do a good job, you will be able to introduce new services much more frequently, which will mean monetization opportunities and a better return on investment on 5G.”

Hewlett Packard Enterprise

HPE has over 30 years of experience in the telecoms industry, with more than 300 telco customers across 160 countries. In the core, more than 700 million subscribers across more than 80 carriers depend on HPE Mobile Core software. HPE's open telco solutions help operators evolve their networks and services to a 5G ready, cloudnative, servicebased architecture. As the edgetocloud platformasaservice company, our experience in hybrid cloud allows us to bring the cloud transformation and secure, carriergrade, standardsbased infrastructure to telecommunications networks.

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