# D7.5 Market Feasibility Study

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| Project Acronym | SONATA |
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| Deliverable Type | | |
|---|---|---|
| R | Document | **X** |
| DEM | Demonstrator, pilot, prototype | |
| DEC | Websites, patent filings, videos, etc. | |
| OTHER | | |
| Dissemination Level | | |
| PU | Public | **X** |
| CO | Confidential, only for members of the consortium (including the Commission Services) | |

## Executive Summary

The following deliverable provides an extended market analysis for the SONATA project, which serves as its main audience. It is a consolidated milestone based on activity that begun on Day 1 of the project, influencing the first year of development and further prioritizing the direction of its upcoming second year. The related exercises have also influenced the project's positioning and open source adoption strategy towards stakeholders.

It defines the target market, technology context, ideal adopter profiles and their challenges, supporting stakeholders, comparable alternatives that are currently developing in the market, and areas where the project's innovation and differentiation can make an impact.

SONATA is focused on Network Function Virtualization (NFV), a cornerstone of future software networks that influences heavily how they are built, deployed and managed. Coupled with SDN, NFV is a building block for future 5G networks and services.

This is an attractive upgrade for network operators of various sizes and scope, whether they are a large communication service provider (CSP) or an enterprise running their own network. The supporting business case includes lower CapEx on hardware procurement and upgrades; flexibility and alleviated vendor lock-in; reduced OpEx while increasing efficiency and ability to scale network operations; and potential for agile service development and improved time-to-market.

SONATA is developing a NFV service platform for the operator, a supporting SDK for service developers and a DevOps workflow that connects these stakeholders together. The project identifies with the MANO layer of the ETSI architecture. Its primary value proposition is to help realize the aforementioned NFV core business case as a chief component in the overall architecture (i.e. NFV orchestrator); alleviate NFV adopters' initial pain points revolving around multi-vendor complexity; and empower CSPs and supporting third-party developers with the workflow and tools needed for the agile service development and deployment envisioned for 5G networks.

The NFV MANO field is crowding quickly, and over 20 comparable solutions have been analyzed in the deliverable. As these solutions are not yet benchmarked or validated in production, the collection of sourced vendor whitepapers and marketing was contrasted with broader, vendor-agnostic analyst reports, surveys and CSP testimonials, referenced throughout the document.

A survey was also launched by the project, aimed at better understanding stakeholder priorities for NFV MANO features and characteristics.

Conclusions are extensive, and can be found consolidated in the final section of the deliverable, organized per topic area.

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# 1 Introduction

## 1.1 Deliverable Purpose

The following deliverable provides an extended market analysis for the SONATA project.

It a consolidated milestone based on activity that begun on Day 1 of the project, influencing the first year of development and further prioritizing the direction of its upcoming second year. The related exercises have also influenced the project's positioning and open source adoption strategy towards stakeholders.

It defines the target market, technology context, ideal adopter profiles and their challenges, supporting stakeholders, comparable alternatives that are currently developing in the market, and areas where the project's innovation and differentiation can make an impact.

At its most specific segment of analysis, it focuses exclusively on NFV's Management and Orchestration (MANO) area, where SONATA's service platform and supporting SDK can provide value to network operators.

The deliverable can be understood as a standalone document, and provides a minimal technical context of NFV, MANO, SDN and future 5G Networks. Further technical design and details can be found in the first year architecture, D2.2 Architecture Design, and lower-level implementation deliverables D3.1 and D4.1 representing initial development. The upcoming D5.2 (summer 2016) will be a first prototype of the SONATA service platform and SDK in an integrated form, and its open source code will be available publicly on GitHub. The ideal reference point for all aforementioned technical documents is the project website: www.sonata-nfv.eu.

Additional forthcoming deliverables for the first year, D7.2 and D7.6, are presenting the impact plans of the project, including stakeholder engagement, dissemination plans, open source strategy, community project contributions, standardization influence, partner exploitation plans, etc. The exercises taken to complete this document have influenced those activities.

## 1.2 Continuous Market Watch and Deliverable Timing

2016 has proved to be a key year for NFV developments, and the deliverable work plan has been extended to compensate.

February's Mobile World Congress 2016 [1], for example, presented two new open source initiatives in the same domain as SONATA, covered in this document. Industry perspective taken at other Q1 and Q2 2016 stakeholder events, such as MPLS+SDN+NFV [2] and Layer123 NFV World Congress [3] have also provided fresh stakeholder perspectives, including a new "reality check" on how NFV adoption and integration is evolving.

In March, a survey was then launched by SONATA in the 5G-PPP [4] Software Networks Working Group and towards additional industry researchers to further evaluate related features and requirements that should be prioritized by the project. The results and analysis of that survey are included in this document.

There is also an ongoing market watch since Day 1 of SONATA that is updated continuously in the project partners' collaborative wiki, tracking trends and solutions developing in the market. This

document serves as a milestone in that activity, which builds on top of its work to deliver an analysis of more than 20 comparable solutions in the MANO area. As reminded later, however, the analysis is done at "face value" (i.e. based on advertised features and architecture characteristics), as NFV MANO solutions have not yet been benchmarked or validated in the market, except for trials currently running behind closed doors between vendors and their CSP customers.

To compensate for potential marketing bias, the work of various analysts, public reports and parallel surveys were consulted and are referenced throughout the document. As to not repeat work that is already in the public domain, the project has focused its resources on meta-analysis across recent market studies and perspectives, comparative analysis of SONATA-like solutions, extended stakeholder consultation, and market feasibility analysis of forthcoming project results.

The end-game objective of these activities is to further influence the project direction and its iterative development cycles in order to ensure maximum stakeholder impact of SONATA.

## 1.3 Document Organization

The deliverable is organized in the following manner:

- Section 1 (this section) is an introduction to the deliverable, as well as to the SONATA project.
- Section 2 is an abridged technology context for the reader, focusing on NFV architecture and its MANO layer, along with brief context on SDN and future 5G networks.
- Section 3 is a presentation of NFV's business case towards network operators. The link to solutions related to MANO and network service development, including SONATA, is to enable and fulfil this business case as a chief component of the larger NFV architecture, as well as create new revenue opportunities in service development and agility.
- Section 4 includes forecasts for NFV adoption and growth, looking at both market size and uptake patterns.
- Section 5 is a value chain and stakeholder analysis, examining the changes being made in telecommunications market and its actors in the transition to Software Networks.
- Section 6 is a consolidation of NFV adoption challenges and other network operator "pain points" that SONATA looks to address.
- Section 7 is then a presentation of SONATA's features and value proposition, including its NFV service platform, orchestrator, SDK and DevOps workflow.
- Section 8 is an extensive comparative study covering over 20 related commercial and open source solutions in SONATA's domain.
- Section 9 is a supporting analysis derived from the project's stakeholder interviews on NFV MANO features and priorities. The survey template is included as the Annex to the deliverable.
- Section 10 provides conclusions and recommendations to SONATA based on the above input, organized by subject matter.

## 1.4 SONATA Project in Brief

The following provides a brief introduction of the SONATA project and its context.

Software Defined Networking (SDN) and Network Function Virtualization (NFV) are emerging as major transformational technologies towards “software networks”, a new paradigm that is evolving the telecom sector with new network capabilities and business opportunities. SONATA addresses the significant challenges associated with both the development and deployment of the complex services envisioned for 5G networks and empowered by these technologies. Core objectives include:

- **Reduce time-to-market of networked services:** SONATA streamlines development with abstract programing models, SDK and a DevOps model that integrates operators, manufacturers and third-party developers.
- **Optimize resources and lower costs of service deployment and operation:** SONATA orchestrates complex services to connectivity, computing and storage resources, and automatically reconfigures running services.
- **Accelerate industry adoption of software networks:** SONATA supports the full service lifecycle: development, testing, orchestration, deployment, management and operations, and is defining a roadmap for uptake of its results towards stakeholders' larger transition to SDN/NFV.

SONATA is developing a NFV framework that provides a programing model and development toolchain for virtualized services, fully integrated with a DevOps-enabled NFV service management and orchestration platform (NFV MANO).

The currently developing results include:

1. Programming model and software development kit (SDK) to facilitate network service development for third-party developers.
2. Service platform with modular NFV orchestration framework (NFVO) for network operators.
3. DevOps model for software networks that integrates these stakeholders together for an agile service lifecycle.

## 1.5 Terminology and List of Acronyms

To be consistent with stakeholder references, the following terminology was used, highlighted here since there are several competing terms for these actors when discussing the market:

- Communication Service Provider (CSP): aka “Network Operator”, “Operator”, “Carrier” and “Telco”, referring to any operator of a carrier-grade network, whether fixed, mobile, etc., and that also provides or supports competitive services through it (the “service provider” half of their profile). Note that a smaller scale profile of a network operator referred to in the deliverable is at the enterprise level.
- Network Equipment Vendor: aka “Vendor” or “Manufacturer”, referring to the actor that provides the equipment or virtualized solutions to their network operator customers (CSP or enterprise). As later explained in the deliverable, their role as a system integrator is increasing.

The following table provides a more comprehensive list of common acronyms found throughout the document.

Table 1: List of Acronyms

| | |
|---|---|
| 5G | “5th Generation” Networks |
| 5G-PPP | 5G Public Private Partnership (industry association and EC partnership) |
| B2B | Business-to-Business |
| B2C | Business-to-Consumer |
| BSS | Business Support System |
| CapEx | Capital Expenditure |
| CD | Continuous Delivery (often added with Continuous Integration, CI/CD) |
| CI | Continuous Integration (often added with Continuous Deployment, CI/CD) |
| CLI | Command Line Interface |
| COTS | Commercial Off-the-Shelf (referring to telecommunications hardware) |
| CPE | Customer Premise Equipment |
| CSP | Communication Service Provider (e.g. telecommunications operator) |
| DevOps | Development and Operations (workflow and organizational concept) |
| Dx | Deliverable # |
| EMS | Element Management System |
| EPC | Evolved Packet Core |
| ETSI | European Telecommunications Standards Institute (SDO) |
| FSM | Functional-specific Manager (SONATA component) |
| GUI | Graphical User Interface |
| ISG | Industry Specification Group |
| MANO | Management and Orchestration (layer of the ETSI NFV architecture) |
| MNO | Mobile Network Operator (a type of CSP) |
| MVNO | Mobile Virtual Network Operator) |
| Mx | Month # of the project work plan (e.g. M2) |
| NFV | Network Function Virtualization |
| NFVI | Network Function Virtualization Infrastructure |
| NFVO | NFV Orchestrator (component of MANO) |
| NS | Network Service |
| OpEx | Operational Expenditure |
| OSS | Operations Support System |
| OTT | Over-the-Top [providers] |
| PNF | Physical Network Function |
| PoC | Proof of Concept |
| PoP | Point of Presence |
| QoE | Quality of Experience |
| QoS | Quality of Service |
| ROI | Return on Investment |
| SDO | Standards Development Organization |
| SME | Small-to-Medium Enterprise |
| SSM | Service-specific Manager (SONATA component) |
| TOSCA | Topology and Orchestration Specification for Cloud Applications (specification) |
| VIM | Virtual Infrastructure Manager (component of MANO) |
| VM | Virtual Machine |
| VNF | Virtual Network Function |
| VNFM | VNF Manager (component of MANO) |
| VoIP | Voice over IP |
| WAN | Wide Area Network |
| WPx | Work Package # (e.g. WP5) |
| YANG | “Yet Another Next Generation” data modeling language |

# 2 Software Networks and Enabling Technology: NFV, SDN and 5G Networks

The following section provides the minimal technology context to understand the core content of the deliverable, related to market-related perspectives and analysis. NFV is first introduced; then the MANO layer (particularly important to SONATA) and where it fits in a common reference architecture from ETSI; the neighboring SDN technology is then briefly explained; and finally, a vision of 5G networks is provided, a milestone where these technologies will converge and act as enablers.

## 2.1 Network Function Virtualization (NFV) in Brief

Network Function Virtualization (NFV) is a corner stone of software networks, and represents a large shift in how networks are built, deployed and managed. NFV does this by introducing a virtualization layer and decoupling the software from the hardware. The software-based assets then become the innovation and differentiating value, while the hardware becomes commodity.

This is an attractive upgrade for network operators of various sizes and scope, whether they are a large communication service provider (CSP) or an enterprise running their own network.

Commercial off-the-shelf (COTS) hardware for software networks will be generic by design, replacing what is now a proprietary landscape with hard dependencies between physical network functions (PNFs) and legacy telecommunication hardware. *Virtual* network functions (VNFs) on top of virtualized infrastructure and generic hardware have a significant impact on network operations, their cost to maintain (OpEx) and upgrade, and the hope of business agility for operators to mix and match from a variety of vendors and VNF developers. Network service development and lifecycle management is also a large focus of NFV, largely facilitating service rollout and maintenance. [5]

ETSI highlights these key differences between current and future NFV-enabled networks [6], paraphrased in the points below:

- **Decoupling software from hardware**: creating two evolutionary tracks that are independent from each other, and creating multi-vendor scenarios.
- **Flexible network function deployment:** allowing a more dynamic relationship to occur between infrastructure resources, and speeding up the network function instantiation and automation via virtualization and cloud technologies.
- **Dynamic operation:** providing greater flexibility to scale network function performance and with finer control, e.g. reacting to actual traffic.

Although the point is often lost in marketing material and vendor white papers, it should be stressed that NFV is a technology that is not in wide use today. The paradigm shift is significant and highly disruptive, and network operators are seeking a gradual transition from their current legacy networks, OSS, physical elements, etc. This roadmap will take years to complete, but initial deployments are already underway in a limited capacity. (See Sections 4 and 6 for roadmap forecasts and current challenges.)

## 2.2 NFV Reference Architecture and the Management & Orchestration (MANO) Layer

ETSI evolved the NFV concept through the NFV Industry Specification Group (ISG) [7]. As they progressed, a reference architecture was released, showed below in Figure 1.

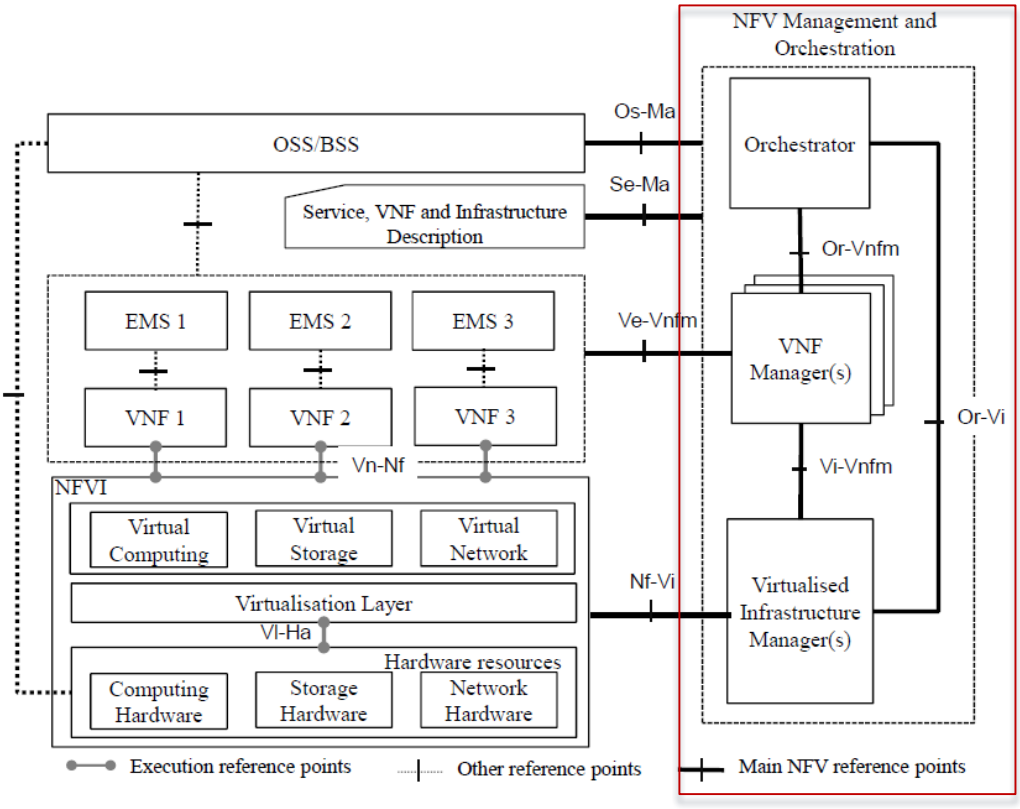



Figure 1: ETSI NFV Reference Architecture (source: ETSI [6]), with MANO domain highlighted

The ETSI NFV Reference Architecture public document [6] provides a detailed description of each building block. For a more simplified technical context of this market-oriented deliverable, only the defined 3 working domains of the NFV architecture are briefly reviewed below:

- **Virtualized Network Function (VNF):** Software implementation of a network function which is capable of running over the NFVI. They replicate the functionality of specialized telecommunications elements and hardware, from a simple firewall to a large suite of services like Evolved Packet Core (EPC). VNFs can be chained together for a network service (NS).

- **NFV Infrastructure (NFVI):** Includes the set of physical resources (compute, storage, network) and the virtualized environment.

- **NFV Management and Orchestration (MANO):** The orchestration and lifecycle management of physical and software resources that support the virtualized infrastructure and VNFs.

The last domain listed, **NFV MANO, is the focus of SONATA and the market context for its service platform**. MANO essentially covers all the virtualization-related management across a NFV-empowered network, and is made up of several components to carry out the responsibility, highlighted above in Figure 1:

- **Virtualized Infrastructure Manager (VIM):** Manages the NFVI resources in a single domain, including the creation, maintenance and tear-down of virtual machines (VMs).
- **VNF Manager (VNFM):** Manages lifecycle of a VNF, in terms of:
    - Creation, maintenance and termination of VNF instances.
    - Fault, configuration, accounting, performance and security management of the VNF.
    - Scales up and down the VNF. There can be a 1-on-1 approach between VNFM and VNF, or several VNFs managed by a single VNFM. (This diversity in approach is becoming a big challenge in integrating multi-vendor VNFs, and discussed later in the deliverable.)
- **NFV Orchestrator (NFVO)** covers both resource and service orchestration:
    - Resource Orchestration: Coordinates, authorizes, releases and engages NFVI resources within a single point of presence (PoP) or across multiple PoPs. The NFVO can directly interact with the VIMs.
    - Service Orchestration: Creates end-to-end network services (NS) between several VNFs, by coordinating with the involved VNFMs. This implies, for example, VNFs of different vendors (easier said than done, as discussed later). The NFVO can also instantiate VNFs, and create VNF forwarding graphs, a topology management of the network services instance.

SONATA focuses on the upper levels of the MANO layer in its platform, including the VNFM and NFVO functionality. The VIM, on the other hand, is covered extensively by existing open source solutions, such as OpenStack [8] and OpenMANO [9], and SONATA's effort here is towards compatibility with several VIM alternatives (multi-vendor in the VIM context), instead of developing yet another. Discussed further in Section 6, there are challenges and needs for innovative - yet pragmatic - solutions for NFV adopters that are indeed on the orchestration layer, where SONATA is being positioned.

It should be noted, however, that SONATA is not just focused on the management and operations side of NFV, but also extends deeply into the service creation area. The project is developing a SDK and DevOps workflow to empower CSPs and third-party developers towards NFV's business case of service agility. (Upcoming Section 7 contains a full SONATA presentation.)

## 2.3 Software-Defined Networking

Software-defined Networking (SDN) is another key technology that enables software networks, and is often paired with NFV when stakeholders consider the full transformation needed towards, for example, 5G networks.

SDN makes the network programmable by separating the control plane from the data plane, relying on switches that can be programmed through a SDN controller. OpenFlow has become a common de-facto standard protocol for this role. [10]

A basic understanding of SDN is needed for at least two topics introduced later in the document.

The first refers to the closer end-to-end orchestration and management that network operators are seeking to support their NFV/SDN roadmap. This requires, for example, a MANO-related solution to

be compatible or easily extensible for a tighter integration with its SDN controller counterpart (a priority for SONATA). Also seen in the developing market are SDN controller solutions going "north" and covering similar functionality that ETSI-compliant architectures associate with MANO (e.g. see Juniper's solution in the comparative analysis of Section 0).

A second topic, covered in the subsection below, is related to the 5G concept of network slicing, where specific "slices" of the network can be configured for an industry vertical in particular. For example, 5G network and service requirements for manufacturing (i.e. "Industry 4.0") would be quite different than next generation streaming media, and a large network operator, leveraging SDN management, could cater towards both through bespoke slices. [11]

Although separate technologies, many experts, including ETSI, see a future where NFV and SDN become less distinguishable as independent topics, and integrated into a unified software network paradigm. [12]

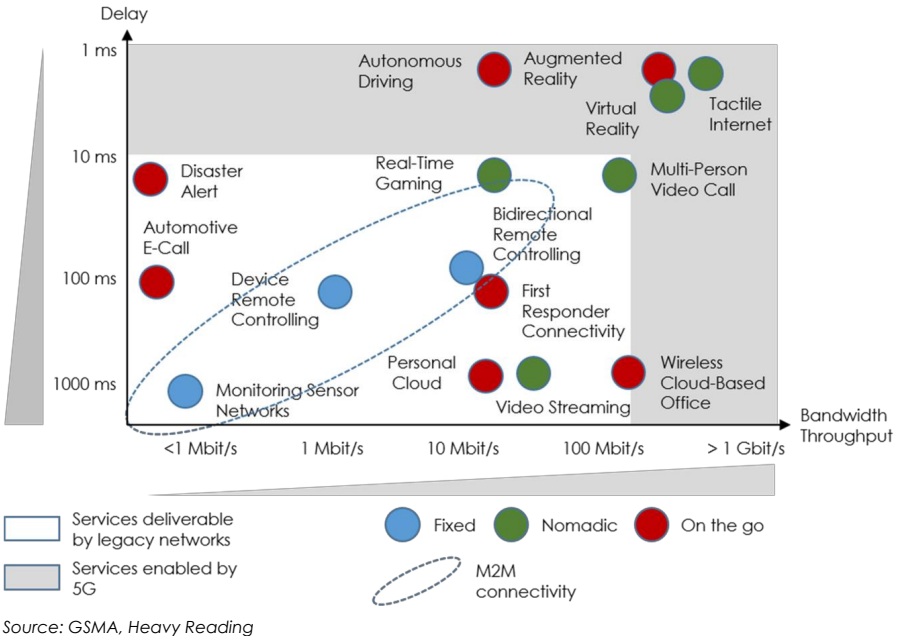
## 2.4 5G Networks and Services

5G represents a vision for the next generation of networks and services. While the term might mistakenly imply an iterative upgrade, it is in fact a fresh and quite disruptive approach to fulfill requirements of future services and scenarios.

The 5G-PPP provides key challenges to fulfill in this vision towards 2020 [4], and those that SONATA can most impact are highlighted in bold:

- Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.
- Saving up to 90% of energy per service provided. The main focus will be in mobile communication networks where the dominating energy consumption comes from the radio access network.
- **Reducing the average service creation time cycle from 90 hours to 90 minutes.**
- **Creating a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision.**
- Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people
- **Ensuring for everyone and everywhere the access to a wider panel of services and applications at lower cost.**

Key to SONATA's focus is the agile development and lifecycle management of the network services that will further enhance applications that exploit 5G (e.g. higher quality video streaming), and those services that empower applications exclusive to 5G due to their extreme requirements (e.g. virtual reality, connected cars). Analysts at Heavy Reading provide an overview of such examples [11], copied in Figure 2 below.




*Source: GSMA, Heavy Reading*

Figure 2: Examples of 5G services per bandwidth and latency requirements (source: GSMA and Heavy Reading [11])

To enable the high degree of challenging requirements, flexibility, programmability and dynamic network operations for 5G, both SDN and NFV are required technologies.

5G networks are estimated to be first deployed in 2020, although various challenges must be met on the way, summarized by analysts at Atos [13]:

- Various regions and groups around the world are currently competing to lead 5G standardization activities, and efforts must be made to coordinate and/or consolidate efforts to avoid fragmentation.
- 5G must accommodate a wide range of use cases from diverse verticals, each with advanced requirements around latency, reliance, coverage and bandwidth. This implies much closer collaboration between CSPs and their vertical stakeholders, and building the tools for development and network "slices" to accommodate them.
- 5G includes a combination of diverse technologies, such as NFV, SDN and others. The maturity of these technologies will vary, and are in fact separate evolutionary paths, thus affecting initial 5G deployments.

Related to the latter, although acting as enablers, SDN and NFV are not exclusive to 5G. They are independent technologies, and therefore can be applied to, for example, evolving 4G LTE networks, as well.

# 3 Business Case for NFV and MANO

To understand the motivation behind SONATA impact, the business case for NFV is summarized below on two levels: NFV in general, and NFV MANO.

The general business case for NFV is presented to provide context of the potential demand for SONATA, as NFV MANO is in fact oriented towards those network operators (i.e. CSP or enterprise) that have *already* bought into a NFV adoption roadmap. It is those NFV adopters that are the target market of the project, together with the third-party service developers that CSPs can support.

## 3.1 Business Case for NFV Adoption

The business case for NFV is extensive, and it must be understood to later dive into the more specific value proposition of what a MANO-related solution, such as SONATA, can deliver.

Network operators, most notably CSPs, look to adopt NFV (and coupled with SDN in the larger software network context), and only take on the complex and costly transition because of clear business benefits. The follow categories have been consolidated through an analysis of CSP motivations and a study of various vendors' NFV portfolios advertised (see Section 0), where the marketing for network operator / CSP "buy in" for NFV is quite consistent. Shortcomings have also been identified, and later expanded in the form of current challenges in Section 6.

### 3.1.1 Lower CapEx on hardware procurement and upgrades

The switch to more generic hardware reduces CapEx. As various hardware vendors can support the same variety of virtualized assets (in theory), increased competition in the COTS hardware space will drive costs down, and eliminate the need for many specialized hardware systems that can now be replaced with software-based solutions.

Hardware lifetime value can also be extended by software function upgrades. Or, the reverse, where generic hardware can be replaced more cheaply, and further scaled by software functions.

Operators can set up redundancy to prepare for contingencies in a much less expensive manner, where workloads are transferred to other machines in a dynamic fashion, maintaining capacity and QoS. CapEx is further decreased as additional expensive, proprietary systems are not needed to provide backup.

### 3.1.2 Flexibility and alleviated vendor lock-in

Related to the above, the decoupling of software with hardware disrupts what was historically based on proprietary solutions and vendor lock-in. Operators will now have better choice when selecting a range of hardware and software based solutions between multiple, competing vendors. The rise of supported open source NFV/SDN solutions is also a shift that operators recognize as a welcome relief, with the potential to integrate several solutions into a holistic suite.

However, as seen in the challenges of Section 6, this is not working as seamlessly as hoped (perhaps unrealistically so), with significant interoperability issues between vendors arising during initial trials. A highly customizable MANO solution will be needed by the CSP to coordinate a multi-vendor NFV environment in a brown-field scenario.

### 3.1.3 Reducing OpEx while increasing efficiency and agility in network operations

The combination of NFV and SDN for software networks brings a much more efficient and agile operation. Performance management, ability to scale dynamically, increased automation and other network management considerations drop the associated OpEx of deploying and maintaining the network.

However, clear challenges with hybrid networks (new virtualized assets working with physical legacy) and coordination of additional layers of management (introduced by the virtualized environment) bring new levels of complexity and demand for highly flexible MANO-like solutions such as SONATA.

### 3.1.4 Facilitated service lifecycle and time-to-market

Virtualized functions (VNFs) can be leveraged for a new generation of network services. A more agile development, deployment, management, configuration, maintenance, etc. of such assets are a welcome improvement from what was a costly and slow process to rollout new services and functionality, in addition to the trialing involved.

CSPs need this accelerated channel to be competitive with new Over-the-Top (OTT) provider services. The gains in service delivery and agility mean new revenue streams for these operators, and offer new platforms to catalyze third-party support and ecosystems.

NFV adoption by itself is not sufficient, nor a basic MANO solution on top, and the CSP requires additional innovative tools and agile development workflows (e.g. DevOps) that SONATA can support.

## 3.2 Business Case for NFV MANO Layer and Service Development Tools

The above covers the primary business case for NFV adoption, referring to the motivation of the network operator, primarily the CSP, to buy into the transition and begin long-term investment towards software networks.

Within that context, **the "business case" for MANO is one of necessity: to enable and ensure delivery on the promise of NFV benefits and ROI**. As hinted at in each of the above cases for adoption, there are new challenges introduced that require a MANO solution to tackle the complexity of the NFV transition, as well as enablers of service agility on the development side.

This is of particular relevance to this report, as it is the area that SONATA's service platform and supporting SDK are directly addressing.

A NFV orchestrator (NFVO), for example, addresses pain points that are not always on the top of today's more immediate needs for an operator's iterative NFV adoption roadmap, but universally agreed to be critical and necessary to support them in the long run. On the development side, to fully realize the business case, there is a need to enable and support those developing and chaining VNFs into network services in a CSP's ecosystem.

# 4 NFV Deployment Timelines and Market Forecast

With the overview of NFV, related technology and business case presented above, the following sections cover the high-level questions that are addressed when estimating market size and timing: the “when”, and “how big”.

The timelines are debatable, especially given the technical challenges in transition, deployment, integration with legacy, etc. (forthcoming Section 6). The market size is also particularly difficult to track, as it is largely substitutive of current network spending, but initial forecasts help project SONATA market feasibility, as explained below.

## 4.1 Estimating NFV Adoption and Deployment Timelines

The eventual adoption of NFV (and SDN), the enablers of future software networks, is a foregone conclusion. Various industry surveys have confirmed that such roadmaps are already underway. IHS and Infonetics, for example, surveyed a large share of CSPs that covers almost 50% of the global telecom CapEx. An overwhelming 97% of CSPs commit to deploying SDN, and 93% NFV. [14]

The question remains: when? Various analysts foresee that 2016 could be an important milestone year for transition between trials and limited production deployment. Although 2020 remains the projected year for initial 5G deployments, the dependency on NFV and SDN requires much earlier trials and iterative, step-by-step production deployments with prioritized use cases.


Figure 3: NFV and SDN early adoption in 2016 (source: Atos [13])

The global roadmaps depicted by IHS, Infonetics, Heavy Reading and Atos analysts are similar, and cover 3 stages of the iterative transformation: [13][14][15]

- Proof of Concept testing (PoC) and Field Trials: Beginning since 2013, with vendors and network operators working together in lab environments around SDN and NFV. Additional prototype field trials started in the next few years by first-movers.
- Initial Commercial Deployments: 2015 saw a year when some early adopters, such as AT&T, performed limited commercial deployments.
- Widespread Commercial Deployments: New phase from 2016 onward, towards 2020, in an iterative deployment pattern that sees hybrid networks (physical/legacy vs. virtualized) that take on early SDN and NFV use cases, such as vCPE.

Heavy Reading analysts foresee a two-stage rollout for NFV adoption. A first stage of incremental upgrade will focus on mid-term gains in service agility (2016 – 2019). [16] A second stage, the full "cloudification" expected at 5G's 2020 milestone, will have CSPs exploit built-for-the-cloud VNFs (as opposed to first generation VNFs migrated from legacy) and architectures based on microservices. Service agility will further evolve with more ambitious organizational transformations in development workflows, such as DevOps. In parallel, better interoperable and integrated NFV deployments will provide the longer-term OpEx savings initially envisioned.

## 4.2 Estimating NFV Market Size

Some analysts argue that the quantitative market forecast for NFV (and SDN) are irrelevant and too complex to calculate, since the majority can be recognized as largely substitutive of current spending on network equipment and technology. For example, according to Gartner, net spending in the area could even decline on the path to 2019. [17]

However, the quantification is still quite important in SONATA's context, since part of that substitutive spending will be going towards required solutions for NFV adoption, including the MANO layer.

IHS estimates total NFV spending for 2019 at $11.6 B, but the fine print shows that new NFV-enabling software (including MANO solutions), as a fraction of that, at $1.2 B. [14]

Table 2: Carrier NFV market for 2019 (source: IHS and Infonetics [14])

| Source | $B | % of 2019 Market | Categories |
|---|---|---|---|
| **New** | $1.2 | 10% | **NFV:** NFV MANO, NFVI software, Outsourced Services |
| **Displaced** | $1.8 | 16% | **NFV:** NFVI Hardware |
| **Existing** | $8.6 | 74% | **NFV:** VNFs |
| **TOTAL** | $11.6 | 100% | **Total Carrier NFV** |

However, a large part of SONATA's value generation is focused on the composition side, where the creation of network services based on chained VNFs (or even new VNFs, themselves) provides revenue in an ecosystem-like market.

Another study by Heavy Reading analysts covers this dynamic, estimating upwards of $450 B of NFV-enabled services by 2020, making up 20% of CSP revenue worldwide. [15]

These figures can of course vary significantly, and indeed do so across analyst reports. However, given the overwhelming percentage of eventual NFV technology adoption, the substitute spending that will go towards software-based solutions, and the end-goal of not just optimizing network operations but enabling better services, it is assumed that the market is indeed there.

Certain drivers and barriers must be tracked that can raise and lower success and speed towards these goals, summarized in Table 3 below. Further in the deliverable, in Section 6, the barriers are looked at in more detail in the perspective of customer (CSP) challenges and pain points that SONATA can help alleviate in their SDN/NFV transition.

Table 3: NFV Adoption Drivers and Barriers (adapted/extended from SDxCentral [18])

| Influencing Adoption Drivers | Influencing Adoption Barriers |
|---|---|
| • compute virtualization adoption service as a catalyst for NFV (and SDN) adoption<br>• continued growth of cloud computing investment and convergence between IT and telecom<br>• aggressive CSP efforts for new sources of revenue and monetization of networks (e.g. competition with OTT), and reduction of OpEx and CapEx | • complexity of initial NFV solutions, and interoperability between them<br>• shortage of adequate skill sets for software networks (SDN, NFV, etc.)<br>• difficulty in integrating with legacy, brown-field scenarios<br>• initial performance issues of first generation virtualized telecom infrastructure, not yet validated<br>• agile development at CSPs is a radical organizational change |

# 5 Stakeholder and Value Chain Analysis: Telecom Sector Transformation via Software Networks

NFV and SDN technologies, and the road to 5G, have caused disruptive shifts for all actors in the classic telecommunications value chain, most notably network operators and equipment vendors, along with their respective business models.

Figure 4 below represents a simplified value chain to reference the involved stakeholders, and the section below highlights how these relationships have changed to adapt to the technology transition.

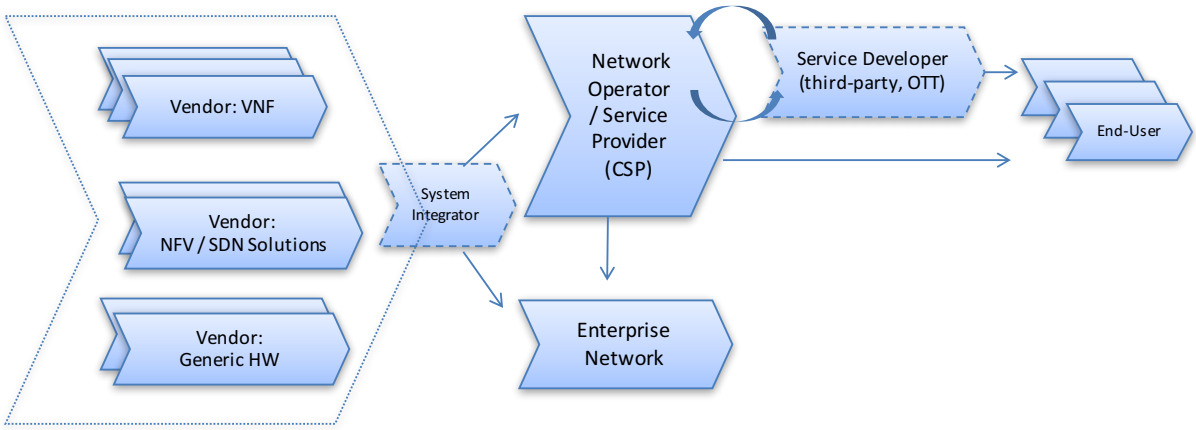



Figure 4: Telecom value chain, adapted for software networks (simplified)

At the far left we have the telecom equipment vendor, now potentially fragmented as hardware becomes more commoditized, and their customers (e.g. CSPs) have a potential piecemeal strategy for NFV/SDN asset adoption across various competitors.

System integration, a much more challenging role in software networks as with any multi-vendor dynamic, is now a focus of vendors to extend their services and prepare for the changing business model. However, this can be a separate, specialized role, with the arrival of large system integrator insurgents from the converging IT world.

The network operator exploits their new multi-vendor options with the NFV operational business case to drop CapEx and OpEx. For CSPs in particular, they also look for more agile and quicker service development, regaining significant market loss from OTT providers. The CSP is recognized as the main adopter of the SONATA service platform and providing a service development ecosystem, and is analyzed in detail in the following Section 6.

However, there is also another network operator profile that will be adopting NFV: the enterprise. In a survey conducted by Ashton Metzler & Associates, 82% of participating telecom industry reps recognize that NFV provides value to an enterprise environment. [19] CSPs still have the most to gain, due to the scaled complexity of their networks and stronger focus on the service development side, but smaller scale deployments of NFV (and SONATA) should not be discounted for the enterprise.

Service platforms, such as SONATA's, can catalyze an ecosystem-driven monetization of CSP's network and support third-party developers (in addition to their own) to create added-value network services for the end-user.

The changing dynamics and priorities of these stakeholders are summarized in Table 4 below.

Table 4: NFV impact and transformation on the telecom value chain

| Telecom Segment Stakeholder | NFV Impact and Transformation |
|---|---|
| **Network Operators (**CSPs, Enterprises, etc.) | • NFV has decoupled network functions with the proprietary hardware that historically locked in network operators to their vendors.<br>• NFV lowers CapEx and OpEx with less expensive hardware and gains in network optimization and operational efficiency.<br>• NFV allows new service agility, rapid innovation, continuous updates and reduced time to market across their network, helping to compete with OTT providers. |
| **Network Equipment Vendors and Solution Providers** | • Large incumbent vendors see software networks as both a liability and opportunity, and must redefine themselves, significantly shifting resources from costly proprietary hardware (replaced with generic COTS) towards SDN / NFV solutions, ecosystems and system integration.<br>• Those vendors with substantial capital and portfolios lean towards end-to-end offerings that encompass all of the customer's (e.g. CSP) needs, and are attempting to replace vendor lock-in with convenience and alleviation of multi-vendor interoperability issues (a counter-argument to NFV's CSP multi-vendor value proposition). Those with larger portfolios are prioritizing a migration of PNFs to VNFs, creating an initial critical mass of early assets for the market changes.<br>• New entries have been empowered, as well. With the convergence of telecommunications with a more software-based IT, smaller solution providers find opportunity with NFV MANO solutions or specialized best-in-class VNFs, attempting to challenge larger, incumbent equipment vendors. |
| **System Integrators and Technology Partners** | • System integration has taken a much more significant role when foreseeing a mix of interoperable solutions deployed at the operator. This is often part of the vendor's transition, but can also be a separate actor with this specialized role, such as system integrators from the converging IT sector.<br>• Virtualizing a network infrastructure has become a business opportunity for large IT technology vendors with a background in cloud computing and virtualization, rolling out NFV-enabling platforms. |
| **Third-party Developers, OTT Providers** | • Focusing on software, NFV/SDN lowers the financial barrier to enter the telecom market, as well as time-to-market for VNFs and network services. This is an opportunity not only for incumbent CSPs, but also for third-party service providers, including SMEs.<br>• High 5G requirements suggest that OTT providers need closer collaboration with the CSPs to ensure sufficient QoS/QoE for the end-user. |

# 6 Challenges and Pain Points for CSPs towards NFV/SDN Adoption and 5G Networks

The promised business case for NFV is extensive for CSPs (Section 3), revolving around savings (lower OpEx, CapEx) and revenue (e.g. new services, agility, business models, etc.). It is a case that has yet to be fulfilled, however, due to the complexity of such a transition and the several technical and organizational barriers the come with it.

Those of a technical nature include several barriers that are familiar with immature, unintegrated technology in brown-field scenarios, where there already exists heavy investment in legacy. Several surveys have been done on the topic, including one by Ashton Metzler & Associates [20] in Figure 5 below. Top concerns include end-to-end service provisioning of hybrid physical/virtual network resources in potentially multiple domains, need of a new generation of agile OSS/BSS (and open interfaces from MANO solutions), immaturity of current NFV/SDN products and challenges in orchestration and end-to-end service management.

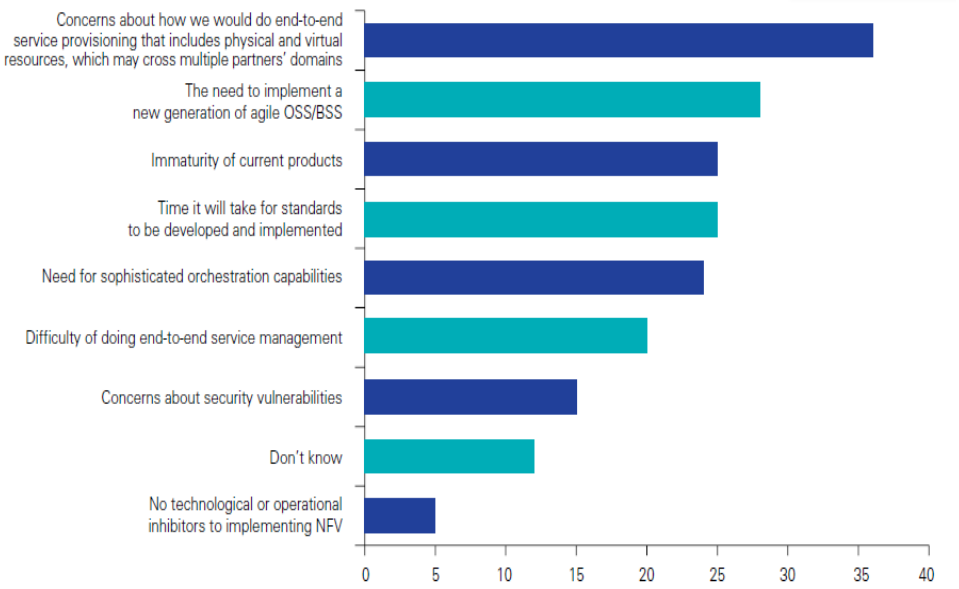



Figure 5: NFV adoption technical inhibitors, number of respondents based on survey of 84 service providers (x-axis) (source: Ashton Metzler & Associates [20])

Those of an organizational nature are proportionate to the massive scope of the transformation to software networks. CSPs have to make radical changes towards a more agile development, deployment and operational culture to exploit the newly gained service agility. This extends to human resources, where a refocused workforce and training for software networks is needed. [21]

2015 and 2016 saw several deployment complications in trials, causing friction between first-mover CSPs and their vendors, with testimonials still coming in during the month of this deliverable publication. [22] [23]

For these early adopters, even with limited successful implementation, the fulfillment of technical goals and business objectives is still lacking. For instance, VNFs are often in their infancy, being part of a large migration of vendor legacy portfolios from physical to virtualized functions. But as they are not built directly for the cloud, they often do not adequately exploit their virtualized

environment and associated benefits. This is a logical move by vendors as they must capitalize on current assets, but operators are anxious to reach the true NFV value proposition and ROI.

At the same time, the "left behind" risk has become a serious threat to long-term roadmaps, where even the most conservative CSP recognizes that NFV/SDN adoption is a necessity in the roadmap to 5G. The customers of those CSPs look to them to be innovative and provide long-term assurances on competitive service, and 2016 has become the year that many of the slow adopters are now ramping up an iterative adoption roadmap.

The following two subsections review particular challenges and pain points for the CSP that SONATA can help alleviate, in addition to being a component for the base benefits of NFV covered in Section 3. Just as the business case can be split into savings and new revenue, these challenges cover both network transformation (overcoming complexity vs. long-term savings) and service development (increased agility and revenue vs. rising losses from OTT competition).

## 6.1 Complications with Multi-Vendor NFV Integration and Legacy Compatibility

The alleviation of vendor lock-in is a core value proposition of the NFV business case. This includes the vision of a multi-vendor, integrated NFV/SDN system at the CSP, mixing and matching best of breed components and VNFs. A survey by Telecom TV of CSPs shows that interoperability with solutions from other vendors is their top priority when considering a NFV PoC or prototype. [24]

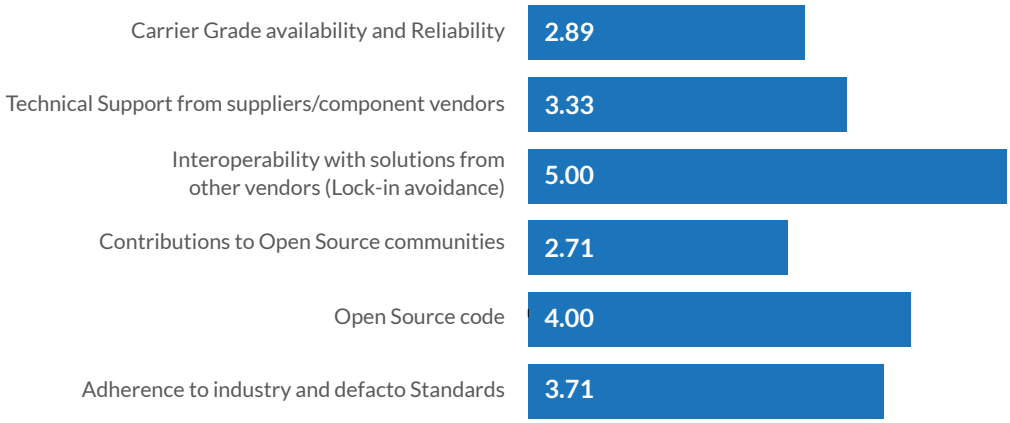



Figure 6: CSP priority factors when developing a PoC or prototype, with multi-vendor interoperability rated highest – 1 low, 6 high (source: Telecom TV [24])

However, the complications arriving with a first attempt of integrated NFV solutions is threatening this vision. Analyst Heavy Reading cites concerns so high that CSPs are rethinking the feasibility of some core aspects of NFV's business case, including the goal of a multi-vendor integrated ecosystem. [15]

The cost and complexity of integration is very high, and often beyond the capacity of the CSP itself. Pre-integrated solutions coming from vendors and independent system integrators are becoming recognized as the "easy option", and creating a rebirth of lock-in dynamics between ecosystems centered around large, incumbent vendors. Even architecture and VNF integration within a single vendor partner ecosystem has provided interoperability issues, delays and restarts in approaches during 2015 and 2016.

An initial multi-vendor interoperability exercise was managed by the New IP Agency, performing tests between 12 vendors, 4 NFVIs and 18 VNFs. The full exercise saw 64% success; 24 of the 39 combinations tested. [25]

The study was mostly limited to NFVI and VNF assets, and did not cover the complex orchestration layer. However, the exercise still applies to the MANO layer, such as tests involving different deployment approaches for VNFMs among vendors (1-on-1 VNFM-VNF pairing vs. generic VNFM for multiple VNFs), along with interoperability between different vendors' OpenStack implementations.

Non-proprietary open source solutions are sometimes becoming a form of "lock-in", as well. [24] These solutions are seldom adopted and integrated directly by the operator, and often are packaged (and heavily customized) via a vendor. In some cases, the result become too differentiated and brings interoperability issues with its open source base and expected community ecosystem.

A survey of more than 2000 telco industry professionals at Telecoms.com Intelligence showed that more than half of respondents already recognized that managing and orchestrating VNFs is a top challenge for them [26], and this priority will continue to grow as they continue their migration, in proportion to the complexity of what needs to be orchestrated.

This is further complicated when interfacing with new SDN controllers and OSS/BSS legacy, where physical elements must also be managed and orchestrated end-to-end in a hybrid physical & virtualized network (the realistic scenario for the next 5 years). Interfaces must be bridged between MANO and OSS/BSS, in addition to integration with other software network architecture assets that include NFVI, SDN controllers, etc.

However, to reach successful deployment of NFV and achieve its full business case, OSS will have to meet NFV/SDN half way, and cannot simply rely on new interfaces on the MANO side. ETSI sees this OSS evolution, including a more holistic view of operations (rather than piece-meal approach), with flexible architectures and end-to-end orchestration and service management. [12]

## 6.2 Agile Service Development Needed Revenue

Competition with OTT providers has been fierce, and wireless communication for CSPs is at risk of becoming commodity.

Ovum estimates that OTT social messaging applications alone cost CSPs over $30 B annually in lost SMS revenues since 2012, which is predicted to reach $54 B by 2017. OTT providers focusing on VoIP will have cost the global telecoms industry $63 B in lost revenues. [27] (via [20])

CSPs must exploit the NFV business case towards service development and agility to win back loss revenue. STL partners performed a market exercise that predicts new "telco cloud" services (i.e. NFV, virtualized) to increase monthly CSP revenues by 10.5% by 2021, shown in Figure 7 below.

These new services must be agile in nature, and the CSP must gain faster product creation, continually up-to-date products, quicker order turnaround, mass customization, increased innovation, faster failure (less investment sunk), more flexible commercial models, more elastic services, greater accessibly and increased stickiness of services. [21]

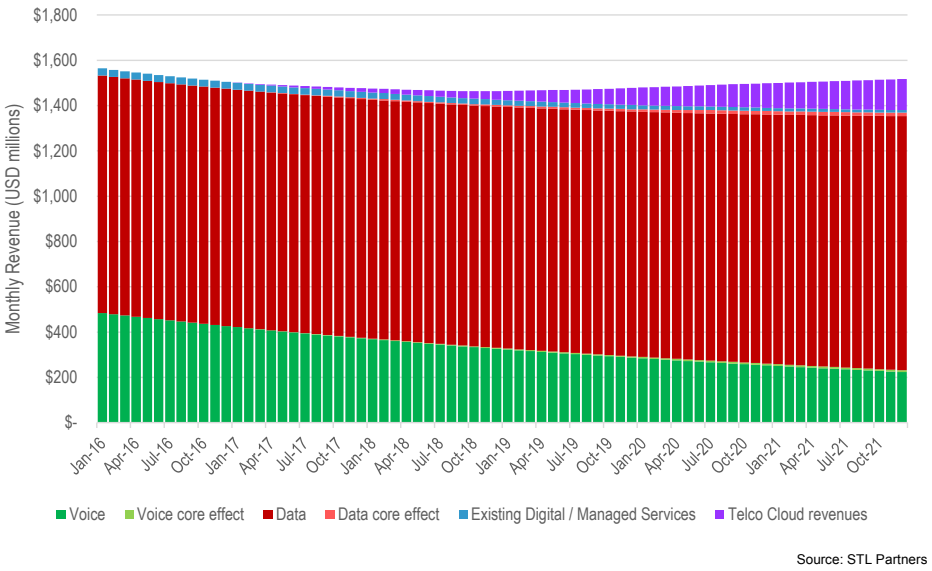
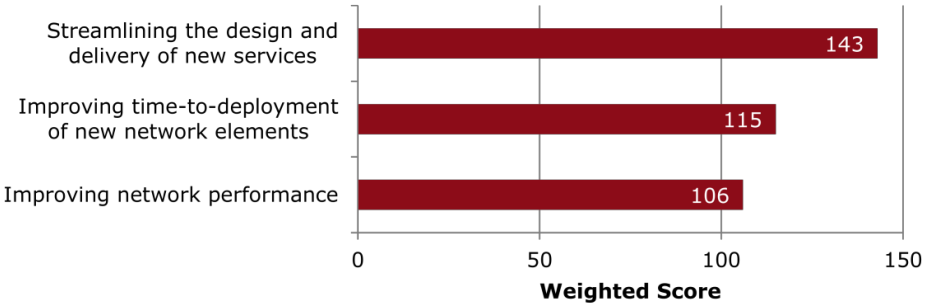



Figure 7: Telco cloud services estimate to increase monthly revenues by 10.5% by Dec 2021 (source: STL Partners [21])

But to realize this vision, CSPs must take on a radical change in their service development and deployment culture, and be empowered by new, agile tools and workflows towards these business critical goals. Time to market for CSP innovation is historically hampered by an over-reliance on their vendors and slow internal cycles, taking up to 12 to 18 months to implement and deploy a new service. [28]

CSPs recognize this shortcoming. In a survey by Heavy Reading of various operators (CSPs), this need of streamlining the design and delivery of new services was a top priority by a significant margin [29], shown in Figure 8 below. Another survey by the same analyst had 57% of CSPs see time to market for new service and applications as their largest related challenge. [30]




*Source: Heavy Reading (Score is a weighted calculation. Items ranked first are valued higher than the following ranks; the score is the sum of all weighted rank counts.)*

Figure 8: Survey of top 3 priorities for operators for their networks (source: Heavy Reading [29])

DevOps is a key enabler of this NFV value proposition of service agility. It involves a software (or service) development method that stresses communication, collaboration and integration between developers and operations professionals.

While DevOps is already a validated improvement in the IT field for agile software development, it has yet to see a significant adoption in the telecom industry. While CSPs have tested automation, they must now make the leap into continuous integration and deployment (CI/CD). [31] To realize the NFV vision, they must adopt a combination of a network-oriented DevOps workflow, with accompany changes in tools, skills and in-house organizational culture.

This agile development must also extend from their own deployed services to enabling new business models that foster ecosystems with third-party developers. They will have to recognize the OTT provider not just as a competitor, but also a partner and customer. Extreme 5G service requirements suggest that OTT providers will need to collaborate closer with CSPs to ensure sufficient QoS/QoE for their end-user. [28] [13]

Similarly, CSPs will need to collaborate heavily with industry verticals in the 5G vision, with win-win business models that create new revenue streams and empower verticals with service development tools to cater towards their own service provision. [32]

# 7 Solution Presentation: SONATA NFV System and Value Proposition

The following sections present the SONATA architecture and its value proposition as a flexible, integrated solution: a NFV service platform with orchestration capabilities, supporting SDK for network service development, and accompanying DevOps workflow.

It acts as a necessary component (MANO) to enable the NFV business case (Section 3) and addresses key CSP challenges associated to a complex NFV adoption and urgent need for a quicker, more agile service development (Section 6).

## 7.1 SONATA Architecture Overview

The following diagram reflects the SONATA architecture [33] that is currently being implemented for a first prototype in the summer of 2016. In the following descriptions the two main SONATA assets are presented: the network service SDK, and the service platform with NFV orchestrator.

A simple scenario is taken into context where a CSP is operating the platform to optimize their network and cater towards third-party developers (in addition to its own), empowering them with the tools and DevOps workflow to create dynamic network services based on catalogs of VNFs. However, the platform can also be used for other network operator profiles, such as an enterprise migrating to a NFV/SDN architecture.

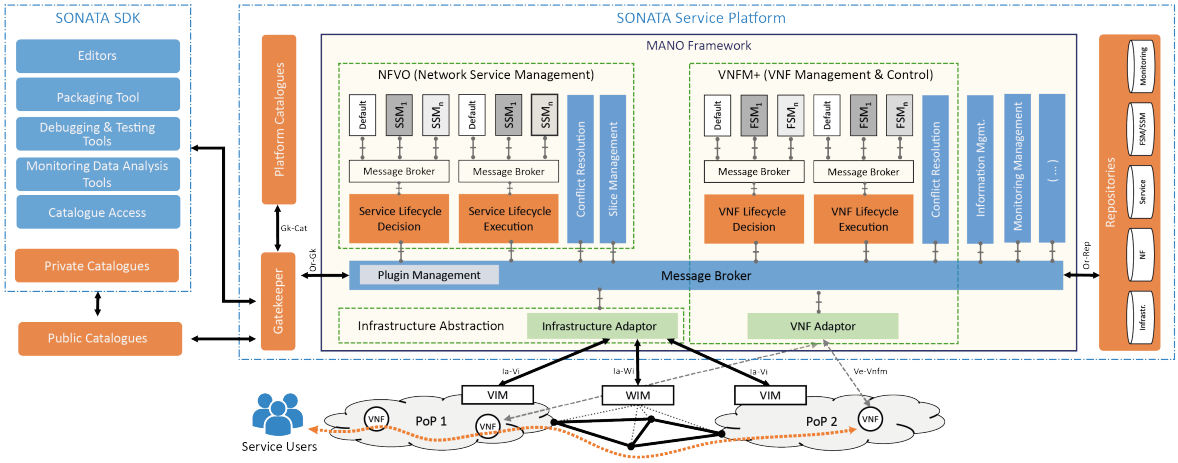



Figure 9: SONATA architecture [33]

### 7.1.1 SONATA Network Service SDK

The first major component of the SONATA architecture is a software development kit (SDK) that supports service developers with both a programming model and a set of software tools. The SDK allows developers to define complex services consisting of multiple VNFs. A CSP (which can also be the service developer) can then deploy and manage the created services on the SONATA service platform through the corresponding gatekeeper component, a verification tool. Services and their components can also be published in catalogs to be reused by other service developers and providers.

### 7.1.2 SONATA Service Platform with NFV Orchestrator

SONATA's flexible service platform is the second major component of the system. Due to the modular design of its MANO framework, the platform offers customization opportunities on two levels.

First, the CSP can modify the platform, e.g., to support a desired business model, by replacing components of the loosely coupled MANO framework, via plugins through a microservices approach.

Second, service developers can influence the orchestration and management functionalities of the platform pertaining to their own services, by bundling small management programs, so-called function- and service-specific managers (FSMs/SSMs), with their services. This enables a new level of service control capabilities for service developers, such as influencing placement decisions of services deployed across multiple points of presence (PoP).

### 7.1.3 SONATA NFV DevOps Workflow

The SONATA system is designed for agile development and operation of network services. It enables a DevOps workflow through the full compatibility and integration between the SDK tools and the service platform. This allows developers and operators to closely collaborate on design, development, deployment, and lifecycle management of network services, as well as optimize and adapt the design and implementation of the services based on collected monitoring information regarding the current state of the service and network resources. This is a complex process that is streamlined, particularly challenging in the case of third-party developers and the hosting CSP platform operator.

## 7.2 SONATA Features and Value Proposition

The following Table 5 highlights key features of SONATA's service platform, SDK and DevOps, as well as the value proposition delivered to network operators (e.g. CSPs) and their ecosystem of service developers.

Table 5: SONATA features and value proposition

| | Feature | Value Proposition |
|---|---|---|
| NFV MANO Business Case | • basic ETSI MANO feature set: resource / service orchestration and VNF management, e.g. deploy, provision, manage, scale and resource placement (see Section 2.2) | • increased efficiency on network infrastructure<br>• higher service levels<br>• dynamic network scalability<br>• simplified network management<br>• NFV business case: lower OpEx, CapEx (see Section 3) |

| | Feature | Value Proposition |
|---|---|---|
| Flexibility and Compatibility for CSP | • customizable by design, including swappable modular plugins, such as lifecycle management, service monitoring, conflict resolution, etc. | • bespoke implementation leads to best-fit solution for network operator and their existing assets<br>• easily extensible for future requirements via a microservices inspired design |
| | • open interfaces for multi-vendor support, independent of stack | • business agility and alleviates vendor lock-in: flexibility between vendors of VNFM, VIM, NFVI, etc.<br>• adaptable to multiple VNFM approaches (included generic VNFM or interfaced vendor-specific VNFM) |
| | • ETSI compliant | • lower investment risk, further compatibility with other NFV components from propietary or open source solutions following similar ETSI compliance |
| | • compatibility with leading community solutions (e.g. OpenStack, OpenFlow) | • ecosystem flexibility (e.g. cloud stack, management software, etc.), and sync with industry de-facto direction “out of the box” |
| | • open interface with legacy OSS/BSS and adaptable for new systems for 5G | • extended ROI for legacy systems, lower integration costs, recognition of iterative NFV adoption and brown-field scenarios<br>• extensible for new OSS/BSS systems to be introduced for 5G |
| | • support for both virtualized (VNF) and physical network functions (PNF) | • compatibility with realistic, iterative NFV adoption roadmap that includes hybrid networks |
| | • enables extended value chain of stakeholders to be involved in development of 5G services<br>• import or create new VNF, compatibility with third-party catalogs | • new B2B opportunities, e.g. third-party developers, solution providers, SMEs, potential revenue sharing with OTT<br>• adapt and differentiate in changing market |
| | • open source, commercial-friendly licensing: Apache v2 | • open source community support, lower procurement costs, vendor/operator customization/extension without licensing conflicts |

| | Feature | Value Proposition |
|---|---|---|
| 5G in Design | • built-in 5G slicing support | • better competitive offering catering to diverse network service requirements for vertical industries |
| | • recursiveness (platform working on top of other implementation of platform) | • operator models with separated network / infrastructure focused providers, or MNO / MVNO models |
| | • improved NFV/SDN integration | • enables better end-to-end operations between MANO and SDN Controller<br>• ready and extensible for 5G SDN-empowered networks |
| Agile Service Development and NFV DevOps | • agile management of full service lifecycle<br>• methodology and tools to implement a modern DevOps workflow for NFV and developed services<br>• multi-organizational by design<br>• compliance component ("Gatekeeper") for vetting network functions and service developed by SDK | • increased productivity, quicker iterations, time-to-market<br>• create ecosystem with internal and external developers, leading to differentiation and increased revenue (CSP)<br>• lower barrier to entry to develop services (third-party)<br>• new business models, closer B2B collaboration |
| | • event-based policies for feature/service relation functionality | • new customization for third-party developers, optimizing QoS/QoE to end-users<br>• more competitive offering by CSP platform operator for supporting developer ecosystem |

# 8 Comparative Study: Alternative NFV MANO Solutions in Development

The following section covers an analysis of over 20 solutions that are comparable to SONATA. These predominately fall under the MANO area of the ETSI NFV architecture, focusing on the NFV Orchestrator (NFVO) and VNF Manager (VNFM).

The majority of these solutions are provided by incumbent equipment vendors that have adapted to the changing dynamics of SDN/NFV's impact on the telecom value chain (see Section 5). They are also met with new insurgents that arrived from the IT world, e.g. cloud computing orchestration. Finally, open source projects are increasing, as well, including Open Source MANO (OSM) and OPEN-O, both announced at the Mobile World Congress in February 2016, representing a collaboration between vendors and operators competing for a common base and potentially de-facto approach.

**An important disclaimer must be provided with the following analysis:** As presented in the beginning of the document, NFV MANO solutions are not in production by network operators today, apart from limited PoCs and field testing. Therefore, these solutions can only be examined at "face value", one based on features and architecture characteristics, but missing independent critical performance benchmarking, interoperability testing, etc. that is needed for a true competitive analysis. **In summary, this analysis is admittedly over-dependent on the bias of vendor marketing.** Network operators find themselves in a similar situation as the customer, where early adopter testimonials, for example, show that the advertised multi-vendor compatibility can fall short of reality (see Section 6).

However, this is unavoidable at this initial state of market maturity. Knowing the key design choices and feature set of current comparable solutions is a good indicator to better understand differentiation and unique selling points marketed between solutions, and see which priority and/or additional innovations that SONATA can focus on to advance the area.

## 8.1 Commercial NFV MANO Solutions

### 8.1.1 Nokia CloudBand

As a large telecom vendor, Nokia, and Alcatel-Lucent before them, focuses on the full portfolio of NFV solution to provide a holistic solution set for their customers, facilitating hosting, orchestration, automation, and management of virtualized network functions.

Nokia CloudBand, acquired in 2016 from Alcatel-Lucent, is a NFV MANO portfolio [34], including:

- CloudBand Network Director (NVFO): covering both resource and service orchestration, as per ETSI NFVO spec functionality, and using the TOSCA standard for description and onboarding services.
- CloudBand Application Manager (VNFM): performing VNF lifecycle management, as per full ETSI VNFM spec functionality, and using OpenStack HEAT templates and OpenStack Mistral workflows. [36]
- CloudBand Infrastructure Software (VIM): virtualizes compute, storage and network services, as per common VIM spec functionality. The solution also provides analytics, monitoring and event/alarm notifications, as well as root cause analysis capabilities from OpenStack Vintage. [37]

Common trends are followed by Nokia, including multi-vendor VNF and VIM compatibility, as well as co-orchestration of VNFs and legacy PNFs.

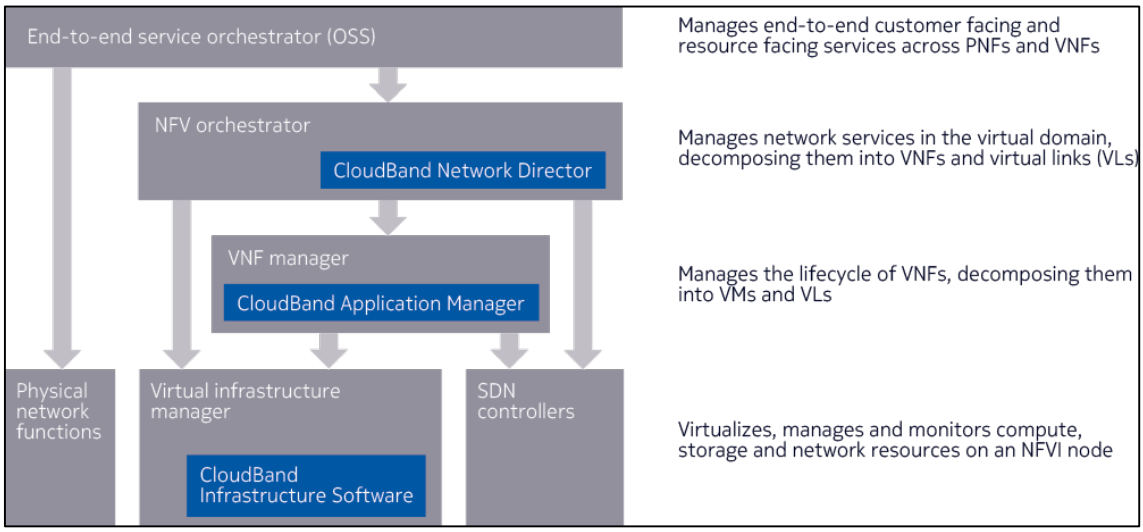



Figure 10: Nokia CloudBand product portfolio (source: Nokia [34])

Several characteristics stand out on CloudBand solution when analyzing the NFV landscape:

- OpenStack collaboration: Nokia's CloudBand unit are active in the OpenStack community, and this is evident in their contributions to various projects such as Vitrage and Mistral. Those projects in particular are then used by CloudBand to improve their portfolio and ensure a synchronized roadmap with industry preferences, in addition to visibility as an influential vendor in open source communities. It represents a classic large vendor open source strategy, and a best practice that is recommended for SONATA.

- Migrating NF catalogue: Nokia's CloudBand has the common advantage shared by other large vendors: a large existing portfolio of legacy network functions. This provides a first priority to migrate existing PNFs to VNFs, strengthening their sustainability with existing customers of their legacy functions by providing familiar solutions for their NFV adoption.

- Partner ecosystem: The combined NFV partner ecosystems of Nokia and former Alcatel-Lucent includes a range of technology partners and complimentary vendors. [38] This includes vendors of VNFs (multi-vendor VNF value proposition), complimentary NFV and SDN solutions (NFVI, SDN controllers, etc.), and technology partners (virtualization vendors, etc.).

- End-to-end supporting services: The combined business portfolios of Nokia and former Alcatel-Lucent share the large vendor competitive advantage of offering consulting, system integration and other support services to their customers.

- SONATA partner: It should be noted that Nokia's CloudBand team is a SONATA partner, and supports the service platform and SDK development, acts as a "reality check" as an active vendor, and provides links to the OpenStack community.

### 8.1.2 NEC / Netcracker Orchestration

A suite of NFV MANO solutions is offered via Netcracker, a subsidiary of NEC. Through a similar large-vendor NFV business strategy, the portfolio is quite holistic and aims to meet the end-to-end needs of their customers. While it follows all the ETSI-specified features of MANO, it positions its offering on what it terms "network orchestration", focusing on the foreseen operator pain point of managing VNFs of multiple vendors (a business benefit, but a technical challenge). The result is a suite of solutions that cover NFVO service & resource orchestration, as well as VNF management.

Their NFVO/VNFM portfolio includes: [39]

- Service Orchestration: MANO functionality enabling end-to-end lifecycle management across networks, including legacy networks, SDN-enabled networks, and cloud and NFVI environments. Special attention is also given to a DevOps-driven service design, automatic service chaining, service fault & performance monitoring, and inventory/topology visualization.

- Network Orchestration: MANO functionality responsible for onboarding multi-vendor VNFs, unifying policy-based service fulfilment and assurance management for virtual networks and controlling VNF lifecycles. This offering also optimizes VNF performance by placement according to security, performance and latency requirements.

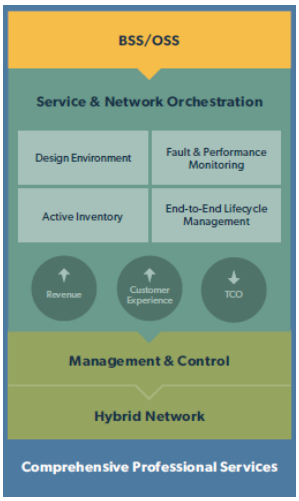



Figure 11: NEC / Netcracker NFV Service and Network Orchestration services (source: NEC / Netcracker [39])

By description, the latter, "Network Orchestration", is a mix of NFV resource orchestration, NFV service orchestration and VNF management (NFVO and VNFM functionality, according to ETSI).

Third-party VNF support is offered, in addition to NEC and Netcracker's own catalogues and marketplace-like features. The multi-vendor trend also carries towards support for various SDN controllers and VIMs.

NEC and Netcracker also supply a wealth of support services around their portfolio, ranging from consultation to systems integration, strengthening their position as an end-to-end vendor.

Particular areas of focus include:

- Hybrid Domains / Legacy Support: Although a common strategy for large vendors, NEC and Netcracker focus heavily on the value proposition of supporting physical network functions and support for legacy OSS integration. This is capturing the common understanding that NFV uptake by operators will be a gradual transformation that must work in brown-field

scenarios, with NFV MANO solutions working between both software-based and legacy networks. This hybrid approach also represents NEC's historic relation with operators as a hardware vendor, ensuring a migration path for their customers that respects currently deployed assets and previous CapEx.

- Service Design and DevOps: Within their service design and orchestration is a particular focus on DevOps, recognizing the IT trend that needs to be adopted by the telecom industry to fulfil the value proposition of software networks with an agile service lifecycle. The approach uses a service design environment with automated import of YANG models and TOSCA deployment templates.

- OpenStack collaboration: NEC is a supporter of the OpenStack community, and uses the dynamic to support their NFV portfolio. It is a strategic investment for the vendor for both technology roadmaps and visibility.

- End-to-end support services: Apart from the NEC supplying the hardware to accompany its subsidiary Netcracker's software assets, the parent company also provides the full set of complimentary end-to-end services that one expects from a large vendor (e.g. see Nokia / CloudBand), including consultancy, system integration, migration support, etc. Although they provide the software to support multi-vendor (e.g. third-party VNFs), the ecosystem is holistic and aimed at fulfilling all of the operator's needs.

- SONATA partner: NEC research lab in Heidelberg, Germany, is part of the SONATA team, and supports the service platform and SDK development, acts as a "reality check" as an active vendor, and provides links to the OpenStack and ETSI NFV ISG community.

### 8.1.3 ADVA Optical Ensemble Orchestrator

ADVA Optical Networking, a telecommunications vendor, offers the Ensemble Orchestrator, an ETSI MANO compliant NFV orchestrator (NFVO).

Standard functionality includes VNF onboarding, network service design, service deployment and service operations, and support for both physical and virtualized network functions. The solution vision also includes recognition of the network "edge" of distributed NFV infrastructures, in the sense that the Ensemble Orchestrator supports VNF placement in central datacenters, multiple PoPs or customer location. [40]

Full VNF lifecycle management is featured, in compliance with ETSI NFV MANO specs, as well as support for pre-defined policies. REST APIs are designed for easier integration into operator OSS/BSS. A strength could be its focus on analytics, including easy integration with another ADVA solution, Ensemble Analytics.

Compatibility with leading VIMs like OpenStack, as well as generic VNF Managers (VNFM), allow the Ensemble Orchestrator to be part of a larger partner NFV ecosystem.

Some distinguishing characteristics include:

- Open APIs: ADVA uses open APIs for easier integration with other proprietary and third-party NFV solutions, as well as operator OSS/BSS. The former is a consistent strategy with those vendors providing a specific MANO solution and not a full NFV suite; in this case, it is an NFVO focused on service orchestration.

- Focus on user interfaces: A web GUI is included, and also supports the Ensemble Dashboard, another ADVA solution consisting of a more extensive management and visualization system.
- Monitoring and Analytics: A complimentary solution, Ensemble Analytics, offers an analytics model for NFV service management, also for hybrid domains mixing physical with virtualized network functions. [41]

### 8.1.4 Affirmed Networks Mobile Content Cloud

Affirmed Networks offers the Mobile Content Cloud, a scalable MANO solution that is delivered on its proprietary platform, but also supports compatibility with many third-party vendors' COTS hardware (the common NFV vision). [42]

The MANO-like solution extends from Affirmed Acuitas EMS offering, and its own Affirmed VNF Manager, and includes service chaining.

Its vEPC includes dynamic capacity scaling, and the portfolio includes several more virtualized solutions, such as the virtualized Wi-Fi Gateway and Active Intelligent vProbe.

The vendor markets the solution as fully ETSI NFV compliant, and an example of a company focusing exclusively on the NFV front with a first-mover strategy. As April 2016, the company has 30 customer deployments and 40 trials underway using their virtualized solution portfolio. [43]

### 8.1.5 Anuta Networks NCX Enterprise Platform

Anuta Network's NCX Platform is a NFV Orchestrator (NFVO) and VNF Manager (VNFM), compliant with the ESTI MANO architecture.

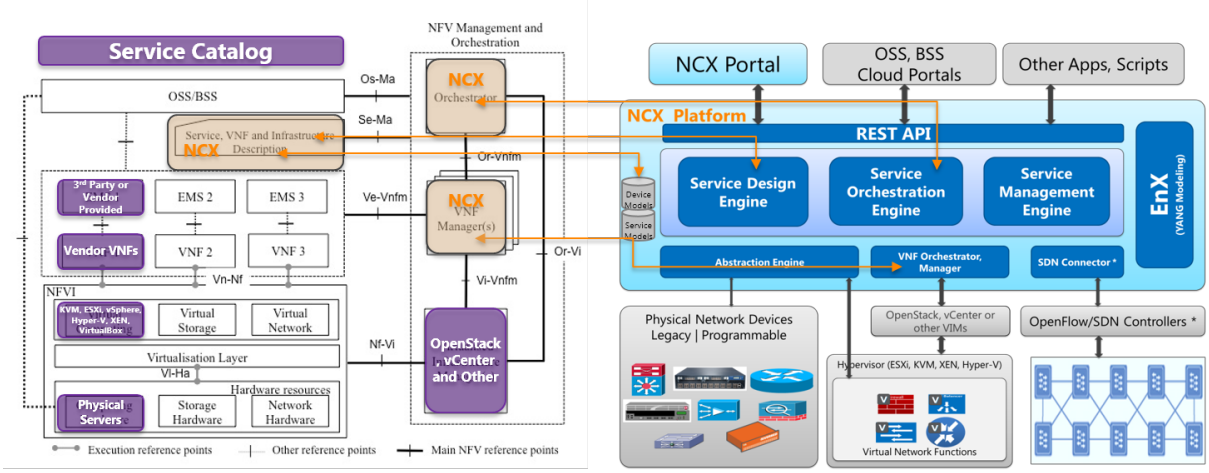



Figure 12: Anuta NCX Platform architecture and mapping to ETSI NFV MANO (source: Anuta [44])

The NCX platform is compatible with multiple vendor products, such as Cisco CSR1000V, Cisco Nexus 1000V, Cisco XRV, VMware DVS, Citrix NetScaler VPX, F5 BIG-IP, Juniper vSRX, Juniper Firefly, Vyatta vRouter & Firewall and Riverbed Steelhead WAN Optimization. [44]

NCX offers full NFV MANO functionality, including life cycle management including VNF instantiation, placement, image management, service definitions, provisioning, commissioning and decommissioning.

Anuta's platform also has characteristics common to its completion, including multi-vendor VNF support, and hybrid support for both physical and virtual assets. [45]

### 8.1.6 ATTO Research ATHENE NFV Platform

ATTO Research's ATHENE NFV Platform is extended on top of a server-switch SDN based service controller. The platform is focused primarily on network service design and chaining of available VNFs. A GUI tool is used with drag & drop features. [46]

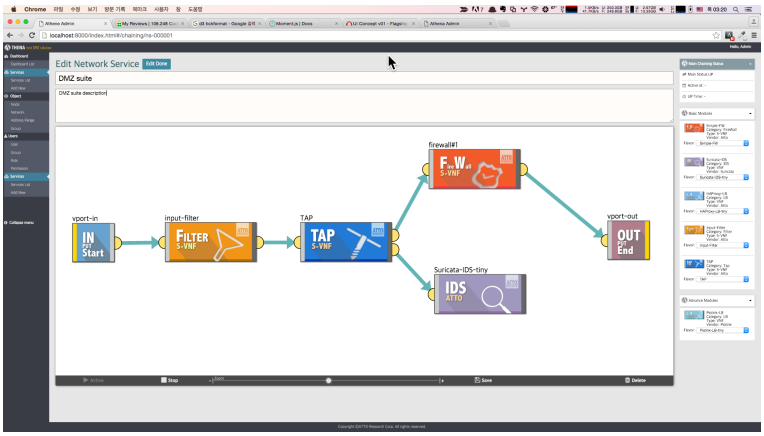



Figure 13: ATTO's ATHENE NFV Platform network service chaining (source: ATTO [46])

VNF Manager (VNFM) functionality is also part of the platform, as well as a limited (unclear in literature) NFV orchestration (NFVO).

The architecture is cluster-based and scalable, meaning that several ATHENE platforms can be operated together through direct (more flexible service chaining) or parallel extension (compensation of bandwidth spikes).

### 8.1.7 Brocade VNF Manager

Brocade, a telecommunication vendor, offers a VNF Manager (VNFM) solution based on the OpenStack Tacker project (see OpenStack Tacker entry in Section 8.2.1). This follows the ideal open source strategy, creating a commercial MANO solution on top of an open source project within a rich and industry-supported community.

As a VNFM in an ETSI-compliant architecture, it supports basic life-cycle management of VNFs and basic health monitoring. [47]

It features an enhanced version of the Brocade GUI framework, and uses standard modelling (TOSCA) for VNF catalogue support. [48]


Figure 14: Brocade VNF Manager monitoring health of deployed VNFs (source: Brocade [48])

Future orchestration (NFVO) functionality is expected, as it is in the roadmap for the underlying Tacker project. It also exploits Brocade's larger portfolio, with an emphasis on compatibility with the Brocade SDN controller, an important aspect for end-to-end NFV/SDN integration.

### 8.1.8 Ciena Blue Planet

Blue Planet, a division of Ciena, provides a NFV Orchestrator as well as what they term a Multi-Domain Service Orchestrator.

The former, an NFVO, provides what is expected from the component of ETSI-compliant architecture. For example: [49]

- VNF instantiation, service chaining and connectivity for virtualized services
- Open, vendor-agnostic architecture
- REST APIs and TOSCA-based templates for programmability and self-service on-boarding of virtual resources and VNFs

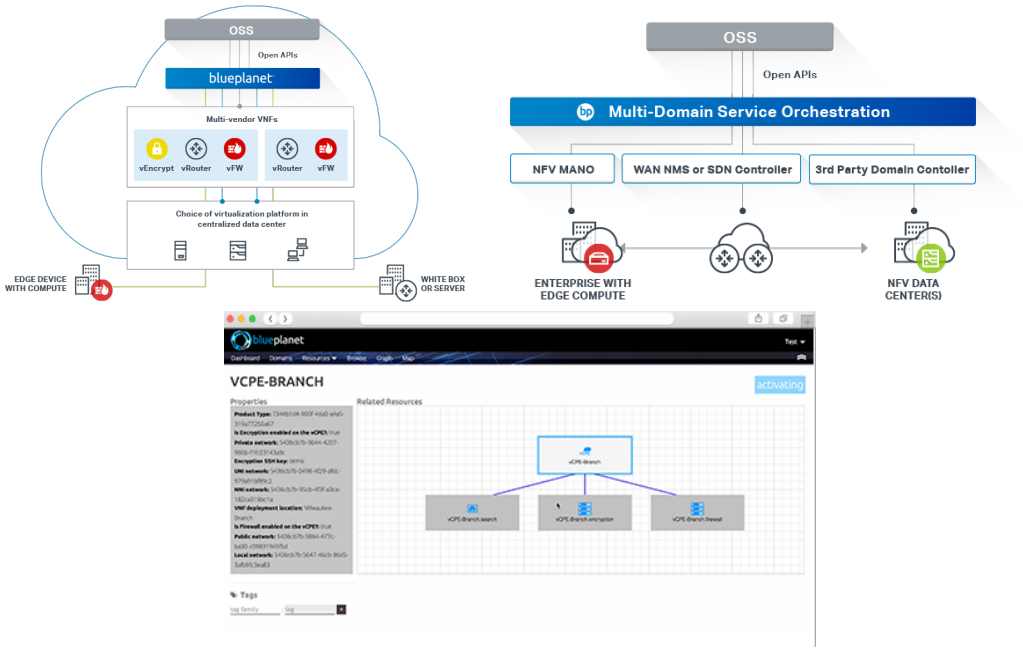



Figure 15: Blue Planet NFV Orchestrator, Multi-Domain Service Orchestration, and visualized service chaining (source: Ciena / Blue Planet [49][50])

Their Multi-Domain Service Orchestrator provides end-to-end service automation and orchestration across multiple technology (physical or virtual) and vendor domains. [50] This solution is in recognition of the challenges that network operators will face when integrating with various legacy assets, third-party SDN controllers and even other NFV MANO orchestrators. Its modular and

programmable structure supports control of multiple technologically diverse domains: cloud, multi-layer WAN, NFV, IP/MPLS, etc.

A large partnership, "Blue Orbit", provides an ecosystem of hardware vendors, VNF and NFVI vendors. [51] Blue Planet was a first-mover in this area, and has various ongoing PoCs and trials underway.

### 8.1.9 Cisco Network Services Orchestrator and Elastic Services Controller

Cisco follows the industry direction as a large, incumbent telecom vendor investing heavily in their NFV portfolio. Two assets cover their NFV MANO strategy:

- Cisco Network Service Orchestrator ("NSO"), enabled by partner Tali-f, and covering the ETSI NFV Orchestrator (NFVO) functionality of both resource and service orchestration. In a model-driven format, service and device configuration and done in YANG format. [52]
- Cisco Elastic Services Controller ("ESC") is the vendor's VNF Manager (VNFM), and ships optionally with the above NFVO, with communication done through the NETCONF protocol. The VNFM is compatible out of the box with OpenStack and VMware VIMs, and supports third-party VNFs. [53]

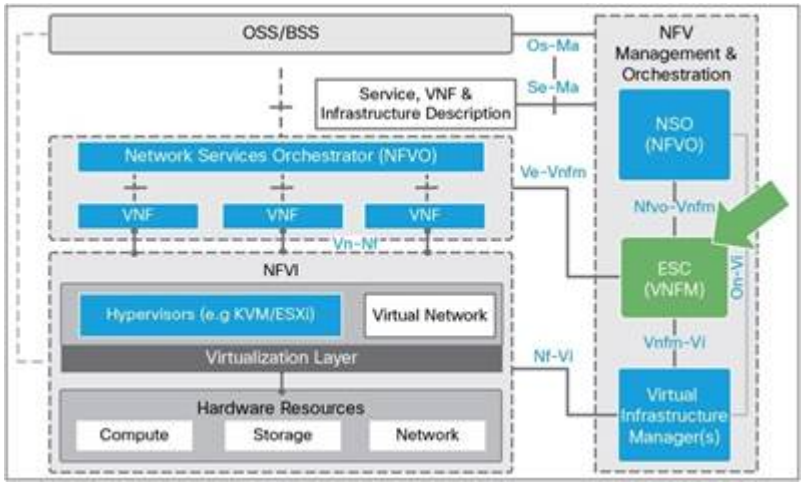



Figure 16: Cisco Elastic Services Controller (ESC) and Network Service Orchestrator (NSO) identified in ETSI NFV architecture (source: Cisco [53])

The NFVO/VNFM MANO combination manifests common characteristics as their competition: multi-vendor VNF, physical/virtual hybrid support, ETSI spec compliance, etc.

A few distinguishing approaches takes place through Cisco's NFVO solution:

- Network Element Drivers: "NEDs" are used to ensure quick compatibility with new devices, using a CLI interface through the NFVO, and done so in the YANG data model format.
- Supporting NFVI: A large differentiation for Cisco is its significant NFVI presence, with supporting technology partnerships (e.g. RedHat, Intel), allowing the vendor to approach customers with a more holistic NFV deployment offering with compute, storage, network, VIM and infrastructure management. [54]

### 8.1.10 Ericsson Network Manager and Cloud Manager

Ericsson, a large telecommunication hardware vendor, has already invested in its cloud assets, extending them for NFV scenarios in software networks. These include:

- Ericsson Network Manager: The Network Manager takes on the role of VNF Manager (VNFM), as well as special 5G-facing requirements such as network slice orchestration. [55]
- Ericsson Cloud Manager: In the NFV environment, this component carries out the standard ETSI MANO role of Network Function Orchestrator (NFVO), as well as the underlying cloud infrastructure. [56]

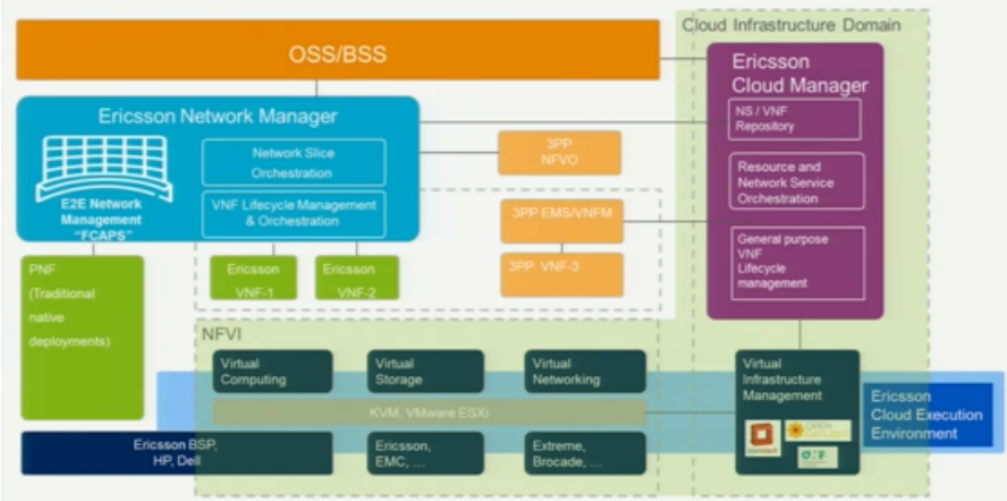



Figure 17: Ericsson complimentary NFV solutions (source: Ericsson [57])

It is expected that other vendors go towards the 5G slicing support, but Ericsson is one of the few that explicitly adds it as a requirement to their MANO solution. [57]

The ecosystem is further supported with NFVI support, through the Ericsson Cloud Execution Environment. The supporting virtualization management includes OpenStack, VMWare (vCenter) and Microsoft Azure, with multi-VIM support done with adapters or agents. This acts as part of Ericsson's "heterogeneous clouds" vision, whereas the NFV approach supports multiple underlying technology and distributed resources.

Open source community support from the vendor includes the OpenStack and OPNFV.

### 8.1.11 Fujitsu Virtuora Service Orchestrator

Fujitsu covers the NFV MANO architecture with their Virtuora Service Orchestrator. The product suite includes standard NFVO and VNFM functionality, as well as a service platform with multi-tenant service design, configuration and management, as well as a customer portal. [58]

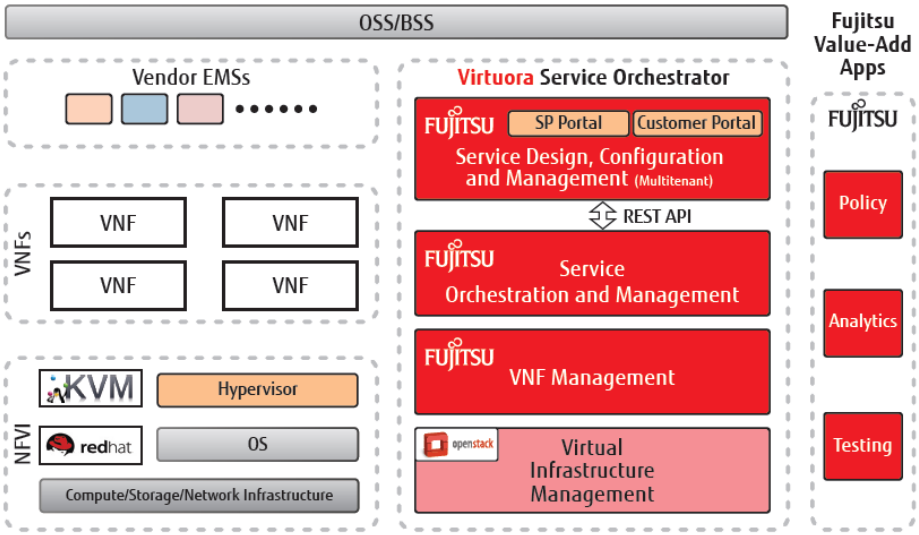



Figure 18: Fujitsu Virtuora Service Orchestrator product suite and ecosystem (source: Fujitsu [59])

Value-added applications extend the suite to include increased functionality in, for example, policy-based orchestration, enhanced analytics and testing. Accompanying solutions in the software network domain also include Fujitsu's own SDN management solution of the same label.

As a large vendor, Fujitsu naturally delivers its own VNFs within its NFV ecosystem, in addition to supporting third-parties.

A partner ecosystem and technology support sees compatibility with NFVI assets and VIMs such as OpenStack.

### 8.1.12 HP Enterprise NFV Director

HPE's (HP Enterprise) NFV portfolio is extensive. HPE NFV Director is its flagship MANO solution. Currently on v3.0, the solution covers everything expected from an ETSI-compliant NFV Orchestrator (NFVO), service and resource orchestration. There is also an emphasis on monitoring and policy-based management. [60]

Monitoring in particular includes VNF-based monitoring, correlation of physical infrastructure views into VNF-specific virtual infrastructure views, and finally of the network service, chained from both VNFs and their physical counterparts, PNFs.

HPE NFV Director has a built-in embedded VNF Manager (VNFM) functionality, but cites support for external VNFMs. This is consistent with the market pattern of NFVOs being delivered with generic "default" VNFMs to provide holistic solutions for the operator, yet advertising compatibility with other vendors' MANO assets.

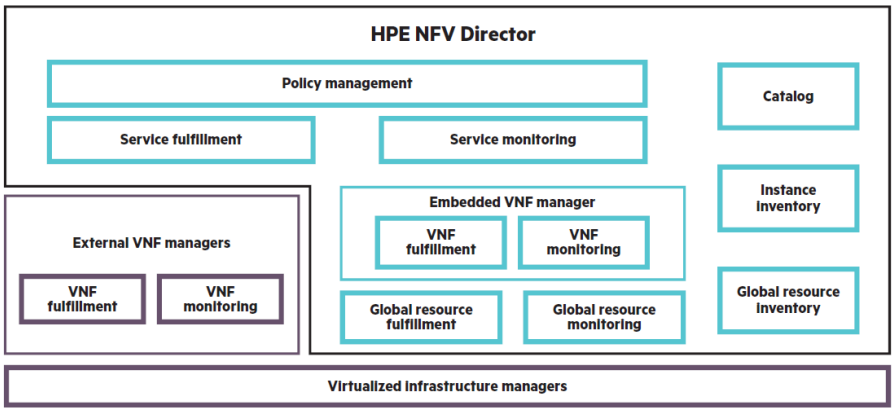



Figure 19: HPE Director v3.0 feature map (source: HPE [60])

A clear portfolio presentation of HPE's OpenNFV architecture [61] (not to be confused with OPNFV) provides a look at its complimentary NFV portfolio solutions. This includes the aforementioned HPE NFV Director for the MANO layer (NFVO/VNFM), as well as its own carrier-grade version of OpenStack, HPE Helion OpenStack at the VIM and NFVI layers.

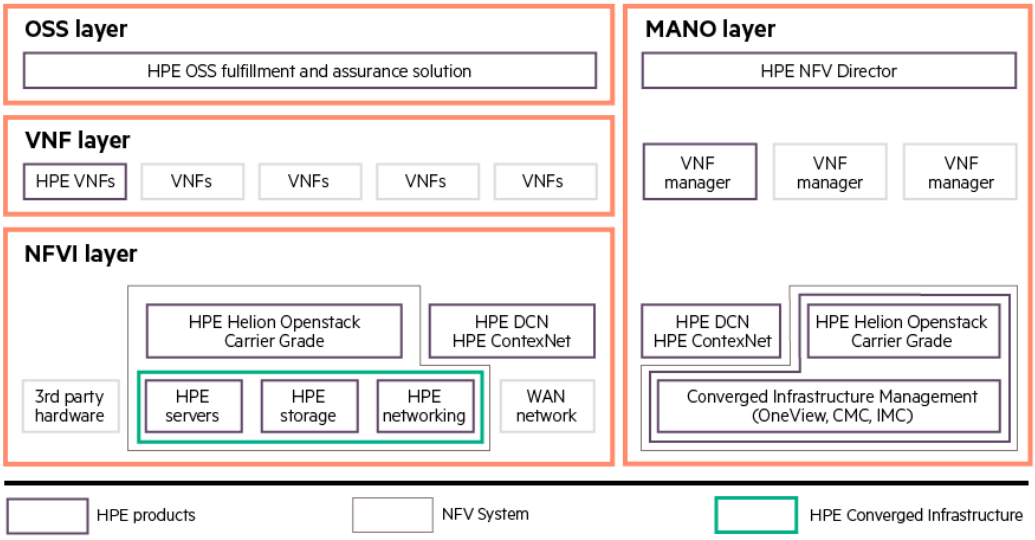



Figure 20: HPE NFV Ecosystem (source: HPE [61])

As a large vendor, HPE's strategy is a full end-to-end NFV portfolio, including the underlying hardware systems. although multi-vendor support is part of its common NFV value proposition. Consulting and integration services round out its supporting business.

HPE currently cites more than 60 NFV PoC in play with partners, standards bodies and customers. [62] It is also quite active in open source and standards communities, including OpenStack, OPNFV, ETSI NFV, etc.

### 8.1.13 Huawei FusionSphere Cloud OS

Huawei's first answer to the NFV MANO layer is through extension of its telecom cloud solution, FusionSphere Cloud OS. [63]

However, with currently available material the exact roadmap is not clear; for example, an architecture map on their website shows a cloud infrastructure framework, but without links to an

NFV implementation or common ETSI reference points. Although it is expected that common competitive MANO features will be included across NFVO and VNFM functionality.

More interesting is the recent announcement of OPEN-Orchestrator Project (OPEN-O), a joint effort by several vendors and technology partners, with a large push from Huawei (see OPEN-O entry in Section 8.2.5). Due to the investment, it is expected that this will heavily influence its commercial portfolio towards the NFV MANO layer.

Also expected from the large vendor is the type of full spectrum of software network related products and services, as part of its transformation strategy to meet operator's needs for NFV/SDN.

### 8.1.14 Juniper Contrail Networking Service Orchestration

Juniper has extended its Contrail Networking portfolio from its SDN roots to a Contrail Service Orchestrator. [64]

A focus on network service design application is available, as well as an administrator and customer portal as additional GUIs.

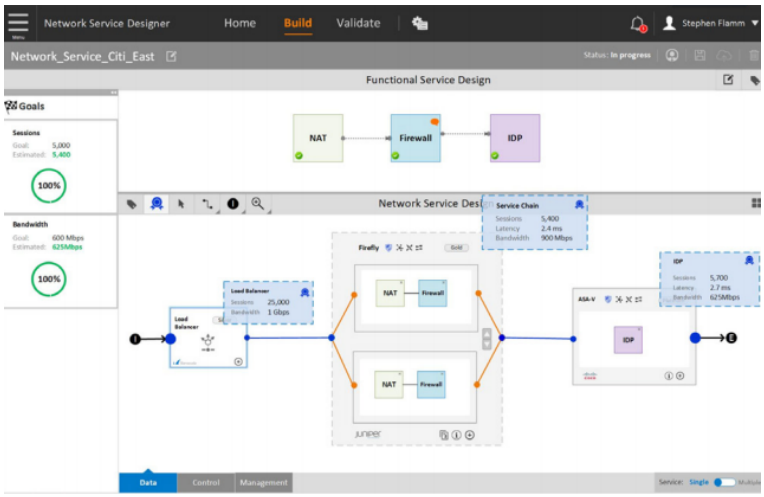



Figure 21: Juniper Contrail network service design application (source: Juniper [66])

In this case, service orchestration is extended from the lower SDN layer, providing functionality similar to that of NFV ETSI architecture, however relying also on an extensive partner program, such as such as Amdocs, IBM, NEC/Netcracker, and others. [65] A Juniper "Cloud CPE" solution is an example use case and offering.

Although coming from different roots, the orchestrator offers similar value proposition and benefits, including VNF lifecycle management, proprietary and third-party VNF catalogs, facilitated integration to existing OSS/BSS via APIs, etc.

Juniper is also meeting service creation with DevOps, with the Junos OS featured in their supplied hardware, extended towards network service use cases. [67]

### 8.1.15 Oracle Communications Network Service Orchestration Solution

Oracle's large telecom vendor portfolio includes the Oracle Network Services Orchestration Solution, a NFV Orchestrator (NFVO) in ETSI terms.

A full breakdown of functionality scope can be found in the diagram below, including onboarding, instantiation, configuration, scaling, healing and termination of VNF and composed network

services. [68] Common characteristics are shared by Oracle's NFVO, such as third-party VNF, VNFM and VIM support where needed.

Oracle has an extended vision of "intelligent" orchestration, features in their whitepaper on the topic [69], including both "decision" intelligence (that of business or technology rules), and that of "analytic" intelligence (data based on network performance and use). It also calls for predictive analysis and hybrid orchestration support, features similar to SONATA in functionality.

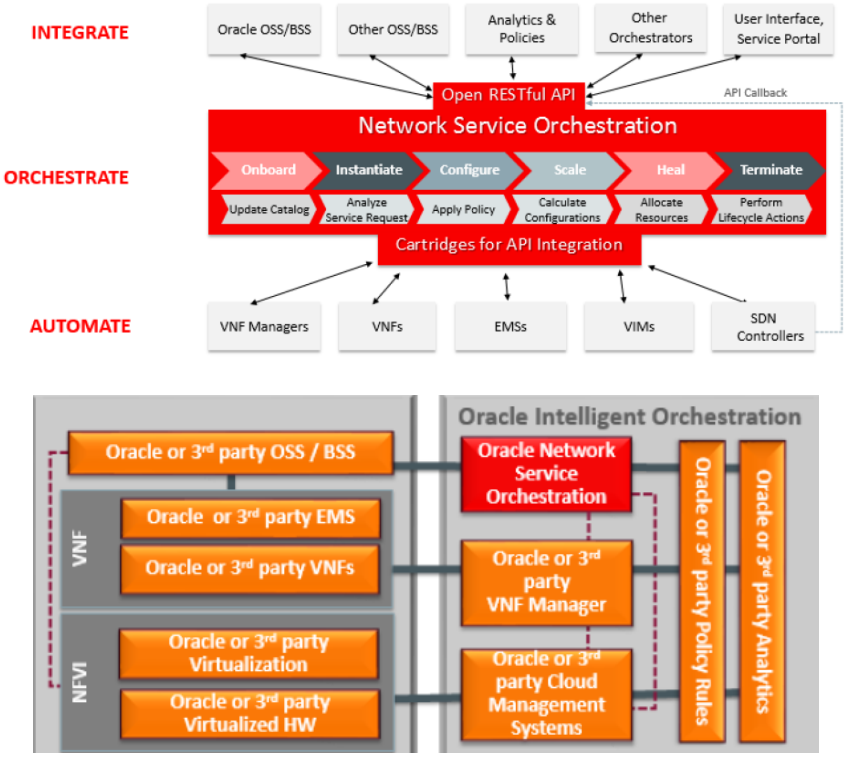



Figure 22: Oracle Communications Network Service Orchestration Solution (top) and context in larger MANO architecture (bottom) (source: Oracle [68])

An ecosystem surrounds their NFVO, with generic or third-party VNFM support and underlying Oracle or third-party cloud infrastructure management system. The extent that they market the third-party support across components and features reinforces that the multi-vendor vision has been accepted by industry leaders as a requirement for competitiveness in next generation software networks.

Outside of the MANO layer, Oracle, as a large vendor, offers a variety of NFVI and hardware offerings, providing a more holistic NFV roadmap for their customers where they can.

### 8.1.16 Amdocs Network Cloud Service Orchestrator

Amdocs was a first-mover in the NFV Orchestrator (NFVO) space with its Network Cloud Service Orchestrator. It features all the ETSI NFVO characteristics, as well as generic VNF Manager (VNFM) to complete the MANO framework.

The solution is an open, catalog-driven solution designed to help CSPs transition from physical networks to cloud service environments, supporting the hybrid roadmap, as well. [70] Using analytics, it creates and manages network services based on real-time network circumstances and

customer information. The solution is multi-vendor VNF support, the marketing norm for NFVO offerings.

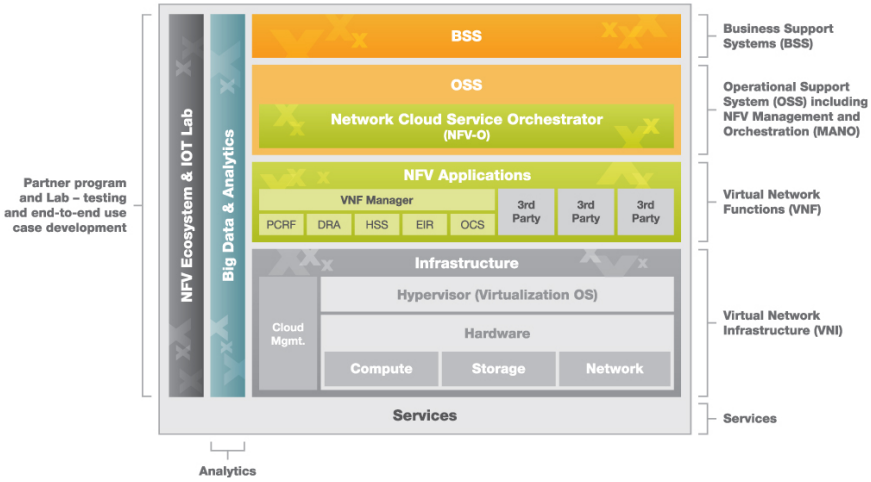



Figure 23: Amdocs Network Cloud Service Orchestrator within NFV environment context (source: Amdocs [71])

An innovation that Amdocs brings to the MANO landscape is its Sensei technology, for intelligent real-time service design and execution, delivering an operation model that covers fulfillment and assurance in a cyclical process, including pre-defined service policies, datacenter status, network status, customer orders and SLA considerations. [71]

As an IT software provider, as opposed to a larger incumbent hardware vendor, Amdocs relies on a partner ecosystem strategy for providing their customers with pre-integrated VNFs and NFVI elements. [72]

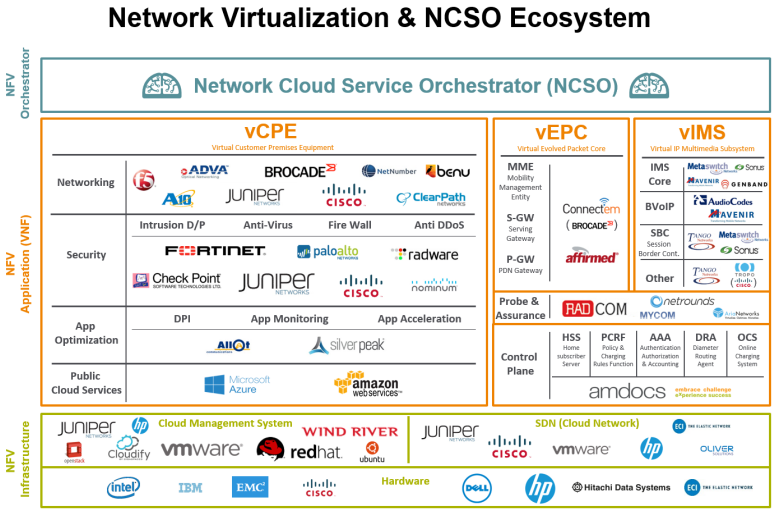



Figure 24: Amdocs partner ecosystem showing diversity of vendor focus (source: Amdocs [72])

### 8.1.17 RIFT.io RIFT.ware

RIFT.ware is a model-driven, open source, ETSI-compliant NFV Orchestrator (NFVO) from RIFT.io. As with the NFVO objective, it focuses on the composition and management of network services. [73] It also acts as the contributing NFV service orchestration for the Open Source MANO project (see OSM entry in Section 8.2.4).

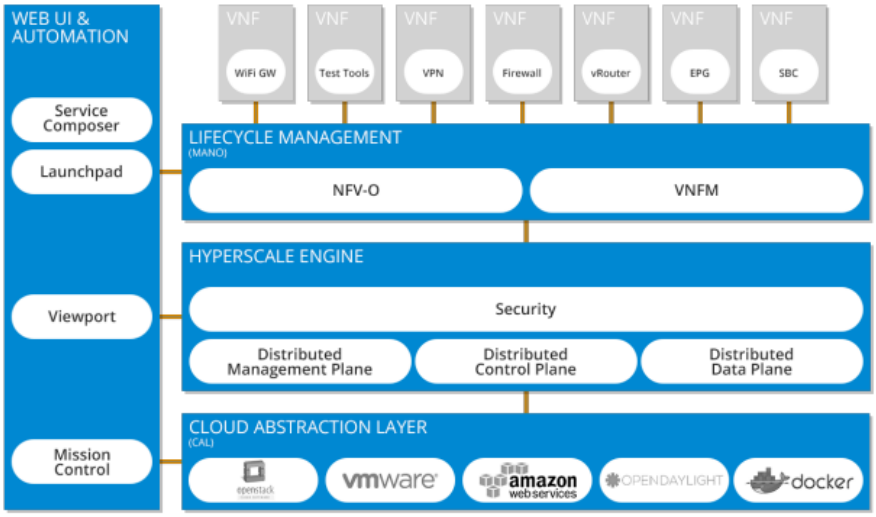



Figure 25: RIFT.ware NFV Stack (source: RIFT.io [74])

The solution provides a modular architecture, so open source adopting vendors and operators can customize and substitute MANO modules and other software network assets, e.g. SDN controllers, existing OSS/BSS, etc. (an approach similar to SONATA).

A model-driven GUI is also included, which is a contributing component to the OSM integrated open source project, as well.

RIFT.ware UI & Automation is an intuitive development and management interface that eliminates the need for multiple CLIs. Developers and administrators can create organizations, define and launch environments, manage pools and environments, and manage and monitor network services and infrastructure environment details.

Partner vendor Intel provides Intel Enhanced Platform Awareness, for optimal network and cloud infrastructure operation.

A licensed version is also available from the company, providing support and maintenance as an accompanying service, via a classic open source business model.

### 8.1.18 Luxoft SuperCloud NFV Orchestration Platform

Luxoft's SuperCloud NFV Orchestration Platform fits ETSI NFV Orchestration (NFVO) and VNF Management (VNFM) specs.

SuperClouds focuses on common value proposition for its solution class: multi-vendor support, third-party VNF ecosystem support, ETSI NFV architecture compliant, intelligent service placement and automation, and SLA awareness. [75]

The architecture covers a service planning and service execution layer, seen in the block diagram below. [76]

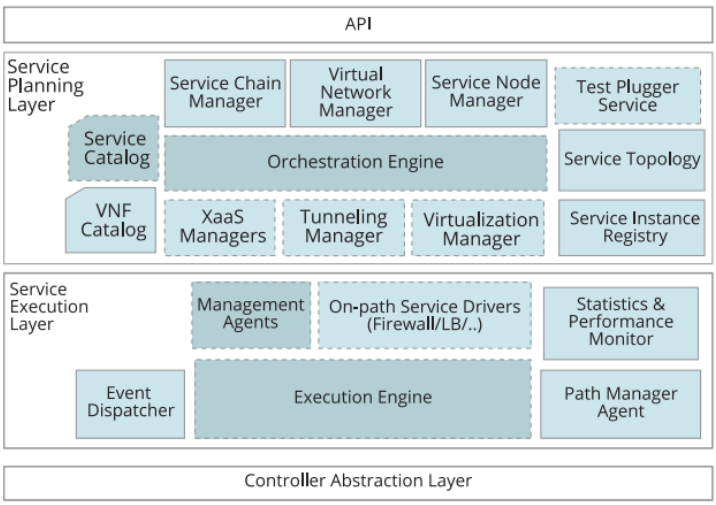



Figure 26: Luxoft SuperCloud NFV Orchestration Platform building block diagram (source Luxoft [76])

Special attention is also given to enabling “DevOps agility” for CSPs, but it is not clear from literature what approach is provided.

Luxoft offers several supporting services, such as consultancy, bespoke customization, testing, deployment and maintenance of their SuperClouds orchestrator.

## 8.2 Open Source NFV MANO Collaborative Projects

### 8.2.1 OpenStack Tacker

OpenStack Tacker is an ESTI-compliant MANO open source project of the OpenStack community. [77]

Recently it has become part of the OpenStack “big tent”, part of the core releases and recognized as the go-to VNF Manager (VNFM) and NFV Orchestrator (NFVO) solution in the community. [78]

Currently it is a functioning VNFM, and among underlying standards is OASIS TOSCA for VNF descriptors. It has large vendor support, and led by Brocade, who uses the base open source VNFM manager for its own commercial solution (see Brocade VNF Manager in Section 8.1.7).

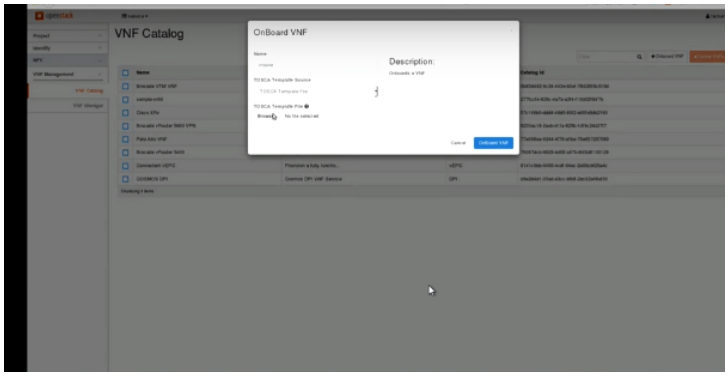



Figure 27: OpenStack Tacker demo screenshot of onboarding VNF (source: OpenStack Tacker [79])

In fact, for 2016 the Tacker roadmap includes extending to NFVO functionality. This is an opportunity for SONATA to collaborate, in particular an approach comparison on the network service descriptors (NSD) and possibly direct implementation of its network service catalogs.

Given its ties to OpenStack, it is of no surprise that it uses this selection as its underlying VIM, but is also keen on becoming technology-agnostic in this regard.

OpenStack Tacker has become a priority open source target for SONATA contribution. A "green field" has been identified for the NS catalogue, for example, and timelines between projects synced so that SONATA's own open source release can support this.

### 8.2.2 OpenBaton

OpenBaton is an open source, ETSI-compliant NFV Orchestrator (NFVO).

OpenBaton was part of the OpenSDNCore [81] project started almost three years ago by Fraunhofer FOKUS with the objective of providing a compliant implementation of the ETSI NFV specification. [80]

OpenBaton is an extensible NFVO that works with OpenStack, and provides a plugin mechanism for supporting additional VIM types. It uses either a generic VNFM or interfaces with third-party VNFMs.

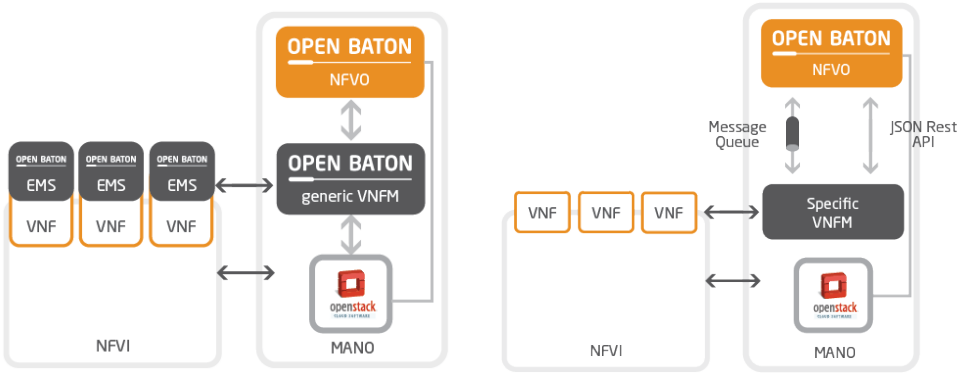



Figure 28: OpenBaton NFVO using generic (left) or third-party VNFMs (right) (source: OpenBaton [80])

The basic release fits the main functionalities of provisioning and managing network services. Future development and releases will focus on increased automation in network service management, including auto-scaling, fault management, TOSCA templates, etc. A dashboard is also included for management of the NFV environment.

### 8.2.3 OPNFV

OPNFV ("Open Platform NFV") is a carrier-grade, integrated, open source platform to accelerate the introduction of new NFV products and services. It is an open source project under the Linux foundation.

Aiming to create a de facto standard open source NFV platform for the industry, OPNFV's goals, as quoted directly from their website [82], are:

- Develop an integrated and tested open source platform that can be used to build NFV functionality, accelerating the introduction of new products and services.
- Include participation of leading end users to validate OPNFV meets the needs of user community.
- Contribute to and participate in relevant open source projects that will be leveraged in the OPNFV platform; ensure consistency, performance and interoperability among open source components.
- Establish an ecosystem for NFV solutions based on open standards and software to meet the needs of end users.
- Promote OPNFV as the preferred platform and community for open source NFV.

Unlike individual open source projects, OPNFV is collection of integrated upstream projects, building NFV Infrastructure (NFVI) and Virtualized Infrastructure Management (VIM) by integrating components like OpenDaylight, OpenStack, Ceph Storage, KVM, Open vSwitch, and Linux. These components, together with APIs, create the foundation infrastructure for the MANO layer's VNFM and NFVO to function.

When launched in 2014, OPNFV initially addressed the NFV Infrastructure (NFVI) and Virtualized Infrastructure Manager (VIM) areas of the ETSI architecture. In 2016, OPNFV has expanded the scope to address Management and Orchestration (MANO), as well. [83]

The diagram below represents OPNFV's second release, "Brahmaputra", and its included upstream projects.

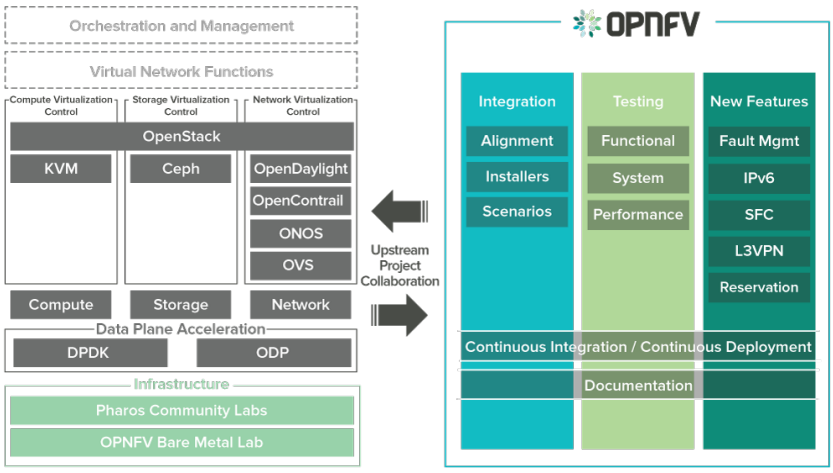



Figure 29: OPNFV Brahmaputra release components (source: OPNFV [84])

Participation is high among leading telecom operators (e.g. Vodafone, Telecom Italia, NTT Docomo, AT&T, China Mobile, etc.), vendors (e.g. Huawei, Juniper, Cisco, Nokia, Ericsson, NEC, Brocade, HPE, Dell, etc.) and technology providers (e.g. RedHat, EMC, etc.).

### 8.2.4 Open Source MANO (OSM)

An operator-driven initiative from ETSI launched the Open Source MANO (OSM) initiative at the Mobile World Congress in February, 2016. It will be a regularly updated, direct implementation of the ETSI MANO architecture and common information model, as well as provide a feedback mechanism towards the ETSI NFV ISG. [85]

The architecture includes RIFT.io for a GUI and the service orchestration functionality of a NFVO (see RIFT.ware entry in Section 8.1.17). Telefonica's OpenMANO acts as the resource orchestration of a NFVO and underlying VIM, and the VNF Configuration and Abstraction from Canonical and JuJu. Other partners include Intel for providing the NFVI for development. [86]

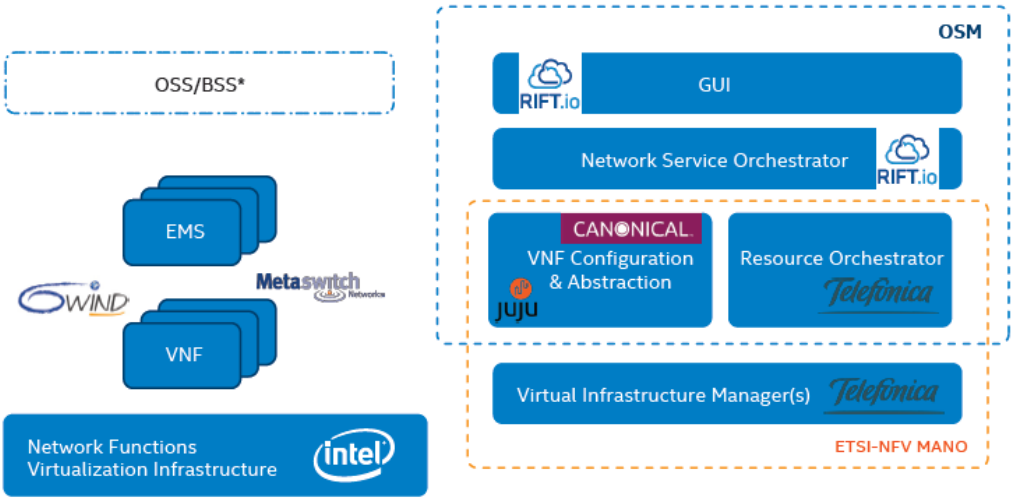



Figure 30: OSM Architecture, simplified version (source: OSM [86])

In April 2016 a concrete roadmap was laid out at the group's kickoff. [87] In the summer of 2016 they will launch "Release 0", integrating and documenting the open source code from Telefonica, RIFT.io, Canonical and other partners.

Common partners with SONATA include Telefonica and BT, and a potential collaboration is being investigated during May 2016.

### 8.2.5 OPEN-O

At Mobile World Congress in February 2016, the OPEN-Orchestrator Project (OPEN-O) was announced. Under the Linux Foundation (also hosting OPNFV), OPEN-O is a collaborative effort towards an open source framework and orchestrator for agile SDN and NFV operations. [88]

The initiative is led by China Mobile and Huawei, with support from Brocade, China Telecom, IBM, DynaTrace, Ericsson, F5 Networks, GigaSpaces, Infoblox, Intel, KT, RedHat, Raisecom, Riverbed and ZTE.

The architecture and release milestones are yet to be announced (as of May 2016), but the goal of creating an integrated orchestrator that covers both NFV and SDN layers in a multi-vendor domain is ambitious. The large vendor support suggests a competitive release.

# 9 Stakeholder Survey on NFV MANO Features

As an additional exercise to the ongoing market watch, SONATA launched a focused survey in February and March 2016, as a **consultation of stakeholder priorities for NFV MANO features.**

The rise of NFV/SDN and the software network paradigm has seen a flood of adoption-related surveys in recent months, several of which have been consulted for this report. There was no need to conduct yet another of that scope, which would have provided little new insight and most likely a smaller sample than many of the large media or analyst backed actions.

Instead, SONATA prepared the survey with the sole purpose of helping to prioritize Year 2 development.

The survey asked respondents to rate features and characteristics (1 low, 5 high) of a NFV MANO platform, as well as some open answers for better insight. These questions were put into several sections: flexibility of MANO orchestration systems; software networks transition and legacy support; network service development, tools and DevOps aspects; relationship with standards groups and opens source communities; and other, miscellaneous technical characteristics.

The survey was circulated through SONATA commercial partners, the 5G-PPP Software Networks Working Group, and extended to additional NFV/SDN R&D contacts in the industry. Follow-up interviews were conducted in some cases to provide additional insight to comments.

22 participants completed the survey and interviews, including 6 network operators / CSPs, 7 vendors labs[1], 4 telecom solution providers, 2 large IT system integrators, and 3 research institutes collaborating directly with industry. Participation was done on the condition of anonymity.

The following sections consolidate and analyze these results per category, and contribute to the conclusions in Section 10. The original survey circulated can be found in the Annex of this document for reference.

## 9.1 Flexibility of MANO Orchestration System

"Flexibility" is a general term that refers to how well and diverse a NFV MANO system can adapt to various scenarios, formats, other solutions, vendors, etc. As covered in Section 6, the openness, flexibility and customizability of NFV-related components is one of the highest priorities of adopting CSPs.

Characteristics related to vendor independence were of course included in the category, including support for multiple VIMs, VNFs, VNFMs and even network controllers (SDN) of different vendors and communities.

Also included were features that SONATA relates to "flexibility" in the sense of 5G scenarios. For example, multi-service provision support (e.g. built for 5G network "slicing"); and recursion support (e.g. service platform working on top of another implementation of the platform) that can handle more complex service provider business models (e.g. MVNO on top of MNO).

[1] 7 vendor labs/groups across 4 vendor ecosystems

Together, these characteristics represent the wider reach of adaptability in ecosystems of multiple vendors, and multiple 5G deployment scenarios. The radar chart below in Figure 31 summarizes the results, where participants were asked to rate these characteristics from 1 (least - center circle) to 5 (highest - outer circle).

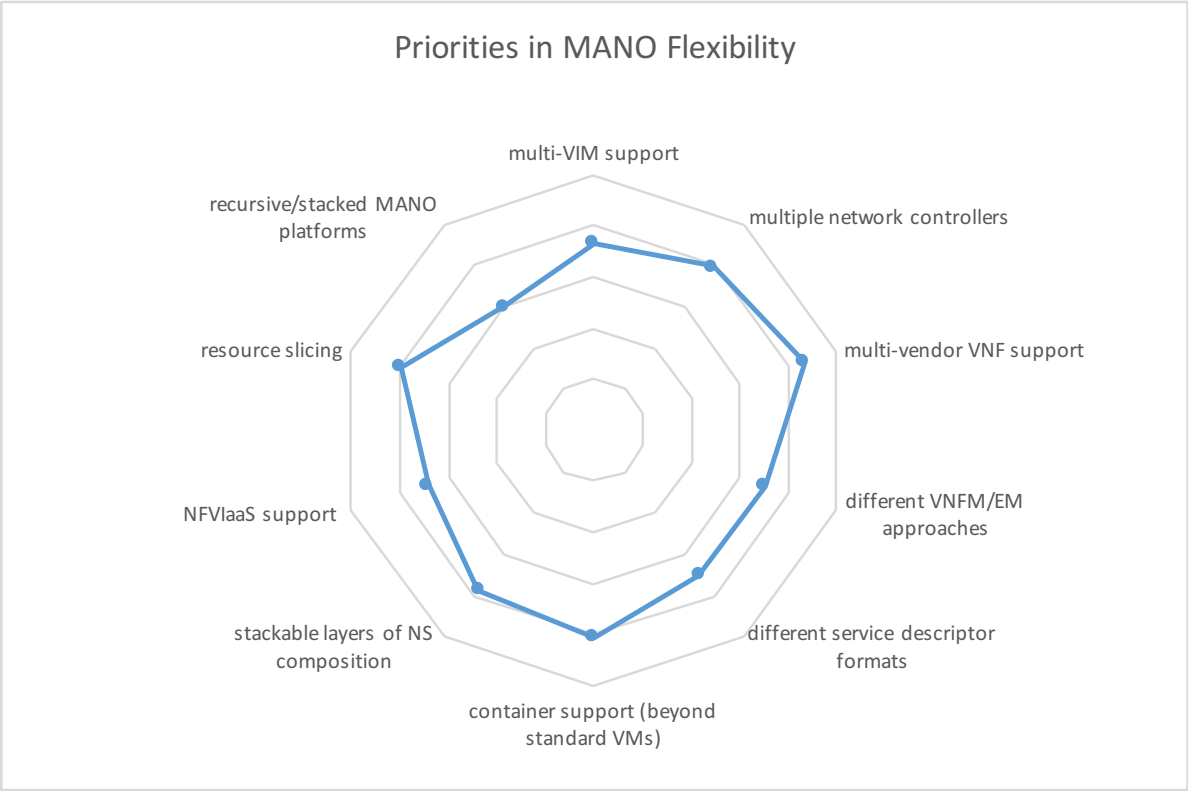



Figure 31: SONATA survey & interview results: importance of flexibility-related features in MANO solutions (1-5, center ring least importance, outer ring highest)

- Despite the lack of variation, the big picture seen is that the average score was 3.5 or higher on all vendor- and scenario-related flexibility support (apart from recursive deployment; see last point). This was supported by participant comments that highlighted customizable integration and alleviation of vendor lock-in (i.e. mix-and-match components and VNFs from different vendors) as a core value proposition of NFV, and a top priority for any MANO solution.

- Multi-vendor VNF support had a leading edge among the majority of participants (furthermore at least half a point higher for CSP participants), consistent with market commentary on the priority of CSPs of integrating the best-in-class of each function by competing vendors.

- Support for multiple VIMs had a slightly lower rating of importance. OpenStack was popular among participants, whether via core or vendor-customized implementations.

- Vendors had a particularly high rating for supporting different descriptor formats, like TOSCA. They understand the need for diverse service support as they prepare competitive platforms for complex ecosystems.

- Of virtualization support beyond standard VMs, container support was cited consistently higher than other options, such as unikernel support, by all respondents, independent of

profile. This is consistent with the IT trend and popularity of container technology such as Docker.

- While some advanced 5G features, such as slicing support, were graded as high priorities, other SONATA design choices to cater towards 5G-envisioned business scenarios, such as recursion and stacked deployment models, were not recognized as such. This could be due to the industry's priority of first supporting the "status quo" models, before tackling orchestration between MVNO-to-MNO scenarios; or a splitting between two service providers focusing on different areas of the software network, such as a service layer vs. underlying infrastructure. A lesson learned here is that a more far-reaching feature like recursion must be presented with clear, pragmatic example scenarios in the 5G 2020+ narrative.

## 9.2 Software Network Transition and Supporting Legacy

NFV is part of a larger, complex transitional roadmap to software networks, impacting heavily the network operator and supporting actors in the telecom value chain. It is building on top of a long history of adopted network assets.

Participants were asked to rate the importance of supporting legacy systems, both proprietary and open source, and identify which systems in particular were their priority. Average results can be found below in Figure 32.

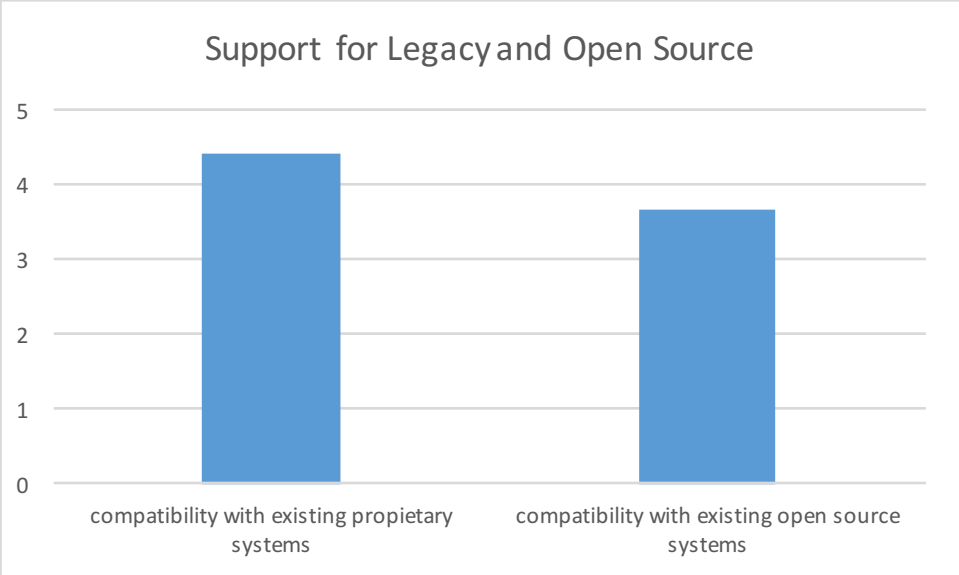



Figure 32: SONATA survey & interview results: importance of supporting legacy and open source systems, 1 (low) to 5 (high)

- Legacy support for proprietary systems was an overwhelmingly high priority, with an average of almost 4.5, with no significant difference between profiles.

- Both CSPs and vendors cited legacy OSS/BSS compatibility to be a key requirement. One CSP strongly dismissed the notion of a "fork-lift" NFV upgrade, referring to a more silo or iterative approach of NFV adoption. Some reminded in the comments that upgrading OSS to meet the NFV/SDN expectations is a daunting but necessary step, as well.

- A few participants cited PNF compatibility, as well, again referring to the hybrid physical/software assets that will need to be orchestrated in the first phase of NFV adoption.
- There was a general concern from a few vendors on the brown-field scenario of too many management systems running together, a significant systems integration challenge.
- Additional legacy support examples included WAN connectivity service models and integration with 3GPP components.
- Legacy support for open source systems was rated less of a priority than its proprietary counterparts, at an average of 3.6 (compared to 4.5). One operator expressed that open source solutions by their nature should be scalable and extendable. Those that provided examples mostly referred to popular open source systems that provide enablement to software networks, such as OpenStack, OpenDayLight, etc., rather than aging legacy projects.
- A few SME solutions providers predicted that their network operator clients would only pull back their requirements for heavy legacy support when software network deployments reach the same performance and reliability.

## 9.3 Network Service Development, Tools and DevOps

NFV empowers service providers to adopt more agile and DevOps-enabled workflows for their platforms and supported developers, answering a current pain point of CSPs (see Section 6) quickly losing revenue to competitors, such as OTT providers. MANO platforms often support network service development through VNF-chaining, and provide the tools and interfaces to help CSPs in this direction, as seen in the comparable solutions of Section 8.

Participants were asked to rate in importance the features and support mechanisms needed to fulfil the value proposition of service agility and quicker time-to-market.

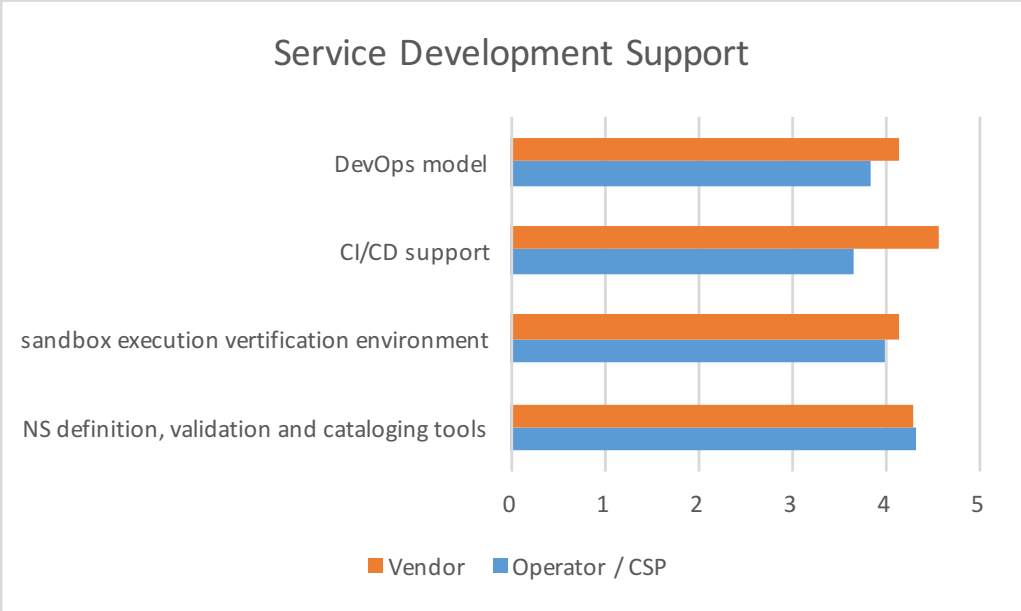



Figure 33: SONATA survey & interview results: service development support priorities between vendors and CSPs, 1 (low) to 5 (high)

- In the area of service development and supporting priorities, there was a bit more differentiation between participant profiles. CI/CD support, and DevOps to a lesser degree, show a higher recognition by vendors than operators. This could be due to vendors' quicker transition to a developer and system integrator role.

- Related to the above, vendors and operators alike cite CSPs slower adaption to the agile development mindset that is needed to embrace the value proposition of service agility in software networks. Several participants reminded that this is as much a cultural and organizational challenge as it is a technical one.

- Common tools and service preferences included Docker, Ansible and GIT. Proactive service monitoring was highlighted by a vendor, as well, including SLAs, inventory, software licensing and rollback requirements.

- A vendor and an operator both cited the same multi-organizational challenge, in the sense that such a workflow would have to support the third-party service developer ecosystems that SONATA is aiming for.

## 9.4 Standards and Open Source Communities

The advancement of software networks (SDN, NFV, etc.) has spurred a stronger presence of open source solutions in the network stack and additional standards initiatives. Examples of active communities include OpenStack, OpenDaylight, OpenFlow, OpenMANO and even first integrations such as OPNFV. On the standards front, ETSI NFV ISG has released NFV architecture specifications. The convergence of network technology with software stacks has also led to the re-use and extension of various existing standards.

Participants were asked to highlight which groups they deem most important for support.

- The most common targets for support included the ETSI NFV ISG, OpenStack and OpenDayLight, recognized by all profiles. Other mentions went to specifications or communities of other types, such as TOSCA and YANG, and a few even referenced OPNFV, the large integration of upstream projects.

- A higher average priority score for open source community support was provided by operators than vendors, 4.3 vs. 3.5, respectively. Conventional wisdom would point to vendors being more keen on proprietary solutions, but given the small sample size and known support (out of self-interest) for strategic open source communities between both sets of stakeholders, it was concluded as coincidental correlation.

- Although vendors scored slightly lower in open source support, they were more consistently engaging such communities, rather than purely adopting. This is expected, as they often influence such communities to ensure their supported technology is widespread, similar to standards engagement. Although recent initiated open source initiatives such as OSM (see Section 8.2.4) are highly supported on the operator side, under the umbrella of ETSI.

- When asked about contributing factors in deciding which communities to support, the answers were consistent and followed the best practices of open source engagement: project maturity, critical mass of support, contribution system/policy, compatible licensing, aligned roadmaps, and supporting documentation. Two operators were also keen on communities that recognize direct operator concerns, and not only through vendors as proxies.

- Backwards compatibility with existing standards, a question that was added to the section, was graded considerably low, particularly by network operators / CSPs, at 2.4. System integrators and solution providers were also relatively uninterested in such requirements. Vendors prioritized such compatibility a bit more, at an average of 3.5. While no additional explanation was given of the differentiation, it could be interpreted that vendors are more protective of their invested standards-supported portfolios and are naturally interested in extending such assets for the virtualized environment.

## 9.5 Additional Technical Characteristics

A variety of additional technical characteristics were asked to be prioritized by participants on a similar scale of 1 (low) to 5 (high).

### 9.5.1 Advanced Resource Management

Advanced resource management features, beyond current expectations from marketed MANO solutions, were graded. Automated efficient placement and dynamic response to resource load were default choices, and each rated high, above 4, by operators, vendors and other profiles alike. Additional features were added by some participants as priorities, most notably support for predictable services.

### 9.5.2 Performance Isolation

“Cloud-like” characteristics (e.g. illusion of unlimited resources), host pinning (e.g. dedicated physical host per tenant), and granular hardware pinning (e.g. CPU pinning, enhanced platform awareness) were surveyed to participants. A slightly higher note was given by vendors over operators across all features, but around the 3 to 4 range by all.

### 9.5.3 Verification of Network Service SLAs

Verification of network service SLAs were presented to the participants in three stages of the lifecycle: design, deployment and runtime. While there was not a differentiation between profiles, priority was granted to later stages in the lifecycle. The design stage, the lowest at 3.6, was proceeded by deployment at 4.2 and a very high runtime priority at 4.8.

# 10 Conclusions and Recommendations for SONATA

The conclusions from input and analysis performed during the project's first year, consolidated in this market feasibility study, helped drive SONATA's mandate (scope, requirements), design (approach, architecture) and positioning (compatibility, open source strategy) for both the recent first year and upcoming second year development cycles. Sources included:

- Ongoing market and technology watch started by SONATA partners on Day 1 of the project.
- Extensive look at the market via the independent analyst reports and surveys referenced throughout the document.
- Stakeholder, value chain and customer challenges analysis based on the aforementioned resources and from the SONATA partners' experience in the telecommunication sector.
- Comparative analysis of over 20 comparable MANO solutions based on whitepapers, literature and marketing material.
- Stakeholder priorities survey and interviews on MANO feature and characteristics, distributed by the project.

The business case of NFV remains strong despite delays in early adopter ROI. While varying in roadmap urgency among CSPs, NFV adoption is universally recognized as a necessary investment and transition to be technically ready and competitively positioned for future 5G networks. Apart from enabling long-term OpEx and CapEx savings, the technology can support a fast-track for innovative service development and agility, needed by CSPs to regain loss margins from OTT providers and recover from the commoditization of their general network services. This is an area where SONATA can provide value with its NFV MANO service platform, developer-supporting SDK and DevOps workflow in a NFV deployment environment.

Out of the comparable MANO solutions and projects studied, several patterns and market characteristics were concluded, reflected below in this section. However, this exercise has been feature-based, with a bias towards vendor marketing, and cannot speak for their ease of implementation, multi-vendor support in action, successful integration with OSS/BSS, performance benchmarking, etc. for overall validation. The solutions are not yet widely deployed in today's carrier and enterprise networks. That said, this study has helped SONATA focus its development in areas where gaps can be filled and innovation delivered, or to meet new, de-facto expectations that have evolved beyond the initial release of the ETSI NFV reference architecture and MANO scope.

For ease of navigation, conclusions have been sorted by subject matter in the subsections below, followed by SONATA positioning and approach taken.

## 10.1 Untested Solutions and Marketing vs. Reality

### Market trends:

- **Scarce differentiation in initial marketing:** At first look, the feature-based differentiation is scarce, where the majority of MANO solutions share similar value proposition and follow ETSI specification to ensure relevance. Some marketing focuses on certain areas more than others (e.g. intelligent placement, service composition interfaces, open APIs, multi-vendor support, etc.), but they are often recognized as part of that ETSI-compliant vision and common benefits. Differentiation begins to pick up however, on the development /

composition side for network services (see subsection below), where vendors differ in strength, often based on adapted legacy solutions in the area.

- **Pending validation, 2016/2017 moment of truth:** It is expected that once such solutions reach maturity and face production trials, greater differentiation will present itself: impact of architectural choices, technical approach, ease of integration, performance benchmarking, etc. are only able to be validated in the next stage of the overall transitional roadmap of NFV/SDN. As timelines provided through analysts and CSP surveys estimate, 2016 and 2017 could be a key period to see that differentiation start to take place, as proven deployment starts replacing marketing, and ambitious feature sets and liberal claims of multi-vendor compatibility meet reality.

**SONATA approach:**

- SONATA's iterative workplan and multiple development cycles fall within this critical period (2016/2017) of NFV maturity. Through the above analysis, gaps were identified among a first generation of NFV implementation/integration approaches and CSP service development capability (organized in the subsections below), and a follow-up stakeholder survey has helped validate, course-correct and prioritize requirements for SONATA's second development cycle.

## 10.2 Multi-Vendor Support

**Market trends:**

- **Multi-vendor VNF Support:** The alleviation of vendor lock-in as a primary value proposition of NFV is too strong to ignore. Customers look for NFV platforms and MANO solutions that can support diverse VNF catalogues from several vendors, and "multi-vendor" in this aspect is a must for any relevant offering. Despite the VNFM conflicts cited below, this flexibility and multi-vendor compatibility should remain a key mandate for any competitive MANO solution, and further validated in the stakeholder survey as a priority.

- **Conflicting VNFM Approaches**: It is becoming a standard practice that a NFVO is built with a generic VNFM included, to reach the full MANO functionality defined by ETSI. Support for third-party VNFMs is a common marketed feature, but regardless they "ship" with a generic VNFM in case of a green-field scenario. Interoperability testing by the New IP Agency (see Section 6.1) has shown that this diversity in VNFM approaches has caused considerable barriers to the multi-vendor vision, particularly in supporting exclusive VNF/VNFM pairing. Proprietary VNFMs have proven difficult in integration with its peers, and a generic component with a common specification is needed to fulfill the multi-vendor VNF vision.

- **Multi-vendor VIM Support:** While OpenStack is a dominant VIM choice with overwhelming support from MANO solutions, the majority of entries are marketed as supporting alternatives (although often not detailed). Regardless, being tied to one underlying technology, no matter how popular, is risky.

- **Large Telecom Vendors' End-to-End Portfolio:** MANO solutions are often accompanied by a larger portfolio of NFV and/or SDN related offerings. Large incumbent equipment vendors are naturally more likely to support their MANO solution with their own VNFs, and in some cases supporting NFVI and accompanied equipment.

- **Partnership Ecosystems:** When a full MANO solution is not provided with in-house assets, vendors engage partners with the missing technology. The bottom line is that in whichever contingency the vendor is approaching the customer with a full MANO (or even NFV stack) portfolio available to integrate. Insurgent solutions should at least envision a partner ecosystem through commercial agreements, or provide out-of-the-box compatibility with open source alternatives. Even more so than MANO, NFVI vendors often rely on the specialization of partners in a joint ecosystem approach. Red Hat and VMWare, for example, enter the telecommunication arena from their virtualization roots, and act as enabling technology partners for many incumbent equipment vendors. Other large vendors, such as Oracle and HP Enterprise, with significant equipment assets in their portfolios, use this in combination with their MANO solutions to provide an end-to-end NFV ecosystem for their customers. The blowback from CSPs suggests that this is often creating a new age of vendor lock-in, sacrificing flexibility with convenience in the wake of multi-vendor integration headaches.

**SONATA approach:**

- SONATA's chief mandate is to be a flexible, agnostic service platform that is adaptable to a CSP's specific network and VNF ecosystem, making multi-vendor requirements a top priority. This including support to orchestrate VNFs of different vendors and developers, different VNFM approaches (including a generic VNFM functionality if none is provided), and multiple underlying VIMs.

- Interfaces are a key development objective, and tracking of CSPs, vendors and system integrators' first false attempts towards the multi-vendor vision has shown the project that it must make the platform and its NFVO as open and extensible as possible to be adapted to future specifications. Its modular architecture and microservices approach also help support this objective.

- For the VIM layer, OpenStack support was chosen by the project for its first year prototype, reflecting the wide adoption and support by the community and comparative solutions. Additional VIMs will be supported in its second cycle, such as OpenMANO.

## 10.3 Openness and Customizability

**Market trends:**

- **Monolithic vs. Modular Architectures:** An overwhelming amount of NFV solutions point to more monolithic architectures that provide complimentary components/products in a vendor-driven ecosystem. RIFT.io and Ciena Blue Planet market their solution as more modular, however. Analyst roadmaps (see Section 4.1) have foreseen a more advanced stage of NFV arriving closer to 2020, which will need a microservices approach to support 5G networks and their service agility.

- **Integration Headaches:** Initial testimonials, for example those cited in Section 6, have shown that multi-vendor interoperability in practice is "easier said than done", in contrast to what has been suggested by initial offerings and their marketing. Although holistically the majority of alternatives share the ETSI MANO feature set, their different componentization between architecture building blocks, delegating functionality between them, and different VNFM approaches have created great difficulty to fulfill the original vision of an integrated multi-vendor NFV/SDN stack and diverse, orchestrated VNF portfolio.

- **Proprietary vs. Open Source:** An even larger jump into flexibility is when the solution itself is open source, allowing bespoke customizability, extensibility and integration by an operator, vendor or systems integrator. While many developing MANO solutions are "based on open source software", they are themselves commercial solutions, often differentiating too much from the original source code and including too many proprietary hooks. This causes interoperability issues with other implementations of the same open source base, as seen in initial tests of different versions of OpenStack (see Section 6.1) in NFV environments. An exception seems to be from RIFT.io, who follows a classic open source business model, offering a licensed version with accompanied support services, but also a fully open source version.

- **Licensing:** Among collaborative projects, such as OpenStack or OSM, a common open source license is Apache v2.0. The is a commercial-friendly license that is often preferred among industry-backed communities and standards development organizations.

**SONATA approach:**

- The modular architecture of SONATA is one of its major innovations. It provides NFV MANO flexibility to network operators with customizable platform functionality and ability to "hot swap" new features via plug-ins. This is in recognition of the bespoke requirements that CSPs are asking for, and the realist vision that SONATA will not necessarily be providing the best-in-breed components "out of the box". This is a future-proofing design choice that allows for enhanced extensibility.

- SONATA seeks a microservices approach for the most bespoke configurability, durability and ease of maintenance possible. Although not an immediate requirement for today's initial NFV implementations, it is foreseen to be an invaluable design choice for the full "cloudification" of networks towards 5G, and already taking flight in the converging IT sector for software development.

- SONATA is fully open source and licensed with Apache v2.0, providing a commercial-friendly solution without copyleft risks in integration with other components. This is quite important for its bespoke customizability and multi-vendor vision. Starting with its first prototype release, SONATA will be hosted on GitHub.

## 10.4 Monitoring and Event-based Policies

**Market trends:**

- **Monitoring of varying degrees:** Unlike the application performance monitoring area in cloud computing, NFV monitoring is seeing a more integrated approach in its respective layer, instead of standalone solutions. The extent of their monitoring is not apparent in all marketing. In some cases, such as Oracle or HPE, analytics is a focus, but in the form of an extended complimentary solution.

- **Event-based Policies:** Several solutions link their monitoring to policy definition for distinct actions, but much of this is on the operator side and details are scarce.

**SONATA approach:**

- In SONATA, monitoring is provided for the VNF/NS as a platform feature, which is common in the domain. The innovation by the project focuses on how it is pushed back to the service

developer and their SDK, as part of a DevOps workflow. Basic support for platform health monitoring is also a feature, so the adopting CSP can track deployment performance. The project has also chosen an extendible monitoring framework that can be extended with further metrics, per CSP requirements.

- SONATA lets CSPs and third-party service developers control specific orchestration and management functionalities pertaining to their network service, through function- and service-specific managers. While event-based policies are featured in some alternative solutions, SONATA's innovation is on how it empowers the third-party developer, not just the hosting CSP. This accessibility for the service developer is provided through the SDK.

## 10.5 Service Composition and DevOps

### Market trends:

- **VNF-chaining and interfaces for NS development:** While VNF chaining for network service creation is a common feature across many MANO-related solutions, there exists a differentiation between workflows and interfaces. Of the later, solutions often come with a GUI, but of varying abstraction and scope. In some cases, these are extended from existing service composition solutions, dashboards (for their administrator counterpart), etc. and adapted for the VNF and NS context.

- **DevOps workflow:** Interfaces for service lifecycle management are seen in many of large vendor suites surveyed. Although customer-facing interfaces are provided in several cases, they often lack a true DevOps workflow vision, or lack the value-added performance data and intelligence pushed back to the service developer.

- **Lower Barrier of Entry for VNF and NS developer:** It will be a more dynamic market, and an insurgent could focus on supplying specific VNFs within an ecosystem. It is more likely though that the business case and innovation would be better targeted on the network service layer for a newcomer, exploiting public catalogs of blueprint VNFs from the CSP or vendor.

### SONATA approach:

- This is an area of high differentiation, and a large focus of SONATA's effort is dedicated towards the SDK, tools and interfaces paired with the platform's Gatekeeper verification system. GUI and CLI support is designed with the developer in mind, compatible with a platform ecosystem vision provided the adopting CSP.

- SONATA's DevOps workflow emphasizes dynamic interfaces between service platform and SDK, and pushes data and monitoring pushed back to the third-party developer. This is a trend that has taken flight in the IT sector's software development, but as the market analysis reports (see Section 6.2), the culture change is still quite lacking in the neighboring telecommunications sector. SONATA's innovative NFV DevOps system for network services is directly addressing the need for exponential gains in service agility and time-to-market that CSPs urgently require to stay competitive, and supports an ecosystem-driven business model that is envisioned for supporting developers and vertical industries for 5G networks.

## 10.6 Legacy Support for an Iterative NFV Adoption Roadmap

**Market trends:**

- **Hybrid VNF/PNF Support:** NFV adoption by operators will not be immediate, and supporting both virtual and physical legacy domains is a requirement to stay competitive as a first-mover vendor before 2020. Based on marketing, this is recognized and supported by all surveyed solutions.

- **Integration and Interfaces with OSS/BSS:** The transition from the operator side must be met with open interfaces to their OSS/BSS by MANO solutions. This requires work on both the solution side and the legacy side, where operators will also need to update their OSS to be relevant in the full transition to software networks and NFV. Incumbent vendors and solution providers with a large OSS-related portfolio can use this as a competitive advantage. The same iterative timeline to 2020 is important here, as well, and flexible interfaces to existing legacy OSS will have the upper hand in adoption.

- **Migration of PNFs to VNFs:** Large vendors are also at an advantage of having legacy PNFs as a first generation of VNFs through a migration process, trying to arrive early to a critical mass in their VNF catalog. This can be an advantage for incumbent vendors when existing legacy customers are making their transition to software networks. However, various testimonials by CSPs in 2016 show a point of disillusionment as these VNFs were not originally "built for the cloud", and do not fully exploit the characteristics envisioned for a virtualized environment.

**SONATA approach:**

- While SONATA is aimed at 5G, the platform is also designed for the more immediate roadmap of NFV adoption. It supports legacy PNFs, as CSPs proceed with a piecemeal transition towards software networks.

- In its second year of development, SONATA is also focusing on the interfaces between its platform and an operator's OSS. These must be as open and extensible as possible, given the integration complexity, differentiation and parallel OSS upgrade roadmaps towards 5G.

## 10.7 5G Network Readiness

**Market trends:**

- **Service vs. Resource Orchestration:** While the debate sometimes takes place on whether service orchestration is part of the NFVO component or separate, it is universally included in commercial MANO offerings in some form or another. They differ in implementation, and whether or not they are treated as separated architectural components or empowered by partner ecosystems.

- **NFV Management vs. SDN Controller Integration:** Large vendors with accompanying SDN controllers in their portfolio can of course exploit their (proprietary) interoperability. But apart from the general recognition of leading projects like OpenDayLight, end-to-end lifecycle management between MANO and SDN domains remains an obstacle.

- **5G Network Slicing Support:** Little is referenced to advanced 5G visions such as network slicing support. A notable exception is Ericsson's portfolio, which sees it as a key

requirement for the MANO layer. Although not explicitly mentioned, it is expected that Huawei and other vendors with a strong emphasis on slicing in their 5G vision will follow suit.

**SONATA approach:**

- SONATA is a full MANO platform, and covers both service and resource orchestration with its modular NFVO. There is, however, still an interoperability gap and better integration needed when seeking end-to-end lifecycle management between the MANO layer and SDN controller. This is a particular area of SONATA research and testing, and a focus of its second year.

- SONATA is building slicing support directly into its platform design, aiming at 5G scenarios. This can promote specialized network services for distinct vertical industries, with bespoke network configuration through its SDN interfaces.

## 10.8 Communities and Standards

**Market trends:**

- **Open Source and Strategic Communities:** Vendors and operators alike recognize that a competitive transition to software networks requires strategic alliances in the push for de-facto technology and approaches in addition to the more classical standards development. Apart from the OpenStack expansion from cloud computing to network operations, OPNFV entered exclusively in the NFV area in late 2014, and in Q1 of 2016 two new collaborations began with OSM and OPEN-O. It should be noted that many vendors and operators are collaborating in more than one, in an apparent diversification strategy when standards and shared technology is still developing in the area.

- **ETSI compliant:** The vast majority of MANO solutions covered in the deliverable were quick to point out in their marketing material that they were indeed ETSI compliant. However, the slight architectural discrepancies in componentization and implementation might overstate the impact of such compliance, as it still introduces interoperability issues with other vendors' MANO alternatives. The ETSI reference architecture is also admittedly vague in some areas. "ETSI compliance", therefore, should be treated as a minimal requirement in these cases, and not raise expectations for easy multi-vendor integration.

- **Existing standards formats:** Common standards such as TOSCA and YAML are widely used, carried over from efforts in cloud computing service orchestration.

**SONATA approach:**

- SONATA is not limiting its open source strategy to its own GitHub hosting, which could result in a silo-like development. The impact of the project is taking a diversification strategy, and collaborating with other community projects. OpenStack Tacker (Section 8.2.1) is an example, and currently planned collaboration will be using SONATA's network service catalogs for implementation, as well as comparing approaches on network service descriptors.

- SONATA is fully ETSI compliant, benefiting from key ETSI NFV ISG operator partners such as Telefonica and BT, which are also investigating potential OSM collaboration (Section 8.2.4). SONATA's participating vendors also have strong OpenStack ties, such as NEC and Nokia's CloudBand unit. The project is also using common industry standards, with solutions based on TOSCA.

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## Annex: "NFV MANO Adoption Priorities for Software Networks" Survey Template

**This survey is for 5G-PPP commercial organisations in the telecom value chain, and designed to further analyse adoption considerations and priorities for MANO (Management and Orchestration) solutions in NFV (Network Function Virtualisation).**

The survey can be completed in 15 minutes.

It has been prepared by the SONATA project (www.sonata-nfv.eu), which is building an open source NFV service platform with orchestrator (NFVO) and supporting developer SDK for the full lifecycle of network services.

Your contact information and organisation name will not be shared, only the anonymous background profile will be used to put the answers into context (e.g. operator, vendor, system integrator, SME-sized solution provider, etc.)

As this is a one-size-fits-all survey, it is understandable that not all questions will apply to everyone. For example, some are geared much more towards operators than other stakeholders such as vendors, system integrators, service developers, etc. But please answer the best you can, as we're looking for a holistic perspective from the value chain.

**Contact info** *(confidential and optional, for follow-up questions)*

- Name:
- Organisation:
- Email:

**Background:**

How would you best describe your role in the telecom value chain? e.g. manufacturer/vendor, network service providers / operators, cloud providers, systems integrator, technology partner, service developer, etc. To clarify, what is an example of a relevant offering from your company, and what profile is the typical customer?

**Flexibility of MANO Orchestration System**

"Flexibility" is a general term that refers to how well and diverse a NFV MANO system could adapt to various scenarios, formats, other solutions, vendors, etc. Please rate the follow characteristics in importance to you and your organisation:

| **Characteristic / Feature** | **importance** (low to high) |
|---|---|
| ▪ support for different VIMs (e.g. more than OpenStack) | (low) 1 2 3 4 5 (high) |
| ▪ support for different network configuration systems (e.g. more than OpenDaylight) | 1 2 3 4 5 |
| ▪ support for multi-vendor VNFs | 1 2 3 4 5 |
| ▪ support for different VNFM/EM approaches, e.g. vendor specific plugin architecture for different VNFM/EM approaches | 1 2 3 4 5 |
| ▪ support for different service descriptor formats / languages (e.g. TOSCA) | 1 2 3 4 5 |
| ▪ changes in layers of virtualization (e.g. more than VMs)<br>▪ containers<br>▪ unikernels<br>▪ other? (please specify) | <br>1 2 3 4 5<br>1 2 3 4 5<br>1 2 3 4 5 |
| ▪ stackable layers of network service composition (e.g. network services containing network services) | 1 2 3 4 5 |
| ▪ stackable layers of network service composition with independent orchestration (e.g. for heterogeneous operational scenarios and evolutionary interworking) | 1 2 3 4 5 |
| ▪ support for multi-service provision<br>▪ NFV Infrastructure as a Service (NVFIaaS)<br>▪ resource "slicing" (e.g. configured for vertical industry sectors) | <br>1 2 3 4 5<br>1 2 3 4 5 |
| ▪ support for recursive / stacked deployments of the MANO platform (e.g. running a MANO platform instance within a slice of the underlying MANO platform) | 1 2 3 4 5 |
| ▪ Comments related to above categories and "flexibility": | |

**Software Networks Transition and Supporting Legacy:**

NFV is part of a larger, complex transition roadmap to software networks, impacting heavily the network operator and supporting actors in the telecom value chain. It's building on top of a long history of adopted network assets. Please rate in importance the following characteristics, and please specify with examples.

| **Characteristic / Feature** | **Importance** (low to high) |
|---|---|
| ▪ compatibility with existing proprietary systems<br>▪ (please specify)<br>▪ (please specify) | 1 2 3 4 5 |
| ▪ compatibility with existing open source systems<br>▪ (please specify)<br>▪ (please specify) | 1 2 3 4 5 |
| ▪ What software network transition challenges and priority areas of legacy interoperability do you foresee as most challenging in adoption for brown-field scenarios (integrating with existing network assets)? | |

**Network Service Development, Toolkit (SDK) and DevOps:**

The focus on network programmability allows NFV supported networks to adopt more agile and DevOps-enabled workflows for their platforms and service developers. Please rate in importance the following characteristics of such a platform and SDK towards network service development, from your perspective in the value chain.

| **Characteristic / Feature** | **Importance** (low to high) |
|---|---|
| ▪ network service definition, validation, and cataloguing tools | 1 2 3 4 5 |
| ▪ "sandbox" execution verification environment | 1 2 3 4 5 |
| ▪ featuring agile development, tools and workflows:<br>▪ continuous integration and deployment<br>▪ DevOps model | <br>1 2 3 4 5<br>1 2 3 4 5 |
| ▪ For a network service provider deploying such a platform, what new service development workflow priorities and challenges do you foresee when confronting a multi-actor DevOps ecosystem? (e.g. network operator and service developers)<br>▪ Which DevOps tools or methods do you think would be beneficial for the development of carrier services? | |

**Standards and Open Source Communities:**

The advancement of software networks (SDN, NFV, etc.) has spurred a strong entry of open source solutions in the network stack and additional standards initiatives. Examples of active communities include OpenStack, OpenDaylight, OpenFlow, OpenMANO and even first integrations such as OPNFV. On the standards front, ETSI NFV ISG has released NFV architecture specifications. The convergence of network technology with software stacks has also led to the re-use and extension of various existing standards. Please rate in importance the support of such initiatives and standards for a NFV MANO solution.

| **Characteristic / Feature** | **Importance** (low to high) |
|---|---|
| ▪ Support for: | |
| ▪ ETSI NFV ISG Specifications | 1 2 3 4 5 |
| ▪ OpenStack APIs | 1 2 3 4 5 |
| ▪ (please specify) | 1 2 3 4 5 |
| ▪ (please specify) | 1 2 3 4 5 |
| ▪ (please specify) | 1 2 3 4 5 |
| ▪ Backwards compatibility with previous versions of standards (please specify): | 1 2 3 4 5 |
| ▪ What areas in the software network stack do you see most advantageous to provide/adopt open source solutions? (as opposed to commercial proprietary solutions)<br>▪ (please specify, and why?)<br>▪ (please specify, and why?)<br>▪ (please specify, and why?) | |
| ▪ What open source projects are you engaging (contributing) and/or adopting (uptake and use)<br>▪ project: (please specify) engagement? adoption?<br>▪ project: (please specify) engagement? adoption?<br>▪ project: (please specify) engagement? adoption? | |
| ▪ What are the 3 most influencing factors in determining your engagement of an open source community?<br>1.<br>2.<br>3. | |

**Miscellaneous Technical Characteristics**

A variety of characteristics that have been taken into account in the design of a NFV MANO solution, not previously covered above:

| **Characteristic / Feature** | **Importance** (low to high) |
|---|---|
| ▪ Resource management (beyond core MANO value of efficient usage of network, compute and storage resources):<br>▪ automated efficient placement<br>▪ dynamic responses to actual resource load<br>▪ (other, please specify) | (low) 1 2 3 4 5 (high)<br>1 2 3 4 5<br>1 2 3 4 5 |
| ▪ Performance isolation<br>▪ "cloud-like" (e.g. illusion of unlimited resources)<br>▪ host pinning (e.g. dedicated physical host per tenant)<br>▪ granular hardware pinning (e.g. CPU pinning, Enhanced Platform Awareness) | 1 2 3 4 5<br>1 2 3 4 5<br>1 2 3 4 5 |
| ▪ Verification to network service SLAs<br>▪ at network service design stage<br>▪ at network service deployment stage<br>▪ at runtime | 1 2 3 4 5<br>1 2 3 4 5<br>1 2 3 4 5 |
| ▪ Related comments: | |