Introduction to Cloud Computing and Network Function Virtualization Infrastructure(NFVI)

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Context

During the summer break of 2024, I had the opportunity to intern at Ericsson for two months. The internship consisted of an overview of Erricsson's proprietary Cloud Execution Environments (CEE) and Software Defined Infrastructure (SDI) and their roles in Ericsson's market-leading Network Functions Virtualization Infrastructure (NFVI) solution.

Network Functions Virtualization Infrastructure (NFVI) is the foundational hardware and software resources that support the virtualization and automation of network services.

A Cloud Execution Environment (CEE) is a virtualized infrastructure that provides the necessary resources and platform for running applications and services in the cloud, ensuring scalability, flexibility, and efficient resource management.

Software-Defined Infrastructure (SDI) is a framework that enables automated and flexible management of compute, storage, and networking resources through software abstraction and virtualization.

Ericsson is a leading provider of telecommunications and networking technology. They focus on developing, implementing, and managing mobile networks (including 5G), offering digital services, and providing managed services for telecommunications operators. In the market, Ericsson plays a critical role by enabling connectivity, supporting the deployment of advanced mobile networks, and driving innovations in areas like cloud computing. With their market-leading NFVI solution and latest Cloud Native Infrastructure solution, which runs on bare-metal, customers can enjoy quick deployment, faster time to market for new services, and low total cost of ownership (TCO).

Following this internship, I worked on two deliverables:

1. A summary of my understanding of how Ericsson provides Cloud Execution Environments (CEE) and Software Defined Infrastructure (SDI) and their roles in Ericsson's market-leading Network Functions Virtualization Infrastructure (NFVI) solution.
2. A project which involved setting up a LAMP stack, which is a bundle of four different software technologies that developers use to build websites and web applications. LAMP is an acronym for the operating system, Linux; the web server, Apache; the database server, MySQL; and the programming language, PHP.

Preface

The purpose of this paper is to articulate my understanding of the topics that were covered during the internship and also summarize how Erricson provided a virtual environment for telecom providers across the world by leveraging the powerful and cost effective means of cloud computing.

The document begins with an introduction to cloud computing, exploring its models and benefits. Following this, it delves into the principles of virtualization, including virtual machines and hypervisors, and then explains containerization and its significance.It also explains Physical Network Function(PNF), Virtual Network Function(VNF) and Cloud Native Network Function(CNF).

The next sections detail Ericsson's technologies, starting with an overview of Network Functions Virtualization Infrastructure (NFVI) and its applications. This is followed by an in-depth look at the Cloud Execution Environment (CEE) and Software-Defined Infrastructure (SDI), highlighting their roles in modern telecommunications networks. The document also examines Docker and Kubernetes, explaining how these tools facilitate containerization and orchestration in cloud environments.

Finally, the report summarizes my practical experiences and the insights gained from setting up and configuring these technologies, emphasizing their importance in the context of Ericsson's market-leading solutions.

Cloud Computing

Cloud computing is a concept and service that allows users to access and store data and applications over the internet instead of on local servers or personal computers. It provides on-demand delivery of computing resources, such as servers, storage, databases, networking, software, and analytics, through a cloud service provider. With cloud computing, you don’t need to make large upfront investments in hardware and spend a lot of time on the heavy lifting of managing that hardware. Examples of cloud service providers include Amazon Web Services(AWS), Microsoft Azure and Google Cloud Platform(GCP).

There are three main cloud models:

- **Public Cloud**: The Public Cloud allows systems and services to be easily accessible to the general public. Public cloud may be less secure because of its openness eg: AWS, Google etc

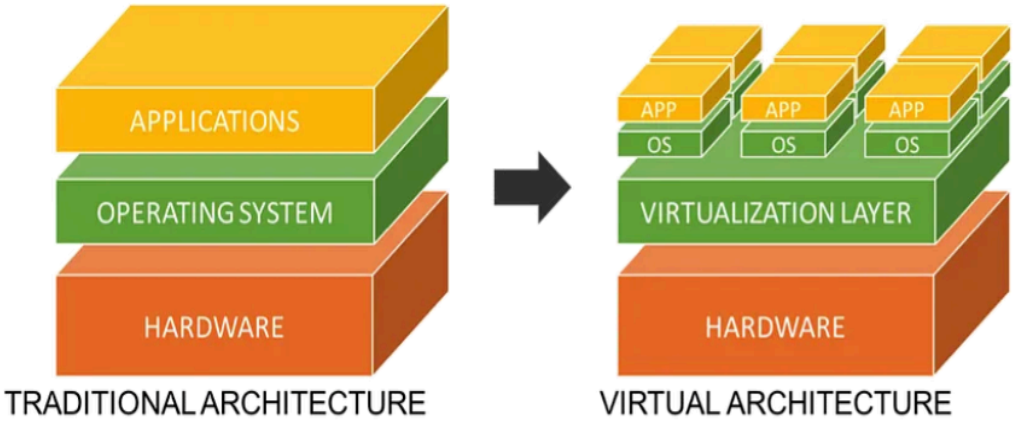
- **Private Cloud**: The Private Cloud provides the same services and allows services to be accessible within an organization privately without going through the internet. It offers increased security

because of its private nature , e.g., Infrastructure or data center used in a Bank to store customer details.

- **Hybrid Cloud**: The Hybrid Cloud is a mixture of public and private cloud. However, the critical activities are performed using private cloud while the non-critical activities are performed using public cloud.

Before moving on to some of the core concepts specific to Ericsson and the cloud services it provides, it is essential to understand the concepts of:

- **Virtualization**: Virtualization is one of the most important concepts in Cloud Computing. It is the ability to create a virtual version of an actual piece of technology, such as an operating system (OS), a server, a storage device or a network resource. It allows a computer to share its hardware resources with multiple digitally separated environments. Each virtualized environment runs within its allocated resources, such as memory, processing power, and storage. Virtualization is used to improve IT throughput and costs by using physical resources as a pool from which virtual resources can be allocated.

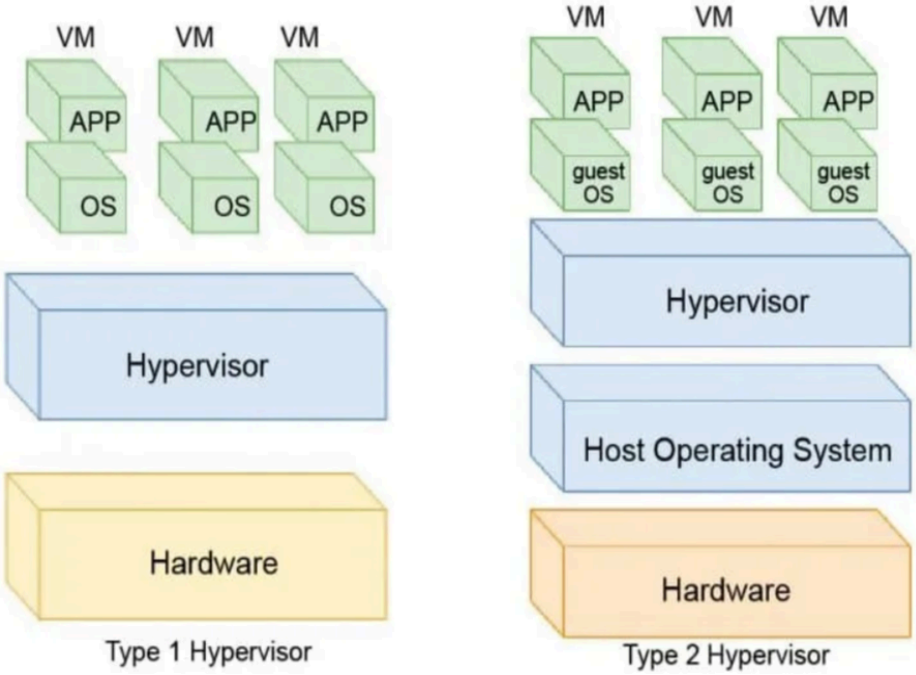


- **Virtual Machine**: A virtual machine is a software-defined computer that runs on a physical computer with a separate operating system and computing resources. The physical computer is called the host machine and virtual machines are guest machines. Multiple virtual machines can run on a single physical machine. Virtual machines are abstracted from the computer hardware by a hypervisor.

- **Hypervisor(Virtualization Layer):** The hypervisor is a software component that manages multiple virtual machines in a computer. It ensures that each virtual machine gets the allocated resources

and does not interfere with the operation of other virtual machines. There are two types of hypervisors.

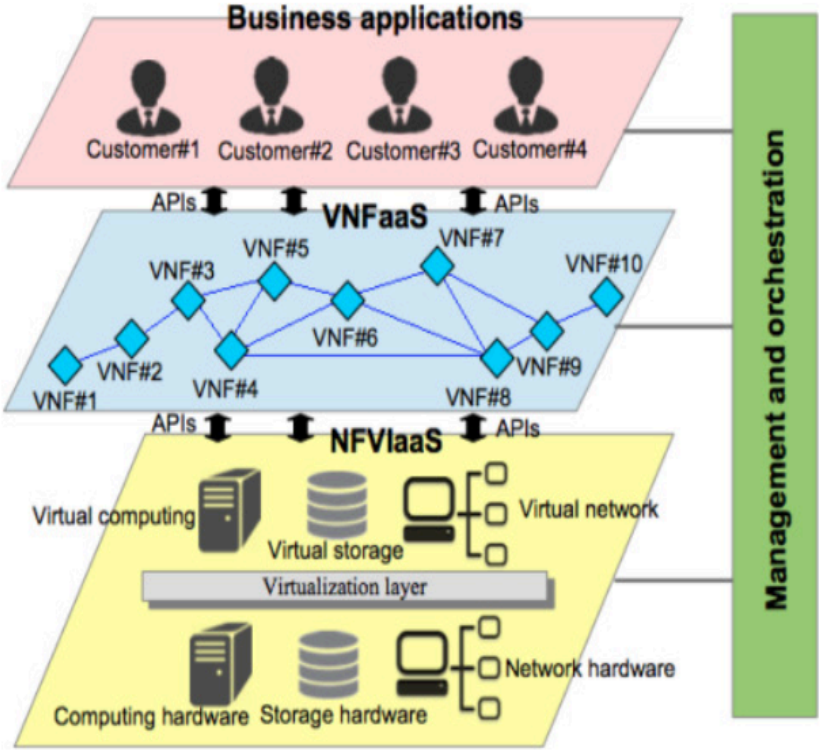
- **Type 1 hypervisor**: A type 1 hypervisor, or bare-metal hypervisor, is a hypervisor program installed directly on the computer's hardware instead of the operating system. Therefore, type 1 hypervisors have better performance and are commonly used by enterprise applications.
- **Type 2 hypervisor**: Also known as a hosted hypervisor, the type 2 hypervisor is installed on an operating system. Type 2 hypervisors are suitable for end-user computing(systems in which non-programmers can create working applications).



- **Containerization:** It is a software deployment process that bundles an application's code with all the files and libraries it needs to run on any infrastructure. Traditionally, to run any application on your computer, you had to install the version that matched your machine's operating system. For example, you needed to install the Windows version of a software package on a Windows machine. However, with containerization, you can create a single software package, or container, that runs on all types of devices and operating systems.

- **Physical Network Functions(PNF)**: The physical layer is responsible for sending computer bits from one device to another along the network. Its role is determining how physical connections to the network are set up, as well as how bits are represented into predictable signals as they are transmitted either electrically, optically or by radio waves.

- **Virtual Network Functions(VNF)**: Virtual Network Functions are software applications that deliver network functions such as directory services, routers, firewalls, load balancers and more. They are developed as virtual machines (VMs) and have often been the next step for telecommunications providers like Ericsson in their digital transformation from the PNFs of legacy network appliances on proprietary hardware.



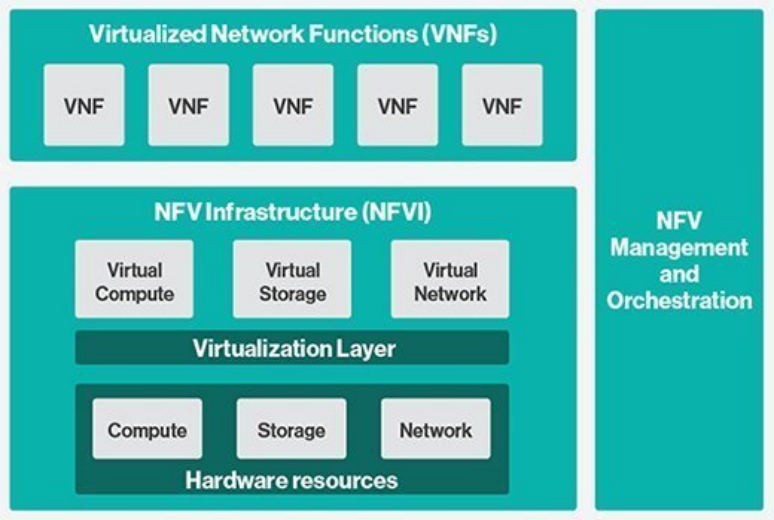
- **Cloud Native Network Function(CNF)**: A Cloud Native Network Function or CNF is defined as a software service that fulfills network functionalities while adhering to cloud native design principles without requiring any hardware. CNF encapsulates PNF and VNF into containers.

Network Function Virtualization Infrastructure(NFVI)

Communication service providers (CSPs) are companies that offer communications and information-related services. This can include Media, Entertainment, Internet service providers (ISPs), Cable companies, Mobile carriers or Television broadcasting operators, leveraging the network infrastructure as a rich, functional platform.

The demands that today's customers place on CSPs have increased dramatically. In this rapidly changing landscape, many providers are struggling to keep pace and deliver new services, manage growing network traffic and allocate resources more efficiently. Ericsson through their experience of working with cloud solutions, have developed a philosophy for how cloud infrastructure should be designed and deployed. It addresses service providers' challenges by delivering system verified cloud infrastructure solutions, which work out of the box. This is where Ericsson's market leading NFVI comes into play, a flexible, cost-effective, scalable, secure and programmable solution. Ericsson has more than 260 cloud infrastructure customers across the world including leading service providers such as Swisscom, Telefónica, Wind Tre, Telstra, DOCOMO, Telkomsel, Far EasTone, XL Axiata and many others.

Network Function Virtualization Infrastructure (NFVI) is a virtualized environment pivotal for deploying and managing both Virtual Network Functions (VNFs) and Cloud-Native Functions (CNFs). It abstracts hardware resources—compute, storage, and networking—into virtualized instances, enabling flexible and efficient network service deployment. NFVI supports dynamic resource allocation and scaling to meet service demands, accommodating both traditional VNFs and modern CNFs. Key components include virtualization technologies, orchestration platforms like Kubernetes for lifecycle management of VNFs and CNFs. NFVI facilitates agile and scalable delivery of network services across various deployment scenarios. NFVI helps CSPs to rapidly adjust to fluctuating network traffic demand, deliver new services faster at lower costs and provide a consistent and high quality user experience.



Application of NFVI

Network Function Virtualization Infrastructure (NFVI) finds extensive applications across various industries. In telecommunications, NFVI supports edge computing and network slicing for 5G deployment. Enterprises deploy NFVI for enhanced network security using virtual firewalls and VPN gateways, alongside optimizing networks with virtual routers and load balancers. Cloud service providers utilize NFVI for rapid service deployment and establishing isolated virtual network environments for multiple tenants. NFVI also contributes to cost efficiency by lowering capital and operational expenses, offering flexible licensing models that scale with network function demands. These diverse applications underscore NFVI's pivotal role in modernizing network architectures.

Cloud Execution Environment (CEE)

In Network Functions Virtualization Infrastructure (NFVI), CEE plays a crucial role in deploying Virtual Network Functions (VNFs) and Cloud-Native Functions (CNFs), enabling flexible and scalable network services. When coupled with Software-Defined Infrastructure (SDI), CEE provides a versatile and programmable layer essential for modern telecommunications networks. Cloud Execution Environment (CEE) serves as a platform for deploying and managing applications within cloud infrastructures. It supports virtualization or containerization to optimize resource utilization and ensure isolation. CEE dynamically manages compute, storage, and network resources, integrating automation and orchestration tools like Kubernetes for scalability. Security measures ensure multi-tenancy (architecture in which a single instance of a software application serves multiple customers), while monitoring tools enhance performance optimization.

Software-Defined Infrastructure(SDI)

Software-Defined Infrastructure (SDI) is a framework where infrastructure components like compute, storage, and networking are virtualized and managed via software. It abstracts hardware resources into programmable entities, centrally controlled through automation and orchestration. SDI facilitates dynamic provisioning, scaling, and management of resources based on application requirements, enhancing flexibility and efficiency. Key components include virtualization technologies such as hypervisors and virtual switches. SDI is pivotal in modern data centers and cloud environments, enabling swift service deployment, optimizing resource use, and supporting agile and scalable infrastructure operations.

Docker and Kubernetes

Docker simplifies application creation, deployment, and operation within containers by packaging applications and their dependencies into standardized units, ensuring consistency and portability across various environments.

Kubernetes, on the other hand, is an open-source container orchestration platform, automates the deployment, scaling, and management of containerized applications. It offers features like load balancing and auto-scaling, and abstracting infrastructure complexities to efficiently handle workloads and facilitate the deployment of resilient, scalable cloud-native applications.

Together, Docker and Kubernetes provide a comprehensive ecosystem for developing, deploying, and managing containerized applications in modern cloud environments.

Conclusion

The internship with Ericsson consisted of daily presentations and interactive sessions for Q&A. I was presented with information and documentation pertaining to the above cloud computing concepts and hence gained invaluable insights into the intricacies of Network Functions Virtualization Infrastructure (NFVI), Cloud Execution Environment (CEE), and Software Defined Infrastructure (SDI). I acquired practical skills in installing and configuring CEE and SDI, familiarizing myself with their components and layout, and explored the roles of Docker and Kubernetes in cloud computing. This experience was instrumental in deepening my understanding of how cutting-edge cloud technologies are implemented and managed in a real-world setting. This comprehensive understanding of cloud computing and software-defined infrastructure helps us appreciate how Ericsson maintains its leadership in the telecommunications market.

Ericsson's extensive expertise in cloud infrastructure was evident throughout my tenure. Their innovative approaches and market-leading solutions provided a robust framework for my learning. I had the opportunity to explore the nuances of NFVI, understanding its critical role in enabling flexible and scalable network functions. My exposure to CEE was particularly enlightening, as I witnessed how it facilitates seamless deployment and management of cloud-native applications. Additionally, delving into SDI allowed me to appreciate the efficiency and agility that software-defined approaches bring to infrastructure management.

Ericsson's commitment to delivering state-of-the-art cloud solutions was a recurring theme throughout my internship. Their emphasis on innovation, reliability, and scalability in cloud infrastructure solutions not only highlighted their market leadership but also reinforced my own aspirations in the field.

This was an excellent industry experience that allowed me to gain a deeper understanding of the technologies that underpin their cloud computing infrastructure. I worked closely with industry professionals, learning about cloud architecture, deployment models, and the various tools and services used to manage and optimize cloud environments.

I thank my mentors who relentlessly provided me with all the information I looked for and were diligent in answering all my questions. As a next step I am working on completing the project to build a small web application using ReactJS and LAMP architecture. The end objective is to have a demo of the project to my mentors and also share this understanding document and get feedback.