44. Reuse Languages - Modularity for Metamodels based on Invasive Composition

(Adding Modularity to a Domain-Specific Language with the Reuseware Metacomposition-Tool)

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Obligatory Literature

- [1] Jakob Henriksson, Jendrik Johannes, Steffen Zschaler, and Uwe Aßmann. Reuseware - adding modularity to your language of choice. Journal of Object Technology, 6(9):127-146, 2007. On Language-Independent Model Modularisation,Transactions on Aspect-Oriented Development, 2008
- [2] http://reuseware.org
- [3] http://wiki.eclipse.org/index.php/GMF Tutorial#Quick Start

44.1 Reuse Languages and Metamodel Modularity

44.1 Building Modularisation into Taipan DSL

A reuse (sub-)language is a sublanguage providing modularity

- Languages need modularization concepts to improve reusability and reduce complexity of applications and tools
- Challenges of modularization (on M1):
  - Modularization needs reuse concepts in syntax and semantics
- Requirement for the reuse language on M2:
  - The reuse language itself should be modular, to be composable with other languages
  - The metamodel of a reuse language should be an M2-module
  - Reuse languages requires additional tooling support
- We have already discussed role-based metamodel composition
  - Here we show how to use invasive composition for metamodel components on M2 and their composition
- A metamodel composition system is a composition system for

44.1 Building Modularisation into Taipan DSL

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Metamodel Composition

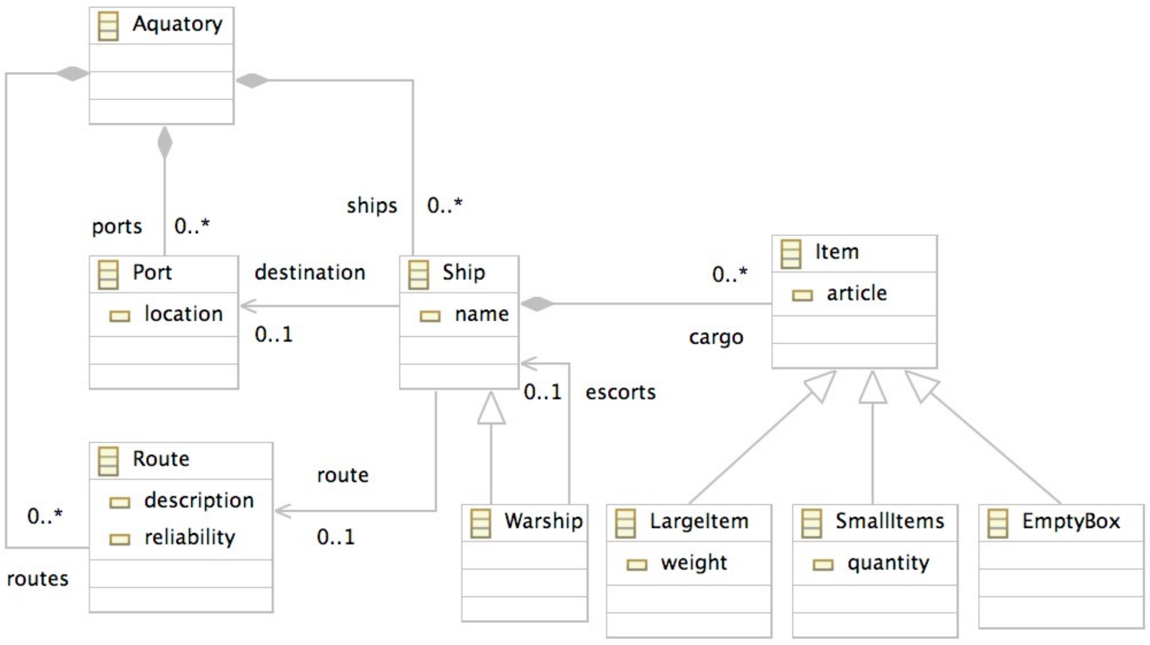
- This chapter presents a toolkit to build reuse languages
  - based on invasive metamodel composition, implemented in the Reuseware toolkit [1][2]
  - Does not influence design of DSL syntax or semantics
    - DSL syntax can be extended at the end
  - Composes modularized models to monolithic models
    - DSL semantics do not require extension
  - Generic tooling can be used with arbitrary DSLs

Building Modularisation into a DSL

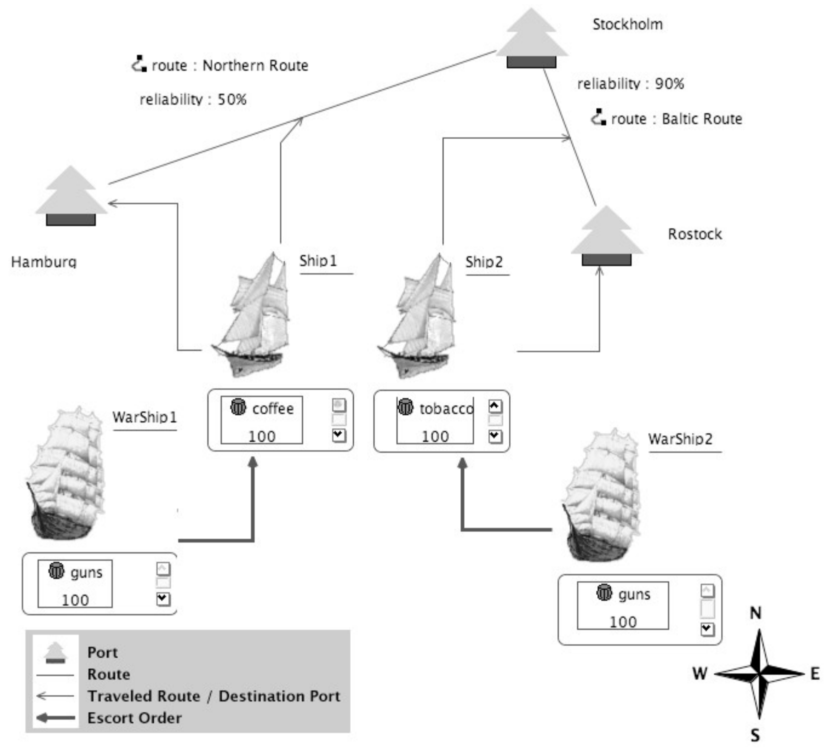
- Reuseware approach
  - Define a ***composition system*** with modularisation concepts (see CBSE course)
  - Composition systems define **component model**
    - E.g., Modules, Packages, Aspects, etc.
  - **Composition techniques**
    - E.g., parameterization, extension, weavings
  - And **composition languages**
    - For the structure in the large
  - Optional: Extend DSL syntax with concepts for variation points
    - Variation points allow definition of templates
  - Define a reuse extension for your DSL
    - Binds the composition system to your DSL
    - E.g., what are the specifics of a module in your DSL, what identifies an aspect, etc.
  - Reuseware can handle modularization in your DSL

Building a DSL: Modularisation – Example

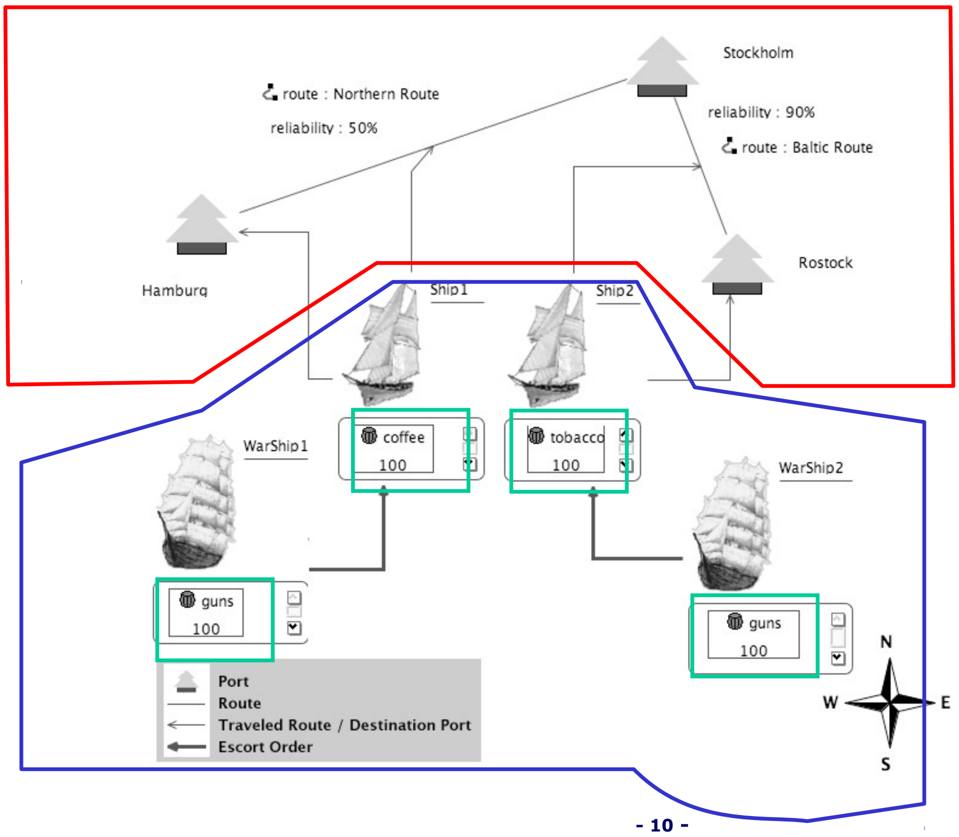
- Taipan DSL[3] for modeling ship fleets (Metamodel excerpt)



A Specification in the Taipan DSL: A Model with Ships



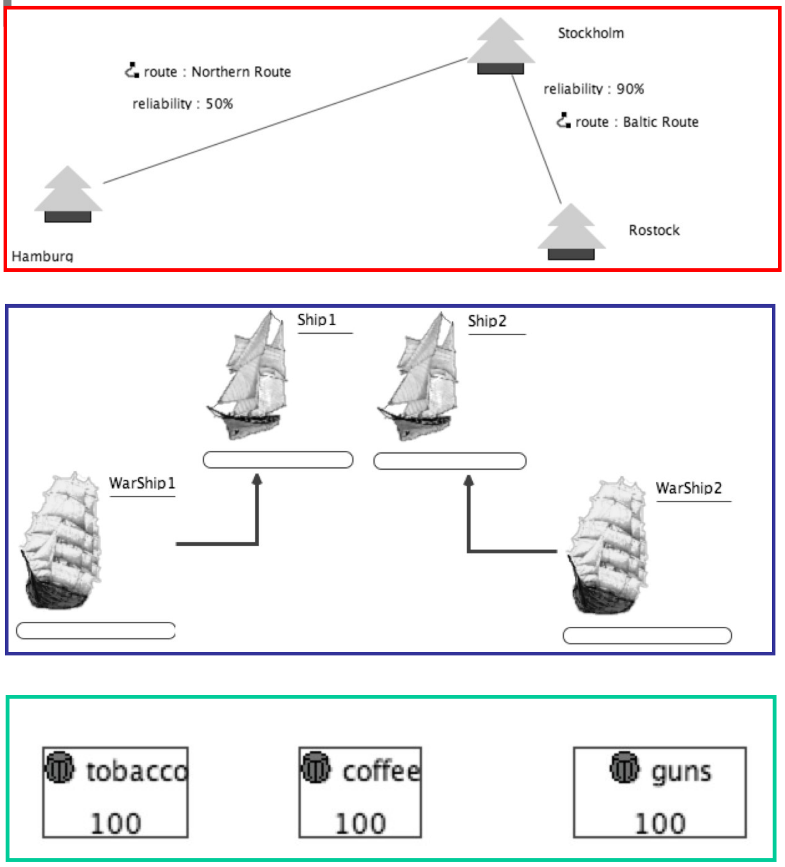
Building a DSL: Modularisation of Metamodel



Different concerns should be separated into model fragments

- Port model (configuration of ports and routes)
- Flotilla model (ships and their relations)
- Cargo model (Cargo and its properties)

Building a DSL: Modularisation of Metamodel



Different concerns should be separated into model fragments

· Port model (configuration of ports and routes)

·Flotilla model (ships and their relations)

·Cargo model (Cargo and its properties)

44.2 Reuseware - Overview

- **Model fragments** (model snippets) are partial models that may contain variation points
  - Offer a ***Composition Interface***
  - ***Composition Interface*** consists of ***Ports***
  - ***Ports*** point at elements of the model fragment that can be accessed for composition
- Composition Programs
  - Define ***composition links*** between Ports
  - Can be executed to produce a composed model where model fragments are merged at the elements pointed out by the linked Ports

Building a DSL: Reuseware - Overview

- Composition Systems
  - Define modularisation concepts
    (e.g., Modules, Packages, Aspects)
  - Define relations between modularisation concepts
    (e.g, an aspect relates to a core)
- Reuse extensions (for DSLs)
  - Define how modularization concepts defined in a composition system are realized in a concrete DSL
  - Define which ports are related to which model elements of a model fragment

Defining Composition Systems with Reuseware

- A composition system defines fragment components with
  - Fragment roles
    - Role a model fragment plays in the modularisation
      (e.g., aspect or core)
    - Fragment roles collaborate through associations between ports
  - Static ports of a fragment component
    - Defined for one fragment role
    - Each fragment playing the role has to offer the port
  - Dynamic ports
    - Defined for one fragment role
    - Each fragment playing the role can offer several of these ports
  - Contribution Associations
    - Defines that two ports are related
    - Executing a composition link between the two ports will trigger
      the copying of model elements
  - Configuration Associations
    - Defines that two ports are related
    - Executing a composition link between the two ports will NOT trigger
      the copying of model elements

ReuseTaipan - a Composition System for the Taipan Metamodel, Specified in Reuseware-FraCL

```
compositionsystem reuseTaipan {

  fragment role TravelSpace {
    static port VehicleContainer;
    dynamic port Routes;
    dynamic port Places;
  }

  fragment role Flotilla {
    static port Vehicles;
    dynamic port RouteSlots;
    dynamic port PlaceSlots;
  }

  contribution Flotilla.Vehicles --> TravelSpace.VehicleContainer;
  configuration Flotilla.RouteSlots --> TravelSpace.Routes;
  configuration Flotilla.PlaceSlots --> TravelSpace.Places;


  fragment role ItemHolder {
    dynamic port ItemSpaces;
  }

  fragment role ItemContainer {
    dynamic port Items;
  }

  contribution ItemContainer.Items --> ItemHolder.ItemSpaces;
}
```

Building a DSL: ReuseTaipan - a Composition System

```
compositionsystem reuseTaipan {

  fragment role TravelSpace {
    static port VehicleContainer;
    dynamic port Routes;
    dynamic port Places;
  }
  fragment role Flotilla {
    static port Vehicles;
    dynamic port RouteSlots;
    dynamic port PlaceSlots;
  }

  contribution Flotilla.Vehicles --> TravelSpace.VehicleContainer;
  configuration Flotilla.RouteSlots --> TravelSpace.Routes;
  configuration Flotilla.PlaceSlots --> TravelSpace.Places;


  fragment role ItemHolder {
    dynamic port ItemSpaces;
  }

  fragment role ItemContainer {
    dynamic port Items;
  }

  contribution ItemContainer.Items --> ItemHolder.ItemSpaces;
}
```

A **TravelSpace** offers a place where vehicles can be placed (**VehicleContainer**) and a number of **Routes** and **Places**

Building a DSL: ReuseTaipan - a Composition System

```
compositionsystem reuseTaipan {

  fragment role TravelSpace {
    static port VehicleContainer;
    dynamic port Routes;
    dynamic port Places;
  }

  fragment role Flotilla {
    static port Vehicles;
    dynamic port RouteSlots;
    dynamic port PlaceSlots;
  }

  contribution Flotilla.Vehicles --> TravelSpace.VehicleContainer;
  configuration Flotilla.RouteSlots --> TravelSpace.Routes;
  configuration Flotilla.PlaceSlots --> TravelSpace.Places;


  fragment role ItemHolder {
    dynamic port ItemSpaces;
  }

  fragment role ItemContainer {
    dynamic port Items;
  }

  contribution ItemContainer.Items --> ItemHolder.ItemSpaces;
}
```

A **Flotilla** offers a set of **Vehicles** and has a number of placeholders for routes **(RouteSlots)** and places **(PlaceSlots)**

Building a DSL: ReuseTaipan - a Composition System

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compositionsystem reuseTaipan {

  fragment role TravelSpace {
    static port VehicleContainer;
    dynamic port Routes;
    dynamic port Places;
  }

  fragment role Flotilla {
    static port Vehicles;
    dynamic port RouteSlots;
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  }

  contribution Flotilla.Vehicles --> TravelSpace.VehicleContainer;
  configuration Flotilla.RouteSlots --> TravelSpace.Routes;
  configuration Flotilla.PlaceSlots --> TravelSpace.Places;

  fragment role ItemHolder {
    dynamic port ItemSpaces;
  }

  fragment role ItemContainer {
    dynamic port Items;
  }

  contribution ItemContainer.Items --> ItemHolder.ItemSpaces;
}
```

A **Flotilla** contributes **Vehicles** to a **TravelSpace**'s **VehicleContainer;** a **RouteSlots** can be configured with a **Route**; a **PlaceSlots** can be configured with a **Place**

Building a DSL: ReuseTaipan - a Composition System

```
compositionsystem reuseTaipan {

  fragment role TravelSpace {
    static port VehicleContainer;
    dynamic port Routes;
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  fragment role Flotilla {
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    dynamic port PlaceSlots;
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  contribution Flotilla.Vehicles --> TravelSpace.VehicleContainer;
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  fragment role ItemHolder {
    dynamic port ItemSpaces;
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  fragment role ItemContainer {
    dynamic port Items;
  }

  contribution ItemContainer.Items --> ItemHolder.ItemSpaces;
}
```

An **ItemHolder** offers different **ItemSpaces**

Building a DSL: ReuseTaipan - a Composition System

```
compositionsystem reuseTaipan {

  fragment role TravelSpace {
    static port VehicleContainer;
    dynamic port Routes;
    dynamic port Places;
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  fragment role Flotilla {
    static port Vehicles;
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  fragment role ItemHolder {
    dynamic port ItemSpaces;
  }

  fragment role ItemContainer {
    dynamic port Items;
  }

  contribution ItemContainer.Items --> ItemHolder.ItemSpaces;
}
```

An **ItemContainer** contains and offers **Items**

Building a DSL: ReuseTaipan - a Composition System

```
compositionsystem reuseTaipan {

  fragment role TravelSpace {
    static port VehicleContainer;
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    dynamic port Places;
  }

  fragment role Flotilla {
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    dynamic port PlaceSlots;
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  contribution Flotilla.Vehicles --> TravelSpace.VehicleContainer;
  configuration Flotilla.RouteSlots --> TravelSpace.Routes;
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  fragment role ItemHolder {
    dynamic port ItemSpaces;
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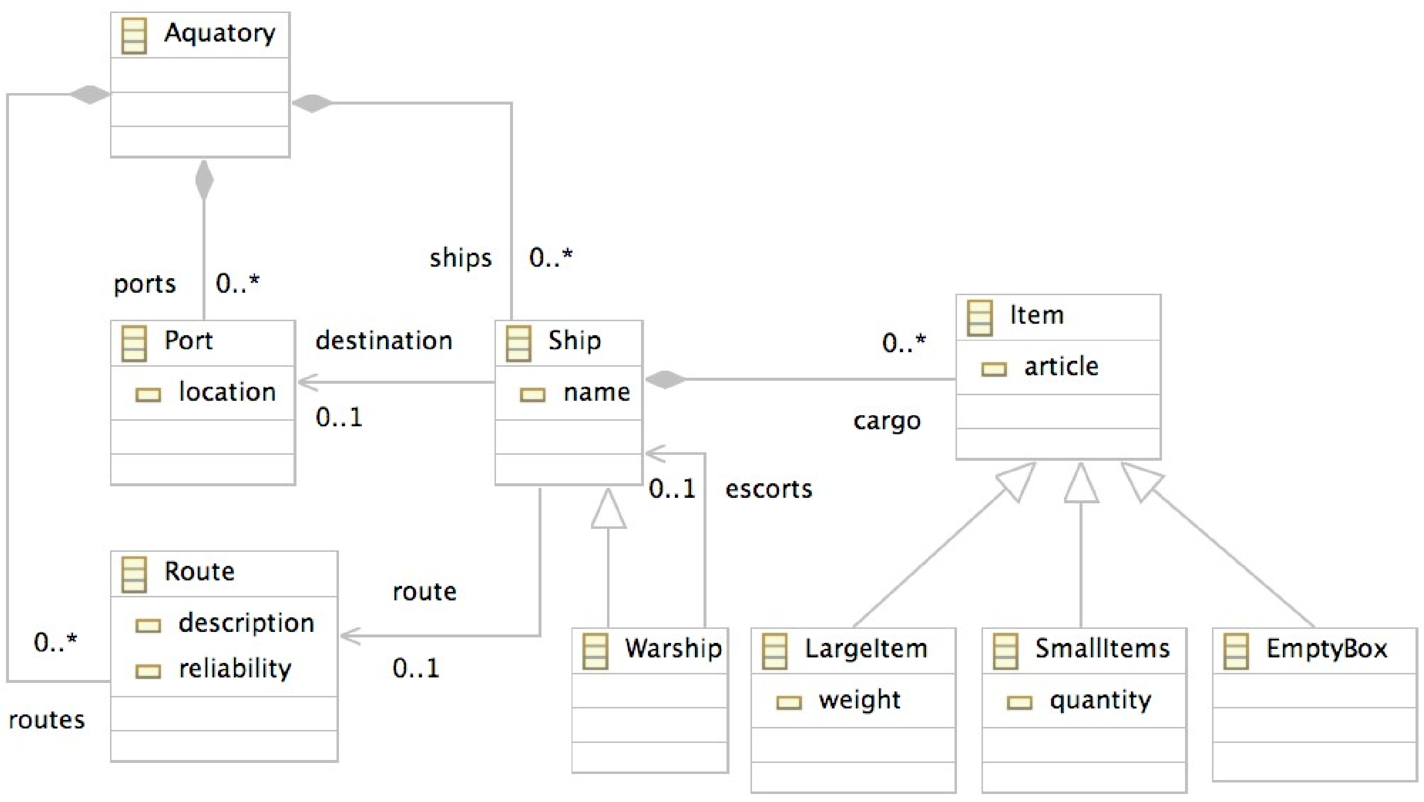
  contribution ItemContainer.Items --> ItemHolder.ItemSpaces;
}
```

Items can be individually assigned to **ItemSpaces**

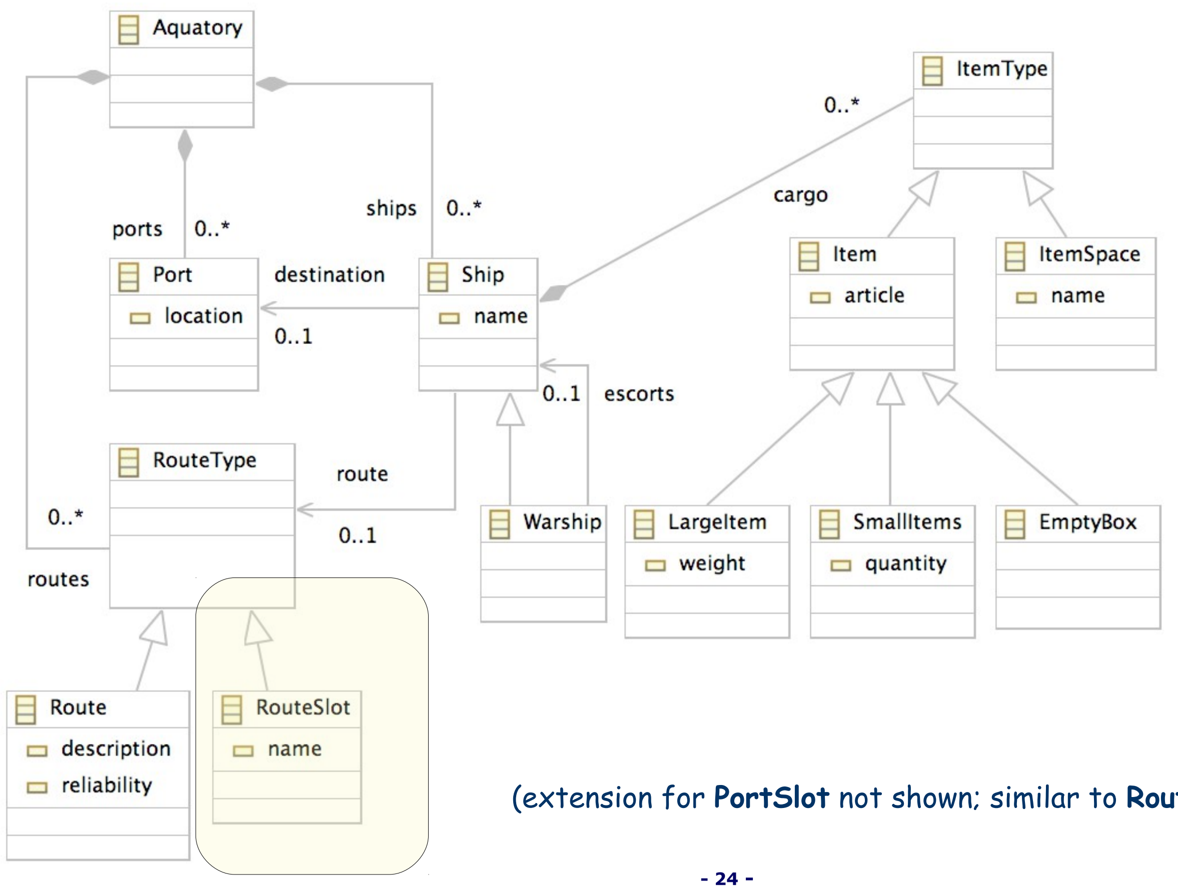
44.3 Building a DSL: Extending a Metamodel for Variation

- Three kinds of variation points required in the metamodels
  - RouteSlot
  - PortSlot
  - ItemSpace
- For each kind of variation point we...
  - Introduce a superclass for the metaclass that defines the elements which may replace the variation point
    - e.g., we introduce **RouteType** as a superclass of **Route** in the case of RouteSlot
  - We redirect all references to the metaclass to the new superclass
    - e.g., all references to **Route** are redirected to **RouteType**
  - We introduce a new subclass for the just introduced superclass that represents the variation point. This class needs properties from which a name can be derived.
    - e.g., we introduce **RouteSlot** as a subclass of **RouteType**

The Taipan Metamodel (Rpt.)



Extending the Taipan Metamodel for Variation



(extension for **PortSlot** not shown; similar to **RouteSlot**)

Building a DSL: Reuseware - Reuse Extensions

- A **reuse extension of a metamodel** is an extended metamodel defining
  - How a composition interface defined by a fragment role (which is defined in a composition system) is linked to the content of a model fragment
  - Each port links to a set of model elements treated as:
    - Prototype: Element that can be copied with its contained elements
    - Anchor: Element that can be referenced by other elements
    - Hook: Variation point where Prototypes can be put
    - Slot: Variation point where Anchors can be put
- Reuseware-CL is a language to define reuse extensions of metamodels
  - to make a metamodel composable

Building a DSL: Binding ReuseTaipan to Taipan DSL

```
reuseextension reuseTaipan implements reuseTaipan
epackages <http://www.eclipse.org/examples/gmf/taipan>
Rootclass TravelSpace {
  fragment role TravelSpace {
    port VehicleContainer {
      Aquatory.ships is hook {}
      Aquatory.ports is hook {}
      Aquatory.routes is hook {}
    }
    port Routes {
      Route is anchor {
        port expr = $self.description$
      }
    }
    port Places {
      Port is anchor {
        port expr = $self.location.concat('Port')$
      }
    }
  }

  fragment role Flotilla {
    port Vehicles {
      Aquatory.ships is prototype {}
      Aquatory.ports is prototype {}
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```

The ReuseTaipan composition system is bound to the Taipan DSL (referred to by the URI of its metamodel)

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    port Routes {
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        port expr = $self.description$
      }
    }
    port Places {
      Port is anchor {
        port expr = $self.location.concat('Port')$
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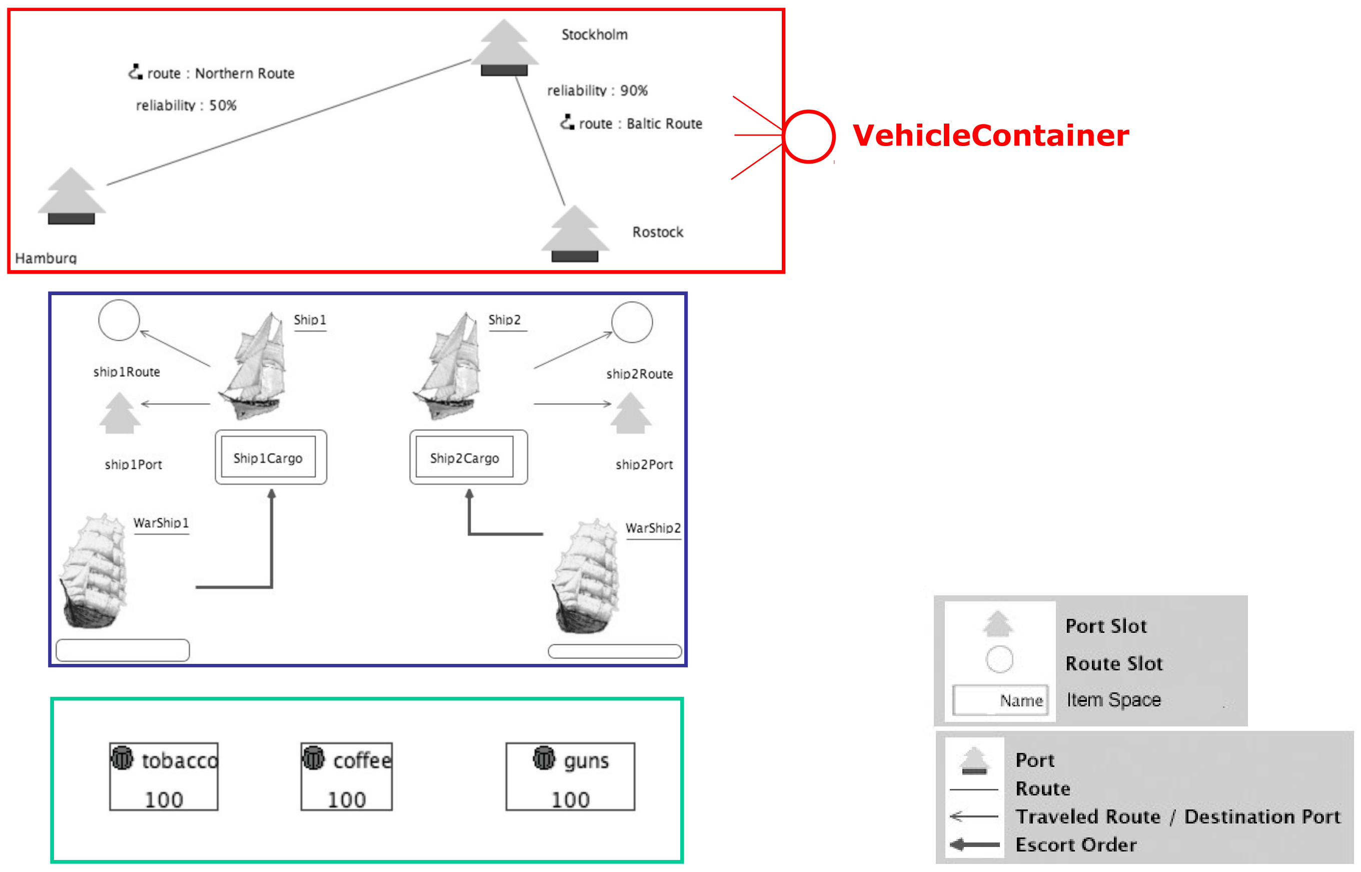
    }
  }

  fragment role Flotilla {
    port Vehicles {
      Aquatory.ships is prototype {}
      Aquatory.ports is prototype {}
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```

The references **ships**, **ports** and **routes** of the metaclass ***Aquatory*** all act as hooks accessible through the ***VehicleContainer*** port

Building a DSL: Binding ReuseTaipan to Taipan DSL



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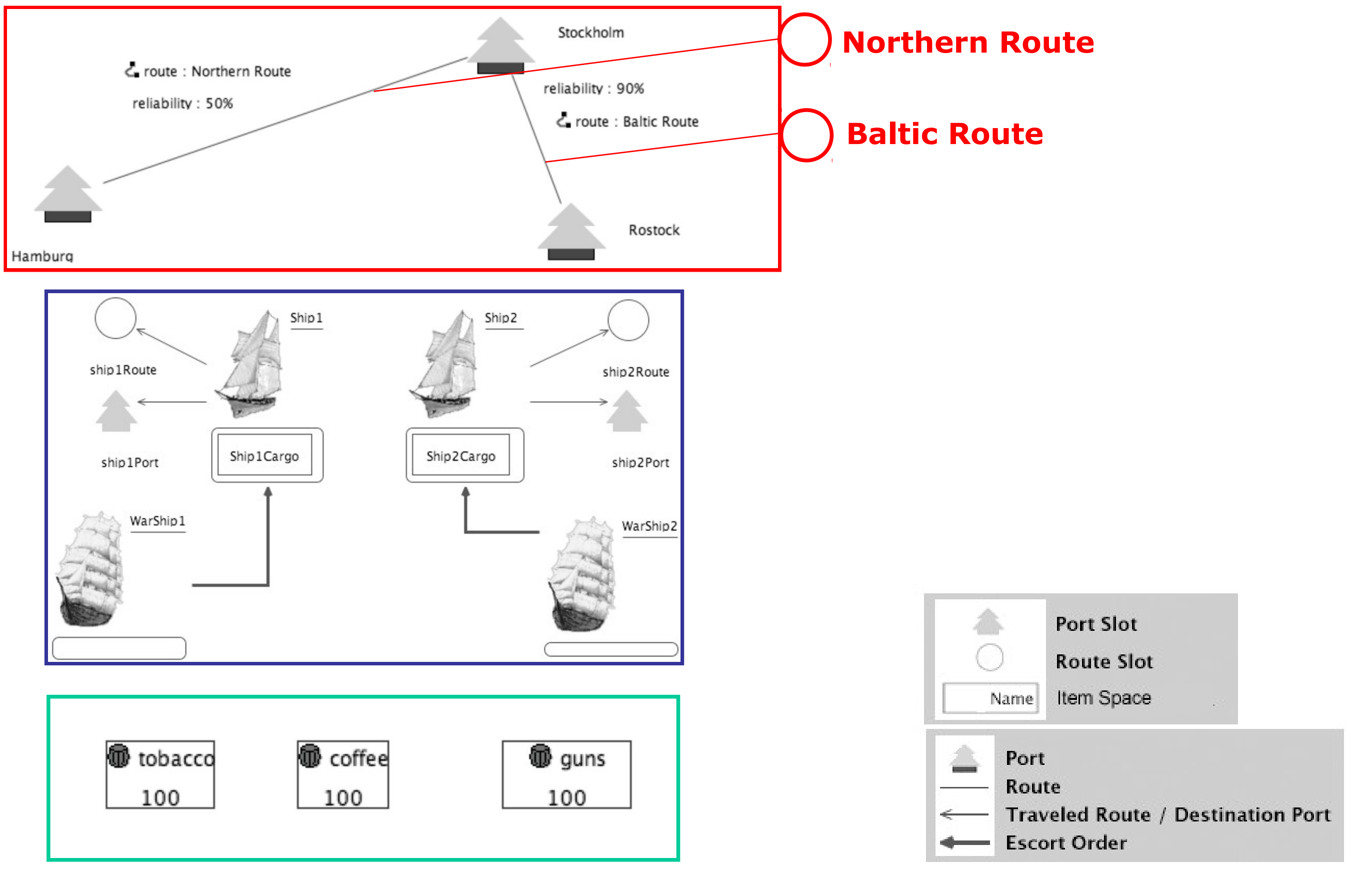
      Route is anchor {
        port expr = $self.description$
      }
    }
    port Places {
      Port is anchor {
        port expr = $self.location.concat('Port')$
      }
    }
  }

  fragment role Flotilla {
    port Vehicles {
      Aquatory.ships is prototype {}
      Aquatory.ports is prototype {}
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```

Each **Route** is an anchor accessible through individual ports; the ports are named using the **description** attribute of the **Route** metaclass
(OCL Expression: self.description)

Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components



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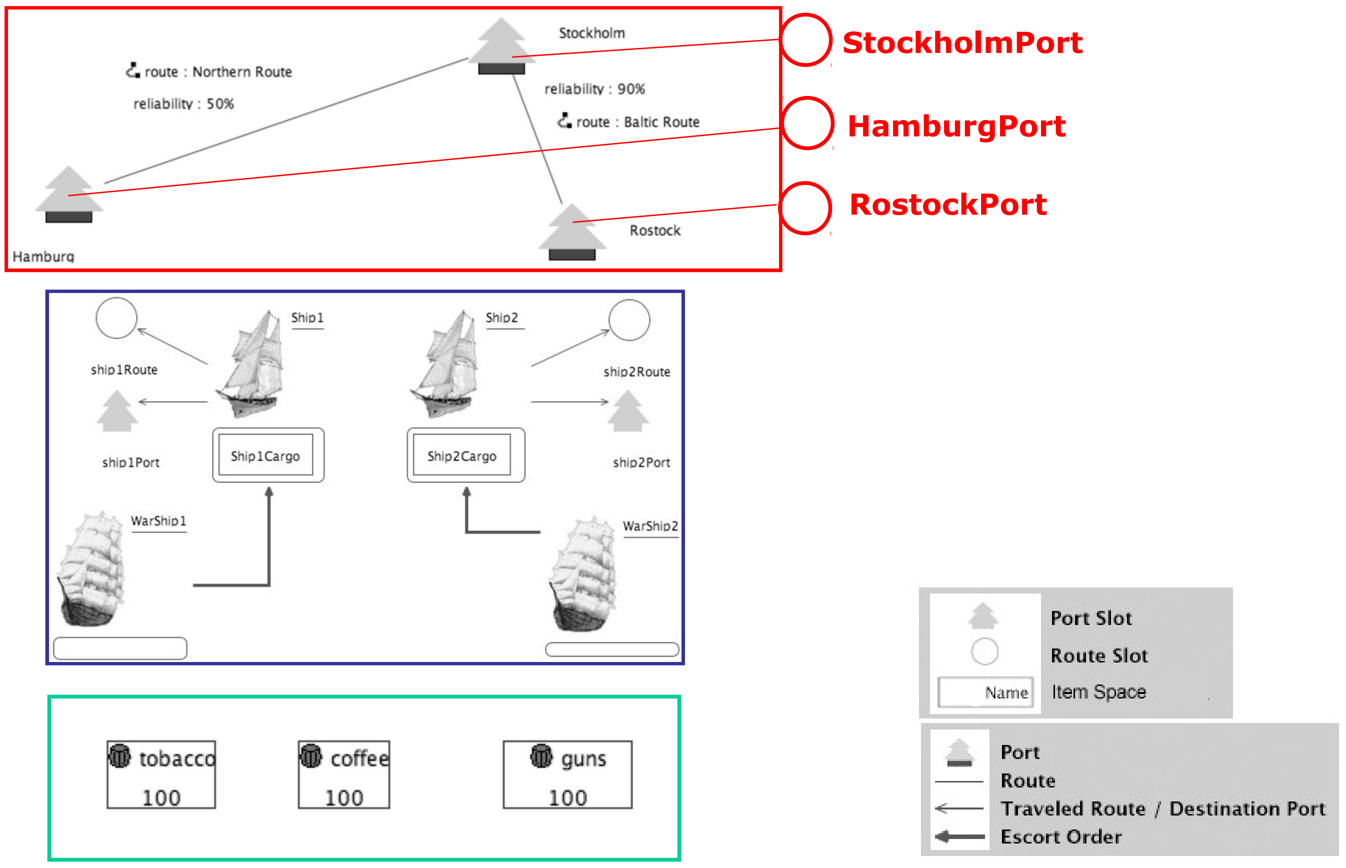
    }
    port Routes {
      Route is anchor {
        port expr = $self.description$
      }
    }
    port Places {
      Port is anchor {
        port expr = $self.location.concat('Port')$
      }
    }
  }

  fragment role Flotilla {
    port Vehicles {
      Aquatory.ships is prototype {}
      Aquatory.ports is prototype {}
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```

Each **Port** is an anchor accessible through individual ports; the ports are named using the **location** attribute of the **Port** metaclass

Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components



Building a DSL: Binding ReuseTaipan to Taipan DSL

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      Route is anchor {
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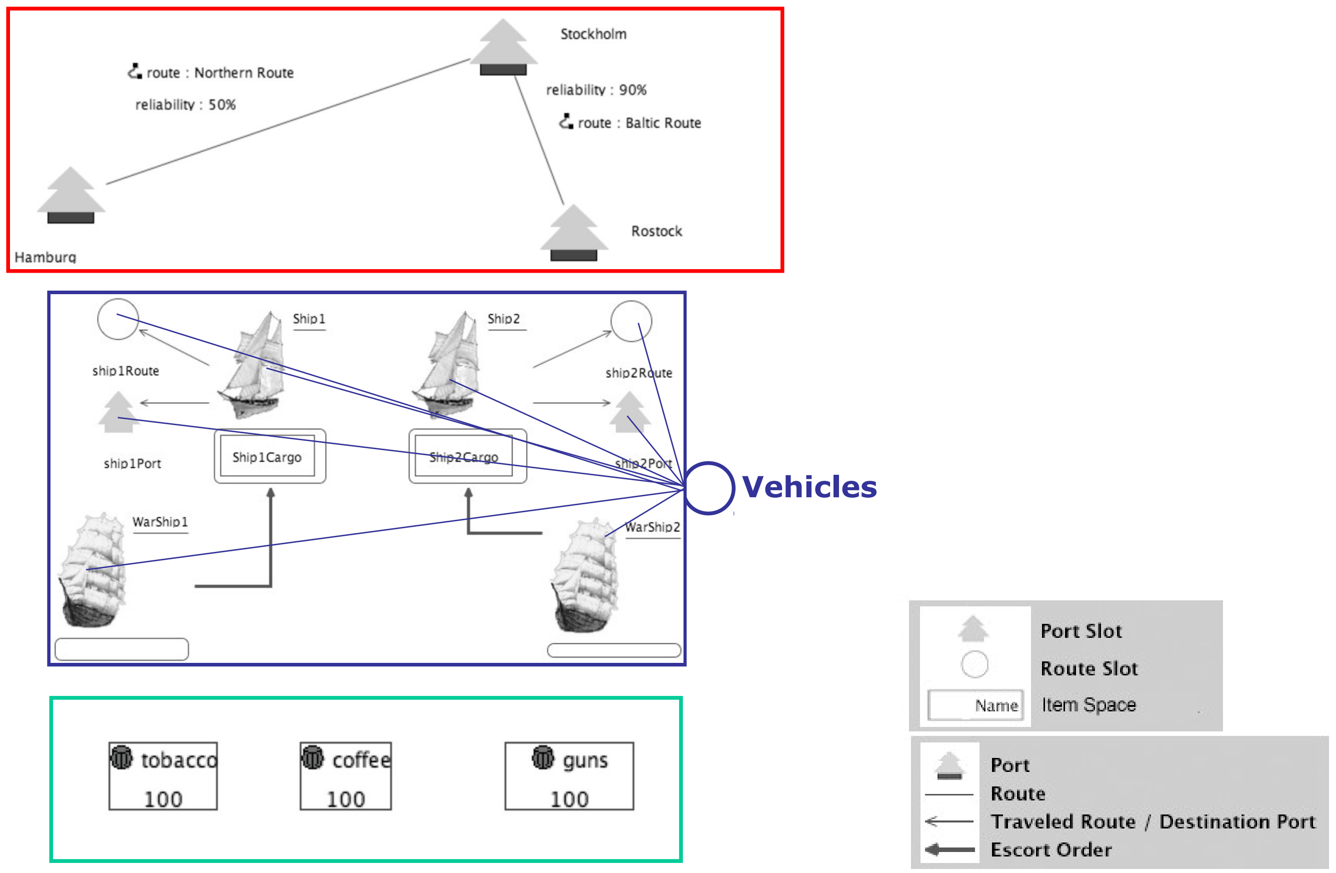
      }
    }
    port Places {
      Port is anchor {
        port expr = $self.location.concat('Port')$
      }
    }
  }

  fragment role Flotilla {
    port Vehicles {
      Aquatory.ships is prototype {}
      Aquatory.ports is prototype {}
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```

All elements of the references **ships**, **ports** and **routes** of the metaclass **Aquatory** act as prototypes accessible through the **Vehicles** port

Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components



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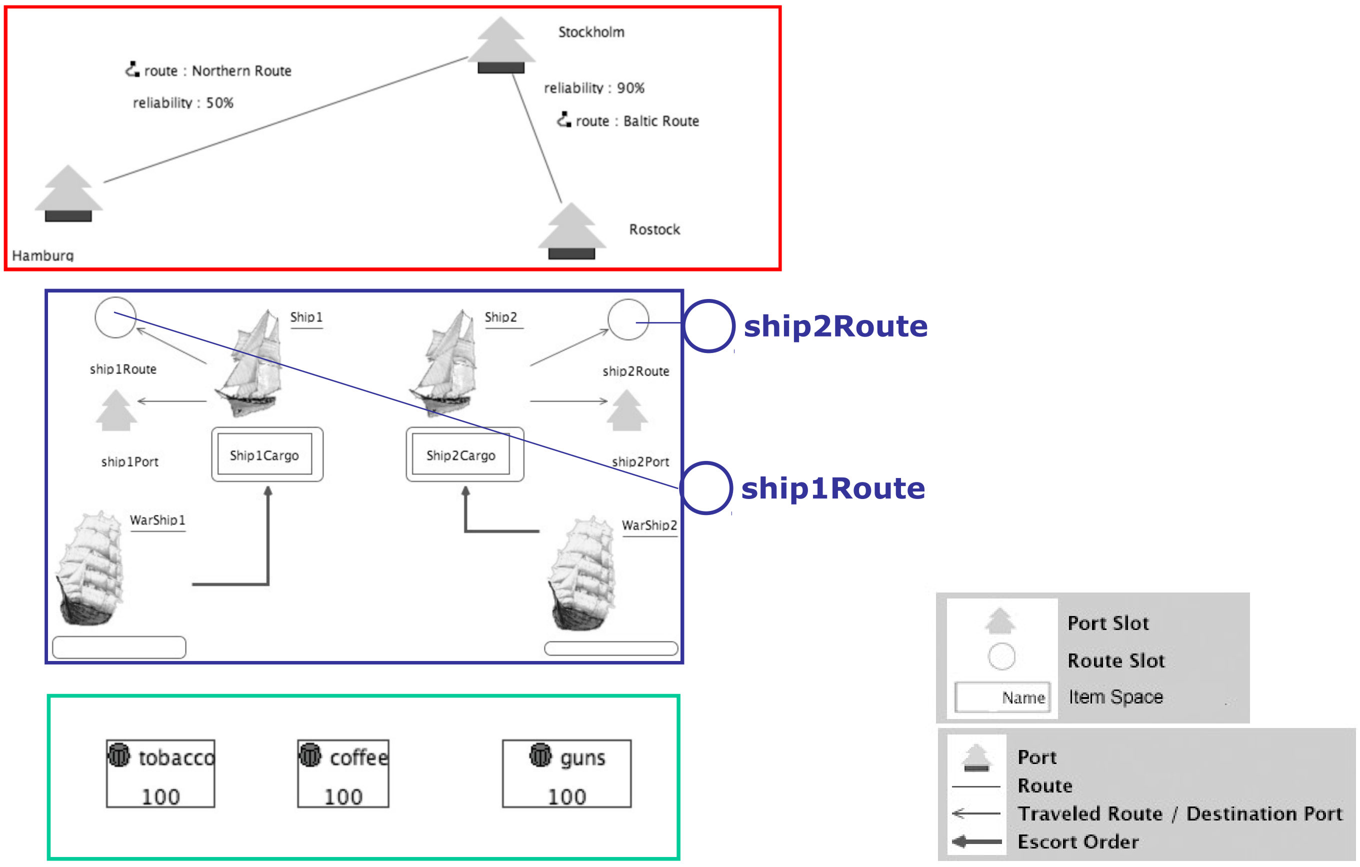
    }
  }

  fragment role Flotilla {
    port Vehicles {
      Aquatory.ships is prototype {}
      Aquatory.ports is prototype {}
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```

Each **RouteSlot** is a slot accessible through individual ports; the ports are named using the **name** attribute of the **RouteSlot** metaclass

Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components



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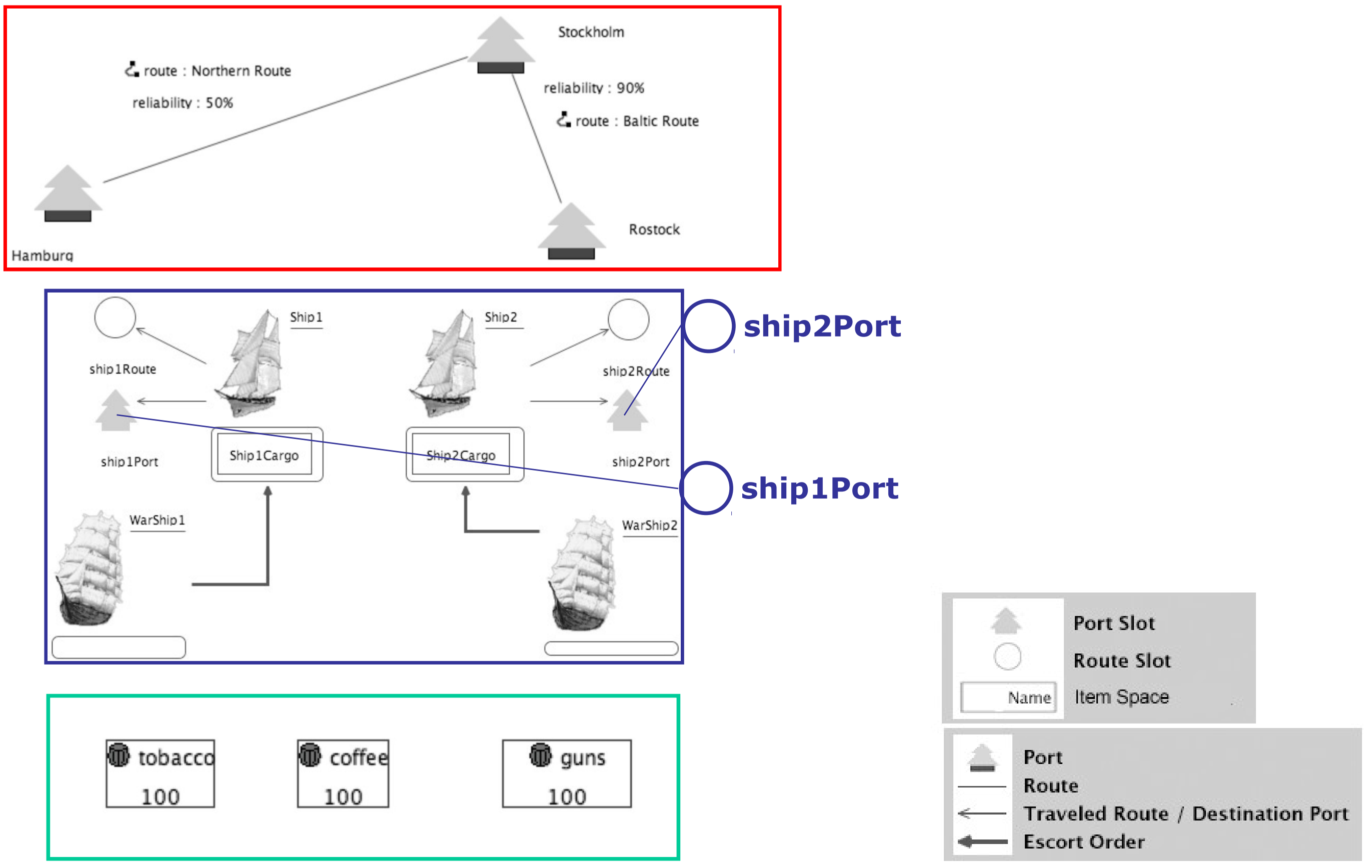
    }
    port Routes {
      Route is anchor {
        port expr = $self.description$
      }
    }
    port Places {
      Port is anchor {
        port expr = $self.location.concat('Port')$
      }
    }
  }

  fragment role Flotilla {
    port Vehicles {
      Aquatory.ships is prototype {}
      Aquatory.ports is prototype {}
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```

Each **PortSlot** is a slot accessible through individual ports; the ports are named using the **name** attribute of the **RouteSlot** metaclass

Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components



Building a DSL: Binding ReuseTaipan to Taipan DSL

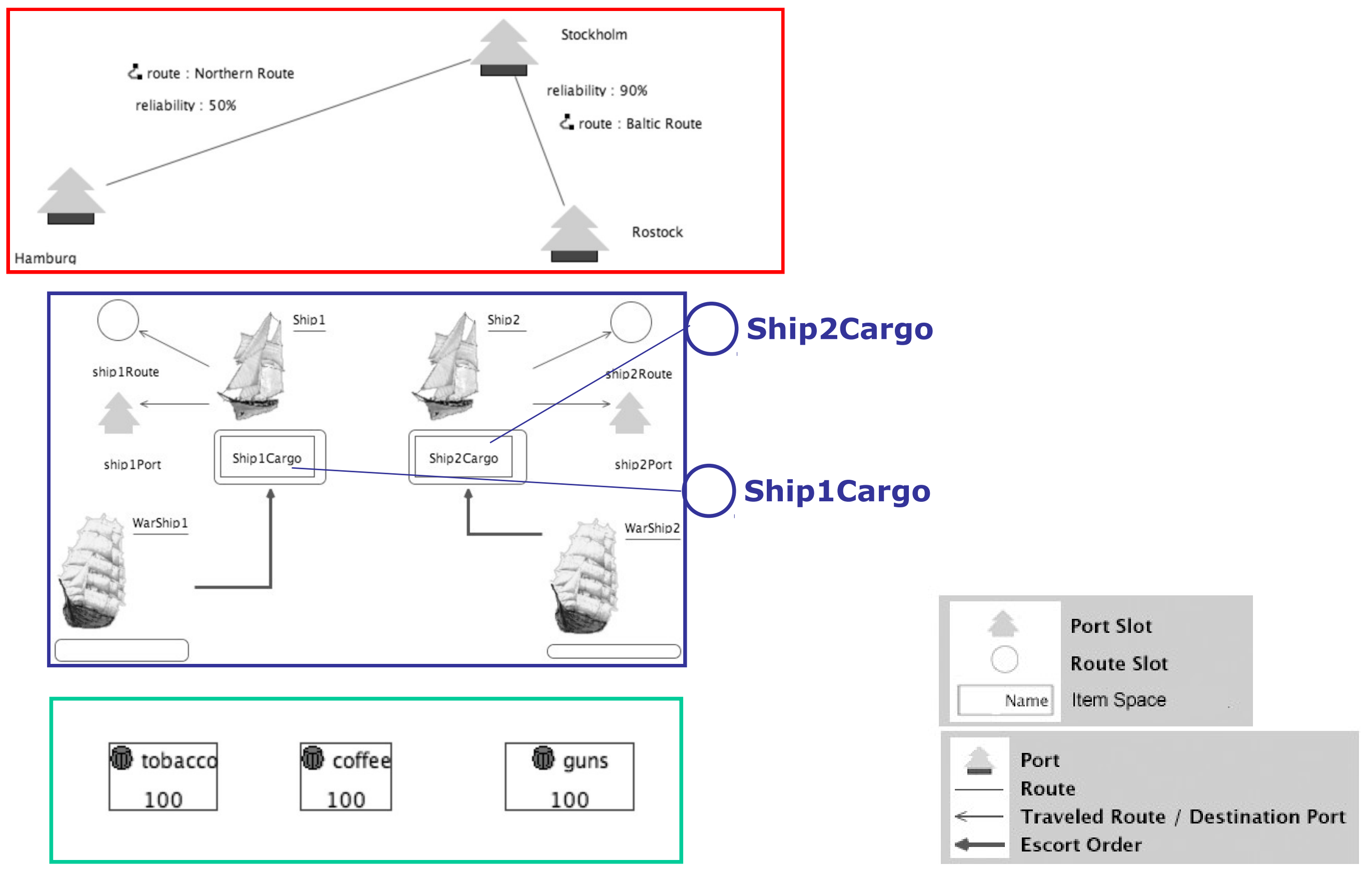
```
  ...

  binding ItemHolder {
    binding ItemSpaces {
      ItemSpace is hook {
        port expr = $self.name$
      }
    }
  }

  binding ItemContainer {
    binding Items {
      Item is prototype {
        port expr = $self.article$
      }
    }
  }
}
```

Each **ItemSpace** is a hook accessible through individual ports; the ports are named using the **name** attribute of the **ItemSpace** metaclass

Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components



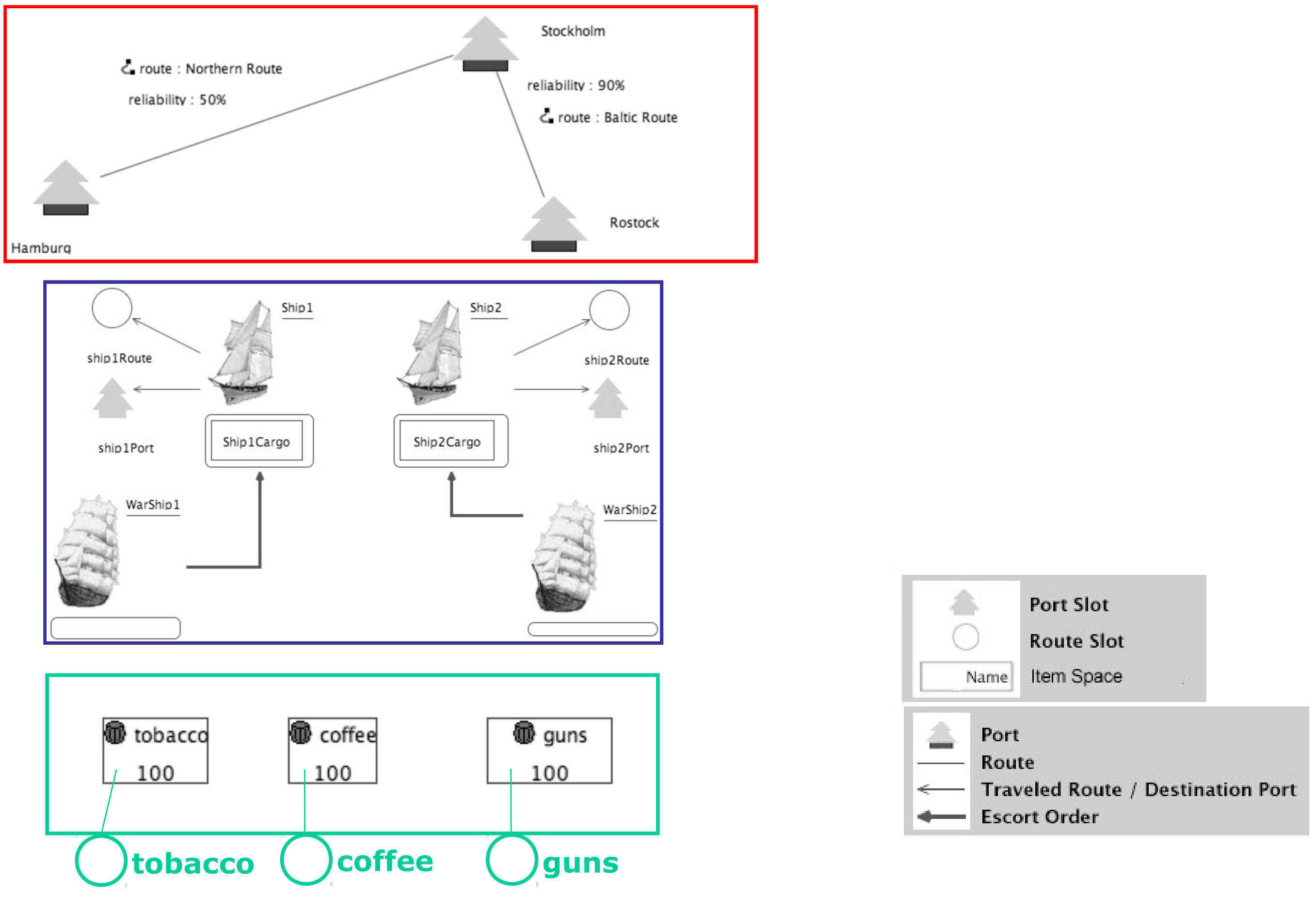
Building a DSL: Binding ReuseTaipan to Taipan DSL

```
...
fragment role ItemHolder {
  port ItemSpaces {
    ItemSpace is hook {
      port expr = $self.name$
    }
  }
}

fragment role ItemContainer {
  port Items {
    Item is prototype {
      port expr = $self.article$
    }
  }
 }
}
```

Each **Item** is a prototype accessible through individual ports; the ports are named using the **article** attribute of the **Items** metaclass

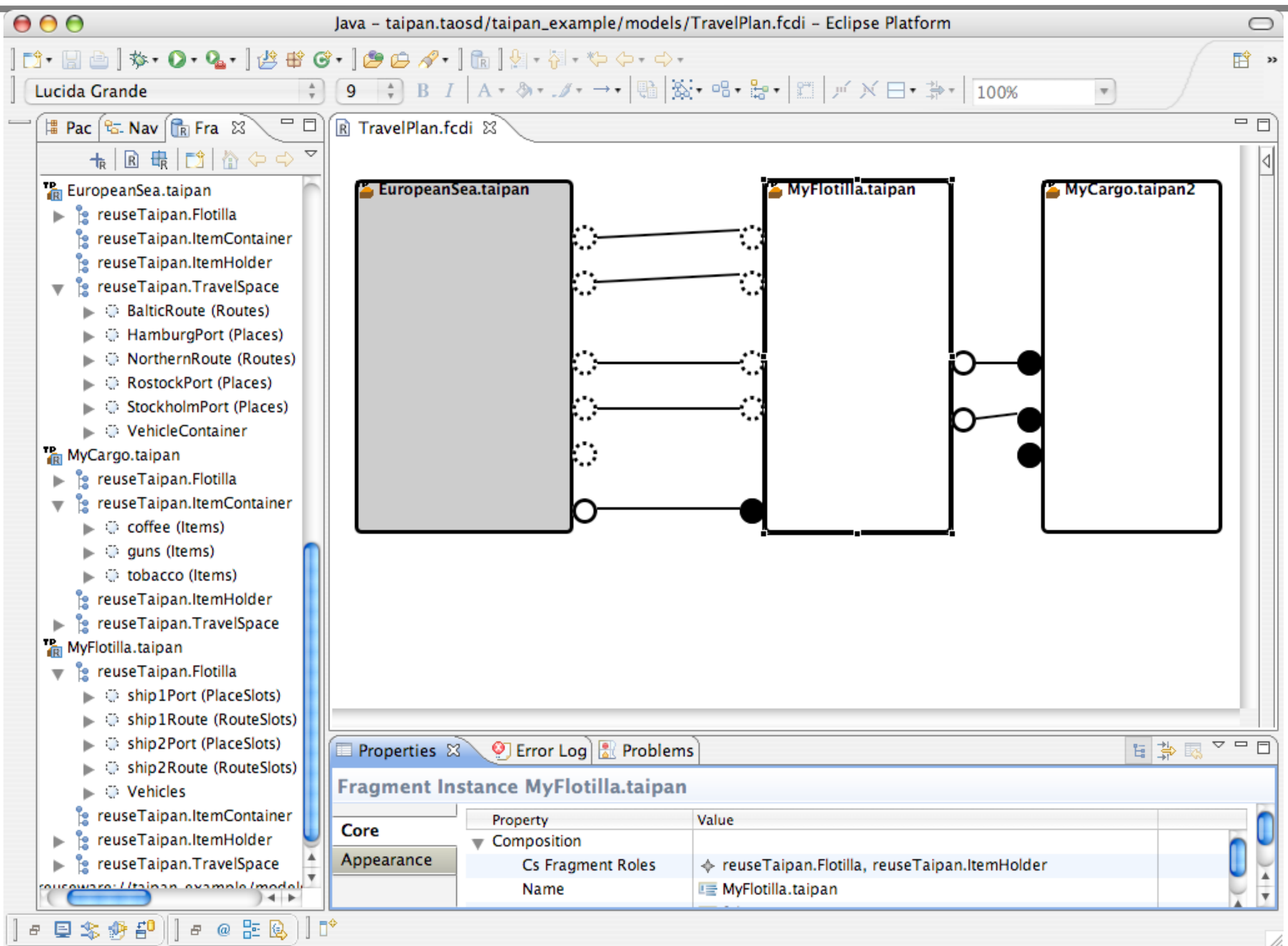
Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components



44.4 Using Reuseware Tooling with a DSL

- Fragment Repository
  - Light-weight repository to manage and find reusable model fragments
  - Can instantly be used to build libraries of model fragments designed in a DSL
- Composition Program Editor
  - Independent of composition systems and reuse extensions
  - Can instantly be used to define compositions for the DSL
  - Layout can be customized if desired

Building a DSL: Using Reuseware Tooling with a DSL



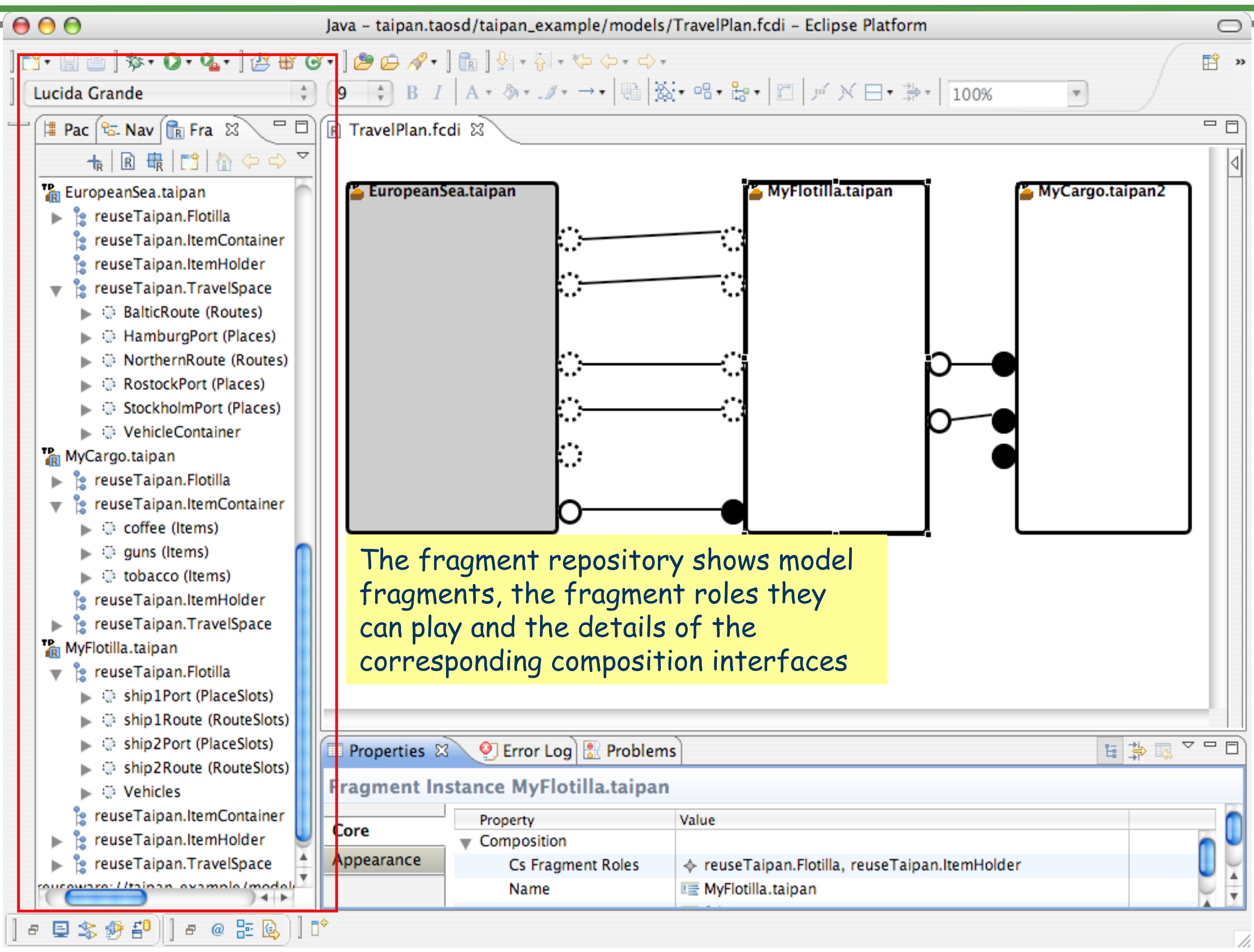
Java – taipan.taosd/taipan_example/models/TravelPlan.fcdi – Eclipse Platform

```
EuropeanSea.taipan
  reuseTaipan.Flotilla
  reuseTaipan.ItemContainer
  reuseTaipan.ItemHolder
  reuseTaipan.TravelSpace
    BalticRoute (Routes)
    HamburgPort (Places)
    NorthernRoute (Routes)
    RostockPort (Places)
    StockholmPort (Places)
    VehicleContainer
MyCargo.taipan
  reuseTaipan.Flotilla
  reuseTaipan.ItemContainer
    coffee (Items)
    guns (Items)
    tobacco (Items)
  reuseTaipan.ItemHolder
  reuseTaipan.TravelSpace
MyFlotilla.taipan
  reuseTaipan.Flotilla
    ship1Port (PlaceSlots)
    ship1Route (RouteSlots)
    ship2Port (PlaceSlots)
    ship2Route (RouteSlots)
    Vehicles
  reuseTaipan.ItemContainer
  reuseTaipan.ItemHolder
  reuseTaipan.TravelSpace
```

Fragment Instance MyFlotilla.taipan

Property	Value
Composition	
Cs Fragment Roles	reuseTaipan.Flotilla, reuseTaipan.ItemHolder
Name	MyFlotilla.taipan

Building a DSL: Using Reuseware Tooling with a DSL



Java – taipan.taosd/taipan_example/models/TravelPlan.fcdi – Eclipse Platform

```
EuropeanSea.taipan
  ▶ reuseTaipan.Flotilla
    reuseTaipan.ItemContainer
    reuseTaipan.ItemHolder
  ▼ reuseTaipan.TravelSpace
      ▶ BalticRoute (Routes)
      ▶ HamburgPort (Places)
      ▶ NorthernRoute (Routes)
      ▶ RostockPort (Places)
      ▶ StockholmPort (Places)
      ▶ VehicleContainer
MyCargo.taipan
  ▶ reuseTaipan.Flotilla
  ▼ reuseTaipan.ItemContainer
      ▶ coffee (Items)
      ▶ guns (Items)
      ▶ tobacco (Items)
    reuseTaipan.ItemHolder
  ▶ reuseTaipan.TravelSpace
MyFlotilla.taipan
  ▼ reuseTaipan.Flotilla
      ▶ ship1Port (PlaceSlots)
      ▶ ship1Route (RouteSlots)
      ▶ ship2Port (PlaceSlots)
      ▶ ship2Route (RouteSlots)
      ▶ Vehicles
    reuseTaipan.ItemContainer
  ▶ reuseTaipan.ItemHolder
  ▶ reuseTaipan.TravelSpace
reuseware://taipan_example/model
```

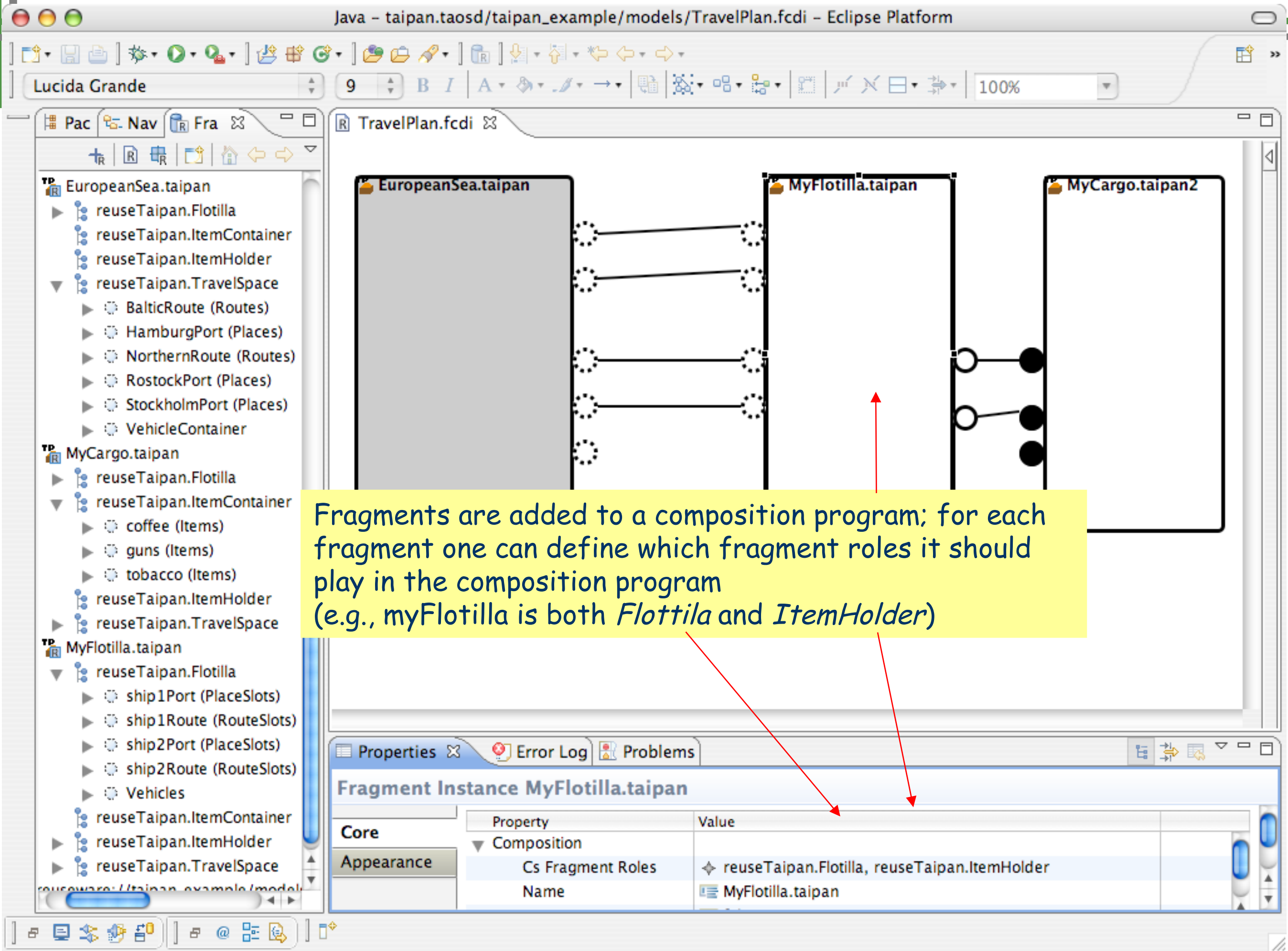
Fragment Instance MyFlotilla.taipan

Core
Appearance

Property	Value
▼ Composition	
Cs Fragment Roles	reuseTaipan.Flotilla, reuseTaipan.ItemHolder
Name	MyFlotilla.taipan

The fragment repository shows model fragments, the fragment roles they can play and the details of the corresponding composition interfaces

Building a DSL: Using Reuseware Tooling with a DSL



Java – taipan.taosd/taipan_example/models/TravelPlan.fcdi – Eclipse Platform

```
EuropeanSea.taipan
  ▶ reuseTaipan.Flotilla
    reuseTaipan.ItemContainer
    reuseTaipan.ItemHolder
  ▼ reuseTaipan.TravelSpace
      ▶ BalticRoute (Routes)
      ▶ HamburgPort (Places)
      ▶ NorthernRoute (Routes)
      ▶ RostockPort (Places)
      ▶ StockholmPort (Places)
      ▶ VehicleContainer
MyCargo.taipan
  ▶ reuseTaipan.Flotilla
  ▼ reuseTaipan.ItemContainer
      ▶ coffee (Items)
      ▶ guns (Items)
      ▶ tobacco (Items)
    reuseTaipan.ItemHolder
  ▶ reuseTaipan.TravelSpace
MyFlotilla.taipan
  ▼ reuseTaipan.Flotilla
      ▶ ship1Port (PlaceSlots)
      ▶ ship1Route (RouteSlots)
      ▶ ship2Port (PlaceSlots)
      ▶ ship2Route (RouteSlots)
      ▶ Vehicles
    reuseTaipan.ItemContainer
  ▶ reuseTaipan.ItemHolder
  ▶ reuseTaipan.TravelSpace
reuseware://taipan_example/model
```

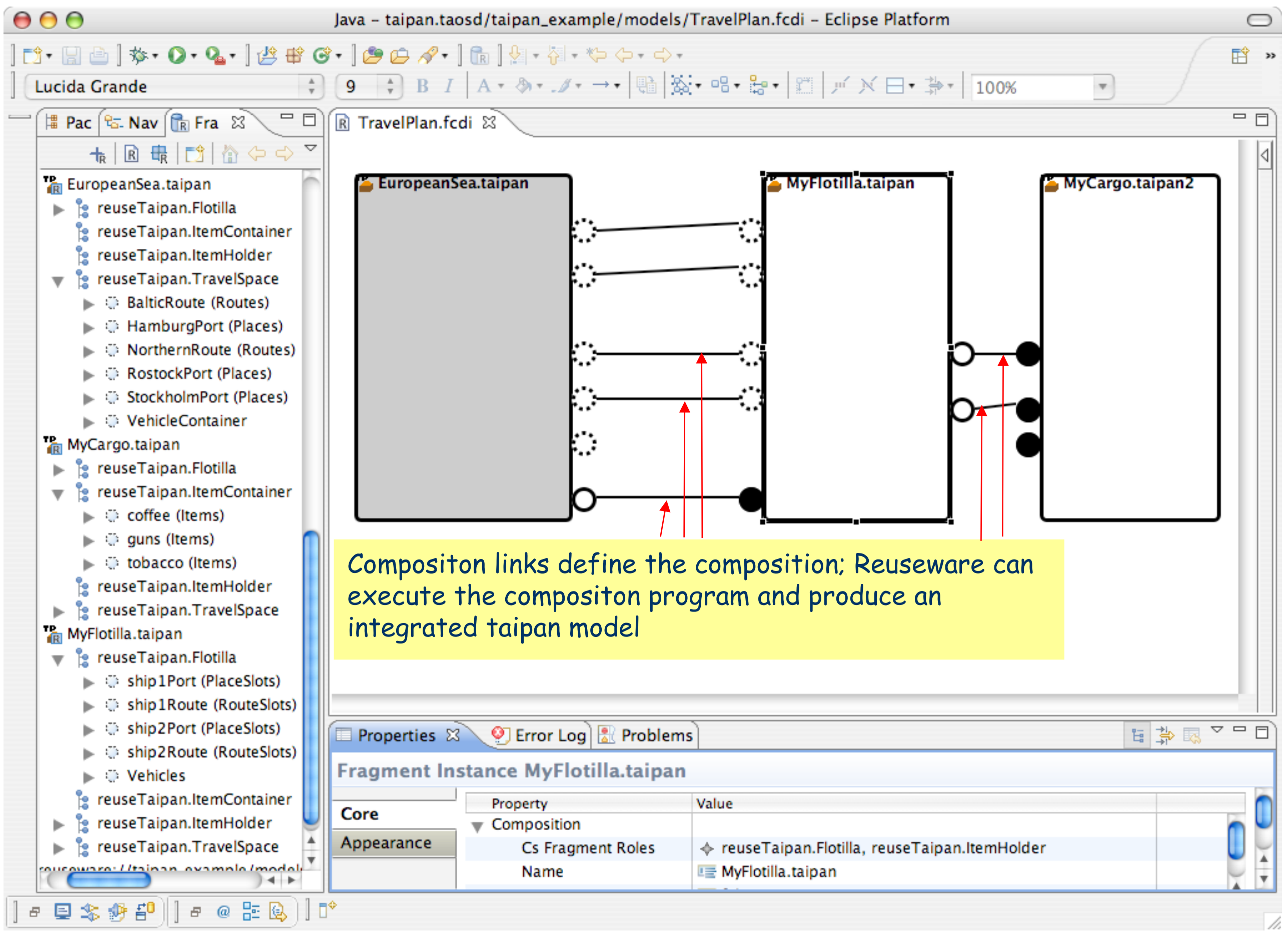
Fragment Instance MyFlotilla.taipan

Core
Appearance

Property	Value
▼ Composition	
Cs Fragment Roles	reuseTaipan.Flotilla, reuseTaipan.ItemHolder
Name	MyFlotilla.taipan

Fragments are added to a composition program; for each fragment one can define which fragment roles it should play in the composition program (e.g., myFlotilla is both *Flottila* and *ItemHolder*)

Building a DSL: Using Reuseware Tooling with a DSL

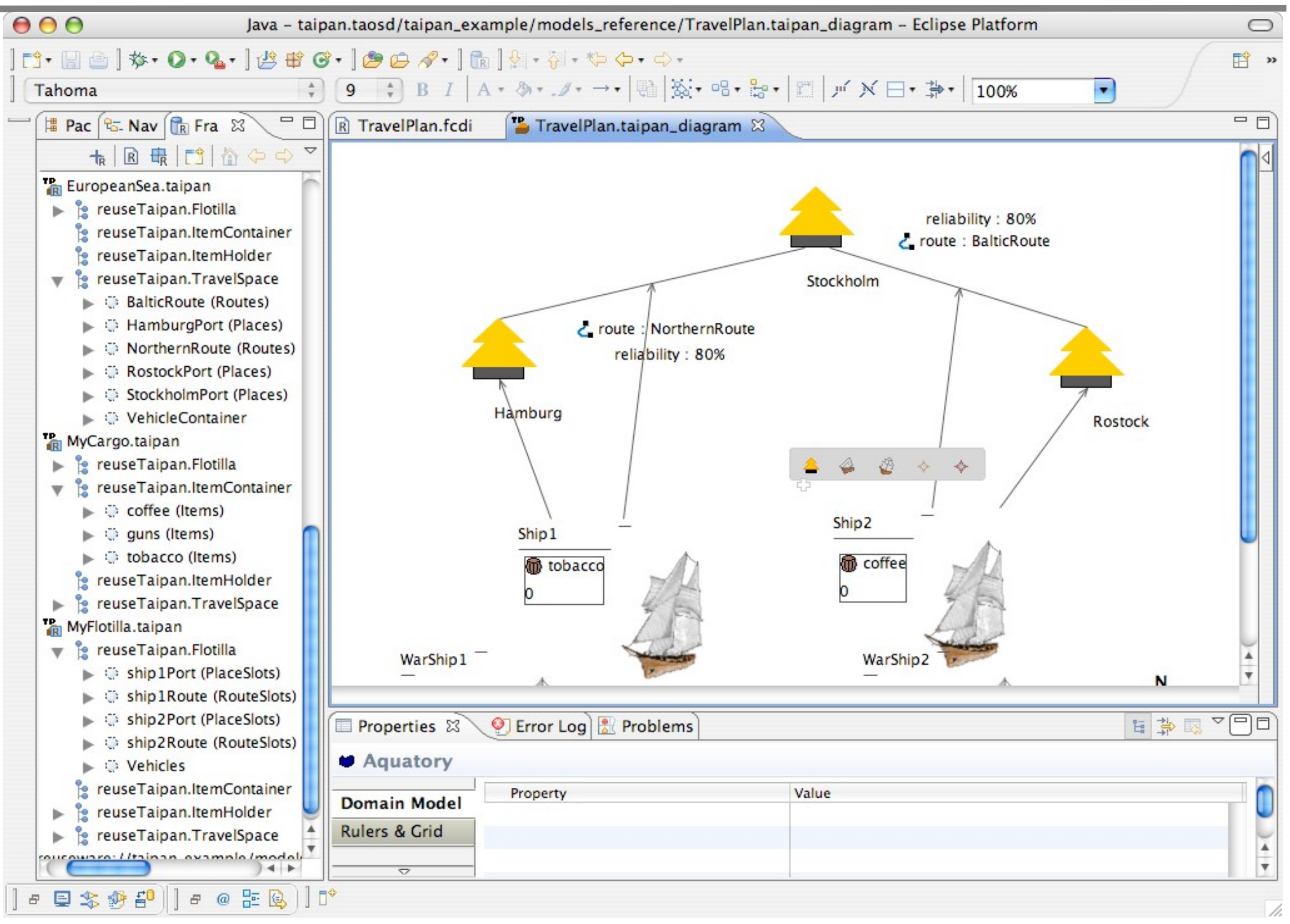


Compositon links define the composition; Reuseware can execute the compositon program and produce an integrated taipan model

Fragment Instance MyFlotilla.taipan

Property	Value
Composition	
Cs Fragment Roles	reuseTaipan.Flotilla, reuseTaipan.ItemHolder
Name	MyFlotilla.taipan

Building a DSL: Using Reuseware Tooling with a DSL



The End

- Reuseware is open source, but also dual licensed, i.e., commercialized by the company www.devboost.de