WHITE PAPER

FLEXIBLE, EXTENSIBLE, ADAPTABLE: TOWARDS A UNIVERSAL TEMPLATE FOR VNF ONBOARDING AND LIFECYCLE MANAGEMENT

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1. Executive summary

Leading communications service providers (CSPs) want to join the digital economy and offer their networks as self-service platforms that use a high degree of automation to deliver communications services on demand. Network functions virtualization (NFV) is a key enabler of this vision. CSPs envisage that a new marketplace for virtual network functions (VNFs) will feed their platforms, increasing innovation and revenues by providing customers with a broad range of networking capabilities from which they can create their own virtual networks. Traditional networks based on physical appliances constrain customer choice because new capabilities take time and are expensive to bring to market.

The NFV marketplace vision depends on vendors being able to onboard VNFs into a CSP's platform in a timely and cost-effective way. VNFs must interoperate with all the platform capabilities they need to know about, and which need to know about them, in order to run reliably and efficiently. For speed and cost reasons, the process of onboarding VNFs to the platform and the processes that subsequently manage their lifecycles should be automated. The processes must deal with the dynamic nature of an NFV environment and they should be adaptable and extensible to handle change in platform capabilities as these are retired, replaced and/or evolved.

Despite nearly five years of work and a plethora of standards, open source and vendor developments, the challenges of integrating VNFs to, and managing them in, CSPs' NFV platforms remain. VNF onboarding goes to the heart of the hardest challenge any industry faces today: how to automate interoperability between diverse and changing software components without breaking those components and, more importantly, the customer services and experience they support. The telecom industry has been applying various approaches to try and resolve the NFV interoperability problem but all have proven shortcomings when applied to the dynamism and complexity of the NFV environment. As a result, the industry has made little progress towards achieving its digital marketplace vision. Unless CSPs adopt a new approach to building and maintaining interoperability between VNFs and their platform environments, an industry "app store" of VNFs remains a pipe dream.

New circumstances demand new solutions and this paper describes a 'model of models' or 'metamodel' approach, which is bringing hope to a stalled market. The power of such a metamodel has been demonstrated by an award-winning TM Forum Catalyst, "Enabling the Digital Services Marketplace with Onboarding Automation", sponsored by leading operators and vendors. The Catalyst uses a *Metamodel for a Virtual Function Package*, contributed by EnterpriseWeb, to model and onboard VNFs from multiple third-party providers in hours rather than weeks. The hope is that over time, TM Forum, Catalyst sponsors and others will build upon the *Metamodel for a Virtual Function Package* to create an industry-standard universal template able to connect diverse, distributed and dynamic software components in an NFV-based runtime environment. This is a critical enabler of CSPs' business vision for the digital network platform.

2. CSPs want to join the digital platform economy

2.1 The business value of the network as a digital platform

Leading communications service providers (CSPs) want to transform themselves into digital service providers (DSPs) with platform business models so that they can compete alongside agile 'FANG'[1] players in the digital economy. They would like their networks to become self-service platforms that use a high degree of automation to deliver communications services on demand, a very different customer experience than CSPs typically offer today. Network functions virtualization (NFV) is a key enabler of CSPs' platform vision, since NFV-driven automation makes services faster, lower cost and more flexible to deploy than they are in the traditional, physical network.

NFV also promises to deliver new value for CSPs. Software-based network function can be created far more quickly once it is no longer dependent on proprietary hardware development cycles, unleashing innovation into the network for rapid monetization. Similarly, the ease with which virtual network functions (VNFs) can be composed into personalized, pay-for-what-you-use service combinations creates the potential for new service revenues.

The availability and rapid onboarding of new VNFs are critical to such monetization opportunities. Leading CSPs would like to see one or more VNF marketplaces – networking industry 'app stores' – which would publish and distribute VNFs from multiple new and established vendors. They believe that NFV marketplaces would open the networking industry up to competition and innovation. CSPs and/or their customers should be able to browse VNF marketplaces for new features they can download to CSPs' platforms and use in their network services. Today's consumer app stores illustrate the power of platform network effects: the broader the choice of VNFs on offer through a CSP's platform, the more attractive it will become. Customers will choose to use a CSP platform that has rich functionality and which makes virtual network creation seamless, fast and secure.

2.2 The VNF marketplace vision is difficult to achieve

This vision is a long way from realization. After years of painstaking platform-based development, even the market-leading CSPs offer a limited choice of network functions today. It is proving extremely difficult to introduce new VNFs into nascent CSP digital platforms. Instead of instant interoperability, VNFs take weeks to onboard. Each new VNF requires a custom process of manual integration into platform tooling which is time-consuming and expensive.

This is because VNFs are not simple, homogenous pieces of software; they are complex and heterogeneous. They have variable configuration and management requirements and they require continuous monitoring and management across their lifecycle. They need to be updated, upgraded and replaced. Perhaps the most important difference between VNFs and the IT applications that well-known consumer platforms run is that IT applications are stand-alone while VNFs need to be chained together to form network services. This creates dependencies between VNFs which compound the difficulties of onboarding and managing them.

Introducing new VNFs into the operator environment – VNF onboarding – is fundamentally a systems integration problem. How do CSPs take VNFs developed in different circumstances and languages, with

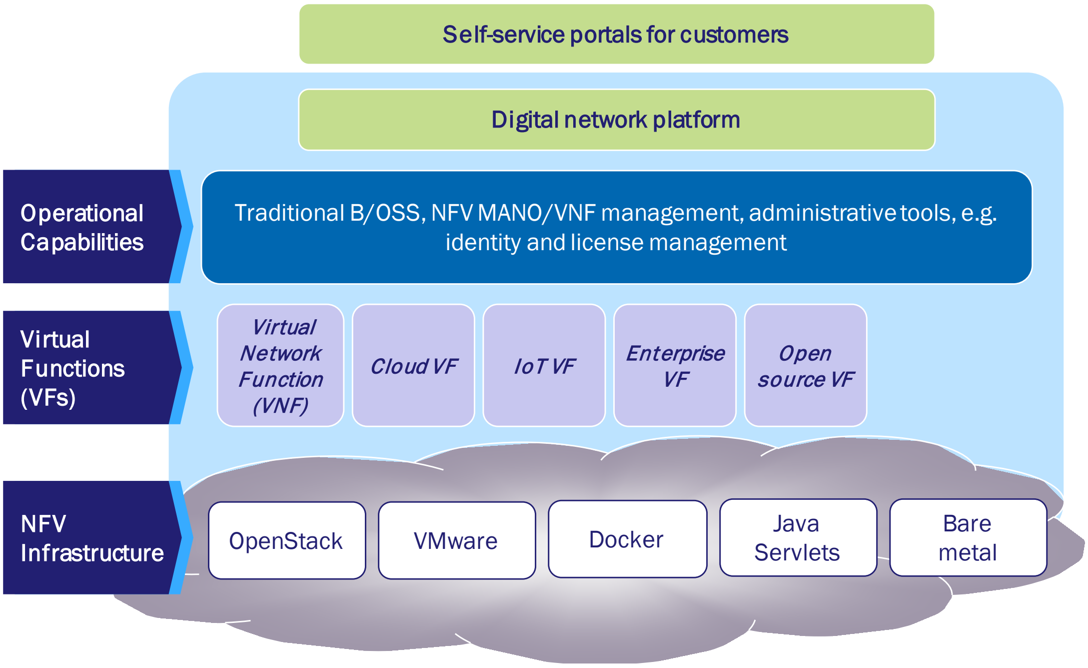
[1] The FANGs are Facebook, Amazon, Netflix and Google, often used as a shorthand for all digital native companies.

different tools and packaging mechanisms, by a diverse set of vendors, and introduce them into a CSP's digital platform?

Each CSP will have built its platform as a curated set of integrated tools and technologies that support the network and its operations. A platform typically has three discrete types of capability, namely:

- **Operational capabilities** (management and orchestration tools) that manage the platform itself, the lifecycles of the services and VNFs it hosts, and customer interactions such as order taking and billing. VNFs need to interoperate with different categories of operational tools including traditional B/OSS, NFV management and orchestration tools and administrative tools.
- The set of **VNFs** from which customer-facing services can be composed. Depending on the scope of an individual operator's customer-facing services, these may contain a broader set of virtual functions (VFs) beyond VNFs.
- **Infrastructure** – the set of hardware and software infrastructure (cloud) technologies that hosts VFs/VNFs in the digital platform. NFV-specific infrastructure is known as NFV infrastructure (NFVI). Figure 1 shows sample technologies that may be present in an NFVI.

Figure 1: Components of a digital network platform [Source: EnterpriseWeb, Analysys Mason, 2017]

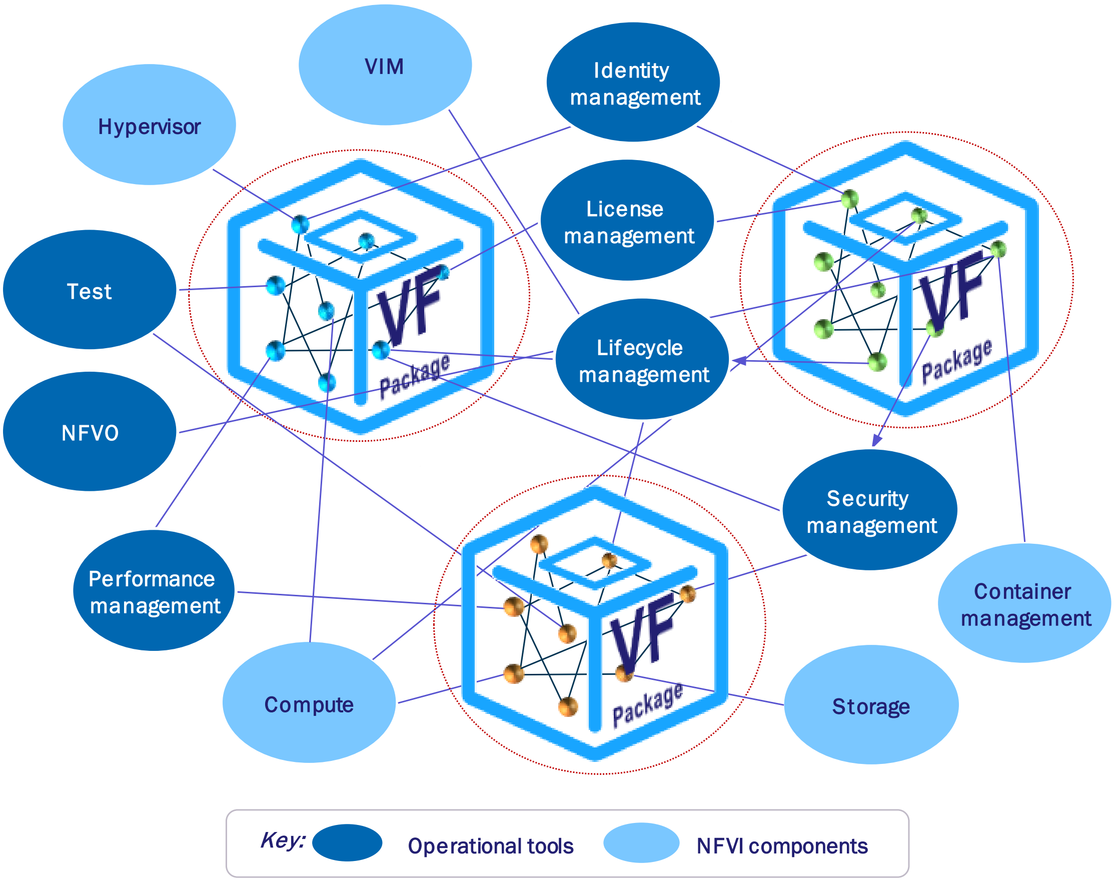


Integration of the tools and components across the platform is needed to ensure that a VNF can be selected from an app store's catalog and instantiated, and that as part of the instantiation process, the VNF automatically connects to the platform resources it needs. This should be the case even if it is the first time the platform and the VNF have interacted with each other. The platform also needs to know how to monitor, scale and optimize the VNF in the context of a service chain and the policies that govern the service chain, and how to tell business systems that they need to start metering and charging for it.

However, unless the CSP buys all its VNFs and platform from the same vendor, which would be counter to the core objectives of NFV, a CSP will need to deal with heterogeneous VNFs. Conversely, VNF vendors will have no control over a CSP's choice of platform tools and technologies, with which it will need to integrate. The industry would like VNFs to arrive 'ready to run' on any CSP's platform. In practice, it is difficult for an alien

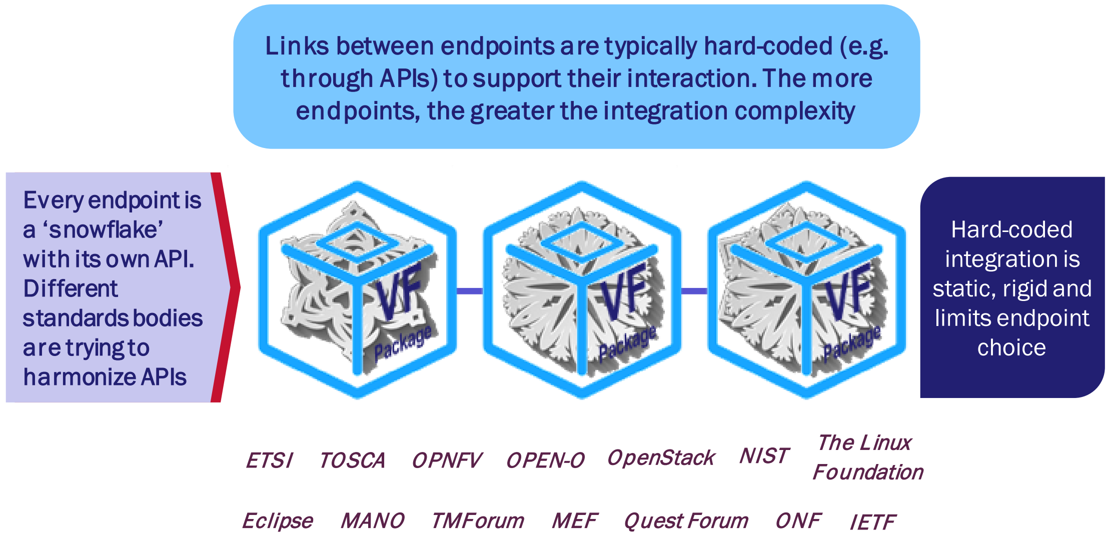
VNF to interoperate out of the box with the idiosyncratic group of components each CSP has decided to use. Nor can VNFs instantly guarantee their performance in diverse platforms. While the money-making and cost-saving potential of NFV lies in its decoupling of network function from proprietary hardware, this introduces complexity through the need to integrate and manage multiple new and disparate components.

Figure 2: Heterogeneous VNFs need to integrate with multiple platform capabilities [Source: Analysys Mason, Enterprise Web, 2017]



It can take weeks or even months to create the necessary interoperability between a single VNF and a CSP's platform. Yet despite the time and effort spent on it, integration built with current tools and approaches is often brittle, inflexible and limited. The integration methods CSPs and vendors currently have at their disposal find it difficult to cope with the diverse ways in which VNFs and other platform components – let's call them all 'endpoints' – have been developed. Nor can they easily deal with the speed and extent of change in those individual endpoints and the overall system – the network – which they collectively comprise.

Figure 3: Integration between endpoints is currently hard coded [Source: Analysys Mason, 2017]



The unprecedented set of challenges that NFV creates demands a new approach to building and maintaining interoperability between VNFs and their external environment. Without such an approach, it will be extremely difficult for CSPs to realize their vision of a rich digital network platform that can dynamically ingest and combine a broad range of VNFs. Customer choice will continue to be constrained and VNF developers will have little incentive to create new functionality, stifling innovation as effectively as the traditional network does today.

3. VNF onboarding needs a new solution

3.1 A metamodel, or universal template, is key

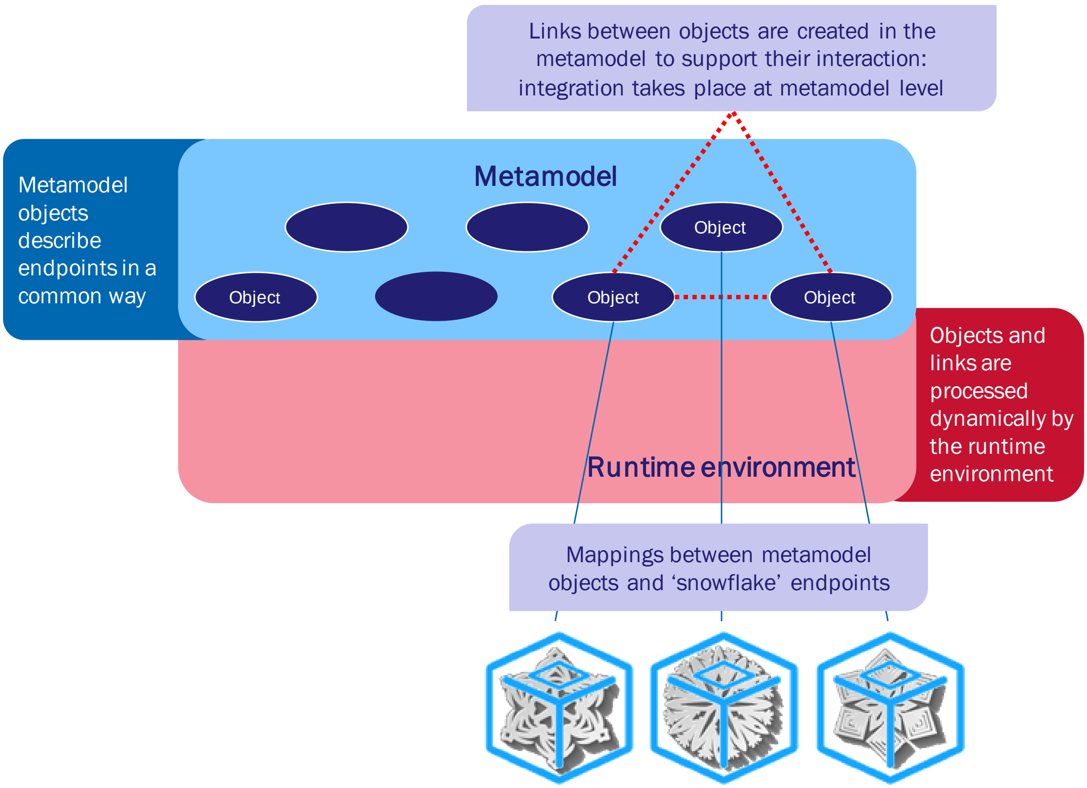
The VNF marketplace vision requires CSPs to be able to integrate VNFs automatically into a dynamic platform, all the components of which, including VNFs, APIs, and standards, evolve over time. This integration must not break those components or, more importantly, the customer services and experience they all support.

No two VNFs, even of the same type, will be designed in the same way or have the same infrastructure and operational requirements. To link them on demand to other platform endpoints requires a new way of describing the entire platform and all its constituent endpoints in a manner that transcends these differences. This platform description must take place at the right level of abstraction, a tricky proposition to resolve. Although the industry recognizes that abstraction is critical to VNF onboarding, many players are proposing over-simplistic and limited abstraction approaches, such as APIs or domain-specific data models, to address an inherently complex, multi-domain problem.

What is needed is a 'model of models', or metamodel that can describe anything and everything in the target scope of automation: a single notation, or templating capability that can simultaneously model related concepts across administrative domains. In the case of VNF onboarding, this means that a metamodel should bring together administrative domains that include individual VNFs, compositions of VNFs as network services, endpoints in management domains, such as resource and service orchestrators, VNF and policy managers and any other endpoints that participate in the onboarding process. A metamodel for VNF onboarding should be a single connected model that supports end-to-end automation of onboarding and lifecycle management processes. In order to do this, it should express endpoint descriptions as machine-readable, and thus executable, 'objects', with relationships and links between them. Objects and links are processed at runtime at metamodel level, eliminating the need for manual integration between the individual endpoints its objects describe. The metamodel and its runtime environment become the control plane for the communication between endpoints and their participation in processes.

During the onboarding process, a CSP or VNF vendor should be able to capture a VNF's attributes, behaviors, constraints, and dependencies using the metamodel's template. This activity should be accelerated by the CSP's/vendor's ability to reuse concepts and types already defined in the metamodel. The resulting software object should be a rich, executable representation of a VNF, based on metadata and link references, with no hard-coded connections. As a "normalized" object in the metamodel, the VNF would be handled using common methods. A mated metamodel runtime environment should immediately and automatically be able to process and manage the VNF, by navigating the object itself and, through its relationships, linked objects, without the VNF vendor or CSP needing to write a single line of integration code between the VNFs and other endpoints the linked objects represent.

Figure 4: What is a metamodel? [Source: Analysys Mason, 2017]



There are caveats here since not all models are created equal. The industry has many standards-based and proprietary models, but each of these typically targets a narrow domain or a specific technology. Implementations based on siloed models still require integration to achieve an end-to-end solution. For clarity, we define a metamodel as having the following properties:

- a unified modelling environment intentionally designed to make heterogeneous endpoints look homogenous

- the ability to capture the variance and unique details associated with different endpoints in a consistent machine-readable manner so that none of them are 'lost in translation' and endpoints can be manipulated as natively as possible
- support for loose-coupling between objects and their composability into higher order objects
- full abstraction between service design and service implementation
- a dynamic runtime environment that co-ordinates and processes the sets of objects that support specific service contexts, for example, VNF onboarding.

3.2 Unified modelling environment

CSPs have been exploiting models for many years without achieving seamless interoperability and automated integration. This is because most of the standards-based models they use address narrow domains. A unified, end-to-end modelling environment is needed to avoid the current struggles CSPs are having to integrate the diverse data models and management requirements of endpoints in different administrative domains. A metamodel needs to be an umbrella model for linking models together in a transparent, flexible and efficient manner across domains, partners, and technologies.

In a VNF onboarding context, the metamodel needs a means of describing all VNFs, and indeed any other component in the platform's runtime environment, in a common, machine-readable language, so that all components can be discovered, composed, orchestrated and policy-managed in the same way, despite their diverse origins, properties and technology implementations. Using a single common pattern to describe any object in the metamodel makes it easy to apply consistent version control, security policies, lifecycle management, and a host of other non-functional but critical tasks.

The metamodel should provide a universal template for onboarding heterogeneous endpoints, including VNF packages, regardless of which industry standard model they have originally used (for example OASIS TOSCA, ETSI NFV, TMF Open API). The metamodel should be open and extensible so that it can accommodate other open source and standard organization modelling approaches as these arise.

3.3 Capturing differences

The metamodel also needs a means of capturing, as part of an endpoint's machine-readable description, its unique characteristics and the detail of how to interact with it. This allows the metamodel to support the diversity that is characteristic of a rapidly-evolving, software-driven market such as NFV. VNF vendors are often criticized for being 'snowflakes' that insist on specific execution requirements and tightly couple their VNFs to management and orchestration components. VNF vendors are increasingly being asked to conform to restrictive standards that can 'lose in translation' the richness and nuances of the endpoints they model. A more flexible, future-forward approach should embrace unique, non-standard properties and behaviors as a healthy sign of innovation.

It sounds like a contradiction to have a metamodel that simultaneously enables normalization at object level while accommodating divergence and idiosyncrasy. The metamodel and its execution environment will need a design that fundamentally supports variance and change. This will require the metamodel provider to draw on deep computer-science capabilities.

3.4 Loose coupling and composability

Unlike conventional integration where endpoints are tightly coupled to each other, metamodel-based integration should support loose coupling between its commonly described objects so that they can be flexibly connected in new ways to address requirements that might not have been originally anticipated. Loose coupling supports the composability of many different and arbitrary types of objects – for example, web services, REST APIs, microservices, systems, databases, devices – into composite applications. This is the reality of the software world in general and the VNF onboarding environment in particular.

3.5 Full abstraction and late binding

Full abstraction enables service designs to be unconstrained by the technical complexity of endpoints. It is important that the metamodel completely eschews hard-coded connections between its objects and the endpoints that fulfil those objects. Instead, the metamodel's execution environment should decide, at runtime and based on policies, which endpoints to assign to metamodel objects that participate in a service design. In other words, the metamodel should support the 'late binding' of network service objects to particular instances of VNFs, to ensure the CSP retains utmost flexibility in how it implements the service.

The metamodel's level of abstraction and late binding capabilities should provide an 'intent-based' interface between service descriptions and the technology-specific endpoints that implement them. Service business logic that references objects and links in the metamodel declares what it wants to do – its business goals – and the metamodel execution environment works out how to achieve these goals based on the policies and context (for example, performance, security, requirements, availability of key resources and so on) that apply to the service at any given time.

3.6 Runtime environment

The metamodel's runtime environment drives automated decisions and implements services. To do so, it needs efficiently to identify and interpret the relevant sets of objects for a particular service context, handle the connections between them and mediate in near real-time the communications between metamodel objects and endpoints participating in the service, performing all necessary translations and transformations. This orchestration activity needs to be carried out at scale and securely.

The runtime environment could be built using a stack of traditional middleware components, such as enterprise service buses, databases, complex event processing, and analytics/rules engines. However, all these tools need to be integrated and differentially deployed and maintained, creating 'accidental' cost and complexity. It is proving challenging for conventional middleware architectures to support the complex distributed applications that are the lifeblood of digital businesses.

For reasons of efficiency and elegance, the metamodel's runtime environment should be defined using the metamodel itself and implemented as a coherent, horizontal set of cloud-native microservices stored in a catalog. At runtime, the environment should reference the catalog to dynamically marshal the microservices it needs to orchestrate service delivery. It should assemble and run appropriate middleware microservices in a single, lightweight system, enabling rapid processing, without cumbersome, hard-coded tool-to-tool communications to create latency and benefiting from the resilience and scalability properties of cloud native architecture.

4. TM Forum Catalyst demonstrates *Metamodel for a Virtual Function Package*

A TM Forum Catalyst, "Enabling the Digital Services Marketplace with Onboarding Automation",[2] is putting the power of a metamodel for VNF onboarding to the test. The Catalyst, which was sponsored by six leading operators, AT&T, China Mobile, Orange, Telstra, Verizon, and Vodafone, used the *Metamodel for a Virtual Function Package*, contributed by EnterpriseWeb, to model and onboard VNFs from multiple third-party providers in days rather than weeks. The metamodel allows CSPs to download VNFs from a digital services marketplace into their platforms to enrich their network-as-a-service offers. The metamodel's runtime environment automatically processes all the objects that connect VNFs to the endpoints needed to manage them across their lifecycles.

The Catalyst uses EnterpriseWeb's runtime environment to allow the metamodel to ingest TOSCA-based network function packages whose internal functionality can be described using multiple industry standards. Importantly, the metamodel links network function packages to metadata descriptions of other non-functional endpoints: the Catalyst specifically supports TM Forum Open APIs, for product catalog, ordering, inventory, billing, service catalog, performance, service level management, and trouble ticketing in this respect. The metamodel automatically associates VF packages with the objects these management endpoints represent when a VNF is onboarded. CSPs and vendor partners are contributing objects to the metamodel in each of these domains: IBM, for example has provided metadata for performance management. Symantec, although not a formal participant in the Catalyst, has added security objects. CSPs and other vendors are free to extend or replace these objects to suit their own/customers' platform environments and use cases.

The TM Forum and Catalyst contributors expect that over time, the industry will build upon the *Metamodel for a Virtual Function Package* to create an industry-standard metamodel able to connect diverse, distributed and dynamic software endpoints in an NFV-based runtime environment. Such a metamodel will support the composition of objects/endpoints into new products and processes without the need for hard coding. In recognition of the Metamodel for a Virtual Function Package's significant role in addressing VNF onboarding challenges, the Catalyst has won a 'Best Contribution to TM Forum Assets' award.

5. Conclusion

Digital marketplaces and platforms for apps, video, shopping, taxi rides, and myriad other purposes are transforming the economic landscape. A digital marketplace for network services is not a nice-to-have vision: it is a critical requirement if CSPs are to remain relevant in the digital economy. CSPs must overcome the challenges of onboarding new VNFs seamlessly, on demand, to their network platforms if they truly wish to become DSPs.

The digital marketplace vision for VNFs is at least half a decade old but the industry is still struggling to realize it. This is because CSPs and vendors remain wedded to tools and approaches which have so far failed to deliver

2 https://projects.tmforum.org/wiki/pages/viewpage.action?pageId=71177320

the outcomes they need. Many believe that if only the industry would conform to the right ‘silver bullet’ standard, then the problem of VNF onboarding would be solved. Unfortunately, there is no consensus as to what that standard should be. Others fear that standardization is premature at such an early stage in the digital evolution of the network, and history suggests that creating software standards is a particularly difficult activity, especially in an age of open source-based experimentation and software-led innovation.

This is a time for new thinking about the VNF onboarding problem. The industry needs a new approach that supports VNF diversity and innovation while making tractable the integration and management of all the endpoints that need to participate in the onboarding process. A metamodel-based solution can provide such a universal template for endpoints and, if designed correctly, will be flexible and extensible enough to adapt to emerging market needs. The *Metamodel for a Virtual Function Package*, now in the public domain, deserves serious attention from any organization frustrated by the proven shortcomings of alternative data models and orchestration solutions built using conventional middleware tools.

6. About EnterpriseWeb’s platform

EnterpriseWeb® offers a platform that radically simplifies the design, deployment, and governance of distributed applications. Organizations can quickly onboard diverse services, systems, databases, and devices into a graph-connected model of software objects – an enterprise “web” of information and capabilities.

EnterpriseWeb’s platform allows customers to flexibly compose these objects with low or no code, since all configuration is carried out using object metadata. The approach supports rapid prototyping of agile, cloud-native services, applications and processes, which can be managed through a single pane of glass interface.

While globalization, outsourcing, cloud-computing, and the Internet of Things have led to the increasing fragmentation of modern organizations, EnterpriseWeb is designed to enable customers to work across business silos, IT layers and partner ecosystems for highly integrated operations.

EnterpriseWeb’s customers and partners develop differentiated and transformative solutions which can be delivered in the cloud, on premises or through hybrid/multi-cloud deployments. EnterpriseWeb has itself developed vertical solutions based on its platform, including: CloudNFV for the telecom network domain and Ideate for R&D management and compliance.

About the CloudNFV application suite

CloudNFV comprises several components. It features a Universal Template for flexibly and rapidly onboarding heterogenous multi-vendor VFs as software objects mapped to industry standards (e.g. ETSI NFV; OASIS TOSCA, TMF OpenAPIs).

VFs are stored in a persistent manner in a Unified Catalog, along with models of related service orchestrators, automation tools, resource orchestrators (for example, NFV orchestrators [NFVOs]), domain controllers (e.g. VNF Managers), infrastructure managers (i.e. VIMs) and other components (e.g. VNF components [VNF-Cs]), which are all dynamically indexed, tagged, and version-controlled for lifecycle management. Customers use the platform’s Design Environment to declaratively compose the objects into dynamic, data-drive, policy-controlled network services.

The platform's Execution Environment computes an optimized plan which it can process directly, leveraging a library of platform services (e.g. integration, orchestration, automation, configuration and dynamic human processes) or it can delegate processing to federated services as specified. At runtime, the Execution Environment provisions the network service, connecting all necessary solution elements and mediating their communications on demand.

CloudNFV is a unified solution with a north-bound API to the OSS/BSS that abstracts NFV and SDN complexity so CSPs can achieve zero-touch management and operations ("MANO") today. The highly scalable and available platform can be deployed on servers at the core of the network or the edge. It can be delivered as a cloud-based service, an appliance, or embedded on a device.

In response to requests from customers and system integrators, EnterpriseWeb has decomposed its platform into a set of discrete capabilities, which can be deployed as microservices. Each set of microservices implements an NFV sub-domain based on ETSI standard interfaces (e.g. NFVO, VNFM, VIM). This allows operators to deploy EnterpriseWeb as a mediator for one-to-many orchestrators, one-to-many controllers, and one-to-many target hosts. The extensible nature of the platform and its flexible deployment options allow operators to start small and expand their virtualization programs over time.

www.enterpriseweb.com

About the author

Caroline Chappell (Principal Analyst) is the lead analyst for Analysys Mason's Software-Controlled Networking research program. Her research focuses on service provider adoption of cloud and the application of cloud technologies to fixed and mobile networks. She is a leading exponent of SDN and NFV and the potential that these technologies have to enhance business agility and enable new revenue opportunities for service providers. Caroline investigates key cloud and network virtualization challenges, and helps telecom customers to devise strategies that mitigate the disruptive effects of cloud and support a smooth transition to the era of software-controlled networks. Caroline has over 25 years' experience as a telecoms analyst and consultant.

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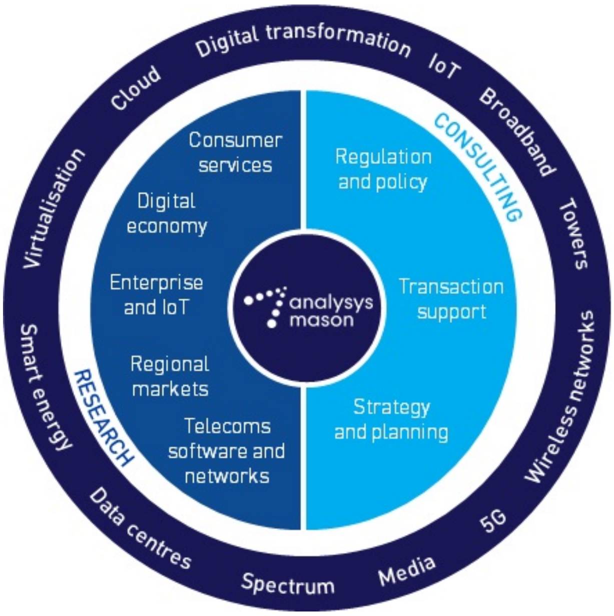

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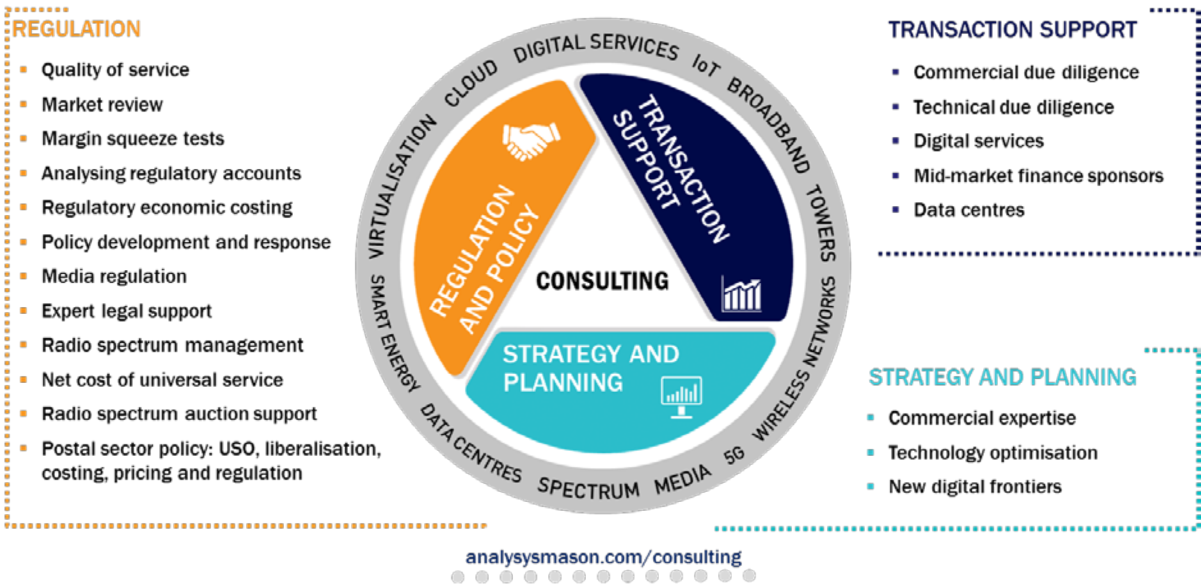

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