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 A YANG Module for uCPE management.

Abstract

This document provides a YANG data model for uCPE management (VYSM) and definition of the uCPE equipment. The YANG Model serves as a base framework for managing an universal Customer-Premises Equipment (uCPE) subsystem. The model can be used by a Network Orchestrator.

Status of This Memo

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1. Introduction

Network Function Virtualization is a technology that allows to virtualize the network services running on dedicated hardware. This technology became a base for universal Customer-Premises Equipment (uCPE). This document defines the uCPE as hardware with x86 capabilities that has a hypervisor. In other words, uCPE is a host that may run multiple Virtual Machines with guest OSs, where each Guest OS may represent a Physical Network Function. This document presents the YANG Model (VYSM) to manage from an Orchestrator the infrastructure inside the uCPE.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [[RFC2119](#)].

Link - is an entity that enables link layer communication of nodes.

Port - node connector to the link.

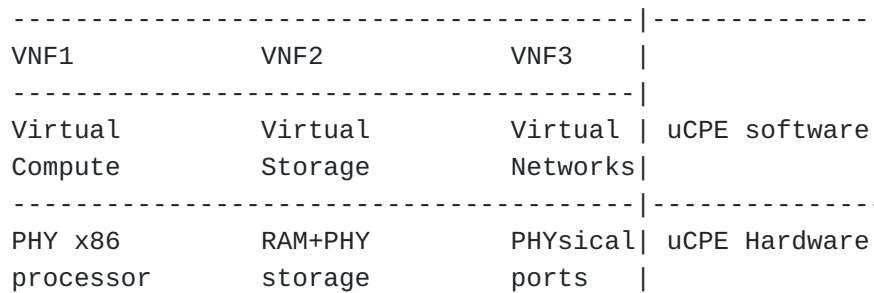
NE - Network Element.

NSYM - Network Yang Module.

VYSM - VNF YANG Model.

3. Universal CPE

Firstly, this document defines the platform that is controlled with VYSM - universal CPE (uCPE). The uCPE as hardware with x86 capabilities that is generally running Linux distribution with additional virtualization layer. Virtualization layer provides virtual compute, virtual storage and virtual network resources. Each VNF running in the uCPE requires the amount of virtual resources (for example: 4 vCPUs, 4GB RAM, 40GB storage, 4 vPorts). VNFs MAY be interconnected between each other and physical ports via Virtual Networks. Topology construction and VM life-cycle management is allowed via high level interface (Configuration can be done in the same transaction). The figure below presents the uCPE architecture.



The next elements can be managed in the uCPE:

*Virtual Network Functions:

- Number of assigned vCPUs.
- Size of allocated RAM.
- VNF day0 config (bootstrap).
- vLinks that are attached to the VNF.

*Virtual Switches:

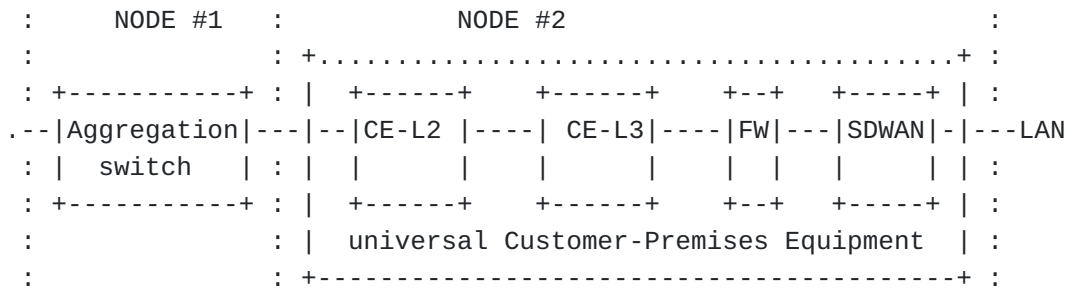
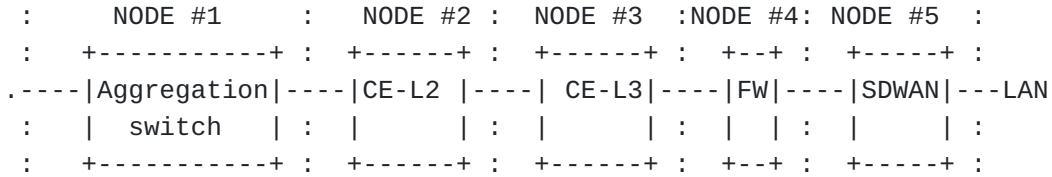
- vLinks that are attached to the vSW.

*Virtual Links(vLinks).

*Physical Ports of the uCPE.

3.1. uCPE purpose

*uCPE replaces multiple types of equipment (Node#1 - Node#5) with 1 unit by virtualizing them as Virtual Network Functions on the top of NFVIs:



*uCPE facilitates the interconnection between the Network Functions (NF) as interconnection between NF is performed via virtual links(that is part of the uCPE management). That means that no need to hire technician to cable the equipment, it could be done via orchestrator.

*uCPE facilitates the 0day configuration of the VNFs as its 0day configuration can be putted remotely.

3.2. uCPE VNF ecosystem example

uCPE supports a Virtual Network Functions of different type:

- *SD-WAN
- *vRouter
- *vFirewall
- *vLB(vLoad Balancer)
- *vCGNAT(vCarrier Grade NAT)
- *virtual WAN Optimistaion

*vWireless LAN controller

*Other...

3.3. Internal uCPE service example

The VNF in the uCPE could be a vRouter or vFirewall or an SD-WAN that is not a default part of virtual network resources of the uCPE. Multiple VNFs MAY be instantiated in the uCPE. With support of links and switches, VNFs MAY participate a service chains. Example of service chains (Note that virtual switch "vs(WAN)" connected to LAN ports and vSW(WAN) is connected to WAN ports):

*vSW(WAN)-l1-vRouter-l2-vSW(LAN).

*vSW(WAN)-l1-vRouter-l2-vSW(Service)-l3-vFirewall-l4-vSW(LAN).

*vSW(WAN)-l1-vRouter-l2-vSW(Service1)-l3-vFirewall-l4-vSW(Service2)-l5-SD-WAN-l6-vSW(LAN).

*vSW(WAN)-l1-SDWAN-l2-vSW(Service)-l3-vFirewall-l4-vSW(LAN).

*

```
vSW(WAN1)--vRouter--+
                        +--vLoadBalance  vFirewall--vSW(LAN)
vSW(WAN2)--vRouter--+  |                    |
                        +-vSW(Service1)+
```

*

```
vSW(WAN1)--vRouter(ISP1)---+
                        +---SD-WAN          vFirewall--vSW(LAN)
vSW(WAN2)--vRouter(ISP2)---+  |                    |
                        +-vSW(Service1)+
```

4. YANG Model for uCPE management

Secondly, this document defines and classifies the YANG Model for uCPE Management. This Module is modeled representation of the specific network requirements. It provides abstraction of network configuration and operations. The YANG Model for uCPE Management does not describe all configuration to be performed on the devices, but provides the configuration that is required for the "Network to Network Element(s)" decomposition process [RFC 8199](#) [[RFC8199](#)]. Example of the decomposition is presented in the figure below.

The Network YANG module exposes the configuration commands via the Northbound interfaces of the orchestrator. Therefore the set of the commands modeled in the VYSM can be inputted via Northbound

interfaces(for example CLI). In the example the command "vm VNF1" is passed via Northbound interface to the orchestrator. It defines the virtual machine name. Further the same configuration MAY be transformed to the one or multiple Network Element payloads (for example xml for NETCONF) that carry an equivalent of commands such as "nf nf-name VNF1"

```

+--+--+--+--+--+--+--+--+
|                                |
|  config t                      |
|      vm VNF1                   |
|                                |
+--+--+--+--+--+--+--+--+
#
#
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
:
:  +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
:  |  Network YANG Module          | <= scope of this document  :
:  +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
:
:      #
:      #####
:      #          #          #
:
:  '-----' '-----' '-----'
:  'Module1  ' ' Module 2  ' ' Module3  '      :
:  '-----' '-----' '-----'      :
:
:      #          #          #
:      #          #          #####
:      #####          #####          #
:      #          #          #
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
#          #          #
Network # element 1      Network # element 2      Network # element3
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
| domains domain VNF1| |tenants tenant name VNF1| |nf nf-name VNF1|
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+

```

5. Components for uCPE Management

This section provides a components overview to manage the uCPE.

There are multiple RFCs and drafts produced by the IETF community, that are referenced in the YANG tree to manage the uCPE. Each document produced by the IETF covers a part of uCPE Management. The list of the documents is provided below:

*[[RFC8530](#)] - logical network elements (VNFs) properties.

*[\[RFC8345\]](#) - definition of networks, nodes, node-termination-points: network includes the uCPE with uCPE's physical termination points.

*[\[I-D.ietf-teas-sf-aware-topo-model\]](#) physical ports and service functions (VNFs) interconnection matrices (PhyPort-VNF, VNF-VNF).

*This document itself provides yang modules that completes the existing documents produced by IETF.

This document introduces yang modules for 'logical network elements properties(VNFs)' part:

*day0-info: mapping between variables inside of the bootstrap config and required values in the list "day0-info". In the bootstrap config the variable could be putted instead value. The value could be set in the day0-info part (check the YANG model) and after the value in the list will be mapped to the variable in the bootstrap config.

*vCPU/vRAM/vDisk/VNF-ports leafs and lists.

The minimal list of yang models required for compilation of the YANG tree to manage the uCPE is presented below:

*ieee-dot1q-types

*ietf-interfaces

*ietf-ip

*ietf-logical-network-element

*ietf-network

*ietf-network-instance

*ietf-ietf-network-topology

*ietf-routing-types

*ietf-te-topology

*ietf-te-topology-sf

*ietf-te-types

*ietf-yang-schema-mount

*etsi-sol-006-deviation

*The YANG modules introduced in this document:

- * -ietf-ucpe-lne-properties
- ietf-ucpe-lt-virtual-link-id
- ietf-ucpe-ni-properties
- ietf-ucpe-node-type

6. Set of YANG Models

This section provides a YANG models that address uCPE network service resources management organized according to the ID [[I-D.ietf-netmod-yang-packages](#)]

<CODE BEGINS> file "ietf-ucpe-network-service-pkg.json"

===== NOTE: '\' line wrapping per BCP XX (RFC XXXX) =====

```
{
  "ietf-yang-instance-data:instance-data-set": {
    "name": "ietf-ucpe-network-service-pkg",
    "pkg-schema": {
      package: "ietf-yang-package-defn-pkg@0.1.0.json"
    },
    "description": "YANG package for universal CPE network service",
    "content-data": {
      "ietf-yang-package-instance:yang-package": {
        "name": "ietf-ucpe-network-service-pkg",
        "version": "0.0.1",
        "timestamp": "2021-09-09T17:00:00Z",
        "organization": "IETF OPSAWG Working Group",
        "contact" : "WG Web:  <http://tools.ietf.org/wg/opsawg/>, \
                    WG List: <mailto:opsawg@ietf.org>, \
                    Author:  <mailto:ietf.dmytro@shytyi.net>",
        "description": "IETF uCPE network service YANG package.\
          \
          This package defines a small sample set of \
          YANG modules that could represent the basic set of \
          modules that a standard universal CPE device might be \
          expected \
          to support.",
        "reference": "XXX, draft-shytyi-opsawg-vysm-10.xml",
        "location": [ "https://github.com/dmytroshytyi/ucpe-ietf/\
                    ietf-ucpe-service@v0.0.1.json" ],
        "module": [
          {
            "name": "ieee-dot1Q-types",
            "revision": "2015-08-18",
            "location": [ "/https://github.com/dmytroshytyi/\
            ucpe-ietf/blob/master/ieee-dot1Q-types.yang" ],
          },
          {
            "name": "ietf-interfaces",
            "revision": "2018-02-20",
            "location": [ "https://github.com/dmytroshytyi/\
            ucpe-ietf/blob/master/\
            ietf-interfaces%402018-02-20.yang" ],
          },
          {
            "name": "ietf-ip",
            "revision": "2018-02-22",
            "location": [ "https://github.com/dmytroshytyi/ucpe-ietf\
```

```
    /blob/master/ietf-ip%402018-02-22.yang" ],
  },
  {
    "name": "ietf-logical-network-element",
    "revision": "2019-01-25",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-logical-network-element%402019-01-25.yang" ],
  },
  {
    "name": "ietf-network",
    "revision": "2018-02-26",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-network%402018-02-26.yang" ],
  },
  {
    "name": "ietf-network-instance",
    "revision": "2019-01-21",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-network-instance%402019-01-21.yang" ],
  },
  {
    "name": "ietf-network-topology",
    "revision": "2018-02-26",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-network-topology%402018-02-26.yang" ],
  },
  {
    "name": "ietf-routing-types",
    "revision": "2017-12-04",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-routing-types%402017-12-04.yang" ],
  },
  {
    "name": "ietf-te-topology",
    "revision": "2019-02-07",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-te-topology%402019-02-07.yang" ],
  },
  {
    "name": "ietf-te-topology-sf",
    "revision": "2019-11-03",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
```

```
    ietf-te-topology-sf%402019-11-03.yang" ],
  },
  {
    "name": "ietf-te-types",
    "revision": "2019-11-18",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-te-types%402019-11-18.yang" ],
  },
  {
    "name": "ietf-ucpe-lne-properties",
    "revision": "2019-11-21",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-ucpe-lne-properties%402019-11-21.yang" ],
  },
  {
    "name": "ietf-ucpe-lt-virtual-link-id",
    "revision": "2020-02-14",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-ucpe-lt-virtual-link-id%402020-02-14.yang" ],
  },
  {
    "name": "ietf-ucpe-ni-properties",
    "revision": "2019-11-27",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-ucpe-ni-properties%402019-11-27.yang" ],
  },
  {
    "name": "ietf-ucpe-node-type",
    "revision": "2020-02-14",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-ucpe-node-type%402020-02-14.yang" ],
  },
  {
    "name": "ietf-ucpe-ni-properties",
    "revision": "2019-11-27",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
ietf-ucpe-ni-properties%402019-11-27.yang" ],
  },
  {
    "name": "ietf-yang-schema-mount",
    "revision": "2019-01-14",
    "location": [ "https://github.com/dmytroshytyi/\
ucpe-ietf/blob/master/\
```

```
    ietf-yang-schema-mount%402019-01-14.yang" ],
  },
  {
    "name": "etsi-nfv-common-deviation",
    "revision": "2020-06-10",
    "location": [ "https://github.com/dmytroshyti/\
ucpe-ietf/blob/master/\
submodules/etsi-nfv-common-deviation.yang" ],
  },
  {
    "name": "etsi-nfv-vnf-deviation",
    "revision": "2020-06-10",
    "location": [ "https://github.com/dmytroshyti/\
ucpe-ietf/blob/master/\
submodules/etsi-nfv-vnf-deviation.yang" ],
  }
]
}
}
```

<CODE ENDS>

7. Diagram overview of YANG Data Model tree for uCPE management

This section provides an overview of the Data YANG Model that MAY be made with "pyang" utility. The figure below presents the tree diagram.

```

module: ietf-logical-network-element
+--rw logical-network-elements
  +--rw logical-network-element* [name]
    +--rw name string
    +--rw managed? boolean
    +--rw description? string
    +--rw root
    +--rw ietf-ucpe:logical-network-element-properties
      +--rw ietf-ucpe:etsi
        | +--rw ietf-ucpe:vnfd? -> /nfv/vnfd/id
        | +--rw ietf-ucpe:vdu? -> /nfv/vnfd[id=current()]\
          | /../vnfd]/vdu/id
      +--rw ietf-ucpe:supporting-node? -> /nw:networks\
        | /network/node/node-id
      +--rw ietf-ucpe:uuid? enumeration
      +--rw ietf-ucpe:uuid-custom-value? string
      +--rw ietf-ucpe:persistence-id? string
      +--rw ietf-ucpe:pci-passthrough
        | +--rw ietf-ucpe:device* [device-name]
        |   +--rw ietf-ucpe:device-name string
        |   +--rw ietf-ucpe:vendor-id? string
        |   +--rw ietf-ucpe:device-id? string
        |   +--rw ietf-ucpe:device-index? int64
      +--rw ietf-ucpe:sf-cp-params* [sf-connection-point-id]
        | +--rw ietf-ucpe:sf-connection-point-id string
        | +--rw ietf-ucpe:io-acceleration
        | | +--rw ietf-ucpe:interface-type? enumeration
        | | +--rw ietf-ucpe:interface-model? enumeration
        | | +--rw ietf-ucpe:number-of-queues? uint64
        | +--rw ietf-ucpe:mac-params
        |   +--rw ietf-ucpe:mac-type? enumeration
        |   +--rw ietf-ucpe:custom-mac-address? string
      +--rw ietf-ucpe:simplified-lne-props
        | +--rw ietf-ucpe:sf-connection-points* \
          | [sf-connection-point-id]
          | | +--rw ietf-ucpe:sf-connection-point-id string
        | +--rw ietf-ucpe:ram? uint64
        | +--rw ietf-ucpe:cpu? uint64
        | +--rw ietf-ucpe:storages* [id]
        |   +--rw ietf-ucpe:id string
        |   +--rw ietf-ucpe:location? string
      +--rw ietf-ucpe:day0-config
        +--rw ietf-ucpe:location? string
        +--rw ietf-ucpe:day0-var-path? string
        +--rw ietf-ucpe:variable* [name]
          +--rw ietf-ucpe:name string
          +--rw ietf-ucpe:value? string

```

```

module: ietf-network

```

```

+--rw networks
  +--rw network* [network-id]
    | +--rw network-id                network-id
    | +--rw network-types
    | | +--rw tet:te-topology!
    | |   +--rw tet-sf:sf!
    | +--rw supporting-network* [network-ref]
    | | +--rw network-ref    -> /networks/network\
    | |                       /network-id
    | +--rw node* [node-id]
    | | +--rw node-id                node-id
    | | +--rw supporting-node* [network-ref node-ref]
    | | | +--rw network-ref    -> ../../../supporting\
    | | |                       -network/network-ref
    | | | +--rw node-ref        -> /networks/network\
    | | |                       /node/node-id
    | | +--rw nt:termination-point* [tp-id]
    | | | +--rw nt:tp-id                tp-id
    | | | +--rw nt:supporting-termination-point* \
    | | |   [network-ref node-ref tp-ref]
    | | | | +--rw nt:network-ref    -> ../../../\
    | | | |   nw:supporting-node/network-ref
    | | | | +--rw nt:node-ref        -> ../../../\
    | | | |   nw:supporting-node/node-ref
    | | | | | +--rw nt:tp-ref        -> \
    | | | | |   /nw:networks/network[nw:network-id=current()]/ \
    | | | | |   ../../network-ref]/node[nw:node-id=current()]/\
    | | | | |   ../node-ref]/termination-point/tp-id
    | | +--rw tet:te-node-id?                te-types:te-node-id
    | | +--rw tet:te!
    | | | +--rw tet:te-node-template*        -> ../../../../\
    | | |   /te/templates/node-template\
    | | |   /name {template}?
    | | | +--rw tet:te-node-attributes
    | | | | +--rw tet-sf:service-function
    | | | | | +--rw tet-sf:connectivity-matrices
    | | | | | | +--rw tet-sf:connectivity-matrix* [id]
    | | | | | | | +--rw tet-sf:id                uint32
    | | | | | | | +--rw tet-sf:from
    | | | | | | | | +--rw tet-sf:service-function-id?    string
    | | | | | | | | +--rw tet-sf:sf-connection-point-id? string
    | | | | | | | | +--rw tet-sf:to
    | | | | | | | | | +--rw tet-sf:service-function-id?    string
    | | | | | | | | | +--rw tet-sf:sf-connection-point-id? string
    | | | | | | | | +--rw tet-sf:enabled?                boolean
    | | | | | | | | +--rw tet-sf:direction? \
    | | | | | | | |   connectivity-direction
    | | | | | | | | +--rw tet-sf:virtual-link-id?    string
    | | | | | +--rw tet-sf:link-terminations

```

```

| | | | +--rw tet-sf:link-termination* [id]
| | | |   +--rw tet-sf:id                               uint32
| | | |   +--rw tet-sf:from
| | | |   | +--rw tet-sf:tp-ref?  -> ../../../../../../\
| | | |   |   ../../nt:termination-point/tp-id
| | | |   +--rw tet-sf:to
| | | |   | +--rw tet-sf:service-function-id?  \
| | | |   |   string
| | | |   | +--rw tet-sf:sf-connection-point-id? \
| | | |   |   string
| | | |   +--rw tet-sf:enabled?                    boolean
| | | |   +--rw tet-sf:direction?                  \
| | | |   connectivity-direction
| | | |   +--rw lt-vlink-id:virtual-link-id?      string

```

module: ietf-network-instance

```

+--rw network-instances
  +--rw network-instance* [name]
    +--rw name                                     string
    +--rw enabled?                                boolean
    +--rw description?                             string
    +--rw (ni-type)?
    +--rw (root-type)
      +--:(vrf-root)
        | +--rw vrf-root
      +--:(vsi-root)
        | +--rw vsi-root
        | +--rw ietf-ucpe-ni:network-instance-properties
        |   +--rw ietf-ucpe-ni:sf-connection-points* \
        |     [sf-connection-point-id]
        |   | +--rw ietf-ucpe-ni:sf-connection-point-id  string
        |   | +--rw ietf-ucpe-ni:stacked-vlans
        |   | | +--rw ietf-ucpe-ni:outer-VLAN-0x8100?  \
        |   | |   d1q:vid-range
        |   | | +--rw ietf-ucpe-ni:inner-VLANs-0x8100*  uint16
        |   | +--rw ietf-ucpe-ni:QinQ
        |   | | +--rw ietf-ucpe-ni:svlan-0x88a8?      d1q:vid-range
        |   | | +--rw ietf-ucpe-ni:cvlans-0x8100*     uint16
        |   | +--rw ietf-ucpe-ni:dot1q-vlan
        |   | +--rw ietf-ucpe-ni:access-tag?          \
        |   |   d1q:vid-range
        |   | +--rw ietf-ucpe-ni:trunk-allowed-vlans* \
        |   |   uint16
        |   | +--rw ietf-ucpe-ni:port-mode?          \
        |   |   enumeration
        |   +--rw ietf-ucpe-ni:io-acceleration
        |   | +--rw ietf-ucpe-ni:dppk
        |   | | +--rw ietf-ucpe-ni:rx-queues?      uint16

```

```

|      | | +-rw ietf-ucpe-ni:tx-queues? uint16
|      | | +-rw ietf-ucpe-ni:cpu-mask?  uint16
|      | +-rw ietf-ucpe-ni:ebpf-xdp
|      +-rw ietf-ucpe-ni:ni-area?        identityref
|      +-rw ietf-ucpe-ni:supporting-node? -> \
|                                     /nw:networks\
|                                     /network/node/node-id
+--:(vv-root)
+--rw vv-root

```

module: ietf-ucpe-lne-properties

```

+--rw nfv
+--rw vnf* [id]
+--rw id                string
+--rw provider          string
+--rw product-name     string
+--rw software-version string
+--rw version          string
+--rw product-info-name? string
+--rw product-info-description? string
+--rw vnf-info*        string
+--rw localization-language? string
+--rw default-localization-language? string
+--rw vdu* [id]
| +-rw id                string
| +-rw name              string
| +-rw description?     string
| +-rw int-cpd* [id]

```

etc... Following ETSI SOL006

8. Security Considerations

At this time, no security considerations are addressed by this memo.

9. IANA Considerations

No request to IANA at this time.

10. Acknowledgements

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*Bo Wu.

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Appendix A. Example of the uCPE resources management

This section provides an overview of the YIN format.

```

<networks xmlns="urn:ietf:params:xml:ns:yang:ietf-network">
  <network>
    <network-id>network-1</network-id>
    <network-types>
      <te-topology xmlns="urn:ietf:params:xml:ns:yang:ietf-te-topology">
        <sf xmlns="urn:ietf:params:xml:ns:yang:ietf-te-topology-sf"/>
      </te-topology>
    </network-types>
    <node>
      <node-id>ucpe1</node-id>
      <te-node-id xmlns="urn:ietf:params:xml:ns:yang:ietf-te-topology" \
        >0.0.0.0</te-node-id>
      <te xmlns="urn:ietf:params:xml:ns:yang:ietf-te-topology">
        <te-node-attributes>
          <service-function
            xmlns="urn:ietf:params:xml:ns:yang:ietf-te-topology-sf">
            <connectivity-matrices>
              <connectivity-matrix>
                <id>1</id>
                <from>
                  <service-function-id>VMone</service-function-id>
                  <sf-connection-point-id>1</sf-connection-point-id>
                </from>
                <to>
                  <service-function-id>SwitchOne</service-function-id>
                  <sf-connection-point-id>11</sf-connection-point-id>
                </to>
                <virtual-link-id>l11</virtual-link-id>
              </connectivity-matrix>
              <connectivity-matrix>
                <id>2</id>
                <from>
                  <service-function-id>VMtwo</service-function-id>
                  <sf-connection-point-id>1</sf-connection-point-id>
                </from>
                <to>
                  <service-function-id>SwitchOne</service-function-id>
                  <sf-connection-point-id>12</sf-connection-point-id>
                </to>
                <virtual-link-id>l12</virtual-link-id>
              </connectivity-matrix>
              <connectivity-matrix>
                <id>3</id>
                <from>
                  <service-function-id>VMthree</service-function-id>
                  <sf-connection-point-id>1</sf-connection-point-id>
                </from>
                <to>

```

```

        <service-function-id>SwitchOne</service-function-id>
        <sf-connection-point-id>13</sf-connection-point-id>
    </to>
    <virtual-link-id>l13</virtual-link-id>
</connectivity-matrix>
<connectivity-matrix>
    <id>4</id>
    <from>
        <service-function-id>VMfour</service-function-id>
        <sf-connection-point-id>1</sf-connection-point-id>
    </from>
    <to>
        <service-function-id>SwitchOne</service-function-id>
        <sf-connection-point-id>14</sf-connection-point-id>
    </to>
    <virtual-link-id>l14</virtual-link-id>
</connectivity-matrix>
</connectivity-matrices>
</service-function>
</te-node-attributes>
</te>
</node>
</network>
</networks>

<logical-network-elements \
    xmlns="urn:ietf:params:xml:ns:yang:ietf-logical-network-element">
<logical-network-element>
    <name>VMfour</name>
    <logical-network-element-properties \
        xmlns="urn:ietf:params:xml:ns:yang:ietf-ucpe-lne-properties">
        <sf-connection-points>
            <sf-connection-point-id>1</sf-connection-point-id>
        </sf-connection-points>
        <supporting-node>ucpe1</supporting-node>
        <ram>1024</ram>
        <cpu>4</cpu>
        <storages>
            <id>1</id>
            <location>vm4.qcow2</location>
        </storages>
    </logical-network-element-properties>
</logical-network-element>
<logical-network-element>
    <name>VMone</name>
    <logical-network-element-properties \
        xmlns="urn:ietf:params:xml:ns:yang:ietf-ucpe-lne-properties">
        <sf-connection-points>
            <sf-connection-point-id>1</sf-connection-point-id>

```

```

    </sf-connection-points>
    <supporting-node>ucpe1</supporting-node>
    <ram>1024</ram>
    <cpu>4</cpu>
    <storages>
      <id>1</id>
      <location>vm1.qcow2</location>
    </storages>
  </logical-network-element-properties>
</logical-network-element>
<logical-network-element>
  <name>VMthree</name>
  <logical-network-element-properties \
    xmlns="urn:ietf:params:xml:ns:yang:ietf-ucpe-lne-properties">
    <sf-connection-points>
      <sf-connection-point-id>1</sf-connection-point-id>
    </sf-connection-points>
    <supporting-node>ucpe</supporting-node>
    <ram>1024</ram>
    <cpu>4</cpu>
    <storages>
      <id>1</id>
      <location>vm3qcow2</location>
    </storages>
  </logical-network-element-properties>
</logical-network-element>
<logical-network-element>
  <name>VMtwo</name>
  <logical-network-element-properties \
    xmlns="urn:ietf:params:xml:ns:yang:ietf-ucpe-lne-properties">
    <sf-connection-points>
      <sf-connection-point-id>1</sf-connection-point-id>
    </sf-connection-points>
    <supporting-node>ucpe1</supporting-node>
    <ram>1024</ram>
    <cpu>4</cpu>
    <storages>
      <id>1</id>
      <location>vm4.iso</location>
    </storages>
  </logical-network-element-properties>
</logical-network-element>
</logical-network-elements>
<network-instances \
  xmlns="urn:ietf:params:xml:ns:yang:ietf-network-instance">
  <network-instance>
    <name>SwitchOne</name>
    <network-instance-properties \
      xmlns="urn:ietf:params:xml:ns:yang:ietf-ucpe-ni-properties">

```

```

<sf-connection-points>
  <sf-connection-point-id>10</sf-connection-point-id>
    <dot1q-vlan>
      <trunk-allowed-vlans>112</trunk-allowed-vlans>
      <trunk-allowed-vlans>113</trunk-allowed-vlans>
      <trunk-allowed-vlans>114</trunk-allowed-vlans>
      <port-mode>trunk</port-mode>
    </dot1q-vlan>
</sf-connection-points>
<sf-connection-points>
  <sf-connection-point-id>11</sf-connection-point-id>
</sf-connection-points>
  <dot1q-vlan>
    <access-tag>111</access-tag>
  </dot1q-vlan>
<sf-connection-points>
  <sf-connection-point-id>12</sf-connection-point-id>
</sf-connection-points>
<sf-connection-points>
  <sf-connection-point-id>13</sf-connection-point-id>
</sf-connection-points>
<sf-connection-points>
  <sf-connection-point-id>14</sf-connection-point-id>
</sf-connection-points>
  <supporting-node>ucpe1</supporting-node>
</network-instance-properties>
</network-instance>
</network-instances>

```

Appendix B. Example of the uCPE resources management (deprecated)

This section provides an overview of the deprecated YANG Model that MAY give an alternative view on the uCPE management.

```

module: ietf-example-ucpe
  +--rw ucpe* [name]
    +--rw name          string
    +--rw links* [link]
      | +--rw link      string
    +--rw phyInterfaces* [interface]
      | +--rw interface  string
      | +--rw ports* [port]
        | +--rw port      string
        | +--rw link?    -> ../../../../links/link
    +--rw switches* [switch]
      | +--rw switch      string
      | +--rw ports* [port]
        | +--rw port      string
        | +--rw name?    string
        | +--rw link?    -> ../../../../links/link
    +--rw vms* [vm]
      +--rw vm            string
      +--rw ports* [port]
        | +--rw port      string
        | +--rw name?    string
        | +--rw link?    -> ../../../../links/link
      +--rw ram?         uint64
      +--rw cpu?         uint64
      +--rw storages* [id]
        | +--rw id        string
        | +--rw location? string
      +--rw day0-config
        +--rw location?   string
        +--rw day0-var-path? string
        +--rw variable* [name]
          +--rw name      string
          +--rw value?    string

```

Appendix C. Deprecated VNF YANG Model

This section provides a deprecated yang model that addresses the configuration of the uCPE resources presented above.

```
<CODE BEGINS> file "ietf-example-ucpe@2019-10-28.yang"
```

```
module ietf-example-ucpe {
  namespace "urn:ietf:params:xml:ns:yang:ietf-example-ucpe";
  prefix ietf-example-ucpe;

  organization
    "SFR";
  contact
    "Dmytro Shytyi
     EMail:ietf.dmytro@shytyi.net";
  description
    "This is a Network Function Virtualization (NFV) YANG
     service model.

     Copyright (c) 2019 IETF Trust and the persons identified as
     authors of the code. All rights reserved.

     Redistribution and use in source and binary forms, with or
     without modification, is permitted pursuant to, and subject to
     the license terms contained in, the Simplified BSD License set
     forth in Section 4.c of the IETF Trust's Legal Provisions
     Relating to IETF Documents
     (https://trustee.ietf.org/license-info).

     This version of this YANG module is part of RFC XXXX
     (https://www.rfc-editor.org/info/rfcXXXX); see the RFC itself
     for full legal notices."

  revision 2019-10-28 {
    description
      "Yang model with vPorts assigned to the interfaces";
    reference
      "draft-shytyi-opsawg-vysm-05";
  }
  revision 2019-10-19 {
    description
      "Yang model was cleaned. Interfaces added";
    reference
      "draft-shytyi-opsawg-vysm-04";
  }
  revision 2019-09-16 {
    description
      "Added 0day config for VNFs.
       Yang model modified according
       to the received comments.";
    reference
      "draft-shytyi-opsawg-vysm-00";
  }
}
```



```

revision 2018-01-07 {
  description
    "Initial revision.";
  reference
    "draft-shytyi-netmod-vysm-01";
}

list ucpe {
  key "name";
  leaf name {
    type string;
    description
      "ID of uCPE where
        a service is instantiated";
  }
  list links {
    key "link";
    leaf link {
      type string;
      description
        "Name of the virtual link from the pool
          of the links";
    }
  }
  description
    "Pool of the virtual links that connect VMs and
      Interfaces";
}

list phyInterfaces {
  key "interface";
  leaf interface {
    type string;
    description
      "Name of physical interface";
  }
}

list ports {
  key "port";
  leaf port {
    type string;
    description
      "Name of the connector";
  }
  leaf link {
    type leafref {
      path "../../../../../links/link";
    }
  }
  description
    "Link that is connected to
      the port via connector";
}

```

```

        description
            "Set of the connectors the
            physical interface has";
    }
    description
        "Set of physical interfaces";
}
list switches {
    key "switch";
    leaf switch {
        type string;
        description
            "Name of the forwarding domain";
    }
    list ports {
        key "port";
        leaf port {
            type string;
            description
                "Name of the connector";
        }
        leaf name {
            type string;
            description
                "Name of the
                subconnector";
        }
        leaf link {
            type leafref {
                path "../../links/link";
            }
            description
                "Link that is connected to the
                switch via port";
        }
        description
            "Set of the connectors the
            forwarding domain has";
    }
    description
        "Set of the forwarding domains";
}
list vms {
    key "vm";
    leaf vm {
        type string;
        description
            "ID of the Virtual Machine";
    }
}

```

```

list ports {
  key "port";
  leaf port {
    type string;
    description
      "Name of the connector";
  }
  leaf name {
    type string;
    description
      "Name of
        the subconnector";
  }
  leaf link {
    type leafref {
      path "../../links/link";
    }
    description
      "Link that connects the
        VM with a switch or Interface
        via connector";
  }
  description
    "Set of Virtual Machine connectors";
}
leaf ram {
  type uint64;
  description
    "Size of RAM to allocate for
      the Guest OS";
}
leaf cpu {
  type uint64;
  description
    "Number of vCPUs to
      allocate for the Guest OS";
}
list storages {
  key "id";
  leaf id {
    type string;
    description
      "Number of
        vDisk attached to the VM";
  }
  leaf location {
    type string;
    description
      "External location where

```

```

        the image (ex.qcow2) is saved.";
    }
    description
        "Virtual storage/vDisk
        attached to the Virtual Machine";
}
container day0-config {
    leaf location {
        type string;
        description
            "0day configuration location";
    }
    leaf day0-var-path {
        type string;
        description
            "path of the file
            that contains the 0day variables";
    }
    list variable {
        key "name";
        leaf name {
            type string;
            description
                "variable name";
        }
        leaf value {
            type string;
            description
                "variable value";
        }
        description
            "list of variables";
    }
    description
        "0day configuration:init config";
}
description
    "Set of the Virtual Machines configured
    on the universal Customer-Premises Equipment";
}
description
    "This is an uCPE management service";
}
}

```

<CODE ENDS>

Appendix D. XML example of deprecated YANG model

The XML example below presents the configuration of the next service in the uCPE, where: vSW(LAN), vSW(WAN), vSW(Service) - virtual switches; l1, l2, l3, l4 - virtual links; VMs represent PNFs (Physical Network Functions) that could be bootstrapped with 0day config/license.

```
+-----+      +-----+      +-----+
|vSW(LAN)|--l2--|VNF-vFirewall|--l3--|      |
+-----+      +-----+      |      |
+-----+      +-----+      |vSW(Service)|
|vSW(WAN)|--l1--|   VNF_vRtr   |--l4--|      |
+-----+      +-----+      +-----+
```

```
<ucpe xmlns="urn:ietf:params:xml:ns:yang:ietf-ucpe">
  <name>ucpe1</name>
  <links>
    <link>l1</link>
  </links>
  <links>
    <link>l2</link>
  </links>
  <links>
    <link>l3</link>
  </links>
  <links>
    <link>l4</link>
  </links>
  <switches>
    <switch>lan</switch>
    <ports>
      <port>10</port>
      <name>l2p10</name>
      <link>l2</link>
    </ports>
  </switches>
  <switches>
    <switch>service</switch>
    <ports>
      <port>10</port>
      <name>l3p10</name>
      <link>l3</link>
    </ports>
    <ports>
      <port>11</port>
      <name>l4p10</name>
      <link>l4</link>
    </ports>
  </switches>
  <switches>
    <switch>wan</switch>
    <ports>
      <port>10</port>
      <link>l1</link>
    </ports>
  </switches>
  <vms>
    <vm>VNF-vRtr</vm>
    <ports>
      <port>1</port>
      <name>l1p1</name>
      <link>l1</link>
    </ports>
  </vms>
</ucpe>
```

```
</ports>
<ports>
  <port>2</port>
  <name>l4p2</name>
  <link>l4</link>
</ports>
<ram>2048</ram>
<cpu>2</cpu>
<storages>
  <id>1</id>
  <location>http://192.168.2.1/vRtr-x86.qcow2</location>
</storages>
<day0-config>
  <location>https://192.168.2.1/vRtr-day0.iso</location>
  <day0-var-path>/config.rom</day0-var-path>
  <variable>
    <name>hostname</name>
    <value>IETF-vRtr</value>
  </variable>
  <variable>
    <name>ipaddress</name>
    <value>192.168.1.2 255.255.255.0</value>
  </variable>
</day0-config>
</vms>
<vms>
  <vm>VNF-vFirewall</vm>
  <ports>
    <port>1</port>
    <name>l3p1</name>
    <link>l3</link>
  </ports>
  <ports>
    <port>2</port>
    <name>l2p2</name>
    <link>l2</link>
  </ports>
  <ram>2048</ram>
  <cpu>2</cpu>
  <storages>
    <id>1</id>
    <location>http://192.168.2.1/vFirewall-x86.qcow2</location>
  </storages>
  <day0-config>
    <location>https://192.168.2.1/vFirewall-day0.iso</location>
    <day0-var-path>/config.rom</day0-var-path>
    <variable>
      <name>hostname</name>
      <value>vFirewall</value>
```

```
</variable>
<variable>
  <name>ipaddress</name>
  <value>192.168.1.3 255.255.255.0</value>
</variable>
</day0-config>
</vms>
</ucpe>
```

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