Jeremy Fuller (IFA Chair, GENBAND) with input from many others, including: U. Rauschenbach (Nokia), M. Flauw (HPE), B. Chatras (Orange), T. Nguyenphu (Nokia) and E. Bayha (Ericsson).
Part 1: ETSI NFV Concepts
- Main Management and Orchestration concepts
- VNF overview
- VNF Package and VNF Descriptor

Part 2: Virtualised Network Function (VNF) lifecycle management (LCM)
- Managing the VNF lifecycle

Part 3: VNF Package and NS Descriptor (NSD) interfaces
- VNF Package management interfaces
- NSD overview and management interfaces

Part 4: Network Service (NS) Lifecycle Management
- Network Service overview
- NS LCM interface

Part 5: Conclusion
PART 1
ETSI NFV CONCEPTS
Virtualisation is a well established technology.

ETSI NFV Management and Orchestration (MANO) adds automated deployment of complex Virtualised Network Functions (VNFs).
Network Functions Virtualisation: Management of NFV Components

**Network Service (NS)** - built from interconnected VNFs and potentially Physical Network Functions (PNFs)

**Virtualised Network Function (VNF)** - built from interconnected VNFCs.

**Virtualised Network Function Component (VNFC)** - software instantiated in a virtualisation container on virtual resources.
Boundaries of ETSI NFV activity

**Out of scope for ETSI NFV**

**Functional and Configuration Management**

ETSI NFV does not address:

- Application-aware Network Service configuration and management.
- VNF application layer configuration and management.

**Limited scope for ETSI NFV**

**NFV Infrastructure and its managements.**

ETSI NFV does define:

- Some requirements for enhancement
- Corresponding information models where applicable

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NFV MANO manages how the VNF or Network Service is realized (Virtualisation Containers, Virtual Links, Software images, ...)

ETSI NFV MANO is VNF application and Network Service function agnostic. If something relates directly to what a VNF application or Network Service does, then it is out of scope of ETSI NFV.
ETSI NFV Architecture, and NFV-MANO

OSS/BSS

EM

VNF

VNF Manager (VNFM)

NFVI

NFV Orchestration (NFVO)

Virtualised Infrastructure Manager (VIM)

(VNF Catalog)

(VNFM)

(VIM)

(NFV Orchestration (NFVO))

(Network Service Management)

(NFV Management & Orchestration)

-Manage combinations of connected VNFs

-Manage individual VNFs

-Manage the use of NFVI resources

(Specified in ETSI GS NFV-MAN 001)

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VNF – Components and connectivity

**Virtualised Network Function Component (VNFC)** – software within a Virtualisation Container (VC) that performs a task or set of tasks for the VNF.

VNF **Internal virtual links (VLs)** – virtual networking - interconnect the VNFCs via **Internal Connection Points (CPs)**.

**External CPs** allow the VNF to connect via **External VLs** to other virtual or physical network functions.

External VLs are part of the Network Service, not the VNF.
It takes many software components and auxiliary files to create a VNF.

The VNF vendor provides the required VNF software components and auxiliary files in a “VNF Package”.
The **VNF Package** contains:

- the **VNF descriptor (VNFD)** that defines metadata for package onboarding and VNF management,
- the **software images** needed to run the VNF, and
- (optional)** additional files** to manage the VNF (e.g. scripts, vendor-specific files, etc.).

The VNF Package is **digitally signed** and delivered by the VNF provider as a whole.

- The VNF Package is immutable (protected from modification).

The VNF Package can be accessed by OSS/BSS, NFVO and VNFM.

Reference:
- ETSI GS NFV-IFA 011
- ETSI GS NFV-SOL 004
The VNFD defines VNF properties, such as:

- Resources needed (amount and type of Virtual Compute, Storage, Networking),
- Software metadata,
- Connectivity (descriptors for):
  - External Connection Points
  - Internal Virtual Links
  - Internal Connection Points
- Lifecycle management behavior (e.g. scaling, instantiation),
- Supported lifecycle management operations, and their configuration,
- Supported VNF specific parameters, and
- Affinity / anti-affinity rules.

The VNFD defines deployment flavours (size-bounded deployment configurations, e.g. related to capacity).

Reference:
- ETSI GS NFV-IFA 011
- ETSI GS NFV-SOL 001*
* Pre-publication stage – drafts available
PART 2
VNF LIFECYCLE MANAGEMENT
Lifecycle management of a VNF is the concept of controlling the process to:

- Bring a VNF into existence,
- Maintain and modify virtualisation related aspects of the VNF during operation,
- Remove the VNF from existence.
VNF lifecycle management requires the VNF Descriptor (ETSI NFV-IFA 011) and a number of interfaces defined in NFV-IFA 007 and NFV-IFA 008.

(*) not all operations
In managing VNFs the VNFM maintains a detailed view of deployed virtualisation aspects for each VNF under its responsibility.

This information can be accessed by the NFVO.
Managing the VNF lifecycle: VNF runtime information

Based on the definitions in the VNFD, **VNF instances** can be created in the NFVI (aka cloud).

The runtime information of each VNF instance, is managed by the VNFM. **VnflInfo** is a subset of this information, which the VNFM exposes via ETSI GS NFV-IFA007, and NFV-IFA008. The NFVO re-exposes this information via NFV-IFA013.

The VnfInfo element includes information such as

- VNF instance identifier, VNF instance state,
- Scale status (current „size“ of VNF),
- Metadata (version info, pointer to VNFD and VNF package, vendor-specific metadata),
- Virtualised resources used (Virtualised Compute, Storage, Network),
- List of VNFCs,
- Configurable parameters,
- External connectivity (external VLs, external CPs), and
- Connectivity to VIM(s) used to manage the resources of the VNF.
Managing the VNF lifecycle:
VNF lifecycle management (LCM) overview

**VNF lifecycle management operations** can influence the allocation of virtualised resources to a VNF instance, and/or modify the state of the VNF instance.

Support of certain operations by a VNF may depend on the capabilities of the VNF itself.

<table>
<thead>
<tr>
<th>Mandatory Operations*</th>
<th>Explanation – Mandatory for the VNF to support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantiate VNF</td>
<td>Allocate virtualised resources, configure them, start the application, trigger configuration of the application.</td>
</tr>
<tr>
<td>Query VNF</td>
<td>Obtain runtime information about the VNF instance (VnflInfo).</td>
</tr>
<tr>
<td>Terminate VNF</td>
<td>Terminate the VNF, and release the virtualised resources.</td>
</tr>
<tr>
<td>Modify VNF Info</td>
<td>Change certain items of the VNF runtime information (VnflInfo).</td>
</tr>
<tr>
<td>Change External VNF Connectivity</td>
<td>Enables changing the external connectivity of a VNF instance</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Optional Operations*</th>
<th>Explanation – Optional for the VNF to support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale VNF and Scale VNF to level</td>
<td>Change the amount of virtualised resources allocated to a VNF.</td>
</tr>
<tr>
<td>Change VNF flavour</td>
<td>Change the deployment flavor of the VNF, which typically includes changing the amount of virtualised resources, and the topology.</td>
</tr>
<tr>
<td>Heal VNF</td>
<td>Virtualisation-related corrective actions to repair a faulty VNF, and/or its VNFC instances and internal VNF Virtual Link(s).</td>
</tr>
<tr>
<td>Operate VNF</td>
<td>Start or stop the VNF software.</td>
</tr>
<tr>
<td>Auto-Scale and Auto-Heal</td>
<td>Variants of Scale VNF and Heal VNF, triggered automatically in the VNFM, by monitoring the VNF</td>
</tr>
</tbody>
</table>

* See ETSI GS NFV-IFA 007 and NFV-IFA 008 for comprehensive list of LCM operations
Managing the VNF lifecycle: Putting it together (an example)

VNF LCM operation message sequence

1. InstantiateVnf
2. NOTIFY\text{(start, InstantiateVnf)}
3. GrantRequest\text{(InstantiateVnf, resourcePlan, constraints)}
4. GrantResponse\text{(OK, configParams)}
5. AllocateVirtNetworks
6. AllocateVirtCompute
7. AllocateVirtStorage
8. NOTIFY\text{(result, InstantiateVnf, allocatedResources)}
The lifecycle management operations and delegation of management tasks within the MANO architecture enables NFV to scale for very large networks.
Managing the VNF lifecycle: Generic VNFM

- One VNFM for all VNFs (from multiple vendors).
- VNF-related Multivendor integration interface: Ve-Vnfm (NFV-IFA 008).
- Provides standard basic management capabilities to all VNFs.
- Additionally, if required, VNF-specific management functionality is covered „lifecycle management scripts“ that are defined by the VNF vendor and included with the VNF package
  - Standardization of a universal scripting language for such scripts is future work.
  - Near-term Generic VNFM implementations may support a few existing scripting languages selected by the VNFM vendor, and VNF vendors have to adapt their VNFs to use one of the available languages.

Source: ETSI GS NFV-IFA 009
Managing the VNF lifecycle: VNFM specific to a set of VNFs

- A VNFM that can manage a particular set of VNFs.
- Typically, delivered by the VNF vendor together with the VNF.
- VNF-related multivendor integration interfaces: Vi-Vnfm (NFV-IFA006) towards VIM, Or-Vnfm (NFV-IFA007) towards NFVO. Interface towards VNF and EM may be proprietary or based on NFV-IFA008.
- Allows the VNF vendor to encapsulate in a VNFM particular VNF-specific, complex or advanced lifecycle management procedures.

Source: ETSI GS NFV-IFA 009
ETSI NFV specified interfaces and operations do not differentiate between whether the VNFM is generic or specific. Thus they are applicable to all types of VNFM.
PART 3
VNF PACKAGE AND NSD INTERFACES
ETSI NFV has created a set of standards to facilitate multi-vendor OSS/BSS interaction with the NFVO.
**Os-Ma-nfvo Reference Point**

- **OSS/BSS**
  - **NFV-IFA013**
  - **NFV-SOL05* (API)**

- **Os-Ma-nfvo**
  - **NSD Management**
  - **VNF Package Management**

- **NFVO**
  - **NS LifeCycle Management**
  - **NS Performance Management**
  - **NS Fault Management**

- **VNFM**

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* Pre-publication stage – drafts available

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Over time new VNFs will be developed and existing VNFs superseded.

ETSI NFV has specified operations to enable the OSS/BSS to on-board VNF Packages to the NFVO and then manage the availability of these VNF Packages.
VNF Package management overview

The VNF Package Management interface allows the management of VNF Packages. The following operations are defined by ETSI GS NFV-IFA 013.

<table>
<thead>
<tr>
<th>Mandatory Operations</th>
<th>Explanation – Mandatory for NFVO to support</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-board VNF Package</td>
<td>On-board a VNF Package in the NFVO</td>
</tr>
<tr>
<td>Enable VNF Package</td>
<td>Enable a previously disabled VNF Package instance</td>
</tr>
<tr>
<td>Disable VNF Package</td>
<td>Disable a previously enabled VNF Package instance, preventing any further use for instantiation of new VNFs with this package</td>
</tr>
<tr>
<td>Delete VNF Package</td>
<td>Delete a VNF Package</td>
</tr>
<tr>
<td>Query On-boarded VNF Package Information</td>
<td>Obtain information about on-boarded VNF Packages</td>
</tr>
<tr>
<td>Fetch On-boarded VNF Package</td>
<td>Fetch a whole on-boarded VNF Package</td>
</tr>
<tr>
<td>Fetch On-boarded VNF Package Artifacts</td>
<td>Fetch selected artifacts contained in an on-boarded VNF package</td>
</tr>
<tr>
<td>Abort VNF Package deletion</td>
<td>Abort the deletion of a VNF Package that is in deletion pending state</td>
</tr>
<tr>
<td>Subscribe</td>
<td>For subscribing to notifications related to VNF Package management changes</td>
</tr>
<tr>
<td>Notify</td>
<td>For delivering notifications related to on-boarding of new VNF Package or of changes of VNF Packages</td>
</tr>
</tbody>
</table>
To enable a OSS/BSS to define a Network Service it must be able to describe its components and how they are interconnected.

This is achieved via a Network Service Descriptor (NSD).
The **Network Service Descriptor (NSD)** defined in NFV-IFA 014 and contains:

- Metadata for onboarding and NS management,
- References to **VNF Descriptor (VNFD)** for the VNFs that are part of this NS,
- References to **PNF Descriptor (PNFD)** for the PNFs that are part of this NS,
- References to **NSD for the nested NS** of this NS,
- **VNF Forwarding Graph Descriptor (VNFGD)** and **Network Forwarding Path Descriptor (NFPD)** describing the topology of the NS,
- **Virtual Link Descriptor (VLD)** used by NFVO to deploy Virtual Links.

The NS Descriptor is stored by the NFVO and can be accessed by OSS/BSS.
Physical Network Function Descriptors (PNFD) is defined in NFV-IFA 014 and enable on-boarding of PNFs.

It focuses on connectivity aspects only.

Physical Network Function Descriptor (PNFD) contains

• Metadata for onboarding PNF,
• Connection Point Descriptor (CPD) specifying how to connect PNFs to VLs.
Over time new Network Services will be developed and existing ones superseded.

ETSI NFV has specified operations to enable the OSS/BSS to on-board NS Descriptors to the NFVO and then manage their availability.
The NSD Management interface allows the management of NSDs and associated PNFDs.

Virtual Link Descriptors (VLDs) and VNF Forwarding Graph Descriptors (VNFFGDs) are considered as part of the NSD and handled along with it.

The following operations are defined by ETSI GS NFV-IFA 013.

<table>
<thead>
<tr>
<th>Mandatory Operations</th>
<th>Explanation – Mandatory for NFVO to support</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-board NSD</td>
<td>On-board an NSD in the NFVO</td>
</tr>
<tr>
<td>Enable NSD</td>
<td>Enable a previously disabled NSD instance</td>
</tr>
<tr>
<td>Disable NSD</td>
<td>Disable a previously enabled NSD instance, preventing any further use for instantiation of new network service with this descriptor</td>
</tr>
<tr>
<td>Update NSD</td>
<td>Update an already on-boarded NSD, creating a new version of the NSD</td>
</tr>
<tr>
<td>Delete NSD</td>
<td>Delete one or more NSDs</td>
</tr>
<tr>
<td>Query NSD</td>
<td>Obtain information about on-boarded NSDs</td>
</tr>
<tr>
<td>On-board PNFD</td>
<td>On-board a PNFD in the NFVO</td>
</tr>
<tr>
<td>Update PNFD</td>
<td>Update an already on-boarded PNFD, creating a new version of the PNFD</td>
</tr>
<tr>
<td>Delete PNFD</td>
<td>Delete one or more PNFDs</td>
</tr>
<tr>
<td>Query PNFD</td>
<td>Obtain information about on-boarded PNFDs</td>
</tr>
<tr>
<td>Subscribe</td>
<td>For subscribing to notifications related to NSD management changes</td>
</tr>
<tr>
<td>Notify</td>
<td>For delivering notifications related to NSD management changes</td>
</tr>
</tbody>
</table>
PART 4
NETWORK SERVICE
LIFECYCLE MANAGEMENT
Os-Ma-nfvo Reference Point

**OSS/BSS**

**NFV**

- NFV-IFA013
- NFV-SOL05* (API)

**NFVO**

- NS LifeCycle Management
- NS Performance Management
- NS Fault Management

**VNFM**

* Pre-publication stage – drafts available

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ETSI GS NFV-IFA011
VNF Package & VNFD

ETSI GS NFV-IFA014
NS Descriptor
Management and Orchestration (MANO) of Network Services and VNFs
For flexibility:

- Physical Network Functions and Virtual Network Functions may be combined in the same network service.
- NFV Network Services may be built in a modular manner, then combined in Composite Network Services.
What is a Network Service?  
A look inside

**NS**

- **VNF**
- **PNF**

*Composite NS*

- **VNF**
- **PNF**

- **Nested NS**

- **SAP**
- **VNF/PNF External Connection Point**

- **Virtual Link (Virtual Network)**
- **VNF Forwarding Graph**

- **NS** has constituent **VNFs** and **PNFs**
- **Composite NS** can have nested **NS** included as reference
- **Virtual Link (VL)** provides the connectivity between constituent **VNFs** and **PNFs**
- **VNF Forwarding Graph (VNFFG)** is composed of **Network Forwarding Paths (NFP)**, each one as a sequence of connection points and a classification and selection rule.
- **A NS** has **Service Access Points (SAP)** used to access the **NS** from the outside
In managing Network Services the NFVO maintains a detailed view of each deployed Network Service.

This information can be accessed by the OSS/BSS.
Managing the NS lifecycle: NS runtime information

The runtime information of each NS instance, is managed by the NFVO. NsInfo, is a subset of this information, which the NFVO exposes via ETSI GS NFV-IFA 013.

The NsInfo element includes information such as:

- NS instance identifier, NS instance state,
- Metadata (associated NSD, NS Flavour),
- Information on constituent VNFs of this NS,
- Information on the PNFs that are part of this NS,
- Information on nested NSs of this NS,
- Information on the SAPs of this NS,
- Connectivity (Virtual Links, VNF Forwarding Graphs)
- Instantiation state (NS is instantiated or not)
- Scale status (current „size“ of NS),
- Additional affinity or anti-affinity rules, provided at NS instantiation time, applicable between the VNF instances (either existing or to be instantiated) of the NS.
A full suite of operations is specified to enable the OSS/BSS to instantiate, query, modify and delete Network Services.
### Mandatory Operations*

<table>
<thead>
<tr>
<th>Operation</th>
<th>Explanation – Mandatory for support by NFVO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantiate NS</td>
<td>Instantiate an NS. References to existing VNF instances and NS instances can be used.</td>
</tr>
<tr>
<td>Scale NS</td>
<td>Scale an NS instance.</td>
</tr>
<tr>
<td>Heal NS</td>
<td>Heal an NS instance (various options on method)</td>
</tr>
<tr>
<td>Update NS</td>
<td>Update an NS instance. This operation is also used in support of fine grained NS LCM.</td>
</tr>
<tr>
<td>Query NS</td>
<td>Obtain runtime information about the NS instances.</td>
</tr>
<tr>
<td>Terminate NS</td>
<td>Terminate an NS.</td>
</tr>
<tr>
<td>Get Operation Status</td>
<td>Provide the status of an NS lifecycle management operation</td>
</tr>
<tr>
<td>Subscribe</td>
<td>For subscribing to notifications related to NS lifecycle changes.</td>
</tr>
<tr>
<td>Notify</td>
<td>For delivering notifications related to NS lifecycle changes, creation/deletion of NS instance identifiers and the associated NsInfo information element instances.</td>
</tr>
<tr>
<td>Terminate Subscription</td>
<td>Terminate a particular subscription</td>
</tr>
<tr>
<td>Query Subscription</td>
<td>Obtain information about existing subscription</td>
</tr>
</tbody>
</table>

### Optional Operations

<table>
<thead>
<tr>
<th>Operation</th>
<th>Explanation – Optional for NFVO to support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto-Scale</td>
<td>Variants of Scale NS triggered automatically in the NFVO, based on auto-scaling rules defined in the NSD</td>
</tr>
</tbody>
</table>

* See ETSI GS NFV-IFA 013 for comprehensive list of operations
PART 5
CONCLUSION
This tutorial has ...

- provided an overview of the main NFV concepts, MANO architecture, interfaces and functional blocks, briefly touched the different deployment options of the VNF Manager.
- outlined what a VNF is, how a VNF is structured and packaged, what the role and composition of the VNF descriptor is and how the descriptions in it relate to the management of the lifecycle of a VNF,
- introduced how the lifecycle of a VNF is managed by its VNF Manager, which are the main lifecycle management operations, and what the typical call flow of a lifecycle management operation looks like, and
- briefly touched the different deployment options of the VNF Manager.
- presented the interfaces used to on-board NS Descriptors and VNF Package
- outlined what a Network Service is, how a NS is structured, what the role and composition of the NS descriptor is and how the descriptions in it relate to the management of the lifecycle of a NS,
- introduced how the lifecycle of a NS is managed by the NFVO, which are the main lifecycle management operations,