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Network Markup Language Base Schema version 1

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Abstract

This document describes a set of normative schemas which allow the description of computer network topologies.

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1 Introduction

This document describes the base schema of the Network Markup Language (NML). Section 2.1 defines the NML classes and their attributes and parameters. Section 2.2 describes the relations defined between NML classes.

A NML network description can be expressed in XML, RDF/XML and Turtle syntax. Section A describes the XSD schema for the XML syntax. Section B describes the OWL 2 schema for the RDF/XML and Turtle syntaxes.

These basic classes defined in this document may be extended, or sub-classed, to represent technology specific classes.

Section 4 provides example use cases. This section is informative. Only sections 2, 3, and appendices A and B are normative and considered part of the recommendation.

1.1 Scope

The Network Markup Language is designed to create a functional description of multi-layer networks (including virtualised networks) and multi-domain networks (including aggregated or abstracted networks). It can not only describe a static network topology, but also its capabilities and its configuration.

NML is aimed at logical connection-oriented network topologies. It can also be used to describe physical networks or packet-oriented networks, although the current base schema current version does not contain classes or properties to explicitly deal with signal degradation, or complex routing tables.

NML only attempts to describe the data plane of a computer network, not the control plane. It does contain extension mechanism to easily tie it with network provisioning standards and with network monitoring standards.

Finally, you will not find a definition for the terms *Network* or *capacity* in this document. This has been a conscious choice. The term *Network* has become so widely used for so many diverse meanings that it is impossible to create a definition that everyone can agree on, while still expressing something useful. See *Topology* for the concept of a network domain and a *Link* with multiple sources and sinks for the concept of a local area network. The term *capacity* is used by different technologies in such a different way (e.g. including or excluding the packet overhead) that it is better to let technology-specific extensions make an explicit definition.

1.2 Notational Conventions

The keywords “MUST”, “MUST NOT”, “REQUIRED”, “SHALL”, “SHALL NOT”, “SHOULD”, “SHOULD NOT”, “RECOMMENDED”, “MAY”, and “OPTIONAL” are to be interpreted as described in [RFC 2119].

This schema defines classes, attributes, relations, parameters and logic. Objects are instances of classes, and the type of an object is a class.

Names of classes are capitalised and written in italics (e.g. the *Node* class). Names of relations are written in camel case and in italics (e.g. the *hasNode* relations).

2 NML Base Schema

The NML Base schema describes an information model for computer networks. This schema is kept intentionally general, with provisions to extend the schema to describe layer-specific information.

The schema consists of classes, attributes, relations, and parameters. Classes describe types of objects and are described in section 2.1. Relations describe the relations between classes and are described in section 2.2. Attributes describe properties of classes. Attributes and parameters are described with their class description.

All classes, relations, attributes and parameters defined in this document have an identifier within the namespace `http://schemas.ogf.org/nml/2012/10/base#`.

2.1 Classes

Figure 1 shows an overview of all the classes in the NML schema in a UML class diagram. In the sections below we discuss each of the elements of the schema.

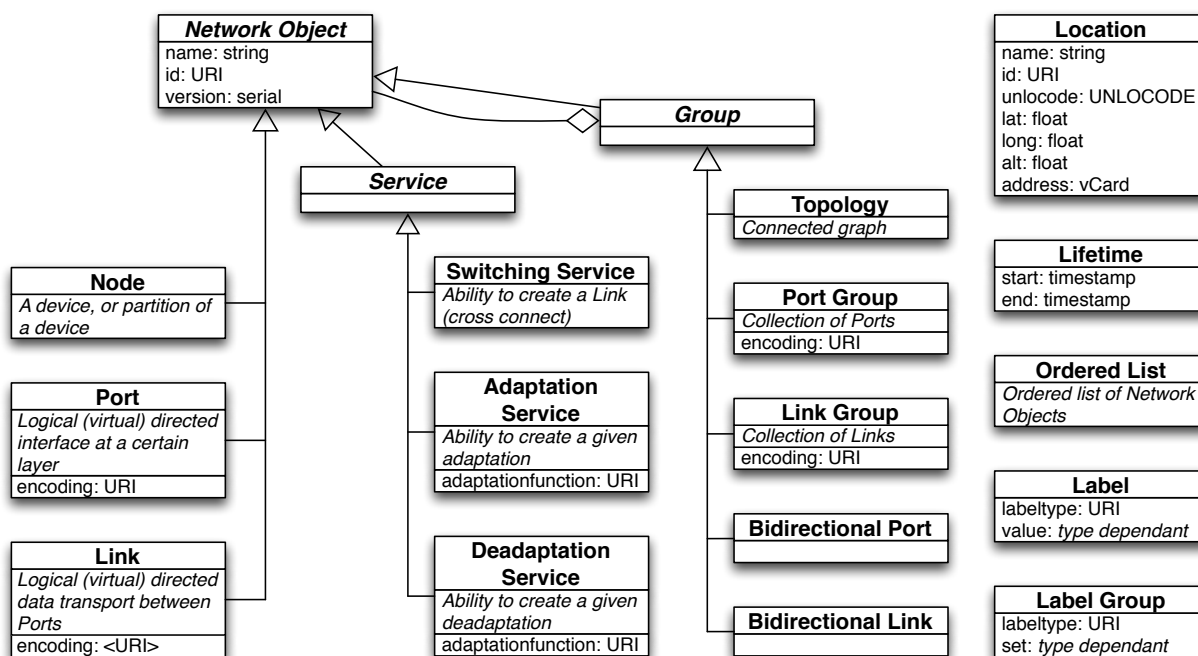


Figure 1: A UML class diagram of the classes in the NML schema and their hierarchy

2.1.1 Network Object

The basic abstract class of the schema is the *Network Object*. Most classes inherit from it.

Network Object is an abstract class. It MUST NOT be instantiated directly.

A *Network Object* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *isAlias* to one or more *Network Objects*
- *locatedAt* to one *Location*

A *Network Object* may have the following attributes:

- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string
- *version* to assign a time stamp

The meaning of the *isAlias* relation is only defined for specific cases (between objects of the same class), and MUST NOT be used between other objects.

The meaning of the *version* attribute is only defined for specific cases (in objects of the *Topology* class), and SHOULD NOT be used in other objects. Clients that receive a *version* attribute for a non-*Topology* object MAY ignore that attribute.

An *id* is a persistent, globally unique object identifier for the *Network Object*. Section 3 describes these identifiers in detail.

name is a human readable string. A name may be written in any language, but it is RECOMMENDED that names are chosen so that all users can easily distinguish between different names. Two objects MAY have the same name. It is RECOMMENDED to use short, descriptive names. A name MUST NOT be used for anything other than display purposes. Normal Unicode recommendations apply: A name MUST NOT contain control or formatting codepoint (anything in the Other categories), and it is RECOMMENDED to only use codepoints from the Basic Multilingual Plane (BMP).

version is a time stamp in ISO 8601 format. The time stamp can be used to publish updates of a *Topology*. If a client receives multiple *Topology* descriptions, each with a different version time stamp, the version with the latest time stamp in the past or present MUST be considered the valid description. *Topology* descriptions with a time stamp in the future MAY be discarded or cached until the denoted time. See also the *Lifetime* object to describe historic or future network changes.

The base *Network Object* is subclassed into the top-level topology components, that are sufficient to cover the description of networks. The classes in this schema that directly inherit from *Network Object* are:

- Node
- Port
- Link
- Service
- Group

These classes are described in more detail below.

2.1.2 Node

A *Node* is generally a device connected to, or part of, the network. A *Node* does not necessarily correspond to a physical machine. It MAY be a virtual device or a group of devices.

Node inherits from *Network Object*.

A *Node* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *hasInboundPort* to one or more *Ports* or *PortGroups*
- *hasOutboundPort* to one or more *Ports* or *PortGroups*
- *hasService* to one or more *Services* of type *Switch*
- *implementedBy* to one or more *Nodes*
- *isAlias* to one or more *Nodes*
- *locatedAt* to one *Location*

A *Node* may have the following attributes:

- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string

2.1.3 Port

A *Port* defines connectivity from a *Network Object* to the rest of the network. A *Port* object is unidirectional. A *Port* does not necessarily correspond to a physical interface. It represents a logical transport entity at a fixed place in the network.

Port inherits from *Network Object*.

A *Port* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *hasLabel* to one *Label*
- *hasService* to one or more *Services* of type *Adaptation* or type *Deadaptation*
- *isAlias* to one or more *Ports*
- *isSink* to one or more *Links*
- *isSource* to one or more *Links*

A *Port* may have the following attributes:

- *encoding* to assign a data encoding identifier
- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string

The *encoding* attribute defines the format of the data streaming through the Port. The identifier for the encoding can be user-defined, or can use a set of well-known layers that are identified on the workinggroup page[NML-LAYERS].

2.1.4 Link

A *Link* object describes a unidirectional data transport from each of its sources to all of its sinks.

A source of a Link is a Network Object that has a *isSource* relation to the Link. A sink of a Link is a Network Object that has a *isSink* relation to the Link.

Link inherits from *Network Object*.

A *Link* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *hasLabel* to one *Label*

- *isAlias* to one or more *Links*
- *isSerialCompoundLink* to one ordered *List* of *Links*

A *Link* may have the following attributes:

- *encoding* to assign a data encoding identifier
- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string

A *Link* may have the following parameter:

- *noReturnTraffic*. A value of **true** changes the definition of *Link* to: data transport from each sources to all sinks, except that there is no data transport from a source to a sink if the source and sink are grouped together in a *BidirectionalPort* group. The default value of *noReturnTraffic* is **false**.

2.1.5 Service

Service describes a capability of the network. That is, it describes how a configuration can be changed dynamically.

Service is an abstract class. It MUST NOT be instantiated directly.

Service inherits from *Network Object*. A *Service* may have the same relations, attributes and parameters as a *Network Object*.

This schema defines three different services, the *SwitchingService* the *AdaptationService* and the *DeadaptationService*. These are described in more detail below.

2.1.6 Switching Service

A *SwitchingService* describes the ability to create cross connects from its inbound *Ports* to its outbound *Ports*.

SwitchingService inherits from *Service*.

A *SwitchingService* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *hasInboundPort* to one or more *Ports* or *PortGroups*
- *hasOutboundPort* to one or more *Ports* or *PortGroups*
- *isAlias* to one or more *Switching Services*

- *providesLink* to one or more *Links* or *LinkGroups*.

A *SwitchingService* may have the following attributes:

- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string

A *SwitchingService* may have the following parameter:

- *labelSwapping*. A value of **false** adds a restriction to the *SwitchingService*: it is only able to create cross connects from an inbound *Port* to an outbound *Port* if the *Label* of the connected *Ports* has the same value. The default value is **false**.

The *providesLink* relation points to *Links* which describe the currently configured cross connects in a *SwitchingService*.

2.1.7 Adaptation Service

An *AdaptationService* describes the capability that data from one or more *Ports* can be embedded in the data encoding of one other *Port*. This is commonly referred to as the embedding of client layer (higher network layer) ports in a server layer (lower network layer) port. The *AdaptationService* describes a multiplexing adaptation function, meaning that different channels (the client layer ports) can be embedded in a single data stream (the server layer port).

Like *Port* and *Link*, *AdaptationService* describes a unidirectional transport function. For the inverse transport function, see *DeadaptationService*.

An *AdaptationServices* describe

AdaptationService inherits from *Service*.

An *AdaptationService* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *isAlias* to one or more *AdaptationServices*
- *providesPort* to one or more *Ports* or *PortGroups*

An *AdaptationService* may have the following attributes:

- *adaptationfunction* to assign an adaptation technology identifier
- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string

2.1.8 De-adaptation Service

A *DeadaptationService* describes the capability that data of one or more ports can be extracted from the data encoding of one other port. This is commonly referred to as the extraction of client layer (higher network layer) ports from the server layer (lower network layer) port. The *DeadaptationService* describes a multiplexing adaptation function, meaning that different channels (the client layer ports) can be extracted from a single data stream (the server layer port).

Like *Port* and *Link*, *AdaptationService* describes a unidirectional transport function. For the inverse transport function, see *AdaptationService*¹.

DeadaptationService inherits from *Service*.

A *DeadaptationService* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *isAlias* to one or more *DeadaptationServices*
- *providesPort* to one or more *Ports* or *PortGroups*

A *DeadaptationService* may have the following attributes:

- *adaptationfunction* to assign a adaptation technology identifier
- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string

2.1.9 Group

A *Group* describes a collections of objects. Any object can be part of a group, including another *Group*.

Group is an abstract class. It MUST NOT be instantiated directly.

Group inherits from *Network Object*. A *Group* may have the same relations, attributes and parameters as a *Network Object*.

This schema defines five different *Groups*:

- Topology

¹Whilst the *DeadaptationService* is an inverse of the *AdaptationService*, it should not be confused with an inverse multiplexing adaptation function. An inverse multiplexing adaptation function embeds a single data stream in multiple underlying data streams. To describe such a network, the experimental *parallelCompound* relation can be used, which is described in a separate document [Dijkstra13].

- Port Group
- Link Group
- Bidirectional Port
- Bidirectional Link

These classes are described in more detail below.

2.1.10 Topology

A *Topology*² is a set of connected *Network Objects*. *connected* means that there is, or it is possible to create, a data transport between any two Network Objects in the same Topology, provided that there are no policy, availability or technical restrictions.

A *Topology* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *hasNode* to one or more *Nodes*
- *hasInboundPort* to one or more *Ports* or *PortGroups*
- *hasOutboundPort* to one or more *Ports* or *PortGroups*
- *hasService* to one or more *Service* of type *Switch*
- *hasTopology* to one or more *Topologys*
- *isAlias* to one or more *Topologys*
- *locatedAt* to one *Location*

A *Topology* may have the following attributes:

- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string
- *version* to assign a serial number

The *version* attribute is described at the *Network Object*.

²At first this was called a Network, then Graph Network. The term Topology was suggested to avoid the confusion surrounding the term Network.

2.1.11 Port Group

A *PortGroup* is an unordered set of *Ports*.

A *PortGroup* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *hasLabelGroup* to one *LabelGroup*
- *hasPort* to one or more *Ports* or *PortGroups*
- *isAlias* to one or more *PortGroups*
- *isSink* to one or more *LinkGroups*
- *isSource* to one or more *LinkGroups*

A *PortGroup* may have the following attributes:

- *encoding* to assign a data encoding identifier
- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string

2.1.12 Link Group

A *LinkGroup* is an unordered set of *Links*.

A *LinkGroup* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *hasLabelGroup* to one *LabelGroup*
- *hasLink* to one or more *Links* or *LinkGroups*
- *isAlias* to one or more *LinkGroups*
- *isSerialCompoundLink* to one ordered *List* of *LinkGroups*

A *LinkGroup* may have the following attributes:

- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string

2.1.13 Bidirectional Port

A *BidirectionalPort* is a group of two (unidirectional) *Ports* or *PortGroups* together forming a bidirectional representation of a physical or virtual port.

A *BidirectionalPort* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *hasPort* to exactly two *Ports* or two *PortGroups*

A *BidirectionalPort* may have the following attributes:

- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string

2.1.14 Bidirectional Link

A *BidirectionalLink* is a group of two (unidirectional) *Links* or *LinkGroups* together forming a bidirectional link.

A *BidirectionalLink* may have the following relations:

- *existsDuring* to one or more *Lifetimes*
- *hasLink* to exactly two *Links* or two *LinkGroups*

A *BidirectionalLink* may have the following attributes:

- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string

2.1.15 Location

A *Location* is a reference to a geographical location or area.

A *Location* may have the following attributes:

- *id* to assign a persistent globally unique URI
- *name* to assign a human readable string
- *long* is the longitude in WGS84 coordinate system (in decimal degrees)
- *lat* is the latitude in WGS84 coordinate system (in decimal degrees)
- *alt* is the altitude in WGS84 coordinate system (in decimal meters)

- *unlocode* is the UN/LOCODE location identifier
- *address* is a vCard address

2.1.16 Lifetime

A *Lifetime* is an interval between which the object is said to be active.

A *Lifetime* may have the following attributes:

- *start* is the start time and date in ISO 8601 datetime notation (YYYYMMDDThhmmssZ)
- *end* is the end time and date in ISO 8601 datetime notation (YYYYMMDDThhmmssZ)

Objects with multiple lifetimes mean that the lifetime of the object is the union of all lifetimes (as opposed to a intersection). Objects without multiple lifetimes mean valid from the time of publication in the most specific Topology version to the next Topology version.

2.1.17 Ordered List

An *OrderedList* is an ordered list of *Network Objects*.

The representation of an *OrderedList* depends on the syntax.

2.1.18 Label

A *Label* is the technology-specific value to distinguish a single data stream embedded in a larger data stream. The *value* can either be a resource label, or a pair of source and destination labels.

A *Label* may have the following attributes:

- *type* to refer to a technology-specific labelset
- *value* is one specific value taken from the labelset

Technology extensions of NML may define additional attributes.

2.1.19 Label Group

A *LabelGroup* is an unordered set of *Labels*.

A *LabelGroup* may have the following attributes:

- *type* to refer to a technology-specific labelset
- *values* is a set of specific values taken from the labelset

Technology extensions of NML may define additional attributes.

2.2 Relations

Relations describe how different *Network Objects* can be combined to form a network topology description. The relations have been described above, but for ease of reference we also give a full list and definition here (in alphabetical order). In principle a *Relation* can go from any object to any other object. The list below includes definitions for a subset of the possible relations. If a particular *Relation* between two *Network Objects* is not listed below, it is undefined.

existsDuring relates a *LifeTime* object to a *Network Object*

hasInboundPort defines the relation between a *Node*, a *SwitchingService* or a *Topology* and their respective *Ports* or *PortGroups*

hasLabelGroup assigns one *LabelGroup* to a *PortGroup*

hasLabel assigns one *Label* to a *Port*

hasLink is used for:

- *Bidirectional Link* to relate exactly two *Links* or two *LinkGroups*
- *LinkGroup* to one or more *Links* or *LinkGroups* to define membership of that group

hasNode relates a *Network Object* to a *Node*, meaning that a *Node* is part of a *Topology*

hasOutboundPort relates either a *Node*, *SwitchingService* or a *Topology* to one or more *Ports* or *PortGroups* as an outbound port

hasPort is used for:

- *BidirectionalPort* to relate exactly two *Ports* or two *PortGroups*
- *PortGroup* to one or more *Ports* or *PortGroups*

hasService relates a *Network Object* to a *Service*. This schema only defines the meaning of:

- *Port* to *AdaptationService*, relating one server-layer *Port* to an adaptation function
- *Port* to *DeadaptationService*, relating one server-layer *Port* to a deadaptation function

- *Node* or *Topology* to *SwitchingService*, describing a switching capability of that *Node* or *Topology*.

hasTopology defines a relation between one *Topology* to one or more *Topologys* for aggregation purposes

implementedBy relates a *Node* to one or more *Nodes* to describe virtualization

isAlias is a relation from a *Network Object* to a *Network Object* to describe that one can be used as the alias of another.

isSerialCompoundLink is used to define that a *Link* or *LinkGroup* represents an ordered *List* of *Links* or *LinkGroups*. This must include cross-connects.

isSink relates a *Port* to one *Link* to define the outgoing traffic port, and similarly for *PortGroup* and *LinkGroup*

isSource relates a *Port* to one *Link* to define its incoming traffic port, and similarly for *PortGroup* and *LinkGroup*

locatedAt relates a *Network Object* to one *Location*

providesLink is used to relate a *SwitchingService* to one or more *Links* or *LinkGroups* to define that these have been created by that *SwitchingService*

providesPort is used to relate an *AdaptationService* or *DeadaptationService* to one or more *Ports* or *PortGroups* to define that these have been created by that *AdaptationService* or *DeadaptationService*

The *hasTopology*, *hasNode*, *implementedBy*, *hasPort*, *hasLabel*, *hasLabelGroup*, and *hasLink* are defined as implicit relations.

2.3 Syntax

The Network Markup Language has two different normative syntaxes. The syntaxes are in regular XML, and another in OWL RDF/XML syntax. The XML syntax is aimed at legacy applications, while the OWL syntax is aimed at more powerful Semantic Web-oriented applications. These syntaxes are defined in Appendices A and B respectively.

3 Identifiers

3.1 Object Identifiers

The namespace for the class objects defined in this document is `http://schemas.ogf.org/nml/base/2013/`
TODO: change to correct year and month of the schema.

All objects and attributes defined in this document reside in this namespace. For example, the link object is identified by `http://schemas.ogf.org/nml/2013/10/base/link`

3.2 Instance Identifiers

Section 2.1.1 requires that instances of Network Objects **MUST** have an *id* attribute, which **MUST** be a unique URI.

It is possible to describe additional information on an instance, in this case an *idRef* attribute can be used.

Implementations that receive a network topology description **MUST** be prepared to accept any valid URI as an identifier.

Implementations that publish a network topology description instance identifiers **MAY** adhere to the syntax of Global Network Identifiers as defined in [URN-OGF-NETWORK], which ensures global uniqueness and that easy recognition of Network Object instances.

Two different Network Objects instance **MUST** have two different identifiers.

Once an identifier is assigned to a resource, it **MUST NOT** be re-assigned to another resource.

A URI **MAY** be interpreted as an International Resource Identifier (IRI) for display purposes, but URIs from external source domains **MUST NOT** be IRI-normalised before transmitting to others.

3.2.1 Lexical Equivalence

Two identifier are lexical equivalent if they are binary equivalent after case folding.

No interpretation of percent-encoding or PUNYCODE decoding should take place.

For the purpose of equivalence comparison, any possible fragment part or query part of the URI is considered part of the URI.

For example the following identifiers are equivalent:

- 1 - urn:ogf:network:example.net:2012:local_string_1234
- 2 - URN:OGF:network:EXAMPLE.NET:2012:Local_String_1234

while the following identifiers are not equivalent (in this case, the percentage encoding even make URI #3 an invalid Global Network Identifier.):

- 1 - urn:ogf:network:example.net:2012:local_string_1234
- 3 - urn:ogf:network:example.net:2012:local%5Fstring%5F1234

3.2.2 Further Restrictions

An assigning organisation **MUST NOT** assign Network Object Identifier longer than 255 characters in length.

Parsers **MUST** be prepared to accept identifiers of up to 255 characters in length.

A Parser **SHOULD** verify if an identifier adheres to the general URI syntax rules, as specified in RFC 3986 [RFC 3986].

Parsers **SHOULD** reject identifiers which do not adhere to the specified rules. A parser encountering an invalid identifier **SHOULD** reply with an error code that includes the malformed identifier, but **MAY** accept the rest of the message, after purging all references to the Network Object with the malformed identifier.

3.2.3 Interpreting Identifiers

A Network Object identifier **MUST** be treated as a opaque string, only used to uniquely identify a Network Object. The local-part of a Global Network Identifier **MAY** have certain meaning to it's assigning organisation, but **MUST NOT** be interpreted by any other organisation.

3.2.4 Network Object Attribute Change

A Network Object may change during its lifetime. If these changes are so drastic that the assigning organisation considers it a completely new Network Object, the assigning organisation should be assigned a new identifier. In this case, other organisations **MUST** treat this object as completely new Network Resource.

If the assigning organisation considers the changes are small, it **MUST** retain the same identifier for the Network Object, and use some mechanism to signal it's peers of the changes in the attributes of the Network Object.

4 Examples

4.1 Examples in XML

The following snippets represent NML structures in the XML format.

- *Topology*

```
<nml:Topology xmlns:nml="http://schemas.ogf.org/nml/2012/10/base"
  id="urn:ogf:network:example.net:2012:org"
  version="20120814">

  <!-- ... -->

</nml:Topology>
```

- *Node*

```
<nml:Node id="urn:ogf:network:example.net:2012:nodeA">
  <nml:name>Node_A</nml:name>
  <nml:Location idRef="urn:ogf:network:example.net:2012:redcity"/>
  <nml:Relation type="http://schemas.ogf.org/nml/2012/10/base/hasOutboundPort">
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_X:out"/>
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_Y:out"/>
  </nml:Relation>
  <nml:Relation type="http://schemas.ogf.org/nml/2012/10/base/hasInboundPort">
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_X:in"/>
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_Y:in"/>
  </nml:Relation>
</nml:Node>
```

- *Ports*

- *UnidirectionalPort*

```
<nml:Port id="urn:ogf:network:example.net:2012:port_X:out">
  <nml:Label labeltype="http://schemas.ogf.org/nml/2012/10/ethernet/vlan">1501</nml:Label>
</nml:Port>
```

- *BidirectionalPort*

```
<nml:BidirectionalPort id="urn:ogf:network:example.net:2012:port_X">
  <nml:name>X</nml:name>
  <nml:Port idRef="urn:ogf:network:example.net:2012:port_X:out"/>
  <nml:Port idRef="urn:ogf:network:example.net:2012:port_X:in"/>
</nml:BidirectionalPort>
```

- *PortGroup*

```
<nml:PortGroup id="urn:ogf:network:example.net:2012:portgroup_X:out">
  <nml:LabelGroup labeltype="http://schemas.ogf.org/nml/2012/10/ethernet/vlan">
    1780–1783
  </nml:LabelGroup>
</nml:PortGroup>
```

- *Link*

- *UnidirectionalLink*

```
<nml:Link id="urn:ogf:network:example.net:2012:linkA:XY"/>

<nml:Port id="urn:ogf:network:example.net:2012:port_X:out">
  <nml:Relation type="http://schemas.ogf.org/nml/2012/10/base/isSource">
    <nml:Link idRef="urn:ogf:network:example.net:2012:linkA:XY"/>
  </nml:Relation>
</nml:Port>

<nml:Port id="urn:ogf:network:example.net:2012:port_Y:in">
  <nml:Relation type="http://schemas.ogf.org/nml/2012/10/base/isSink">
    <nml:Link idRef="urn:ogf:network:example.net:2012:linkA:XY"/>
  </nml:Relation>
</nml:Port>
```

- *UnidirectionalLink that is composed of more than one sub-link*

```
<nml:Link id="urn:ogf:network:example.net:2012:link_XW">
  <nml:Relation type="http://schemas.ogf.org/nml/2012/10/isSerialCompoundLink">
    <nml:Link idRef="urn:ogf:network:example.net:2012:linkA:XY">
      <nml:Relation type="http://schemas.ogf.org/nml/2012/10/next">
        <nml:Link idRef="urn:ogf:network:example.net:2012:linkB:YZ"/>
      </nml:Relation>
    </nml:Link>
    <nml:Link idRef="urn:ogf:network:example.net:2012:linkB:YZ">
      <nml:Relation type="http://schemas.ogf.org/nml/2012/10/next">
        <nml:Link idRef="urn:ogf:network:example.net:2012:linkC:ZW"/>
      </nml:Relation>
    </nml:Link>
    <nml:Link idRef="urn:ogf:network:example.net:2012:linkC:ZW"/>
  </nml:Relation>
</nml:Link>
```

- *BidirectionalLink*

```
<nml:BidirectionalLink id="urn:ogf:network:example.net:2012:link_XWX">
  <nml:name>Link between ports X and W</nml:name>
  <nml:Link idRef="urn:ogf:network:example.net:2012:link_XW"/>
  <nml:Link idRef="urn:ogf:network:example.net:2012:link_WX"/>
</nml:BidirectionalLink>
```

- *LinkGroup*

```
<nml:LinkGroup id="urn:ogf:network:example.net:2012:domainy_domainx">
  <nml:LabelGroup labeltype="http://schemas.ogf.org/nml/2012/10/ethernet/vlan">
    1780–1783
  </nml:LabelGroup>
</nml:LinkGroup>
```

- *Labels*

- *Label*

```
<nml:Label labeltype="http://schemas.ogf.org/nml/2012/10/ethernet/vlan">1501</nml:Label>
```

– *LabelGroup*

```
<nml:LabelGroup labeltype="http://schemas.ogf.org/nml/2012/10/ethernet/vlan">
  1780–1783
</nml:LabelGroup>
```

• *Location*

```
<nml:Location id="urn:ogf:network:example.net:2012:redcity">
  <nml:name>Red City</nml:name>
  <nml:latitude>30.600</nml:latitude>
  <nml:longitude>12.640</nml:longitude>
</nml:Location>
```

• *Services*

– *SwitchingService*

```
<nml:Node id="urn:ogf:network:example.net:2012:nodeA">
  <nml:name>Node_A</nml:name>
  <nml:Relation type="http://schemas.ogf.org/nml/2012/10/base/hasInboundPort">
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_X:in" />
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_Y:in" />
  </nml:Relation>
  <nml:Relation type="http://schemas.ogf.org/nml/2012/10/base/hasOutboundPort">
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_X:out" />
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_Y:out" />
  </nml:Relation>
  <nml:SwitchingService idRef="urn:ogf:network:example.net:2012:nodeA:switchingService"/>
</nml:Node>

<nml:SwitchingService id="urn:ogf:network:example.net:2012:nodeA:switchingService">
  <nml:Relation type="http://schemas.ogf.org/nml/2012/10/base/hasInboundPort">
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_X:in" />
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_Y:in" />
  </nml:Relation>
  <nml:Relation type="http://schemas.ogf.org/nml/2012/10/base/hasOutboundPort">
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_X:out" />
    <nml:Port idRef="urn:ogf:network:example.net:2012:nodeA:port_Y:out" />
  </nml:Relation>
</nml:SwitchingService>
```

– *AdaptationService*

```
<nml:Port id="urn:ogf:network:example.net:2012:port_X:in">
  <nml:AdaptationService
    idRef="urn:ogf:network:example.net:2012:port_X:in:adaptationService"/>
</nml:Port>

<nml:AdaptationService
  id="urn:ogf:network:example.net:2012:port_X:in:adaptationService">
  <nml:Port idRef="urn:ogf:network:example.net:2012:port_X.1501:in"/>
</nml:AdaptationService>

<nml:Port id="urn:ogf:network:example.net:2012:port_X.1501:in">
  <nml:Label labeltype="http://schemas.ogf.org/nml/2012/10/ethernet/vlan">1501</nml:Label>
</nml:Port>
```

– *DeadaptationService*

```
<nml:Port id="urn:ogf:network:example.net:2012:port_X.1501:in">
```

```

<nml:Label labeltype="http://schemas.ogf.org/nml/2012/10/ethernet/vlan">1501</nml:Label>
<nml:DeadadaptationService
  idRef="urn:ogf:network:example.net:2012:port_X.1501:in:deadadaptationService" />
</nml:Port>

<nml:DeadadaptationService
  id="urn:ogf:network:example.net:2012:port_X.1501:in:deadadaptationService">
  <nml:Port idRef="urn:ogf:network:example.net:2012:port_X:in" />
</nml:DeadadaptationService >

```

4.2 Examples in OWL

The following snippets represent NML structures in the OWL format.

- *Topology*

```

<?xml version="1.0" encoding="utf-8"?>
<rdf:RDF
  xmlns:nml="http://schemas.ogf.org/nml/2012/10/base#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:owl="http://www.w3.org/2002/07/owl#"
  xmlns:nml:eth="http://schemas.ogf.org/nml/2012/10/ethernet#"
>
<nml:Topology rdf:about="urn:ogf:network:example.net:2012:org">
  <nml:version>20120814</nml:version>

  <!-- ... -->

</nml:Topology>

```

- *Node*

```

<nml:Node rdf:about="urn:ogf:network:example.net:2012:nodeA">
  <nml:name>Node A</nml:name>
  <nml:locatedAt rdf:resource="urn:ogf:network:example.net:2012:redcity"/>
  <nml:hasOutboundPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_X:out"/>
  <nml:hasOutboundPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_Y:out"/>
  <nml:hasInboundPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_X:in"/>
  <nml:hasInboundPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_Y:in"/>
</nml:Node>

```

- *Ports*

- *UnidirectionalPort*

```

<nml:Port rdf:about="urn:ogf:network:example.net:2012:port_X:out">
  <nml:eth:vlan>1501</nml:eth:vlan>
</nml:Port>

```

- *BidirectionalPort*

```

<nml:BidirectionalPort rdf:about="urn:ogf:network:example.net:2012:port_X">
  <nml:name>X</nml:name>
  <nml:hasPort rdf:resource="urn:ogf:network:example.net:2012:port_X:out"/>
  <nml:hasPort rdf:resource="urn:ogf:network:example.net:2012:port_X:in"/>
</nml:BidirectionalPort>

```


– *PortGroup*

```
<nml:PortGroup rdf:about="urn:ogf:network:example.net:2012:portgroup_X:out">
  <nml:hasLabel>
    <nml:LabelGroup labeltype="http://schemas.ogf.org/nml/2012/10/ethernet#vlan">
      1780–1783
    </nml:LabelGroup>
  </nml:hasLabel>
</nml:PortGroup>
```

• *Link*

– *UnidirectionalLink*

```
<nml:Link rdf:about="urn:ogf:network:example.net:2012:linkA:XY"/>

<nml:Port rdf:about="urn:ogf:network:example.net:2012:port_X:out">
  <nml:isSource rdf:resource="urn:ogf:network:example.net:2012:linkA:XY"/>
</nml:Port>

<nml:Port id="urn:ogf:network:example.net:2012:port_Y:in">
  <nml:isSink rdf:resource="urn:ogf:network:example.net:2012:linkA:XY"/>
</nml:Port>
```

– *UnidirectionalLink that is composed of more than one sub-link*

```
<nml:Link rdf:about="urn:ogf:network:example.net:2012:link_XW">
  <nml:isSerialCompoundLink>
    <nml:ListItem rdf:resource="urn:ogf:network:example.net:2012:link_XW_1">
      <nml:item rdf:resource="urn:ogf:network:example.net:2012:linkA:XY"/>
      <nml:next rdf:resource="urn:ogf:network:example.net:2012:link_XW_2"/>
    </nml:ListItem>
  </nml:isSerialCompoundLink>
</nml:Link>

<nml:ListItem rdf:resource="urn:ogf:network:example.net:2012:link_XW_2">
  <nml:item rdf:resource="urn:ogf:network:example.net:2012:linkB:YZ"/>
  <nml:next rdf:resource="urn:ogf:network:example.net:2012:link_XW_3"/>
</nml:ListItem>

<nml:ListItem rdf:resource="urn:ogf:network:example.net:2012:link_XW_3">
  <nml:item rdf:resource="urn:ogf:network:example.net:2012:linkC:ZW"/>
</nml:ListItem>
```

– *BidirectionalLink*

```
<nml:BidirectionalLink rdf:about="urn:ogf:network:example.net:2012:link_XWX">
  <nml:name>Link between ports X and W</nml:name>
  <nml:hasLink rdf:about="urn:ogf:network:example.net:2012:link_XW"/>
  <nml:hasLink rdf:about="urn:ogf:network:example.net:2012:link_WX"/>
</nml:BidirectionalLink>
```

– *LinkGroup*

```
<nml:LinkGroup rdf:about="urn:ogf:network:example.net:2012:domainy_domainx">
  <nml:eth:vlan>1780–1783</nml:eth:vlan>
</nml:LinkGroup>
```

• *Labels*

– *Label*

```
<rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/ethernet#vlan">
  <owl:subPropertyOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#hasLabel" />
</rdf:Description>
</rdf:Description><nml:eth:vlan>1501</nml:eth:vlan>
```

– *LabelGroup*

```
<rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/ethernet#vlan">
  <owl:subPropertyOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#hasLabel" />
</rdf:Description>
<nml:eth:vlan>1780–1783</nml:eth:vlan>
```

• *Location*

```
<nml:Location id="urn:ogf:network:example.net:2012:redcity">
  <nml:name>Red City</nml:name>
  <nml:latitude>30.600</nml:latitude>
  <nml:longitude>12.640</nml:longitude>
</nml:Location>
```

• *Services*

– *SwitchingService*

```
<nml:Node rdf:about="urn:ogf:network:example.net:2012:nodeA">
  <nml:name>Node_A</nml:name>
  <nml:hasInboundPort>
    <nml:hasPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_X:in" />
    <nml:hasPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_Y:in" />
  </nml:hasInboundPort>
  <nml:hasOutboundPort>
    <nml:hasPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_X:out" />
    <nml:hasPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_Y:out" />
  </nml:hasOutboundPort>
  <nml:hasService rdf:about="urn:ogf:network:example.net:2012:nodeA:switchingService" />
</nml:Node>

<nml:SwitchingService rdf:about="urn:ogf:network:example.net:2012:nodeA:switchingService">
  <nml:hasInboundPort>
    <nml:hasPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_X:in" />
    <nml:hasPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_Y:in" />
  </nml:hasInboundPort>
  <nml:hasOutboundPort>
    <nml:hasPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_X:out" />
    <nml:hasPort rdf:resource="urn:ogf:network:example.net:2012:nodeA:port_Y:out" />
  </nml:hasOutboundPort>
</nml:SwitchingService>
```

– *AdaptationService*

```
<nml:Port rdf:about="urn:ogf:network:example.net:2012:port_X:in">
  <nml:hasService rdf:resource="urn:ogf:network:example.net:2012:port_X:in:adaptationService">
</nml:Port>

<nml:AdaptationService
  rdf:about="urn:ogf:network:example.net:2012:port_X:in:adaptationService">
  <nml:providesPort rdf:resource="urn:ogf:network:example.net:2012:port_X:1501:in" />
</nml:AdaptationService>

<nml:Port rdf:about="urn:ogf:network:example.net:2012:port_X:1501:in">
```

```
<nmleth:vlan>1501</nmleth:vlan>  
</nml:Port>
```

– *DeadaptationService*

```
<nml:Port rdf:about="urn:ogf:network:example.net:2012:port_X.1501:in">  
  <nmleth:vlan>1501</nmleth:vlan>  
  <nml:hasService>  
    <nml:DeadaptationService  
      rdf:resource="urn:ogf:network:example.net:2012:port_X.1501:in:deadaptationService">  
      <nml:providesPort rdf:about="urn:ogf:network:example.net:2012:port_X:in"/>  
    </nml:DeadaptationService>  
  </nml:hasService>  
</nml:Port>
```

5 Security Considerations

There are important security concerns associated with the generation and distribution of network topology information. For example, ISPs frequently consider network topologies to be proprietary. We do not address these concerns in this document, but implementers are encouraged to consider the security implications of generating and distributing network topology information.

6 Glossary

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Appendix A XML Schema

This section describes the normative schema of XML documents using the XML Schema language.

```
<?xml version="1.0" encoding="UTF-8"?>

<!--
File: nmlbase.xsd - Main XSD schema definition
Version: $Id$
Purpose: This is the main XSD schema file, it defines the
        general topology elements of NML.
-->

<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
  targetNamespace="http://schemas.ogf.org/nml/2012/10/base#"
  xmlns:nml="http://schemas.ogf.org/nml/2012/10/base#"
  elementFormDefault="qualified">

  <xs:complexType name="NetworkObject">
    <xs:sequence>
      <xs:element name="name" type="xs:string" minOccurs="0" maxOccurs="1"/>
      <xs:element name="relation" type="nml:RelationType" minOccurs="0" />
      <xs:element name="Location" type="nml:LocationType" minOccurs="0" maxOccurs="1"/>
      <xs:element name="parameter" type="nml:ParameterType" minOccurs="0"/>
      <xs:choice>
        <xs:element name="lifetime" type="nml:LifeTimeType" minOccurs="0" maxOccurs="1"/>
        <xs:element name="existDuring" type="nml:ExistDuringType" minOccurs="0" maxOccurs="1"/>
      </xs:choice>
    </xs:sequence>
    <xs:attribute name="id" type="xs:anyURI" use="optional"/>
    <xs:attribute name="idRef" type="xs:anyURI" use="optional"/> <!-- referencing and inheritance -->
    <xs:attribute name="version" type="xs:unsignedInt" use="optional"/>
  </xs:complexType>

  <xs:complexType name="RelationType">
    <xs:choice>
      <xs:element ref="nml:Node"/>
      <xs:element ref="nml:Port" minOccurs="1"/>
      <xs:element ref="nml:PortGroup"/>
      <xs:element ref="nml:Link"/>
      <xs:element ref="nml:LinkGroup"/>
    </xs:choice>
    <xs:attribute name="type" use="required"/>
    <xs:simpleType>
      <xs:restriction base="xs:string">
        <xs:enumeration value="http://schemas.ogf.org/nml/2012/10/base#implementedBy"/>
        <xs:enumeration value="http://schemas.ogf.org/nml/2012/10/base#hasInboundPort"/>
        <xs:enumeration value="http://schemas.ogf.org/nml/2012/10/base#hasOutboundPort"/>
        <xs:enumeration value="http://schemas.ogf.org/nml/2012/10/base#isSource"/>
        <xs:enumeration value="http://schemas.ogf.org/nml/2012/10/base#isSink"/>
        <xs:enumeration value="http://schemas.ogf.org/nml/2012/10/base#isSerialCompoundLink"/>
        <xs:enumeration value="http://schemas.ogf.org/nml/2012/10/base#isAlias"/>
        <xs:enumeration value="http://schemas.ogf.org/nml/2012/10/base#next"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:complexType>

  <xs:complexType name="LocationType">
    <xs:all>
      <xs:element name="long" type="xs:float" minOccurs="0" maxOccurs="1"/>
      <xs:element name="lat" type="xs:float" minOccurs="0" maxOccurs="1"/>
      <xs:element name="alt" type="xs:float" minOccurs="0" maxOccurs="1"/>
      <xs:element name="unlocode" type="xs:string" minOccurs="0" maxOccurs="1"/>
      <xs:element name="name" type="xs:string" minOccurs="0" maxOccurs="1"/>
      <!-- address: rfc6351 xCard: vCard XML Representation -->
      <xs:element name="address" minOccurs="0" maxOccurs="1"/>
    </xs:complexType>
```

```

        <xs:sequence>
          <xs:any minOccurs="1" />
        </xs:sequence>
      </xs:complexType>
    </xs:element>
  </xs:all>
</xs:complexType>

<xs:complexType name="ParameterType">
  <xs:simpleContent>
    <xs:extension base="xs:string">
      <xs:attribute name="name" type="xs:string" use="required" />
    </xs:extension>
  </xs:simpleContent>
</xs:complexType>

<xs:complexType name="LifeTimeType">
  <xs:sequence>
    <xs:element name="start" type="xs:dateTime" />
    <xs:choice>
      <xs:element name="end" type="xs:dateTime" minOccurs="0" maxOccurs="1" />
      <xs:element name="duration" type="xs:duration" minOccurs="0" maxOccurs="1" />
    </xs:choice>
  </xs:sequence>
  <xs:attribute name="id" type="xs:anyURI" use="optional" />
</xs:complexType>

<xs:complexType name="ExistDuringType">
  <xs:attribute name="idRef" type="xs:anyURI" use="required" />
</xs:complexType>

<xs:group name="Group">
  <xs:choice>
    <xs:element ref="nml:Topology" />
    <xs:element ref="nml:LinkGroup" />
    <xs:element ref="nml:PortGroup" />
    <xs:element ref="nml:BidirectionalLink" />
    <xs:element ref="nml:BidirectionalPort" />
  </xs:choice>
</xs:group>

<!-- Topology -->

<xs:group name="BaseTopologyContent">
  <xs:sequence>
    <xs:element ref="nml:Link" minOccurs="0" />
    <xs:element ref="nml:Port" minOccurs="0" />
    <xs:element ref="nml:Node" minOccurs="0" />
    <xs:group ref="nml:Service" minOccurs="0" />
    <xs:group ref="nml:Group" minOccurs="0" />
    <xs:any minOccurs="0" />
  </xs:sequence>
</xs:group>

<xs:complexType name="TopologyType">
  <xs:complexContent>
    <xs:extension base="nml:NetworkObject">
      <xs:group ref="nml:BaseTopologyContent" />
    </xs:extension>
  </xs:complexContent>
</xs:complexType>

<xs:element name="Topology" type="nml:TopologyType" />

<!-- Link -->

<xs:group name="BaseLinkContent">
  <xs:sequence>
    <xs:group ref="nml:Label" minOccurs="0" />
    <xs:any minOccurs="0" />
  </xs:sequence>
</xs:group>

```

```

</xs:sequence>
</xs:group>

<xs:complexType name="LinkType">
  <xs:complexContent>
    <xs:extension base="nml:NetworkObject">
      <xs:group ref="nml:BaseLinkContent"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>

<xs:element name="Link" type="nml:LinkType"/>

<!-- Port -->

<xs:group name="BasePortContent">
  <xs:sequence>
    <xs:group ref="nml:Label" minOccurs="0"/>
    <xs:any minOccurs="0"/>
  </xs:sequence>
</xs:group>

<xs:complexType name="PortType">
  <xs:complexContent>
    <xs:extension base="nml:NetworkObject">
      <xs:group ref="nml:BasePortContent"/>
      <xs:attribute name="encoding" type="xs:anyURI" use="optional"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>

<xs:element name="Port" type="nml:PortType"/>

<!-- Node -->

<xs:complexType name="NodeType">
  <xs:complexContent>
    <xs:extension base="nml:NetworkObject">
      <xs:sequence>
        <xs:any minOccurs="0"/>
      </xs:sequence>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>

<xs:element name="Node" type="nml:NodeType"/>

<!-- Service -->

<xs:group name="Service">
  <xs:choice>
    <xs:element ref="nml:SwitchingService"/>
    <xs:element ref="nml:AdaptationService"/>
    <xs:element ref="nml:DeadadaptationService"/>
  </xs:choice>
</xs:group>

<xs:complexType name="SwitchingServiceType">
  <xs:complexContent>
    <xs:extension base="nml:NetworkObject">
      <xs:sequence>
        <xs:element ref="nml:Link" minOccurs="0"/>
      </xs:sequence>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>

<xs:element name="SwitchingService" type="nml:SwitchingServiceType"/>

```

```

<xs:complexType name="AdaptationServiceType">
  <xs:complexContent>
    <xs:extension base="nml:NetworkObject">
      <xs:sequence>
        <xs:element ref="nml:Port" minOccurs="0"/>
      </xs:sequence>
      <xs:attribute name="adaptationFunction" type="xs:anyURI" use="optional"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>

<xs:element name="AdaptationService" type="nml:AdaptationServiceType"/>

<xs:complexType name="DeadaptationServiceType">
  <xs:complexContent>
    <xs:extension base="nml:NetworkObject">
      <xs:sequence>
        <xs:element ref="nml:Port" minOccurs="0"/>
      </xs:sequence>
      <xs:attribute name="deadaptationFunction" type="xs:anyURI" use="optional"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>

<xs:element name="DeadaptationService" type="nml:DeadaptationServiceType"/>

<!-- Label -->

<xs:group name="Label">
  <xs:choice>
    <xs:element name="Label" type="nml:LabelType"/>
    <xs:element name="Label" type="nml:LabelAttrType"/>
    <xs:element name="Label" type="nml:LabelExtType"/>
  </xs:choice>
</xs:group>

<xs:complexType name="LabelType">
  <xs:simpleContent>
    <xs:extension base="xs:string">
      <xs:attribute name="labelencoding" type="xs:anyURI" use="required"/>
    </xs:extension>
  </xs:simpleContent>
</xs:complexType>

<xs:complexType name="LabelAttrType">
  <xs:attribute name="labelencoding" type="xs:anyURI" use="required"/>
  <xs:attribute name="value" type="xs:string" use="required"/>
</xs:complexType>

<xs:complexType name="LabelExtType"> <!-- with any inside -->
  <xs:sequence>
    <xs:any minOccurs="0"/>
  </xs:sequence>
  <xs:attribute name="labelencoding" type="xs:anyURI" use="required"/>
</xs:complexType>

<!-- LinkGroup -->

<xs:group name="BaseLinkGroup">
  <xs:sequence>
    <xs:group ref="nml:LabelGroup" minOccurs="0"/>
    <xs:element ref="nml:Link" minOccurs="0"/>
    <xs:element ref="nml:LinkGroup" minOccurs="0"/>
  </xs:sequence>
</xs:group>

<xs:complexType name="LinkGroupType">
  <xs:complexContent>
    <xs:extension base="nml:NetworkObject">

```

```

        <xs:group ref="nml:BaseLinkGroup"/>
        <xs:attribute name="layerencoding" type="xs:anyURI" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>

  <xs:element name="LinkGroup" type="nml:LinkGroupType"/>

  <!-- PortGroup -->

  <xs:group name="BasePortGroup">
    <xs:sequence>
      <xs:group ref="nml:LabelGroup" minOccurs="0"/>
      <xs:element ref="nml:Port" minOccurs="0"/>
      <xs:element ref="nml:PortGroup" minOccurs="0"/>
    </xs:sequence>
  </xs:group>

  <xs:complexType name="PortGroupType">
    <xs:complexContent>
      <xs:extension base="nml:NetworkObject">
        <xs:group ref="nml:BasePortGroup"/>
        <xs:attribute name="layerencoding" type="xs:anyURI" use="optional"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>

  <xs:element name="PortGroup" type="nml:PortGroupType"/>

  <!-- BidirectionalLink -->

  <xs:group name="BaseBidirectionalLink">
    <xs:choice>
      <xs:sequence>
        <xs:element ref="nml:Link"/>
        <xs:element ref="nml:Link"/>
      </xs:sequence>
      <xs:sequence>
        <xs:element ref="nml:LinkGroup"/>
        <xs:element ref="nml:LinkGroup"/>
      </xs:sequence>
    </xs:choice>
  </xs:group>

  <xs:complexType name="BidirectionalLinkType">
    <xs:complexContent>
      <xs:extension base="nml:NetworkObject">
        <xs:group ref="nml:BaseBidirectionalLink"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>

  <xs:element name="BidirectionalLink" type="nml:BidirectionalLinkType"/>

  <!-- BidirectionalPort -->

  <xs:group name="BaseBidirectionalPort">
    <xs:choice>
      <xs:sequence>
        <xs:element ref="nml:Port"/>
        <xs:element ref="nml:Port"/>
      </xs:sequence>
      <xs:sequence>
        <xs:element ref="nml:PortGroup"/>
        <xs:element ref="nml:PortGroup"/>
      </xs:sequence>
    </xs:choice>
  </xs:group>

```

```

<xs:complexType name="BidirectionalPortType">
  <xs:complexContent>
    <xs:extension base="nml:NetworkObject">
      <xs:group ref="nml:BaseBidirectionalPort"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>

<xs:element name="BidirectionalPort" type="nml:BidirectionalPortType"/>

<!-- LabelGroup -->

<xs:group name="LabelGroup">
  <xs:choice>
    <xs:element name="LabelGroup" type="nml:LabelGroupType"/>
    <xs:element name="LabelGroup" type="nml:LabelGroupAttrType"/>
    <xs:element name="LabelGroup" type="nml:LabelGroupExtType"/>
  </xs:choice>
</xs:group>

<xs:complexType name="LabelGroupType">
  <xs:simpleContent>
    <xs:extension base="xs:string">
      <xs:attribute name="labelencoding" type="xs:anyURI" use="required"/>
    </xs:extension>
  </xs:simpleContent>
</xs:complexType>

<xs:complexType name="LabelGroupAttrType">
  <xs:attribute name="labelencoding" type="xs:anyURI" use="required"/>
  <xs:attribute name="value" type="xs:string" use="required"/>
</xs:complexType>

<xs:complexType name="LabelGroupExtType"> <!-- with any inside -->
  <xs:sequence>
    <xs:any minOccurs="0"/>
  </xs:sequence>
  <xs:attribute name="labelencoding" type="xs:anyURI" use="required"/>
</xs:complexType>

</xs:schema>

```

Appendix B OWL Schema

This section describes the normative schema of the OWL syntax using the following OWL ontology. First is the OWL syntax used for the RDF/XML notation, and we also include the Notation3 version of the ontology.

B.1 OWL RDF/XML Schema

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:nml="http://schemas.ogf.org/nml/2012/10/base#">
  <Ontology rdf:about="http://schemas.ogf.org/nml/2012/10/base#">
    <rdfs:label>NML Schema</rdfs:label>
  </Ontology>

  <!--
  //////////////////////////////////////
  //
  // Annotation properties
  //
  //////////////////////////////////////
  -->

  <!--
  //////////////////////////////////////
  //
  // Datatypes
  //
  //////////////////////////////////////
  -->

  <!--
  //////////////////////////////////////
  //
  // Object Properties
  //
  //////////////////////////////////////
  -->

  <!-- http://schemas.ogf.org/nml/2012/10/base#existsDuring -->

  <ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#existsDuring">
    <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Lifetime"/>
    <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#NetworkObject"/>
  </ObjectProperty>

  <!-- http://schemas.ogf.org/nml/2012/10/base#hasInboundPort -->

  <ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#hasInboundPort">
    <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Port"/>
    <rdfs:domain>
      <Class>
        <unionOf rdf:parseType="Collection">
          <rdfs:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Node"/>
          <rdfs:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#SwitchingService"/>
          <rdfs:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Topology"/>
        </unionOf>
      </Class>
    </rdfs:domain>
  </ObjectProperty>
```

```

        </unionOf>
      </Class>
    </rdfs:domain>
  </ObjectProperty>

  <!-- http://schemas.ogf.org/nml/2012/10/base#hasLabel -->
  <ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#hasLabel">
    <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Label"/>
    <rdfs:domain>
      <Class>
        <unionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Link"/>
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Port"/>
        </unionOf>
      </Class>
    </rdfs:domain>
  </ObjectProperty>

  <!-- http://schemas.ogf.org/nml/2012/10/base#hasLabelGroup -->
  <ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#hasLabelGroup">
    <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#LabelGroup"/>
    <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#PortGroup"/>
  </ObjectProperty>

  <!-- http://schemas.ogf.org/nml/2012/10/base#hasLink -->
  <ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#hasLink">
    <rdfs:domain>
      <Class>
        <unionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#BidirectionalLink"/>
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#LinkGroup"/>
        </unionOf>
      </Class>
    </rdfs:domain>
    <rdfs:range>
      <Class>
        <unionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Link"/>
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#LinkGroup"/>
        </unionOf>
      </Class>
    </rdfs:range>
  </ObjectProperty>

  <!-- http://schemas.ogf.org/nml/2012/10/base#hasNode -->
  <ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#hasNode">
    <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Node"/>
    <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Topology"/>
  </ObjectProperty>

  <!-- http://schemas.ogf.org/nml/2012/10/base#hasOutboundPort -->
  <ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#hasOutboundPort">
    <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Port"/>
    <rdfs:domain>
      <Class>
        <unionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Node"/>
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#SwitchingService"/>
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Topology"/>
        </unionOf>
      </Class>
    </rdfs:domain>
  </ObjectProperty>

```



```

<!-- http://schemas.ogf.org/nml/2012/10/base#hasPort -->
<ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#hasPort">
  <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Port"/>
  <rdfs:domain>
    <Class>
      <unionOf rdf:parseType="Collection">
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#BidirectionalPort"/>
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#PortGroup"/>
      </unionOf>
    </Class>
  </rdfs:domain>
</ObjectProperty>

```

```

<!-- http://schemas.ogf.org/nml/2012/10/base#hasService -->
<ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#hasService">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#NetworkObject"/>
  <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Service"/>
</ObjectProperty>

```

```

<!-- http://schemas.ogf.org/nml/2012/10/base#hasSink -->
<ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#hasSink">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Link"/>
  <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Port"/>
</ObjectProperty>

```

```

<!-- http://schemas.ogf.org/nml/2012/10/base#hasSource -->
<ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#hasSource">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Link"/>
  <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Port"/>
</ObjectProperty>

```

```

<!-- http://schemas.ogf.org/nml/2012/10/base#hasTopology -->
<ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#hasTopology">
  <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Topology"/>
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Topology"/>
</ObjectProperty>

```

```

<!-- http://schemas.ogf.org/nml/2012/10/base#implementedBy -->
<ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#implementedBy">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Node"/>
  <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Node"/>
</ObjectProperty>

```

```

<!-- http://schemas.ogf.org/nml/2012/10/base#isAlias -->
<ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#isAlias">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#NetworkObject"/>
  <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#NetworkObject"/>
</ObjectProperty>

```

```

<!-- http://schemas.ogf.org/nml/2012/10/base#isSerialCompoundLink -->
<ObjectProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#isSerialCompoundLink">
  <rdfs:range rdf:resource="http://schemas.ogf.org/nml/2012/10/base#List"/>
  <rdfs:domain>
    <Class>
      <unionOf rdf:parseType="Collection">
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Link"/>
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#LinkGroup"/>
      </unionOf>
    </Class>
  </rdfs:domain>
</ObjectProperty>

```

```

    </rdfs:domain>
  </ObjectProperty>

  <!-- http://schemas.opengis.net/nml/2012/10/base#isSink -->
  <ObjectProperty rdf:about="http://schemas.opengis.net/nml/2012/10/base#isSink">
    <rdfs:domain>
      <Class>
        <unionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://schemas.opengis.net/nml/2012/10/base#Port"/>
          <rdf:Description rdf:about="http://schemas.opengis.net/nml/2012/10/base#PortGroup"/>
        </unionOf>
      </Class>
    </rdfs:domain>
    <rdfs:range>
      <Class>
        <unionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://schemas.opengis.net/nml/2012/10/base#Link"/>
          <rdf:Description rdf:about="http://schemas.opengis.net/nml/2012/10/base#LinkGroup"/>
        </unionOf>
      </Class>
    </rdfs:range>
  </ObjectProperty>

  <!-- http://schemas.opengis.net/nml/2012/10/base#isSource -->
  <ObjectProperty rdf:about="http://schemas.opengis.net/nml/2012/10/base#isSource">
    <rdfs:domain>
      <Class>
        <unionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://schemas.opengis.net/nml/2012/10/base#Port"/>
          <rdf:Description rdf:about="http://schemas.opengis.net/nml/2012/10/base#PortGroup"/>
        </unionOf>
      </Class>
    </rdfs:domain>
    <rdfs:range>
      <Class>
        <unionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://schemas.opengis.net/nml/2012/10/base#Link"/>
          <rdf:Description rdf:about="http://schemas.opengis.net/nml/2012/10/base#LinkGroup"/>
        </unionOf>
      </Class>
    </rdfs:range>
  </ObjectProperty>

  <!-- http://schemas.opengis.net/nml/2012/10/base#locatedAt -->
  <ObjectProperty rdf:about="http://schemas.opengis.net/nml/2012/10/base#locatedAt">
    <rdfs:range rdf:resource="http://schemas.opengis.net/nml/2012/10/base#Location"/>
    <rdfs:domain rdf:resource="http://schemas.opengis.net/nml/2012/10/base#Node"/>
  </ObjectProperty>

  <!-- http://schemas.opengis.net/nml/2012/10/base#providesLink -->
  <ObjectProperty rdf:about="http://schemas.opengis.net/nml/2012/10/base#providesLink">
    <rdfs:domain rdf:resource="http://schemas.opengis.net/nml/2012/10/base#SwitchingService"/>
    <rdfs:range>
      <Class>
        <unionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://schemas.opengis.net/nml/2012/10/base#Link"/>
          <rdf:Description rdf:about="http://schemas.opengis.net/nml/2012/10/base#LinkGroup"/>
        </unionOf>
      </Class>
    </rdfs:range>
  </ObjectProperty>

  <!-- http://schemas.opengis.net/nml/2012/10/base#providesPort -->
  <ObjectProperty rdf:about="http://schemas.opengis.net/nml/2012/10/base#providesPort">
    <rdfs:domain>
      <Class>

```

```

        <unionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#AdaptationService"/>
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#DeadaptationService"/>
        </unionOf>
      </Class>
    </rdfs:domain>
    <rdfs:range>
      <Class>
        <unionOf rdf:parseType="Collection">
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Port"/>
          <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#PortGroup"/>
        </unionOf>
      </Class>
    </rdfs:range>
  </ObjectProperty>

<!--
////////////////////////////////////
//
//  Data properties
//
////////////////////////////////////
-->

<!-- http://schemas.ogf.org/nml/2012/10/base#adaptationfunction -->
<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#adaptationfunction">
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
  <rdfs:domain>
    <Class>
      <unionOf rdf:parseType="Collection">
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#AdaptationService"/>
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#DeadaptationService"/>
      </unionOf>
    </Class>
  </rdfs:domain>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#address -->
<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#address">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Location"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#alt -->
<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#alt">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Location"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#float"/>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#encoding -->
<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#encoding">
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
  <rdfs:domain>
    <Class>
      <unionOf rdf:parseType="Collection">
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Port"/>
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#PortGroup"/>
      </unionOf>
    </Class>
  </rdfs:domain>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#endtime -->

```

```

<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#endtime">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Lifetime"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#dateTime"/>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#labeltype -->

<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#labeltype">
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
  <rdfs:domain>
    <Class>
      <unionOf rdf:parseType="Collection">
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Label"/>
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#LabelGroup"/>
      </unionOf>
    </Class>
  </rdfs:domain>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#labelvalue -->

<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#labelvalue">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Label"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#labelvalues -->

<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#labelvalues">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#LabelGroup"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#lat -->

<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#lat">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Location"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#float"/>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#long -->

<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#long">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Location"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#float"/>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#name -->

<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#name">
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
  <rdfs:domain>
    <Class>
      <unionOf rdf:parseType="Collection">
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#Location"/>
        <rdf:Description rdf:about="http://schemas.ogf.org/nml/2012/10/base#NetworkObject"/>
      </unionOf>
    </Class>
  </rdfs:domain>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#starttime -->

<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#starttime">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Lifetime"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#dateTime"/>
</DatatypeProperty>

```

```

<!-- http://schemas.ogf.org/nml/2012/10/base#time -->
<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#time">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Lifetime"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#unlocode -->
<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#unlocode">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Location"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</DatatypeProperty>

<!-- http://schemas.ogf.org/nml/2012/10/base#version -->
<DatatypeProperty rdf:about="http://schemas.ogf.org/nml/2012/10/base#version">
  <rdfs:domain rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Topology"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</DatatypeProperty>

<!--
////////////////////////////////////
//
// Classes
//
////////////////////////////////////
-->

<!-- http://schemas.ogf.org/nml/2012/10/base#AdaptationService -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#AdaptationService">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Service"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#BidirectionalLink -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#BidirectionalLink">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Group"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#BidirectionalPort -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#BidirectionalPort">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Group"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#DeadaptationService -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#DeadaptationService">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Service"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#Group -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#Group">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#NetworkObject"/>
</Class>

```

```
<!-- http://schemas.ogf.org/nml/2012/10/base#Label -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#Label"/>

<!-- http://schemas.ogf.org/nml/2012/10/base#LabelGroup -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#LabelGroup">
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#Lifetime -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#Lifetime"/>

<!-- http://schemas.ogf.org/nml/2012/10/base#Link -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#Link">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#NetworkObject"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#LinkGroup -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#LinkGroup">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Group"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#List -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#List"/>

<!-- http://schemas.ogf.org/nml/2012/10/base#Location -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#Location">
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#NetworkObject -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#NetworkObject"/>

<!-- http://schemas.ogf.org/nml/2012/10/base#Node -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#Node">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#NetworkObject"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#Port -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#Port">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#NetworkObject"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#PortGroup -->
<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#PortGroup">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Group"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#Service -->
```

```

<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#Service">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#NetworkObject"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#SwitchingService -->

<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#SwitchingService">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Service"/>
</Class>

<!-- http://schemas.ogf.org/nml/2012/10/base#Topology -->

<Class rdf:about="http://schemas.ogf.org/nml/2012/10/base#Topology">
  <rdfs:subClassOf rdf:resource="http://schemas.ogf.org/nml/2012/10/base#Group"/>
</Class>
</rdf:RDF>

<!-- Generated by the OWL API (version 3.2.3.22702) http://owlapi.sourceforge.net -->

```

B.2 OWL Notation3 Schema

```

@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix xml: <http://www.w3.org/XML/1998/namespace> .
@prefix nml: <http://schemas.ogf.org/nml/2012/10/base#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

<http://schemas.ogf.org/nml/2012/10/base> rdf:type owl:Ontology ;
      rdfs:label "NML_Schema" .

### http://schemas.ogf.org/nml/base#existsDuring
nml:existsDuring rdf:type owl:ObjectProperty ;
  rdfs:range nml:Lifetime ;
  rdfs:domain nml:NetworkObject .

### http://schemas.ogf.org/nml/base#hasInboundPort
nml:hasInboundPort rdf:type owl:ObjectProperty ;
  rdfs:range nml:Port ;
  rdfs:domain [ rdf:type owl:Class ;
    owl:unionOf ( nml:Node
      nml:SwitchingService
      nml:Topology
    )
  ] .

### http://schemas.ogf.org/nml/base#hasLabel
nml:hasLabel rdf:type owl:ObjectProperty ;
  rdfs:range nml:Label ;
  rdfs:domain [ rdf:type owl:Class ;
    owl:unionOf ( nml:Link
      nml:Port
    )
  ] .

### http://schemas.ogf.org/nml/base#hasLabelGroup
nml:hasLabelGroup rdf:type owl:ObjectProperty ;
  rdfs:range nml:LabelGroup ;
  rdfs:domain nml:PortGroup .

### http://schemas.ogf.org/nml/base#hasLink
nml:hasLink rdf:type owl:ObjectProperty ;
  rdfs:range [ rdf:type owl:Class ;
    owl:unionOf ( nml:Link
      nml:LinkGroup
    )
  ] ;

```

```

    rdfs:domain [ rdf:type owl:Class ;
                  owl:unionOf ( nml:BidirectionalLink
                                  nml:LinkGroup
                                )
                  ] .

### http://schemas.opengroup.org/nml/base#hasNode
nml:hasNode rdf:type owl:ObjectProperty ;
            rdfs:range nml:Node ;
            rdfs:domain nml:Topology .

### http://schemas.opengroup.org/nml/base#hasOutboundPort
nml:hasOutboundPort rdf:type owl:ObjectProperty ;
                    rdfs:range nml:Port ;
                    rdfs:domain [ rdf:type owl:Class ;
                                  owl:unionOf ( nml:Node
                                                  nml:SwitchingService
                                                  nml:Topology
                                                )
                                  ] .

### http://schemas.opengroup.org/nml/base#hasPort
nml:hasPort rdf:type owl:ObjectProperty ;
            rdfs:range nml:Port ;
            rdfs:domain [ rdf:type owl:Class ;
                          owl:unionOf ( nml:BidirectionalPort
                                          nml:PortGroup
                                        )
                          ] .

### http://schemas.opengroup.org/nml/base#hasService
nml:hasService rdf:type owl:ObjectProperty ;
               rdfs:domain nml:NetworkObject ;
               rdfs:range nml:Service .

### http://schemas.opengroup.org/nml/base#hasSink
nml:hasSink rdf:type owl:ObjectProperty ;
            rdfs:domain nml:Link ;
            rdfs:range nml:Port .

### http://schemas.opengroup.org/nml/base#hasSource
nml:hasSource rdf:type owl:ObjectProperty ;
              rdfs:domain nml:Link ;
              rdfs:range nml:Port .

### http://schemas.opengroup.org/nml/base#hasTopology
nml:hasTopology rdf:type owl:ObjectProperty ;
                rdfs:range nml:Topology ;
                rdfs:domain nml:Topology .

### http://schemas.opengroup.org/nml/base#implementedBy
nml:implementedBy rdf:type owl:ObjectProperty ;
                  rdfs:domain nml:Node ;
                  rdfs:range nml:Node .

### http://schemas.opengroup.org/nml/base#isAlias
nml:isAlias rdf:type owl:ObjectProperty ;
            rdfs:domain nml:NetworkObject ;
            rdfs:range nml:NetworkObject .

### http://schemas.opengroup.org/nml/base#isSerialCompoundLink
nml:isSerialCompoundLink rdf:type owl:ObjectProperty ;
                          rdfs:range nml:List ;
                          rdfs:domain [ rdf:type owl:Class ;
                                        owl:unionOf ( nml:Link
                                                        nml:LinkGroup
                                                      )
                                        ] .

### http://schemas.opengroup.org/nml/base#isSink
nml:isSink rdf:type owl:ObjectProperty ;
            rdfs:range [ rdf:type owl:Class ;
                          owl:unionOf ( nml:Link
                                          nml:LinkGroup
                                        )
                        ] ;
            rdfs:domain [ rdf:type owl:Class ;
                          owl:unionOf ( nml:Port
                                          nml:PortGroup
                                        )
                        ] .

```



```

### http://schemas.opengis.net/nml/base#isSource
nml:isSource rdf:type owl:ObjectProperty ;
  rdfs:domain [ rdf:type owl:Class ;
    owl:unionOf ( nml:Port
      nml:PortGroup
    )
  ] ;
  rdfs:range [ rdf:type owl:Class ;
    owl:unionOf ( nml:Link
      nml:LinkGroup
    )
  ] .

### http://schemas.opengis.net/nml/base#locatedAt
nml:locatedAt rdf:type owl:ObjectProperty ;
  rdfs:range nml:Location ;
  rdfs:domain nml:Node .

### http://schemas.opengis.net/nml/base#providesLink
nml:providesLink rdf:type owl:ObjectProperty ;
  rdfs:domain nml:SwitchingService ;
  rdfs:range [ rdf:type owl:Class ;
    owl:unionOf ( nml:Link
      nml:LinkGroup
    )
  ] .

### http://schemas.opengis.net/nml/base#providesPort
nml:providesPort rdf:type owl:ObjectProperty ;
  rdfs:range [ rdf:type owl:Class ;
    owl:unionOf ( nml:Port
      nml:PortGroup
    )
  ] ;
  rdfs:domain [ rdf:type owl:Class ;
    owl:unionOf ( nml:AdaptationService
      nml:DeadadaptationService
    )
  ] .

#####
# Data properties
#
#####

### http://schemas.opengis.net/nml/base#adaptationfunction
nml:adaptationfunction rdf:type owl:DatatypeProperty ;
  rdfs:range xsd:string ;
  rdfs:domain [ rdf:type owl:Class ;
    owl:unionOf ( nml:AdaptationService
      nml:DeadadaptationService
    )
  ] .

### http://schemas.opengis.net/nml/base#address
nml:address rdf:type owl:DatatypeProperty ;
  rdfs:domain nml:Location ;
  rdfs:range xsd:string .

### http://schemas.opengis.net/nml/base#alt
nml:alt rdf:type owl:DatatypeProperty ;
  rdfs:domain nml:Location ;
  rdfs:range xsd:float .

### http://schemas.opengis.net/nml/base#encoding
nml:encoding rdf:type owl:DatatypeProperty ;
  rdfs:range xsd:string ;
  rdfs:domain [ rdf:type owl:Class ;
    owl:unionOf ( nml:Port
      nml:PortGroup
    )
  ] .

### http://schemas.opengis.net/nml/base#endtime
nml:endtime rdf:type owl:DatatypeProperty ;
  rdfs:domain nml:Lifetime ;
  rdfs:range xsd:dateTime .

### http://schemas.opengis.net/nml/base#labeltype

```

```

nml:labeltype rdf:type owl:DatatypeProperty ;
    rdfs:range xsd:string ;
    rdfs:domain [ rdf:type owl:Class ;
        owl:unionOf ( nml:Label
            nml:LabelGroup
        )
    ] .

### http://schemas.ogf.org/nml/base#labelvalue
nml:labelvalue rdf:type owl:DatatypeProperty ;
    rdfs:domain nml:Label ;
    rdfs:range xsd:string .

### http://schemas.ogf.org/nml/base#labelvalues
nml:labelvalues rdf:type owl:DatatypeProperty ;
    rdfs:domain nml:LabelGroup ;
    rdfs:range xsd:string .

### http://schemas.ogf.org/nml/base#lat
nml:lat rdf:type owl:DatatypeProperty ;
    rdfs:domain nml:Location ;
    rdfs:range xsd:float .

### http://schemas.ogf.org/nml/base#long
nml:long rdf:type owl:DatatypeProperty ;
    rdfs:domain nml:Location ;
    rdfs:range xsd:float .

### http://schemas.ogf.org/nml/base#name
nml:name rdf:type owl:DatatypeProperty ;
    rdfs:range xsd:string ;
    rdfs:domain [ rdf:type owl:Class ;
        owl:unionOf ( nml:Location
            nml:NetworkObject
        )
    ] .

### http://schemas.ogf.org/nml/base#starttime
nml:starttime rdf:type owl:DatatypeProperty ;
    rdfs:domain nml:Lifetime ;
    rdfs:range xsd:dateTime .

### http://schemas.ogf.org/nml/base#time
nml:time rdf:type owl:DatatypeProperty ;
    rdfs:domain nml:Lifetime ;
    rdfs:range xsd:string .

### http://schemas.ogf.org/nml/base#unlocode
nml:unlocode rdf:type owl:DatatypeProperty ;
    rdfs:domain nml:Location ;
    rdfs:range xsd:string .

### http://schemas.ogf.org/nml/base#version
nml:version rdf:type owl:DatatypeProperty ;
    rdfs:domain nml:Topology ;
    rdfs:range xsd:string .

#####
# Classes
#

#####

### http://schemas.ogf.org/nml/base#AdaptationService
nml:AdaptationService rdf:type owl:Class ;
    rdfs:subClassOf nml:Service .

### http://schemas.ogf.org/nml/base#BidirectionalLink
nml:BidirectionalLink rdf:type owl:Class ;
    rdfs:subClassOf nml:Group .

### http://schemas.ogf.org/nml/base#BidirectionalPort
nml:BidirectionalPort rdf:type owl:Class ;
    rdfs:subClassOf nml:Group .

### http://schemas.ogf.org/nml/base#DeadaptationService
nml:DeadaptationService rdf:type owl:Class ;
    rdfs:subClassOf nml:Service .

### http://schemas.ogf.org/nml/base#Group
nml:Group rdf:type owl:Class ;

```

```

    rdfs:subClassOf nml:NetworkObject .

### http://schemas.ogf.org/nml/base#Label
nml:Label rdf:type owl:Class .

### http://schemas.ogf.org/nml/base#LabelGroup
nml:LabelGroup rdf:type owl:Class ;
    rdfs:subClassOf owl:Thing .

### http://schemas.ogf.org/nml/base#Lifetime
nml:Lifetime rdf:type owl:Class .

### http://schemas.ogf.org/nml/base#Link
nml:Link rdf:type owl:Class ;
    rdfs:subClassOf nml:NetworkObject .

### http://schemas.ogf.org/nml/base#LinkGroup
nml:LinkGroup rdf:type owl:Class ;
    rdfs:subClassOf nml:Group .

### http://schemas.ogf.org/nml/base#List
nml:List rdf:type owl:Class .

### http://schemas.ogf.org/nml/base#Location
nml:Location rdf:type owl:Class ;
    rdfs:subClassOf owl:Thing .

### http://schemas.ogf.org/nml/base#NetworkObject
nml:NetworkObject rdf:type owl:Class .

### http://schemas.ogf.org/nml/base#Node
nml:Node rdf:type owl:Class ;
    rdfs:subClassOf nml:NetworkObject .

### http://schemas.ogf.org/nml/base#Port
nml:Port rdf:type owl:Class ;
    rdfs:subClassOf nml:NetworkObject .

### http://schemas.ogf.org/nml/base#PortGroup
nml:PortGroup rdf:type owl:Class ;
    rdfs:subClassOf nml:Group .

### http://schemas.ogf.org/nml/base#Service
nml:Service rdf:type owl:Class ;
    rdfs:subClassOf nml:NetworkObject .

### http://schemas.ogf.org/nml/base#SwitchingService
nml:SwitchingService rdf:type owl:Class ;
    rdfs:subClassOf nml:Service .

### http://schemas.ogf.org/nml/base#Topology
nml:Topology rdf:type owl:Class ;
    rdfs:subClassOf nml:Group .

### Generated by the OWL API (version 3.2.3.22702) http://owlapi.sourceforge.net
```

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Normative References

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- [RFC 2119] Scott Bradner. Key words for use in RFCs to Indicate Requirement Levels. RFC 2119 (Best Current Practice), March 1997. URL <http://tools.ietf.org/html/rfc2119>.
- [RFC 3986] Tim Berners-Lee, Roy T. Fielding, and Larry Masinter. Uniform Resource Identifier (URI): Generic Syntax RFC 3986 (Standards Track), January 2005. URL <http://tools.ietf.org/html/rfc3986>.

Informative References

- [Dijkstra13] Freek Dijkstra, et al. Experimental Features for NML 1. Work in Progress.
- [NML-LAYERS] NML Working Group Identifiers for (sub)layer encodings. **TODO:** URL <http://schemas.ogf.org/nml/2012/10/layers>