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WHITE PAPER

Optimizing uCPE Architectures:
Minimize Footprint to Maximize Value

A Heavy Reading white paper produced for Enea

ENEA

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INTRODUCTION

Communications service providers (CSPs) are looking at ways to lower both their capex and their opex when delivering network services. Historically, customer premises equipment (CPE) was a hardware-based appliance that CSPs used to deliver Layer 4-7 services such as firewall and wide-area network (WAN) optimization. With the disaggregation that comes from network functions virtualization (NFV), suppliers have delivered virtual CPE (vCPE) that runs Layer 4-7 services on an industry-standard IT server. With greater adoption of cloud-based architectures, universal CPE (uCPE) platforms are emerging. uCPE allows multiple services to be efficiently run from a single server, due to some of the functionality being delivered from the cloud. uCPE provides clear economic value for CSPs, as it addresses both sides of the cost equation. uCPE allows CSPs to consolidate the number of hardware platforms needed to deliver network services, and because the services are software-based (and not tied to specific hardware), services can be delivered and managed more efficiently.

Hardware components such as CPU, memory and storage drive a large portion of the cost of uCPE. Virtualization software (e.g., hypervisor), virtualized network function (VNF) software and orchestration software, however, drive an increasing share of the cost. How the CSP chooses to implement uCPE will have an impact on the cost. Cloud-based VNFs will need less to be supported on the uCPE, and therefore will cost less than in a customer premises-based VNF implementation.

CSPs have a host of considerations when selecting a uCPE platform. Some of the attributes CSPs need to consider include latency, packet processing, core throughput and resiliency. Choosing software that has been optimized will allow CSPs to minimize the number of cores and memory needed to deliver the requisite performance. Open source solutions and open application programming interfaces (APIs) should be part of CSPs' evaluations, as they allow CSPs to benefit from community-driven innovation and help reduce integration challenges.

In addition, CSPs must consider the management and operational aspects, with NETCONF/YANG technologies a viable lightweight option to handle them. Service function chaining (SFC) allows CSPs to layer additional functionality onto the uCPE platform, by linking multiple network services together. Deep packet inspection (DPI) provides the ability to apply policies at a more granular level to give CSPs greater control over their network traffic.

Enea supplies virtualization software that has been optimized for maximum throughput and latency. Its NFV Access solution runs on multi-architecture white-box hardware, scaling from the smallest ARM v8 processor up to the largest Intel Xeon E. It supports multiple orchestration and management options, including NETCONF, Docker and OpenStack. Enea also offers DPI to deliver more intelligent SFC, traffic management and optimization.

MARKET DRIVERS FOR uCPE ECOSYSTEM

Business Trends

CSPs are transforming their networks to leverage new technologies that will allow them to lower their costs and generate new revenue streams. The disaggregation of hardware and software driven by NFV enables them to deliver VNFs on white-box/COTS servers, rather than proprietary, vertically-integrated platforms. Using a software-based approach allows for faster innovation cycles, since hardware is no longer a limiting factor. The emergence of lower-cost, high-volume white boxes along with standardized software APIs increases supplier choice and reduces risk for CSPs.

To deliver enterprise network services, CSPs can use equipment residing in their own data centers, or on the customer premises. In order to maximize their profits, CSPs need to ensure they are using the most cost-effective solutions on the customer premises, and increasingly, they are using uCPE. This approach gives CSPs greater agility and flexibility by allowing them to offer a range of services from a single platform, and push new features and functionality via software, rather than truck rolls.

CSPs can make new services available more quickly and cost-effectively by sending new software to the uCPE, rather than deploying new appliances. In addition to traditional firewall, WAN optimization and load-balancing services, CSPs can also add over-the-top SD-WAN connectivity by leveraging solutions being delivered by new entrants to the uCPE market. Based on SDN principles, with SD-WAN, the control plane and data plane are separated, with network control now being managed from the cloud. This frees up the uCPE to handle software-based functions such as security.

Technical Trends

Currently, on-premises deployments have been mostly focused on rudimentary Layer 4-7 network services that, instead of being delivered on discrete appliances, are now supported on a single commodity hardware platform. They are generally running a single VNF such as vRouter, VPN, firewall and SD-WAN. This platform is the foundation for more advanced value-added services, layered on top in virtual machines (VMs) and/or containers, such as advanced security/surveillance and Internet of Things (IoT) gateways to be deployed in the future.

Understanding that CSPs will want to put as much functionality onto a given platform as possible – particularly for the vCPE and SD-WAN use cases – some VNF owners have begun to extend the capabilities of their VNFs. For example, a firewall VNF may now also provide tunnel management, load balancing and support for multiple backhauls. Packing more features into a single VNF saves on footprint, and reduces integration time and cost. For on-premises uCPE, it is more optimal to integrate as much functionality in one VNF as possible, as this minimizes the memory and core footprint for a given service. This approach also reduces the number of suppliers a CSP needs to work with.

CSPs are also increasingly adopting cloud-based architectures. CSPs will benefit by having microservices-based, containerized VNFs coming from their traditional suppliers that are re-architecting their functions, and from new entrants that were born in the cloud. This will help drive cloud-based VNF delivery and therefore reduce the cost of the equipment needed on the customer premises, since the intelligence will reside in the cloud. In a customer premises-based delivery model, CSPs will benefit from being able to run more functions on the uCPE, as containers are much more lightweight than VM-based VNFs. In both cases, CSPs will receive more granular functionality, making it faster, easier and more cost-effective to deploy, manage and scale their services.

COST STRUCTURE FOR uCPE

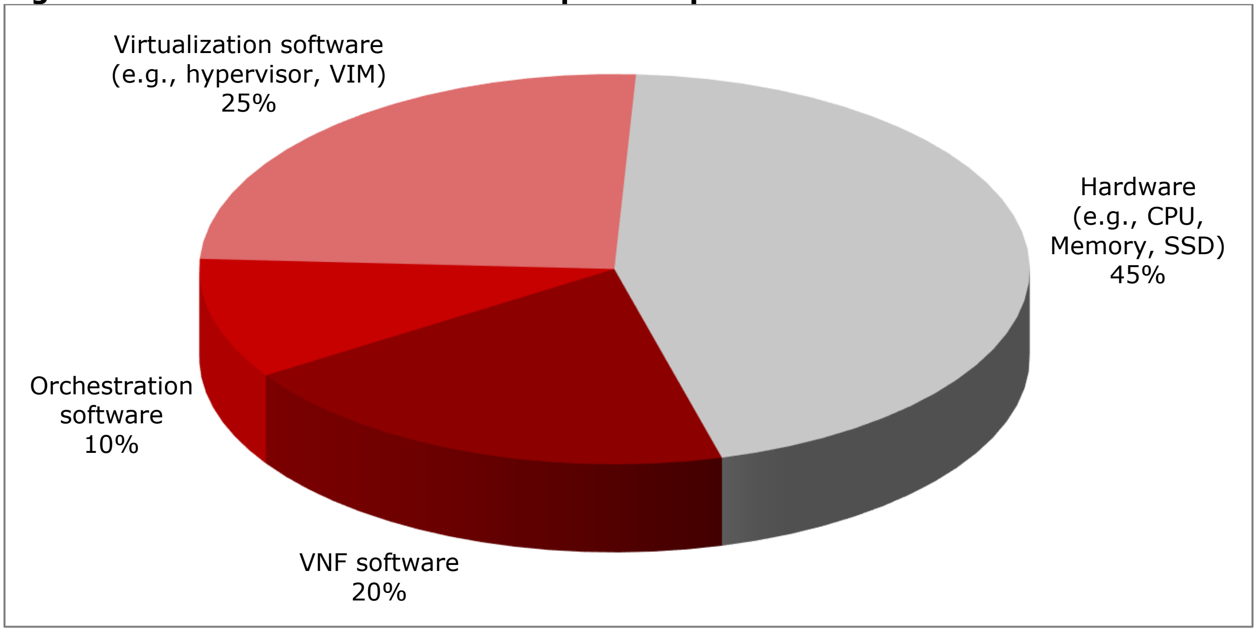
In order to make the uCPE use case work, CSPs are looking to lower the cost of the uCPE to less than $1,000. This is at the top of the range that network services appliances cost today.

From a hardware perspective, the challenge is to ensure there is enough processing power to support data-plane-heavy VNFs, while providing the performance in terms of throughput and latency needed to support enterprise SLAs.

With VNFs, one must also take into account the virtualization and management software needed to manage them, as well as the virtualized resources. Because of the tight correlation between software architecture and hardware requirements, each layer of the stack needs to be considered and optimized. The operational impact of the architectural choices must also be considered, as lower-power options can reduce the hardware complexity, and therefore reduce capex cost, as well as the physical footprint.

As discussed later in this section, there are numerous variables that determine the cost – most importantly, the deployment model. **Figure 1** shows a reasonable estimation of the different components that drive the acquisition cost of uCPE in a customer premises-based VNF model.

Figure 1: Estimated Breakdown of Capex Components for uCPE



Source: Heavy Reading

Typical Hardware Costs

The cost of uCPE hardware can drive as much as half of the cost for a uCPE implementation. As noted in the ETSI NFV ISG documentation on performance:

> *Parameters such as processor architecture, number of cores, clock rate, size of the internal processor cache(s), memory channels, memory latency, bandwidth of peripheral buses and inter-processor buses, instruction set, etc., have a strong impact on the performance of the specific application or VNF running on that HW.*

Some VNFs put significant pressure on memory when handling huge amounts of data, while others require large amounts of network I/O, which could starve other VNFs running on the same platform.

The ETSI NFV ISG has defined four workload categories:

- **Data plane:** These include functions responsible for packet handling. ETSI expects these workloads to be I/O operations and memory R/W intensive.
- **Control plane:** These include functions that handle communication between functions not directly responsible for data communication between edge applications. ETSI expects these workloads to be less transaction-heavy, but represent more complex transactions, resulting in higher CPU load and lower R/W load.
- **Signal processing:** These include functions that relate to digital processing. ETSI expects these workloads to be very CPU-intensive and highly delay-sensitive.
- **Storage:** These include all tasks regarding disk storage. ETSI expects these workloads to show a range of R/W and I/O requirements.

CSPs will need to ensure that they provide hardware solutions with the right mix of architectural elements for the set of VNFs they wish to deliver. They will have to have at their disposal a variety of configurations – likely with a mix of Intel and ARM architectures, since each is optimized for different characteristics – in order to achieve the performance their customers expect. Regardless of configuration, CSPs should look for hardware that minimizes the number of cores and amount of RAM required to deliver the required processing speeds.

Minimizing the hardware footprint is important in terms of capex. One can reasonably expect that hardware as a portion of the costs will decline over time, as continued innovations at the component level drive prices down.

Typical Software Costs

Software drives an increasing share of the cost of a vCPE implementation. There are many components of software in this context. VNF and its associated management software represent around half of the software cost. Virtualization software, such as the hypervisor and virtualized infrastructure manager (VIM), constitutes a smaller share. For data-plane-heavy VNFs, acceleration software may be needed to achieve the needed packet processing performance. By leveraging tools such as Data Plane Development Kit (DPDK) at compile time, an application can provide improved performance in terms of throughput and latency. As mentioned above, the architectural choices made from a hardware perspective will impact the software that can run on top of it.

Impact of Deployment Scenarios on Cost Goals

CSPs have a choice of how to implement uCPE, and that choice will affect the cost of that uCPE. In both scenarios, the aim is to minimize the cost of the uCPE while delivering feature and performance parity to the traditional appliance-based approach to network services.

Customer Premises-Based VNFs

CSPs could choose to put most or all of the VNF functionality onto a server at the customer premises. This gives the enterprise more control, and is the least disruptive option operationally, as they would manage the service similarly to how they did in an appliance-based approach. However, because the uCPE needs to support more complex software, the hardware platform needs to be more robust – that is, more CPU and memory – and will therefore be more costly.

Cloud-Based VNFs

CSPs could instead run most of the VNF functionality in the cloud, making it possible for the uCPE to be a relatively low-cost white box. In this scenario, the uCPE would primarily be responsible for Layer 2/3 connectivity. Most of the cost of the uCPE in this scenario would come from the network interface cards (NICs). The CSP could choose to run some limited VNFs at the customer location as well, but that decision would have to be weighed by the performance that is possible on the less robust hardware at the customer premises.

ARCHITECTURE & FUNCTIONALITY CONSIDERATIONS

Infrastructure Requirements

As mentioned earlier, CSPs need to minimize their costs for uCPE, but they cannot compromise performance as a result. A virtualization platform that has optimized software enables lower hardware costs, since fewer cores and less memory are needed to deliver the necessary performance.

CSPs must consider the necessary latency, throughput/performance and resiliency for that application or service:

- **Latency:** The time a network packet is processed from uCPE ingress to uCPE egress
- **Throughput/performance:** How many packets can be processed in a given amount of time
- **Throughput/core:** How much data per second per core the solution can handle
- **Resiliency:** The level of tolerance for failure (i.e., can it handle a delay of a second, millisecond, nanosecond?)

Figure 2 presents some of the attributes of uCPE that CSPs need to consider when evaluating solutions. The order in which they are presented indicates their relative importance.

Figure 2: Important uCPE Infrastructure Attributes

Attribute	Ranges	Impact
RAM/memory footprint	<1 GB to 12 GB	Minimizing the RAM footprint reduces the cost of the underlying hardware.
CPU utilization	Single core to 4 cores	Using fewer cores reduces the cost of the underlying hardware.
Platform boot speed (excl. BIOS)	<3 seconds to 30 seconds	To maximize service uptime, CSPs need to minimize boot speed, with under 3 seconds being a reasonable expectation.
Virtualized traffic throughput over vSwitch	1 Gbit/s to 10 Gbit/s	Enterprise SLAs mandate service performance and will not tolerate any degradation. CSPs should demand their uCPE deliver at least 10 Gbit/s line-rate throughput.
Virtualized network latency over vSwitch	Average 10-75 milliseconds	Similarly, enterprise SLAs also mandate latency requirements. CSPs should expect uCPE to deliver less than 15 millisecond latency over vSwitch.

Source: Enea, Heavy Reading

Another important consideration is the extensibility of the platform. It should be possible to start with a minimal feature set, and expand as required for the business. With extensibility, CSPs pay only for what they need and use.

Importance of Open Source in the Whole Solution

Open source software should be used throughout uCPE solutions. Leveraging the innovation that comes from community-driven development allows solution providers to deliver more value to their customers in a shorter period of time than could have been done on their own. While open source software is not free, it reduces time to market and reduces the risk of vendor lock-in, and those savings are reflected in the solutions that leverage open source.

In the context of uCPE, open source software is used at multiple layers of the stack. In the data plane, for example, DPDK can be optimized to maximize performance of physical and virtualized functions. At the virtualization layer, KVM/QEMU and Docker Containers are used for the hypervisor and image packaging, reducing costs and minimizing footprint.

Related to open source is open APIs. These are critical to minimize integration challenges. Using open APIs on the northbound interface allows for more choice on orchestration and operations support systems (OSSs). Using them on the southbound interface facilitates management of more uCPE types.

Management/Operational Considerations

CSPs must also consider the operational issues around uCPE, including the platform itself and the VNFs running on that platform. One option for the VIM is OpenStack. However, OpenStack was designed to manage data center resources, and is more powerful (meaning it requires more significant resources to run) than is needed in most cases. Using proprietary management solutions is another alternative, but this can be limiting and expensive – the very attributes that uCPE is most aiming to change.

One option that avoids the cost and innovation limitations of the options referenced above is to use more lightweight solutions, such as management over NETCONF/YANG. Increasingly, CSPs are basing FCAPS on NETCONF, which can also be used to support VNF lifecycle management. Extensions to these well-known tools exist that provide a lightweight alternative for configuration management. Additionally, this option can also configure and deploy VNFs including service chaining.

Value-Added Capabilities

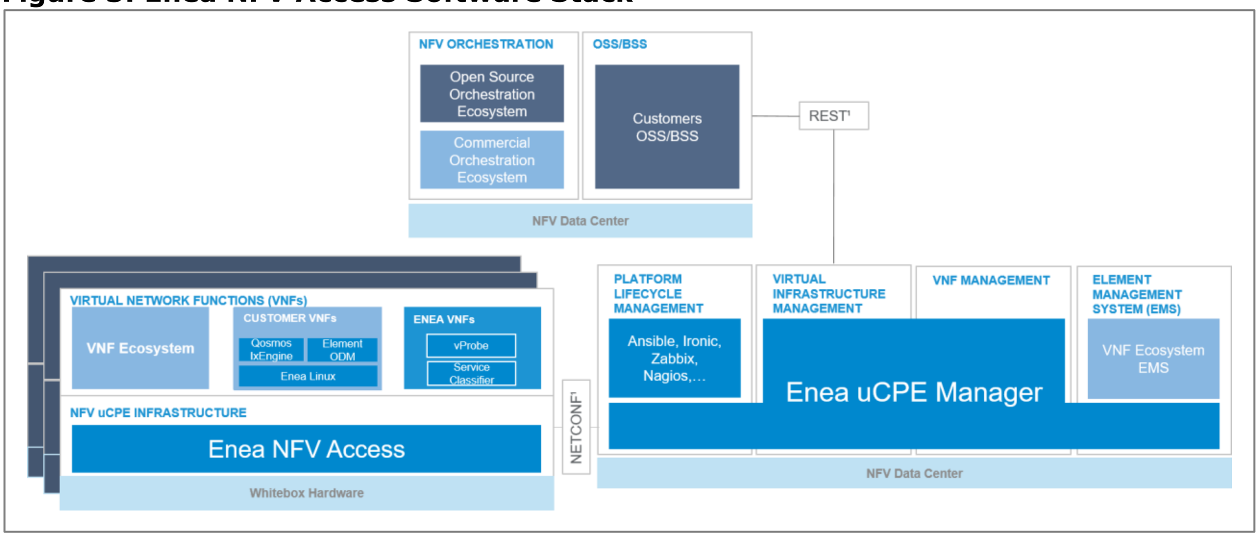
uCPE needs to support value-added capabilities in addition to the baseline features described above. SFC allows for multiple network services to be linked together in an ordered way to define how packets will be routed as part of an end-user service. With SFC, rather than make changes to the hardware, operators can configure network services in software.

DPI supports more efficient and dynamic service chaining based on tag processing. It allows operators to classify traffic so they can apply firewall and quality-of-service policies at a more granular level. The insights gained from DPI also play an important role in monitoring and troubleshooting network traffic, in addition to supporting more intelligent traffic management and reconfiguration. Traffic management at a macro level helps to optimize usage of valuable – and costly – network resources.

WHY ENEA?

Enea provides virtualization software that leverages open source technologies in support of operators' NFV infrastructure deployment strategies. Its NFV Access is a lightweight virtualization software platform that minimizes the uCPE footprint while maximizing throughput and latency. Enea's software supports multi-architectures so operators have more choice and flexibility for the underlying white-box hardware, from the largest Intel Xeon E down to the smallest ARM ARMv8 processor. Its Edgelink orchestration interface gives customers the flexibility to manage and orchestrate over their preferred standard, including NETCONF, Docker and OpenStack. The Enea Qosmos Service Classifier and software-based Layer 7 DPI enables more intelligent SFC and traffic management and optimization.

Figure 3: Enea NFV Access Software Stack



Source: Enea

CONCLUSION

uCPE is a compelling option for CSPs to more efficiently deliver a host of network services. Rather than hardware-based appliances, uCPE allows CSPs to leverage standardized IT servers in combination with the cloud – an approach that provides both lower platform acquisition costs and lower ongoing operational expense. Using software that has been optimized for performance helps reduce the hardware required for the uCPE platform. Open source software and APIs, along with protocols such as NETCONF and YANG, provide the innovation and ease of management that CSPs require. SFC helps CSPs maximize the value of their uCPE, while DPI provides them more control over their network traffic.

Enea's uCPE platform has been optimized to minimize hardware components without sacrificing performance. Its NFV Access solution can be run on multiple architectures to ensure CSP choice and flexibility.