March 2015

Precise Semantics of UML Composite Structures (PSCS)

Version 1.0 FTF Convenience Document (clean)

OMG Document Number: ptc/ 2015-03-19

Standard document URL: http://www.omg.org/spec/PSCS

Associated Files:

Description: PSCS 1.0 FTF SyntaxAndSemantics.xmi
Doc Number: ptc/2015-03-22
Status: Normative
Description: PSCS 1.0 FTF SysML_Semantics.xmi (informative)
Doc Number: ptc/2015-03-23
Status: Informative
Description: PSCS 1.0 FTF SysML_TestSuites.xmi (informative)
Doc Number: ptc/2015-03-24
Status: Informative
Description: PSCS revised submission - Assertion Library XMI
Doc Number: ptc/2015-03-25
Status: Normative
Description: PSCS revised submission - Test Suites XMI
Doc Number: ptc/2015-03-26
Status: Normative
Description: PSCS revised submission - GenericAssociation.xmi (informative)
Doc Number: ptc/2015-03-27
Status: Informative
Description: PSCS revised submission - Semantics of MARTE XMI (informative)
Doc Number: ptc/2015-03-28
Status: Informative
Description: PSCS revised submission - MARTE Test Suites XMI (informative)
Doc Number: ptc/2015-03-29
Status: Informative

DISCLAIMER OF WARRANTY

RESTRICTED RIGHTS LEGEND

TRADEMARKS

COMPLIANCE

The copyright holders listed above acknowledge that the Object Management Group (acting itself or through its designees) is and shall at all times be the sole entity that may authorize developers, suppliers and sellers of computer software to use certification marks, trademarks or other special designations to indicate compliance with these materials.

Software developed under the terms of this license may claim compliance or conformance with this specification if and only if the software compliance is of a nature fully matching the applicable compliance points as stated in the specification. Software developed only partially matching the applicable compliance points may claim only that the software was based on this specification, but may not claim compliance or conformance with this specification. In the event that testing suites are implemented or approved by Object Management Group, Inc., software developed using this specification may claim compliance or conformance with the specification only if the software satisfactorily completes the testing suites.

Table of Contents

Preface

OMG

Founded in 1989, the Object Management Group, Inc. (OMG) is an open membership, not-for-profit computer industry standards consortium that produces and maintains computer industry specifications for interoperable, portable, and reusable enterprise applications in distributed, heterogeneous environments. Membership includes Information Technology vendors, end users, government agencies, and academia.

OMG member companies write, adopt, and maintain its specifications following a mature, open process. OMG's specifications implement the Model Driven Architecture® (MDA®), maximizing ROI through a full-lifecycle approach to enterprise integration that covers multiple operating systems, programming languages, middleware and networking infrastructures, and software development environments. OMG's specifications include: UML® (Unified Modeling Language™); CORBA® (Common Object Request Broker Architecture); CWM™ (Common Warehouse Metamodel); and industry-specific standards for dozens of vertical markets.

More information on the OMG is available at http://www.omg.org/.

OMG Specifications

As noted, OMG specifications address middleware, modeling and vertical domain frameworks. All OMG Specifications are available from the OMG website at:

http://www.omg.org/spec

Specifications are organized by the following categories:

Business Modeling Specifications
Middleware Specifications

- CORBA/IIOP
- Data Distribution Services
- Specialized CORBA

IDL/Language Mapping Specifications
Modeling and Metadata Specifications

- UML, MOF, CWM, XMI
- UML Profile

Modernization Specifications
Platform Independent Model (PIM), Platform Specific Model (PSM), Interface Specifications

- CORBAServices
- CORBAFacilities

OMG Domain Specifications
CORBA Embedded Intelligence Specifications
CORBA Security Specifications

All of OMG's formal specifications may be downloaded without charge from our website. (Products implementing OMG specifications are available from individual suppliers.) Copies of specifications, available in PostScript and PDF format, may be obtained from the Specifications Catalog cited above or by contacting the Object Management Group, Inc. at:

OMG Headquarters
109 Highland Avenue
Needham, MA 02494
USA
Tel: +1-781-444-0404
Fax: +1-781-444-0320
Email: *pubs@omg.org*

Certain OMG specifications are also available as ISO standards. Please consult http://www.iso.org

Typographical Conventions

The type styles shown below are used in this document to distinguish programming statements from ordinary English. However, these conventions are not used in tables or section headings where no distinction is necessary.

Times/Times New Roman - 10 pt.: Standard body text

Helvetica/Arial - 10 pt. Bold: OMG Interface Definition Language (OMG IDL) and syntax elements.

`Courier/Courier New - 10 pt. Bold:` Programming language elements.

Helvetica/Arial - 10 pt: Exceptions

NOTE: Terms that appear in italics are defined in the glossary. Italic text also represents the name of a document, specification, or other publication.

1 Scope

This specification defines an extension of fUML syntax and semantics to enable modeling and execution of UML composite structures. The term “composite structures” refers to the ability of UML classes to be structured as defined in Clause 9 of the UML specification.

The syntactic extensions add the capability for a fUML class to have an internal structure that may include public, private, and protected ports as well as a network of parts linked by connectors.

The semantic extensions supplement the fUML execution model with appropriate visitor classes, strategy classes, and semantic mappings to account for structural and behavioral semantics implied by the syntactic extensions.

The overall purpose of this specification is illustrated in Figure 1, with extension of fUML syntax on the left-hand side, extension of fUML semantics on the right-hand side and extension of the semantic mapping in the middle.

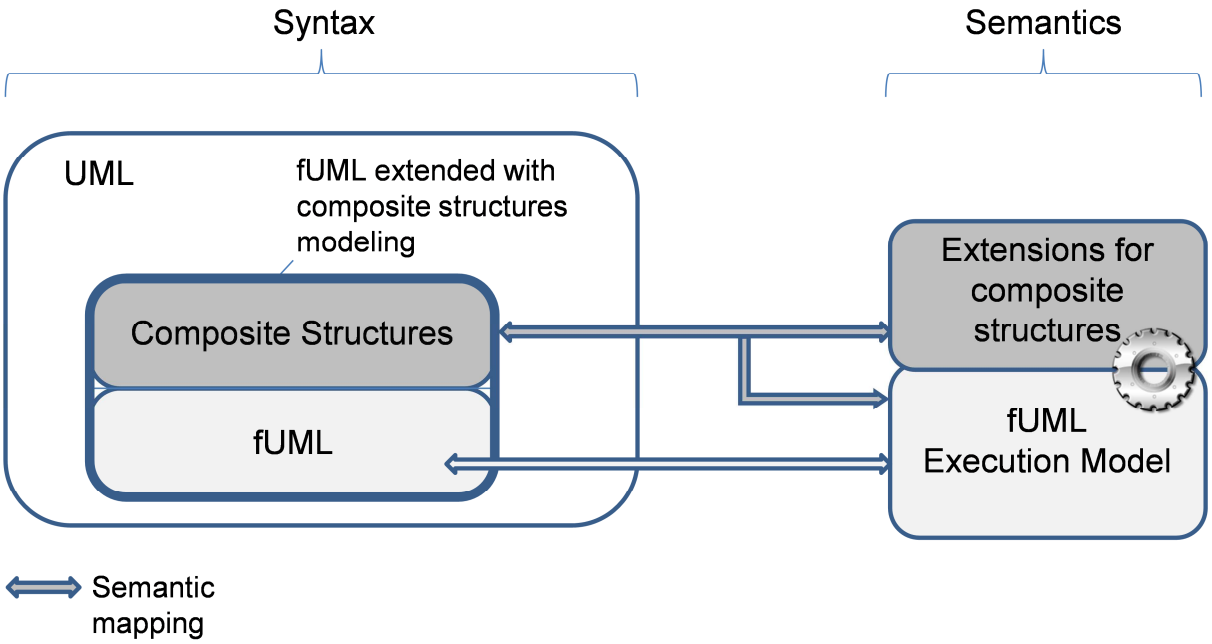


Figure 1: Scope of this Specification

2 Conformance

This specification defines a precise semantics for a subset of UML 2 concepts associated with the notion of a structured class. This definition is based on the Foundational UML Subset (henceforth referred to as "fUML" in the remainder of this clause), which is specified in the OMG recommendation "Semantics of a Foundational Subset for Executable UML Models" (OMG document formal/2011-02-01). Hence, *except where explicitly noted in this clause*, the definitions, interpretations (meaning), and types of conformance and related terms in this specification fully match their corresponding definitions, interpretations, and types in fUML. Thus, as in fUML, conformance to this specification has two aspects:

1. Syntactic Conformance. A conforming model must be restricted to the abstract syntax subset defined in Clause 7 of this document

2. Semantic Conformance. A conforming execution tool must provide execution semantics for a conforming model consistent with the semantics specified in Clause 8 of this document. Passing all the tests of the test suites in clause 9 are sufficient to demonstrate conformance with the semantics specified in clause 8.

2.1 Conformance Levels

Unlike fUML, only a single monolithic conformance level is defined in this specification, corresponding to Conformance Level 3 of fUML, which is itself based on Conformance Level 3 of UML.

2.2 Genericity of the Execution Model

To support a variety of different execution paradigms and environments, the specification of the execution model incorporates a degree of genericity. This is achieved in two ways: (1) by leaving some key semantic elements unconstrained, and (2) by defining explicit semantic variation points. A particular execution tool can then realize specific semantics by suitably constraining the unconstrained semantic aspects and providing specifications for any desired variation at semantic variation points.

The semantic areas that are not explicitly constrained by the execution model in this specification are the same as the ones defined in Clause 2.3 of the fUML specification. Different execution tools may semantically vary in the above areas in executing the same model, while still being conformant to the semantics specified by the execution model in this specification. Additional semantic specifications or constraints may be provided for a specific execution tool in these areas, so long as it remains, overall, conformant to the execution model. For instance, a particular tool may be limited to a single centralized time source such that all time measurements can be fully ordered.

In contrast to the above areas, the items below are explicit semantic variation points. That is, the execution model as given in this specification by default fully specifies the semantics of these items. However, it is allowable for a conforming execution tool to define alternate semantics for them, so long as this alternative is fully specified as part of the conformance statement for the tool.

- The semantic variation points defined in Clause 2.3 of the fUML specification. Note, however, that default event dispatching strategy defined for fUML is replaced by a new default strategy specific to this specification (see 8.4.1.2.1).

- In addition, this specification introduces three new semantic variation points and corresponding default strategies for them:

    - The method of reading and writing of the structural features of an Interface, depending on how they are realized by the corresponding behavior classifier (see 8.4.1.2.3)

- The method of propagating requests in situations where there are multiple possible paths (see 8.5.1.2.6).

- The method for constructing an object, which includes creation of a topology of objects, interaction points and links, as well as initialization of corresponding properties according to any specified default values (see 8.4.1.2.3)

If a conforming execution tool wishes to implement a semantic variation in one of the above areas, then a specification most be provided for this variation via a specialization of the appropriate execution model class as identified above. This specification must be provided as a fUML model in the “base UML” subset interpretable by the base semantics of Clause 10 of the fUML specification. Further, it must be defined in what cases the variation is used and, if different variants may be used in different cases, when each variant applies, and/or how what variant to use, is to be specified in a conforming model accepted by the execution tool.

3 Normative References

The following normative documents contain provisions which, through reference in this text, constitute provisions of this specification. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

- OMG Unified Modeling Language (OMG UML), Superstructure, Version 2.4.1, formal/2011-08-06, August 2011.

- Semantics of a Foundational Subset for Executable UML Models (FUML), Version 1.1 Beta, ptc/2012-10-18, October 2012.

4 Terms and Definitions

There are no formal definitions of terms in this specification.

5 Symbols

There are no symbols defined in this specification.

6 Additional Information

6.1 Changes to Adopted OMG Specifications

This specification does not require any changes to adopted OMG specifications. Nevertheless, while compliant with the UML 2.4.1 metamodel and notation, this specification adopts clarifications from UML 2.5 regarding constraints and semantics of UML.

6.2 Acknowledgments

This specification was originally authored by:
- Conrad Bock (NIST)
- Yves Bernard (EADS)
- Michael Chonoles (Lockheed Martin)
- Arnaud Cuccuru (Commissariat à l'Energie Atomique)
- Peter Denno (NIST)
- Sébastien Gérard (Commissariat à l'Energie Atomique)
- Sanford Friedenthal (INCOSE)
- Nerijus Jankevicius (No Magic)
- Julio Medina (Universidad de Cantabria)
- Eldad Palachi (International Business Machines)
- Laurent Rioux (THALES)
- Nicolas Rouquette (JPL/NASA)
- Ed Seidewitz (Model Driven Solutions)
- Bran Selic (Simula Research Laboratory)
- Ed Shaw (NexJ Systems)
- Daniel Siegl (LieberLieber)

The work done by CEA in this specification has been partially funded by the OpenES CATRENE Project: CA703 - 2013 (http://www.ecsi.org/openes). The work done by Universidad de Cantabria in this specification has been partially funded by the Spanish Government under grant TIN2011-28567-C03-02 (HI-PARTES).

7 Abstract Syntax

7.1 Overview

This clause describes how the fUML syntax model is extended to include modeling of UML Composite Structures. This extension refers to all UML metaclasses, constraints, and relationships that enable a fUML Class to be structured. The term “structured” here means that a class may have public, private, and protected ports as well as a network of parts linked through connectors. The Semantics Clause 8 defines precise semantics for the elements introduced in this section.

The fUML Abstract Syntax model mimics the package architecture of the unmerged UML 2.4.1 metamodel, keeping only packages (and elements defined in these packages) that are relevant to the foundational subset of UML. For consistency with the fUML syntax, the Composite Structures syntax model described in this clause also mimics the package architecture of the unmerged UML 2.4.1 metamodel. UML packages relevant to modeling composite structures are copied in the proposed syntax model. Elements in copied packages which are not relevant for this specification are removed. When a relationship contained in an imported package (including package merge relationships) targets a UML metaclass or package which is already part of the fUML subset, that relationship is redirected towards the fUML equivalent metaclass.

As compared to the fUML Abstract Syntax model, the proposed model does not carry out package merges, thereby avoiding duplication of the content of fUML syntax. However, package merge relationships included in this syntax model are specified in a way that, when the merges are carried out, a model corresponding to the fUML subset extended with UML composite structures modeling is produced. In addition, the result of the merge is also that any former references from elements of the fUML Semantics model to elements of the fUML Abstract Syntax model now target elements of the fUML subset extended with UML Composite Structures modeling. These packages as well as their relationships are shown in Figure 2.

The root package for the Abstract Syntax is CompositeStructuresSyntaxAndSemantics. This package merges both fUML syntax and semantics. All other packages shown in the diagram are directly or indirectly contained by this Package. Packages in yellow are newly introduced Packages (i.e., there is no equivalent package in fUML syntax model). Packages in white are Packages which were already included in the fUML subset, but need to be included in this specification as well since they contain elements which were explicitly excluded from fUML. Packages in grey are Packages which were already part of fUML and which do not include additional content. These packages are, however, required for the merging process described above.

The following subclauses describe packages copied from the UML 2.4.1 unmerged metamodel that actually add content to fUML (i.e., packages in yellow and white from Figure 2). Each subclause provides rationale for copying the corresponding package, as well as an overview of elements contained in these packages and how they relate to fUML syntax elements. Each subclause also highlights additional constraints introduced by this specification related to Composite Structures modeling.

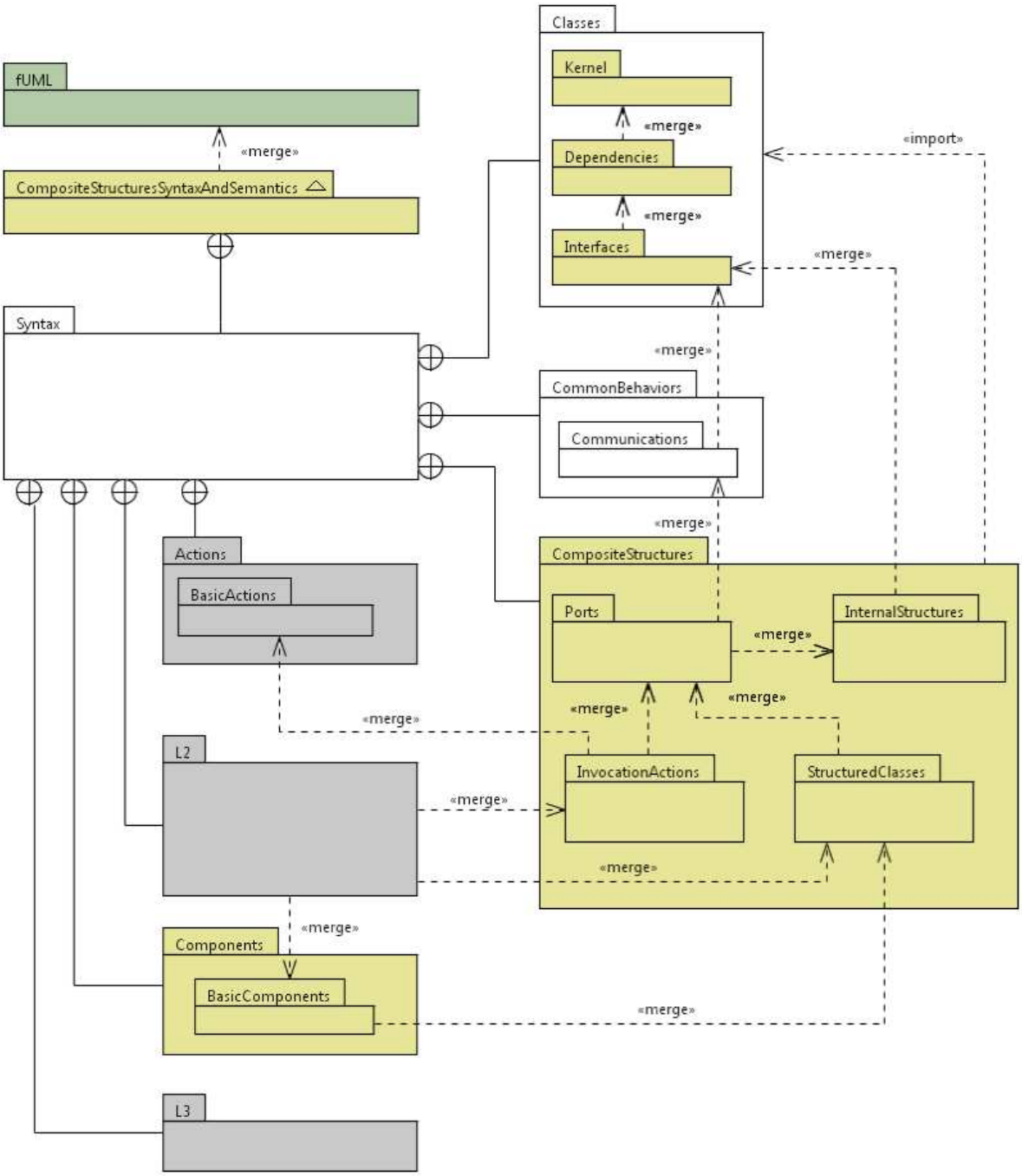


Figure 2: Abstract Syntax Package Architecture

7.2 Classes

7.2.1 Overview

The Classes package is partially copied into the Composite Structures syntax model. This is because it contains the subpackages Dependencies, Interfaces, and Kernel, which are required for Composite Structures modeling. The copy of the Classes package is partial since only these three subpackages are copied. Note that the Classes package is already part of the fUML Abstract Syntax model. However, the packages Dependencies and Interfaces were explicitly removed from that model. Note also that Kernel was already part of fUML. It is included in this specification to account for OpaqueExpressions, which were removed from fUML. The following subclauses provide details about the content of these three subpackages.

7.2.2 Dependencies

7.2.2.1 Overview

The Dependencies package is copied for two reasons. First, it introduces the metaclass Usage, which is needed to specify the required interfaces of a port. Second, it introduces the metaclass Realization, which is a generalization of InterfaceRealization defined in the Interfaces package. Note that metaclasses DirectedRelationship and Substitution, as well as association A_mapping_abstraction are not included, since they are not relevant to Composite Structures modeling.

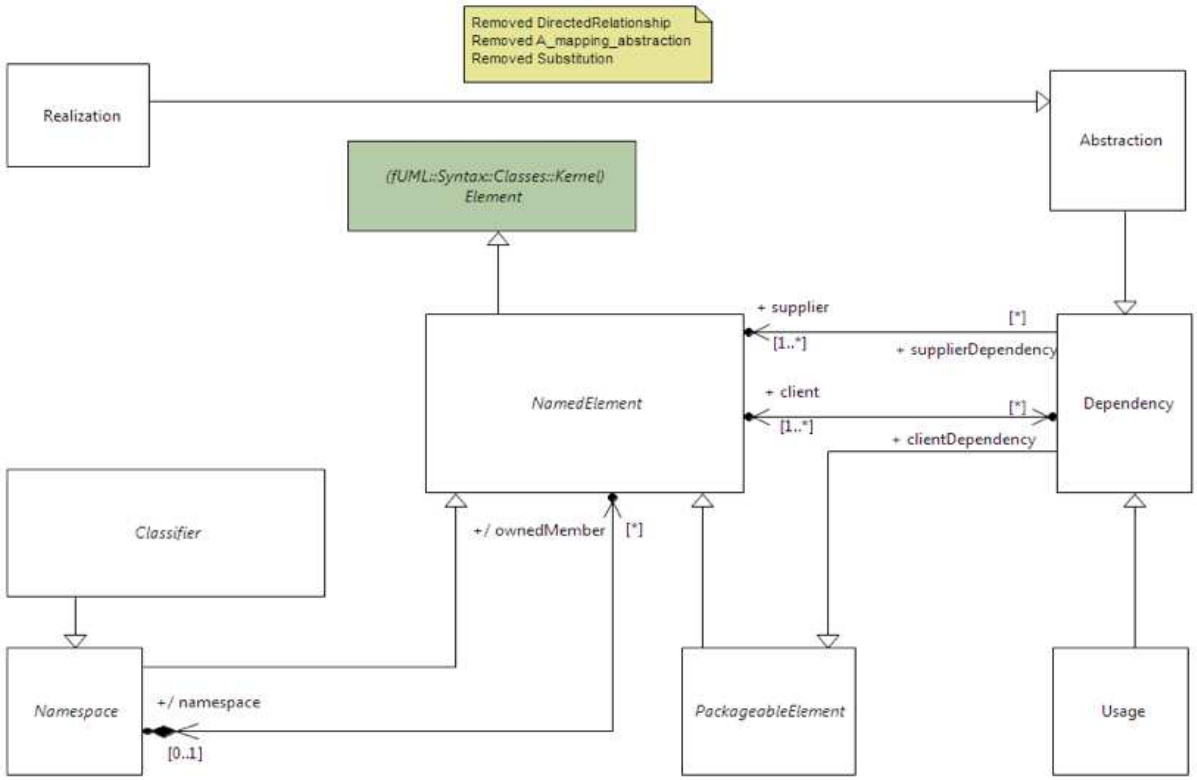


Figure 3: Dependencies diagram

7.2.2.2 Class descriptions

7.2.2.2.1 Abstraction

Abstraction is introduced to enable modeling of InterfaceRealization. This is an indirect generalization of

InterfaceRealization.

Generalizations

- Dependency (from CompositeStructuresSyntaxAndSemantics::Syntax::Classes::Dependencies)

Attributes

- None

Associations

- None

7.2.2.2.2 Classifier

Classes::Dependencies::Classifier does not extend fUML Classifier. It is included in the Composite Structures syntax model because it is needed for the merging process described in the Overview subclause of the Abstract Syntax Clause 7.

Generalizations

- Namespace (from CompositeStructuresSyntaxAndSemantics::Syntax::Classes::Dependencies)

Attributes

- None

Associations

- None

7.2.2.2.3 Dependency

Dependency is introduced to enable modeling of both Usage and InterfaceRealization relationships. It is a generalization of these two metaclasses.

Generalizations

- PackageableElement (from CompositeStructuresSyntaxAndSemantics::Syntax::Classes::Dependencies)

Attributes

- None

Associations

- client : NamedElement [1..*]
- supplier : NamedElement [1..*]

7.2.2.2.4 NamedElement

Classes::Dependencies::NamedElement extends (merge increment) fUML NamedElement with the ability to indicate all the Dependencies that reference this NamedElement as a client (property clientDependency).

Generalizations

- Element (from fUML::Syntax::Classes::Kernel)

Attributes

- None

Associations

- clientDependency : Dependency [0..*]
- namespace : Namespace [0..1]

7.2.2.2.5 Namespace

Classes::Dependencies::Namespace does not extend fUML Namespace. It is included in the Composite Structures syntax model because it is needed for the merging process described in the Overview subclause of the Abstract Syntax Clause 7.

Generalizations

- NamedElement (from CompositeStructuresSyntaxAndSemantics::Syntax::Classes::Dependencies)

Attributes

- None

Associations

- ownedMember : NamedElement [0..*]

7.2.2.2.6 PackageableElement

Classes::Dependencies::PackeageableElement does not extend fUML PackageableElement. It is included in the Composite Structures syntax model to make the merging process (described in the Overview subclause of the Abstract Syntax clause 7) meaningful.

Generalizations

- NamedElement (from CompositeStructuresSyntaxAndSemantics::Syntax::Classes::Dependencies)

Attributes

- None

Associations

- None

7.2.2.2.7 Realization

Realization is introduced to enable modeling of InterfaceRealization. This is a generalization of InterfaceRealization.

Generalizations

- Abstraction (from CompositeStructuresSyntaxAndSemantics::Syntax::Classes::Dependencies)

Attributes

- None

Associations

- None

7.2.2.2.8 Usage

Usage is introduced since it is required to specify required interfaces of a port.

Generalizations

- Dependency (from CompositeStructuresSyntaxAndSemantics::Syntax::Classes::Dependencies)

Attributes

- None

Associations

- None

7.2.3 Interfaces

7.2.3.1 Overview

The Interfaces package is introduced to enable the definition of required and/or provided features associated with ports. It also includes a mechanism for specifying that a given BehavioredClassifier realizes the features of an Interface. At run time, this information is used to determine if a given object (instance of a BehavioredClassifier) is a valid target for the invocation of a BehavioralFeature (where this feature is specified by an interface).

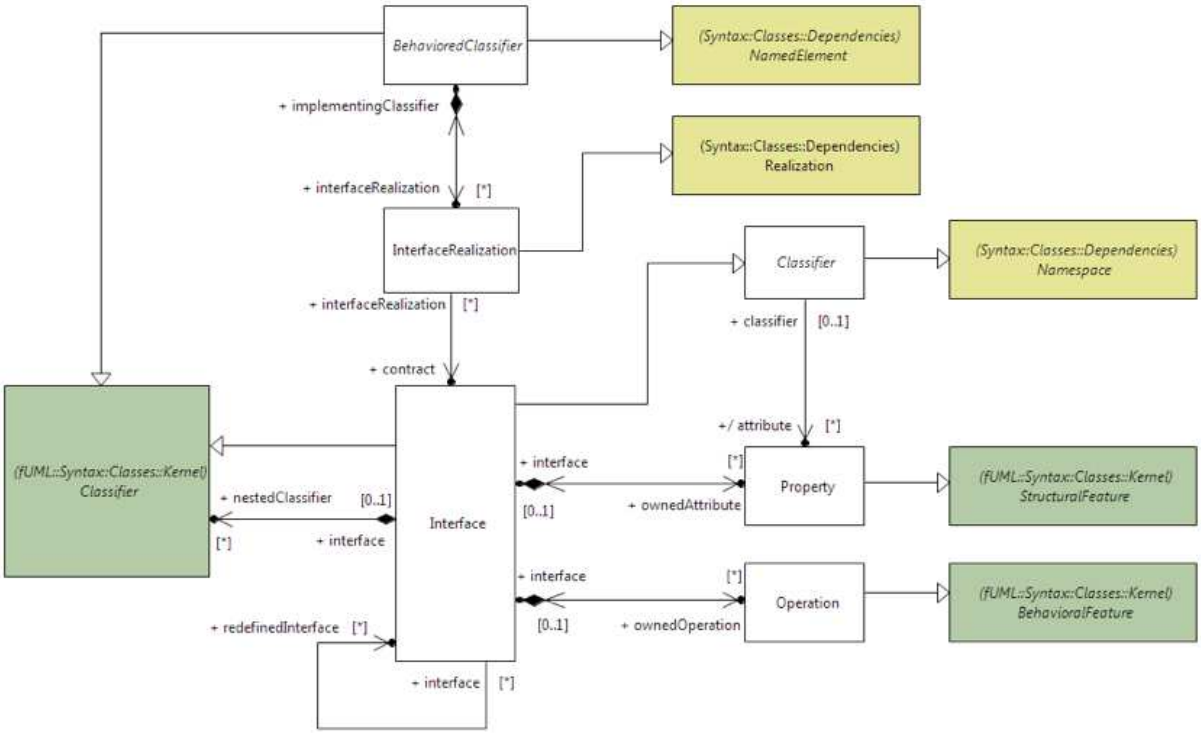


Figure 4: Interfaces Diagram

7.2.3.2 Class descriptions

7.2.3.2.1 BehavioredClassifier

Classes::Interfaces::BehavioredClassifier extends (merge increment) fUML BehavioredClassifier with the ability to own a collection of InterfaceRealization relationships.

Generalizations

- Classifier (from fUML::Syntax::Classes::Kernel)
- NamedElement (from CompositeStructuresSyntaxAndSemantics::Syntax::Classes::Dependencies)

Attributes

- None

Associations

- interfaceRealization : InterfaceRealization [0..*]

7.2.3.2.2 Classifier

Classes::Interfaces::Classifier does not extend fUML Classifier. It is included in the Composite Structures syntax model because it is needed for the merging process described in the Overview subclause of the Abstract Syntax clause 7.

Generalizations

- Namespace (from CompositeStructuresSyntaxAndSemantics::Syntax::Classes::Dependencies)

Attributes

- None

Associations

- attribute : Property [0..*]

7.2.3.2.3 Interface

Interface is introduced to enable specification of features provided or required on a Port. Through InterfaceRealization relationships, it also enables specifying features that are realized by a given BehavioredClassifier.

Generalizations

- Classifier (from fUML::Syntax::Classes::Kernel)
- Classifier (from CompositeStructuresSyntaxAndSemantics::Syntax::Classes::Interfaces)

Attributes

- None

Associations

- nestedClassifier : Classifier [0..*]
- ownedAttribute : Property [0..*]
- ownedOperation : Operation [0..*]
- redefinedInterface : Interface [0..*]

7.2.3.2.4 InterfaceRealization

InterfaceRealization is introduced since it is used to specify the provided Interfaces of a Port. In addition, it is also used to specify that features of the contract Interface are realized by the implementingClassifier of a BehavioredClassifier.

Generalizations

- Realization (from CompositeStructuresSyntaxAndSemantics::Syntax::Classes::Dependencies)

Attributes

- None

Associations

- contract : Interface [1]
- implementingClassifier : BehavioredClassifier [1]

7.2.3.2.5 Operation

Classes::Interfaces::Operation extends (merge increment) fUML Operation with the capability to be owned by an Interface.

Generalizations

- BehavioralFeature (from fUML::Syntax::Classes::Kernel)

Attributes

- None

Associations

- interface : Interface [0..1]

7.2.3.2.6 Property

Classes::Interfaces::Property extends (merge increment) fUML Property with the capability to be owned by an Interface.

Generalizations

- StructuralFeature (from fUML::Syntax::Classes::Kernel)

Attributes

- None

Associations

- interface : Interface [0..1], References the Interface that owns the Property

7.2.4 Kernel

7.2.4.1 Overview

The Kernel package is partially copied into the Composite Structures syntax model. This is because that package contains OpaqueExpression, which was explicitly removed from fUML. In this specification,

OpaqueExpressions are typically used to associate default values with properties of composite structures, in the case where other kinds of ValueSpecification supported by fUML cannot be used easily. The main use case concerns situations where properties represent collections of elements.

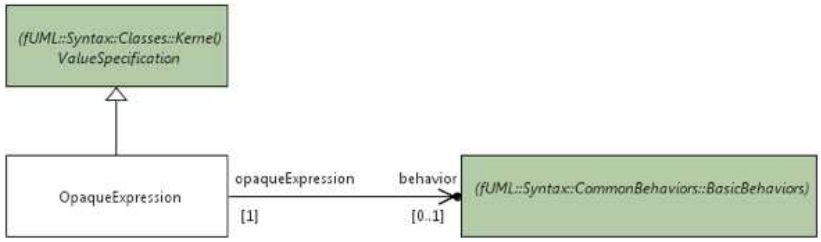


Figure 5: Expressions Diagram

7.2.4.2 Class Descriptions

7.2.4.2.1 OpaqueExpression

Classes::Kernel::OpaqueExpression extends Classes::Kernel::ValueSpecification with the ability to reference a Behavior. Properties language and body are not included in this specification. An OpaqueExpression can only be defined by a Behavior that is restricted to have no Parameters other than a return Parameter. The values of the OpaqueExpression are given by invoking the Behavior and returning the values on the return Parameter.

Generalizations

- ValueSpecification (from fUML::Syntax::Classes::Kernel)

Attributes

- None

Associations

- behavior : Behavior [0..1]

7.3 CommonBehaviors

7.3.1 Overview

The CommonBehaviors package is partially copied into the Composite Structures syntax model. This is because that package contains the sub-package Communications, which is required for Composite Structures modeling. More precisely, it allows Receptions to be owned by Interfaces, as a way of enabling a classifier to specify that it provides or requires Receptions for Signals for some of its Ports. The copy of the CommonBehaviors package is partial in the sense that only this sub-package is copied. Note that the CommonBehaviors::Communications package is already part of the fUML Abstract Syntax model. However, the Interface metaclass was explicitly removed from the fUML subset. The following subclause provides details about the content of this sub-package.

7.3.2 Communications

7.3.2.1 Overview

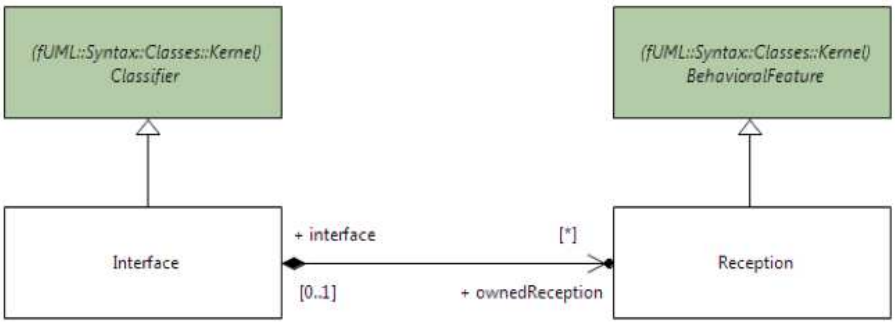


Figure 6: Communications diagram

7.3.2.2 Class descriptions

7.3.2.2.1 Interface

CommonBehaviors::Communications::Interface extends (merge increment) Classes::Interfaces::Interface with the ability to own receptions.

Generalizations

- Classifier (from fUML::Syntax::Classes::Kernel)

Attributes

- None

Associations

- ownedReception : Reception [0..*]

7.3.2.2.2 Reception

CommonBehaviors::Communications::Reception does not extend fUML Reception. It is included in the Composite Structures syntax model because it is needed for the merging process described in the Overview subclause of the Clause 7.

Generalizations

- BehavioralFeature (from fUML::Syntax::Classes::Kernel)

Attributes

- None

Associations

- None

7.4 Components

7.4.1 Overview

The Components package is partially copied into the Composite Structures syntax model. This is because the Components package contains the sub-package BasicComponents, which is required for Composite Structures modeling. More precisely, it extends (merge increment) CompositeStructures::StructuredClasses::Connector with the property kind , which enables determining whether a given connector is for delegation or for assembly. Note that metaclass Component as well as package Components::PackagingComponents are excluded from this specification, since they do not introduce any concepts impacting the semantics of UML Composite Structures.

7.4.2 BasicComponents

Figure 7: BasicComponents diagram

7.4.2.1 Overview

7.4.2.2 Class descriptions

7.4.2.2.1 Connector

Components::BasicComponents::Connector extends (merge increment) CompositeStructures::StructuredClasses::Connector with a property indicating the kind (delegation or assembly) of a connector.

Generalizations

- None

Attributes

- kind : ConnectorKind [1]

Associations

- None

7.4.2.2.2 ConnectorKind (Enumeration)

Generalizations

- None

Literals

- assembly
- delegation

7.5 CompositeStructures

7.5.1 Overview

The CompositeStructures package is completely copied into the Composite Structures syntax model. This is because all of its subpackages introduce key modeling concepts underlying Composite Structures. This includes packages InternalStructures, InvocationActions, Ports and StructuredClasses. The following subclauses provide details about the content of these subpackages.

7.5.2 InternalStructures

7.5.2.1 Overview

The InternalStructures package is introduced to enable modeling of the internal structure of a class as a network of parts, linked through connectors. The topology of parts and connectors places constraints on the runtime structure of a class instance.

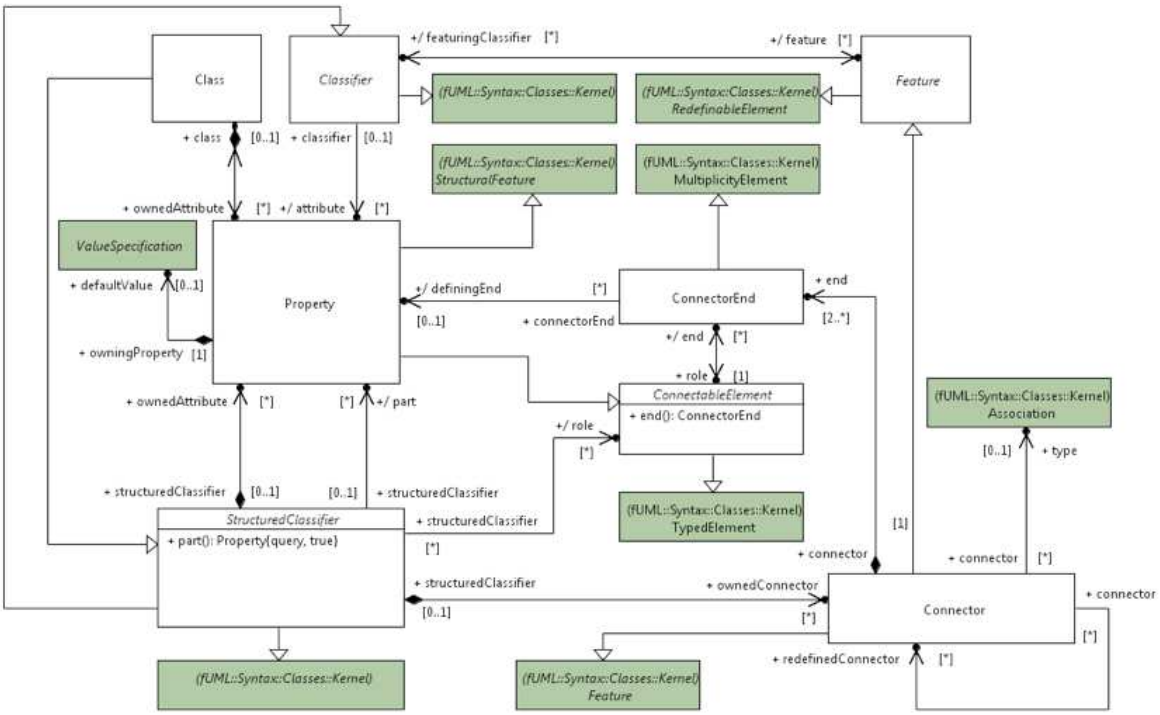


Figure 8: InternalStructures diagram

7.5.2.2 Class descriptions

7.5.2.2.1 Class

CompositeStructures::InternalStructures::Class extends (merge increment) fUML Class by making it a StructuredClassifier.

Generalizations

- StructuredClassifier (from CompositeStructuresSyntaxAndSemantics::Syntax::CompositeStructures::InternalStructures)

Attributes

- None

Associations

- ownedAttribute : Property [0..*]

7.5.2.2.2 Classifier

CompositeStructures::InternalStructures::Classifier does not extend fUML Classifier. This metaclass is included in the Composite Structures syntax model because it is needed for the merging process described in the Overview subclause of the Abstract Syntax Clause 7.

Generalizations

- Namespace (from fUML::Syntax::Classes::Kernel)

Attributes

- None

Associations

- attribute : Property [0..*]
- feature : Feature [0..*]

7.5.2.2.3 ConnectableElement

ConnectableElement is introduced as an abstract metaclass representing elements than can be interconnected by being attached to the connector ends of connectors.

Generalizations

- TypedElement (from fUML::Syntax::Classes::Kernel)

Attributes

- None

Associations

- end : ConnectorEnd [0..*]

7.5.2.2.4 Connector

Connector is introduced to enable modeling of interconnections between parts and/or roles, in the context of a structured classifier.

Generalizations

- Feature (from fUML::Syntax::Classes::Kernel)
- Feature (from CompositeStructuresSyntaxAndSemantics::Syntax::CompositeStructures::InternalStructures)

Attributes

- None

Associations

- end : ConnectorEnd [2..*]
- redefinedConnector : Connector [0..*]
- type : Association [0..1]

7.5.2.2.5 ConnectorEnd

ConnectorEnd is introduced to allow modeling of Connectors.

Generalizations

- MultiplicityElement (from fUML::Syntax::Classes::Kernel)

Attributes

- None

Associations

- definingEnd : Property [0..1]
- role : ConnectableElement [1]

7.5.2.2.6 Feature

CompositeStructures::InternalStructures::Feature does not extend fUML Feature. It is included in the Composite Structures syntax model because it is needed for the merging process described in the Overview subclause of the Abstract Syntax Clause 7.

Generalizations

- RedefinableElement (from fUML::Syntax::Classes::Kernel)

Attributes

- None

Associations

- featuringClassifier : Classifier [0..*],

7.5.2.2.7 Property

CompositeStructures::InternalStructures::Property extends (merge increment) fUML Property. By being a ConnectableElement, a Property can be connected to other connectable elements through connectors.

Generalizations

- ConnectableElement (from CompositeStructuresSyntaxAndSemantics::Syntax::CompositeStructures::InternalStructures)
- StructuralFeature (from fUML::Syntax::Classes::Kernel)

Attributes

- None

Associations

- class : Class [0..1]

- defaultValue : ValueSpecification [0..1]

7.5.2.2.8 StructuredClassifier

StructuredClassifier is introduced to enable modeling of internal structures comprising a network of parts and roles linked by connectors.

Generalizations

- Classifier (from fUML::Syntax::Classes::Kernel)
- Classifier (from CompositeStructuresSyntaxAndSemantics::Syntax::CompositeStructures::InternalStructures)

Attributes

- None

Associations

- ownedAttribute : Property [0..*]
- ownedConnector : Connector [0..*]
- part : Property [0..*]
- role : ConnectableElement [0..*]

7.5.3 InvocationActions

7.5.3.1 Overview

The InvocationActions package introduces extensions to fUML InvocationAction and Trigger to account for ports of an EncapsulatedClassifier.

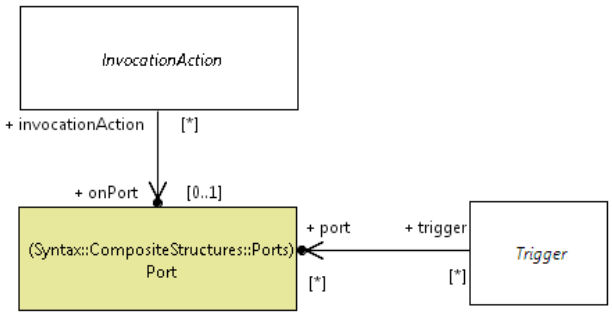


Figure 9: InvocationActions diagram

7.5.3.2 Class descriptions

7.5.3.2.1 InvocationAction

CompositeStructures::InvocationActions::InvocationAction extends (merge increment) fUML InvocationAction so that, in addition of targeting an object, the invocation (i.e., the call for an operation or the emission of a signal) can be made through a specific Port of this object (onPort).

Generalizations

- None

Attributes

- None

Associations

- onPort : Port [0..1]

7.5.3.2.2 Trigger

CompositeStructures::InternalStructures::Trigger extends (merge increment) fUML Trigger so that a list of Ports can be associated with a Trigger.

Generalizations

- None

Attributes

- None

Associations

- port : Port [0..*]

7.5.4 Ports

7.5.4.1 Overview

The Ports package introduces mechanisms enabling a classifier to have Ports.

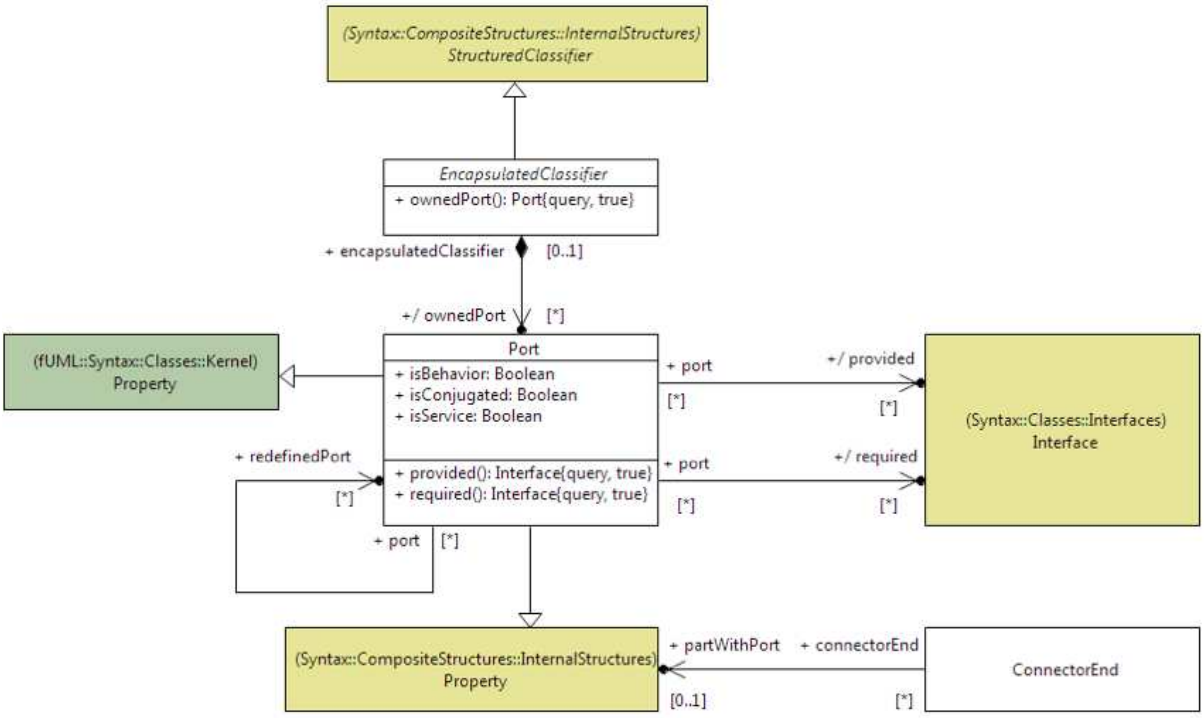


Figure 10: Ports diagram

7.5.4.2 Class descriptions

7.5.4.2.1 ConnectorEnd

CompositeStructures::Ports::ConnectorEnd extends (merge increment) CompositeStructures::InternalStructures::ConnectorEnd with an additional property (partWithPort), which, when the connected role is a Port, specifies that an instance of this Port is connected in the context of a specific property of the context Classifier.

Generalizations

- None

Attributes

- None

Associations

- partWithPort : Property [0..1]

7.5.4.2.2 EncapsulatedClassifier

EncapsulatedClassifier extends StructuredClassifier with the ability to own a set of Ports.

Generalizations

- StructuredClassifier (from CompositeStructuresSyntaxAndSemantics::Syntax::CompositeStructures::InternalStructures)

Attributes

- None

Associations

- ownedPort : Port [0..*]

7.5.4.2.3 Port

Port enables specification of interaction points through which instances of an encapsulated classifier can be connected and communicate with their environment or internal parts. Port also enables the specification of a set of Features provided or required by the owning EncapsulatedClassifier, that is, Features defined by provided or required Interfaces associated with the Port.

Generalizations

- Property (from fUML::Syntax::Classes::Kernel)
- Property (from CompositeStructuresSyntaxAndSemantics::Syntax::CompositeStructures::InternalStructures)

Attributes

- isBehavior : Boolean [1]
- isConjugated : Boolean [1]
- isService : Boolean [1]

Associations

- provided : Interface [0..*]
- redefinedPort : Port [0..*]
- required : Interface [0..*]

Additional constraints

- behavior_port_belongs_to_an_active_class
  A behavior port can only belong to an active class.

```
inv: encapsulatedClassifier->notEmpty() and
(encapsulatedClassifier.oclIsKindOf(Class) and
encapsulatedClassifier.isActive))
```

7.5.5 StructuredClasses

7.5.5.1 Overview

The StructuredClasses package is introduced to enable a Class to be structured, which is a key aspect of UML Composite Structures.

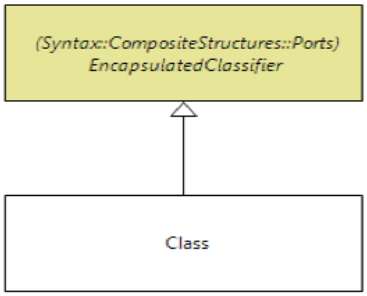


Figure 11: StructuredClasses diagram

7.5.5.2 Class descriptions

7.5.5.2.1 Class

CompositeStructures::StructuredClasses::Class extends (merge increment) fUML Class with the ability to be structured. A Class can have an internal structure comprising a network of linked parts, as well as a set of Ports.

Generalizations

- EncapsulatedClassifier (from CompositeStructuresSyntaxAndSemantics::Syntax::CompositeStructures::Ports)

Attributes

- None

Associations

- None

8 Semantics

8.1 Overview

The Semantics clause defines precise semantics for elements introduced in the Abstract Syntax clause. The semantic definition consists in extending the fUML execution model (defined in the Semantics clause of the "Semantics of a Foundational Subset for Executable UML Models" specification) with appropriate semantic visitors, semantic strategies, and the definition of a semantic mapping between these elements and elements defined in the Abstract Syntax clause. By convention, all classes introduced in the extended execution model are prefixed by "CS_", which stands for "Composite Structures". Structural and behavioral semantics of UML composite structures are both covered by this extension.

Structural Semantics

In this specification, structural semantics concerns the run time manifestation of (structured/encapsulated) classes, which implies defining how ports, parts and connectors are represented at run time (see fUML Terms and Definitions for a more general definition).

Behavioral Semantics

In this specification, behavioral semantics concerns the interpretation of Activities making statements (through appropriate activity nodes and edges) related to the life cycle of objects (construction, destruction, observation and modification) and to communications between those objects (see fUML Terms and Definitions for a more general definition).

Semantic Strategies and Semantic Variants

The definition of semantic strategies (i.e., the places where this specification allows for semantic variability) and semantic variants (i.e., sets of consistent semantic choices in the scope of allowed variability) follows the same principles as in fUML. Each semantic strategy is defined by an abstract strategy class in the execution model. Defining a particular semantic choice consists of defining a concrete realization of this abstract strategy class. As in fUML, grouping concrete semantic strategy classes in order to define a consistent semantic variant is a tool implementation concern (cf. 8.2.2.1 of "Semantics of a Foundational Subset for Executable UML Models", subclause on Configuring the Execution Environment at a Locus).

This specification introduces three new semantic strategies. CS_StructuralFeatureOfInterfaceAccessStrategy (8.4.1.2.3) deals with reading and writing of structural features of an Interface, specifying how these features are actually realized by a given behaviored classifier. CS_RequestPropagationStrategy (8.5.1.2.6) deals with propagation of requests in the case where multiple possible propagation paths exist (e.g., multiple interaction points, multiple links). CS_ConstructStrategy (8.5.1.2.3) deals with instantiation of composite structures, by constructing topologies of objects, interaction points and links, as well as dealing with default values of corresponding properties. In addition, this specification introduces CS_DispatchOperationOfInterfaceStrategy (8.4.1.2.1), a new default realization of fUML DispatchStrategy. This realization deals with dispatching of operations of an Interface, specifying how these operations are actually realized by a behaviored classifier.

Instantiation of Composite Structures

The UML specification says: *"Links corresponding to Connectors may be created upon the creation of the instance of the containing StructuredClassifier"* and *"The topologies that result from matching the multiplicities of ConnectorEnds and those of ConnectableElements they interconnect cannot always be deduced from the model. Specific examples in which the topology can be determined from the multiplicities are shown in Figure 11-6 and Figure 11-7"*. The only action defined by UML for creating an object is CreateObjectAction, which has the following semantics: *"A CreateObjectAction is an Action that creates a direct instance of a given Classifier and places the new instance on its result OutputPin. [...] The new instance has no values for its*

StructuralFeatures and participates in no links". These semantics are formalized in the fUML execution model.

In order to comply with fUML while taking into account the semantics of UML Composite Structures about object creation (which implies the creation of a topology of instances and links, which contradicts semantics of CreateObjectAction where created objects are empty), this specification overrides semantics of CallOperationAction in the case where the standard stereotype Create is applied on the called Operation, and this operation has no associated method. In this case, a construction strategy is applied (see CS_ConstructStrategy in 8.5.1.2.3). Since Profiles and Stereotypes were not included in fUML, this specification provides some extensions, described in the following paragraph.

Dealing with Profiles and Stereotypes

The UML abstract syntax for profiles and stereotypes is not part of the fUML subset. However, for the purposes of fUML execution semantics, a UML profile can be interpreted exactly as its equivalent CMOF model, which can be represented in fUML (with the same considerations used when representing the rest of the UML abstract syntax in fUML). The application of a stereotype can then be treated as an object of the equivalent CMOF class for the stereotype tied to the appropriate UML metaobject by a link of the equivalent CMOF association for the extension.

Since the bUML subset used for the execution model does not include associations, when the UML abstract syntax is represented in bUML, associations are essentially ignored and all navigation is via the meta-class-owned end properties defined by the associations. Since the equivalent CMOF association for an extension is navigable only from the equivalent CMOF class for the stereotype to the extended UML metaclass, the usual UML abstract syntax conventions imply that the CMOF class for the stereotype owns the "base_metaclassName" property, but that there is not a corresponding "extension_stereotypeName" property added to the UML metaclass. This means that, in order to determine whether a metaobject has a specific stereotype applied, one needs to search the extent of the equivalent CMOF class for the stereotype to see if there is one that extends the given metaobject. This can be done using bUML code of the following form:

```
ExtensionalValueList extent = locus.getExtent(stereotypeClass);
ExtensionalValue extensionObject = null;
int i = 1;
while (i <= extent.size() && extensionObject == null) {
    ExtensionalValue object = extent.getValue(i - 1);
    if(object.getFeatureValue(baseEnd).values.getValue(0).equals(baseObject)) {
        extensionObject = object;
    }
    i = i + 1;
}
```

The result of the above code is that extensionObject contains the equivalent CMOF object for the stereotype applied to the model element represented by baseObject or, if the stereotype is not applied, it is null.

Note that doing the above requires that the equivalent CMOF class for the stereotype is actually instantiated at the execution locus, in order for its extent to be looked up. This means that it would be possible for a stereotype to be applied to a model at one execution, but not applied to that same model at a different execution locus. No fUML semantics have previously put any such requirement on the instantiation of abstract syntax metaclasses.

It also requires that the specific metaobject representing a stereotypeClass be known. The root package of the equivalent CMOF model of a profile has to be registered, rather than the individual stereotypes within the profile, so that a stereotype could be looked up by its qualified name, to avoid possible name conflicts. In this specification, this mechanism is added to the execution model by the specialization of ExecutionFactory (see 8.6.1.2.1). Then the equivalent class for a stereotype could be looked up using a call such as the following:

```
Class_ createStereotypeClass = locus.factory.getStereotypeClass("StandardProfile", "Create");
```

The following subclauses provide details about how the fUML execution model is extended to address semantics of UML Composite Structures.

8.2 Actions

8.2.1 CompleteActions

8.2.1.1 Overview

The CompleteActions package introduces two extensions to fUMLsemantics. The first one is related to ReadExtentAction, and it accounts for the introduction of classes CS_Object (8.5.2.2.4) and CS_Reference (8.5.2.2.5). The second one is related to ReadIsClassifiedObjectAction, and enables to determine if an object is classified by an Interface. Extensions are depicted in Figure 12.

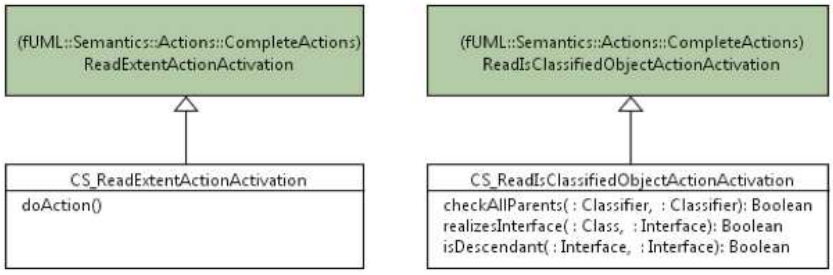


Figure 12: CompleteActions diagram

8.2.1.2 Class descriptions

8.2.1.2.1 CS_ReadExtentActionActivation

CS_ReadExtentActionActivation extends fUML ReadExtentActionActivation to account for the introduction of classes CS_Object (8.5.2.2.4) and CS_Reference (8.5.2.2.5). As compared to fUML semantics (which produces a collection of References to Objects available at the execution Locus), for each CS_Object (classified by the given ReadExtentAction classifier) that is available at the execution Locus, a CS_Reference is produced instead of a fUML Reference.

Generalizations

- ReadExtentActionActivation (from fUML::Semantics::Actions::CompleteActions)

Attributes

- None

Associations

- None

Operations

```
[1] public doAction()
        // Get the extent, at the current execution locus, of the classifier
        // (which must be a class) identified in the action.
        // Place references to the resulting set of objects on the result pin.
        // Extends default fUML semantics in the sense that produced tokens contain
        // CS_References instead of References, in the case where the object is a
        // CS_Object
        ReadExtentAction action = (ReadExtentAction) (this.node);
        ExtensionalValueList objects = this.getExecutionLocus().getExtent(
```

```
                        action.classifier);
        ValueList references = new ValueList();
        for (int i = 0; i < objects.size(); i++) {
                Value object = objects.getValue(i);
                Reference reference = null ;
                if (object instanceof CS_Object) {
                        reference = new CS_Reference() ;
                        ((CS_Reference)reference).compositeReferent = (CS_Object)object ;
                }
                else {
                        reference = new Reference() ;
                }
                reference.referent = (Object_) object;
                references.addValue(reference);
        }
        this.putTokens(action.result, references);
```

8.2.1.2.2 CS_ReadIsClassifiedObjectActionActivation

CS_ReadIsClassifiedObjectActionActivation extends fUML ReadIsClassifiedObjectActionActivation to account for Interfaces. In the case where the Classifier identified by the ReadIsClassifiedObjectAction is not an Interface, it behaves like in fUML. In the case where the Classifier is an Interface, it checks if the given type (or one of its direct or indirect ancestors) has an InterfaceRealization relationships with the given classifier. If an InterfaceRealization is found, the object is classified by this Interface.

Generalizations

- ReadExtentActionActivation (from fUML::Semantics::Actions::CompleteActions)

Attributes

- None

Associations

- None

Operations

```
[1] public checkAllParents(type:Classifier, classifier:Classifier) : Boolean
        // If the given classifier is not an Interface, behaves like in fUML.
        // Otherwise, check if the given type (or one of its direct or indirect ancestors)
        // has an InterfaceRealization relationships with the given classifier.
        boolean matched = false ;
        if (!(classifier instanceof Interface)) {
          matched = super.checkAllParents(type, classifier);
        }
        else if (! (type instanceof Class_)){
          matched = false ;
        }
        else if (this.realizesInterface((Class_)type, (Interface)classifier)) {
          matched = true ;
        }
        else {
          ClassifierList directParents = type.general;
          int i = 1;
          while(!matched & i <= directParents.size()) {
            Classifier directParent = directParents.get(i - 1);
            matched = this.checkAllParents(directParent, classifier);
            i = i + 1;
          }
        }
        return matched ;

[2] public isDescendant(contract:Interface, interface_:Interface) : Boolean
        // Checks if the given contract is a descendant of the given interface_
```

```
        boolean matched = false ;
        ClassifierList descendants = contract.general ;
        int i = 1 ;
        while (i <= descendants.size() && ! matched) {
          if (descendants.getValue(i-1) instanceof Interface) {
            Interface descendant = (Interface)descendants.getValue(i-1) ;
            if (descendant == interface_) {
              matched = true ;
            }
            else {
              matched = this.isDescendant(descendant, interface_) ;
            }
          }
          i = i + 1 ;
        }
        return matched ;

[3] public Boolean realizesInterface(Class_ type, Interface interface_) {
        // Checks if the given type has an InterfaceRealization relationship
        // with the given interface or a descendant of the interface.
        InterfaceRealizationList realizations = type.interfaceRealization ;
        boolean realized = false ;
        int i = 1 ;
        while (i <= realizations.size() && !realized) {
          InterfaceRealization realization = realizations.get(i - 1) ;
          Interface contract = realization.contract ;
          if (contract == interface_) {
            realized = true ;
          }
          else if (this.isDescendant(contract, interface_)) {
            realized = true ;
          }
          i = i + 1 ;
        }
        return realized ;
```

8.2.2 IntermediateActions

8.2.2.1 Overview

Extensions introduced by the IntermediateActions deal with structural semantics of Composite Structures, in connection with the introduction of classes CS_Object (8.5.2.2.4), CS_Reference (8.5.2.2.5), CS_Link (8.5.2.2.2), and CS_InteractionPoint (8.5.2.2.1). These extensions are depicted in Figure 13.

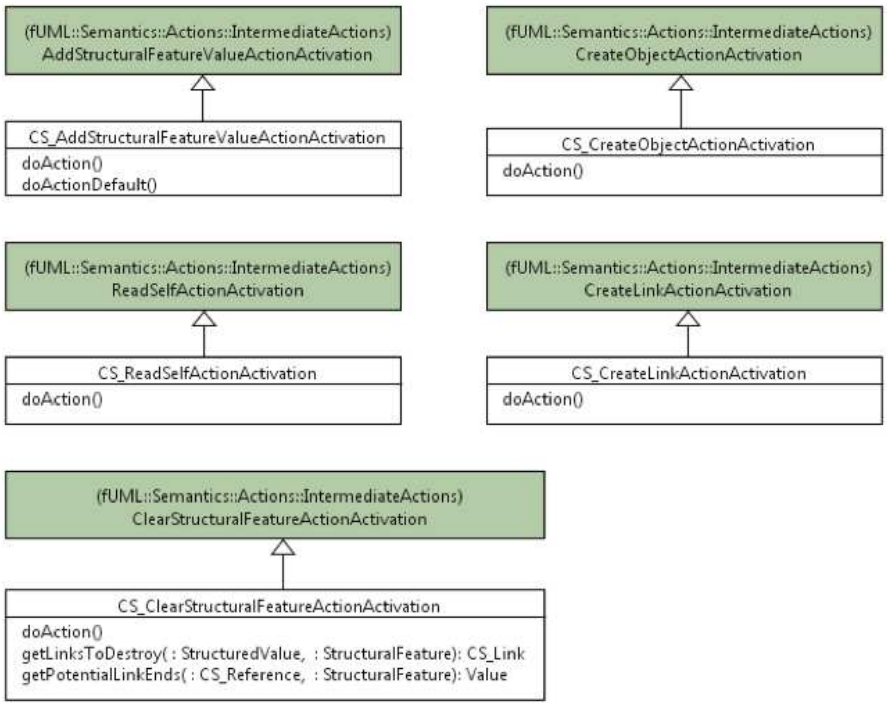


Figure 13: IntermediateActions diagram

8.2.2.2 Class descriptions

8.2.2.2.1 CS_AddStructuralFeatureValueActionActivation

CS_AddStructuralFeatureValueActionActivation extends fUML AddStructuralFeatureValueActionActivation so that, if the StructuralFeature identified by the Action is a Port, a CS_InteractionPointis inserted as a Value for the Port instead of a CS_Reference. In the case where the StructuralFeature is not a Port but identifies an association end, fUML semantics are also extended so that a CS_Linkis created instead of a fUML Link.

Generalizations

- AddStructuralFeatureValueActionActivation (from fUML::Semantics::Actions::IntermediateActions)

Attributes

- None

Associations

- None

Operations

```
[1] public doAction()
        // If the feature is a port and the input value to be added is a CS_Reference,
        // Replaces this CS_Reference by a CS_InteractionPoint, and then behaves
        // as usual.
        // If the feature is not a port, behaves as usual

        AddStructuralFeatureValueAction action = (AddStructuralFeatureValueAction)
(this.node);
        StructuralFeature feature = action.structuralFeature;

        if (!(feature instanceof Port)) {
                // Behaves as usual
```

```
        this.doActionDefault() ;
}
else {
        ValueList inputValues = this.takeTokens(action.value);
        // NOTE: Multiplicity of the value input pin is required to be 1..1.
        Value inputValue = inputValues.getValue(0);
        if (inputValue instanceof Reference) {
        // First constructs an InteractionPoint from the inputValue
        Reference reference = (Reference) inputValue;
        CS_InteractionPoint interactionPoint = new CS_InteractionPoint();
        interactionPoint.referent = reference.referent;
        interactionPoint.definingPort = (Port) feature;
        // The value on action.object is necessarily instanceof
        // CS_Reference (otherwise, the feature cannot be a port)
        CS_Reference owner = (CS_Reference) this.takeTokens(
                action.object).getValue(0);
        interactionPoint.owner = owner;
        // Then replaces the CS_Reference by a CS_InteractionPoint in the inputValues
        inputValues.remove(0);
        inputValues.addValue(0, interactionPoint);
        // Finally concludes with usual fUML behavior of
        // AddStructuralFeatureValueAction (i.e., the usual behavior when
        // the value on action.object pin is a StructuredValue)
        Integer insertAt = 0;
        if (action.insertAt != null) {
                insertAt = ((UnlimitedNaturalValue) this.takeTokens(
                        action.insertAt).getValue(0)).value.naturalValue;
        }
        if (action.isReplaceAll) {
                owner.setFeatureValue(feature, inputValues, 0);
        }
        else {
                FeatureValue featureValue = owner.getFeatureValue(feature);

                if (featureValue.values.size() > 0 & insertAt == 0) {
                // If there is no insertAt pin, then the structural
                // feature must be unordered, and the insertion position is
                // immaterial.
                insertAt = ((ChoiceStrategy) this.getExecutionLocus().factory
                        .getStrategy("choice"))
                        .choose(featureValue.values.size());
                }
                if (feature.multiplicityElement.isUnique) {
                // Remove any existing value that duplicates the input value
                Integer j = position(interactionPoint, featureValue.values, 1);
                if (j > 0) {
                        featureValue.values.remove(j - 1);
                        if (insertAt > 0 & j < insertAt) {
                        insertAt = insertAt - 1;
                        }
                }
                }

                if (insertAt <= 0) {
                // Note: insertAt = -1 indicates an unlimited value of
                // "*"
                featureValue.values.addValue(interactionPoint);
                } else {
                featureValue.values.addValue(insertAt - 1, interactionPoint);
                }
        }
        if (action.result != null) {
                this.putToken(action.result, owner);
        }
        }
        else {
        // behaves as usual
        this.doActionDefault() ;
        }
}
```

```
[2] public doActionDefault()
	// Get the values of the object and value input pins.
	// If the given feature is an association end, then create a link
	// between the object and value inputs.
	// Otherwise, if the object input is a structural value, then add a
	// value to the values for the feature.
	// If isReplaceAll is true, first remove all current matching links or
	// feature values.
	// If isReplaceAll is false and there is an insertAt pin, insert the
	// value at the appropriate position.
	// This operation captures same semantics as fUML
	// AddStructuralFeatureValueActionActivation.doAction(), except that
	// when the feature is an association end, a CS_Link will be created instead
	// of a Link

	AddStructuralFeatureValueAction action = (AddStructuralFeatureValueAction)
(this.node);
	StructuralFeature feature = action.structuralFeature;
	Association association = this.getAssociation(feature);

	Value value = this.takeTokens(action.object).getValue(0);
	ValueList inputValues = this.takeTokens(action.value);

	// NOTE: Multiplicity of the value input pin is required to be 1..1.
	Value inputValue = inputValues.getValue(0);

	int insertAt = 0;
	if (action.insertAt != null) {
		insertAt = ((UnlimitedNaturalValue) this
			.takeTokens(action.insertAt).getValue(0)).value.naturalValue;
	}

	if (association != null) {
		LinkList links = this.getMatchingLinks(association, feature, value);

		Property oppositeEnd = this.getOppositeEnd(association, feature);
		int position = 0;
		if (oppositeEnd.multiplicityElement.isOrdered) {
		position = -1;
		}

		if (action.isReplaceAll) {
		for (int i = 0; i < links.size(); i++) {
			Link link = links.getValue(i);
			link.destroy();
		}
		} else if (feature.multiplicityElement.isUnique) {
		for (int i = 0; i < links.size(); i++) {
			Link link = links.getValue(i);
			FeatureValue featureValue = link.getFeatureValue(feature);
			if (featureValue.values.getValue(0).equals(inputValue)) {
			position = link.getFeatureValue(oppositeEnd).position;
			if (insertAt > 0 & featureValue.position < insertAt) {
				insertAt = insertAt - 1;
			}
			link.destroy();
			}
		}
		}

		CS_Link newLink = new CS_Link();
		newLink.type = association;

		// This necessary when setting a feature value with an insertAt
		// position
		newLink.locus = this.getExecutionLocus();

		newLink.setFeatureValue(feature, inputValues, insertAt);

		ValueList oppositeValues = new ValueList();
		oppositeValues.addValue(value);
		newLink.setFeatureValue(oppositeEnd, oppositeValues, position);
```

```
            newLink.locus.add(newLink);

        } else if (value instanceof StructuredValue) {
            StructuredValue structuredValue = (StructuredValue) value;

            if (action.isReplaceAll) {
            structuredValue.setFeatureValue(feature, inputValues, 0);
            } else {
            FeatureValue featureValue = structuredValue
                    .getFeatureValue(feature);

            if (featureValue.values.size() > 0 & insertAt == 0) {
                    // *** If there is no insertAt pin, then the structural
                    // feature must be unordered, and the insertion position is
                    // immaterial. ***
                    insertAt = ((ChoiceStrategy) this.getExecutionLocus().factory
                            .getStrategy("choice")).choose(featureValue.values
                                    .size());
            }

            if (feature.multiplicityElement.isUnique) {
                    // Remove any existing value that duplicates the input value
                    int j = position(inputValue, featureValue.values, 1);
                    if (j > 0) {
                    featureValue.values.remove(j - 1);
                    if (insertAt > 0 & j < insertAt) {
                            insertAt = insertAt - 1;
                    }
                    }
            }

            if (insertAt <= 0) { // Note: insertAt = -1 indicates an
                    // unlimited value of "*"
                    featureValue.values.addValue(inputValue);
            } else {
                    featureValue.values.addValue(insertAt - 1, inputValue);
            }
            }
        }

        if (action.result != null) {
            this.putToken(action.result, value);
        }
```

8.2.2.2.2 CS_ClearStructuralFeatureActionActivation

FUML semantics are extended so that, when a StructuralFeature is cleared, any links representing an instance of a Connector in which the StructuralFeature is involved (i.e., it is a role or a partWithPort for a ConnectorEnd of this Connector) are destroyed.

Generalizations

- ClearStructuralFeatureActionActivation (from fUML::Semantics::Actions::IntermediateActions)

Attributes

- None

Associations

- None

Operations

```
[1] public doAction()
  // Get the value of the object input pin.
  // If the given feature is an association end, then
```

```
  // destroy all links that have the object input on the opposite end.
  // Otherwise, if the object input is a structured value, then
  // set the appropriate feature of the input value to be empty.
  ClearStructuralFeatureAction action = (ClearStructuralFeatureAction)(this.node);
  StructuralFeature feature = action.structuralFeature;
  Association association = this.getAssociation(feature);
  Value value = this.takeTokens(action.object).get(0);
  if(association != null) {
    LinkList links = this.getMatchingLinks(association, feature, value);
    for(int i = 0; i < links.size(); i++) {
        Link link = links.get(i);
        link.destroy();
    }
  } else if(value instanceof StructuredValue) {
    // If the value is a data value, then it must be copied before
    // any change is made.
    if(!(value instanceof Reference)) {
      value = value.copy();
    }
    else {
      // extension to fUML
      CS_LinkList linksToDestroy = this.getLinksToDestroy((StructuredValue)value, feature) ;
      for (int i = 0 ; i < linksToDestroy.size() ; i++) {
        linksToDestroy.get(i).destroy() ;
      }
      //
    }
    ((StructuredValue)value).setFeatureValue(action.structuralFeature, new ValueList(), 0);
  }
  if(action.result != null) {
    this.putToken(action.result, value);
  }

[2] public getLinksToDestroy(value: StructuredValue, feature:StructuralFeature) : CS_Link[*]
  // Retrieves links that must be destroyed when the given feature
  // is cleared in the context of the given value
  CS_LinkList linksToDestroy = new CS_LinkList() ;
  if (value instanceof CS_Reference) {
    CS_Reference context = (CS_Reference)value ;
    // Retrieves the feature values for the structural feature associated with this action,
    // in the context of this reference
    FeatureValue featureValue = context.getFeatureValue(feature) ;
    if (feature instanceof Port) {
      // all values are interaction points
      // any link targeting this interaction point must be destroyed
      for (int i = 0 ; i < featureValue.values.size() ; i++) {
        CS_InteractionPoint interactionPoint = (CS_InteractionPoint)featureValue.values.get(i)
;
        CS_LinkList connectorInstances = context.compositeReferent.getLinks(interactionPoint)
;
        for (int j = 0 ; j < connectorInstances.size() ; j++) {
          CS_Link link = connectorInstances.get(j) ;
          linksToDestroy.add(link) ;
        }
      }
    }
    else { // feature is an attribute
      // Retrieve all potential link ends,
      // separating potential link ends corresponding to the given feature,
      // and potential link ends corresponding to other features.
      // By "potential link ends", we refer to the values of a given feature,
      // as well as interaction points associated with this value, if any.
      ValueList allValuesForFeature = new ValueList() ;
      ValueList allOtherValues = new ValueList() ;
      for (int i = 0 ; i < context.referent.featureValues.size() ; i++) {
        StructuralFeature currentFeature = context.referent.featureValues.get(i).feature ;
        ValueList values = this.getPotentialLinkEnds(context, currentFeature) ;
        for (int j = 0 ; j < values.size() ; j++) {
          Value v = values.get(j) ;
          if (currentFeature != feature) {
            allOtherValues.add(v) ;
```

```
          }
          else {
            allValuesForFeature.add(v) ;
          }
        }
      }
      // Retrieves all links available at the locus
      ExtensionalValueList extensionalValues = this.getExecutionLocus().extensionalValues ;
      CS_LinkList allLinks = new CS_LinkList() ;
      for (int i = 0 ; i < extensionalValues.size() ; i ++) {
        ExtensionalValue extensionalValue = extensionalValues.get(i) ;
        if (extensionalValue instanceof CS_Link) {
          allLinks.add((CS_Link)extensionalValue) ;
        }
      }
      // Retrieves links representing connector instances in the context object
      for (int i = 0 ; i < allLinks.size() ; i++) {
        CS_Link link = allLinks.get(i) ;
        boolean linkHasToBeDestroyed = false ;
        for (int j = 0 ; j < allValuesForFeature.size() && !linkHasToBeDestroyed; j++) {
          Value v = allValuesForFeature.get(j) ;
          StructuralFeature featureForV = link.getFeature(v) ;
          if (featureForV != null) {
            // Check if feature values of this link for other features
            // contains elements identified in allOtherValue
            for (int k = 0 ; k < link.featureValues.size() && !linkHasToBeDestroyed ; k++) {
              FeatureValue otherFeatureValue = link.featureValues.get(k) ;
              if (otherFeatureValue.feature != featureForV) {
                for (int l = 0; l < otherFeatureValue.values.size() && !linkHasToBeDestroyed ;
l++) {
                  for (int m = 0 ; m < allOtherValues.size() && !linkHasToBeDestroyed ; m++) {
                    if (otherFeatureValue.values.get(l) == allOtherValues.get(m)) {
                      linkHasToBeDestroyed = true ;
                    }
                  }
                }
              }
            }
          }
        }
        if (linkHasToBeDestroyed) {
          linksToDestroy.add(link) ;
        }
      }
    }
  }
  return linksToDestroy ;

[3] public getPotentialLinkEnds(context : CS_Reference, feature : StructuralFeature) :
Value[*]
  // Retrieves all feature values for the context object for the given feature,
  // as well as all interaction point for these values
  ValueList potentialLinkEnds = new ValueList() ;
  FeatureValue featureValue = context.getFeatureValue(feature) ;
  for (int i = 0 ; i < featureValue.values.size() ; i++) {
    Value v = featureValue.values.get(i) ;
    potentialLinkEnds.add(v) ;
    if (v instanceof CS_Reference) {
      // add all interaction points associated with v
      for (int j = 0 ; j < ((CS_Reference)v).referent.featureValues.size() ; j++) {
        if (((CS_Reference)v).referent.featureValues.get(j).feature instanceof Port) {
          ValueList interactionPoints =
(((CS_Reference)v).referent.featureValues.get(j)).values ;
          for (int k = 0 ; k < interactionPoints.size() ; k++) {
            potentialLinkEnds.add(interactionPoints.get(k)) ;
          }
        }
      }
    }
  }
  return potentialLinkEnds ;
```

8.2.2.2.3 CS_CreateLinkActionActivation

FUML semantics are extended so that a CS_Linkis created instead of a fUML Link.

Generalizations

- CreateLinkActionActivation (from fUML::Semantics::Actions::IntermediateActions)

Attributes

- None

Associations

- None

Operations

```
[1] public doAction()
        // Get the extent at the current execution locus of the association for
        // which a link is being created.
        // Destroy all links that have a value for any end for which
        // isReplaceAll is true.
        // Create a new link for the association, at the current locus, with the
        // given end data values,
        // inserted at the given insertAt position (for ordered ends).
        // fUML semantics is extended in the sense that a CS_Link is created instead of
        // a Link

        CreateLinkAction action = (CreateLinkAction) (this.node);
        LinkEndCreationDataList endDataList = action.endData;

        Association linkAssociation = this.getAssociation();
        ExtensionalValueList extent = this.getExecutionLocus().getExtent(
                linkAssociation);

        Link oldLink = null;
        for (int i = 0; i < extent.size(); i++) {
                ExtensionalValue value = extent.getValue(i);
                Link link = (Link) value;

                boolean noMatch = true;
                int j = 1;
                while (noMatch & j <= endDataList.size()) {
                LinkEndCreationData endData = endDataList.getValue(j - 1);
                if (endData.isReplaceAll
                        & this.endMatchesEndData(link, endData)) {
                        oldLink = link;
                        link.destroy();
                        noMatch = false;
                }
                j = j + 1;
                }
        }

        CS_Link newLink = new CS_Link();
        newLink.type = linkAssociation;

        // This is necessary when setting a feature value with an insertAt position
        newLink.locus = this.getExecutionLocus();

        for (int i = 0; i < endDataList.size(); i++) {
                LinkEndCreationData endData = endDataList.getValue(i);

                int insertAt;
                if (endData.insertAt == null) {
                insertAt = 0;
                } else {
                insertAt = ((UnlimitedNaturalValue) (this
```

```
                .takeTokens(endData.insertAt).getValue(0))).value.naturalValue;
        if (oldLink != null) {
                if (oldLink.getFeatureValue(endData.end).position < insertAt) {
                insertAt = insertAt - 1;
                }
        }
        }
        newLink.setFeatureValue(endData.end,
                this.takeTokens(endData.value), insertAt);
}

this.getExecutionLocus().add(newLink);
```

8.2.2.2.4 CS_CreateObjectActionActivation

FUML semantics are extended so that a CS_Referenceis produced instead of a fUML Reference, in the case where the execution locus instantiate a CS_Object instead of a fUML Object. With the extensions defined in this specification, a fUML Object is instantiated only in the case where the classifier identified by the Action is a Behavior.

Generalizations

- CreateObjectActionActivation (from fUML::Semantics::Actions::IntermediateActions)

Attributes

- None

Associations

- None

Operations

```
[1] public doAction()
        // Create an object with the given classifier (which must be a class) as
        // its type, at the same locus as the action activation.
        // Place a reference to the object on the result pin of the action.
        // Extends fUML semantics in the sense that the reference placed
        // on the result pin is a CS_Reference (in the case where the instantiated object
        // is a CS_Object) not a Reference
        // Note that Locus.instantiate(Class) is extended in this specification
        // to produce a CS_Object instead of an Object in the case where the class
        // to be instantiated is not a behavior

        CreateObjectAction action = (CreateObjectAction) (this.node);

        Reference reference ;
        Object_ referent = this.getExecutionLocus().instantiate((Class_) (action.classifier));
        if (referent instanceof CS_Object) {
                reference = new CS_Reference() ;
                ((CS_Reference)reference).compositeReferent = (CS_Object)referent ;
        }
        else {
                reference = new Reference() ;
        }
        reference.referent = referent ;

        this.putToken(action.result, reference);
```

8.2.2.2.5 CS_ReadSelfActionActivation

FUML semantics are extended so that a CS_Reference is produced instead of a fUML reference.

Generalizations

- ReadSelfActionActivation (from fUML::Semantics::Actions::IntermediateActions)

Attributes

- None

Associations

- None

Operations

```
[1] public doAction()
        // Get the context object of the activity execution containing this
        // action activation and place a reference to it on the result output
        // pin.
        // Extends fUML semantics in the sense that the reference placed on
        // the result pin is a CS_Reference, not a Reference

        // Debug.println("[ReadSelfActionActivation] Start...");

        CS_Reference context = new CS_Reference();
        context.referent = this.getExecutionContext();
        if (context.referent instanceof CS_Object) {// i.e. alternatively, it can be an
execution
                context.compositeReferent = (CS_Object)context.referent ;
        }

        // Debug.println("[ReadSelfActionActivation] context object = " +
        // context.referent);

        OutputPin resultPin = ((ReadSelfAction) (this.node)).result;
        this.putToken(resultPin, context);
```

8.3 Classes

8.3.1 Kernel

8.3.1.1 Overview

The Kernel package introduces extensions to some fUML Evaluation classes. These extensions are depicted in Figure 14.

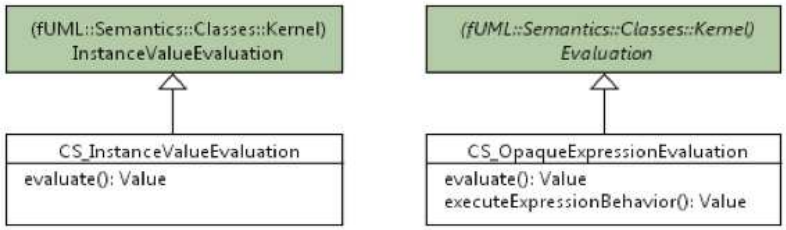


Figure 14: Kernel diagram

8.3.1.2 Class descriptions

8.3.1.2.1 CS_InstanceValueEvaluation

FUML semantics are extended so that, if the evaluated instance specification is for an object which is not typed by a Behavior, a CS_Reference(to a CS_Object) is returned instead of Reference (to a fUML Object).

Generalizations

- InstanceValueEvaluation (from fUML::Semantics::Classes::Kernel)

Attributes

- None

Associations

- None

Operations

```
[1] public evaluate() : Value
        // If the instance specification is for an enumeration, then return the
        // identified enumeration literal.
        // If the instance specification is for a data type (but not a primitive
        // value or an enumeration), then create a data value of the given data
        // type.
        // If the instance specification is for an object, then create an object
        // at the current locus with the specified types.
        // Set each feature of the created value to the result of evaluating the
        // value specifications for the specified slot for the feature.
        // Extends fUML semantics in the sense that when the instance specification
        // is for an object which is not typed by a Behavior, A CS_Reference (to a
        // CS_Object) is produced instead of a Reference (to an Object)

        // Debug.println("[evaluate] InstanceValueEvaluation...");

        InstanceSpecification instance = ((InstanceValue) this.specification).instance;
        ClassifierList types = instance.classifier;
        Classifier myType = types.getValue(0);

        Debug.println("[evaluate] type = " + myType.name);

        Value value;
        if (instance instanceof EnumerationLiteral) {
                // Debug.println("[evaluate] Type is an enumeration.");
                EnumerationValue enumerationValue = new EnumerationValue();
                enumerationValue.type = (Enumeration) myType;
                enumerationValue.literal = (EnumerationLiteral) instance;
                value = enumerationValue;
        }
        else {
                StructuredValue structuredValue = null;

                if (myType instanceof DataType) {
                // Debug.println("[evaluate] Type is a data type.");
                DataValue dataValue = new DataValue();
                dataValue.type = (DataType) myType;
                structuredValue = dataValue;
                }
                else {
                Object_ object = null;
                if (myType instanceof Behavior) {
                        // Debug.println("[evaluate] Type is a behavior.");
                        object = this.locus.factory.createExecution(
                                (Behavior) myType, null);
                }
                else {
                        // Debug.println("[evaluate] Type is a class.");
                        object = new CS_Object();
                        for (int i = 0; i < types.size(); i++) {
                        Classifier type = types.getValue(i);
                        object.types.addValue((Class_) type);
                        }
                }
```

```
            this.locus.add(object);

            Reference reference ;
            if (object instanceof CS_Object) {
                    reference = new CS_Reference();
                    ((CS_Reference)reference).compositeReferent = (CS_Object)object ;
            }
            else {
                    reference = new Reference() ;
            }
            reference.referent = object;
            structuredValue = reference;
            }

            structuredValue.createFeatureValues();

            // Debug.println("[evaluate] " + instance.slot.size() +
            // " slot(s).");

            SlotList instanceSlots = instance.slot;
            for (int i = 0; i < instanceSlots.size(); i++) {
            Slot slot = instanceSlots.getValue(i);
            ValueList values = new ValueList();

            // Debug.println("[evaluate] feature = " +
            // slot.definingFeature.name + ", " + slot.value.size() +
            // " value(s).");
            ValueSpecificationList slotValues = slot.value;
            for (int j = 0; j < slotValues.size(); j++) {
                    ValueSpecification slotValue = slotValues.getValue(j);
                    // Debug.println("[evaluate] Value = " +
                    // slotValue.getClass().getName());
                    values.addValue(this.locus.executor.evaluate(slotValue));
            }
            structuredValue.setFeatureValue(slot.definingFeature, values, 0);
            }

            value = structuredValue;
    }

    return value;
```

8.3.1.2.2 CS_OpaqueExpressionEvaluation

CS_OpaqueExpressionEvaluation defines semantics for the evaluation of OpaqueExpressions. The evaluation consists in executing the Behavior associated with the evaluated OpaqueExpression.

The fUML semantics for the evaluation of ValueSpecification is based on the assumption that at most a single Value is returned. In CS_OpaqueExpressionEvaluation, this assumption is reflected in operation evaluate (described below). There are however cases where one would expect that the evaluation of ValueSpecification returns a collection of Values. A typical use case concerns a default value for a property with a lower bound greater than 1.

To support this use case, CS_OpaqueExpressionEvaluation introduces the operation executeExpressionBehavior, which returns a collection of values. This operation is used by CS_DefaultConstructStrategy, when instantiating objects corresponding to parts with default values specified by OpaqueExpressions. Other construction strategies might consider using this operation as well.

Generalizations

- Evaluation (from fUML::Semantics::Classes::Kernel)

Attributes

- None

Associations

- None

Operations

```
[1] public evaluate() : Value
        // Execute the behavior associated with the context OpaqueExpression, if any.
        // If multiple return values are computed, then return the first one.
        // If no values are computed, return null
        ValueList evaluation = this.executeExpressionBehavior() ;
        if (evaluation.size() > 0) {
                return evaluation.get(0) ;
        }
        else {
                return null ;
        }

[2] public executeExpressionBehavior() : Value[*]
        // If a behavior is associated with the context OpaqueExpression,
        // then execute this behavior, and return computed values.
        // Otherwise, return an empty list of values.
        ValueList evaluation = new ValueList() ;
        OpaqueExpression expression = (OpaqueExpression)this.specification ;
        Behavior behavior = expression.behavior ;
        if (behavior != null) {
                ParameterValueList inputs = new ParameterValueList() ;
                ParameterValueList results = this.locus.executor.execute(behavior, null,
inputs) ;
                for (int i = 0 ; i < results.size() ; i++) { // results.size should be 1
                        ParameterValue parameterValue = results.get(i) ;
                        ValueList values = parameterValue.values ;
                        for (int j = 0 ; j < values.size() ; j++) {
                                evaluation.add(values.get(j)) ;
                        }
                }
        }
        return evaluation ;
```

8.4 CommonBehaviors

8.4.1 Communications

8.4.1.1 Overview

The Communications package only introduces extensions related to semantic strategies. These extensions are depicted in Figure 15.

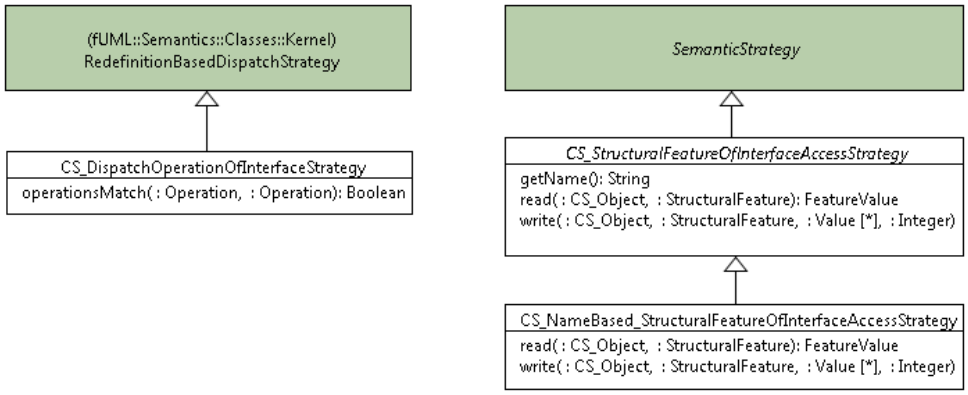


Figure 15: Communications diagram

8.4.1.2 Class descriptions

8.4.1.2.1 CS_DispatchOperationOfInterfaceStrategy

CS_DispatchOperationOfInterfaceStrategy extends RedefinitionBasedDispatchStrategy, which is the default semantic strategy provided by fUML for operation call dispatching. The extension consists in taking into account the introduction of Interfaces (cf. Clause 7.2.3.2.3). If the called Operation belongs to an Interface (cf. 8.5.1.2.2, CS_CallOperationActionActivation), this strategy is used to determine if an Operation of the target Object (i.e., an Operation that belongs to a Class typing this Object) matches the Operation of the Interface. It matches if it has the same name and signature.

Generalizations

- RedefinitionBasedDispatchStrategy (from fUML::Semantics::Classes::Kernel)

Attributes

- None

Associations

- None

Operations

```
[1] public operationsMatch(ownedOperation:Operation, baseOperation:Operation) : Boolean
       // Override operationsMatch, in the case where baseOperation belongs
       // to an Interface.
       // In this case, ownedOperation matches baseOperation if it has the same name and
signature
       // Otherwise, behaves like fUML RedefinitionBasedDispatchStrategy
       boolean matches = true ;
       if (baseOperation.namespace instanceof Interface) {
              matches = (baseOperation.name == ownedOperation.name) ;
              matches = matches && (baseOperation.ownedParameter.size() ==
                            ownedOperation.ownedParameter.size()) ;
              ParameterList ownedOperationParameters = ownedOperation.ownedParameter ;
              ParameterList baseOperationParameters = baseOperation.ownedParameter ;
              for (int i = 0 ; matches == true && i < ownedOperationParameters.size() ; i++)
{
                     Parameter ownedParameter = ownedOperationParameters.getValue(i) ;
                     Parameter baseParameter = baseOperationParameters.getValue(i) ;
                     matches = (ownedParameter.type == baseParameter.type) ;
                     matches = matches && (ownedParameter.multiplicityElement.lower ==
                                   ownedParameter.multiplicityElement.lower) ;
                     matches = matches && (ownedParameter.multiplicityElement.upper ==
                                   ownedParameter.multiplicityElement.upper) ;
```

```
                    matches = matches && (ownedParameter.direction ==
ownedParameter.direction) ;
                }
        }
        else {
                matches = super.operationsMatch(ownedOperation, baseOperation) ;
        }

        return matches ;
```

8.4.1.2.2 CS_NameBased_StructuralFeatureOfInterfaceAccessStrategy

CS_NameBased_StructuralFeatureOfInterfaceAccessStrategy is the default realization provided by this specification for the semantic strategy CS_StructuralFeatureOfInterfaceAccessStrategy. This default realization requires that, for a given Class to actually realize the StructuralFeatures of an Interface, it must define or inherit StructuralFeatures that match the StructuralFeatures of the Interface. StructuralFeatures match if they have same name, compatible type, and same multiplicity. Note that UML does not impose that the realizing Classes have StructuralFeatures matching the structural features of the realized Interfaces. For example, alternative strategies may require that the realizing Classes provide “get” and “set” Operations matching the StructuralFeatures of the realized Interfaces.

Generalizations

- CS_StructuralFeatureOfInterfaceAccessStrategy (from CompositeStructuresSyntaxAndSemantics::Semantics::CommonBehaviors::Communications)

Attributes

- None

Associations

- None

Operations

```
[1] public read(cs_Object:CS_Object, feature:StructuralFeature) : FeatureValue
        // returns a copy of the first feature value of cs_Object where the name
        // of the corresponding feature matches the name of the feature given as a parameter
        // Otherwise, returns an empty feature value
        FeatureValueList featureValues = cs_Object.featureValues ;
        FeatureValue matchingFeatureValue = null ;
        for (int i = 0 ; i < featureValues.size() && matchingFeatureValue == null ; i++) {
                FeatureValue featureValue = featureValues.getValue(i) ;
                if (featureValue.feature.name.equals(feature.name)) {
                matchingFeatureValue = featureValue ;
                }
        }
        if (matchingFeatureValue != null) {
                matchingFeatureValue = matchingFeatureValue.copy() ;
                matchingFeatureValue.feature = feature ;
        }
        else {
                matchingFeatureValue = new FeatureValue() ;
                matchingFeatureValue.feature = feature ;
                matchingFeatureValue.values = new ValueList() ;
                matchingFeatureValue.position = 0 ;
        }

        return matchingFeatureValue ;

[2] public write(cs_Object:CS_Object, feature:StructuralFeature, values:Value[*],
position:Integer)
        // Retrieves the first feature value of cs_Object where the name of the corresponding
feature
        // matches the name of the feature given as a parameter
```

```
// Then updates the values for this feature value
FeatureValueList featureValues = cs_Object.featureValues ;
FeatureValue matchingFeatureValue = null ;
for (int i = 0 ; i < featureValues.size() && matchingFeatureValue == null ; i++) {
        FeatureValue featureValue = featureValues.getValue(i) ;
        if (featureValue.feature.name.equals(feature.name)) {
                matchingFeatureValue = featureValue ;
        }
}
if (matchingFeatureValue != null) {
        cs_Object.setFeatureValue(matchingFeatureValue.feature, values, position) ;
}
```

8.4.1.2.3 CS_StructuralFeatureOfInterfaceAccessStrategy

CS_StructuralFeatureOfInterfaceAccessStrategy is a new semantic strategy. It deals with reading and writing of structural features of an Interface, specifying how these features are actually realized by a given behaviored classifier. It is involved in the case where a WriteStructuralFeatureAction (or, more precisely, its concrete descendant metaclasses) or ReadStructuralFeatureValueAction concerns a StructuralFeature which belongs to an Interface. It is effectively used by CS_Object (cf. 8.5.2.2.4, operations getFeatureValue and setFeatureValue). This specification provides a default realization for this strategy: CS_NameBased_StructuralFeatureOfInterfaceAccessStrategy,

Generalizations

- SemanticStrategy (from fUML::Semantics::Loci::LociL1)

Attributes

- None

Associations

- None

Operations

```
[1] public getName() : String
        // StructuralFeatureAccessStrategy are always named "structuralFeature"
        return "structuralFeature";

[2] public abstract read(cs_Object:CS_Object, feature:StructuralFeature) : FeatureValue

[3] public abstract write(cs_Object:CS_Object, feature:StructuralFeature, values:Value[*],
position:Integer)
```

8.5 CompositeStructures

8.5.1 InvocationActions

8.5.1.1 Overview

Extensions introduced by InvocationActions mostly deal with semantics of invocation actions, when executed in the context of composite structures. These extensions are depicted in Figure 16.

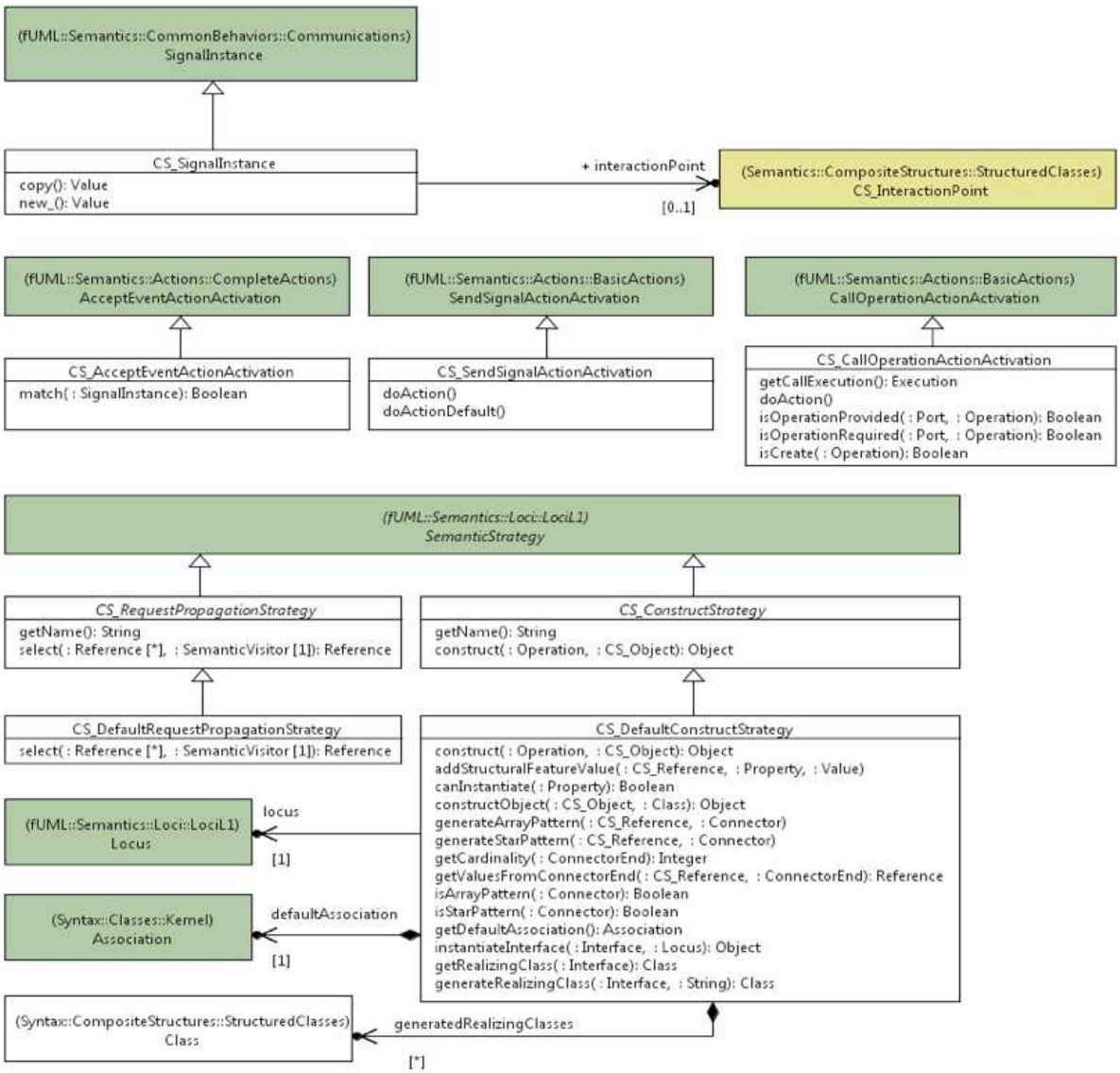


Figure 16: InvocationActions diagram

8.5.1.2 Class descriptions

8.5.1.2.1 CS_AcceptEventActionActivation

FUML semantics are extended to account for the fact that a signal instance can be received on a specific port. For a signal instance to match with a trigger of the AcceptEventAction, fUML requires that the type of the signal instance matches the Signal of the trigger. In addition, if the trigger specifies a list of Ports, the signal instance matches the trigger only if it occurred on a port identified in the list (cf. 8.5.1.2.8, CS_SignalInstance, property interactionPoint).

Generalizations

- AcceptEventActionActivation (from fUML::Semantics::Actions::CompleteActions)

Attributes

- None

Associations

- None

Operations

```
[1] public match(signalInstance:SignalInstance) : Boolean
        // Return true if the given signal instance matches a trigger of the accept
        // event action of this activation.
        // Matching implies that the type of the signalInstance matches the Signal
        // of one of the triggers.
        // When the type matches with the Signal, and if the trigger specifies a
        // list of ports,
        // the signalInstance matches the trigger only if it occurred on a port
        // identified in the list.

        AcceptEventAction action = (AcceptEventAction)(this.node) ;
        TriggerList triggers = action.trigger ;
        Signal signal = signalInstance.type ;

        Boolean matches = false;
        Integer i = 1;
        while (!matches & i <= triggers.size()) {
                Trigger t = triggers.getValue(i-1) ;
                matches = ((SignalEvent)t.event).signal == signal ;
                if (matches && t.port.size()>0 ) {
                PortList portsOfTrigger = t.port ;
                Port onPort =
                        ((CS_SignalInstance)signalInstance).interactionPoint.definingPort ;
                Boolean portMatches = false ;
                Integer j = 1 ;
                while (! portMatches & j <= portsOfTrigger.size() ) {
                        portMatches = onPort == portsOfTrigger.getValue(j-1) ;
                        j = j + 1 ;
                }
                matches = portMatches ;
                }
                i = i + 1;
        }

        return matches;
```

8.5.1.2.2 CS_CallOperationActionActivation

FUML semantics are extended from two aspects. The first aspects accounts for property onPort of the CallOperationAction. If onPort is not specified, fUML semantics are unchanged. If onPort is specified, instead of dispatching directly to the target reference by calling operation dispatch (as in fUML):

- If the invoked BehavioralFeature is on a provided Interface but not on any required Interface, then, when the InvocationAction is executed, the invocation is made into the object given on the target InputPin through the given Port

- If the invoked BehavioralFeature is on a required Interface but not on any provided Interface, then, if the InvocationAction is being executed inside the object given on the target InputPin, the invocation is forwarded out of the target object through the given Port.

- If the invoked BehavioralFeature is on both a provided and a required Interface, then, if the InvocationAction is being executed inside the object given on the target InputPin, the invocation is made out of the target object through the given Port.

Otherwise the invocation is made into the target object through the given Port.

The second aspects deals with instantiation semantics of composite structures. If the CallOperationAction concerns a constructor (i.e., the Operation has stereotype «Create» applied) and if this Operation has no method,

the construction strategy registered at the execution locus (cf. 8.5.1.2.3, CS_ConstructStrategy) is executed to construct the target Object.

Generalizations

- CallOperationActionActivation (from fUML::Semantics::Actions::BasicActions)

Attributes

- None

Associations

- None

Operations

```
[1] public getCallExecution() : Execution
  // If onPort is not specified, behaves like in fUML
  // If onPort is specified, and if the value on the target input pin is a
  // reference, dispatch the operation
  // to it and return the resulting execution object.
  // As compared to fUML, instead of dispatching directly to target reference
  // by calling operation dispatch:
  // - If the invoked BehavioralFeature is on a provided Interface but not on any required
Interface,
  // then, when the InvocationAction is executed, the invocation is made into the object given
on
  // the target InputPin through the given Port
  // - If the invoked BehavioralFeature is on a required Interface but not on any provided
Interface,
  // then, if the InvocationAction is being executed inside the object given on the target
InputPin,
  // the invocation is forwarded out of the target object through the given Port.
  // - If the invoked BehavioralFeature is on both a provided and a required Interface,
  // then, if the InvocationAction is being executed inside the object given on the target
InputPin,
  // the invocation is made out of the target object through the given Port.
  // Otherwise the invocation is made into the target object through the given Port.
  CallOperationAction action = (CallOperationAction)(this.node);
  Execution execution = null ;
  if (action.onPort == null ) {
    execution = super.getCallExecution() ;
  }
  else {
    Value target = this.takeTokens(action.target).get(0);
    if (target instanceof CS_Reference) {
      // Tries to determine if the operation call has to be
      // dispatched to the environment or to the internals of
      // target, through onPort
      CS_Reference targetReference = (CS_Reference)target ;
      Object_ executionContext = this.group.activityExecution.context ;
      boolean operationIsOnProvidedInterface =
        this.isOperationProvided(action.onPort, action.operation) ;
      boolean operationIsOnRequiredInterface =
        this.isOperationRequired(action.onPort, action.operation) ;
      // Operation on a provided interface only
      if (operationIsOnProvidedInterface && !operationIsOnRequiredInterface) {
        execution = targetReference.dispatchIn(action.operation, action.onPort);
      }
      // Operation is on a required interface only
      else if (!operationIsOnProvidedInterface && operationIsOnRequiredInterface){
        // If not executing in the context of the target,
        // Semantics are undefined.
        // Otherwise, dispatch outside.
        if (executionContext == targetReference.referent ||
               targetReference.compositeReferent.contains(executionContext)) {
          execution = targetReference.dispatchOut(action.operation, action.onPort);
        }
```

```
      }
      // Operation is both on a provided and a required interface
      else if (operationIsOnProvidedInterface && operationIsOnRequiredInterface) {
        if (executionContext == targetReference.referent ||
              targetReference.compositeReferent.contains(executionContext)) {
          execution = targetReference.dispatchOut(action.operation, action.onPort);
        }
        else {
          execution = targetReference.dispatchIn(action.operation, action.onPort);
        }
      }
    }
  }
  return execution;

[2] public doAction()
  CallOperationAction action = (CallOperationAction)(this.node);
  // First determines if this is a call to a constructor and if a default
  // construction strategy needs to be applied.
  // This is a call to a constructor if the called operation has
  // stereotype <<Create>> applied.
  // The default construction strategy is used if no method is associated with the
  // <<Create>> operation.
  // Otherwise, behaves like in fUML.
  if (action.onPort == null && this.isCreate(action.operation)
      && action.operation.method.size() == 0) {
    Locus locus = this.getExecutionLocus() ;
    CS_ConstructStrategy strategy = ((CS_ConstructStrategy)locus.
                                     factory.getStrategy("constructStrategy")) ;
    Value target = this.takeTokens(action.target).get(0);
    if (target instanceof CS_Reference) {
      strategy.construct(action.operation, ((CS_Reference)target).compositeReferent) ;
      ParameterList parameters = action.operation.ownedParameter ;
      OutputPinList resultPins = action.result ;
      ValueList values = new ValueList() ;
      values.add(target) ;
      int i = 1 ;
      while(i <= parameters.size()) {
        Parameter parameter = parameters.get(i - 1);
        if(parameter.direction == ParameterDirectionKind.return_) {
          OutputPin resultPin = resultPins.get(0);
          this.putTokens(resultPin, values);
        }
        i = i + 1;
      }
    }
  }
  else {
    super.doAction();
  }

[3] public isOperationProvided()
  boolean isProvided = false ;
  if (operation.owner instanceof Interface) {
    // We have to look in provided interfaces of the port if
    // they define directly or indirectly the Operation
    Integer interfaceIndex = 1 ;
    // Iterates on provided interfaces of the port
    InterfaceList providedInterfaces = port.provided ;
    while (interfaceIndex <= providedInterfaces.size() && !isProvided) {
      Interface interface_ = providedInterfaces.get(interfaceIndex-1) ;
      // Iterates on members of the current Interface
      Integer memberIndex = 1 ;
      while (memberIndex <= interface_.member.size() && !isProvided) {
        NamedElement cddOperation = interface_.member.get(memberIndex-1) ;
        if (cddOperation instanceof Operation) {
          isProvided = operation == cddOperation ;
        }
        memberIndex = memberIndex + 1 ;
      }
      interfaceIndex = interfaceIndex + 1 ;
```

```
    }
  }
  return isProvided ;

[4] public isOperationProvided()
  boolean isRequired = false ;
  Integer interfaceIndex = 1 ;
  // Iterates on provided interfaces of the port
  InterfaceList requiredInterfaces = port.required ;
  while (interfaceIndex <= requiredInterfaces.size() && !isRequired) {
    Interface interface_ = requiredInterfaces.get(interfaceIndex-1) ;
    // Iterates on members of the current Interface
    Integer memberIndex = 1 ;
    while (memberIndex <= interface_.member.size() && !isRequired) {
      NamedElement cddOperation = interface_.member.get(memberIndex-1) ;
      if (cddOperation instanceof Operation) {
        isRequired = operation == cddOperation ;
      }
      memberIndex = memberIndex + 1 ;
    }
    interfaceIndex = interfaceIndex + 1 ;
  }
  return isRequired ;
[5] public isCreate()
  CS_ExecutionFactory executionFactory = (CS_ExecutionFactory)this.getExecutionLocus().factory
;
  Class_ stereotypeCreate = executionFactory.getStereotypeClass("StandardProfile", "Create") ;
  if (stereotypeCreate == null) {
    // standard profile is not applied
    return false ;
  }
  return executionFactory.getStereotypeApplication(stereotypeCreate, o) != null ;
```

8.5.1.2.3 CS_ConstructStrategy

CS_ConstructStrategy is a new semantic strategy. It deals with instantiation semantics of composite structures. The context in which this strategy is involved is described in 8.5.1.2.2, CS_CallOperationActionActivation. This specification defines a default realization for this strategy: CS_DefaultConstructStrategy.

Generalizations

- SemanticStrategy (from fUML::Semantics::Loci::LociL1::SemanticStrategy)

Attributes

- None

Associations

- None

Operations

```
[1] public getName() : String
  // a CS_ConstructionStrategy is always named "constructStrategy"
  return "constructStrategy";

[2] public abstract construct(constructor:Operation, context:CS_Object) : Object
```

8.5.1.2.4 CS_DefaultConstructStrategy

CS_DefaultConstructStrategy is the default realization provided by this specification for semantic strategy CS_ConstructStrategy. This strategy deals with instantiation of composite structures as follows:

- **Instantiation of parts and ports:** Parts (i.e., composite Properties) are instantiated according to their

multiplicity lower bound. The same rule applies for Ports. It means that, if the lower bound of parts is 0, the topology resulting from the instantiation of a composite structure is empty. This case is illustrated in Figure 17. Instantiation of a value for a Port results in the creation of a CS_InteractionPoint, which itself refer to a CS_Object typed by the type of the Port. If the Port is typed by an Interface, the CS_Object is typed by a Class which realizes this Interface. This Class is dynamically generated, following rules defined in Operation getRealizingClass specified below.

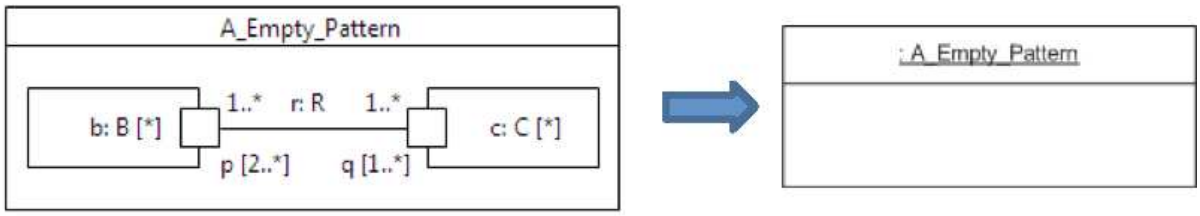


Figure 17: Instantiation of a composite structure resulting in an empty topology

- **Instantiation of connectors:** Instantiation of Connectors occurs only for binary Connectors. The number of Connectors to be instantiated depends on the multiplicity lower bound of their ConnectorEnds, as well as on the number of parts/ports (identified by these ends) that have been instantiated according to rules previously mentioned. It means that, if no parts/ports have been instantiated, the instantiation of connectors will not occur, as illustrated in Figure 17. It also means that, if the lower bound on ends of a Connector is 0, the instantiation will not occur as well. This case is illustrated in Figure 18. Instantiation of a Connector results in the creation of a CS_Link. This link is typed by the type of the Connector, which is an Association. If the Connector is not typed, the created link is typed by an Association which is dynamically generated, following rules defined in Operation getDefaultAssociation specified below. The elements which act as values for the parts/ports identified by the ConnectorEnds also act as values for the ends of the created CS_Link (i.e., FeatureValues corresponding to the Association ends).

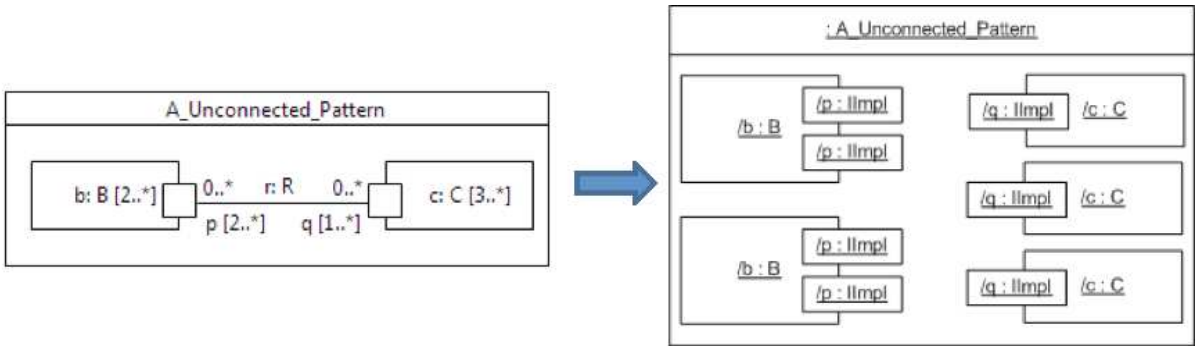


Figure 18: Instantiation of a composite structure resulting in an unconnected topology

It is not always possible to unambiguously compute the topology of links that results from the instantiation of a composite structure. The two cases supported by this default strategy are the Array topology and the Star topology. The Array topology is the result of a situation where: the multipilicity lower bound of ConnectorEnds is 1, and the number of elements identified by each ConnectorEnd is the same for all the ConnectorEnds of the Connector. The number of ends identified by a ConnectorEnd is computed by multiplying the multipilicity lower bound of the ConnectorEnd::role by the multiplicity lower bound of the ConnectorEnd::partWithPort. If the ConnectorEnd has no partWithPort, the number of ends it identifies is simply the multiplicity lower bound of its role. An example of Array topology is illustrated in Figure 19.

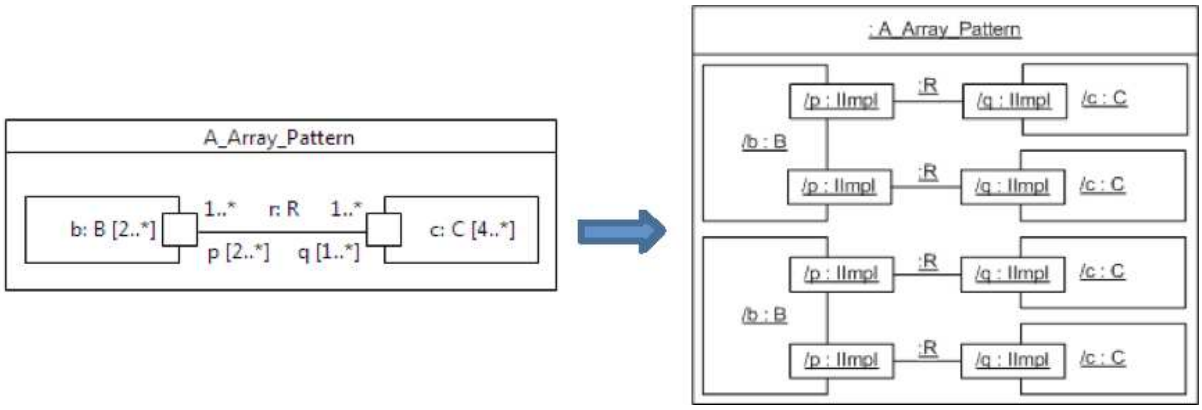


Figure 19: Instantiation of a composite structure resulting in an Array topology

The Star topology is the result of a situation where the multiplicity lower bound of each ConnectorEnd is equal to the number of ends it identifies. An example of Star topology is illustrated in Figure 20. For other combinations of part/port/connector end multiplicity lower bound, this default strategy does not instantiate any link.

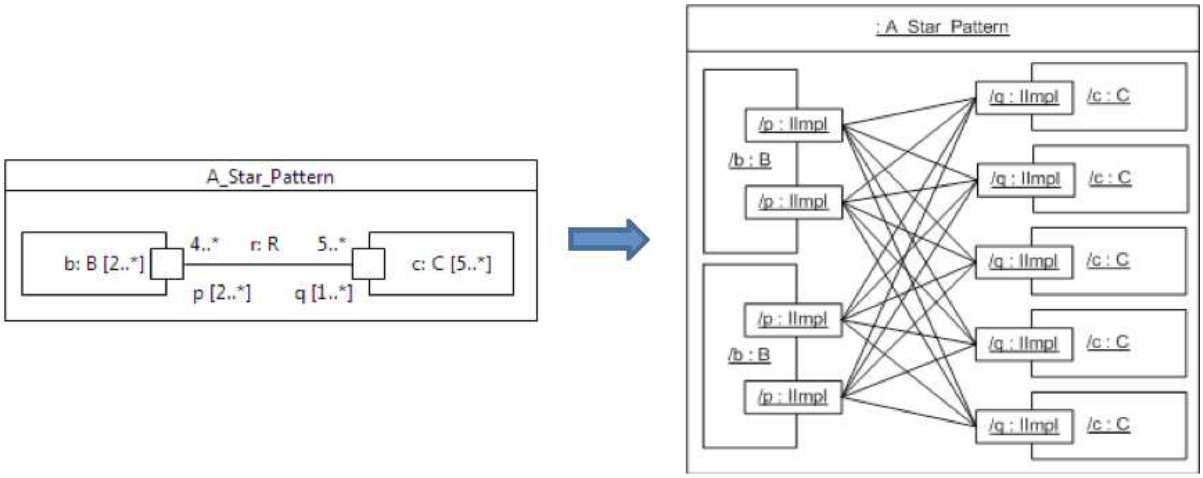


Figure 20: Instantiation of a composite structure resulting in a Star topology

- **Assignment of default values**: If a default value is specified for a part, this construction strategy evaluates the ValueSpecification, and assigns the result of the evaluation to the value of this part.

Generalizations

- CS_ConstructStrategy (from CompositeStructuresSyntaxAndSemantics::Semantics::CompositeStructures::InvocationActions)

Attributes

- None

Associations

- defaultAssociation : Association [0..1], the Association used to type CS_Links derived from untyped Connectors. This Association is generated once and reused for all CS_Links derived from untyped Connectors.
- generatedRealizingClasses : Class [*], the set of Classes generated to type Port objects, in the case of Ports typed by Interfaces.
- locus : Locus [1], the locus in which elements will be instantiated. It is obtained from a context

CS_Object, which is passed as an argument to operation construct.

Operations

```
[1] public addStructuralFeatureValue(context:CS_Reference, feature:Property, value:Value)
        FeatureValue featureValue = context.getFeatureValue(feature) ;
        if (featureValue != null) {
                ValueList values = featureValue.values ;
                if (feature instanceof Port) {
                        // insert an interaction point
                        CS_InteractionPoint interactionPoint = new CS_InteractionPoint() ;
                        interactionPoint.definingPort = (Port)feature ;
                        interactionPoint.referent = (CS_Object)value ;
                        interactionPoint.owner = context ;
                        values.add(interactionPoint) ;
                }
                else if (value instanceof CS_Object) {
                        // insert a reference
                        CS_Reference reference = new CS_Reference() ;
                        reference.compositeReferent = (CS_Object)value ;
                        reference.referent = (CS_Object)value ;
                        values.add(reference) ;
                }
                else {
                        values.add(value) ;
                }
        }

[2] public canInstantiate(p:Property) : Boolean
        // Instantiate is possible if:
        // - p is composite
        // - p is typed
        // - This type is a Class and it is not abstract
        // - Or p is a Port and the type is an Interface
        if (p.isComposite) {
                if (p.typedElement.type != null) {
                        if (p.typedElement.type instanceof Class_) {
                                return ! ((Class_)p.typedElement.type).isAbstract ;
                        }
                }
                else if (p.typedElement.type instanceof Interface) {
                        return p instanceof Port ;
                }
        }
        return false ;

[3] public construct(constructor:Operation, context:CS_Object) : Object
        this.locus = context.locus ;
        return this.constructObject(context, (Class_)constructor.type) ;

[4] public constructObject(context:CS_Object, type:Class) : Object
  CS_Reference referenceToContext = new CS_Reference() ;
  referenceToContext.referent = context ;
  referenceToContext.compositeReferent = (CS_Object)context ;
  // FIXME detect infinite recursive instantiation
  PropertyList allAttributes = type.attribute ;
  int i = 1 ;
  // Instantiate ports and parts
  while (i <= allAttributes.size()) {
    Property p = allAttributes.get(i - 1) ;
    if (p.default_ != null) {
      ValueSpecification defaultValueSpecification = p.default_ ;
      Evaluation evaluation =
                (Evaluation)context.locus.factory.instantiateVisitor(defaultValueSpecification)
;
      evaluation.specification = defaultValueSpecification ;
      evaluation.locus = context.locus ;
      if (evaluation instanceof CS_OpaqueExpressionEvaluation) {
        ValueList evaluations =
                ((CS_OpaqueExpressionEvaluation)evaluation).executeExpressionBehavior() ;
```

```
        for (int j = 0 ; j < evaluations.size() ; j++) {
          this.addStructuralFeatureValue(referenceToContext, p, evaluations.get(j)) ;
        }
      }
      else {
        Value defaultValue = evaluation.evaluate() ;
        this.addStructuralFeatureValue(referenceToContext, p, defaultValue) ;
      }
    }
    else if (this.canInstantiate(p)) {
      int j = 1 ;
      while (j <= p.multiplicityElement.lower) {
        Object_ value ;
        // if p is a Port typed by an Interface
        // creates an Object without type, but with FeatureValues corresponding to
        // structural features of the interface.
        if (p instanceof Port && p.typedElement.type instanceof Interface) {
          value = this.instantiateInterface((Interface)p.typedElement.type, this.locus) ;
          this.addStructuralFeatureValue(referenceToContext, p, value);
        }
        else {
          value = context.locus.instantiate((Class_)p.typedElement.type) ;
          // TODO account for existing constructors
          value = this.constructObject((CS_Object)value, (Class_)p.typedElement.type) ;
          this.addStructuralFeatureValue(referenceToContext, p, (CS_Object)value) ;
          if (((Class_)p.typedElement.type).isActive) {
            value.startBehavior((Class_)p.typedElement.type, new ParameterValueList()) ;
          }
        }
        j = j + 1 ;
      }
    }
    i = i + 1 ;
  }
  // Instantiate connectors
  NamedElementList allMembers = type.member ;
  i = 1 ;
  while (i <= allMembers.size()) {
    NamedElement member = allMembers.get(i - 1) ;
    if (member instanceof Connector) {
      Connector connector = (Connector)member ;
      if (this.isArrayPattern(connector)) {
        this.generateArrayPattern(referenceToContext, connector) ;
      }
      else if (this.isStarPattern(connector)) {
        this.generateStarPattern(referenceToContext, connector) ;
      }
    }
    i = i + 1 ;
  }
  return referenceToContext.referent ;

[5] public generateArrayPattern(context:CS_Reference, connector:Connector)
       ConnectorEnd end1 = connector.end.getValue(0) ;
       ConnectorEnd end2 = connector.end.getValue(1) ;
       ReferenceList end1Values = this.getValuesFromConnectorEnd(context, end1) ;
       ReferenceList end2Values = this.getValuesFromConnectorEnd(context, end2) ;
       for (int i = 0 ; i < end1Values.size() ; i++) {
              CS_Link link = new CS_Link() ;
              if (connector.type == null) {
                     link.type = this.getDefaultAssociation() ;
              }
              else {
                     link.type = connector.type ;
              }
              ValueList valuesForEnd1 = new ValueList() ;
              valuesForEnd1.add(end1Values.get(i)) ;
              ValueList valuesForEnd2 = new ValueList() ;
              valuesForEnd2.add(end2Values.get(i)) ;
              link.setFeatureValue(link.type.ownedEnd.getValue(0), valuesForEnd1, -1) ;
              link.setFeatureValue(link.type.ownedEnd.getValue(1), valuesForEnd2, -1) ;
```

```
                link.addTo(context.referent.locus) ;
        }

[6] public generateRealizingClass(interface_:Interface, className:String) : Class
        Class_ realizingClass = new Class_() ;
        realizingClass.setName(className) ;
        InterfaceRealization realization = new InterfaceRealization() ;
        realization.contract = interface_ ;
        realization.implementingClassifier = realizingClass ;
        realizingClass.interfaceRealization.addValue(realization);
        // TODO Deal with structural features of the interface
        // TODO Make a test case for reading/writing structural features of an interface
        return realizingClass ;

[7] public generateStarPattern(context:CS_Reference, connector:Connector)
        ConnectorEnd end1 = connector.getEnds().get(0) ;
        ConnectorEnd end2 = connector.getEnds().get(1) ;
        List<Reference> end1Values = this.getValuesFromConnectorEnd(context, end1) ;
        List<Reference> end2Values = this.getValuesFromConnectorEnd(context, end2) ;
        for (int i = 0 ; i < end1Values.size() ; i++) {
                for (int j = 0 ; j < end2Values.size(); j++) {
                        CS_Link link = new CS_Link() ;
                        if (connector.type == null) {
                                link.type = this.getDefaultAssociation() ;
                        }
                        else {
                                link.type = connector.type ;
                        }
                        List<Value> valuesForEnd1 = new ArrayList<Value>() ;
                        valuesForEnd1.add(end1Values.get(i)) ;
                        List<Value> valuesForEnd2 = new ArrayList<Value>() ;
                        valuesForEnd2.add(end2Values.get(j)) ;
                        link.setFeatureValue(link.type.getOwnedEnds().get(0), valuesForEnd1, -
1) ;
                        link.setFeatureValue(link.type.getOwnedEnds().get(1), valuesForEnd2, -
1) ;
                        link.addTo(context.referent.locus) ;
                }
        }

[8] public getCardinality(end:ConnectorEnd) : Integer
        int lowerOfRole = end.role.actualConnectableElement.multiplicityElement.lower ;
        if (lowerOfRole == 0) {
                return 0 ;
        }
        else if (end.partWithPort == null) {
                return lowerOfRole ;
        }
        else {
                int lowerOfPart = end.partWithPort.multiplicityElement.lower ;
                return lowerOfRole * lowerOfPart ;
        }

[9] public getDefaultAssociation() : Association
        // Computes an returns an Association with two untyped owned ends,
        // with multiplicity [*].
        // This association can be used to type links instantiated from untyped connectors
        if (defaultAssociation == null) {
          defaultAssociation = new Association() ;
          defaultAssociation.name = "DefaultGeneratedAssociation";
          Property end1 = new Property() ;
          end1.setName("x"); ;
          end1.setLower(0);
          end1.setUpper(-1);
          end1.setIsOrdered(true);
          end1.setIsUnique(true);
          defaultAssociation.addOwnedEnd(end1);
          Property end2 = new Property() ;
          end2.setName("y");
          end2.setLower(0);
          end2.setUpper(-1);
```

```
          end2.setIsOrdered(true);
          end2.setIsUnique(true);
          defaultAssociation.addOwnedEnd(end2);
        }
        return defaultAssociation ;

[10] public getRealizingClass(interface_:Interface) : Class
        Class_ realizingClass = null ;
        // TODO For cached RealizingClasses, search based on InterfaceRealizations rather than
name
        String realizingClassName = interface_.qualifiedName + "GeneratedRealizingClass" ;
        int i = 1 ;
        while (i <= generatedRealizingClasses.size() && realizingClass == null) {
          Class_ cddRealizingClass = generatedRealizingClasses.getValue(i - 1) ;
          if (cddRealizingClass.name.equals(realizingClassName)) {
            realizingClass = cddRealizingClass ;
          }
          i = i + 1 ;
        }
        if (realizingClass == null) {
          realizingClass = this.generateRealizingClass(interface_, realizingClassName) ;
          generatedRealizingClasses.addValue(realizingClass) ;
        }
        return realizingClass ;

[11] public getValuesFromConnectorEnd(context:CS_Reference, end:ConnectorEnd) : Value[*]
  ReferenceList endValues = new ReferenceList() ;
  if (end.partWithPort != null) {
    FeatureValue valueForPart = context.getFeatureValue(end.partWithPort) ;
    if (valueForPart != null) {
      for (int i = 0 ; i < valueForPart.values.size() ; i++) {
        Reference reference = (Reference)valueForPart.values.get(i) ;
        FeatureValue valueForPort =
                      reference.getFeatureValue((Port)end.role.actualConnectableElement) ;
        if (valueForPort != null) {
          for (int j = 0 ; j < valueForPort.values.size() ; j++) {
            endValues.add((Reference)valueForPort.values.get(j)) ;
          }
        }
      }
    }
  }
  else {
    FeatureValue valueForRole=
context.getFeatureValue((Property)end.role.actualConnectableElement) ;
    if (valueForRole != null) {
      for (int i = 0 ; i < valueForRole.values.size() ; i++) {
        endValues.add((Reference)valueForRole.values.get(i)) ;
      }
    }
  }
  return endValues ;

[12] public instantiateInterface(interface_:Interface, locus:Locus) : Object
        Class_ realizingClass = this.getRealizingClass(interface_) ;
        Object_ object = locus.instantiate(realizingClass) ;
        return object ;

[13] public isArrayPattern(c:Connector) : Boolean
  // This is an array pattern if:
  // - c is typed by an association FIXME this may no longer be required in UML 2.5
  // - c is binary
  // - lower bound of the two connector ends is 1
  // - Cardinality of ends are equals
  if (c.end.size() == 2) {
    if (c.end.get(0).role.actualConnectableElement.multiplicityElement.lower == 1) {
      if (c.end.get(1).role.actualConnectableElement.multiplicityElement.lower == 1) {
        if (this.canInstantiate(c.end.get(0).role.actualConnectableElement) &&
            this.canInstantiate(c.end.get(1).role.actualConnectableElement)) {
          int cardinality1 = this.getCardinality(c.end.get(0)) ;
          int cardinality2 = this.getCardinality(c.end.get(1)) ;
```

```
          return cardinality1 == cardinality2 ;
        }
      }
    }
  }
  return false ;

[14] public isStarPattern(c:Connector) : Boolean
  // This is a star pattern if:
  // - c is binary
  // - lower bound of end1 equals cardinality of end1
  // - lower bound of end2 equals cardinality of end2
  if (c.end.size() == 2) {
    if (this.canInstantiate(c.end.get(0).role.actualConnectableElement) &&
        this.canInstantiate(c.end.get(1).role.actualConnectableElement)) {
      int cardinalityOfEnd1 = this.getCardinality(c.end.get(0)) ;
      int lowerBoundofEnd1 =
c.end.get(0).role.actualConnectableElement.multiplicityElement.lower ;
      if (cardinalityOfEnd1 == lowerBoundofEnd1) {
        int cardinalityOfEnd2 = this.getCardinality(c.end.get(1)) ;
        int lowerBoundofEnd2 =
c.end.get(1).role.actualConnectableElement.multiplicityElement.lower ;
        return cardinalityOfEnd2 == lowerBoundofEnd2 ;
      }
    }
  }
  return false ;
```

8.5.1.2.5 CS_DefaultRequestPropagationStrategy

CS_DefaultRequestPropagationStrategy is the default realization provided by this specification for semantic strategy CS_RequestPropagationStrategy. If the request concerns the emission of a Signal and there are multiple possible targets, the signal is broadcasted to all the targets. If the request concerns an Operation call and there are multiple possible targets, the call is propagated to the first target.

Generalizations

- CS_RequestPropagationStrategy (from CompositeStructuresSyntaxAndSemantics::Semantics::CompositeStructures::InvocationActions)

Attributes

- None

Associations

- None

Operations

```
[1] public select(potentialTargets:Reference[*], context:SemanticVisitor) : Reference[*]
       // returns all potential targets in the case where the context is a
SendSignalActionActivation
       // returns the first potential target in the case where the context is anything else
       ReferenceList selectedTargets = new ReferenceList() ;
       if (context instanceof SendSignalActionActivation) {
              for (int i = 0 ; i < potentialTargets.size() ; i++) {
                selectedTargets.addValue(potentialTargets.getValue(i)) ;
              }
       }
       else {
              if (potentialTargets.size() >= 1) {
                selectedTargets.addValue(potentialTargets.get(0)) ;
              }
       }
       return selectedTargets;
```

8.5.1.2.6 CS_RequestPropagationStrategy

CS_RequestPropagationStrategy is a semantic strategy which deals with propagation of requests in the case where multiple possible propagation paths exist (e.g., multiple interaction points, multiple links. An example of such a situation is depicted in Figure 20). Its purpose is to select, among a list of potential targets, the actual targets to which the request will be propagated. It is used by the various send and dispatch operations provided by class CS_Object. In this specification, the default realization for this strategy is CS_DefaultRequestPropagationStrategy.

Generalizations

- SemanticStrategy (from fUML::Semantics::Loci::LociL1)

Attributes

- None

Associations

- None

Operations

```
[1] public getName() : String
        // a CS_RequestPropagationStrategy are always named "requestPropagation"
        return "requestPropagation";

[2] public abstract select(potentialTargets:Reference[*], context:SemanticVisitor) :
Reference[*]
```

8.5.1.2.7 CS_SendSignalActionActivation

FUML semantics are extended to account for property onPort of the SendSignalAction. If onPort is not specified, fUML semantics are unchanged. If onPort is specified, instead of sending directly to the target reference by calling operation send (as in fUML):

- If the SendSignalAction is being executed inside the object given on the target InputPin, the invocation is made out of the target object through the given Port.

- Otherwise, the invocation is made into the target object through the given Port.

Generalizations

- SendSignalActionActivation (from fUML::Semantics::Actions::BasicActions)

Attributes

- None

Associations

- None

Operations

```
[1] public doAction()
  // If onPort is not specified, behaves like in fUML
  // If onPort is specified,
  // Get the value from the target pin. If the value is not a reference,
  // then do nothing.
  // Otherwise, construct a signal using the values from the argument pins
  // As compared to fUML, instead of sending directly to target reference
```

```
  // by calling operation send:
  // - If the InvocationAction is being executed inside the object given
  // on the target InputPin, the invocation is made out of the target object
  // through the given Port.
  // - Otherwise the invocation is made into the target object through the
  // given Port.
  SendSignalAction action = (SendSignalAction)(this.node);
  if (action.onPort == null) {
    // Behaves like in fUML
    this.doActionDefault() ;
  }
  else {
    Value target = this.takeTokens(action.target).get(0) ;
    if (target instanceof CS_Reference) {
      // Constructs the signal instance
      Signal signal = action.signal;
      CS_SignalInstance signalInstance = new CS_SignalInstance();
      signalInstance.type = signal;
      PropertyList attributes = signal.ownedAttribute ;
      InputPinList argumentPins = action.argument ;
      Integer i = 0 ;
      while ( i < attributes.size()) {
        Property attribute = attributes.get(i);
        InputPin argumentPin = argumentPins.get(i);
        ValueList values = this.takeTokens(argumentPin);
        signalInstance.setFeatureValue(attribute, values, 0);
        i = i + 1 ;
      }
      // Tries to determine if the signal has to be
      // sent to the environment or to the internals of
      // target, through onPort
      CS_Reference targetReference = (CS_Reference)target ;
      Object_ executionContext = this.group.activityExecution.context ;
      if (executionContext == targetReference.referent ||
           targetReference.compositeReferent.contains(executionContext)) {
        targetReference.sendOut(signalInstance, action.onPort);
      }
      else {
        targetReference.sendIn(signalInstance, action.onPort);
      }
    }
  }

[2] public doActionDefault()
        // Get the value from the target pin. If the value is not a reference,
        // then do nothing.
        // Otherwise, construct a signal using the values from the argument pins
        // and send it to the referent object.
        // This operation captures same semantics as fUML
        // SendSignalActionActivation.doAction() except that it constructs
        // a CS_SignalInstance instead of a SignalInstance

        SendSignalAction action = (SendSignalAction) (this.node);
        Value target = this.takeTokens(action.target).getValue(0);

        if (target instanceof Reference) {
                Signal signal = action.signal;

                CS_SignalInstance signalInstance = new CS_SignalInstance();
                signalInstance.type = signal;

                PropertyList attributes = signal.ownedAttribute;
                InputPinList argumentPins = action.argument;
                for (int i = 0; i < attributes.size(); i++) {
                        Property attribute = attributes.getValue(i);
                        InputPin argumentPin = argumentPins.getValue(i);
                        ValueList values = this.takeTokens(argumentPin);
                        signalInstance.setFeatureValue(attribute, values, 0);
                }

                ((Reference) target).send(signalInstance);
```

```
}
```

8.5.1.2.8 CS_SignalInstance

CS_SignalInstance extends fUML SignalInstance to account for the fact that a signal instance has been received on a specific interaction point (property interactionPoint). This information is used by CS_AcceptEventActionActivationto determine if a signal instance matches one of the triggers of its AcceptEventAction, in the case where those triggers specify a list of ports.

Generalizations

- SignalInstance (from fUML::Semantics::CommonBehaviors::Communications)

Attributes

- None

Associations

- interactionPoint : CS_InteractionPoint[0..1], The InteractionPoint on which this signal instance occurred.

Operations

```
[1] public copy() : Value
        // Create a new signal instance with the same type, interaction point and
        // feature values as this signal instance.
        CS_SignalInstance newValue = (CS_SignalInstance) (super.copy());
        newValue.type = this.type ;
        newValue.interactionPoint = this.interactionPoint ;
        return newValue;

[2] public new_() : Value
        // Create a new signal instance with no type or feature values.
        return new CS_SignalInstance();
```

8.5.2 StructuredClasses

8.5.2.1 Overview

The StructuredClasses package introduces extensions to fUML in order to support the runtime manifestation of parts, ports and connectors. These extensions are depicted in Figure 21.

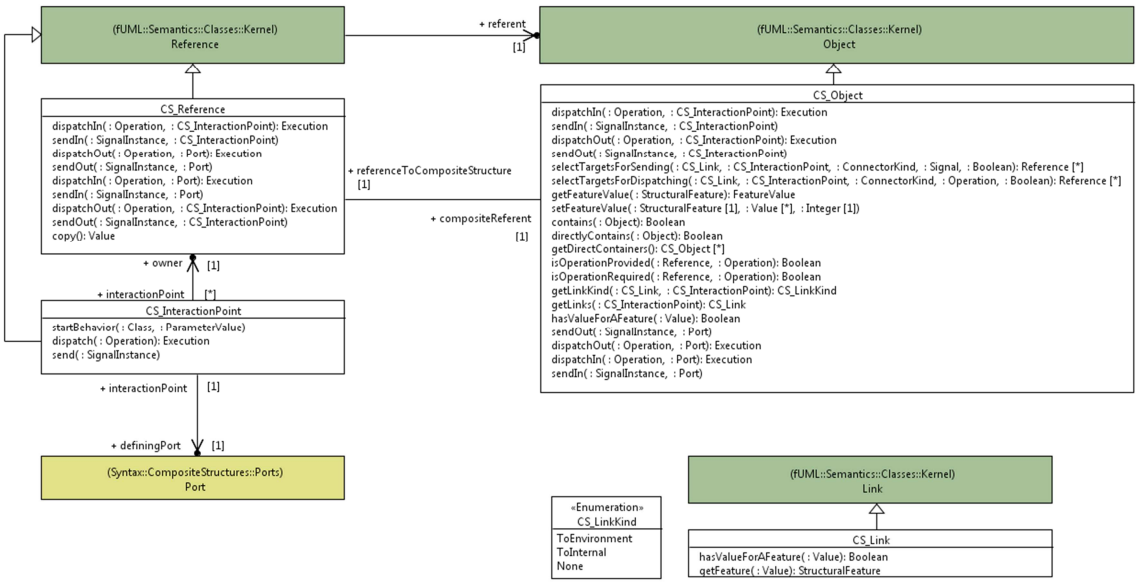


Figure 21: StructuredClasses diagram

8.5.2.2 Class descriptions

8.5.2.2.1 CS_InteractionPoint

CS_InteractionPoint provides support for the runtime manifestation of Ports. It is a Reference to an Object which is a value for a Port, in the context of a CS_Object. Figure 22 illustrates the relationships between CS_Object, CS_Reference, FeatureValue and CS_InteractionPoint, when instantiating a composite structure with a Port typed by a Class.

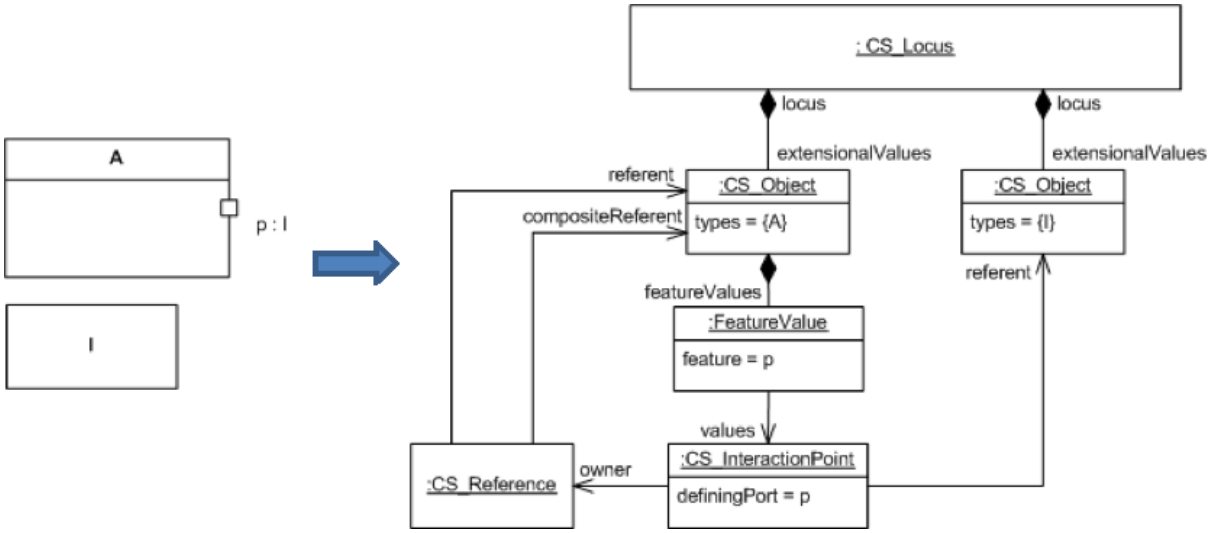


Figure 22: Runtime relationships between CS_Object, CS_Reference, FeatureValue and CS_InteractionPoint resulting from the instantiation of a Composite Structure

Generalizations

- Reference (from fUML::Semantics::Classes::Kernel)

Attributes

- None

Associations

- owner : CS_Reference[1], Represents the reference to the CS_Object owning this CS_InteractionPort.
- definingPort : Port[1], The Port for which this CS_InteractionPoint is a runtime manifestation

Operations

```
[1] public dispatch(operation:Operation) : Execution
       // Delegates dispatching to the owning object
       return this.owner.dispatchIn(operation, this) ;

[2] public send(signalInstance:SignalInstance)
       // Delegates sending to the owning object
       this.owner.sendIn(signalInstance, this) ;

[3] public startBehavior(classifier:Class, inputs:ParameterValue[*])
       // Overridden to do nothing
```

8.5.2.2.2 CS_Link

CS_Link extends fUML Link with helper Operations, used by CS_Objectto determine links through which requests can be propagated. As in fUML, a CS_Link is the runtime manifestation of an Association instance. In this specification, it is also used to represent connector instances, though there is no explicit relationship between CS_Link and Connector. Subclause 8.5.1.2.4(CS_DefaultConstructStrategy) specifies how CS_Links are instantiated from Connectors.

A CS_Link can also be created using a CreateLinkAction. Note that this kind of Action relies on LinkEndData for identifying the actual end objects to be connected. As currently defined in UML, the identification of an end object by a LinkEndData requires the existence of an Association, and has no consideration for Connectors (this is the reason why there is no explicit relationships between CS_Link and Connector). The manual instantiation of a Connector is thereby specified with a CreateLinkAction, where elements to be linked act are values for roles identified by the Connector. If the Connector is typed by an Association, the LinkEndData of the CreateLinkAction relies on this Association. In the case where the Connector is not typed, a generic Association (with untyped ends) can be used to specify the LinkEndData of the CreateLinkAction. Such a generic Association is specified in informative Annex C.

Generalizations

- Link (from fUML::Semantics::Classes::Kernel)

Attributes

- None

Associations

- None

Operations

```
[1] public hasValueForAFeature(value:Value) : Boolean
  // Returns true if the given value object is used as a value for a FeatureValue of this link
  FeatureValueList allFeatureValues = this.getFeatureValues() ;
  Integer i = 1 ;
  boolean isAValue = false ;
  while (i <= allFeatureValues.size() && !isAValue) {
    FeatureValue featureValue = allFeatureValues.getValue(i-1);
    isAValue = !featureValue.values.isEmpty() && featureValue.values.getValue(0).equals(value)
```

```
;
    i = i + 1 ;
  }
  return isAValue ;

[2] public getFeature(value:Value) : StructuralFeature
  FeatureValueList allFeatureValues = this.getFeatureValues() ;
  Integer i = 1 ;
  StructuralFeature feature = null ;
  while (i <= allFeatureValues.size() && feature == null) {
    FeatureValue featureValue = allFeatureValues.get(i-1);
    if (!featureValue.values.isEmpty() && featureValue.values.get(0).equals(value)) {
      feature = featureValue.feature ;
    }
    i = i + 1 ;
  }
  return feature ;
```

8.5.2.2.3 CS_LinkKind

CS_LinkKind is an enumeration that characterizes a CS_Link, in the context of a CS_Object, with respect to a CS_InteractionPoint, if the interaction point belongs to this object, and if it is used as an end of the link. The link kind of a link is determined as follows:

- The links targets the environment of the object (enumeration literal **ToEnvironment**) if all the feature values of the link (but one for the interaction point) refer to values which are not themselves values for features of this object.
- If all the feature values of the link refer to values which are themselves values for features of this object, the link targets the internals of the object (enumeration literal **ToInternal**).
- Otherwise, the link has no particular meaning in the context defined by the object and the interaction point (enumeration literal **None**).

These rules are formalized in 8.5.2.2.4, CS_Object, operation getLinkKind.

Generalizations

- None

Enumeration literals

- ToEnvironment
- ToInternal
- None

8.5.2.2.4 CS_Object

CS_Object extends fUML Object to specify the runtime manifestation of a composite structure. FUML Object owns a single Operation for sending a signal (Operation send) and a single Operation for dispatching an operation call (Operation dispatch), which are used to specify the semantics of SendSignalAction and CallOperationAction, respectively. In fUML, these actions always directly target an Object. With composite structures, these InvocationActions can also be made through ports, with invocations being propagated either to the environment or the internals of the composite structure instance. The rules for determining if an invocation is propagated inside or outside of a composite structure, through a port, are specified in 8.5.1.2.7, CS_SendSignalActionActivation, and 8.5.1.2.2, CS_CallOperationActionActivation.

To support propagation of invocations through ports, either inside or outside of the composite structure instance, CS_Object introduces variants of send and dispatch Operations of fUML Object: sendIn, sendOut, dispatchIn, dispatchOut, which are specified below. Propagation of invocations is made following existing CS_Link, which

represent connector instances between CS_InteractionPoints and/or CS_References (which represent values for parts). Sending and dispatching inside of a CS_Object through a CS_InteractionPoint accounts for the fact that the defining port is behavior or not.

CS_Object also accounts for the realization of StructuralFeatures of Interfaces, by overriding Operations getFeatureValue and setFeatureValue. Their behavior depends on the CS_StructuralFeatureOfInterfaceAccessStrategy registered at the execution locus.

Generalizations

- Object (from fUML::Semantics::Classes::Kernel)

Attributes

- None

Associations

- None

Operations

```
[1] public contains(object:Object) : Boolean
  // Determines if the object given as a parameter is directly
  // or indirectly contained by this CS_Object
  boolean objectIsContained = this.directlyContains(object) ;
  // if object is not directly contained, restart the research
  // recursively on the objects owned by this CS_Object
  for (int i = 0 ; i < this.featureValues.size() && !objectIsContained ; i++) {
    FeatureValue featureValue = this.featureValues.getValue(i) ;
    ValueList values = featureValue.values ;
    for (int j = 0 ; j < values.size() && !objectIsContained ; j++) {
      Value value = values.getValue(j) ;
      if (value instanceof CS_Object) {
        objectIsContained = ((CS_Object)value).contains(object) ;
      }
      else if (value instanceof CS_Reference) {
        CS_Object referent = ((CS_Reference)value).compositeReferent ;
        objectIsContained = referent.contains(object) ;
      }
    }
  }
  return objectIsContained;

[2] public directlyContains(object:Object) : Boolean
  // Determines if the object given as a parameter is directly
  // contained by this CS_Object
  boolean objectIsContained = false ;
  for (int i = 0 ; i < this.featureValues.size() && !objectIsContained ; i++) {
    FeatureValue featureValue = this.featureValues.getValue(i) ;
    ValueList values = featureValue.values ;
    for (int j = 0 ; j < values.size() && !objectIsContained ; j++) {
      Value value = values.getValue(j) ;
      if (value == object) {
        objectIsContained = true ;
      }
      else if (value instanceof CS_Reference) {
        objectIsContained = (((CS_Reference)value).referent == object) ;
      }
    }
  }
  return objectIsContained;

[3] public dispatchIn(operation:Operation, interactionPoint:CS_InteractionPoint) : Execution
  // If the interaction point refers to a behavior port, does nothing [for the moment... ?],
  // since the only kind of event supported in fUML is SignalEvent
  // If it does not refer to a behavior port, select appropriate delegation links
```

```
  // from interactionPoint, and propagates the operation call through
  // these links
  Execution execution = null ;
  if (interactionPoint.definingPort.isBehavior) {
    // Do nothing
  }
  else {
    boolean operationIsProvided = true ;
    ReferenceList potentialTargets = new ReferenceList() ;
    CS_LinkList cddLinks = this.getLinks(interactionPoint) ;
    Integer linkIndex = 1 ;
    while (linkIndex <= cddLinks.size()) {
      ReferenceList validTargets =
this.selectTargetsForDispatching(cddLinks.getValue(linkIndex – 1),
                      interactionPoint, ConnectorKind.delegation, operation,
operationIsProvided) ;
      Integer targetIndex = 1 ;
      while(targetIndex <= validTargets.size()) {
        potentialTargets.add(validTargets.getValue(targetIndex-1)) ;
        targetIndex = targetIndex + 1 ;
      }
      linkIndex = linkIndex + 1 ;
    }
    // If potentialTargets is empty, no delegation target have been found,
    // and the operation call will be lost
    if (! (potentialTargets.size()==0)) {
      CS_RequestPropagationStrategy strategy =
       (CS_RequestPropagationStrategy)this.locus.factory.getStrategy("requestPropagation") ;
      // Choose one target non-deterministically
      ReferenceList targets = strategy.select(potentialTargets,
                              new CallOperationActionActivation()) ;
      Reference target = targets.getValue(0) ;
      execution = target.dispatch(operation) ;
    }
  }
  return execution ;

[4] public dispatchIn(operation:Operation, onPort:Port) : Execution
       // delegates dispatching to composite referent
       // Select a CS_InteractionPoint value playing onPort,
       // and dispatches the operation call to this interaction point
       FeatureValue featureValue = this.getFeatureValue(onPort) ;
       ValueList values = featureValue.values ;
       Integer choice = ((ChoiceStrategy) this.locus.factory
              .getStrategy("choice"))
              .choose(featureValue.values.size()) - 1;
       CS_InteractionPoint interactionPoint = (CS_InteractionPoint)values.getValue(choice) ;
       return interactionPoint.dispatch(operation) ;

[5] public dispatchOut(operation:Operation, interactionPoint:CS_InteractionPoint) : Execution
  // Select appropriate delegation links from interactionPoint,
  // and propagates the operation call through these links
  // Appropriate links are links which target elements
  // in the environment of this CS_Object.
  // These can be delegation links (i.e, the targeted elements must
  // require the operation) or assembly links (i.e., the target elements
  // must provide the operation)

  Execution execution = null ;
  boolean operationIsNotProvided = false ; // i.e. it is required
  ReferenceList allPotentialTargets = new ReferenceList() ;
  ReferenceList targetsForDispatchingIn = new ReferenceList() ;
  ReferenceList targetsForDispatchingOut = new ReferenceList() ;
  CS_LinkList cddLinks = this.getLinks(interactionPoint) ;
  Integer linkIndex = 1 ;
  while (linkIndex <= cddLinks.size()) {
    ReferenceList validAssemblyTargets =  this.selectTargetsForDispatching(
                      cddLinks.getValue(linkIndex - 1),
                      interactionPoint,
                      ConnectorKind.assembly,
                      operation,
```

```
                    operationIsNotProvided) ;
    Integer targetIndex = 1 ;
    while(targetIndex <= validAssemblyTargets.size()) {
      allPotentialTargets.addValue(validAssemblyTargets.getValue(targetIndex-1)) ;
      targetsForDispatchingIn.addValue(validAssemblyTargets.getValue(targetIndex-1)) ;
      targetIndex = targetIndex + 1 ;
    }
    ReferenceList validDelegationTargets = this.selectTargetsForDispatching(
                    cddLinks.getValue(linkIndex - 1),
                    interactionPoint,
                    ConnectorKind.delegation,
                    operation,
                    operationIsNotProvided) ;
    targetIndex = 1 ;
    while(targetIndex <= validDelegationTargets.size()) {
      allPotentialTargets.addValue(validDelegationTargets.getValue(targetIndex-1)) ;
      targetsForDispatchingOut.addValue(validDelegationTargets.getValue(targetIndex-1)) ;
      targetIndex = targetIndex + 1 ;
    }
    linkIndex = linkIndex + 1 ;
  }

  CS_RequestPropagationStrategy strategy =

       (CS_RequestPropagationStrategy)this.locus.factory.getStrategy("requestPropagation") ;
  ReferenceList selectedTargets = strategy.select(allPotentialTargets,
                                          new SendSignalActionActivation()) ;

  for (int j = 0 ; j < selectedTargets.size() ; j++) {
    Reference target = selectedTargets.getValue(j) ;
    for (int k = 0 ; k < targetsForDispatchingIn.size() && execution == null ; k++) {
      Reference cddTarget = targetsForDispatchingIn.getValue(k) ;
      if (cddTarget == target) {
        execution = target.dispatch(operation) ;
      }
    }
    for (int k = 0 ; k < targetsForDispatchingOut.size() && execution == null ; k++) {
      // The target must be an interaction point
      // i.e. a delegation connector for a required operation can only target a port
      CS_InteractionPoint cddTarget =
(CS_InteractionPoint)targetsForDispatchingOut.getValue(k) ;
      if (cddTarget == target) {
        CS_Reference owner = cddTarget.owner ;
        execution = owner.dispatchOut(operation, cddTarget) ;
      }
    }
  }
  return execution ;

[6] public dispatchOut(operation:Operation, onPort:Port) : Execution
       // Select a CS_InteractionPoint value playing onPort,
       // and dispatches the operation to this interaction point
       Execution execution = null ;
       FeatureValue featureValue = this.getFeatureValue(onPort) ;
       ValueList values = featureValue.values ;
       ReferenceList potentialTargets = new ReferenceList() ;
       for (int i = 0 ; i < values.size() ; i++) {
              potentialTargets.addValue((Reference)values.getValue(i)) ;
       }
       CS_RequestPropagationStrategy strategy =

       (CS_RequestPropagationStrategy)this.locus.factory.getStrategy("requestPropagation") ;
       ReferenceList targets = strategy.select(potentialTargets,new
CallOperationActionActivation());
       // if targets is empty, no dispatch target has been found,
       // and the operation call is lost
       if (targets.size() >= 1) {
              CS_InteractionPoint target = (CS_InteractionPoint)targets.getValue(0) ;
              execution = this.dispatchOut(operation, target) ;
       }
       return execution ;
```

```
[7] public getDirectContainers() : CS_Object[*]
       // Retrieves all the extensional values at this locus which are direct
       // containers for this CS_Object
       // An extensional value is a direct container for an object if:
       // - it is a CS_Object
       // - it directly contains this object (i.e. CS_Object.directlyContains(Object)==true)
       CS_ObjectList containers = new CS_ObjectList() ;
       for (int i = 0 ; i < this.locus.extensionalValues.size() ; i++) {
              ExtensionalValue extensionalValue = this.locus.extensionalValues.getValue(i) ;
              if (extensionalValue != this && extensionalValue instanceof CS_Object) {
              CS_Object cddContainer = (CS_Object)extensionalValue ;
              if (cddContainer.directlyContains(this)) {
                     containers.add(cddContainer) ;
              }
              }
       }
       return containers ;

[8] public getFeatureValue(feature:StructuralFeature) : FeatureValue
  // In the case where the feature belongs to an Interface,
  // fUML semantics is extended in the sense that reading is
  // delegated to a CS_StructuralFeatureOfInterfaceAccessStrategy
  if (feature.namespace instanceof Interface) {
    CS_StructuralFeatureOfInterfaceAccessStrategy readStrategy=
       (CS_StructuralFeatureOfInterfaceAccessStrategy)this.locus.factory.
              getStrategy("structuralFeature") ;
              return readStrategy.read(this, feature) ;
       }
       else {
              return super.getFeatureValue(feature);
       }

[9] public getLinkKind(link:CS_Link, interactionPoint:CS_InteractionPoint) : CS_LinkKind
       // If the given interaction point belongs to the given object,
       // and if the given interaction point is used as an end of the link,
       // then the links targets the environment of the object (enumeration literal
ToEnvironment)
       // if all the feature values of the link
       // (but one for the interaction point) refer to values which are not themselves values
       // for features of the interaction point.
       // If all the feature values of the link refer to values which are themselves values
for
       // features of the interaction point,
       // the link targets the internals of the object (enumeration literal ToInternal).
       // Otherwise, the link has no particular meaning
       // in the context defined by the object and the interaction point (enumeration literal
None).
       if (! link.hasValueForAFeature(interactionPoint)) {
              return CS_LinkKind.None ;
       }
       CS_LinkKind kind = CS_LinkKind.ToInternal ;
       FeatureValueList featureValues = link.getFeatureValues() ;
       Integer i = 1 ;
       while (i <= featureValues.size() && kind != CS_LinkKind.None) {
              FeatureValue value = featureValues.getValue(i-1) ;
              if (value.values.isEmpty()) {
              kind = CS_LinkKind.None ;
              }
              else {
              Value v = value.values.getValue(0) ;
              boolean vIsAValueForAFeatureOfContext = false ;
              if (v.equals(interactionPoint)) {
                     vIsAValueForAFeatureOfContext = true ;
              }
              else if (v instanceof CS_InteractionPoint) {
                     v = ((CS_InteractionPoint)v).owner ;
                     vIsAValueForAFeatureOfContext = this.hasValueForAFeature(v) ;
              }
              else {
                     vIsAValueForAFeatureOfContext = this.hasValueForAFeature(v) ;
              }
```

```
                if (!vIsAValueForAFeatureOfContext) {
                        kind = CS_LinkKind.ToEnvironment ;
                }
                }
                i = i + 1 ;
        }
        return kind ;

[10] public getLinks(interactionPoint:CS_InteractionPoint) : CS_Link[*]
        // Get all links (available at the locus of this object) where the given
        // interaction point is used as a feature value
        // (i.e. the interaction is an end such links)
        ExtensionalValueList extensionalValues = this.locus.extensionalValues ;
        Integer i = 1 ;
        CS_LinkList connectorInstances = new CS_LinkList() ;
        while (i <= extensionalValues.size()) {
                ExtensionalValue value = extensionalValues.getValue(i-1) ;
                if (value instanceof CS_Link) {
                CS_Link link = (CS_Link)value ;
                if (this.getLinkKind(link, interactionPoint) != CS_LinkKind.None) {
                        connectorInstances.addValue(link) ;
                }
                }
                i = i + 1 ;
        }
        return connectorInstances ;

[11] public hasValueForAFeature(value:Value) : Boolean
        // Returns true if the given value object is used as a value for a feature
        // value of this object
        FeatureValueList allFeatureValues = this.getFeatureValues() ;
        Integer i = 1 ;
        boolean isAValue = false ;
        while (i <= allFeatureValues.size() && !isAValue) {
                FeatureValue featureValue = allFeatureValues.getValue(i-1);
                if (!featureValue.values.isEmpty()) {
                ValueList valuesForCurrentFeature = featureValue.values ;
                Integer j = 1 ;
                while (j <= valuesForCurrentFeature.size() && !isAValue) {
                        isAValue = featureValue.values.getValue(j-1).equals(value) ;
                        j = j + 1 ;
                }
                }
                i = i + 1 ;
        }
        return isAValue ;

[12] public isOperationProvided(reference:Reference, operation:Operation) : Boolean
  // Determines if the given reference provides the operation
  // If the reference is an interaction point, it provides the operation if this operation
  // is a member of one of its provided interfaces
  // If the reference is NOT an interactionPoint, it provides this operation if
  // this operation is an operation of one of its type, or one of its type provides a
  // realization for this operation (in the case
  // where the namespace of this Operation is an interface)
  boolean isProvided = false ;
  if (reference instanceof CS_InteractionPoint) {
    if (operation.owner instanceof Interface) {
      // We have to look in provided interfaces of the port if
      // they define directly or indirectly the Operation
      Integer interfaceIndex = 1 ;
      // Iterates on provided interfaces of the port
      InterfaceList providedInterfaces =
((CS_InteractionPoint)reference).definingPort.provided() ;
      while (interfaceIndex <= providedInterfaces.size() && !isProvided) {
        Interface interface_ = providedInterfaces.getValue(interfaceIndex-1) ;
        // Iterates on members of the current Interface
        Integer memberIndex = 1 ;
        while (memberIndex <= interface_.member.size() && !isProvided) {
          NamedElement cddOperation = interface_.member.getValue(memberIndex-1) ;
          if (cddOperation instanceof Operation) {
```

```
            isProvided = operation == cddOperation ;
          }
          memberIndex = memberIndex + 1 ;
        }
        interfaceIndex = interfaceIndex + 1 ;
      }
    }
  }
  else {
    // We have to look if one of the Classifiers typing this reference
    // directly or indirectly provides this operation
    ClassifierList types = reference.getTypes() ;
    Integer typeIndex = 1 ;
    while (typeIndex <= types.size() && !isProvided) {
      if (types.getValue(typeIndex - 1) instanceof Class_) {
        Integer memberIndex = 1 ;
        NamedElementList members = ((Class_)types.getValue(typeIndex - 1)).member ;
        while (memberIndex <= members.size() && !isProvided) {
          NamedElement cddOperation = members.getValue(memberIndex-1) ;
          if (cddOperation instanceof Operation) {
            CS_DispatchOperationOfInterfaceStrategy strategy =
                            new CS_DispatchOperationOfInterfaceStrategy() ;
            isProvided = strategy.operationsMatch((Operation)cddOperation, operation) ;
          }
          memberIndex = memberIndex + 1 ;
        }
      }
      typeIndex = typeIndex + 1 ;
    }
  }
  return isProvided ;

[13] public isOperationRequired(reference:Reference, operation:Operation) : Boolean
  // Determines if the given reference requires the operation
  // If the reference is an interaction point, it requires the operation if this operation
  // is a member of one of its required interfaces
  // If the reference is not a interaction point, it cannot require an operation
  boolean matches = false ;
  if (reference instanceof CS_InteractionPoint) {
    Integer interfaceIndex = 1 ;
    // Iterates on provided interfaces of the port
    InterfaceList requiredInterfaces =
((CS_InteractionPoint)reference).definingPort.required() ;
    while (interfaceIndex <= requiredInterfaces.size() && !matches) {
      Interface interface_ = requiredInterfaces.getValue(interfaceIndex-1) ;
      // Iterates on members of the current Interface
      Integer memberIndex = 1 ;
      while (memberIndex <= interface_.member.size() && !matches) {
        NamedElement cddOperation = interface_.member.getValue(memberIndex-1) ;
        if (cddOperation instanceof Operation) {
          matches = operation == cddOperation ;
        }
        memberIndex = memberIndex + 1 ;
      }
      interfaceIndex = interfaceIndex + 1 ;
    }
  }
  return matches ;

[14] public selectTargetsForDispatching(link:CS_Link, interactionPoint:CS_InteractionPoint,
connectorKind:ConnectorKind, operation:Operation, toInternal:Boolean) : Reference[*]
  // From the given link, operation and interaction point,
  //retrieves potential targets (i.e. end values of link)
  // through which request can be propagated
  // These targets are attached to interaction point through the given link,
  // and respect the following rules:
  // - if toInternal is true, connectorKind must be Delegation,
  // the given link has to target the internals of this CS_Object,
  // and a valid target must provide the Operation
  // - if toInternal is false, the given link has to target the environment of this CS_Object.
  //   - if connectorKind is assembly, a valid target has to provide the operation
```

```
  //   - if connectorKind is delegation, a valid target has to require the operation
  ReferenceList potentialTargets = new ReferenceList() ;
  if (toInternal && connectorKind == ConnectorKind.delegation) {
    if (this.getLinkKind(link, interactionPoint) == CS_LinkKind.ToInternal) {
      Integer i = 1 ;
      while(i <= link.getFeatureValues().size()) {
        ValueList values = link.getFeatureValues().get(i-1).values ;
        if (!values.isEmpty() && values.get(0) instanceof Reference) {
          Reference cddTarget = (Reference)values.get(0) ;
          if (cddTarget != interactionPoint && this.isOperationProvided(cddTarget, operation))
{
            potentialTargets.add(cddTarget) ;
          }
        }
        i = i + 1 ;
      }
    }
  }
  else { // to environment
    if (this.getLinkKind(link, interactionPoint) == CS_LinkKind.ToEnvironment) {
      Integer i = 1 ;
      while(i <= link.getFeatureValues().size()) {
        ValueList values = link.getFeatureValues().get(i-1).values ;
        if (!values.isEmpty() && values.get(0) instanceof Reference) {
          Reference cddTarget = (Reference)values.get(0) ;
          if (connectorKind == ConnectorKind.assembly) {
            if (! (cddTarget instanceof CS_InteractionPoint)) { // This is an assembly link
              if (this.isOperationProvided(cddTarget, operation)) {
                potentialTargets.add(cddTarget) ;
              }
            }
            else {
              // This is an assembly if the interaction point is not a feature value
              // for a container of this CS_Object
              CS_ObjectList directContainers = this.getDirectContainers() ;
              boolean isAssembly = true ;
              Integer j = 1 ;
              if (! this.hasValueForAFeature(cddTarget)) {
                while (isAssembly && j <= directContainers.size()) {
                  CS_Object container = directContainers.get(j - 1) ;
                  if (container.hasValueForAFeature(cddTarget)) {
                    isAssembly = false ;
                  }
                  j++ ;
                }
              }
              else {
                isAssembly = false ;
              }
              if (isAssembly) {
                if (this.isOperationProvided(cddTarget, operation)) {
                  potentialTargets.add(cddTarget) ;
                }
              }
            }
          }
          else { // delegation
            // This is a delegation if the target is an interaction point
            // and if this interaction is a feature value for a container of this CS_Object
            if (cddTarget instanceof CS_InteractionPoint) {
              CS_ObjectList directContainers = this.getDirectContainers() ;
              boolean isDelegation = false ;
              Integer j = 1 ;
              while (!isDelegation && j <= directContainers.size()) {
                CS_Object container = directContainers.get(j - 1) ;
                if (container.hasValueForAFeature(cddTarget)) {
                  isDelegation = true ;
                }
                j++ ;
              }
              if (isDelegation) {
                if (this.isOperationRequired(cddTarget, operation)) {
```

```
                potentialTargets.add(cddTarget) ;
              }
            }
          }
        }
      }
      i = i + 1 ;
    }
  }
  return potentialTargets ;

[15] public selectTargetsForSending(link:CS_Link, interactionPoint:CS_InteractionPoint,
connectorKind:ConnectorKind, signal:Signal, toInternal:Boolean) : Reference[*]
  // From the given link, signal and interaction point,
  // retrieves potential targets (i.e. end values of link)
  // through which request can be propagated
  // These targets are attached to interaction point through the given link,
  // and respect the following rules:
  // - if toInternal is true, connectorKind must be Delegation,
  // the given link has to target the internals of this CS_Object
  // - if toInternal is false, the given link has to target the environment of this CS_Object.
  ReferenceList potentialTargets = new ReferenceList() ;
  if (toInternal && connectorKind == ConnectorKind.delegation) {
    if (this.getLinkKind(link, interactionPoint) == CS_LinkKind.ToInternal) {
      Integer i = 1 ;
      while(i <= link.getFeatureValues().size()) {
        ValueList values = link.getFeatureValues().get(i-1).values ;
        if (!values.isEmpty()) {
          Integer j = 1 ;
          while (j <= values.size()) {
            Reference cddTarget = (Reference)values.get(j-1) ;
            if (!cddTarget.equals(interactionPoint)) {
              potentialTargets.add(cddTarget) ;
            }
            j = j + 1 ;
          }
        }
        i = i + 1 ;
      }
    }
  }
  else { // to Environment
    if (this.getLinkKind(link, interactionPoint) == CS_LinkKind.ToEnvironment) {
      Integer i = 1 ;
      while(i <= link.getFeatureValues().size()) {
        ValueList values = link.getFeatureValues().get(i-1).values ;
        if (!values.isEmpty() && values.get(0) instanceof Reference) {
          Reference cddTarget = (Reference)values.get(0) ;
          if (connectorKind == ConnectorKind.assembly) {
            if (! (cddTarget instanceof CS_InteractionPoint)) { // This is an assembly link
              potentialTargets.add(cddTarget) ;
            }
            else {
              // This is an assembly if the interaction point is not a feature value
              // for a container of this CS_Object
              CS_ObjectList directContainers = this.getDirectContainers() ;
              boolean isAssembly = true ;
              Integer j = 1 ;
              if (! this.hasValueForAFeature(cddTarget)) {
                while (isAssembly && j <= directContainers.size()) {
                  CS_Object container = directContainers.get(j - 1) ;
                  if (container.hasValueForAFeature(cddTarget)) {
                    isAssembly = false ;
                  }
                  j++ ;
                }
              }
              else {
                isAssembly = false ;
              }
```

```
            if (isAssembly) {
              potentialTargets.add(cddTarget) ;
            }
          }
        }
        else { // delegation
          // This is a delegation if the target is an interaction point
          // and if this interaction is a feature value for a container of this CS_Object
          if (cddTarget instanceof CS_InteractionPoint) {
            CS_ObjectList directContainers = this.getDirectContainers() ;
            boolean isDelegation = false ;
            Integer j = 1 ;
            while (!isDelegation && j <= directContainers.size()) {
              CS_Object container = directContainers.get(j - 1) ;
              if (container.hasValueForAFeature(cddTarget)) {
                isDelegation = true ;
              }
              j++ ;
            }
            if (isDelegation) {
              potentialTargets.add(cddTarget) ;
            }
          }
        }
      }
      i = i + 1 ;
    }
  }
  return potentialTargets ;

[16] public sendIn(signalInstance:SignalInstance, interactionPoint:CS_InteractionPoint)
  // If the interaction is a behavior port,
  // creates a CS_SignalInstance from the signal instance,
  // sets its interaction point,
  // and sends it to the target object using operation send
  // If this is not a behavior port,
  // select appropriate delegation targets from interactionPoint,
  // and propagates the signal to these targets
  if (interactionPoint.definingPort.isBehavior) {
    CS_SignalInstance newSignalInstance = (CS_SignalInstance)signalInstance.copy() ;
    newSignalInstance.interactionPoint = interactionPoint ;
    this.send(newSignalInstance) ;
  }
  else {
    boolean receptionIsProvided = true ;
    ReferenceList potentialTargets = new ReferenceList() ;
    CS_LinkList cddLinks = this.getLinks(interactionPoint) ;
    Integer linkIndex = 1 ;
    while (linkIndex <= cddLinks.size()) {
      ReferenceList validTargets = this.selectTargetsForSending(
                                   cddLinks.getValue(linkIndex - 1),
                                   interactionPoint,
                                   ConnectorKind.delegation,
                                   signalInstance.type,
                                   receptionIsProvided) ;
      Integer targetIndex = 1 ;
      while(targetIndex <= validTargets.size()) {
        potentialTargets.add(validTargets.getValue(targetIndex-1)) ;
        targetIndex = targetIndex + 1 ;
      }
      linkIndex = linkIndex + 1 ;
    }
    // If potential targets is empty, no delegation target has been found,
    // and the signal is lost
    // Otherwise, do the following concurrently
    for (int i = 0 ; i < potentialTargets.size() ; i++) {
      Reference target = potentialTargets.getValue(i) ;
      CS_SignalInstance newSignalInstance = (CS_SignalInstance)signalInstance.copy() ;
      newSignalInstance.interactionPoint = interactionPoint ;
      target.send(newSignalInstance) ;
```

```
    }
  }

[17] public sendIn(signalInstance:SignalInstance, onPort:Port)
       // Select a Reference value playing onPort,
       // and send the signal instance to this interaction point
       FeatureValue featureValue = this.getFeatureValue(onPort) ;
       ValueList values = featureValue.values ;
       ReferenceList potentialTargets = new ReferenceList() ;
       for (int i = 0 ; i < values.size() ; i++) {
              potentialTargets.addValue((Reference)values.getValue(i)) ;
       }
       CS_RequestPropagationStrategy strategy =

       (CS_RequestPropagationStrategy)this.locus.factory.getStrategy("requestPropagation") ;
       ReferenceList targets = strategy.select(potentialTargets, new
SendSignalActionActivation()) ;
       for (int i = 0 ; i < targets.size() ; i++) {
              Reference target = targets.getValue(i) ;
              target.send(signalInstance) ;
       }

[18] public sendOut(signalInstance:SignalInstance, interactionPoint:CS_InteractionPoint)
  // Select appropriate delegation links from interactionPoint,
  // and propagates the signal instance through these links
  // Appropriate links are links which target elements
  // in the environment of this CS_Object.
  // These can be delegation links (i.e, the targeted elements must
  // require a reception for the signal) or assembly links (i.e., the target elements
  // must provide a reception for the signal)

  boolean receptionIsNotProvided = false ; // i.e. it is required
  ReferenceList allPotentialTargets = new ReferenceList() ;
  ReferenceList targetsForSendingIn = new ReferenceList() ;
  ReferenceList targetsForSendingOut = new ReferenceList() ;

  CS_LinkList cddLinks = this.getLinks(interactionPoint) ;
  Integer linkIndex = 1 ;
  while (linkIndex <= cddLinks.size()) {
    ReferenceList validAssemblyTargets = this.selectTargetsForSending(
                                          cddLinks.getValue(linkIndex - 1),
                                          interactionPoint,
                                          ConnectorKind.assembly,
                                          signalInstance.type,
                                          receptionIsNotProvided) ;
    Integer targetIndex = 1 ;
    while(targetIndex <= validAssemblyTargets.size()) {
      allPotentialTargets.addValue(validAssemblyTargets.getValue(targetIndex-1)) ;
      targetsForSendingIn.addValue(validAssemblyTargets.getValue(targetIndex-1)) ;
      targetIndex = targetIndex + 1 ;
    }
    ReferenceList validDelegationTargets = this.selectTargetsForSending(
                                          cddLinks.getValue(linkIndex - 1),
                                          interactionPoint,
                                          ConnectorKind.delegation,
                                          signalInstance.type,
                                          receptionIsNotProvided) ;
    targetIndex = 1 ;
    while(targetIndex <= validDelegationTargets.size()) {
      allPotentialTargets.addValue(validDelegationTargets.getValue(targetIndex-1)) ;
      targetsForSendingOut.addValue(validDelegationTargets.getValue(targetIndex-1)) ;
      targetIndex = targetIndex + 1 ;
    }
    linkIndex = linkIndex + 1 ;
  }

  CS_RequestPropagationStrategy strategy =
       (CS_RequestPropagationStrategy)this.locus.factory.getStrategy("requestPropagation") ;
  ReferenceList selectedTargets = strategy.select(allPotentialTargets,
                                          new SendSignalActionActivation()) ;
  for (int j = 0 ; j < selectedTargets.size() ; j++) {
```

```
    Reference target = selectedTargets.getValue(j) ;
    for (int k = 0 ; k < targetsForSendingIn.size() ; k++) {
      Reference cddTarget = targetsForSendingIn.getValue(k) ;
      if (cddTarget == target) {
        target.send(signalInstance) ;
      }
    }
    for (int k = 0 ; k < targetsForSendingOut.size() ; k++) {
      // The target must be an interaction point
      // i.e. a delegation connector for a required reception can only target a port
      CS_InteractionPoint cddTarget = (CS_InteractionPoint)targetsForSendingOut.getValue(k) ;
      if (cddTarget == target) {
        CS_Reference owner = cddTarget.owner ;
        owner.sendOut(signalInstance, cddTarget) ;
      }
    }
  }

[19] public sendOut(signalInstance:SignalInstance, onPort:Port)
  // Select a CS_InteractionPoint value playing onPort,
  // and send the signal instance to this interaction point
  FeatureValue featureValue = this.getFeatureValue(onPort) ;
  ValueList values = featureValue.values ;
  ReferenceList potentialTargets = new ReferenceList() ;
  for (int i = 0 ; i < values.size() ; i++) {
    potentialTargets.addValue((Reference)values.getValue(i)) ;
  }
  CS_RequestPropagationStrategy strategy =

        (CS_RequestPropagationStrategy)this.locus.factory.getStrategy("requestPropagation") ;
  ReferenceList targets = strategy.select(potentialTargets, new SendSignalActionActivation())
;
  for (int i = 0 ; i < targets.size() ; i++) {
    CS_InteractionPoint target = (CS_InteractionPoint)targets.getValue(i) ;
    this.sendOut(signalInstance, target) ;
  }
[20] public setFeatureValue(feature:StructuralFeature, values:Value[*], position:Integer)
  // In the case where the feature belongs to an Interface,
  // fUML semantics is extended in the sense that writing is
  // delegated to a CS_StructuralFeatureOfInterfaceAccessStrategy
  if (feature.namespace instanceof Interface) {
    CS_StructuralFeatureOfInterfaceAccessStrategy writeStrategy =
(CS_StructuralFeatureOfInterfaceAccessStrategy)this.locus.factory.getStrategy("structuralFeatu
re");
    writeStrategy.write(this, feature, values, position) ;
  }
  else {
    super.setFeatureValue(feature, values, position);
  }
```

8.5.2.2.5 CS_Reference

CS_Reference extends fUML Reference to account for new capabilities introduced by CS_Object (i.e., variants of send and dispatch operations introduced to deal with sending and dispatching inside or outside of a composite structure instance, through a port). CS_Reference is a reference to a CS_Object (property compositeReferent, which subsets inherited property Object::referent). All operations of CS_Reference are realized by delegation to its referent CS_Object.

Generalizations

- Reference (from fUML::Semantics::Classes::Kernel)

Attributes

- None

Associations

- compositeReferent : CS_Object[1], The composite object referenced by this CS_Reference. This property subsets Reference::referent.

Operations

```
[1] public copy() : Value
       // Create a new reference with the same referent and composite referent
       // as this reference.
       CS_Reference newValue = new CS_Reference();
       newValue.referent = this.referent;
       newValue.compositeReferent = this.compositeReferent;
       return newValue;

[2] public dispatchIn(operation:Operation, interactionPoint:CS_InteractionPoint) : Execution
       //Delegates dispatching to composite referent
       return this.compositeReferent.dispatchIn(operation, interactionPoint) ;

[3] public dispatchIn(operation:Operation, onPort:Port) : Execution
       // delegates dispatching to composite referent
       return this.compositeReferent.dispatchIn(operation, onPort) ;

[4] public dispatchOut(operation:Operation, onPort:Port) : Execution
       // delegates dispatching to composite referent
       return this.compositeReferent.dispatchOut(operation, onPort) ;

[5] public dispatchOut(operation:Operation, interactionPoint:CS_InteractionPoint) : Execution
       // Delegates dispatching (through the interaction point, to the environment)
       // to compositeReferent
       return this.compositeReferent.dispatchOut(operation, interactionPoint) ;

[6] public sendIn(signalInstance:SignalInstance, interactionPoint:CS_InteractionPoint)
       // delegates sending to composite referent
       this.compositeReferent.sendIn(signalInstance, interactionPoint) ;

[7] public sendIn(signalInstance:SignalInstance, onPort:Port)
       // delegates sending to composite referent
       this.compositeReferent.sendIn(signalInstance, onPort) ;

[8] public sendOut(signalInstance:SignalInstance, onPort:Port)
       // delegates sending to composite referent
       this.compositeReferent.sendOut(signalInstance, onPort) ;

[9] public sendOut(signalInstance:SignalInstance, interactionPoint:CS_InteractionPoint)
       // Delegates sending (through the interaction point, to the environment)
       // to compositeReferent
       this.compositeReferent.sendOut(signalInstance, interactionPoint) ;
```

8.6 Loci

8.6.1 LociL3

8.6.1.1 Overview

The LociL3 package includes extensions to fUML Locus, ExecutionFactor and Executor, in order to account for new semantic visitors introduced by this specification. These extensions are depicted in Figure 23.

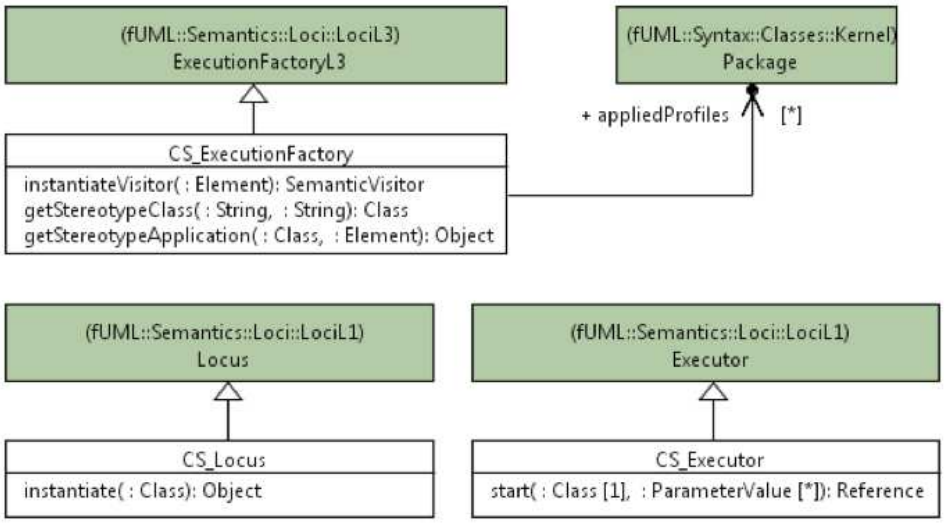


Figure 23: LociL3 diagram

8.6.1.2 Class descriptions

8.6.1.2.1 CS_ExecutionFactory

CS_ExecutionFactory extends fUML ExecutionFactoryL3 to account for new semantic visitors introduced by this specification. It also include mechanisms to deal with Profiles and Stereotype applications (property appliedProfiles, and operations getStereotypeClass and getStereotypeApplication). The principles underlying these mechanisms are described in 8.1, Dealing with Profiles and Stereotypes.

Generalizations

- ExecutionFactoryL3 (from fUML::Semantics::Loci::LociL3)

Attributes

- None

Associations

- appliedProfiles : Package [*], profiles containing any stereotype applied on elements being executed. Implementations shall initialized this collection before starting any execution.

Operations

```
[1] public getStereotypeClass(profileName:String, stereotypeName:String) : Classifier

[2] public getStereotypeApplication(stereotype:Class, element:Element) : Object
  ExtensionalValueList extent = locus.getExtent(stereotype);
  Object extensionObject = null;
  int i = 1;
  while (i <= extent.size() && extensionObject == null) {
    ExtensionalValue object = extent.getValue(i - 1);
    if(object.getFeatureValue(baseEnd).values.getValue(0).equals(element)) {
      extensionObject = (Object)object;
    }
    i = i + 1;
  }
  return extensionObject ;

[3] public instantiateVisitor(element:Element) : SemanticVisitor
```

```
// Extends fUML semantics in the sense that newly introduced
// semantic visitors are instantiated instead of fUML visitors
SemanticVisitor visitor = null ;
if (element instanceof ReadExtentAction) {
	visitor =new CS_ReadExtentActionActivation() ;
}
else if (element instanceof ReadIsClassifiedObjectAction) {
	visitor = new CS_ReadIsClassifiedObjectActionActivation() ;
}
else if (element instanceof AddStructuralFeatureValueAction) {
	visitor = new CS_AddStructuralFeatureValueActionActivation() ;
}
else if (element instanceof ClearStructuralFeatureAction) {
	visitor = new CS_ClearStructuralFeatureValueActionActivation() ;
}
else if (element instanceof CreateLinkAction) {
	visitor = new CS_CreateLinkActionActivation() ;
}
else if (element instanceof CreateObjectAction) {
	visitor = new CS_CreateObjectActionActivation() ;
}
else if (element instanceof ReadSelfAction) {
	visitor = new CS_ReadSelfActionActivation() ;
}
else if (element instanceof InstanceValue) {
	visitor = new CS_InstanceValueEvaluation() ;
}
else if (element instanceof AcceptEventAction) {
	visitor = new CS_AcceptEventActionActivation() ;
}
else if (element instanceof CallOperationAction) {
	visitor = new CS_CallOperationActionActivation() ;
}
else if (element instanceof SendSignalAction) {
	visitor = new CS_SendSignalActionActivation() ;
}
else if (element instanceof OpaqueExpression) {
	visitor = new CS_OpaqueExpressionEvaluation() ;
}
else {
	visitor = super.instantiateVisitor(element) ;
}
return visitor ;
```

8.6.1.2.2 CS_Executor

FUML semantics are extended so that, when the start operation produces a CS_Object, a CS_Reference is returned instead of a fUML Reference.

Generalizations

- Executor (from fUML::Semantics::Loci::LociL1)

Attributes

- None

Associations

- None

Operations

```
[1] public start(type:Class, inputs:ParameterValue[*]) : Reference
	// Instantiate the given class and start any behavior of the resulting
	// object.
	// (The behavior of an object includes any classifier behaviors for an
	// active object or the class of the object itself, if that is a
```

```
        // behavior.)
        // fUML semantics is extended in the sense that when the instantiated object
        // is a CS_Object, a CS_Reference is returned (instead of a Reference)

        Debug.println("[start] Starting " + type.name + "...");

        Object_ object = this.locus.instantiate(type);

        Debug.println("[start] Object = " + object);
        object.startBehavior(type, inputs);

        Reference reference ;
        if (object instanceof CS_Object) {
                reference = new CS_Reference();
                ((CS_Reference)reference).compositeReferent = (CS_Object)object ;
        }
        else {
                reference = new Reference() ;
        }
        reference.referent = object;

        return reference;
```

8.6.1.2.3 CS_Locus

FUML semantics are extended so that the instantiate operation produces a CS_Object instead of an Object, in the case where the Class to be instantiated is not a Behavior.

Generalizations

- Locus (from fUML::Semantics::Loci::LociL1)

Attributes

- None

Associations

- None

Operations

```
[1] public instantiate(type:Class) : Object
        // Extends fUML semantics by instantiating a CS_Object
        // in the case where type is not a Behavior.
        // Otherwise behaves like in fUML

        Object_ object = null;

        if (type instanceof Behavior) {
                object = super.instantiate(type);
        } else {
                object = new CS_Object() ;
                object.types.addValue(type);
                object.createFeatureValues();
                this.add(object);
        }

        return object;
```

9 Test Suites

This clause describes suites of test cases that can be used to demonstrate conformance to this specification. All test cases are included in a single UML model, complying with syntax defined in Clause 7 of this specification. This clause is decomposed into four test suites, each one focusing on a specific aspect of UML composite structures semantics.

Test Suite 1 focuses on semantics of instantiation, and validates topologies resulting from the instantiation of composite structures, as well as management of default values for properties. Test Suite 2 focuses on communication aspects, such as propagation of requests across ports, through connectors. Test Suite 3 also focuses on communication aspects, in the specific cases where property onPort of InvocationAction is used, and when reactions may occur only if a message was received on a specific port. Test Suite 4 finally focuses on destruction semantics of UML Composite Structures, such as the recursive destruction of parts and ports, and automatic deletion of links (representing connector instances) where connected roles are removed.

Test cases consist in combinations of structural and behavioral elements, whose executions shall verify some assertions. Assertions are specified using basic functions specified in a library, which is itself an executable UML model complying syntax defined in clause of this specification. A tool may demonstrate compliance with this specification if no assertion fails when executing the test cases. In the following subclauses, structural aspects are depicted with appropriate diagrams, while behavioral aspects are usually depicted in Alf. Exceptions include cases where extensions to Alf would be required to specify behavioral aspects (such as in Test Suite 3). In these cases, Activity diagrams are used to specify behaviors.

The architecture of the Test Suite is depicted in Figure 24. Subclause 9.1 describes the assertion library used across all test cases (package AssertionLibrary in the upper part of Figure 24). Subclauses 9.2, 9.3, 9.4 and 9.5 describe the various test suites (packages Test Suite 1, Test Suite 2, Test Suite 3, and Test Suite 4, on the left part of Figure 24), as well as variants of these Test Suites (all packages with suffix bis, ter, and quater, in Figure 24).

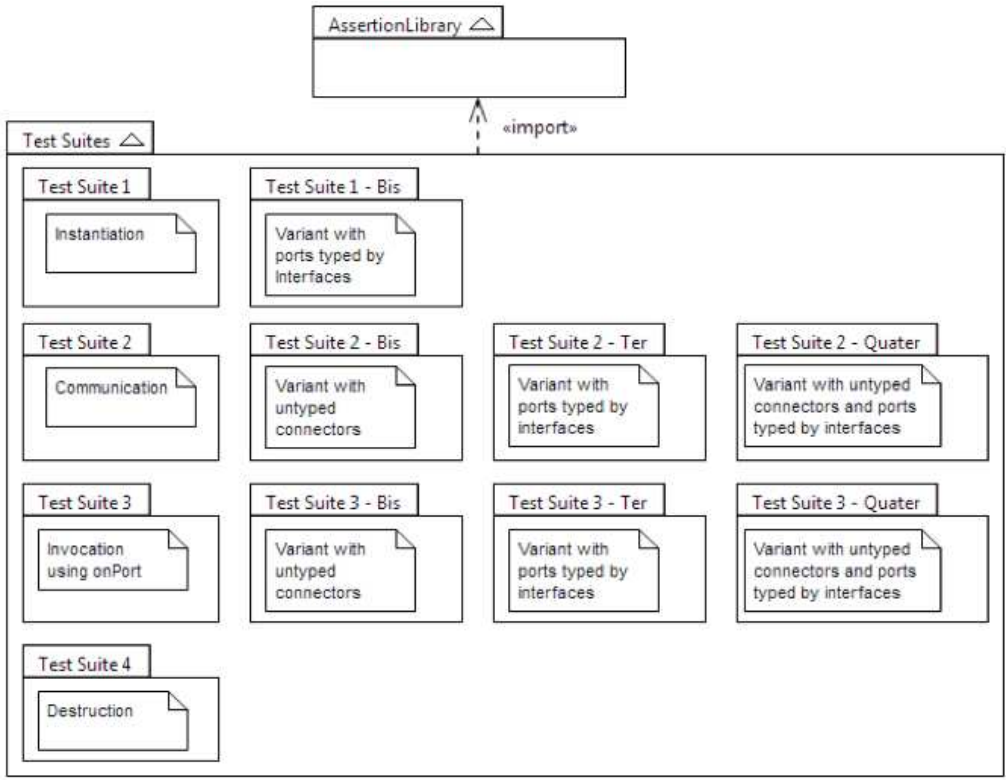


Figure 24: Test Suites architecture diagram

9.1 Assertion library

The assertion library includes five activities, specified in Alf as follows. These activities are the basis for all test cases included in this specification.

```
[1] activity Write(in value: any) {
  // Writes value on the standard output channel
  // StandardOutputChannel is part of the foundational
  // model library, which is part of the fUML specification
  StandardOutputChannel.allInstances()[1].write(value);
}

[2] activity AssertTrue(in label: String, in condition: Boolean) {
  // Asserts that the given condition is true
  WriteLine(label + ": " + ToString(condition));
}

[3] activity AssertFalse(in label: String, in condition: Boolean) {
  // Asserts that the given condition is false
  WriteLine("! " + label + ": " + ToString(!condition));
}

[4] activity AssertEqual(in label: String, in value1: any, in value2: any) {
  // Asserts equality between value1 and value2
  Write(label + "==");
  Write(value2 instanceof String? "\"" + (String)value2 + "\"": value2);
  AssertTrue("", value1==value2);
}

[5] activity AssertList(in label: String, in list: any[*] sequence, in expected: any[*]
sequence) {
  // Asserts that lists list and expected are equals
  // (i.e., same size, and same content)
  AssertEquals(label + "->size()", list->size(), expected->size());
  for (i in 1..IntegerFunctions::Min(list->size(),expected->size())) {
    AssertEquals(label + "[" + IntegerFunctions::ToString(i) + "]", list[i], expected[i]);
  }
}
```

9.2 Test Suite 1: Instantiation

This test suite focuses on instantiation semantics of UML Composite Structures. It validates topologies resulting from the instantiation of composite structures, as well as management of default values for properties. Subclause 9.2.1 describes a utility class and a couple of utility activities used by test cases defined in this subclause. Subclauses 9.2.2, 9.2.3 and 9.2.4 include test cases implying assembly connectors. Subclauses 9.2.5 and 9.2.6 deal with management of default values. Subclauses 9.2.7 and 9.2.8 include test cases implying delegation connectors. Subclause 9.2.9 finally deals with instantiation of a structure with multiple hierarchy levels. Subclause 9.2.10 describes a variant of Test Suite 1 with ports typed by interfaces.

9.2.1 Utilities

Utilities includes four assertion activities, each one corresponding to a topology supported by construction strategy CS_DefaultConstructStrategy, specified in 8.5.1.2.4. The Alf specification for these activities is as follows:

```
[1] activity AssertEmptyPattern(in ends1 : any[], in ends2 : any[]) {
  // Asserts empty topology
  // ends1 and ends2 shall be empty
  AssertEquals("EmptyPattern - ends1->size()", ends1->size(), 0) ;
  AssertEquals("EmptyPattern - ends2->size()", ends2->size(), 0) ;
}
```

```
[2] activity AssertUnconnectedPattern(in ends1 : any[], in ends2 : any[],
                                      in n1 : Integer, in n2 : Integer,
                                      in helper : AbstractAssertCompositeHelper) {
  // Asserts unconnected topology
  // Check cardinalities
  // Size of ends1 must be equal to expected size n1
  // Size of ends2 must be equal to expected size n2
  AssertEquals("UnconnectedPattern - ends1->size()", ends1->size(), n1) ;
  AssertEquals("UnconnectedPattern - ends2->size()", ends2->size(), n2) ;
  // Checks connections
  // There shall not be any connection between elements of ends1 and elements of ends2
  for (i in 1..ends1->size()) {
    for (j in 1..ends2->size()) {
      helper.assertNotConnected("UnconnectedPattern - ends1["
                                + ToString(i)
                                + "] is not connected to ends2["
                                + ToString(j) + "]",
                                ends1[i], ends2[j]) ;
    }
  }
}

[3] activity AssertArrayPattern(in ends1 : any[], in ends2 : any[], in n : Integer,
                                in helper : AbstractAssertCompositeHelper) {
  // Asserts array topology
  // Check cardinalities
  // Size of ends1 must be equal to expected size n
  // Size of ends2 must be equal to expected size n
  AssertEquals("ArrayPattern - ends1->size()", ends1->size(), n) ;
  AssertEquals("ArrayPattern - ends2->size()", ends2->size(), n) ;
  upper = Min(ends1->size(), ends2->size()) ;
  // Check connections
  // Each element of ends1 must be connected to one and only
  // one element of ends2, with same index.
  for (i in 1..upper) {
    for (j in 1..upper) {
      if (i == j) {
        helper.assertConnected("ArrayPattern - ends1["
                               + ToString(i)
                               + "] is connected to ends2["
                               + ToString(j) + "]",
                               ends1[i], ends2[j]) ;
      }
      else {
        helper.assertNotConnected("ArrayPattern - ends1["
                                  + ToString(i)
                                  + "] is not connected to ends2["
                                  + ToString(j) + "]",
                                  ends1[i], ends2[j]) ;
      }
    }
  }
}

[4]activity AssertStarPattern(in ends1 : any[], in ends2 : any[],
                              in n1 : Integer, in n2 : Integer,
                              in helper : AbstractAssertCompositeHelper) {
  // Asserts star topology
  // Check cardinalities
  // Size of ends1 must be equal to expected size n1
  // Size of ends2 must be equal to expected size n2
  AssertEquals("StarPattern - ends1->size()", ends1->size(), n1) ;
  AssertEquals("StarPattern - ends2->size()", ends2->size(), n2) ;
  // Checks connections
  // Each element of ends1 must be connected to
  // all elements of ends2, and vice-versa.
  for (i in 1..ends1->size()) {
    for (j in 1..ends2->size()) {
      helper.assertConnected("StarPattern - ends1["
                             + ToString(i)
                             + "] is connected to ends2["
```

```
                                + ToString(j) + "]",
                                ends1[i], ends2[j]) ;
    }
  }
}
```

All these activities have an input parameter typed by the abstract class AbstractAssertCompositeHelper. This abstract class is extended in following subclauses, to determine if connections exist between two elements. These specific realizations imply Associations defined in corresponding test cases. Figure 25 illustrates the specification of this class where, for both operations assertConnected and assertNotConnected, parameter message is typed by String, and parameters end1 and end2 are not typed.

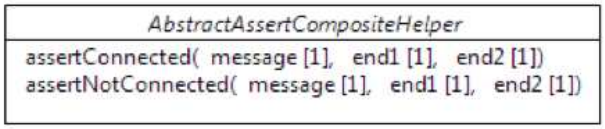


Figure 25: AbstractAssertCompositeHelper

9.2.2 Assembly connector between parts

This test case addresses instantiation semantics in the case of assembly connectors between parts. Structural aspects of this test case are depicted in Figure 26 and Figure 27.

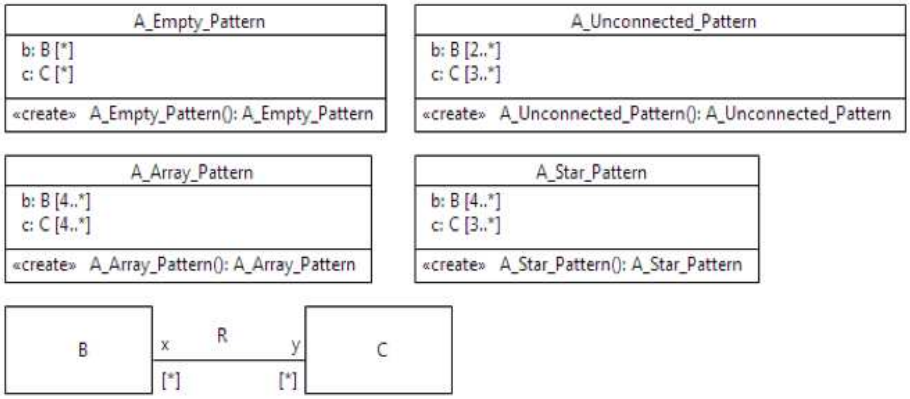


Figure 26: Assembly Connector between parts – Classes

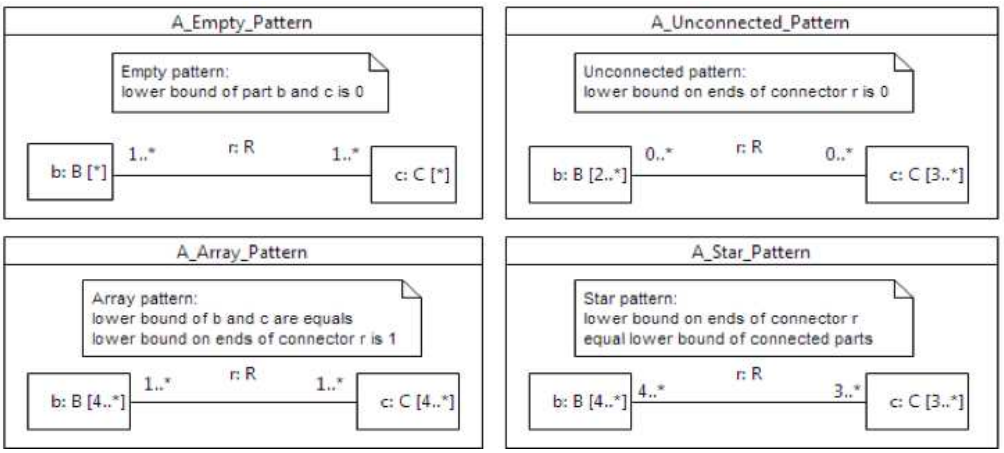


Figure 27: Assembly Connector between parts – Internal Structure

Corresponding test case behavior is:

```
activity TestCase_Assembly_P_P() {
  helper = new AssertCompositeHelper() ;
  WriteLine("-- Running test case: Assembly connector between two parts --") ;

  // Testing instantiation of A_Empty_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Empty_Pattern -") ;
  a_empty = new A_Empty_Pattern();
  AssertEmptyPattern(a_empty.b, a_empty.c) ;

  // Testing instantiation of A_Unconnected_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Unconnected_Pattern -") ;
  a_unconnected = new A_Unconnected_Pattern();
  AssertUnconnectedPattern(a_unconnected.b, a_unconnected.c, 2, 3, helper) ;

  // Testing instantiation of A_Array_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Array_Pattern") ;
  a_array = new A_Array_Pattern();
  AssertArrayPattern(a_array.b, a_array.c, 4, helper) ;

  // Testing instantiation of A_Star_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Star_Pattern") ;
  a_star = new A_Star_Pattern();
  AssertStarPattern(a_star.b, a_star.c, 4, 3, helper) ;

  WriteLine("-- End of test case --") ;
}
```

9.2.3 Assembly connector between a part with port and a part

This test case addresses instantiation semantics in the case of an assembly connector between a part with port and a part. Structural aspects of this test case are depicted in Figure 28 and Figure 29.

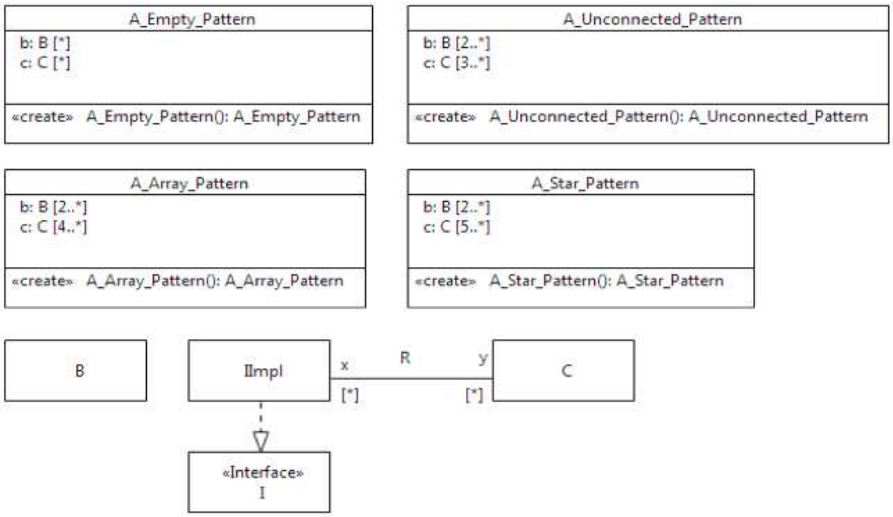


Figure 28: Assembly Connector between part with port and part – Classes

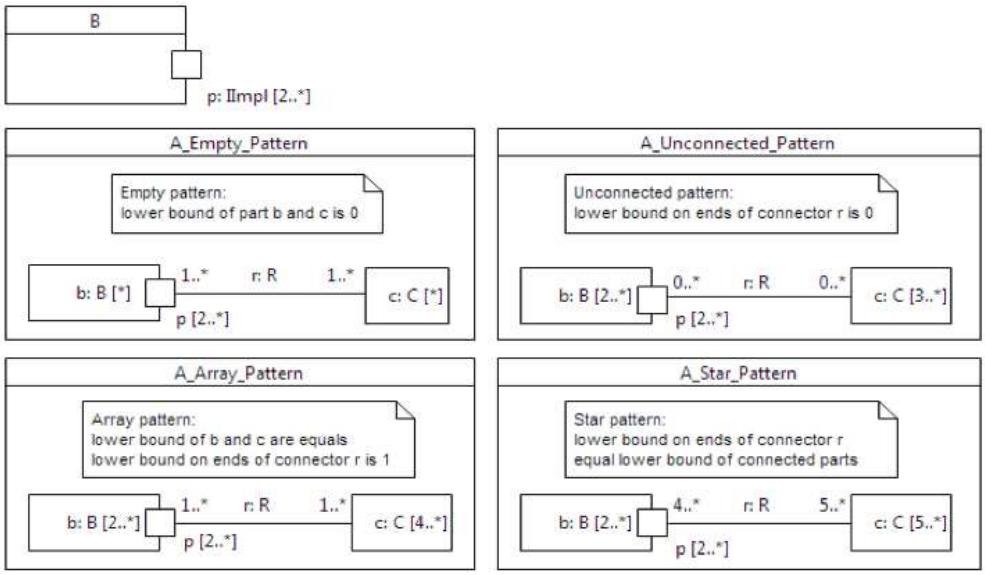


Figure 29: Assembly Connector between part with port and part – Internal structures

Corresponding test case behavior is:

```
activity TestCase_Assembly_PWP_P() {
  helper = new AssertCompositeHelper() ;

  WriteLine("-- Running test case: Assembly connector between a part with port and a part --")
;

  // Testing instantiation of A_Empty_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Empty_Pattern -") ;
  a_empty = new A_Empty_Pattern() ;
  AssertEmptyPattern(a_empty.b, a_empty.c) ;

  // Testing instantiation of A_Unconnected_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Unconnected_Pattern -") ;
  a_unconnected = new A_Unconnected_Pattern();
  AssertUnconnectedPattern(a_unconnected.b.p, a_unconnected.c, 4, 3, helper) ;

  // Testing instantiation of A_Array_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Array_Pattern -") ;
  a_array = new A_Array_Pattern();
  AssertArrayPattern(a_array.b.p, a_array.c, 4, helper) ;

  // Testing instantiation of A_Star_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Star_Pattern -") ;
  a_star = new A_Star_Pattern();
  AssertStarPattern(a_star.b.p, a_star.c, 4, 5, helper) ;
}
```

9.2.4 Assembly connector between a part with port and a part with port

This test case addresses instantiation semantics in the case of an assembly connector between a part with port and a part with port. Structural aspects of this test case are depicted in Figure 30 and Figure 31.

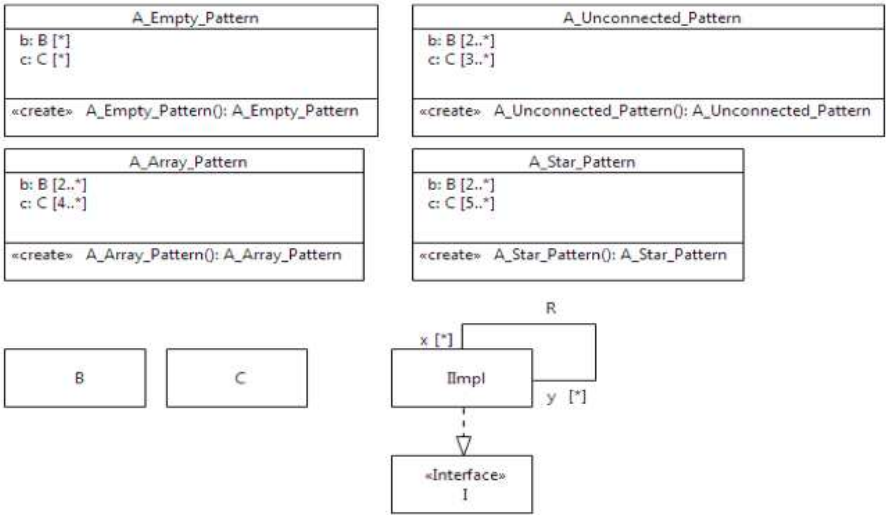


Figure 30: Assembly Connector between part with port and part with port - Classes

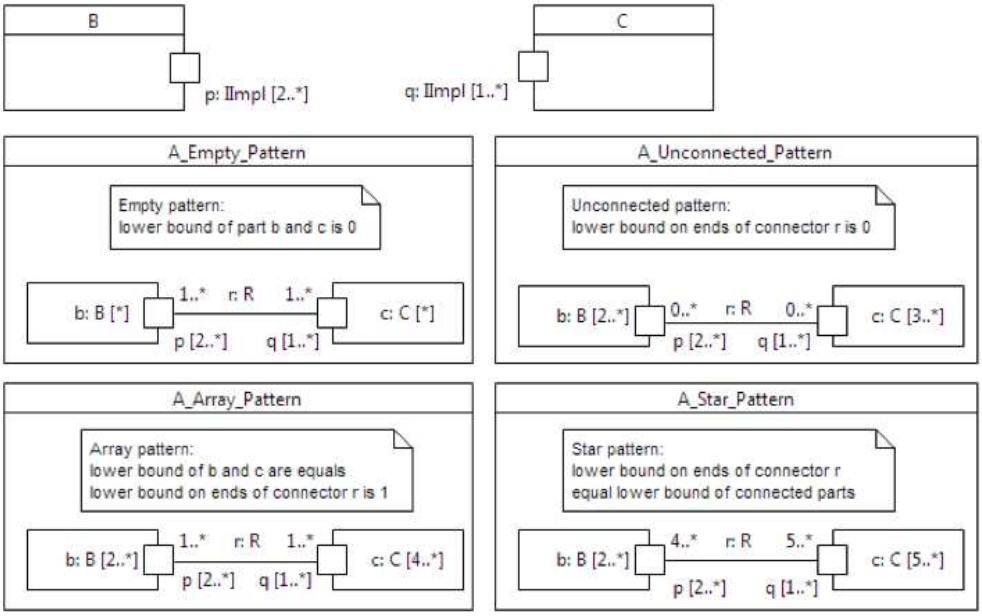


Figure 31: Assembly Connector between part with port and part with port – Internal structures

Corresponding test case behavior is:

```
activity TestCase_Assembly_PWP_PWP () {
  helper = new AssertCompositeHelper() ;

  WriteLine("-- Running test case: Assembly connector between a part with port
             and a part with port --") ;

  // Testing instantiation of A_Empty_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Empty_Pattern -") ;
  a_empty = new A_Empty_Pattern() ;
  AssertEmptyPattern(a_empty.b, a_empty.c) ;

  // Testing instantiation of A_Unconnected_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Unconnected_Pattern -") ;
  a_unconnected = new A_Unconnected_Pattern();
  AssertUnconnectedPattern(a_unconnected.b.p, a_unconnected.c.q, 4, 3, helper) ;
```

```
  // Testing instantiation of A_Array_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Array_Pattern -") ;
  a_array = new A_Array_Pattern();
  AssertArrayPattern(a_array.b.p, a_array.c.q, 4, helper) ;

  // Testing instantiation of A_Star_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Star_Pattern -") ;
  a_star = new A_Star_Pattern();
  AssertStarPattern(a_star.b.p, a_star.c.q, 4, 5, helper) ;
}
```

9.2.5 Default values for basic types

This test case addresses instantiation of default values for properties typed by primitive types and enumerations. Structural aspects of this test case are depicted in Figure 32.

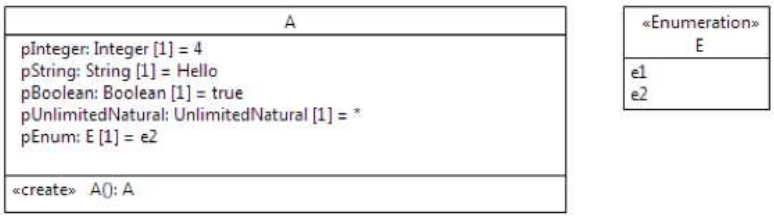


Figure 32: Default values for basic types

Corresponding test case behavior is:

```
activity 'Test Case - Default Values'() {
  WriteLine("-- Running test case - Instantiation of Default values - basic types --") ;
  a = new A() ;
  AssertEquals("Default value of a.pInteger", a.pInteger, 4) ;
  AssertEquals("Default value of a.pString", a.pString, "Hello") ;
  AssertEquals("Default value of a.pBoolean", a.pBoolean, true) ;
  AssertEquals("Default value of a.pUnlimitedNatural", a.pUnlimitedNatural, *) ;
  AssertEquals("Default value of a.pEnum", a.pEnum, E::e2) ;
  WriteLine("-- End of test case --") ;
}
```

9.2.6 Default values for structures

This test case addresses instantiation of default values for properties typed by composite structures. Structural aspects of this test case are depicted in Figure 33.

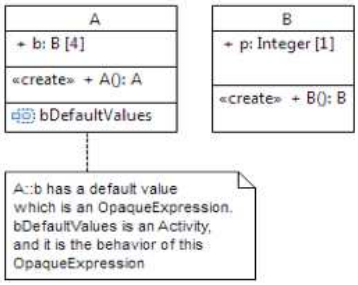


Figure 33: Default values for structures

Detailed behavior of Activity bDefaultValues is:

```
activity bDefaultValues() : B[]{
```

```
        b1 = new B() ; b1.p = 1 ;
        b2 = new B() ; b2.p = 2 ;
        b3 = new B() ; b3.p = 3 ;
        b4 = new B() ; b4.p = 4 ;
        return new B[]{b1, b2, b3, b4} ;
}
```

Corresponding test case behavior is:

```
activity 'Test Case - Default Values - Structures'() {
  WriteLine("-- Running test case - Instantiation of Default values - Structures --") ;
  a = new A() ;
  AssertEquals("Default value of a.b[1].p", a.b[1].p, 1) ;
  AssertEquals("Default value of a.b[2].p", a.b[2].p, 2) ;
  AssertEquals("Default value of a.b[3].p", a.b[3].p, 3) ;
  AssertEquals("Default value of a.b[4].p", a.b[4].p, 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.2.7 Delegation between a port and a part

This test case addresses instantiation semantics in the case of a delegation connector between a port and a part. Structural aspects of this test case are depicted in Figure 34 and Figure 35.

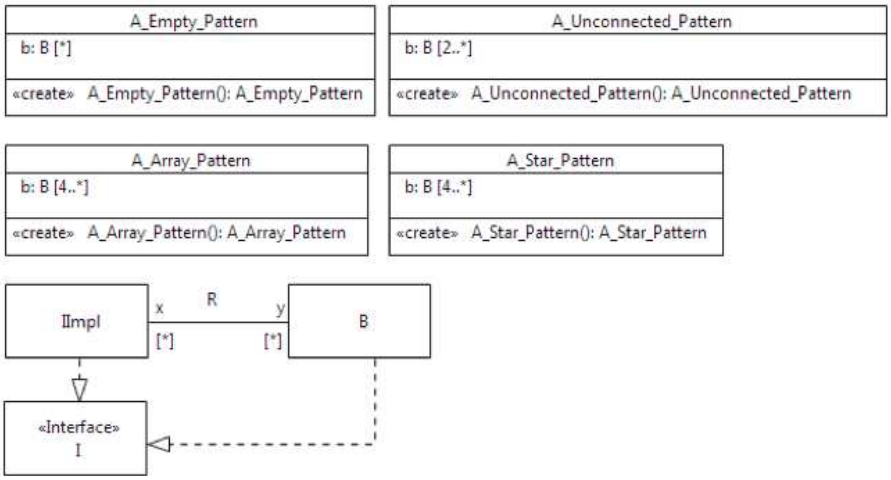


Figure 34: Delegation between port and part – Classes

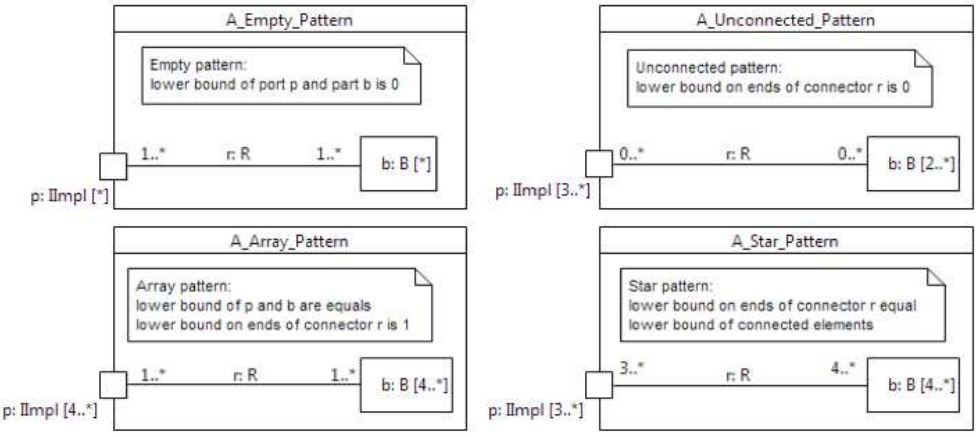


Figure 35: Delegation between port and part – Internal structures

Corresponding test case behavior is:

```
activity TestCase_Delegation_Port_P() {
  helper = new AssertCompositeHelper() ;

  WriteLine("-- Running test case: Delegation connector between a port and a part --") ;

  a = new A_Array_Pattern() ;

  // Testing instantiation of A_Empty_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Empty_Pattern -") ;
  a_empty = new A_Empty_Pattern();
  AssertEmptyPattern(a_empty.p, a_empty.b) ;

  // Testing instantiation of A_Unconnected_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Unconnected_Pattern -") ;
  a_unconnected = new A_Unconnected_Pattern();
  AssertUnconnectedPattern(a_unconnected.p, a_unconnected.b, 3, 2, helper) ;

  // Testing instantiation of A_Array_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Array_Pattern") ;
  a_array = new A_Array_Pattern();
  AssertArrayPattern(a_array.p, a_array.b, 4, helper) ;

  // Testing instantiation of A_Star_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Star_Pattern") ;
  a_star = new A_Star_Pattern();
  AssertStarPattern(a_star.p, a_star.b, 3, 4, helper) ;

}
```

9.2.8 Delegation between a port and a part with port

This test case addresses instantiation semantics in the case of a delegation connector between a port and a part with port. Structural aspects of this test case are depicted in Figure 36 and Figure 37.

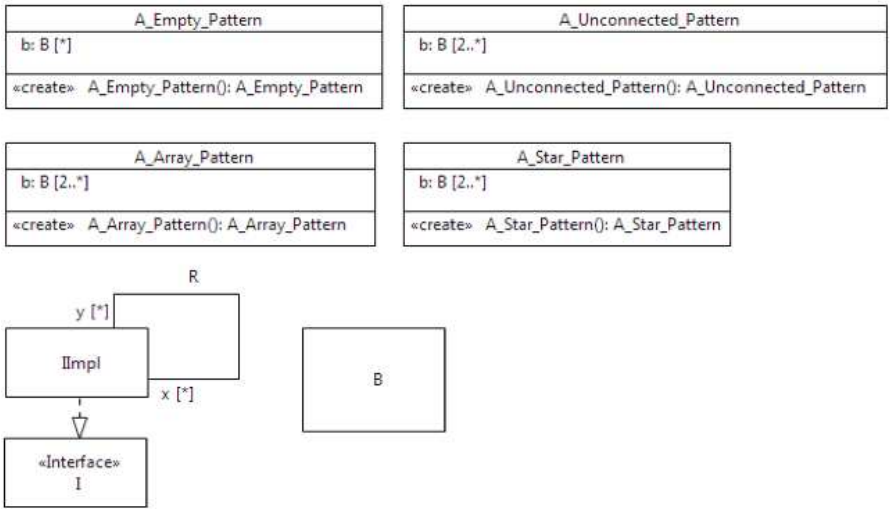


Figure 36: Delegation between a port and a part with port – Classes

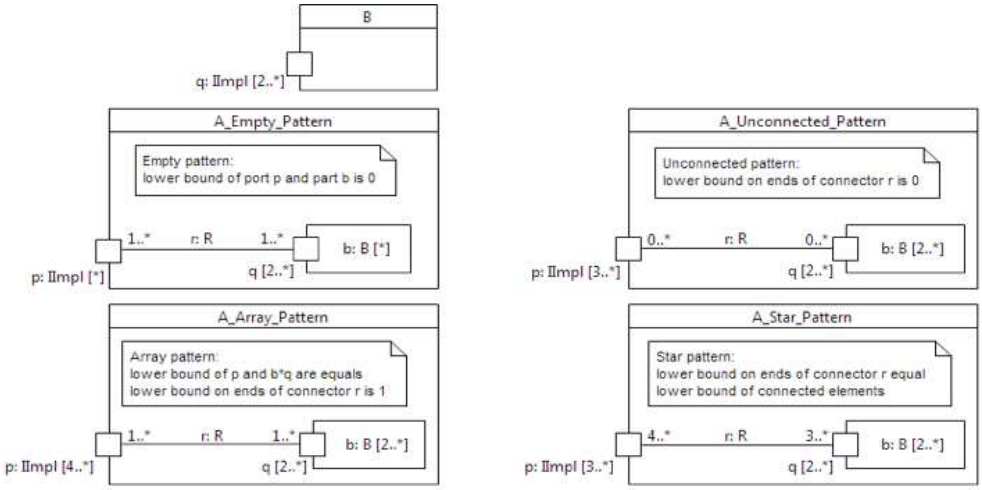


Figure 37: Delegation between a port and part with port – Internal structures

Corresponding test case behavior is:

```
activity TestCase_Assembly_Port_PWP() {
  helper = new AssertCompositeHelper() ;

  WriteLine("-- Running test case: Delegation connector between a port and a part with port --
") ;

  // Testing instantiation of A_Empty_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Empty_Pattern -") ;
  a_empty = new A_Empty_Pattern();
  AssertEmptyPattern(a_empty.p, a_empty.b) ;

  // Testing instantiation of A_Unconnected_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Unconnected_Pattern -") ;
  a_unconnected = new A_Unconnected_Pattern();
  AssertUnconnectedPattern(a_unconnected.p, a_unconnected.b.q, 3, 4, helper) ;

  // Testing instantiation of A_Array_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Array_Pattern -") ;
  a_array = new A_Array_Pattern();
  AssertArrayPattern(a_array.p, a_array.b.q, 4, helper) ;

  // Testing instantiation of A_Star_Pattern
  WriteLine("") ;
  WriteLine("- Testing instantiation of A_Star_Pattern -") ;
  a_star = new A_Star_Pattern();
  AssertStarPattern(a_star.p, a_star.b.q, 3, 4, helper) ;

}
```

9.2.9 Hierarchy

This test case addresses instantiation a composite structure with multiple hierarchy levels. Structural aspects of this test case are depicted in Figure 38.

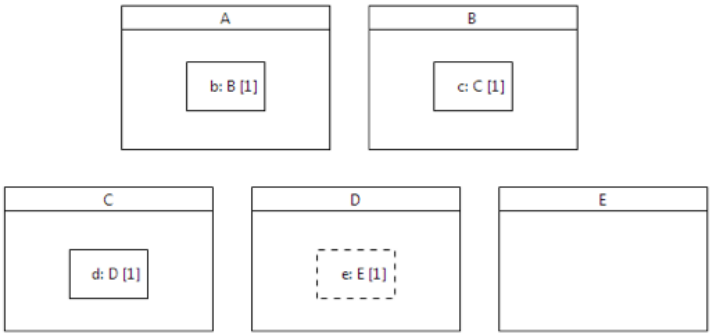


Figure 38: Hierarchy

Corresponding test case behavior is:

```
activity TestCase_Hierarchy() {
  WriteLine("-- Running test case: Hierarchical instantiation --") ;
  a = new A() ;
  // a.b is not empty
  WriteLine("") ;
  AssertTrue("a.b is not empty", ListSize(a.b) > 0) ;
  // a.b.c is not empty
  AssertTrue("a.b.c is not empty", ListSize(a.b.c) > 0) ;
  // a.b.c.d is not empty
  AssertTrue("a.b.c.d is not empty", ListSize(a.b.c.d) > 0) ;
  // a.b.c.d.e is empty (e is shared, not composite)
  AssertTrue("a.b.c.d.e is empty", ListSize(a.b.c.d.e) == 0) ;
}
```

9.2.10 Variants of Test Suite 1

The normative Test Suite model contains a variant of Test Suite 1 (package Test Suite 1 – Bis, depicted in Figure 24), which contains variants of test cases 9.2.3, 9.2.4, 9.2.7, and 9.2.8. In these variants, ports are typed by Interfaces.

9.3 Test Suite 2: Communication

This test suite focuses on communication semantics of UML Composite Structures. Subclause 9.3.1 addresses reception of signals on behavior ports. Subclause 9.3.2 addresses loss of messages in case of operation calls received on a non-behavior port without delegation connectors. Subclauses 9.3.3, 9.3.4, 9.3.5, and 9.3.6 address forwarding of messages in case of a single delegation link. Subclauses 9.3.7, 9.3.8, 9.3.9, and 9.3.10 address forwarding of messages across multiple links, corresponding to a single connector. Finally, subclauses 9.3.11, 9.3.12, 9.3.13, and 9.3.14address forwarding of messages across multiple links, each link corresponding to a particular connector. Subclause 9.3.15 describes variants of Test Suite 2 where connectors are not typed and/or ports are typed by interfaces.

9.3.1 BehaviorPort – Signal

This test case addresses reception of a signal on a behavior port. If the signal is correctly dispatched to the classifier behavior of the receiving object, some assertions can be validated. Structural aspects of this test case are depicted in Figure 39 and Figure 40.

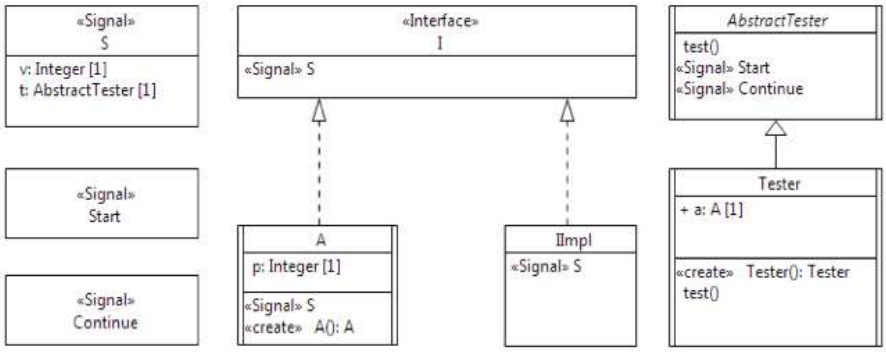


Figure 39: Behavior port Signal – Classes, Signals and Interfaces

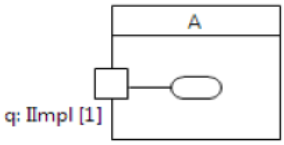


Figure 40: Behavior port Signal – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - BehaviorPort - Signal'() {
  // Instantiate Tester
  t = new Tester() ;
  t.Start() ;
}
```

Classifier behavior of Tester is:

```
activity TesterClassifierBehavior() {
  accept(Start) ;
  this.a.q.S(4, this) ;
  accept(Continue) ;
  this.test() ;
}
```

Method of Tester::test is:

```
activity test() {
  WriteLine("-- Running test case: Reception of a Signal on a behavior port --") ;
  AssertTrue("Signal delegated to classifier behavior", this.a.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

Classifier behavior of A is:

```
activity AClassifierBehavior() {
  accept (s : S) {
    this.p = s.v ;
    s.t.Continue() ;
  }
}
```

9.3.2 Loss of Messages – Operation

This test case addresses loss of an operation call on non-behavior port with no delegation connector. If the operation call is not forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 41 and Figure 42.

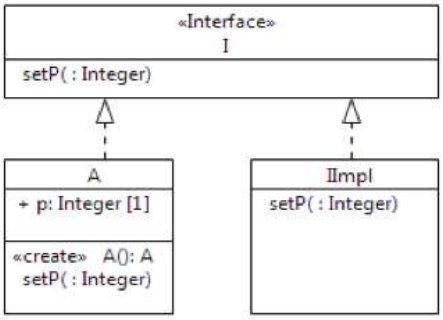


Figure 41: Loss of messages – Casses and Interfaces

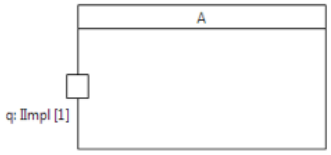


Figure 42: Loss of messages – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - Loss of Messages - Operation'() {
  WriteLine("-- Running test case: Loss of Operation call on
             non-behavior ports with no delegation connector --") ;
  a = new A() ;
  a.q.setP(4) ;
  AssertFalse("Operation call received", a.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

Method of A::setP is:

```
activity setP(in v : Integer) {
       this.p = v ;
}
```

9.3.3 Single Delegation – PortToPart – Operation

This test case addresses forwarding of an operation through a single delegation link, corresponding to a single connector. If the operation call is forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 43 and Figure 44.

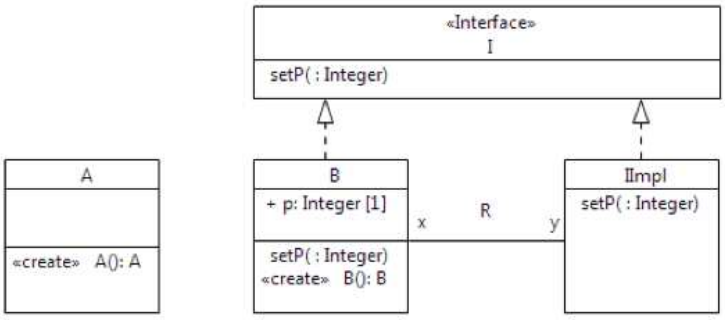


Figure 43: Single Delegation from Port to Part (Operation) – Classes and Interfaces

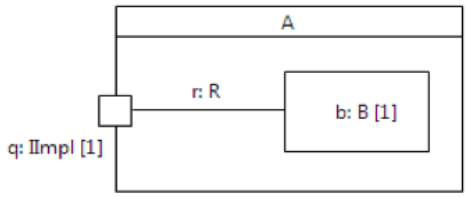


Figure 44: Single Delegation from Port to Part (Operation) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - SingleDelegation - PortToPart - Operation'() {
  WriteLine("-- Running test case: Single delegation connector -
             Operation delegated from port to part --") ;
  a = new A() ;
  a.q.setP(4) ;
  AssertTrue("Operation call delegated", a.b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

Method of B::setP is:

```
activity setP(in v : Integer) {
  this.p = v ;
}
```

9.3.4 Single Delegation – PortToPart – Signal

This test case addresses forwarding of a signal through a single delegation link, corresponding to a single connector. If the signal is correctly forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 45 and Figure 46.

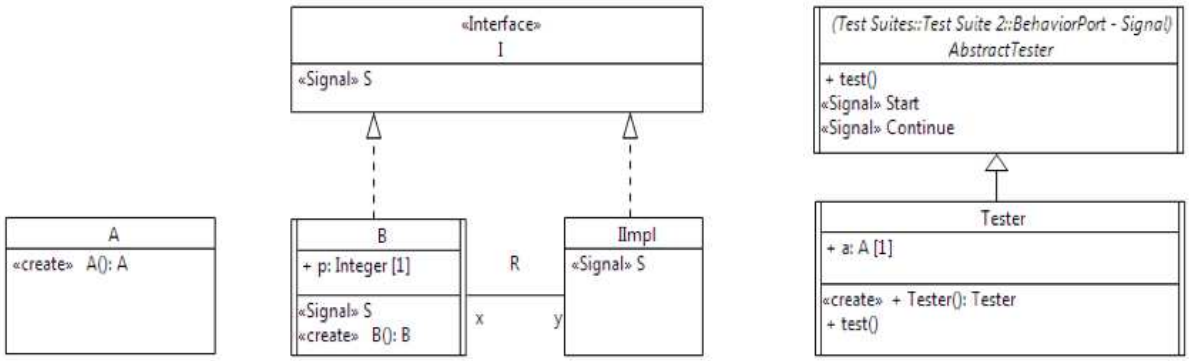


Figure 45: Single Delegation from Port to Part (Signal) – Classes, Signals and Interfaces

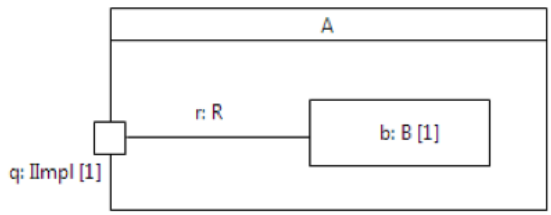


Figure 46: Single Delegation from Port to Part (Signal) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - BehaviorPort - Signal'() {
  // Instantiate Tester
  t = new Tester() ;
  t.Start() ;
}
```

Classifier behavior of Tester is:

```
activity TesterClassifierBehavior() {
  accept(Start) ;
  this.a.q.S(4, this) ;
  accept(Continue) ;
  this.test() ;
}
```

Method of Tester::test is:

```
activity test() {
  WriteLine("-- Running test case: Single delegation connector -
             Signal delegated from port to part --") ;
  AssertTrue("Signal delegated to classifier behavior", this.a.b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

Classifier behavior of B is:

```
activity BClassifierBehavior() {
  accept (s : S) {
    this.p = s.v ;
    s.t.Continue() ;
  }
}
```

9.3.5 Single Delegation – PortToPartWithPort – Operation

This test case addresses forwarding of an operation call through a single delegation link, corresponding to a single connector, expressed between a port and a part with port. If the operation call is forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 47 and Figure 48. Note that classes A and B are reused from 9.3.3.

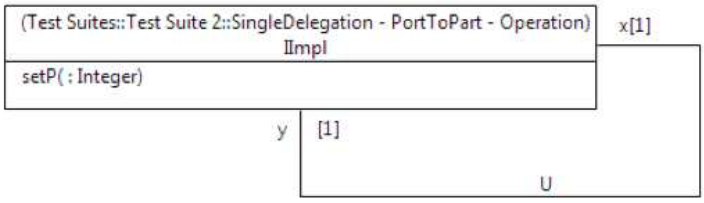


Figure 47: Single Delegation from Port to Part with Port (Operation) – Classes and Interfaces

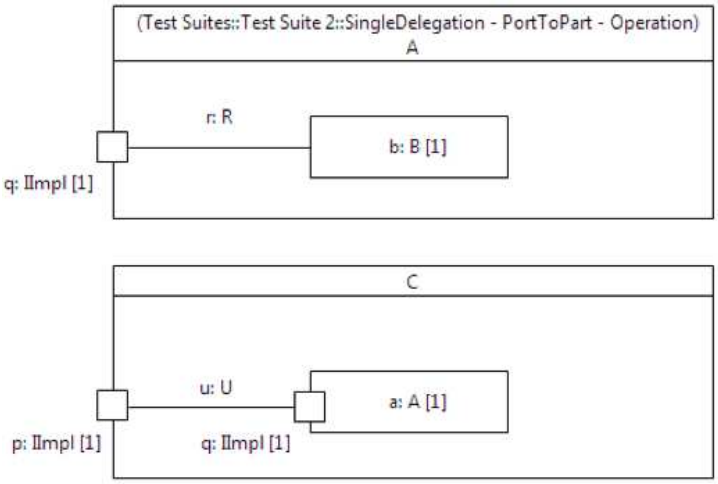


Figure 48: Single Delegation from Port to Part with Port (Operation) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - SingleDelegation - PortToPWP - Operation'() {
  WriteLine("-- Running test case: Single delegation connector -
            Operation delegated from port to part with port --") ;
  c = new C() ;
  c.p.setP(4) ;
  AssertTrue("Operation call delegated", c.a.b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.3.6 Single Delegation – PortToPartWithPort – Signal

This test case addresses forwarding of a signal through a single delegation link, corresponding to a single connector, expressed between a port and a part with port. If the signal is correctly forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 49 and Figure 50. Note that classes A and B are reused from 9.3.4.

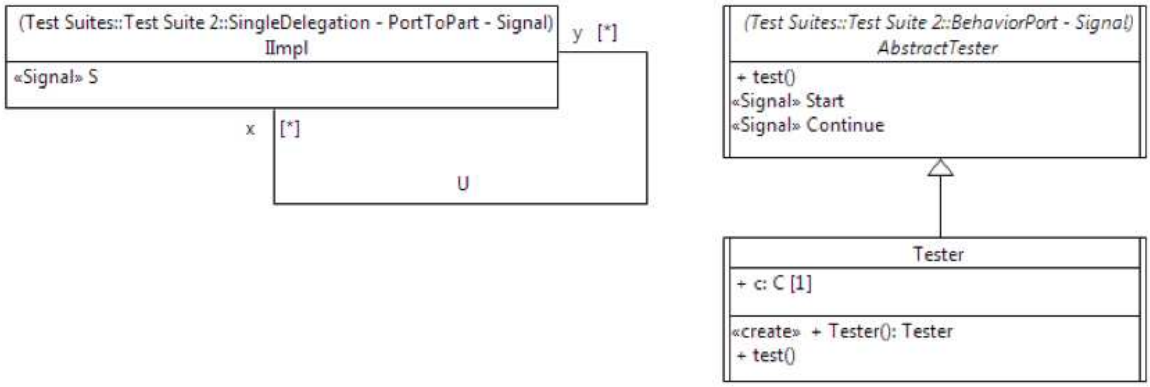


Figure 49: Single Delegation from Port to Part with Port (Signal) – Classes, Signals and Interfaces

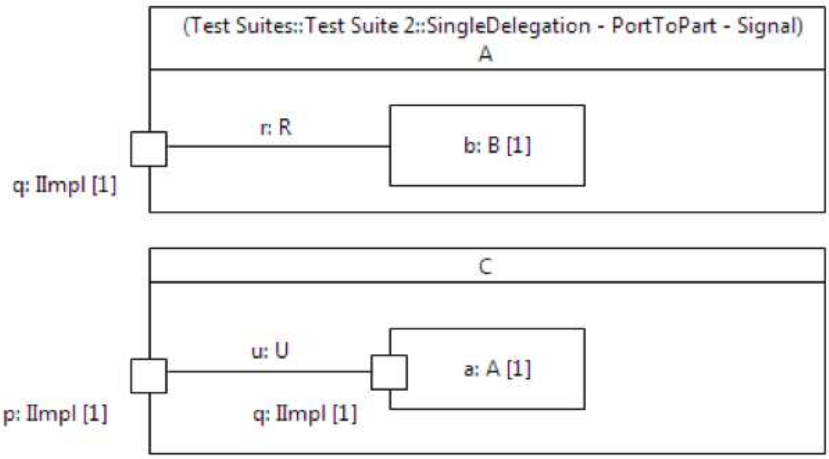


Figure 50: Single Delegation from Port to Part with Port (Signal) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - SingleDelegation - PortToPWP - Signal'() {
  t = new Tester() ;
  t.Start() ;
}
```

Classifier behavior of Tester is:

```
activity TesterClassifierBehavior() {
  accept(Start) ;
  this.c.p.S(4, this) ;
  accept(Continue) ;
  this.test() ;
}
```

Method of Tester::test is:

```
activity test() {
  WriteLine("-- Running test case: Single delegation connector -
             Signal delegated from port to part with port --") ;
  AssertTrue("Signal delegated", this.c.a.b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.3.7 Multiple Delegation – SameConnector – PortToPart – Operation

This test case addresses forwarding of an operation call in presence of multiple delegation links, corresponding to a single connector, expressed between a port and a part. If the operation call is forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 51. Note that classes B and IImpl are reused from 9.3.3.

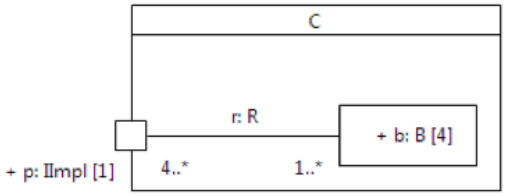


Figure 51: Multiple Delegation with Single Connector from Port to Part (Operation) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - MultipleDelegation - SameConnector - PortToPart - Operation'() {
  WriteLine("-- Running test case: Single delegation connector -
             Multiple links - Operation delegated from port to part --") ;
  c = new C() ;
  c.p.setP(4) ;
  AssertTrue("Operation call delegated", c.b[1].p == 4 || c.b[2].p == 4
                                      || c.b[3].p == 4 || c.b[4].p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.3.8 Multiple Delegation – SameConnector – PortToPart – Signal

This test case addresses forwarding of a signal through multiple delegation links, corresponding to a single connector, expressed between a port and a part. If the signal is correctly forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 52 and Figure 53. Note that classes A and B are reused from 9.3.4.

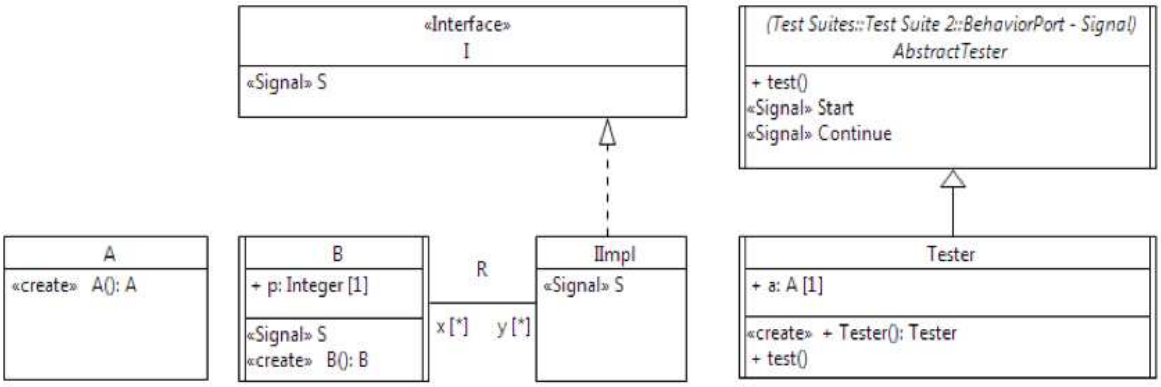


Figure 52: Multiple Delegations with Single Connector from Port to Part (Signal) – Classes, Signals and Interfaces

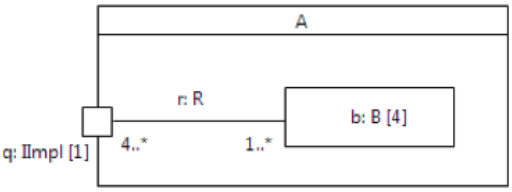


Figure 53: Multiple Delegations with Single Connector from Port to Part (Signal) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - MultipleDelegation - SameConnector - PortToPart - Signal'() {
  t = new Tester() ;
  t.Start() ;
}
```

Classifier behavior of Tester is:

```
activity TesterClassifierBehavior() {
  accept(Start) ;
  this.a.q.S(4, this) ;
  accept(Continue) ;
  accept(Continue) ;
  accept(Continue) ;
  accept(Continue) ;
  this.test() ;
}
```

Method of Tester::test is:

```
activity test() {
  WriteLine("-- Running test case: Single delegation connector -
            Multiple links - Signal delegated from port to part --") ;
  AssertTrue("Signal delegated on all links (shall be true for default strategy)",
             this.a.b[1].p == 4 && this.a.b[2].p == 4
           && this.a.b[3].p == 4 && this.a.b[4].p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.3.9 Multiple Delegation – SameConnector – PortToPartWithPort – Operation

This test case addresses forwarding of an operation call in presence of multiple delegation links, corresponding to a single connector, expressed between a port and a part with port. If the operation call is forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 54. Note that classes A and IImpl are reused from 9.3.3.

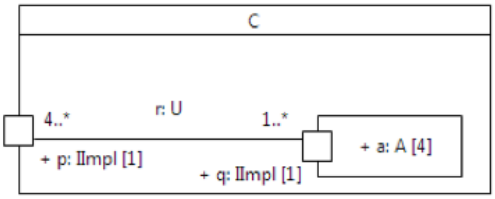


Figure 54: Multiple Delegation with Single Connector from Port to Part with Port (Operation) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - MultipleDelegation - SameConnector - PortToPWP - Operation'() {
  WriteLine("-- Running test case: Single delegation connector -
             Multiple links - Operation delegated from port to part with port--") ;
  c = new C() ;
  c.p.setP(4) ;
  AssertTrue("Operation call delegated", c.a[1].b.p == 4 || c.a[2].b.p == 4
                                      || c.a[3].b.p == 4 || c.a[4].b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.3.10 Multiple Delegation – SameConnector – PortToPartWithPort – Signal

This test case addresses forwarding of a signal through multiple delegation links, corresponding to a single connector, expressed between a port and a part with port. If the signal is correctly forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 55 and Figure 56. Note that classes A and IImpl are reused from 9.3.4.

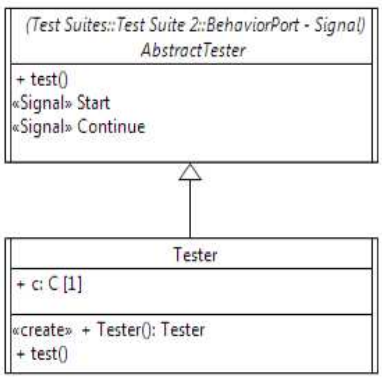


Figure 55: Multiple Delegations with Single Connector from Port to Part with Port (Signal) – Classes, Signals and Interfaces

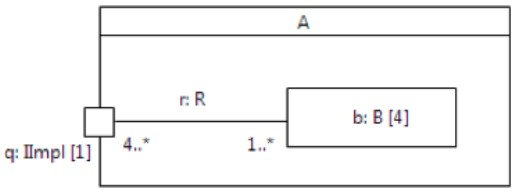


Figure 56: Multiple Delegations with Single Connector from Port to Part with Port (Signal) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - MultipleDelegation - SameConnector - PortToPWP - Signal'() {
  t = new Tester() ;
  t.Start() ;
}
```

Classifier behavior of Tester is:

```
activity TesterClassifierBehavior() {
  accept(Start) ;
  this.c.p.S(4, this) ;
  accept(Continue) ;
  accept(Continue) ;
  accept(Continue) ;
  accept(Continue) ;
  this.test() ;
}
```

Method of Tester::test is:

```
activity test() {
  WriteLine("-- Running test case: Single delegation connector -
             Multiple links - Signal delegated from port to part with port --") ;
  AssertTrue("Signal delegated on all links (shall be true for default strategy)",
             this.c.a[1].b.p == 4 && this.c.a[2].b.p == 4
          && this.c.a[3].b.p == 4 && this.c.a[4].b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.3.11 Multiple Delegation – MultipleConnector – PortToPart – Operation

This test case addresses forwarding of an operation call in presence of multiple delegation links, each link corresponding to a particular connector, expressed between a port and a part. If the operation call is forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 57 and Figure 58. Note that classes B and IImpl are reused from 9.3.3.

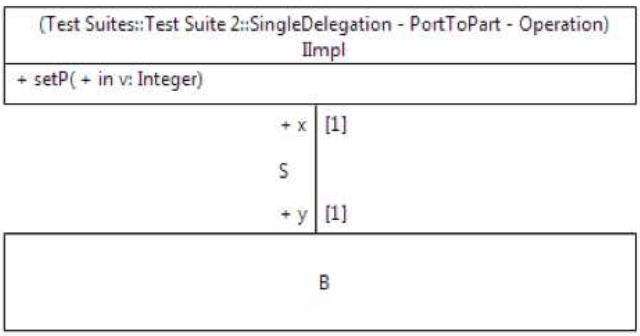


Figure 57: Multiple Delegations with Multiple Connectors from Port to Part (Operation) – Classes

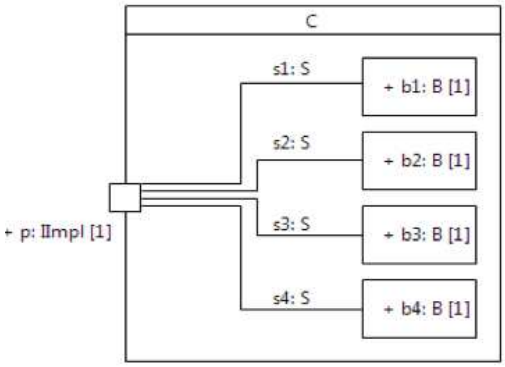


Figure 58: Multiple Delegations with Multiple Connectors from Port to Part (Operation) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - MultipleDelegation - MultipleConnectors - PortToPart - Operation'() {
  WriteLine("-- Running test case: Multiple delegation connectors -
             Multiple links - Operation delegated from port to part --") ;
  c = new C() ;
  c.p.setP(4) ;
  AssertTrue("Operation call delegated", c.b1.p == 4 || c.b2.p == 4 || c.b3.p == 4 || c.b4.p
== 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.3.12 Multiple Delegation – MultipleConnector – PortToPart – Signal

This test case addresses forwarding of a signal through multiple delegation links, each link corresponding to a particular connector, expressed between a port and a part. If the signal is correctly forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 59 and Figure 60. Note that classes A and B are reused from 9.3.4.

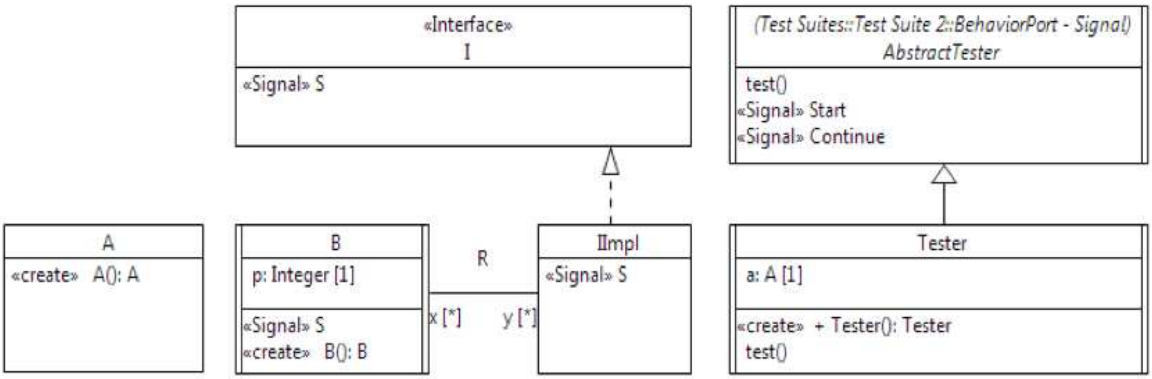


Figure 59: Multiple Delegations with Multiple Connectors from Port to Part (Signal) – Classes, Signals and Interfaces

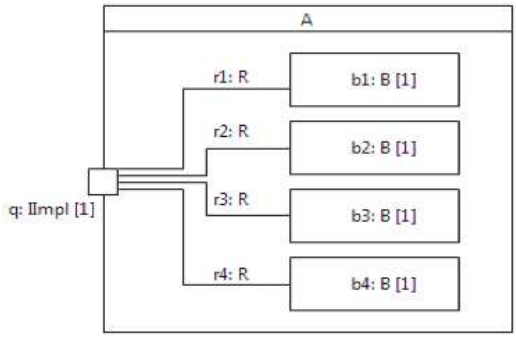


Figure 60: Multiple Delegations with Multiple Connectors from Port to Part (Signal) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - MultipleDelegation - MultipleConnectors - PortToPart - Signal'() {
  t = new Tester() ;
  t.Start() ;
}
```

Classifier behavior of Tester is:

```
activity TesterClassifierBehavior() {
  accept(Start) ;
  this.a.q.S(4, this) ;
  accept(Continue) ;
  accept(Continue) ;
  accept(Continue) ;
  accept(Continue) ;
  this.test() ;
}
```

Method of Tester::test is:

```
activity test() {
  WriteLine("-- Running test case: Multiple delegation connectors -
             Multiple links - Signal delegated from port to part --") ;
  AssertTrue("Signal delegated on all links (shall be true for default strategy)",
             this.a.b1.p == 4 && this.a.b2.p == 4
          && this.a.b3.p == 4 && this.a.b4.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.3.13 Multiple Delegation – MultipleConnector – PortToPartWithPort – Operation

This test case addresses forwarding of an operation call in presence of multiple delegation links, each link corresponding to a particular connector, expressed between a port and a part with port. If the operation call is forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 61. Note that classes A and IImpl are reused from 9.3.3.

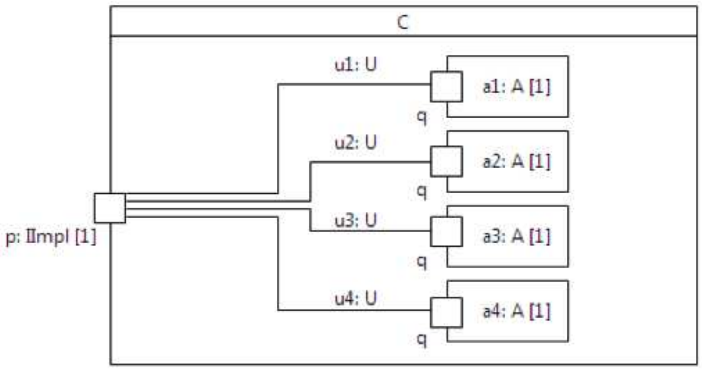


Figure 61: Multiple Delegation with Multiple Connectors from Port to Part with Port (Operation) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - MultipleDelegation - MultipleConnectors - PortToPWP - Operation'() {
  WriteLine("-- Running test case: Multiple delegation connectors -
             Multiple links - Operation delegated from port to part with port --") ;
  c = new C() ;
  c.p.setP(4) ;
  AssertTrue("Operation call delegated", c.a1.b.p == 4 || c.a2.b.p == 4
                                      || c.a3.b.p == 4 || c.a4.b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.3.14 Multiple Delegation – MultipleConnector – PortToPartWithPort – Signal

This test case addresses forwarding of a signal through multiple delegation links, each link corresponding to a particular connector, expressed between a port and a part with port. If the signal is correctly forwarded, some assertions can be validated. Structural aspects of this test case are depicted in Figure 62 and Figure 63. Note that classes A and IImpl are reused from 9.3.4.

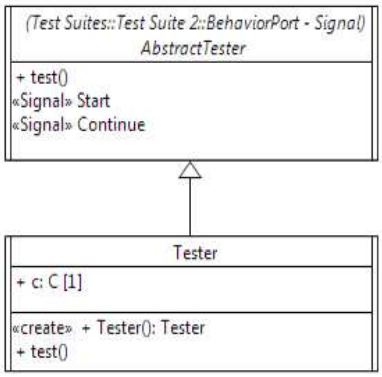


Figure 62: Multiple Delegations with Multiple Connectors from Port to Part with Port (Signal) – Classes

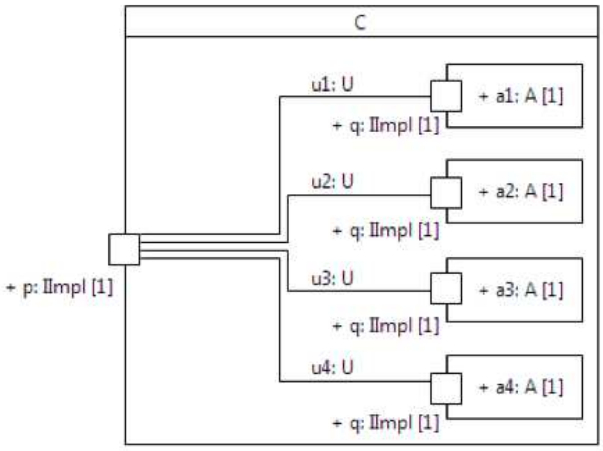


Figure 63: Multiple Delegations with Multiple Connectors from Port to Part with Port (Signal) – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - MultipleDelegation - MultipleConnectors - PortToPWP - Signal'() {
  t = new Tester() ;
  t.Start() ;
}
```

Classifier behavior of Tester is:

```
activity TesterClassifierBehavior() {
  accept(Start) ;
  this.c.p.S(4, this) ;
  accept(Continue) ;
  accept(Continue) ;
  accept(Continue) ;
  accept(Continue) ;
  this.test() ;
}
```

Method of Tester::test is:

```
activity test() {
       WriteLine("-- Running test case: Multiple delegation connectors -
                  Multiple links - Signal delegated from port to part with port --") ;
  AssertTrue("Signal delegated on all links (shall be true for default strategy)",
              this.c.a1.b.p == 4 && this.c.a2.b.p == 4
           && this.c.a3.b.p == 4 && this.c.a4.b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.3.15 Variants of Test Suite 2

The normative Test Suite model contains 3 variants of Test Suite 2 (packages Tests Suite 2 - Bis, - Ter, - Quater, depicted in Figure 24), which contain variants of all Test Suite 2 test cases. Test Suite 2 - Bis contains variants where connectors are not typed. Test Suite 2 - Ter contains variants where ports are typed by interfaces. Test Suite 2 - Quater contains variants where connectors are not typed and ports are typed by interfaces.

9.4 Test Suite 3: Communication (onPort)

This test suite focuses on communication semantics of UML Composite Structures, in the cases where property onPort of InvocationAction is used. Subclause 9.4.1 introduces Classes, Interfaces and Associations which are shared amongst the various test cases involving operation calls. The test cases are described in subclauses 9.4.2,

9.4.3, 9.4.4, and 9.4.5. Subclause 9.4.6 introduces Classes, Signals, Interfaces and Associations which are shared amongst the various test cases involving signals. These test cases are described in subclauses 9.4.7 and 9.4.8. Subclause 9.4.9 describes variants of Test Suite 3 where connectors are not typed and/or ports are typed by interfaces.

9.4.1 Operation common

Classes, Interfaces and Associations shared amongst test cases of Test Suite 3 involving operation calls are depicted in Figure 64.

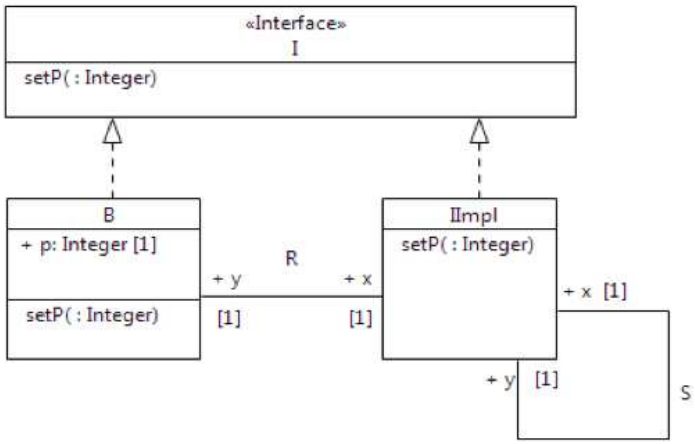


Figure 64: Classes, Interfaces and Associations shared amongst test cases of Test Suite 3 involving operation calls

Method of B::setP is:

```
activity setP(in v : Integer) {
  this.p = v ;
}
```

9.4.2 Operation on Provided Interface

This test case addresses invocation of an Operation on a provided interface of a Port. If the operation call is forwarded into the port's owner, some assertions can be validated. Structural aspects of this test case are depicted in Figure 65 and Figure 66.

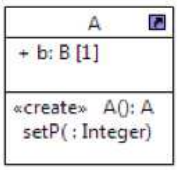


Figure 65: Operation on a Provided Interface – Classes

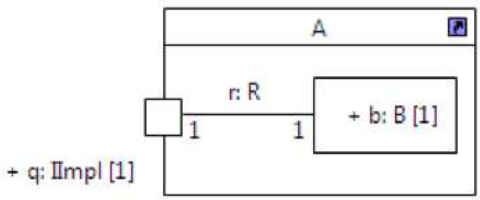


Figure 66: Operation on a Provided Interface – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - Feature on Provided Interface'() {
  WriteLine("-- Running test case: Feature on Provided Interface --") ;
  a = new A() ;
  a.setP(4) ;
  AssertTrue("Invocation made into a through q", a.b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

Method of A::setP is depicted in the Activity diagram of Figure 67.

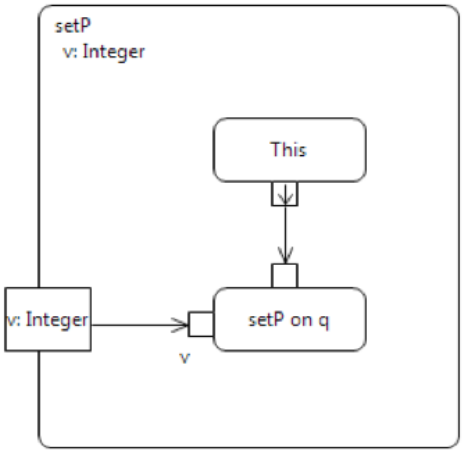


Figure 67: Method of A::setP

9.4.3 Operation on Required Interface

This test case addresses invocation of an Operation on a required interface of a Port. If the operation call is forwarded outside of the port's owner, some assertions can be validated. Structural aspects of this test case are depicted in Figure 68 and Figure 69. Note that class A is reused from 9.4.2.

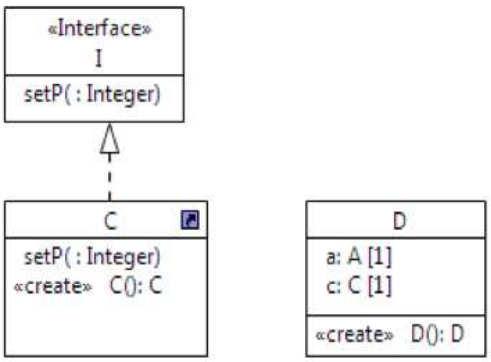


Figure 68: Operation on a Required Interface – Classes

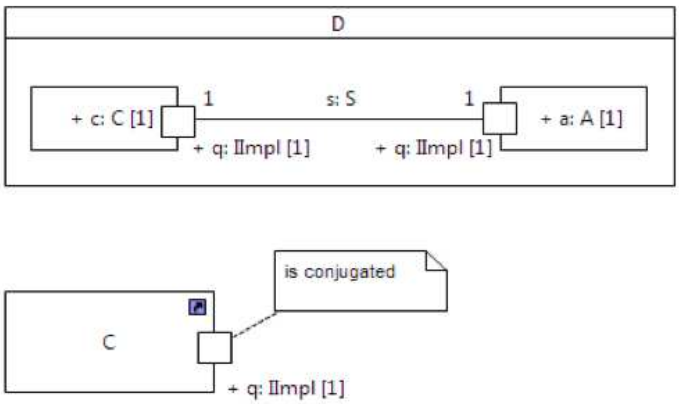


Figure 69: Operation on a Required Interface – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - Feature on Required Interface'() {
  WriteLine("-- Running test case: Feature on Required Interface --") ;
  d = new D() ;
  d.c.setP(4) ;
  AssertTrue("Invocation forwarded out of c through q", d.a.b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

Method of C::setP is depicted in the Activity diagram of Figure 70.

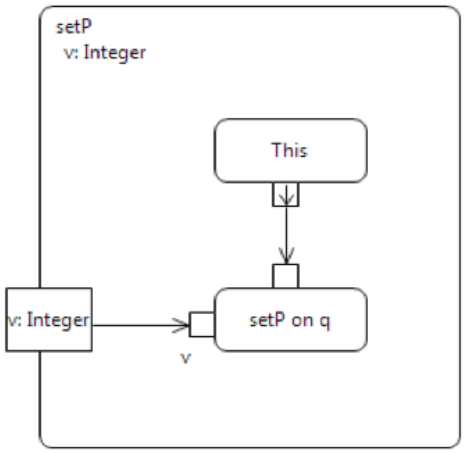


Figure 70: Method of C::setP

9.4.4 Operation on Both Provided and Required Interface

This test case addresses invocation of an Operation which is both on a provided and a required interface of a Port. If the operation call is forwarded outside of the port's owner (i.e., in the test case, the invocation is made inside of the port's owner), some assertions can be validated. Structural aspects of this test case are depicted in Figure 71 and Figure 72. Note that classes A and C is reused from 9.4.3.

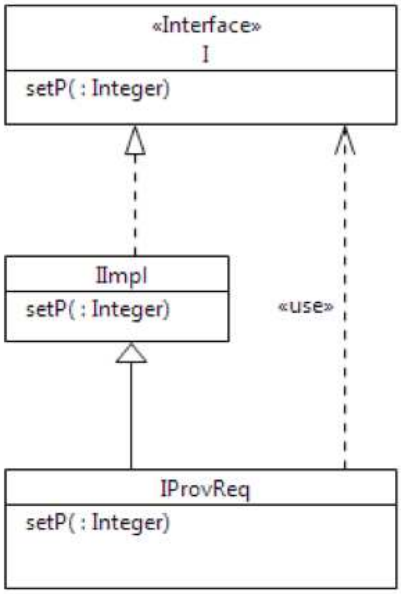


Figure 71: Operation on both Provided and Required Interface – Classes

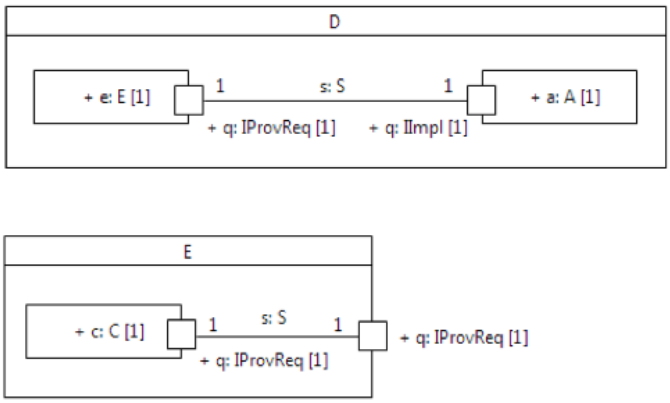


Figure 72: Operation on Both Provided and Required Interface – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - Feature on both Required and Provided Interface'() {
  WriteLine("-- Running test case: Feature on both Required and Provided Interface --") ;
  d = new D() ;
  d.e.c.setP(4) ;
  AssertTrue("Invocation forwarded out of e through q", d.a.b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.4.5 Operation on Required Interface with Delegation Chain

This test case addresses invocation of an Operation on a required interface of a Port, with a chain of delegation and assembly connectors. If the operation call is forwarded outside of the port's owner following appropriate connectors, some assertions can be validated. Structural aspects of this test case are depicted in Figure 73 and Figure 74. Note that classes A and C is reused from 9.4.3.

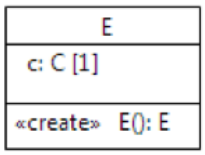
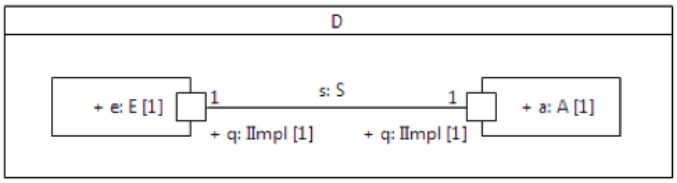


Figure 73: Operation on a Required Interface with Delegation Chain – Classes



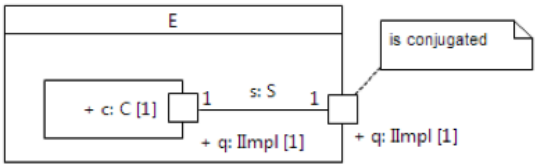


Figure 74: Operation on a Required Interface with Delegation Chain – Internal structures

Corresponding test case behavior is:

```
activity 'Test case - Feature on Required Interface with Delegation Chain'() {
  WriteLine("-- Running test case: Feature on Required Interface with Delegation Chain--") ;
  d = new D() ;
  d.e.c.setP(4) ;
  AssertTrue("Invocation forwarded out of e through q", d.a.b.p == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.4.6 Signal common

Classes, Signals, Interfaces and Associations shared amongst test cases of Test Suite 3 involving signals are depicted in Figure 75 and Figure 76.

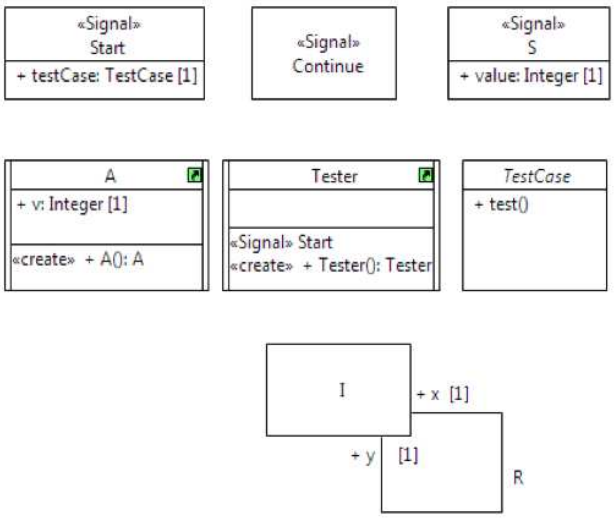


Figure 75: Classes, Interfaces and Associations shared amongst test cases of Test Suite 3 involving signals

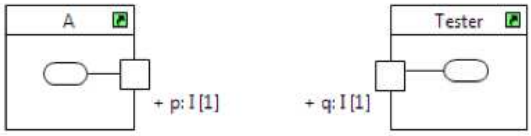


Figure 76: Composite structures shared amongst test cases of Test Suite 3 involving signals

Classifier behaviors of A and Tester are depicted in activity diagrams of Figure 77 and Figure 78 respectively.

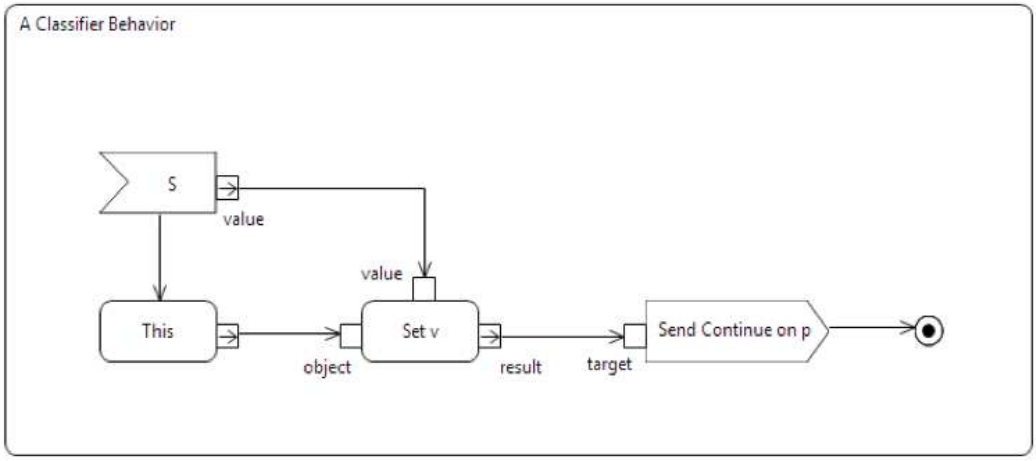


Figure 77: Classifier behavior of A

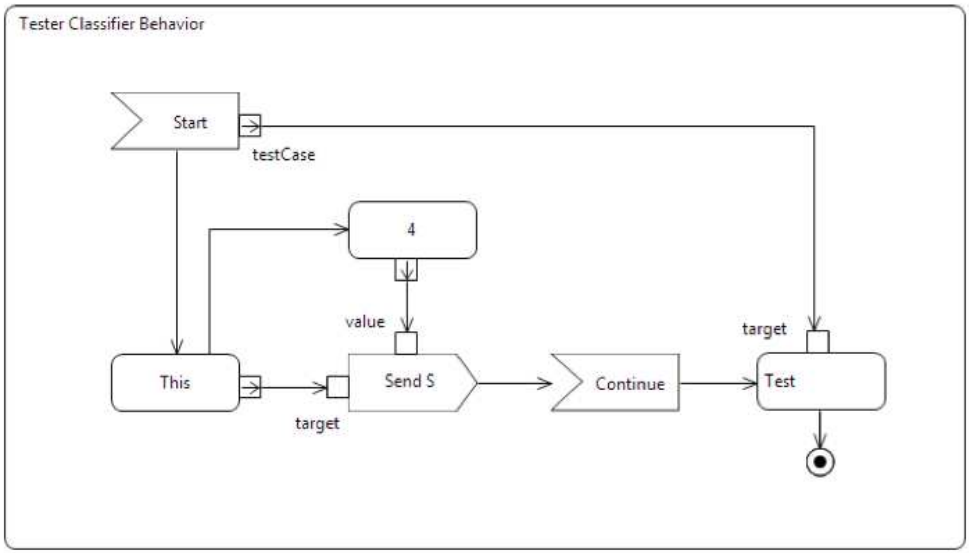


Figure 78: Classifier behavior of Tester

9.4.7 Assembly

This test case addresses sending of a signal on a Port. If the signal is forwarded outside of the port's owner, some assertions can be validated. Structural aspects of this test case are depicted in Figure 79 and Figure 80.

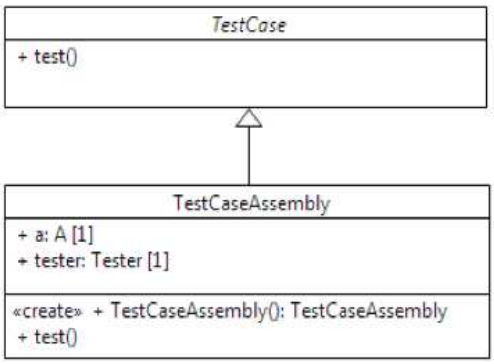


Figure 79: Assembly - Classes

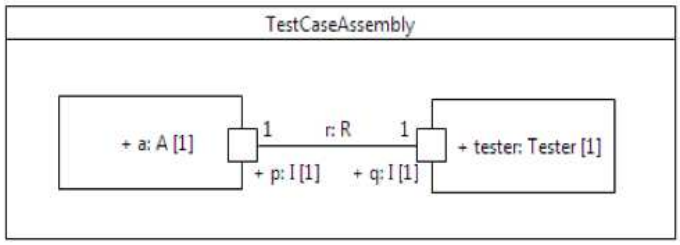


Figure 80: Assembly – Internal structures

Corresponding test case behavior is:

```
activity TestCaseBehavior() {
  WriteLine("-- Running test case - SendSignalAction using onPort -
             Single assembly connector --") ;
  testCase = new TestCaseAssembly() ;
  testCase.tester.Start(testCase) ;
}
```

Method of TestCaseAssembly::test is:

```
activity test() {
  AssertTrue("Signal correctly sent and received", this.a.v == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.4.8 Assembly and Delegation

This test case addresses sending of a signal on a Port. As compared to test case of 9.4.7, this test case implies a chain of delegation and assembly connectors. If the signal is forwarded outside of the port's owner, some assertions can be validated. Structural aspects of this test case are depicted in Figure 81 and Figure 82.

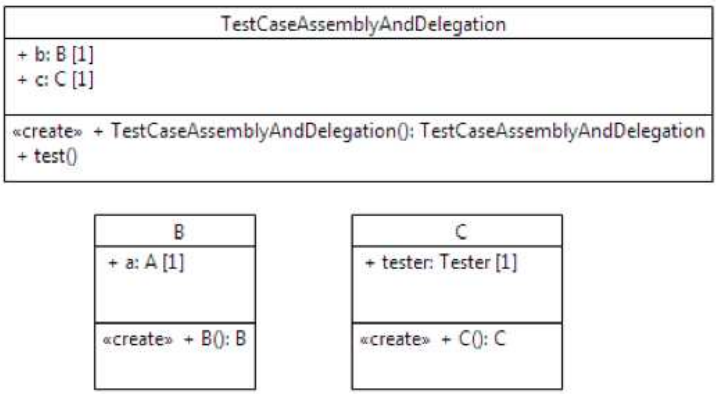


Figure 81: Assembly and Delegation – Classes

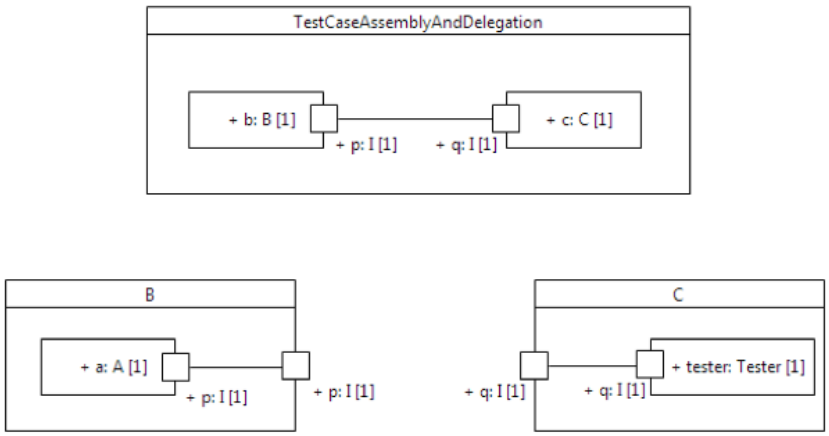


Figure 82: Assembly and Delegation – Internal structures

Corresponding test case behavior is:

```
activity TestCaseBehavior() {
  WriteLine("-- Running test case - SendSignalAction using onPort -
             Delegation/Assembly connector chain--") ;
  testCase = new TestCaseAssemblyAndDelegation() ;
  testCase.c.tester.Start(testCase) ;
}
```

Method of TestCaseAssemblyAndDelegation::test is:

```
activity test() {
  AssertTrue("Signal correctly sent and received", this.b.a.v == 4) ;
  WriteLine("-- End of test case --") ;
}
```

9.4.9 Variants of Test Suite 3

The normative Test Suite model contains 3 variants of Test Suite 3 (packages Tests Suite 3 - Bis, - Ter, - Quater, depicted in Figure 24), which contain variants of all Test Suite 3 test cases. Test Suite 3 - Bis contains variants where connectors are not typed. Test Suite 3 - Ter contains variants where ports are typed by interfaces. Test Suite 3 - Quater contains variants where connectors are not typed and ports are typed by interfaces.

9.5 Test Suite 4: Destruction

This test suite focuses on destruction semantics of UML Composite Structures. Subclause 9.5.1 concerns

recursive destruction of parts and ports, when a composite object is destroyed. Subclause 9.5.2 deals with removal of an instance from part, which implies destruction of links representing connectors and which are establishing a connection with the removed instance. Subclause 9.5.3 is similar, except that the instance is removed from a port.

9.5.1 Recursive destruction of parts and ports

This test case validates recursive destruction of parts and ports in the case where a composite object is destroyed. Note that all classes are reused from 9.2.4. Corresponding test case behavior is:

```
activity TestCaseBehavior() {
  a = new A_Star_Pattern() ;
  WriteLine("-- Running Test Case: Recursive destruction of parts and ports --") ;
  Write("# Instances of B: ") ; Write(B.allInstances()->size()) ; WriteLine("") ;
  Write("# Instances of C: ") ; Write(C.allInstances()->size()) ; WriteLine("") ;
  Write("# Instances of IImpl: ") ; Write(IImpl.allInstances()->size()) ; WriteLine("") ;
  WriteLine("... Destruction of a ...") ;
  a.destroy() ;
  AssertTrue("All instances of B recursively destroyed", B.allInstances()->size() == 0) ;
  AssertTrue("All instances of C recursively destroyed", C.allInstances()->size() == 0) ;
  AssertTrue("All instances of IImpl recursively destroyed", IImpl.allInstances()->size() ==
0) ;
  WriteLine("-- End of Test Case --") ;
}
```

9.5.2 Removing instance from part

This test case validates that the removal of an instance from a part implies destruction of related links. Note that all classes and associations are reused from 9.3.3. Corresponding test case behavior is:

```
activity 'Removing instance from part'() {
  WriteLine("-- Running test case: Removing instance from a part
             implies destruction of related links --") ;
  a = new A() ;
  b = a.b ;
  q = a.q ;
  a.b = null ;
  AssertTrue("Link has been destroyed", R.x(y => q)->size() == 0 && R.y(x => b)->size() == 0)
;
  WriteLine("-- End of test case --") ;
}
```

9.5.3 Removing instance from port

This test case validates that the removal of an instance from a port implies destruction of related links. Note that all classes and associations are reused from 9.3.3. Corresponding test case behavior is:

```
activity 'Removing instance from port'() {
  WriteLine("-- Running test case: Removing instance from a port
             implies destruction of related links --") ;
  a = new A() ;
  b = a.b ;
  q = a.q ;
  a.q = null ;
  AssertTrue("Link has been destroyed", R.x(y => q)->size() == 0 && R.y(x => b)->size() == 0)
;
  WriteLine("-- End of test case --") ;
}
```

Annex A Semantics of MARTE PpUnits (informative)

The broad field of embedded systems, to which MARTE is dedicated, relies directly in the capacity of specifying, predicting, and/or assessing the usage that the system does of the available resources. For real-time systems this is strongly related to the scheduling of the platform execution capacity and the arbitration protocols needed in the mutually exclusive accesses to shared resources. For this reason models of Composite Structures subject to real-time constraints, or targeted to embedded platforms, need the semantics of the MARTE elements used on them to be clearly described. This should be done in such a way that restricts the "Genericity of the Execution Model" claimed in section 2.3 of fUML specification. This implies directly the need to specify the semantics of time, concurrency, and inter-object communication mechanisms, which were explicitly left open in fUML.

Considering the large amount of potential modelling intents for which MARTE is able to be applied, the adequate strategy to describe semantics here should follow an approach similar to the one used in MARTE section 2.4 (Conformance with MARTE). According to that approach potential usages of the specification (and consequently the tools provided by tool vendors for them) are categorized in a series of "compliance cases".

The description of the corresponding "Semantics Variation Cases" would encompass aspects like: the modelling elements in play (stereotypes, base UML elements, and concrete values for the attributes that condition the desired semantics), the additional rules for their usage (expressed either with OCL or by means of textually described constraints), and the transformations or equivalent models in the target sub-domains or languages.

But an exhaustive search for all coherent sets of semantics of all elements in MARTE for all those potential users and compliance cases is an overwhelming effort not targeted in this specification. Instead, this annex fixes the semantics of a concrete set of elements and modelling patterns. The actors to whom this semantics is address are those named as "Software Architect" in MARTE section 6.2.3 (How to use this specification), in particular those who design real-time systems with the additional need of having their final artifacts suitable to be validated by means of schedulability analysis.

Then, according to this modelling intent, the semantics of the combination of specific MARTE elements in its Generic Resource Modeling (GRM) and High-Level Application Modeling (HLAM) sections need to be provided. The two basic structural elements in MARTE for which the formalization of semantics is needed are the Real-time Unit (RtUnit), and the Passive Protected Unit (PpUnit). These concepts are described in the HLAM sub-profile of MARTE, and are the fundamental building blocks for programming real-time applications with high level languages from the analytical point of view [1] [2] [3]. The construction of analysis models to validate these design intent models is possible [4] under the assumption of a generic execution platform and a behavioral semantics that respects best practices and widely known models of interaction taken from the real-time systems community [2] [5].

An initial set of modeling rules for the semantics of RtUnits, which included those for describing the platform, was proposed in [4] as a set of rules for the modeling of tasks that may be (a) Independent, (b) Related by means of shared resources, or (c) by control flow dependencies. This annex expresses the semantics for PpUnits as stated in clause 1 (Scope) of this specification, namely by defining semantic visitors that specify the needed semantics as extension of the PSCS execution model.

The basis for modeling with schedulability analysis in mind is the specification of three basic models, the platform, the logic of the application and the stimuli workload the system is expected to support. Over the initial set of modeling rules, proposed in [4], here we enhance and extend it to address also execution semantics of the PpUnits used in high level application models.

Then besides the semantics that is formalized in the next clause, when tasks share passive data the PpUnit modeling construct is used, and in this case these additional rules apply:

- The ExecKind of PpUnit services is ImmediatRemote
- All services of the PpUnit use the same protection protocol: ImmediateCeiling or PriorityInheritance
- The ConcurrencyPolicy of PpUnit is Guarded.

The concurrencyPolicy of the kind Concurrent might be enabled in order to have the writer/reader ConcurrencyKind available, but this behavior requires additional capabilities from the analysis techniques to take really advantage of it, so in principle it is discouraged.

A.1 Semantics

A.1.1 Overview

Extensions to the normative composite structures execution model are depicted in Figure 83 and Figure 84.

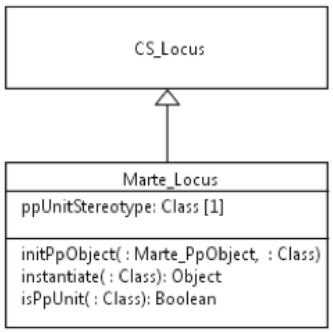


Figure 83: Locus extension diagram

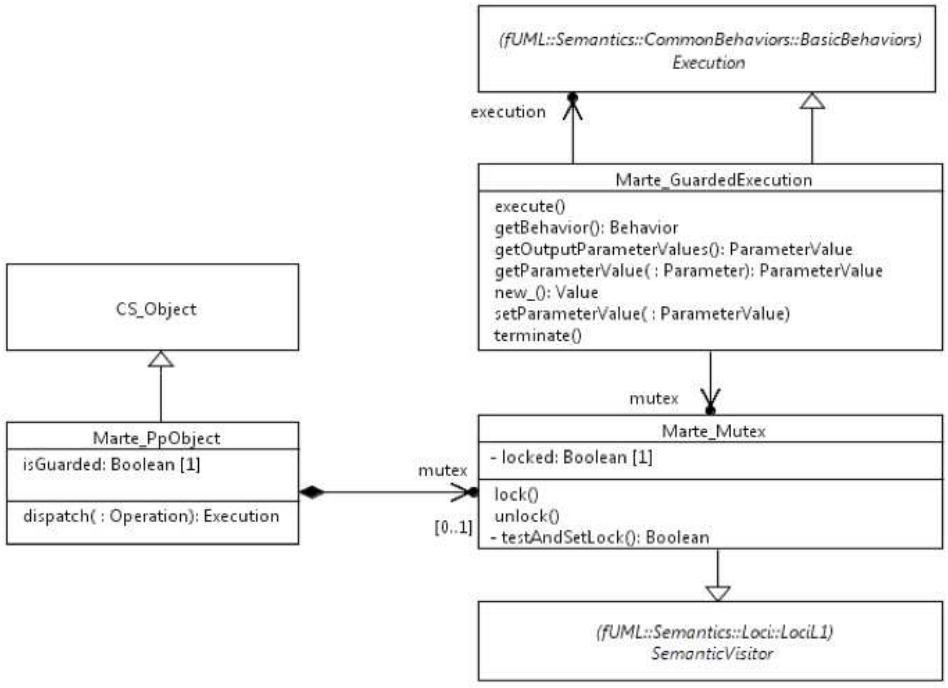


Figure 84: Object and Execution extension diagram

A.1.2 Class descriptions

A.1.2.1 Marte_GuardedExecution

Marte_GuardedExecution extends fUML Execution so that only one execution issued by a Marte_PpObject (i.e., an Object classified by a Marte PpUnit) can execute at a time. Mutual exclusion is guaranteed by the usage of a Marte_Mutex.

Generalizations

- Execution (from fUML::Semantics::CommonBehaviors::BasicBehaviors)

Attributes

- None

Associations

- execution : Execution, the actual encapsulated Execution, whose call to execute is guarded by the lock of a mutex (see operation execute below).
- mutex : Marte_Mutex, a reference to the mutex that will be used to guard the execution of the encapsulated Execution. This mutex is owned by the Marte_PpObject that produced this Marte_GuardedExecution.

Operations

```
[1] public execute()
        // Ensures mutual exclusion of executions
        // issued by a same Marte_PpObject, due to a dispatch.
        // The execution of each encapsulated execution is protected
        // by locking mutex prior to execution.
        // This mutex belongs to a Marte_PpObject,
        // and it is shared by all Marte_GuardedExecution
        // that has been issued by this Marte_PpObject.
        this.mutex.lock();
        this.execution.execute() ;
        this.mutex.unlock();

[2] public getBehavior() : Behavior
        // delegates to the encapsulated execution
        return this.execution.getBehavior();

[3] public getOutputParameterValues() : ParameterValue [*]
        // delegates to the encapsulated execution
        return this.execution.getOutputParameterValues();

[4] public getParameterValue(parameter:Parameter) : ParameterValue
        // delegates to the encapsulated execution
        return this.execution.getParameterValue(parameter);

[5] public new_() : Value
        return new Marte_GuardedExecution();

[6] public setParameterValue(parameterValue:ParameterValue)
        // delegates to the encapsulated execution
        this.execution.setParameterValue(parameterValue);

[7] public terminate()
        // delegates to the encapsulated execution
        this.execution.terminate();
```

A.1.2.2 Marte_Locus

Marte_Locus extends CS_Locus so that, when a Class with stereotype PpUnit stereotype has to be instantiated, a Marte_PpObject is returned instead of a CS_Object.

Generalizations

- CS_Locus

Attributes

- ppUnitStereotype : Class, the Marte PpUnit stereotype

Associations

- None

Operations

```
[1] public initPpObject(object:Marte_PpObject, stereotypedClass:Class)
       // Initializes properties of the given Marte_PpObject, according to the
       // given stereotypedType. This Class is a classifier of the given object,
       // and it has stereotype PpUnit applied. The property values associated
       // with the stereotype application are used to initialize properties of the
       // Marte_PpObject.

[2] public instantiate(class:Class) : Object
       // Extends CS_Locus so that, if the given type has
       // stereotype PpUnit applied, a Marte_PpObject is
       // instantiated instead of a CS_Object.
       // Otherwise, behaves like in CS_Locus.
       Object_ object ;
       if (this.isPpUnit(type)) {
              object = new Marte_PpObject();
              object.types.add(type);
              object.createFeatureValues();
              this.add(object);
              this.initPpObjet((Marte_PpObject)object, type) ;
       }
       else {
              object = super.instantiate(type) ;
       }
       return object ;

[3] public isPpUnit(type:Class) : Boolean
       // Determines if the given type has stereotype PpUnit applied
```

A.1.2.3 Marte_Mutex

Marte_Mutex is a new kind of SemanticVisitor, introduced to guarantee mutual exclusion of multiple Marte_GuardedExecutions issued by a same Marte_PpObject.

Generalizations

- SemanticVisitor (from fUML::Semantics::Loci::LociL1)

Attributes

- locked : Boolean, indicates whether this Marte_Mutex is locked

Associations

- None

Operations

```
[1] public lock()
        // Loops until the calling object
        // has been able to lock this mutex
        while (this.testAndSetLock()) { }

[2] public unlock()
        // Unlocks the mutex
        _beginIsolation();
        this.locked = false;
        _endIsolation();

[3] public testAndSetLock() : Boolean
        // If the context mutex is not locked,
        // locks it and returns false.
        // Returns true otherwise
        boolean wait = true;
        _beginIsolation();
        if (!this.locked) {
                this.locked = true;
                wait = false;
        }
        _endIsolation();
        return wait;
```

A.1.2.4 Marte_PpObject

Marte_PpObject extends CS_Object so that, when operation dispatch is called, a Marte_GuardedExecution is returned instead of a fUML Execution, if this Marte_PpObject is guarded.

Generalizations

- CS_Object

Attributes

- isGuarded : Boolean, determines whether this Marte_PpObject is guarded. Its value is based on the value of property concPolicy of stereotype PpUnit, which is applied on a Class typing this object.

Associations

- mutex : Marte_Mutex, the mutex owned by this object. It is used to guarantee mutual exclusion of executions produced by this object.

Operations

```
[1] public dispatch(operation:Operation) : Execution
        // First construct an Execution for the given operation,
        // as specified by CS_Object.
        // If this Marte_PpObject is guarded,
        // the constructed execution is encapsulated in a
        // Marte_GuardedExecution, which is returned.
        // This execution keeps a reference to the mutex
        // owned by this Object.
        // Otherwise, simply returns the constructed execution
        Execution execution = super.dispatch(operation);
        if (this.isGuarded) {
                Marte_GuardedExecution guarded = new Marte_GuardedExecution() ;
                guarded.execution = execution ;
                guarded.mutex = this.mutex ;
                execution = guarded ;
        }
        return execution ;
```

A.2 PpUnit Test suite

This test suite encompasses two test cases, described in subclauses A.2.1 and A.2.2. Its purpose is to demonstrate that concurrent calls to operations of a guarded PpUnit are serialized.

A.2.1 No Ports – Globally Guarded

The structural aspects of this test case are depicted in Figure 85 and Figure 86. Four active objects (classified by A) share a single PpUnit object (classified by B). The active objects concurrently call operation B::compute() on the shared object. Since PpUnit B is guarded (property concPolicy == guarded), these calls shall be serialized.

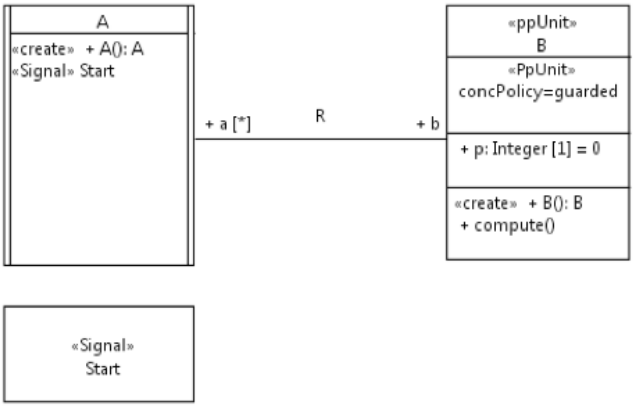


Figure 85: Class diagram

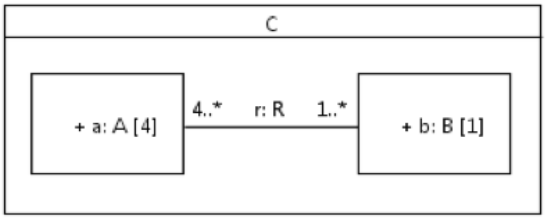


Figure 86: Composite structure diagram

The classifier behavior of A is:

```
activity AClassifierBehavior() {
    accept(Start) ;
    b = R.b(this) ;
    b.compute() ;
}
```

The method of operation B::compute() is:

```
activity compute() {
    WriteLine("--------------------------------------") ;
    WriteLine("- Incrementing p:") ;
    this.p = this.p + 10 ;
    WriteLine("     - value of p: " + ToString(this.p)) ;
    WriteLine("- Decrementing p:") ;
    this.p = this.p - 10 ;
    WriteLine("     - value of p: " + ToString(this.p)) ;
    WriteLine("--------------------------------------") ;
    WriteLine("") ;
}
```

The corresponding test case behavior is:

```
activity TestCaseBehavior() {
    c = new C() ;
    for (a in c.a) {
        a.Start() ;
    }
}
```

In a valid execution trace, the various executions of B::compute() shall be serialized, so that no interleaving can be observed:

```
-------------------------------------
- Incrementing p:
     - value of p: 10
- Decrementing p:
     - value of p: 0
-------------------------------------
-------------------------------------
- Incrementing p:
     - value of p: 10
- Decrementing p:
     - value of p: 0
-------------------------------------
-------------------------------------
- Incrementing p:
     - value of p: 10
- Decrementing p:
     - value of p: 0
-------------------------------------
-------------------------------------
- Incrementing p:
     - value of p: 10
- Decrementing p:
     - value of p: 0
-------------------------------------
```

A.2.2 Ports – Globally Guarded

The structural aspects of this test case are depicted in Figure 87 and Figure 88. This is a variant of the test case depicted in subclause A.2.1, where instances of A communicate with the shared instance of B through ports and connectors. The active objects concurrently call operation B::compute() on the shared object. Since PpUnit B is guarded (property concPolicy == guarded), these calls shall be serialized.

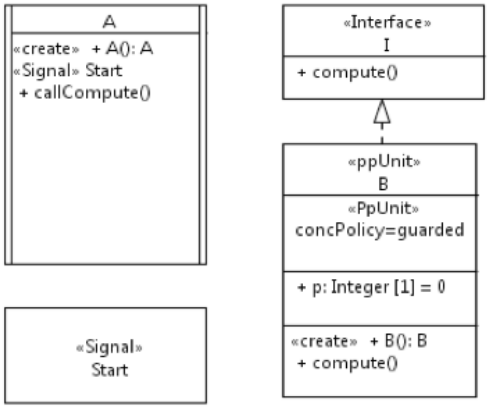


Figure 87: Class diagram

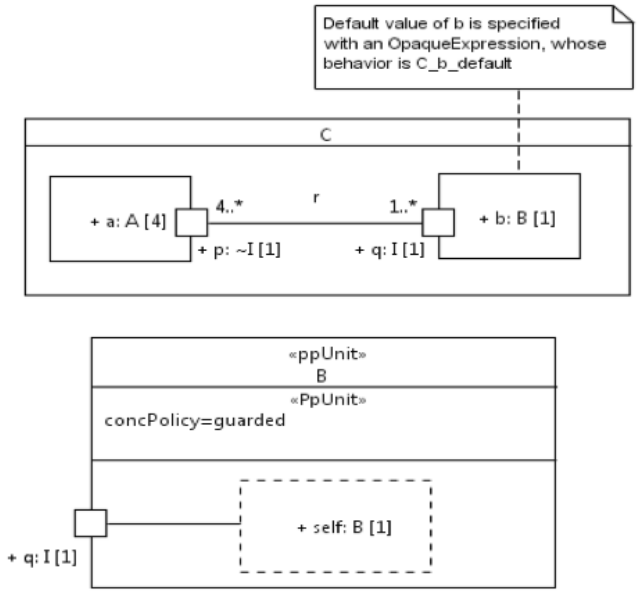


Figure 88: Composite structure diagram

The classifier behavior of A is:

```
activity AClassifierBehavior() {
    accept(Start) ;
    this.callCompute() ;
}
```

The method of operation A::callCompute() is specified in the activity diagram of Figure 89. Action “This” is a ReadSelfAction, and “Call compute on port p” is a CallOperationAction for operation I::compute(), with property onPort set to A::p.

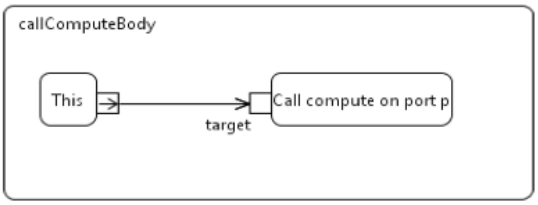


Figure 89: Activity diagram of A::callCompute() method

The method of operation B::compute() is:

```
activity compute() {
    WriteLine("--------------------------------------") ;
    WriteLine("- Incrementing p:") ;
    this.p = this.p + 10 ;
    WriteLine("     - value of p: " + ToString(this.p)) ;
    WriteLine("- Decrementing p:") ;
    this.p = this.p - 10 ;
    WriteLine("     - value of p: " + ToString(this.p)) ;
    WriteLine("--------------------------------------") ;
    WriteLine("") ;
}
```

Activity C_b_default (which is the behavior associated with the OpaqueExpression default value of C::b) is:

```
activity C_b_default() : B {
    b = new B() ;
    b.self = b ;
    // Default is a generic association,
    // specified in the non-normative library GenericAssociation
    // Cf. clause Annex C
    Default.createLink(x => b.q, y => b.self) ;
    return b ;
}
```

The corresponding test case behavior is:

```
activity TestCaseBehavior() {
    c = new C() ;
    for (a in c.a) {
        a.Start() ;
    }
}
```

In a valid execution trace, the various executions of B::compute() shall be serialized, so that no interleaving can be observed:

```
-------------------------------------
- Incrementing p:
     - value of p: 10
- Decrementing p:
     - value of p: 0
-------------------------------------
-------------------------------------
- Incrementing p:
     - value of p: 10
- Decrementing p:
     - value of p: 0
-------------------------------------
-------------------------------------
- Incrementing p:
     - value of p: 10
- Decrementing p:
     - value of p: 0
-------------------------------------
-------------------------------------
- Incrementing p:
     - value of p: 10
- Decrementing p:
     - value of p: 0
-------------------------------------
```

A.3 References

[1] A. Burns, B. Dobbing and T. Vardanega. Guide for the use of the Ada Ravenscar Profile in high integrity systems. University of York Technical Report YCS-2003-348 January 2003.

[2] A. Burns and A. Wellings. HRT-HOOD: A Structured Design Method for Hard Real-Time Systems. Elsevier Science, Amsterdam, NL, 1995. ISBN 0-444-82164-3.

[3] S. Mazzini, M. D'Alessandro, M. Di Natale, G. Lipari, and T. Vardanega. Issues in Mapping HRT-HOOD to UML. In G. Buttazzo, editor, Proceedings 15th Euromicro Conference on Real-Time Systems (ECRTS), pages 221-228. IEEE, July 2003.

[4] J. Medina and Á. García Cuesta. Model-Based Analysis and Design of Real-Time Distributed Systems with Ada and the UML Profile for MARTE. 16th Int. Conf. On Reliable Software Technologies, Ada-Europe'2011, Edinburg (UK), in Lecture Notes in Computer Science, LNCS Vol. 6652, pp. 89-102, June 2011.

[5] J. Medina and A. Pérez Ruiz. High Level Modeling for Real-Time Applications with UML & MARTE. Proceedings of the 25th Euromicro Conference on Real-Time Systems (ECRTS'13) WiP Session, pp. 13-16, July 2013.

Annex B Semantics of SysML Blocks, ProxyPorts, and FlowProperties (informative)

SysML is a general purpose graphical modeling language that is used to describe systems in terms of their requirements, structure, behavior, and constraints. The core constructs used to model structure include blocks and their properties (e.g., value properties, part properties, constraint properties, and ports), associations, and connectors. These core structural constructs can be integrated with various behavioral constructs to describe how the system behaves.

SysML is intended to support many different types of behavior modeling paradigms. SysML, as with UML, includes activities, interactions and state machines for modeling behavior. Other forms of behavior, such as those described by differential equations, can be captured using SysML parametrics. The core structural elements can be integrated with other domain specific models and associated modeling paradigms to specify behavior in a way that is appropriate for the application.

The execution semantics for any particular type of behavior modeling approach must be specified in order to execute a model that is described in SysML. For example, parametrics can be executed by mapping them to various solvers such as Modelica, Mathematica, or Simulink, which each contain their own semantics.

The Semantics of a Foundational Subset for Executable UML (fUML) specifies the semantics for executing a subset of UML/SysML activities. The Precise Semantics of UML Composite Structures further extends these semantics to specify how the structural elements such as structured classes with ports impact the execution of activities. SysML requires further interpretation of these semantics for those areas of SysML that are different from UML.

Semantics specified in this clause only address a subset of SysML. This subset includes use cases where Blocks can have in or out FlowProperties (i.e., no inout). Blocks can also have ProxyPorts, typed by InterfaceBlocks with FlowProperties.

Subclause B.1 specifies the semantics for this subset. They describe how values written on out FlowProperties propagate through links existing between block instances, following links specified by connectors (either directly between parts, or between proxy ports on these parts). Subclause B.2 specifies a suite of test cases that can be used to demonstrate conformance to these semantics.

B.1 Semantics

B.1.1 Overview

Extensions to the normative Composite Structure execution model are depicted in Figure 90, Figure 91, and Figure 92.

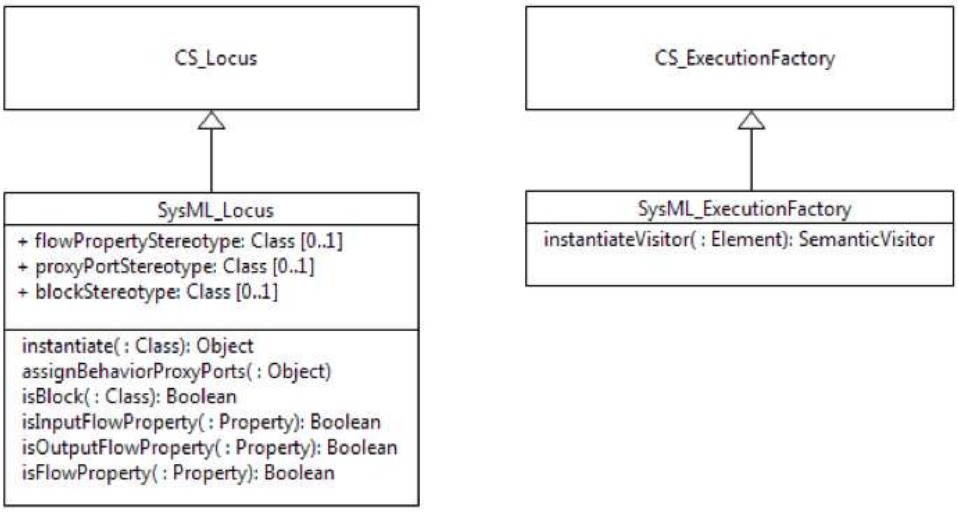


Figure 90: SysML Loci Extensions Diagram

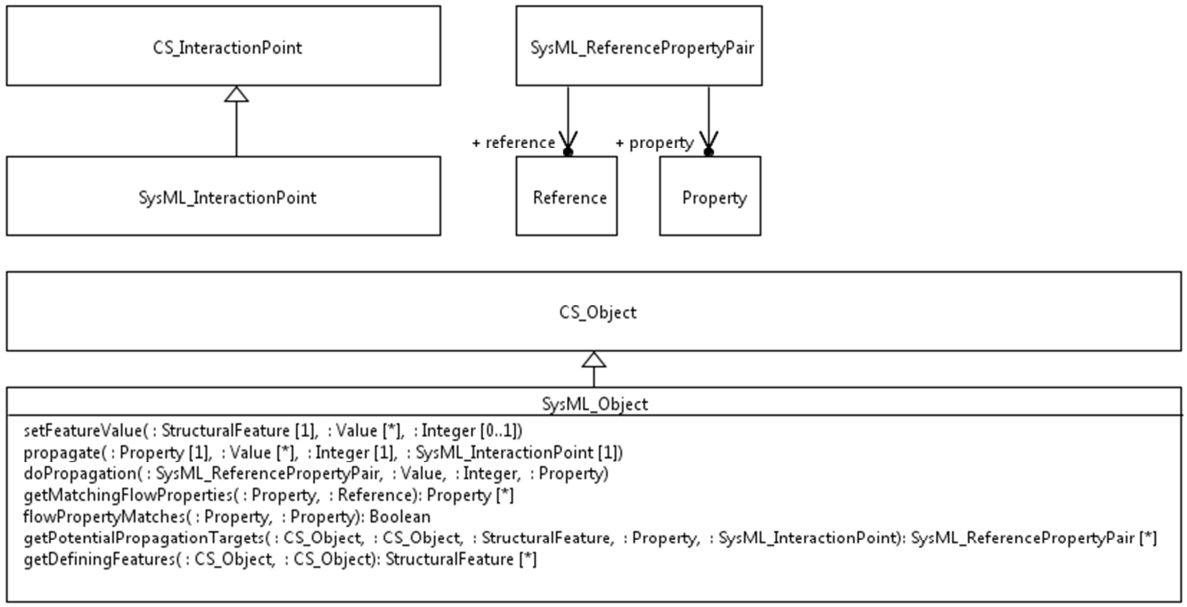


Figure 91: SysML Values Extensions Diagram

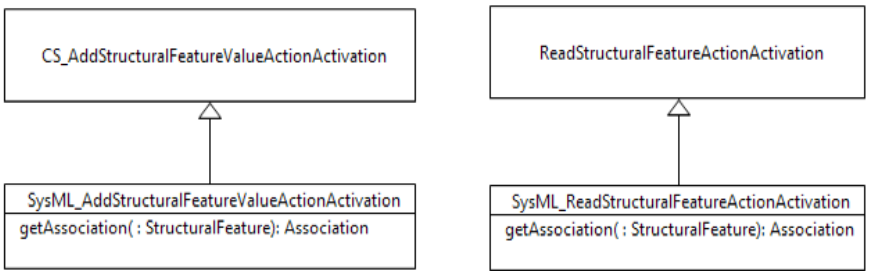


Figure 92: SysML Actions Extensions Diagram

B.1.2 Class descriptions

B.1.2.1 SysML_AddStructuralFeatureValueActionActivation

SysML_AddStructuralFeatureValueAction extends CS_AddStructuralFeatureValueActionActivationt o deal with Associations that do not own all their ends. In SysML, properties typed by Blocks are defined with an Association between the containing Block and the type of the Properties. As compared to fUML which requires these ends to be owned by the Association, SysML requires these ends to be owned by the containing Block.

Generalizations

- CS_AddStructuralFeatureValueActionActivation

Attributes

- None

Associations

- None

Operations

```
[1] public getAssociation(feature:StructuralFeature) : Association [0..1]
        // If the structural feature for the action of this activation is an
        // association end,
        // then get the associated association,
        // ONLY IF THIS FEATURE IS OWNED BY THE ASSOCIATION (SysML extension)
        Association association = null;
        if(feature instanceof Property) {
                association = ((Property)feature).association;
        }
        if (association != null) {
                int i = 1 ;
                boolean ownedByAssocation = false ;
                while (i <= association.ownedEnd.size() && !ownedByAssocation) {
                        Property current = association.ownedEnd.getValue(i - 1) ;
                        if (current == feature) {
                                ownedByAssocation = true ;
                        }
                        i = i + 1 ;
                }
                if (!ownedByAssocation) {
                        association = null ;
                }
        }
        return association;
```

B.1.2.2 SysML_ExecutionFactory

SysML_ExecutionFactory extends CS_ExecutionFactory to deal with instantiation of semantic visitors introduced by this extension.

Generalizations

- CS_ExecutionFactory

Attributes

- None

Associations

- None

Operations

```
[1] public instantiateVisitor(element:Element) : SemanticVisitor
        // Extends CS_ExecutionFactory to instantiate
        // SysML semantic visitors
        SemanticVisitor visitor = null ;
        if (element instanceof AddStructuralFeatureValueAction) {
                visitor = new SysML_AddStructuralFeatureValueActionActivation() ;
        }
        else if (element instanceof ReadStructuralFeatureAction) {
                visitor = new SysML_ReadStructuralFeatureActionActivation() ;
        }
        else {
                visitor = super.instantiateVisitor(element) ;
        }
        return visitor ;
```

B.1.2.3 SysML_InteractionPoint

SysML_InteractionPoint extends CS_InteractionPoint. The only kind of SysML port supported in this annex is behavior proxy ports. This kind of port does not required extensions to CS_InteractionPoint. However, since the other kind of SysML ports would require some extensions, this class is introduced to be used as a common ancestor to these potential extensions, that could be defined in extensions to the proposed execution model.

Generalizations

- CS_InteractionPoint

Attributes

- None

Associations

- None

Operations

- None

B.1.2.4 SysML_Locus

SysML_Locus extends CS_Locus by instantiating SysML_Objects instead of CS_Objects, in the case where the Type (from which instances are produced) is a Block. When instantiating a SysML_Object, it also deals with the automatic assignment of values for the behavior ProxyPorts of the Block typing the instantiated object. These values are SysML_InteractionPoint whose referents are the instantiated object itself. In other words, the instantiated object and the values for the behavior ProxyPorts of the typing Block are the same object. These mechanism is implemented in Operation assignBehaviorProxyPorts specified below.

SysML_Locus also owns utility properties and operations. All the *Stereotype properties below are references to Stereotype definitions from the SysML profile. These references are used to determine if model elements from a model being executed carry applications of the corresponding Stereotypes (see isBlock, isProxyPort, isFlowProperty, isInputFlowProperty, isOutputFlowProperty operations specified below).

Generalizations

- CS_Locus

Attributes

- blockStereotype : Class [0..1], the Block stereotype definition
- flowPropertyStereotype : Class [0..1], the FlowProperty stereotype definition
- proxyPortStereotype : Class [0..1], the ProxyPort stereotype definition

Associations

- None

Operations

```
[1] public assignBehaviorProxyPorts(object:Object)
  // For each FeatureValue of the given object,
  // if the definingFeature is a behavior ProxyPort,
  // assigns a value to this FeatureValue that is a
  // SysML_InteractionPoint, whose referent is the
  // given object itself
  int featureValueIndex = 1 ;
  while (featureValueIndex <= object.featureValues.size()) {
    FeatureValue currentFeatureValue = object.featureValues.get(featureValueIndex - 1) ;
    if (currentFeatureValue.feature instanceof Port) {
      Port p = (Port)currentFeatureValue.feature ;
      if (p.isBehavior && this.isProxyPort(p)) {
        ValueList values = new ValueList() ;
        CS_Reference owner = new CS_Reference() ;
        owner.referent = object ;
        owner.compositeReferent = (CS_Object)object ;
        SysML_InteractionPoint interactionPoint = new SysML_InteractionPoint() ;
        interactionPoint.definingPort = p ;
        interactionPoint.referent = object ;
        interactionPoint.owner = owner ;
        values.add(interactionPoint) ;
        currentFeatureValue.values = values ;
      }
    }
    featureValueIndex = featureValueIndex + 1 ;
  }

[2] public instantiate(type:Class):Object
       // If the type is a Block, instantiate a SysML_Object.
       // Otherwise behaves like in CS_Locus
       if (isBlock(type)) {
              Object_ object = null;
              object = new SysML_Object() ;
              object.types.add(type);
              this.add(object);
              object.createFeatureValues();
              this.assignBehaviorProxyPorts(object);
              return object;
       }
       else {
              return super.instantiate(type);
       }

[3] public isBlock(type:Class):Boolean

[4] public isFlowProperty(property:Property):Boolean

[5] public isInputFlowProperty(property:Property):Boolean

[6] public isOutputFlowProperty(property:Property):Boolean

[7] public isProxyPort(port:Port):Boolean
```

B.1.2.5 SysML_Object

SysML_Object extends CS_Object to deal with propagation of values when writing a value on an out FlowProperty of this object.

Generalizations

- CS_Object

Attributes

- None

Associations

- None

Operations

```
[1] public doPropagation(potentialTargets:SysML_ReferencePropertyPair,
                         values:Value[*],
                         position:Integer,
                         from:Property)
  // Performs the actual propagation for the given potentialTargets.
  // First, the potentialTargets list is partitionned by target objects.
  // For each partition (which is represented as a list of SysML_ReferencePropertyPair),
  // in the case where the list contains a single element, the propagation is done.
  // If the list contains more than 1 element,
  // tries to filer it by name, and repeats the operation recursively if the size
  // of the filtered list is 1.
  // The given values are written on objects identified by each SysML_ReferencePropertyPair.
  // If the given from property is typed by a block and has aggregation kind composite,
  // and if the property identified by SysML_ReferencePropertyPair is also composite,
  // then the value is moved rather than being simply copied (thereby dealing with
  // transfer of ownership).
  SysML_ReferencePropertyPairListList potentialTargetsByObject = new
SysML_ReferencePropertyPairListList() ;
  IntegerList added = new IntegerList() ;
  int i = 1 ;
  while (i <= potentialTargets.size()) {
    if (! added.contains) {
      added.addValue ;
      SysML_ReferencePropertyPair pair = potentialTargets.getValue(i - 1);
      SysML_ReferencePropertyPairList newList = new SysML_ReferencePropertyPairList() ;
      newList.addValue(pair) ;
      potentialTargetsByObject.addValue(newList) ;
      Object_ targetObject = pair.reference.referent ;
      int j = i + 1;
      while (j <= potentialTargets.size()) {
        SysML_ReferencePropertyPair pair2 = potentialTargets.getValue(j - 1) ;
        if (pair2.reference.referent == targetObject){
          newList.addValue(pair2) ; added.addValue(j - 1) ;
        }
        j = j + 1 ;
      }
    }
    i = i + 1 ;
  }
  FeatureValueList featureValuesToClean = new FeatureValueList() ;
  i = 1 ;
  while (i <= potentialTargetsByObject.size()) {
    SysML_ReferencePropertyPairList targets = potentialTargetsByObject.getValue(i - 1) ;
    if (targets.size() == 0){
      // No matching flow properties were found
    }
    else if (targets.size() == 1) {
      // Exactly one matching flow property was found
      ValueList valuesCopy = new ValueList() ;
```

```
      int valueIndex = 1 ;
      while (valueIndex <= values.size()){
        valuesCopy.add(values.getValue(valueIndex - 1).copy()) ;
        valueIndex = valueIndex + 1 ;
      }
      SysML_ReferencePropertyPair pair = targets.getValue(0) ;
      pair.reference.setFeatureValue(pair.property, valuesCopy, position);
      // if the type of from is a Class,
      // and if both properties from and pair.property are composite,
      // the value is moved, not copied.
      // the propagated values must be removed from property from
      if (from.getType() instanceof Class) {
        if (from.getAggregation() == AggregationKind.COMPOSITE_LITERAL &&
            pair.property.getAggregation() == AggregationKind.COMPOSITE_LITERAL) {
          FeatureValue fromFeatureValue = this.getFeatureValue(from) ;
          if (!featureValuesToClean.contains(fromFeatureValue)) {
            featureValuesToClean.addValue(fromFeatureValue) ;
          }
        }
      }
    }
    else {
      // Multiple matching flow properties
      // Tries to match by name
      SysML_ReferencePropertyPairList filteredByName = new SysML_ReferencePropertyPairList() ;
      int pairIndex = 1 ;
      while (pairIndex <= targets.size()) {
        SysML_ReferencePropertyPair currentPair = targets.getValue(pairIndex - 1) ;
        if (from.getName() != null && currentPair.property.getName() != null) {
          if (from.getName().equals(currentPair.property.getName())) {
            filteredByName.addValue(currentPair) ;
          }
        }
        pairIndex = pairIndex + 1 ;
      }
      if (filteredByName.size() == 1) {
        this.doPropagation(filteredByName, values, position, from);
      }
    }
    i = i + 1 ;
  }
  // cleaning features values of composite properties
  i = 1 ;
  while (i <= featureValuesToClean.size()){
    FeatureValue featureValue = featureValuesToClean.get(i - 1) ;
    featureValue.values.removeAll(values); i = i + 1 ;
  }

[2] public flowPropertyMatches(from:Property, to:Property):Boolean
  // Determines if the to FlowProperty matches the from FlowProperty
  // Property to matches Property from if it is an in FlowProperty and
  // if it is type compatible
  // Note that, by construction, Property from is always an out
  // FlowProperty
  // Not also that this solution does not account for propagation across
  // delegation connectors, only through assembly connectors.
  SysML_Locus sysML_Locus = (SysML_Locus)this.locus ;
  if (sysML_Locus.isInputFlowProperty(to)) {
    if (to.typedElement.type == null ||
        to.typedElement.type.isCompatibleWith(from.typedElement.type)) {
      return true ;
    }
  }
  return false ;

[3] public getDefiningFeatures(container:CS_Object, contained:CS_Object):StructuralFeature[*]
  // Retrieves the defining features for the given contained object,
  // in the context of the given container
  StructuralFeatureList definingFeatures = new StructuralFeatureList() ;
  FeatureValueList featureValues = container.getFeatureValues() ;
  int featureValueIndex = 1 ;
```

```
  while (featureValueIndex <= featureValues.size()) {
    FeatureValue currentFeatureValue = featureValues.getValue(featureValueIndex - 1) ;
    int valueIndex = 1 ;
    boolean found = false ;
    while (valueIndex <= currentFeatureValue.values.size() && !found) {
      Value currentValue = currentFeatureValue.values.getValue(valueIndex - 1) ;
      if (currentValue instanceof Reference) {
        if (((Reference)currentValue).referent == contained) {
          definingFeatures.addValue(currentFeatureValue.feature) ;
          found = true ;
        }
      }
      valueIndex = valueIndex + 1 ;
    }
    featureValueIndex = featureValueIndex + 1 ;
  }
  return definingFeatures ;

[4] public getMatchingFlowProperties(from:Property, context:Reference):Property[*]
  // Retries FlowProperties that match the given from property,
  // in the given context Reference.
  PropertyList matchingFlowProperties = new PropertyList() ;
  int featureValueIndex = 1 ;
  FeatureValueList featureValues = context.getFeatureValues() ;
  while (featureValueIndex <= featureValues.size()) {
    FeatureValue currentFeatureValue = featureValues.getValue(featureValueIndex - 1) ;
    StructuralFeature feature = currentFeatureValue.feature ;
    if (this.flowPropertyMatches(from, (Property)feature)) {
      matchingFlowProperties.addValue((Property)feature) ;
    }
    featureValueIndex = featureValueIndex + 1 ;
  }
  return matchingFlowProperties ;

[5] public getPotentialPropagationTargets(container:CS_Object,
                                          contained:CS_Object,
                                          feature:StructuralFeature,
                                          from:Property,
                                          sourceInteractionPoint:SysML_InteractionPoint
                                          ) : SysML_ReferencePropertyPair[*]
 // Retrieves potential propagation targets, in the case where:
 // - Values are written on the given contained object, on out FlowProperty from,
 //   through the given sourceInteractionPoint (can be null)
 // - Object contained is contained by the given container, acting as a value for
 //   the given StructuralFeature feature
 SysML_ReferencePropertyPairList potentialPropagationTargets = new
SysML_ReferencePropertyPairList();
 FeatureValue featureValue = container.getFeatureValue(feature) ;
 Value referenceToContained = featureValue.values.getValue(0) ;
 ExtensionalValueList extensionalValues = this.locus.extensionalValues ;
 int linkIndex = 1 ;
 // Retrieves all links at the execution locus, and determines if these links
 // should be followed to propagate the values
 while (linkIndex <= extensionalValues.size()) {
   ExtensionalValue extensionalValue = extensionalValues.getValue(linkIndex-1) ;
   if (extensionalValue instanceof CS_Link) {
     CS_Link link = (CS_Link)extensionalValue ;
     StructuralFeature linkFeature = link.getFeature(referenceToContained) ;
     if (linkFeature != null) {
       // This link connect the given contained object to something
       FeatureValueList featureValues = link.getFeatureValues() ;
       FeatureValue currentFeatureValue = featureValues.getValue(0) ;
       Reference potentialTarget ;
       Reference source ;
       // retrieves the actual source and target for this link
       if (currentFeatureValue.feature != linkFeature) {
         potentialTarget =((Reference)featureValues.getValue(0).values.getValue(0)) ;
         source =((Reference)featureValues.getValue(1).values.getValue(0)) ;
       }
       else {
         potentialTarget =((Reference)featureValues.getValue(1).values.getValue(0)) ;
```

```
        source =((Reference)featureValues.getValue(0).values.getValue(0)) ;
      }
      boolean select = true ;
      // if a sourceInteractionPoint has been passed as an argument of this operation,
      // and if the source of the link is not this sourceInteractionPoint,
      // this link shall not be retained for propagation
      if (sourceInteractionPoint != null && ! (sourceInteractionPoint == source)) {
        select = false ;
      }
      if (select) {
        // if the potential target has flow properties that match the given from property,
        // it is added in the list of potential targets
        PropertyList matchingFlowProperties =
                                    this.getMatchingFlowProperties(from, potentialTarget) ;
        int matchingFlowPropertyIndex = 1 ;
        while (matchingFlowPropertyIndex <= matchingFlowProperties.size()) {
          Property currentProperty =
                                    matchingFlowProperties.getValue(matchingFlowPropertyIndex
- 1) ;
          SysML_ReferencePropertyPair pair = new SysML_ReferencePropertyPair() ;
          pair.property = currentProperty ;
          pair.reference = potentialTarget ;
          potentialPropagationTargets.addValue(pair) ;
          matchingFlowPropertyIndex = matchingFlowPropertyIndex + 1 ;
        }
      }
    }
   }
   linkIndex = linkIndex + 1 ;
 }
 return potentialPropagationTargets ;

[6] public propagate(from:Property,
                     values:Value[*],
                     position:Integer,
                     interactionPoint:SysML_InteractionPoint)
  // Propagate values written on property from,
  // from the given interactionPoint, or through all
  // valid links if no interaction point is given
  CS_ObjectList containers = this.getDirectContainers() ;
  SysML_ReferencePropertyPairList potentialTargets = new SysML_ReferencePropertyPairList() ;
  int containerIndex = 1 ;
  while (containerIndex <= containers.size()) {
    CS_Object currentContainer =  containers.get(containerIndex - 1) ;
    StructuralFeatureList definingFeatures = this.getDefiningFeatures(currentContainer, this)
;
    int featureIndex = 1 ;
    while (featureIndex <= definingFeatures.size()) {
      StructuralFeature currentFeature = definingFeatures.getValue(featureIndex - 1) ;
      SysML_ReferencePropertyPairList targets =
                      this.getPotentialPropagationTargets(currentContainer, this,
                                                          currentFeature, from,
interactionPoint) ;
      int targetIndex = 1 ;
      while (targetIndex <= targets.size()) {
        SysML_ReferencePropertyPair currentTarget = targets.getValue(targetIndex - 1) ;
        potentialTargets.addValue(currentTarget) ;
        targetIndex = targetIndex + 1 ;
      }
      featureIndex = featureIndex + 1 ;
    }
    containerIndex = containerIndex + 1 ;
  }
  this.doPropagation(potentialTargets, values, position, from);

[7] public setFeatureValue( feature:StructuralFeature, values:Value[*], position:Integer)
  // If the feature is a Port, behaves like in the composite structure execution model
  // If the feature is a an out FlowProperty,
  // behaves like in the composite structure execution model,
  // and then deal with the propagation of the written value.
  SysML_Locus sysML_Locus = (SysML_Locus)this.locus ;
```

```
if (feature instanceof Port) {
  super.setFeatureValue(feature, values, position);
}
else if (feature instanceof Property) {
  Property p = (Property)feature ;
  super.setFeatureValue(feature, values, position);
  if (sysML_Locus.isOutputFlowProperty(p)) {
    this.propagate(p, values, position, null);
  }
}
else {
  super.setFeatureValue(feature, values, position);
}
```

B.1.2.6 SysML_ReadStructuralFeatureActionActivation

SysML_AddStructuralFeatureValueAction extends fUML ReadStructuralFeatureActionActivation to deal with Associations that do not own all their ends (see SysML_AddStructuralFeatureValueActionActivation, B.1.2.1, for a description of cases where Associations do not own all their ends).

Generalizations

- ReadStructuralFeatureActionActivation (from fUML::Semantics::Actions::IntermediateActions)

Attributes

- None

Associations

- None

Operations

```
[1] public getAssociation(feature:StructuralFeature) : Association [0..1]
       // If the structural feature for the action of this activation is an
       // association end,
       // then get the associated association,
       // ONLY IF THIS FEATURE IS OWNED BY THE ASSOCIATION (SysML extension)
       Association association = null;
       if(feature instanceof Property) {
              association = ((Property)feature).association;
       }
       if (association != null) {
              int i = 1 ;
              boolean ownedByAssocation = false ;
              while (i <= association.ownedEnd.size() && !ownedByAssocation) {
                     Property current = association.ownedEnd.getValue(i - 1) ;
                     if (current == feature) {
                            ownedByAssocation = true ;
                     }
                     i = i + 1 ;
              }
              if (!ownedByAssocation) {
                     association = null ;
              }
       }
       return association;
```

B.1.2.7 SysML_ReferencePropertyPair

SysML_ReferencePropertyPair enables to represent a pair composed of a reference to a Property, and a reference to a Reference. It is used to represent a target for the propagation of a value, when a value is written on an out FlowProperty of a SysML_Object (see B.1.2.1, Operations setFeatureValue and setFeatureValueOnInteractionPoint).

Generalizations

- None

Attributes

- None

Associations

- property : Property
- reference : Reference

Operations

- None

B.2 Test suites

This subclause describes suites of test cases that can be used to demonstrate conformance to the semantics specified in B.1. Test Suite 1 focuses on propagation of values when writing a value on an out flow property, in the context of an object classified by a Block without Ports. Test Suite 2 introduces variants of Test Suite 1 where objects are classified by Blocks with behavior ProxyPorts.

In the test cases specified below, the CS_DefaultConstructStrategyis not used. All systems are constructed manually, by instantiating and assigning values corresponding to parts. In addition, statements like `Default.createLink(x => source, y => target)` specify the creation of a link typed by Association *Default*. These statements are required to establish connections between source and target objects, which can be values for parts (i.e., CS_References) or ProxyPorts (i.e., SysML_InteractionPoints). *Default* is the generic Association defined in Annex C of this specification (i.e., two untyped owned ends, with ordered/unique multiplicity *).

B.2.1 Test Suite 1: Parts Directly Connected

B.2.1.1 Writing on FlowProperties Typed by ValueTypes

This test case addresses propagation of values when writing a value on an out FlowProperty typed by a ValueType. The object on which the value is written has no interaction points (i.e., it is classified by a Block without Ports). This source object is connected directly to a target object which has a single matching FlowProperty. When the value is written on the FlowProperty of the source object, this value is copied on the matching FlowProperty of the target object. Structural aspects of this test case are depicted in Figure 93 and Figure 94.

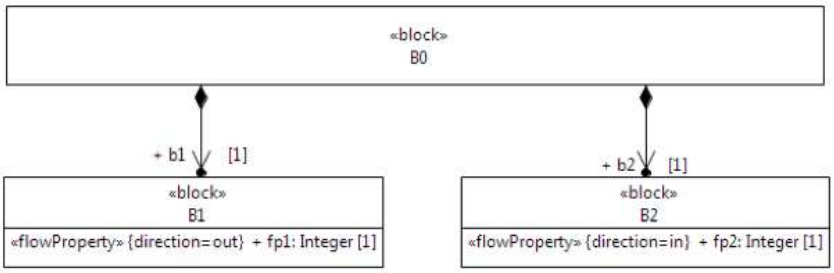


Figure 93: Block Definition Diagram

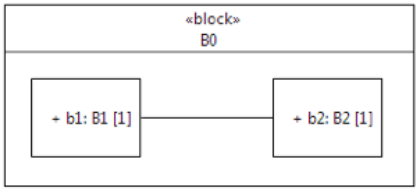


Figure 94: Internal Block Diagram

The corresponding test case behavior is:

```
activity TestCaseBehavior() {
  WriteLine("-- Untyped connector between parts with flow properties --") ;
  WriteLine("-- Multiplicity 1 on parts, connector ends, and flow properties --") ;
  WriteLine("-- Flow properties typed by a ValueType --") ;
  // Constructing the system
  let b0 : B0 = new B0() ;
  b0.b1 = new B1() ;
  b0.b2 = new B2() ;
  Default.createLink(x => b0.b1, y => b0.b2) ;
  // Testing
  b0.b1.fp1 = 4 ;
  WriteLine("") ;
  AssertTrue("Value successfully propagated", b0.b2.fp2 == 4) ;
  AssertTrue("Value has been copied (i.e., not moved)", b0.b1.fp1 == 4 && b0.b2.fp2 == 4) ;
  WriteLine("") ;
  WriteLine("-- End of test case --") ;
}
```

B.2.1.2 Writing on FlowProperties Typed by Blocks

This test case addresses propagation of values when writing a value on an out FlowProperty typed by a Block. The object on which the value is written has no interaction points (i.e., it is classified by a Block without Ports). This source object is connected directly to a target object which has a single matching FlowProperty. The two matching FlowProperties are composite Properties. The propagation of the written value thereby requires a transfer of ownership. It means that, when the value is written on the FlowProperty of the source object, this value is moved (i.e., not copied as for FlowProperties typed by ValueTypes) on the matching FlowProperty of the target object. Structural aspects of this test case are depicted in Figure 95 and Figure 96 .

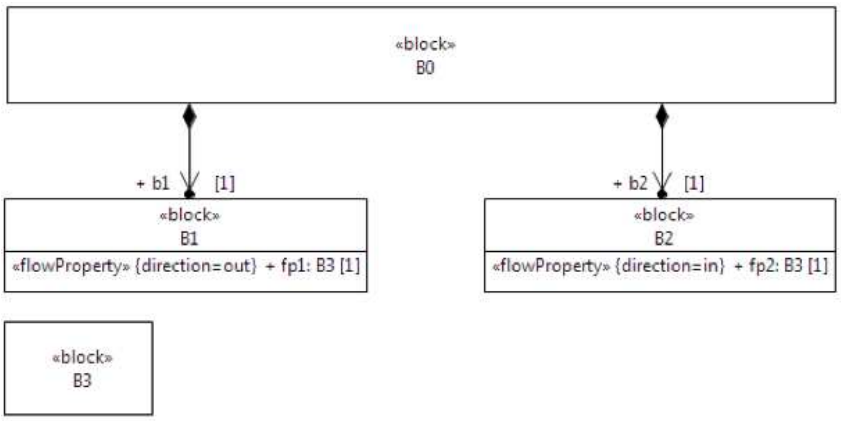


Figure 95: Block Definition Diagram

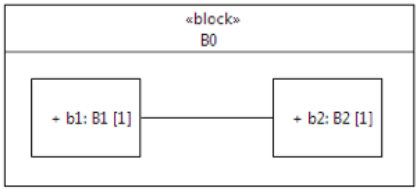


Figure 96: Internal Block Diagram

The corresponding test case behavior is:

```
activity TestCaseBehavior() {
  WriteLine("-- Untyped connector between parts with flow properties --") ;
  WriteLine("-- Multiplicity 1 on parts, connector ends, and flow properties --") ;
  WriteLine("-- Flow properties typed by a Block --") ;
  // Constructing the system
  let b3 : B3 = new B3() ;
  let b0 : B0 = new B0() ;
  b0.b1 = new B1() ;
  b0.b2 = new B2() ;
  Default.createLink(x => b0.b1, y => b0.b2) ;
  // Testing
  b0.b1.fp1 =b3  ;
  WriteLine("") ;
  AssertTrue("Value successfully propagated", b0.b2.fp2 == b3) ;
  AssertTrue("Value has been moved (i.e., not copied)", b0.b1.fp1 == null && b0.b2.fp2 == b3)
;
  WriteLine("") ;
  WriteLine("-- End of test case --") ;
}
```

B.2.2 Test Suite 2: Connectors Between Behavior ProxyPorts

B.2.2.1 Writing on FlowProperties Typed by ValueTypes

This test case addresses instantiation of Blocks with behavior ProxyPorts, as well as propagation of values when writing a value on an out FlowProperty typed by a ValueType. The object on which the value is written has an interaction point (i.e., it is classified by a Block with a ProxyPort). Since the defining port for this interaction point is behavior, the value of the interaction point is a reference to the object itself. The interaction point of this source object is connected to the interaction point of a target object, which has a single matching FlowProperty. When the value is written on the FlowProperty of the source object, this value is copied on the matching FlowProperty of the target object. Structural aspects of this test case are depicted in Figure 97 and Figure 98.

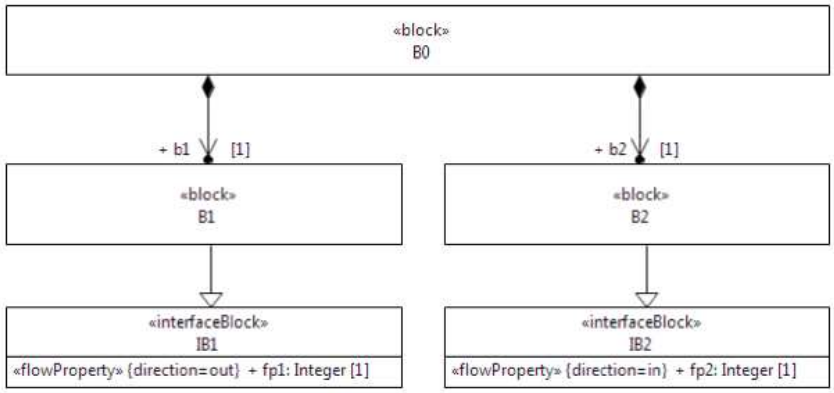


Figure 97: Block Definition Diagram

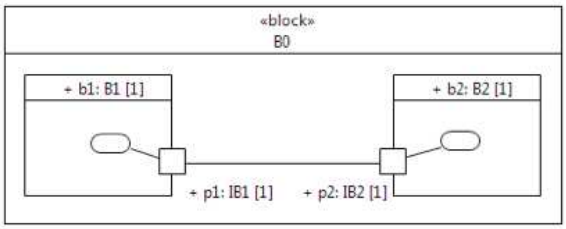


Figure 98: Internal Block Diagram

The corresponding test case behavior is:

```
activity TestCaseBehavior() {
  WriteLine("-- Untyped connector between behavior proxy ports with flow properties --") ;
  WriteLine("-- Multiplicity 1 on parts, ports, connector ends, and flow properties --") ;
  WriteLine("-- Flow properties typed by a ValueType --") ;
  // Constructing the system
  let b0 : B0 = new B0() ;
  b0.b1 = new B1() ;
  b0.b2 = new B2() ;
  Default.createLink(x => b0.b1.p1, y => b0.b2.p2) ;
  // Testing
  WriteLine("") ;
  AssertTrue("b0.b1 and b0.b1.p1 are the same object", b0.b1 == b0.b1.p1) ;
  AssertTrue("b0.b2 and b0.b2.p2 are the same object", b0.b2 == b0.b2.p2) ;
  b0.b1.p1.fp1 = 4 ;
  AssertTrue("Value successfully propagated", b0.b2.p2.fp2 == 4) ;
  AssertTrue("Value has been copied (i.e., not moved)", b0.b1.p1.fp1 == 4 && b0.b2.p2.fp2 ==
4) ;
  WriteLine("") ;
  WriteLine("-- End of test case --") ;
}
```

B.2.2.2 Writing on FlowProperties Typed by Blocks

This test case addresses instantiation of Blocks with behavior ProxyPorts, as well as propagation of values when writing a value on an out FlowProperty typed by a Block. The object on which the value is written has an interaction point (i.e., it is classified by a Block with a ProxyPort). Since the defining port for this interaction point is behavior, the value of the interaction point is a reference to the object itself. The interaction point of this source object is connected to the interaction point of a target object, which has a single matching FlowProperty. The two matching FlowProperties are composite Properties. The propagation of the written value thereby requires a transfer of ownership. It means that, when the value is written on the FlowProperty of the source object, this value is moved (i.e., not copied as for FlowProperties typed by ValueTypes) on the matching FlowProperty of the target object. Structural aspects of this test case are depicted in Figure 99 and Figure 100.

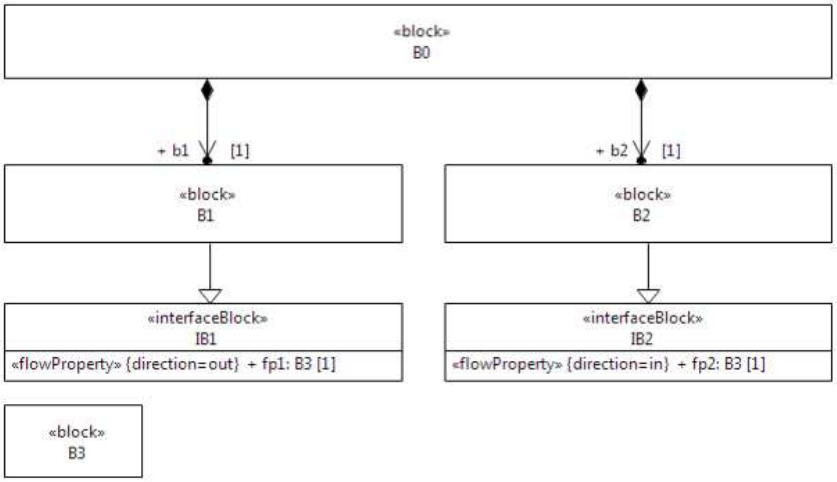


Figure 99: Block Definition Diagram

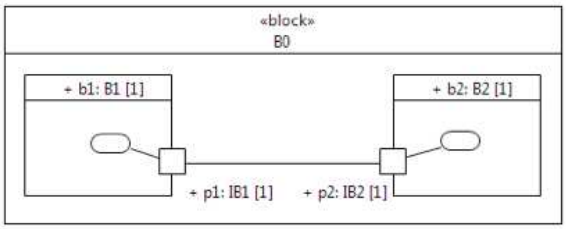


Figure 100: Internal Block Diagram

The corresponding test case behavior is:

```
activity TestCaseBehavior() {
  WriteLine("-- Untyped connector between behavior proxy ports with flow properties --") ;
  WriteLine("-- Multiplicity 1 on parts, ports, connector ends, and flow properties --") ;
  WriteLine("-- Flow properties typed by a Block --") ;
  // Constructing the system
  let b0 : B0 = new B0() ;
  b0.b1 = new B1() ;
  b0.b2 = new B2() ;
  Default.createLink(x => b0.b1.p1, y => b0.b2.p2) ;
  // Testing
  WriteLine("") ;
  AssertTrue("b0.b1 and b0.b1.p1 are the same object", b0.b1 == b0.b1.p1) ;
  AssertTrue("b0.b2 and b0.b2.p2 are the same object", b0.b2 == b0.b2.p2) ;
  let b3 : B3 = new B3() ;
  b0.b1.p1.fp1 = b3 ;
  AssertTrue("Value successfully propagated", b0.b2.p2.fp2 == b3) ;
  AssertTrue("Value has been moved (i.e., not copied)", b0.b1.p1.fp1 == null && b0.b2.p2.fp2
== b3) ;
  WriteLine("") ;
  WriteLine("-- End of test case --") ;
}
```

B.2.2.3 Block with Multiple Behavior ProxyPorts

This test case is a variant of the two previous test cases. The object on which the value is written has two interaction points (i.e., it is classified by a Block with two behavior ProxyPort). When the value is written on the FlowProperty of the source object, though a given interaction point, this value is propagated only through links where this interaction point is involved. Structural aspects of this test case are depicted in Figure 101 and Figure 102.

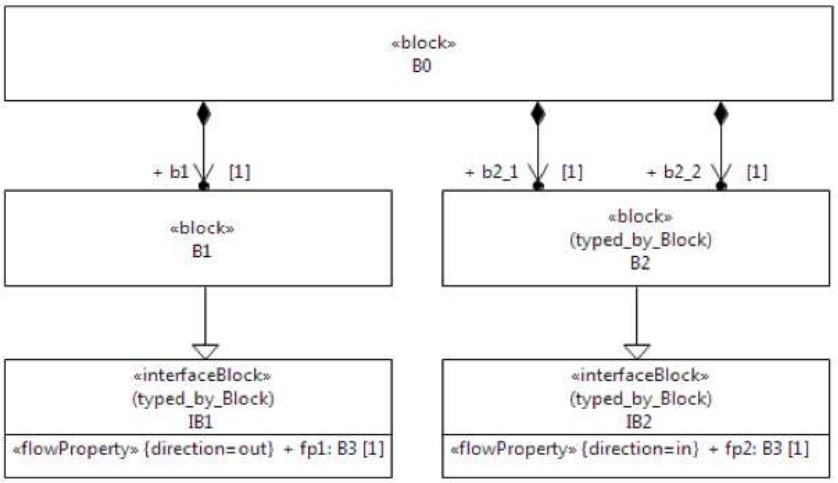


Figure 101: Block Definition Diagram

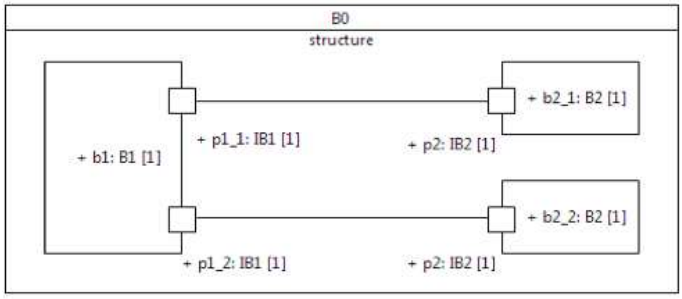


Figure 102: Internal Block Diagram

The corresponding test case behavior is:

```
activity TestCaseBehavior() {
  WriteLine("-- Untyped connector between behavior proxy ports with flow properties --") ;
  WriteLine("-- Multiple Behavior Proxy Ports") ;
  WriteLine("-- Multiplicity 1 on parts, ports, connector ends, and flow properties --") ;
  WriteLine("-- Flow properties typed by a Block --") ;
  // Constructing the system
  b0 = new B0() ;
  b0.b1 = new B1() ;
  b0.b2_1 = new B2() ;
  b0.b2_2 = new B2() ;
  Default.createLink(x => b0.b1.p1_1, y => b0.b2_1.p2) ;
  Default.createLink(x => b0.b1.p1_2, y => b0.b2_2.p2) ;
  // Testing
  WriteLine("") ;
  let b3 : B3 = new B3() ;
  b0.b1.p1_1.fp1 = b3 ;
  AssertTrue("Value successfully propagated to b0.b2_1.p2", b0.b2_1.p2.fp2 == b3) ;
  AssertTrue("Value successfully propagated to b0.b2_2.p2", b0.b2_2.p2.fp2 == b3) ;
  WriteLine("") ;
  WriteLine("Writing directly on b0.b1.fp1...") ;
  let b4 : B3 = new B3() ;
  b0.b1.fp1 = b4 ;
  AssertTrue("Value successfully propagated to b0.b2_1.p2", b0.b2_1.p2.fp2 == b4) ;
  AssertTrue("Value successfully propagated to b0.b2_2.p2", b0.b2_2.p2.fp2 == b4) ;
  WriteLine("") ;
  WriteLine("-- End of test case --") ;
}
```

Annex C A Generic Association for Instantiation of Untyped Connectors (informative)

In this specification, CS_Link is used to represent connector instances, though there is no explicit relationship between CS_Link and Connector. Subclause 8.5.1.2.4 (CS_DefaultConstructStrategy) specifies how CS_Links are instantiated from Connectors.

A CS_Link can also be created using a CreateLinkAction. Note that this kind of Action relies on LinkEndData for identifying the actual end objects to be connected. As currently defined in UML, the identification of an end object by a LinkEndData requires the existence of an Association, and has no consideration for Connectors (this is the reason why there is no explicit relationships between CS_Link and Connector). The manual instantiation of a Connector is thereby specified with a CreateLinkAction, where elements to be linked act as values for roles identified by the Connector. If the Connector is typed by an Association, the LinkEndData of the CreateLinkAction relies on this Association. In the case where the Connector is not typed, a generic Association (with untyped ends) can be used to specify the LinkEndData of the CreateLinkAction.

Machine readable file GenericAssociation.xmi contains such an Association called *Default*. Examples of how this association can be used are given in the SysML test suites, B.2.