

# Toward Measurement and Analysis of Virtualized Infrastructure: Scaffolding from an Ontological Perspective

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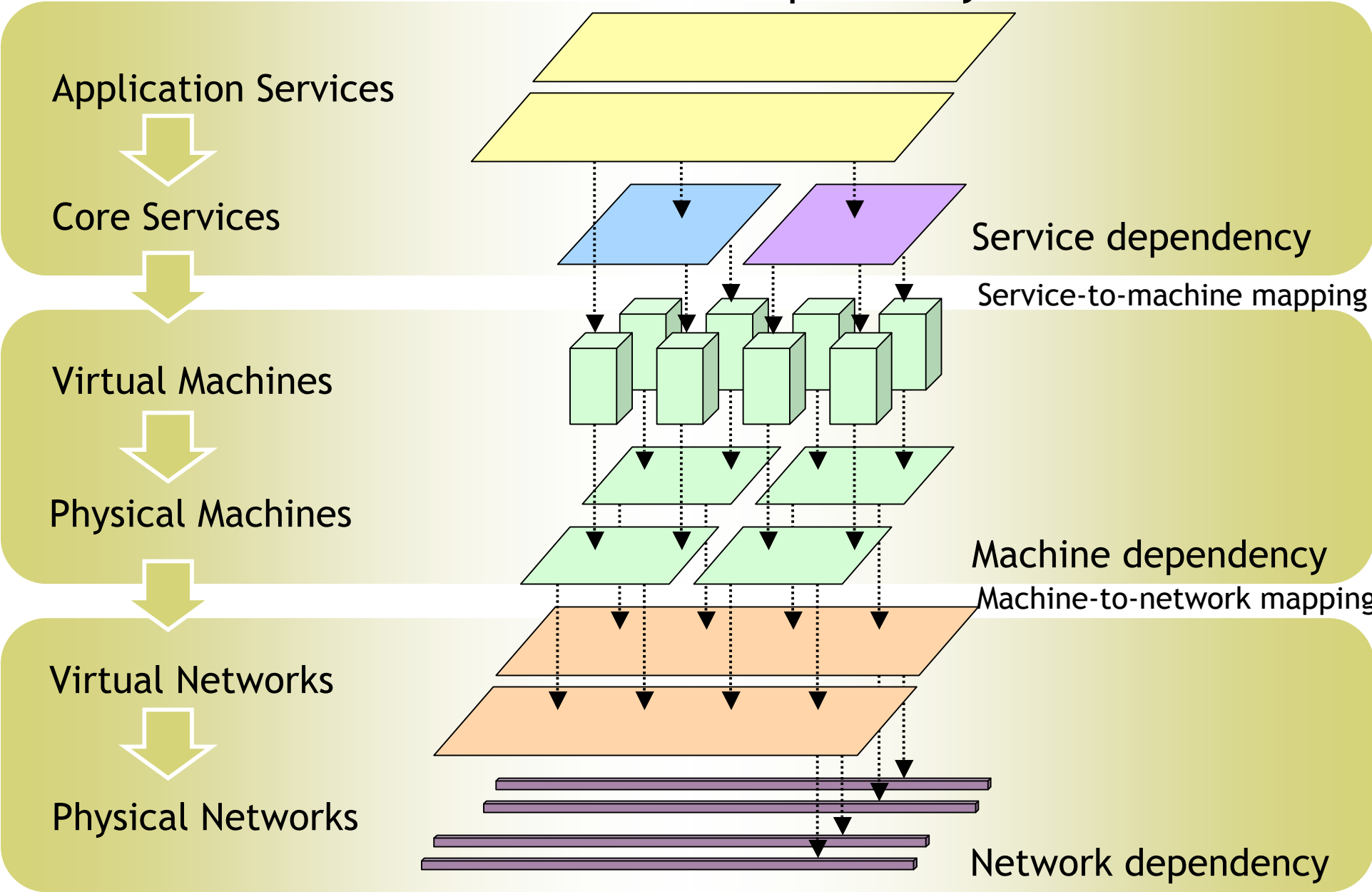
# Measurement and analysis of virtualized infrastructure

- Context: cloud computing
  - Virtualized infrastructure
  - Sheer scale and extensive use of virtualization will make it almost intractable
- Measurement and analysis are important here too:
  - Dependency as another topology graph
  - Analysis of availability / impact / security
- An initial attempt in the WIDE cloud:
  - VRDF (Virtual Resource Description Framework)

## VRDF project objective

- Develop a framework to describe and analyze complex dependency of services, virtual machines, virtual routers and VLANs
  - ... in order to improve the availability of Data Centers and maintain their security level
- Describe dependency of VM to physical machine
- Describe dependency of virtual nets to networking devices
- Assess the impact of failure
- Analyze dependency

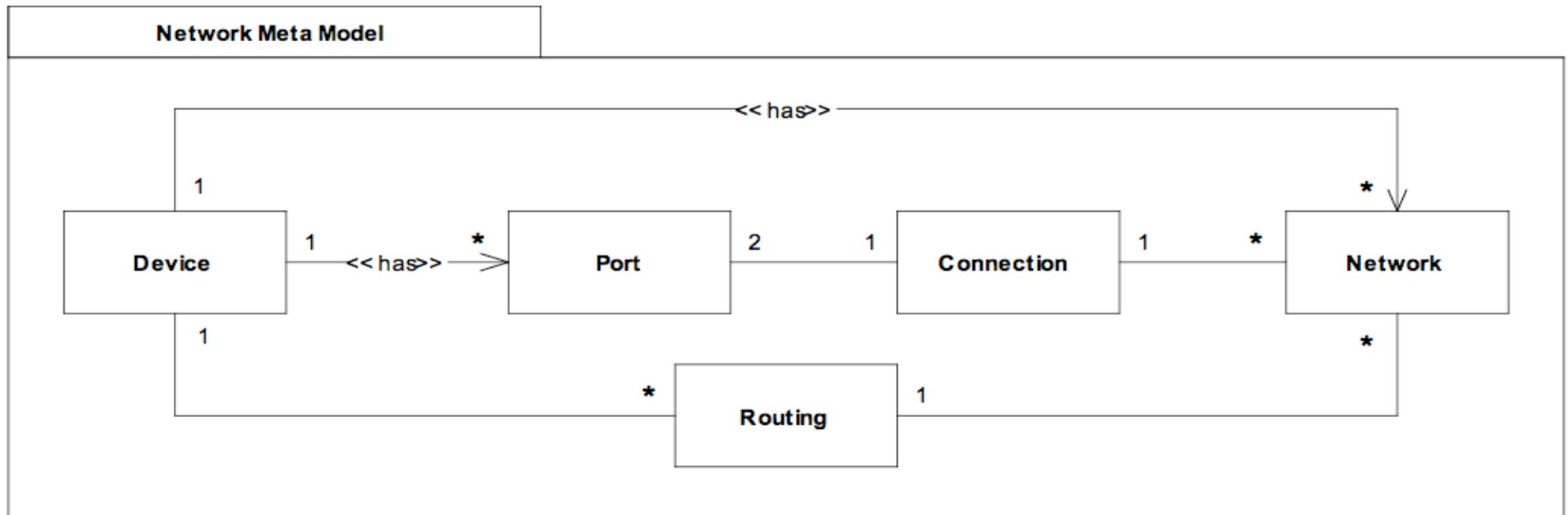
# VRDF: 3 tiers of dependency



# Project deliverables

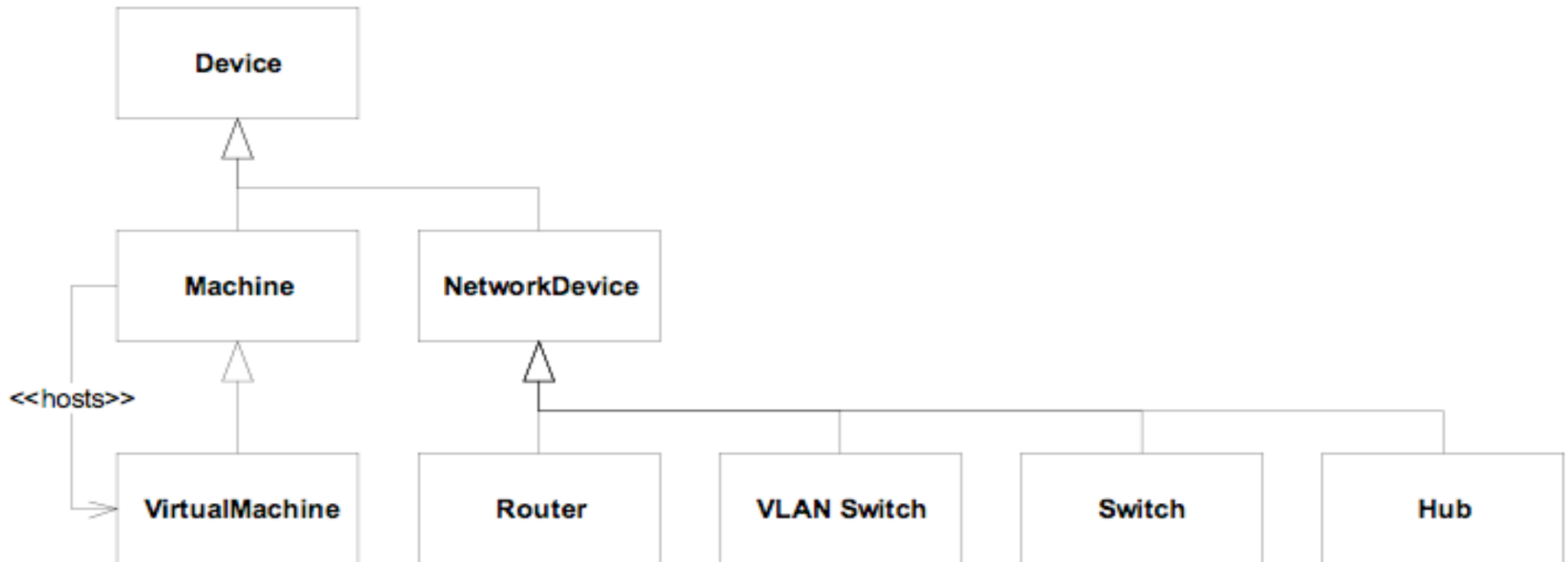
- Information model and RDF schema definitions for virtual asset enumeration and dependency analysis
- Initial set of SWRL rules for such analysis
- Initial proof of concept that works with Protégé
- Delivered to METI in March 2010

# Network layer meta-model

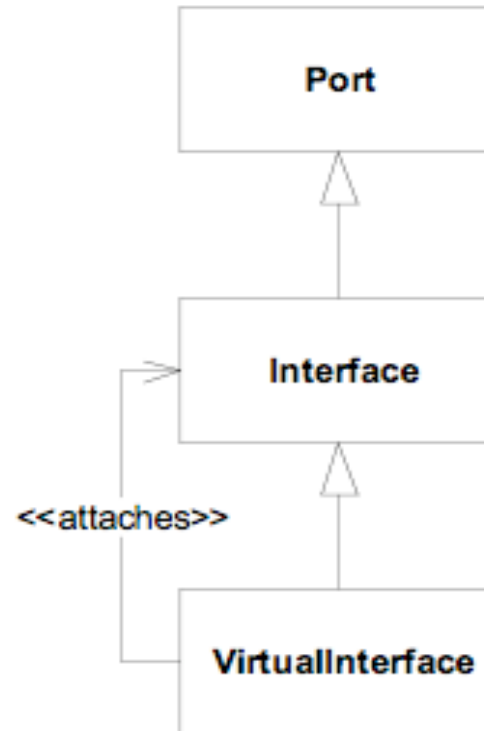


# Device classes

- Subject to extension

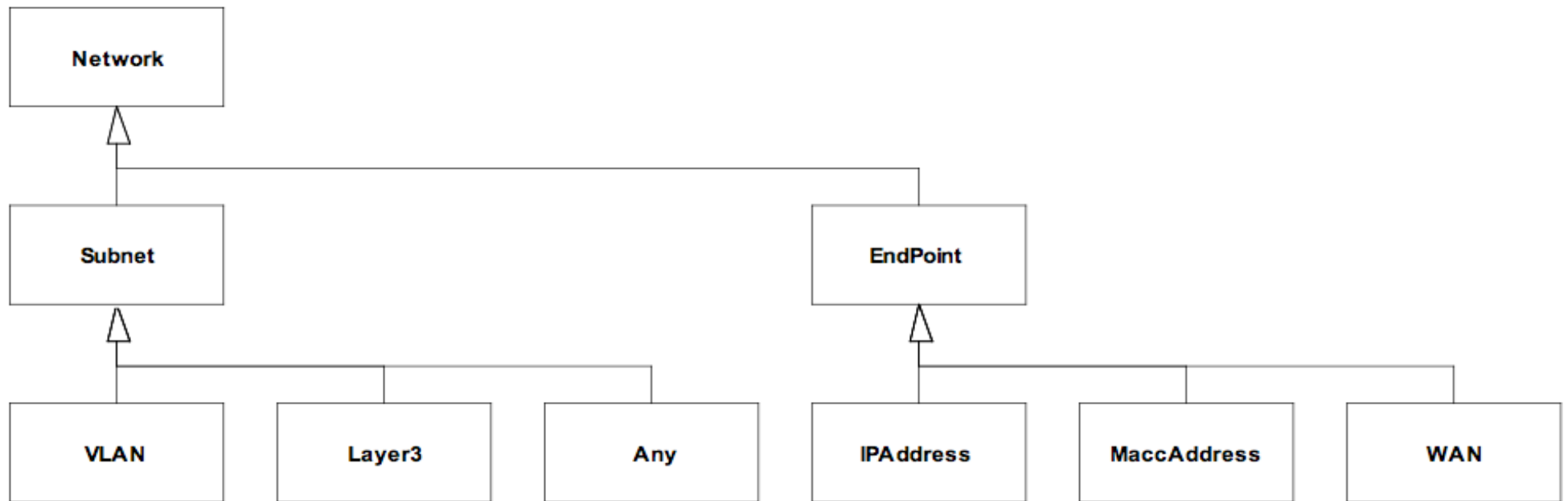


# Virtual Interfaces in VRDF

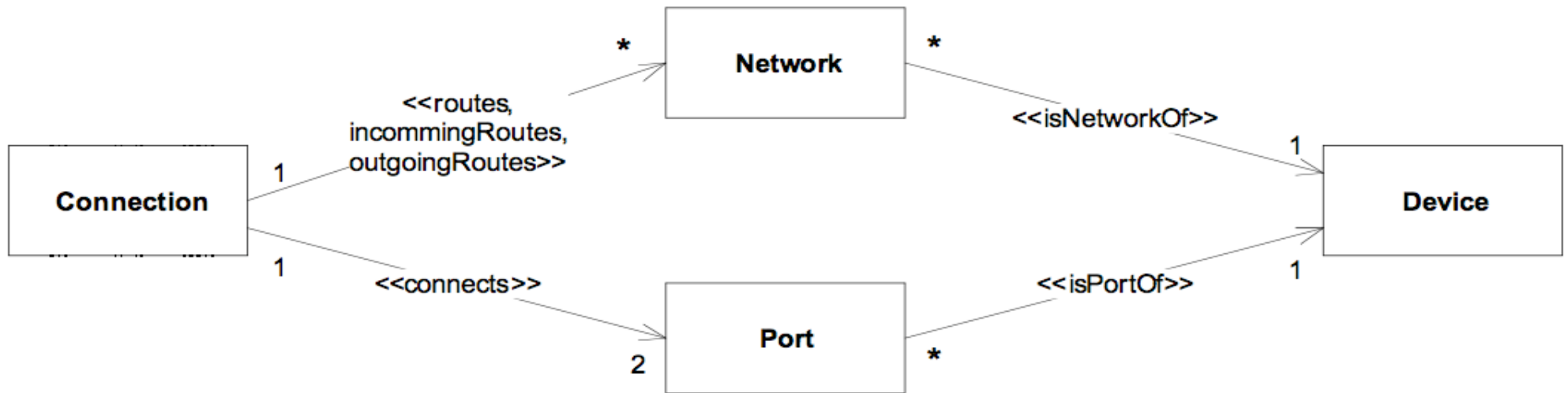




# Network resources



# Connection



# RDF schema

```

<owl:Class rdf:ID="Routing">
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#>
        >1</owl:cardinality>
      <owl:onProperty>
        <owl:ObjectProperty rdf:ID="isRoutingOf"/>
      </owl:onProperty>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:ID="Switch">
  <rdfs:subClassOf>
    <owl:Class rdf:ID="NetworkDevice"/>
  </rdfs:subClassOf>
  <owl:disjointWith>
    <owl:Class rdf:ID="VLANSwitch"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:ID="Router"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:ID="Hub"/>
  </owl:disjointWith>
</owl:Class>
<owl:Class rdf:ID="VirtualMachine">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty>
        <owl:ObjectProperty rdf:ID="hostedBy"/>
      </owl:onProperty>
      <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#>
        >1</owl:cardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Class rdf:ID="Machine"/>
  </rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:about="#VLAN">
  <owl:disjointWith>
    <owl:Class rdf:about="#Layer3"/>
  </owl:disjointWith>

```

**SUBCLASS EXPLORER**  
For Project: vrdf

Asserted Hierarchy

- owl:Thing
  - Connection
    - Bridge
    - MacVLAN
    - PortVLAN
    - TaggedVLAN
  - Device
    - Machine
      - VirtualMachine
    - NetworkDevice
      - Hub
      - Router
      - Switch
      - VLANSwitch
  - Network
    - EndPoint
      - IPAddress
      - MacAddress
      - WAN
    - Subnet
      - Any
      - Layer3
      - VLAN
  - Port
    - Interface
      - VirtualInterface
  - Routing
    - Filter
    - NAT
  - swrla:Entity
    - swrla:RuleGroup
  - Trouble
    - HardwareBroken
    - HardwareError
    - MissConfiguration
    - Shutdown
    - SoftwareError

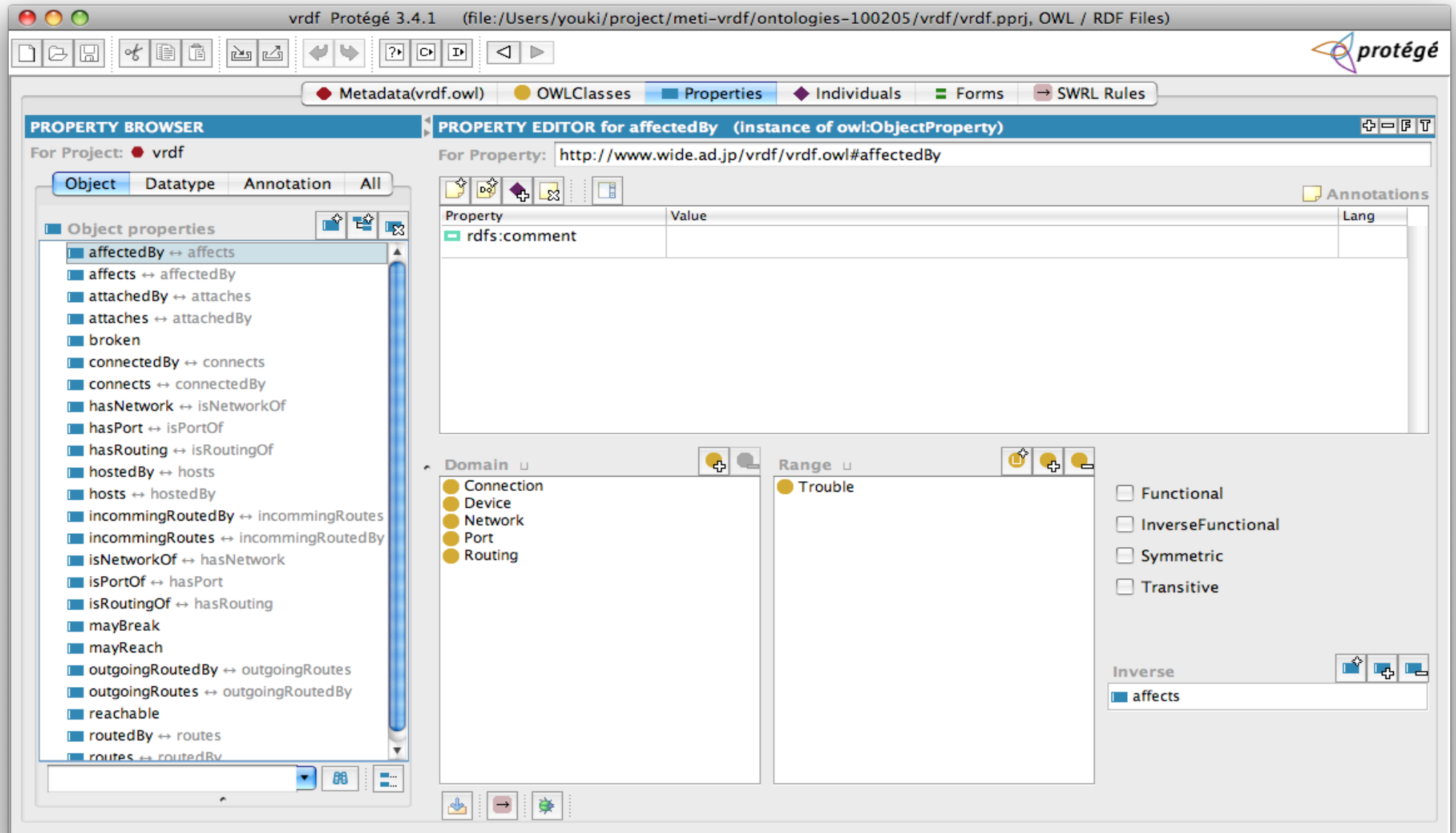
**PROPERTY BROWSER**  
For Project: vrdf

Object Datatype Annotation All

Object properties

- affectedBy \* affects
- affects \* affectedBy
- attachedBy \* attaches
- attaches \* attachedBy
- connectedBy \* connects
- connects \* connectedBy
- hasNetwork \* isNetworkOf
- hasPort \* isPortOf
- hasRouting \* isRoutingOf
- hostedBy \* hosts
- hosts \* hostedBy
- incomingRoutedBy \* incomingRoutes
- incomingRoutes \* incomingRoutedBy
- isNetworkOf \* hasNetwork
- isPortOf \* hasPort
- isRoutingOf \* hasRouting
- mayReach
- outgoingRoutedBy \* outgoingRoutes
- outgoingRoutes \* outgoingRoutedBy
- reachable
- routedBy \* routes
- routes \* routedBy

# RDF schema viewed in Protégé



# SWRL rules in Protégé

vrdf Protégé 3.4.1 (file:/Users/youki/project/medi-vrdf/ontologies-100205/vrdf/vrdf.pprj, OWL / RDF Files)

Metadata(vrdf.owl) OWLClasses Properties Individuals Forms **SWRL Rules**

SWRL Rules

Enabled	Name	Expression
<input checked="" type="checkbox"/>	http://www.wide.ad.jp/vrdf/Def_AffectsDeviceToNetwork	$\rightarrow \text{Device}(?x) \wedge \text{affects}(?a, ?x) \wedge \text{hasNetwork}(?x, ?y) \rightarrow \text{affects}(?a, ?y)$
<input checked="" type="checkbox"/>	http://www.wide.ad.jp/vrdf/Def_AffectsDeviceToPort	$\rightarrow \text{Device}(?x) \wedge \text{affects}(?a, ?x) \wedge \text{hasPort}(?x, ?y) \rightarrow \text{affects}(?a, ?y)$
<input checked="" type="checkbox"/>	http://www.wide.ad.jp/vrdf/Def_AffectsDeviceToRouting	$\rightarrow \text{Device}(?x) \wedge \text{affects}(?a, ?x) \wedge \text{hasRouting}(?x, ?y) \rightarrow \text{affects}(?a, ?y)$
<input checked="" type="checkbox"/>	http://www.wide.ad.jp/vrdf/Def_AffectsNetworkToConnection	$\rightarrow \text{Network}(?x) \wedge \text{affects}(?a, ?x) \wedge \text{routedBy}(?x, ?y) \rightarrow \text{affects}(?a, ?y)$
<input checked="" type="checkbox"/>	http://www.wide.ad.jp/vrdf/Def_AffectsPortToConnection	$\rightarrow \text{Port}(?x) \wedge \text{affects}(?a, ?x) \wedge \text{connectedBy}(?x, ?y) \rightarrow \text{affects}(?a, ?y)$
<input checked="" type="checkbox"/>	http://www.wide.ad.jp/vrdf/Def_EndPointReachable	$\rightarrow \text{EndPoint}(?x) \wedge \text{EndPoint}(?y) \wedge \text{mayReach}(?x, ?y) \rightarrow \text{reachable}(?x, ?y)$
<input checked="" type="checkbox"/>	http://www.wide.ad.jp/vrdf/Def_incommingOutgoingRouteRe...	$\rightarrow \text{incommingRoutes}(?x, ?y) \wedge \text{outgoingRoutes}(?x, ?z) \wedge \text{differentFrom}(?y, ?z) \rightarrow \text{mayReach}(?y, ?z)$
<input checked="" type="checkbox"/>	http://www.wide.ad.jp/vrdf/Def_incommingRouteReach	$\rightarrow \text{incommingRoutes}(?x, ?y) \wedge \text{routes}(?x, ?z) \wedge \text{differentFrom}(?y, ?z) \rightarrow \text{mayReach}(?y, ?z)$
<input checked="" type="checkbox"/>	http://www.wide.ad.jp/vrdf/Def_outgoingRouteReach	$\rightarrow \text{routes}(?x, ?y) \wedge \text{outgoingRoutes}(?x, ?z) \wedge \text{differentFrom}(?y, ?z) \rightarrow \text{mayReach}(?y, ?z)$
<input checked="" type="checkbox"/>	http://www.wide.ad.jp/vrdf/Def_RouteReach	$\rightarrow \text{routes}(?x, ?y) \wedge \text{routes}(?x, ?z) \wedge \text{differentFrom}(?y, ?z) \rightarrow \text{mayReach}(?y, ?z) \wedge \text{mayReach}(?z, ?y)$
<input checked="" type="checkbox"/>	http://www.wide.ad.jp/vrdf/Def_TransMayReach	$\rightarrow \text{mayReach}(?x, ?y) \wedge \text{mayReach}(?y, ?z) \wedge \text{differentFrom}(?x, ?z) \rightarrow \text{mayReach}(?x, ?z)$
<input checked="" type="checkbox"/>	Rule-16	$\rightarrow \text{affects}(?a, ?b) \wedge \text{incommingRoutes}(?b, ?x) \wedge \text{outgoingRoutes}(?b, ?y) \wedge \text{differentFrom}(?x, ?y) \rightarrow \text{mayBreak}(?x, ?y)$
<input checked="" type="checkbox"/>	Rule-17	$\rightarrow \text{affects}(?a, ?b) \wedge \text{incommingRoutes}(?b, ?x) \wedge \text{routes}(?b, ?y) \wedge \text{differentFrom}(?x, ?y) \rightarrow \text{mayBreak}(?x, ?y)$
<input checked="" type="checkbox"/>	Rule-18	$\rightarrow \text{affects}(?a, ?b) \wedge \text{routes}(?b, ?x) \wedge \text{outgoingRoutes}(?b, ?y) \wedge \text{differentFrom}(?x, ?y) \rightarrow \text{mayBreak}(?x, ?y)$
<input checked="" type="checkbox"/>	Rule-19	$\rightarrow \text{affects}(?a, ?b) \wedge \text{routes}(?b, ?x) \wedge \text{routes}(?b, ?y) \wedge \text{differentFrom}(?x, ?y) \rightarrow \text{mayBreak}(?x, ?y) \wedge \text{mayBreak}(?y, ?x)$
<input checked="" type="checkbox"/>	Rule-20	$\rightarrow \text{mayBreak}(?x, ?y) \wedge \text{mayBreak}(?y, ?z) \wedge \text{differentFrom}(?x, ?z) \rightarrow \text{mayBreak}(?x, ?z)$

SWRLJesTab **Rules** Classes Property Assertion Axioms Individuals Axioms Inferred Individuals Inferred Axioms

Imported Rules and Queries

```

http://www.wide.ad.jp/vrdf/Def_outgoingRouteReach: routes(?x, ?y) ^ outgoingRoutes(?x, ?z) ^ differentFrom(?y, ?z) -> mayReach(?y, ?z)
Rule-16: affects(?a, ?b) ^ incommingRoutes(?b, ?x) ^ outgoingRoutes(?b, ?y) ^ differentFrom(?x, ?y) -> mayBreak(?x, ?y)
http://www.wide.ad.jp/vrdf/Def_AffectsDeviceToPort: affects(?a, ?x) ^ hasPort(?x, ?y) ^ Device(?x) -> affects(?a, ?y)
http://www.wide.ad.jp/vrdf/Def_AffectsDeviceToNetwork: affects(?a, ?x) ^ hasNetwork(?x, ?y) ^ Device(?x) -> affects(?a, ?y)
Rule-20: mayBreak(?x, ?y) ^ mayBreak(?y, ?z) ^ differentFrom(?x, ?z) -> mayBreak(?x, ?z)
Rule-17: affects(?a, ?b) ^ incommingRoutes(?b, ?x) ^ routes(?b, ?y) ^ differentFrom(?x, ?y) -> mayBreak(?x, ?y)
Rule-18: affects(?a, ?b) ^ routes(?b, ?x) ^ outgoingRoutes(?b, ?y) ^ differentFrom(?x, ?y) -> mayBreak(?x, ?y)
http://www.wide.ad.jp/vrdf/Def_TransMayReach: mayReach(?x, ?y) ^ mayReach(?y, ?z) ^ differentFrom(?x, ?z) -> mayReach(?x, ?z)
http://www.wide.ad.jp/vrdf/Def_EndPointReachable: mayReach(?x, ?y) ^ EndPoint(?x) ^ EndPoint(?y) -> reachable(?x, ?y)
http://www.wide.ad.jp/vrdf/Def_incommingOutgoingRouteReach: incommingRoutes(?x, ?y) ^ outgoingRoutes(?x, ?z) ^ differentFrom(?y, ?z) -> mayReach(?y, ?z)
Rule-19: affects(?a, ?b) ^ routes(?b, ?x) ^ routes(?b, ?y) ^ differentFrom(?x, ?y) -> mayBreak(?x, ?y) ^ mayBreak(?y, ?x)
http://www.wide.ad.jp/vrdf/Def_AffectsPortToConnection: affects(?a, ?x) ^ connectedBy(?x, ?y) ^ Port(?x) -> affects(?a, ?y)
http://www.wide.ad.jp/vrdf/Def_RouteReach: routes(?x, ?y) ^ routes(?x, ?z) ^ differentFrom(?y, ?z) -> mayReach(?y, ?z) ^ mayReach(?z, ?y)
http://www.wide.ad.jp/vrdf/Def_incommingRouteReach: incommingRoutes(?x, ?y) ^ routes(?x, ?z) ^ differentFrom(?y, ?z) -> mayReach(?y, ?z)
http://www.wide.ad.jp/vrdf/Def_AffectsDeviceToRouting: affects(?a, ?x) ^ hasRouting(?x, ?y) ^ Device(?x) -> affects(?a, ?y)

```

# Summary

- Measurement of Virtualized Infrastructure
  - Dependency as another topology graph
  - Analysis of availability / impact / security
- Scaffolding from an Ontological Perspective:
  - Enumeration of virtual & physical resources
  - Description of dependency
  - RDF schema
  - Initial attempt to use rule engines e.g., SWRL
- Remaining tasks:
  - Service dependency
  - Data extraction tools
- Contact: Youki Kadobayashi, NAIST ([youki-k\\_at\\_is.naist.jp](mailto:youki-k_at_is.naist.jp))