Meta Object Facility (MOF) Core Specification

OMG Available Specification – Version 2.4 ~~Beta~~Convenience

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1 Scope

<u>Issue 15143: Replace section</u>

<u>This MOF 2 Core specification provides the basis for metamodel definition in OMG's family of MDA languages and is based on a simplification of UML2's class modeling capabilities. In addition to providing the means for metamodel definition it adds core capabilities for model management in general, including Identifiers, a simple generic Tag capability and Reflective operations which are generically defined and can be applied regardless of metamodel.</u>

<u>MOF 2 Core is built on by other OMG MOF specifications, including the following (in this list 'MOF based model' means any model that instantiates a metamodel defined using MOF, which includes metamodels themselves):</u>

- <u>MOF 2 XMI – for interchanging MOF-based models in XML</u>
- <u>MOF 2 IDL – defines a platform-specific API for MOF Core operations for OMG's CORBA platform</u>
- <u>MOF 2 Facility and Object Lifecycle – for connecting to and managing collections of MOF-based model elements</u>
- <u>MOF 2 Versioning and Development Lifecycle – for managing versions and configurations of MOF-based models</u>
- <u>MOF Queries Views and Transformations – for transforming MOF-based models</u>
- <u>MOF Models to Text – for generating text, such as programs, from MOF-based models</u>
- <u>Object Constraint Language – for specifying constraints on MOF-based models</u>

~~This MOF 2.0 Core specification is in response to the Object Management Group Request For Proposals ad/01-11-14 (*MOF 2.0 Core RFP)*. This MOF 2.0 specification is based on the following OMG Specifications:~~

- ~~MOF 1.4 Specification -- MOF 2.0 is a major revision of the MOF 1.4 Specification. MOF 2.0 addresses issues deferred to MOF 2.0 by the MOF 1.4 RTF. For information on migration from MOF 1.4 to MOF 2.0 please refer to the "Migration from MOF 1.4" chapter.~~

- ~~UML 2.0 Infrastructure Convenience Document: ptc/04-10-14 -- MOF 2.0 reuses a subset of the UML 2.0 Infrastruc-ture Library packages.~~

~~MOF 2.0 XMI Convenience document: ptc/04-06-11 -- Defines the XML mapping requirements for MOF 2.0 and UML 2.0.~~

2 Conformance

There are two compliance points:

- Essential MOF (EMOF)

- Complete MOF (CMOF)

Issue 15143: Update text

Compliant products shall support one or more of the following technology mappings: MOF 2.0 XMI (ptc/04-06-11), MOF 2.0 IDL, and MOF 2.0 Java binding. Additional conformance rules based on MOF 2.0 IDL and MOF 2.0 Java binding will beare specified in separate these specifications.

3 Normative References

Readers of this MOF 2 Core specification are expected to be familiar with the UML specification, since UML provides the structures forming MOF metamodels. The structures supported by MOF are at the level of those in the UML 2 Infrastructure: specifically the Basic package for the EMOF compliance level and Constructs for the CMOF compliance level. However, for ease of definition, MOF uses full UML Superstructure models directly, albeit with constraints (defined in the chapters for EMOF and CMOF). Hence the normative reference is the Classes chapter of the following specification:
  • UML 2.4 Superstructure Specification: ptc/2010-08-02

Issue 15143: Update text to replace references to 2.0

Issue 12175 Update reference to refer to UML 2.4 Infrastructure

Issue 15398: replace for use of UML 2.4 Superstructure

_Readers of this MOF 2.0 Core specification are expected to be familiar with the UML ~~Infrastructure V 2.0~~ specification. since UML provides the structures forming MOF metamodels. The structures supported by MOF are at the level of those in the UML 2 Infrastructure: specifically the Basic package for the EMOF compliance level and Constructs for the CMOF compliance level. However, for ease of definition, MOF uses full UML Superstructure models directly, albeit with constraints (defined in the chapters for EMOF and CMOF). ~~The MOF 2.0 model packages Essential MOF (EMOF) and Complete MOF (CMOF) are constructed by merging the UML2 Infrastructure Library packages~~.
Hence the normative reference is the Classes chapter of the following specification:
  • UML 2.4 Superstructure Specification: ptc/2010-11-14

~~The main body of the document describes the technical specification itself. This specification references the following documents:~~

~~UML 2.0 Infrastructure Convenience Document: ptc/04-10-14~~

~~MOF 2.0 XMI Convenience document: ptc/04-06-11~~

4 Terms and Definitions

There are no formal definitions in this specification that are taken from other documents.

5 Symbols

There are no symbols defined in this specification.

6 Additional Information

6.1 Mailing Lists

The following mailing list is available for requesting information and reporting issues:

- issues@omg.org — to handle issue management and revision to the specifications, or

- via the OMG web site.

6.2 Technical Specification

The technical specification is presented in the main body of this document. It comprises a set of new packages that will result in a major revision to the architecture and foundation constructs of the MOF 1.4 specification.

6.3 How to Read this Specification

Part one is best read first, beginning to end. The rest is organized based on package structure and can be read in any order.

6.4 Acknowledgements

The following companies submitted and/or supported parts of this specification:

- Adaptive

- Borland

- Ceira Technologies

- Compuware

- Data Access Technologies

- DSTC

- Gentleware Intellicorp

- Hewlett-Packard

- Hyperion

- International Business Machines

- IONA

- Kinetium

- MetaMatrix

- Project Technology

- SOFTEAM

- Sun Microsystems

- Telelogic AB

- Unisys

- University of Kent

- University of York

- X-Change Technologies Group

- 88solutions

The submitters acknowledge the generous help in preparation of this specification from others outside the team. In particular, the U2P, UU and 3C teams proposing UML 2 have contributed much to this effort.

Part I – Introduction

The Internet has connected data sources and applications across the planet driving an expectation of easy and transparent data exchange between applications. Incompatible metadata across different systems have been a primary limitation on data exchange. Metadata are data about data. They are the data used by tools, databases, middleware, etc. to describe structure and meaning of data.

Unfortunately, many applications use proprietary models of metadata. The differences between metadata models impede data exchange across application boundaries. Resolving these differences will accelerate integration of important applications that require interchange, such as data warehousing, business intelligence, e-commerce, and information portals.

15143: remove reference to MOF 1.4

The Meta Object Facility (MOF), an adopted OMG standard, (latest revision MOF 1.4) provides a metadata management framework, and a set of metadata services to enable the development and interoperability of model and metadata driven systems. Examples of these systems that use MOF include modeling and development tools, data warehouse systems, metadata repositories etc. A number of technologies standardized by OMG, including UML, MOF, CWM, SPEM, XMI, and various UML profiles, use MOF and MOF derived technologies (specifically XMI and more recently JMI which are mappings of MOF to XML and Java respectively) for metadata-driven interchange and metadata manipulation.

MOF has contributed significantly to some of the core principles of the emerging OMG Model Driven Architecture. Building on the modeling foundation established by UML, MOF introduced the concept of formal metamodels and Platform Independent Models (PIM) of metadata (examples include several standard OMG metamodels including UML, MOF itself, CWM, SPEM, Java EJB, EDOC, EAI etc.) as well as mappings from PIMs to specific platforms (Platform Specific Models and mapping examples include MOF-to-IDL mapping in the MOF specification, MOF-to-XML DTD mapping in the XMI specification, MOF-to-XML Schema mapping in the XMI production of XML Schema specification, and MOF-to-Java in the JMI specification).

Issue 15143: Update text

The OMG adopted the MOF 1.1 specification in November 1997 coincident with the adoption of UML 1.1 as a result of unprecedented collaboration between the vendors proposing UML 1.1 and MOF 1.1 specifications. This collaboration continues to this day as the vendors working on UML 2.0 Infrastructure and MOF 2.0 are attempting even greater reuse (as required by the OMG RFPs) and integration of modeling concepts to provide a solid foundation for MDA. It is fair to mention that this integration work has proven to be more challenging than expected but is expected to drive the next generation of model and metadata driven systems in the industry.

Issue 15143: Delete and update obsolete text

Since then, MOF Revision Task Forces have produced several minor revisions, the most recent being the MOF 1.4 specification, which was adopted in October 2001.
MOF 2 is represented by a set of specifications: MOF 2 Core, MOF 2 IDL Mapping, MOF 2 XMI Mapping, MOF 2 Facility and Object Lifecycle, MOF 2 Versioning and Development Lifecycle, MOF 2 Query/View/Transformations, MOF Model to Text.

The use of MOF and XMI over the last few years has raised numerous application and implementation issues by vendors. As of the time of this writing over 150 formal usage and implementation issues have been submitted to the OMG for consideration. While a vast majority of these issues have been addressed by MOF 1.4, some are considered too major to be addressed by a Revision Task Force (RTF), and therefore, a series of MOF 2.0 RFPs (seven so far: MOF 2.0 Core, MOF 2.0 IDL Mapping, MOF 2.0 XMI Mapping, MOF 2.0 Versioning and MOF 2.0 Query/View/Transformations, MOF 2.0 Facility RFP, MOF 2.0 Facility RFP) have been issued.

The reader must keep in mind that the individual ~~RFPs~~ specifications ~~and the proposals~~ can be used incrementally and independently, and this modularity ~~is~~ was a design goal of MOF 2.~~0.~~ For example, vendors can implement the MOF 2.~~0 Model~~ Core as a framework for metamodeling and metadata representation and management without using MOF 2.~~0~~ IDL or MOF 2.~~0 Java mapping~~ Facility. This was considered very important to provide more choice for MOF implement~~eo~~rs. ~~Likewise, not all MOF vendors agree that metadata versioning and federation are required features of all MOF systems, and hence the decision to separate out more focused requirements in separate RFPs. Time will tell if this component-based approach to building specifications will be successful, but the submitters are convinced that we are on the right track.~~

This MOF 2.~~0~~ specification integrates and reuses the complementary UML 2.~~0~~ Infrastructure ~~submission~~ specification to provide a more consistent modeling and metadata framework for OMG's Model Driven Architecture. UML 2.~~0~~ provides the modeling framework and notation, MOF 2.~~0~~ provides the metadata management framework and metadata services. ~~The manner in which the specification addresses individual RFP requirements is explained in the Scope of this specification.~~ Considerable progress has been made in eliminating overlapping modeling constructs in UML 1 and MOF 1 specifications (for example, the confusion between MOF References and UML AssociationEnds has been eliminated). More importantly the modeling constructs from the UML2 Infrastructure Library are reused (using import) by both the MOF 2, UML2 Infrastructure, and UML2 Superstructure specifications.

~~One of the challenges the MOF 2.0 Core and MOF 2.0 XMI Mapping submissions face is to maintain a stable interchange model (XMI) while MOF 2 and UML 2 are changing quite significantly. To accomplish this, we have begun applying the design principles that have been used in the XMI for XML Schemas and now the MOF 2.0 XMI mapping submission. This is to use a very small subset of the modeling concepts in MOF. We call this Essential MOF or EMOF which basically models simple classes with attributes and operations to fix the basic mapping from MOF to XML and Java. Additional mapping rules are provided in a manner consistent with XMI 2.0 for more complex modeling constructs. Please refer to the MOF 2.0 XMI Convenience document: ptc/04-06-11 for more details.~~

The next chapters describe the language architecture, proofs of concepts, and formalism approach used to define MOF 2.~~0~~.

7 MOF Architecture

This chapter describes the architecture of the MOF and how it serves as the platform-independent metadata management foundation for MDA. The chapter also summarizes major architectural decisions that influenced the design of MOF 2.0. Finally, the relationship of MOF 2.0 to UML 2.0 and the use of MOF to instantiate UML 2.0 and future OMG metamodels is summarized.

7.1 MOF 2.0 Design Rationale

The primary purpose of this major revision of MOF is to provide a next-generation platform-independent metadata framework for OMG that builds on the unification accomplished in MOF 1.4, XMI 1.2, XMI production of XML Schemas, and JMI 1.0. The modeling foundation of the MOF 2.0 has strongly influenced and, at the same time, has been strongly influenced by the UML 2.0 Infrastructure specification because of a shared vision of reusing the core modeling concepts between UML 2.0, MOF 2.0, and other emerging OMG metamodels. The fact that some of the same companies and designers worked on both the specifications and championed these design principles has made this unification and reuse possible. Continuing the tradition of MOF since 1997, MOF2 can be used to define and integrate a family of metamodels using simple class modeling concepts. As in MOF1 only UML class modeling notation is used to describe MOF compliant metamodels. What is significant about MOF2 is that we have unified the modeling concepts in MOF2 and UML2 and reused a common UML2 Infrastructure library in both the MOF2 and UML2 specifications. The major benefits of this approach include:

Simpler rules for modeling metadata (just understand a subset of UML class modeling without any additional notations or modeling constructs).

Various technology mappings from MOF (such as XMI, JMI, etc.) now also apply to a broader range of UML models including UML profiles.

Broader tool support for metamodeling (any UML modeling tool can be used to model metadata more easily).

15143: Remove obsolete paragraph

~~While much progress has been made in unification of the modeling concepts in MOF 2 and UML 2, the goal of reuse of meta model packages across object and non-object systems continues to be challenging. To address this the initial MOF 2.0 Core submission included a chapter titled "Common Concepts." In the revised submission (in part to meet current submission deadlines and because this task proved to be more difficult than anticipated) we have scaled back these goals to focus on reuse between just UML and MOF. The MOF2 submission team recommends additional OMG RFPs be issued to address this broader reuse of metamodel packages between object and non-object systems.~~

In any case MOF2 can be used to define (without the need to reuse specific metamodel packages) both object and nonobject oriented metamodels (as was true with MOF1).

Based on the experience of implementors of MOF, XMI, and JMI in the context of well known industry standard metamodels such as UML and CWM, some of the overriding design concerns and goals are:

1. Ease of use in defining and extending existing and new metamodels and models of software infrastructure. We wanted to make sure that defining and extending metamodels and models of metadata is as simple as defining and extending normal object models. The reuse of a 'common core' between UML 2.0, MOF 2.0 and additional key metamodels (CWM, EAI) is key to accomplishing this goal. Future RFPs for CWM2, EAI2 etc. are expected to either reuse the common core or propose changes to improve the reusability.

2. Making the MOF model itself much more modular and reusable. Note that this was also an overriding design goal for the UML 2.0 Infrastructure submission. In a sense, we have begun the work of component-oriented modeling where model packages themselves become reusable across modeling frameworks. The roots of this

work began when CWM was being defined. The complexity of modeling the data warehousing problem domain necessitated this divide-and-conquer approach. The refactoring done so far has resulted in a more modular set of packages suitable for object modeling.

3. The use of model refactoring to improve the reusability of models. Some of the lessons learned were influenced by the refactoring experience from the programming language domain at the class level that is much more widely used. Also influencing our work was the experience of the CWM design team and the UML 2.0 design teams. While this approach has resulted in a larger number of fine grained packages, we believe this approach will improve reuse and speed the development of metamodels and new modeling frameworks. A direct result of this effort is the reuse of a subset of 'Common Core' metamodel packages by MOF 2.0 and UML 2.0 Specifications.

4. Ensure that MOF 2.0 is technology platform independent and that it is more practical to map from MOF 2.0 to a number of technology platforms such as J2EE, .Net, CORBA, Web Services, etc. The experience gained in the definition of the MOF, XMI, and JMI specifications, which already define many technology mappings from and to the MOF model, has been a solid foundation for this effort. It is a design goal that MOF implementations using different language mappings can interoperate (for example using XML interchange).

5. Orthogonality (or separation of concerns) of models and the services (utilities) applied to models is a very important goal for MOF 2.0. One of the lessons learned in MOF 1 and XMI 1 was that the original design of MOF was overly influenced and constrained by the assumed lifecycle semantics of CORBA based metadata repositories. As it turned out, the industry embraced a more loosely coupled way to interchange metadata (as well as data) as evidenced by the popularity of XML and XMI. Interestingly, vendors used MOF in many different ways - to integrate development tools, data warehouse tools, application management tools, centralized and distributed repositories, developer portals etc. It became clear that to provide implementation flexibility, we had to decouple the modeling concepts from the desirable metadata services such as metadata interchange (using XML streams versus using Java/CORBA objects), Reflection, Federation, Life Cycle, Versioning, Identity, Queries, etc. We consider this orthogonality of models from services to be a very significant feature of MOF 2.0. Because of the variety of implementation choices and services available, many of the more complex services (Federation, Versioning, Query, etc.) are subjects of additional OMG RFPs.

6. MOF 2.0 models reflection using MOF itself as opposed to just specifying reflection as a set of technology-specific interfaces. This is in the spirit of item 5 above to model Reflection as an independent service. This approach also clearly separates the concerns of reflection, life cycle management, etc., which were combined together in MOF 1.

7. MOF 2.0 models the concept of identifier. The lack of this capability in MOF, UML, CWM, etc., made interoperability of metadata difficult to implement. The submitters understand that modeling identifiers is not easy, but we plan to show its usefulness in a simple domain - identifiers for metadata first. A key design goal is to make it easy to map this model of identifier to W3C identifier and referencing mechanisms such as the URI.

8. Reuse of modeling frameworks and model packages at various metalayers by better packaging of MOF 'Capabilities'. Note that some commonly used types and services can be used in defining the MOF itself, various metamodels (such as UML and CWM), as well as user models and even user objects. A by-product of the orthogonality principle is that some MOF capabilities can be used at multiple metalayers.

7.2 How Many "Meta Layers"?

Issue 15143: replace reference to MOF 1.4

One of the sources of confusion in the OMG suite of standards is the perceived rigidness of a 'Four layered metamodel architecture' which is referred to in various OMG specifications. Note that key modeling concepts are Classifier and Instance or Class and Object, and the ability to navigate from an instance to its metaobject (its classifier). This fundamental concept can be used to handle any number of layers (sometimes referred to as metalevels). The MOF 1.42 Reflection interfaces allow traversal across any number of metalayers recursively. Note that most systems use a small MOF Core Specification, v2.0 **9** number of levels (usually less than or equal to four).

Example numbers of layers include 2 (generic reflective systems - Class/Object), 3 (relational database systems - SysTable/Table/Row), and 4 (UML 2.0 Infrastructure, UML 1.4 and MOF 1.4 specification - MOF/UML/User Model/User Object). MOF 1 and MOF 2.0 allow any number of layers greater than or equal to 2. (The minimum number of layers is two so we can represent and navigate from a class to its instance and vice versa). Suffice it to say MOF 2.0 with its reflection model can be used with as few as 2 levels and as many levels as users define.

7.3 Reuse of Common Core Packages by UML 2.0 and MOF 2.0

Issue 15143: Update the text

The UML 2.0 Infrastructure Library uses fine grained packages to bootstrap the rest of UML 2.0. A design goal (and RFP Requirement) is to reuse this infrastructure in the definition of the MOF 2.0 Model. In MOF 2.0 this reuse is simply accomplished by using a standard CMOF extensibility mechanism -- importing, combining, and merging existing MOF 2.0 compliant packages. Importing packages makes model elements contained in the imported package visible in the importing package. Merging packages extends model elements in the merging package with new feature deltas from the merged package. The details are covered in the UML 2.0 Infrastructure Convenience document in the section on PackageMerge. Note that we have designed both the UML 2.0 model and the MOF 2.0 model are designed to be compliant to MOF 2.0 and be instantiable from MOF 2.0.

Standard class modeling concepts (importing, subclassing, adding new classes, associations and adding associations between existing classes) are used for MOF 2.0 extensibility. (This is identical to the extensibility mechanism in MOF 1). These concepts are used to define additional packages (such as Reflection, Extents, and Identities) in MOF 2.0 as well as in any other MOF 2.0 compliant model.
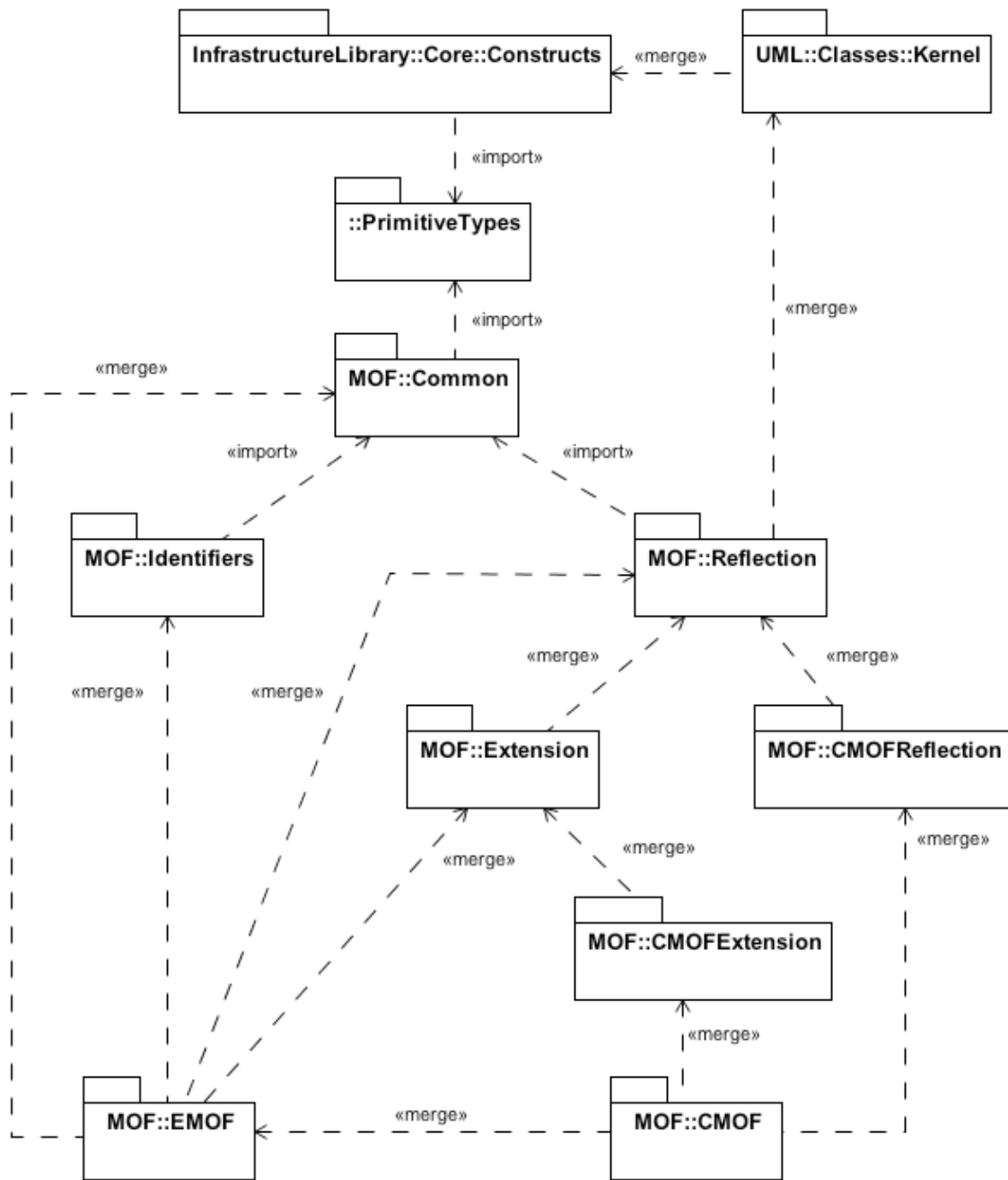
Figure 7.1 – MOF imports from the UML Core

Issue 15824: update figure 7.1

8 Language Formalism

This chapter explains techniques used to describe the MOF. The MOF is described using both textual and graphic presentations. The specification uses a combination of languages - a subset of UML, an object constraint language, and precise natural language - to precisely describe the abstract syntax and semantics of the MOF. Unlike MOF 1 and UML 1 where slightly different techniques (sometimes subtly different) were used, the MOF2 specification reuses much of the formalisms in the UML 2.0 Infrastructure. In particular, EMOF and CMOF are both described using CMOF, which is also used to describe UML2. EMOF is also completely described in EMOF by applying package import, and merge semantics from its CMOF description. As a result, EMOF and CMOF are described using themselves, and each is derived from, or reuses part of, the UML 2.0 Infrastructure Library.

8.1 Metamodel Specification

Issue 15143: Update text

Please refer to the chapter "Language Formalism" in the UML 2.0 Infrastructure Convenience document. The CMOF model reuses the same formalisms and in fact simply imports and merges packages in the UML 2.0 Infrastructure Library. EMOF is somewhat simpler as described in the next section.

8.2 Using Packages to Partition and Extend Metamodels

Packages in UML2 Constructs can be used for two purposes. The first is package import; a mechanism for grouping related model elements together in order to manage complexity and facilitate reuse. Since a Package is also a Namespace, model elements referenced across package boundaries must be qualified by their full package name. Package import relaxes this constraint by making model elements in the imported package directly visible in the importing package where they may be used in associations with other model elements, specialized with sub-classes that provide additional features, etc. The second use of packages is to facilitate combining new or reusable metamodeling features to create extended modeling languages. Package merging combines the features of the merged package with the merging package to define new integrated language capabilities. After package merge, classes in the merging package contain all the features of similarly named classes in the merged package.

8.3 Changes from MOF 1.4 (optional)

Here, changes compared with MOF 1.4 are described as appropriate. See also Chapter 16 "Migration from MOF 1.4 to MOF 2.0."

8.4 Null

Null is used in this specification to indicate the absence of a value. For example, a single-valued property that is null has no value, and when an operation returns null, it is returning no value.

Part II – Capabilities

The MOF models use a number of building-block concepts meant for widespread reuse by other models and metamodels. These separate concerns or "capabilities" contain several packages addressing different modeling and metadata management concerns. These packages are then merged into EMOF and CMOF, and other metamodels as needed in order to extend those models with the capabilities. The packages described in this part are:

Reflection: extends a model with the ability to be self describing.

Identifiers: Provides an extension for uniquely identifying metamodel objects without relying on model data that may be subject to change.

Extension: A simple means for extending model elements with name/value pairs.

The various packages making up the supported capabilities are instances of CMOF::Package, and all of its contents are instances of classes in the CMOF Model.

The following chapters describe each of the packages making up the supported capabilities.

9 Reflection

An advantage of metaobjects generally is that they enable use of objects without prior knowledge of the objects' specific features. In a MOF context, an object's class (i.e., its metaobject) reveals the nature of the object - its kind, its features. The Reflection Package allows this discovery and manipulation of metaobjects and metadata.

Issue 15143: Delete obsolete note

~~Note – The Factory class has some overlap with the MOF Life cycle RFP and will need to be reconciled when submissions for that RFP are adopted.~~

Issue 5948: Add Element::/metaclass

Issue 15824: Fix imports/merges and make certain operations {query}

Issue 15832: Move 4 operations from Element to Object

Issue 15859: Update operations
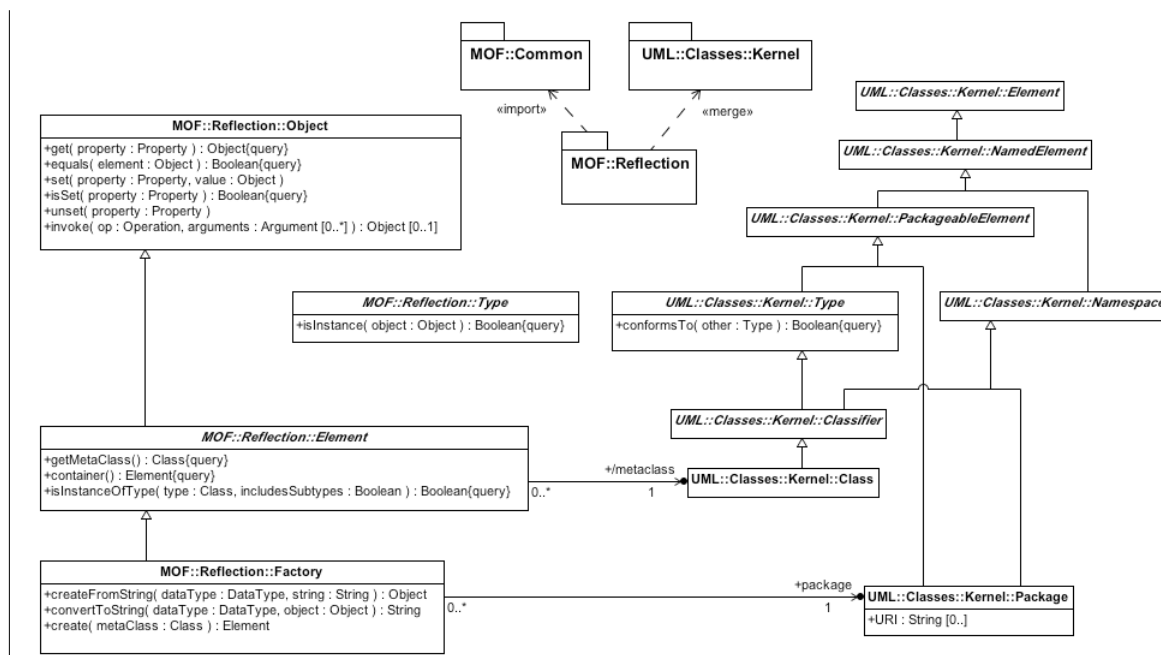
Figure 10.1 – The Reflection package

9.1 Element

Every Element has a Class that describes its properties and operations. The Element is an Instance of this Class. Element merges and extends Basic::Element. All model elements that specialize Reflection::Element inherit reflective capabilities. In particular, this includes all model elements from UML2 Infrastructure.

All the conditions in Section 12.5, "EMOF Definitions and Usage Guidelines for the Basic Model," on page 36 are also part of the reflective behavior.

If any reflective operation attempts to create cyclic containment, an IllegalArgumentException is thrown.

Properties

Issue 5498: Add derived property

/metaclass: Class

Returns the Class that describes this element. This is a derived property provided for convenience and consistency.

No additional properties.

Operations

Issue 15832: Move equals, get, set, isSet, unset to Object

getMetaClass() : Class

Returns the Class that describes this element.

container(): Element

Returns the parent container of this element if any. Return Null if there is no containing element.

equals(object: Object): Boolean

Determines if the object equals this Element instance. For instances of Class, returns true if the element and this Element instance are references to the same Object. For instances of DataType, returns true if the object has the same value as this Element instance. Returns false for all other cases.

get(property: Property) : Object

Gets the value of the given property. If the Property has multiplicity upper bound of 1, get() returns the value of the Property. If Property has multiplicity upper bound >1, get() returns a ReflectiveSequence containing the values of the Property. If there are no values, the ReflectiveSequence returned is empty. ReflectiveSequence is defined in Section 10.5, "MOF::Common," on page 24.

Exception: throws IllegalArgumentException if Property is not a member of the Class from class().

set(property: Property, object: Object)

If the Property has multiplicity upper bound = 1, set() atomically updates the value of the Property to the object parameter. If Property has multiplicity upper bound >1, the Object may be either a ReflectiveCollection or a ReflectiveSequence. The behavior is identical to the following operations performed atomically:

  ReflectiveSequence list = element.get(property);
  list.clear();
  list.addAll((ReflectiveSequence) object);

There is no return value.

Exception: throws IllegalArgumentException if Property is not a member of the Class from getMetaClass().

Exception: throws ClassCastException if the Property's type isInstance(element) returns false and Property has multi-plicity upper bound = 1

Exception: throws ClassCastException if Element is not a ReflectiveSequence and Property has multiplicity upper bound > 1

Exception: throws IllegalArgumentException if element is null, Property is of type Class, and the multiplicity upper bound > 1.

isSet(property: Property): Boolean

If the Property has multiplicity upper bound of 1, isSet() returns true if the value of the Property is different than the default value of that property. If Property has multiplicity upper bound >1, isSet() returns true if the number of objects in the list is > 0.

Exception: throws IllegalArgumentException if Property is not a member of the Class from class().

unset(property: Property)

If the Property has multiplicity upper bound of 1, unset() atomically sets the value of the Property to its default value for DataType type properties and null for Class type properties. If Property has multiplicity upper bound >1, unset() clears the ReflectiveSequence of values of the Property. The behavior is identical to the following operations performed atomically:

 ReflectiveSequence list = object.get(property);
 list.clear();

There is no return value. After unset() is called, object.isSet(property) == false.

Exception: throws IllegalArgumentException if Property is not a member of the Class from getMetaClass().

Constraints

No additional constraints.

Semantics

Issue 13127: Clarify semantics

Class Element is the superclass of all classes defined in MOF, and is an implicit superclass of all metaclasses defined using MOF: this superclass relationship to Element does not need to be explicitly modeled in MOF-compliant metamodels, and if implicit in this way Element is not included in the list of superclasses.

By creating Properties with type Element it is possible to reference elements in any MOF-compliant model, similar to the use of xsd:any in XML Schemas.

Each element can access its metaClass in order to obtain a Class that provides a reflective description of that element. By having both MOF and instances of MOF be rooted in class Element, MOF supports any number of meta layers as described in Chapter 7, "MOF Architecture."

Class Element is the superclass of all model elements in MOF, and is the superclass of all instances of MOF model elements. Each element can access its metaClass in order to obtain a Class that provides a reflective description of that element. By having both MOF and instances of MOF be rooted in class Element, MOF supports any number of meta layers as described in Chapter 7, "MOF Architecture."

The following describes the interaction between default values, null, isSet, and unSet.

Single-valued properties:

If a single-valued property has a default:

- It is set to that default value when the element is created. isSet=false.

- If the value of that property is later explicitly set, ~~even to the default value~~, isSet=true, unless it is set to the default value (if any) in which case isSet=false.

- If the property is unSet, then the value of the property returns to the default, and isSet=false.

If a single-valued property does not have a default:

- At creation, its value is null. isSet=false.

- If the value of that property is later explicitly set, even to null, isSet=true.

- If the property is unSet, then the value of the property returns to null, and isSet=false.

Multi-valued properties:

- When the element is created, it is an empty list. isSet=false.

- If the list is modified in any way (except unSet), isSet=true.

- If the list is unSet, it is cleared and becomes an empty list. isSet=false.

The implementation of isSet is up to the implementer. ~~In the worst case it can be implemented by having an additional boolean, but usually for a particular implementation it can be implemented more efficiently (e.g., by having an internal distinguished value used to represent "no value set").~~ For default values, implementations are not required to access stored metadata at runtime. It is adequate to generate a constant in the implementation class for the default.

Rationale

Element is introduced in package Reflection so that it can be combined with Core::Basic to produce EMOF which can then be merged into CMOF to provide reflective capability to MOF and all instances of MOF.

Changes from MOF 1.4

The reflective capabilities of Element have been refined and renamed from MOF1.4, but remain functionally similar.

9.2 Factory

Note – This section will need to be reconciled with the work underway in MOF lifecycle RFP.

An Element may be created from a Factory. A Factory is an instance of the MOF Factory class. A Factory creates instances of the types in a Package.

Properties

- package: Package [1] Returns the package this is a factory for.

Operations

createFromString(dataType: DataType, string: String): Object

Creates an Object initialized from the value of the String. Returns null if the creation cannot be performed.

The format of the String is defined by the XML Schema SimpleType corresponding to that datatype.

Exception: NullPointerException if datatype is null.

Exception: IllegalArgumentException if datatype is not a member of the package returned by getPackage().

convertToString(datatype: DataType, object: Object): String

Creates a String representation of the object. Returns null if the creation cannot be performed. The format of the String is defined by the XML Schema SimpleType corresponding to that dataType.

Issue 8627: add extra condition to exception

Exception: IllegalArgumentException if datatype is not a member of the package returned by getPackage() or the supplied object is not a valid instance of that datatype.

create(metaClass: Class): Element

Creates an element that is an instance of the metaClass. Object::metaClass == metaClass and metaClass.isInstance(object) == true.

All properties of the element are considered unset. The values are the same as if object.unset(property) was invoked for every property.

Returns null if the creation cannot be performed. Classes with abstract = true always return null.

The created element's metaClass == metaClass.

Exception: NullPointerException if class is null.

Exception: IllegalArgumentException if class is not a member of the package returned by getPackage().

Constraints

The following conditions on metaClass: Class and all its Properties must be satisfied before the metaClass: Class can be instantiated. If these requirements are not met, create() throws exceptions as described above.

[1] Meta object must be set.

[2] Name must be 1 or more characters.

[3] Property type must be set.

[4] Property: 0 <= LowerBound <= UpperBound required.

[5] Property: 1 <= UpperBound required.

[6] Enforcement of read-only properties is optional in EMOF.

Issue 6903: Remove constraint

[7] Properties of type Class must be unique.

[8] Properties of type Class cannot have defaults.

[9] Multivalued properties cannot have defaults.

[10] Property: Container end must not have upperBound >1, a property can only be contained in one container.

[11] Property: Only one end may be composite.

[12] Property: Bidirectional opposite ends must reference each other.

[13] Property and DataType: Default value must match type. Items 3-13 apply to all Properties of the Class.

These conditions also apply to all superclasses of the class being instantiated.

Changes from MOF 1.4

None

9.3 Object

Reflection introduces Object as a supertype of Element in order to be able to have a Type that represents both elements and data values. Object represents 'any' value and is the equivalent of java.lang.Object in Java.

Issue 15832: Move the following operations from element

Operations

equals(object: Object): Boolean

Determines if the object equals this Object instance. For instances of Class, returns true if the object and this Object instance are references to the same Object. For instances of DataType, returns true if the object has the same value as this Object instance. Returns false for all other cases.

get(property: Property) : Object

Gets the value of the given property. If the Property has multiplicity upper bound of 1, get() returns the value of the Property. If Property has multiplicity upper bound >1, get() returns a ReflectiveCollection containing the values of the Property. If there are no values, the ReflectiveCollection returned is empty.

Exception: throws IllegalArgumentException if Property is not a member of the Class from class().

set(property: Property, object: Object)

If the Property has multiplicity upper bound = 1, set() atomically updates the value of the Property to the object parameter. If Property has multiplicity upper bound >1, the Object must be a kind of ReflectiveCollection. The behavior is identical to the following operations performed atomically:

```
ReflectiveSequence list = element.get(property);
list.clear();
list.addAll((ReflectiveCollection) object);
```

There is no return value. Exception: throws IllegalArgumentException if Property is not a member of the Class from getMetaClass().

Exception: throws ClassCastException if the Property's type isInstance(element) returns false and Property has multi-plicity upper bound = 1

Exception: throws ClassCastException if Element is not a ReflectiveCollection and Property has multiplicity upper bound > 1

Exception: throws IllegalArgumentException if element is null, Property is of type Class, and the multiplicity upper bound > 1.

Issue 8269: isSet returns true regardless if it's the same as the default

Issue 15821: isSet returns true if it is the same as the default (overrides 8269)

isSet(property: Property): Boolean

If the Property has multiplicity upper bound of 1, isSet() returns true if the value of the Property is different than the default value of that property. If Property has multiplicity upper bound >1, isSet() returns true if the number of objects in the list is > 0.

Exception: throws IllegalArgumentException if Property is not a member of the Class from getMetaClass ().

unset(property: Property)

If the Property has multiplicity upper bound of 1, unset() atomically sets the value of the Property to its default value for DataType type properties and null for Class type properties. If Property has multiplicity upper bound >1, unset()

clears the ReflectiveCollection of values of the Property. The behavior is identical to the following operations performed atomically:

```
ReflectiveCollection list = object.get(property);
list.clear();
```

There is no return value.

After unset() is called, object.isSet(property) == false.

Exception: throws IllegalArgumentException if Property is not a member of the Class from getMetaClass().

10 Identifiers

An element has an identifier in the context of an extent that distinguishes it unambiguously from other elements.

There are practical uses for object identifiers. Identifiers can simplify serializing references to external objects for interchange. They can serve to coordinate data updates where there has been replication, and can provide clear identification of objects in communication, such as from user interfaces. Identifiers support comparing for identity where implementations might have multiple implementation objects that are to be considered, for some purposes, to be the same object. Identifiers also facilitate Model Driven Development by providing an immutable identifier that can be used to correlate model elements across model transformations where both the source and target models may be subject to change. Model to model reconciliation requires some means of determining how model elements were mapped that does not rely on user data (such as names) that may be subject to change.

Issue 15859: update operations

Issue 15824: Fix imports/merges and make certain operations {query}
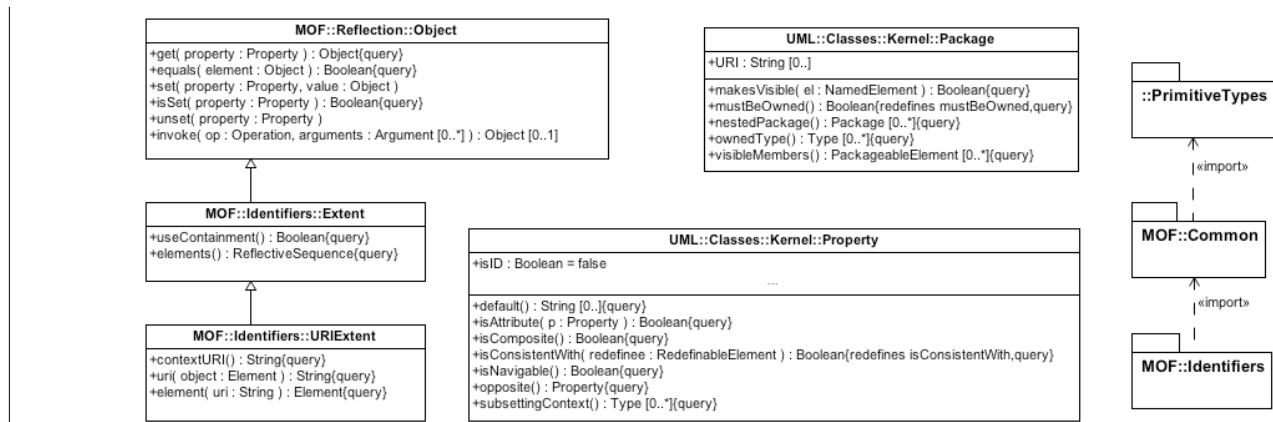
Figure 10.1 – The Identifiers package

10.1 Extent

An Extent is a context in which an Element in a set of Elements in a set can be identified. An element may be a member of zero or more extents. An Extent is not an Element, it is part of a MOF capability.

Properties

No additional properties.

Operations

useContainment(): Boolean

When true, recursively include all elements contained by members of the elements().

elements(): ReflectiveSequence

Returns a ReflectiveSequence of the elements directly referenced by this extent. If exclusive()==true, these elements must have container()==null. Extent.elements() is a reflective operation, not a reference between Extent and Element. See Chapter 4, "Reflection" for a definition of ReflectiveSequence.

Constraints

No additional constraints.

Semantics

When the element is created, it is not assigned to any Extent.

Rationale

Extents provide a context in which MOF Elements can be identified independent of any value in the Element.

Changes from MOF 1.4

MOF 1.4 defined that objects have identity based on a MOF id. MOF2 reuses the URI identity mechanism for better integration with current XML standards.

Issue 15397: Remove sections for package and Property since now in UML

10.2 Package

Identifiers extends Basic::Package with a URI that can be used as an external identifier for a package.

Properties

uri: String - Provides an identifier for the package that can be used for many purposes. A URI is the universally unique identification of the package following the IETF URI specification, RFC 2396 http://www.ietf.org/rfc/rfc2396.txt. UML 1.4 and MOF 1.4 were assigned URIs to their outermost package. The package URI appears in XMI files when instances of the package's classes are serialized.

Operations

No additional operations.

Constraints

No additional constraints.

Semantics .

The URI assigned to the package should be unique and remain unchanged.

Rationale

URIs are the universal standard for identification of all information accessible by computer software.

Changes from MOF 1.4

None.

10.3 Property

Identifiers extends Basic::Property with the ability to designate a property as an identifier for the containing element.

Properties

10.4 URIExtent

An extent that provides URI identifiers. A URIExtent can have a URI that establishes a context that may be used in determining identifiers for elements identified in the extent. Implementations may also use values of properties with isID==true in determining the identifier of the element.

Properties

No additional properties.

Operations

contextURI(): String Specifies an identifier for the extent that establishes a URI context for identifying elements in the extent. An extent has an identifier if a URI is assigned. URI is defined in IETF RFC-2396 available at http://www.ietf.org/rfc/rfc2396.txt.

uri(element: Element): String Returns the URI of the given element in the extent. Returns Null if the element is not in the extent.**24** MOF Core Specification, v2.0

element(uri: String): Element Returns the Element identified by the given URI in the extent. Returns Null if there is no element in the extent with the given URI. Note the Element does not (necessarily) contain a property corresponding to the URI. The URI identifies the element in the context of the extent. The same element may have a different identifier in another extent.

Constraints

No additional constraints.

Semantics

The URI may incorporate the value of Properties that are marked as an identifier (isID==true).

Rationale

URIs are defacto standard identifiers. They are useful for identifying MOF elements and navigating links between them.

Changes from MOF 1.4

URIExtent did not exist in MOF 1.4.

10.5 MOF::Common

This package defines common elements used throughout MOF.

Issue 6910: change parameter to addAll to reflectiveCollection

Issue 15859: update operations

Issue 15824: Fix imports/merges and make certain operations {query}
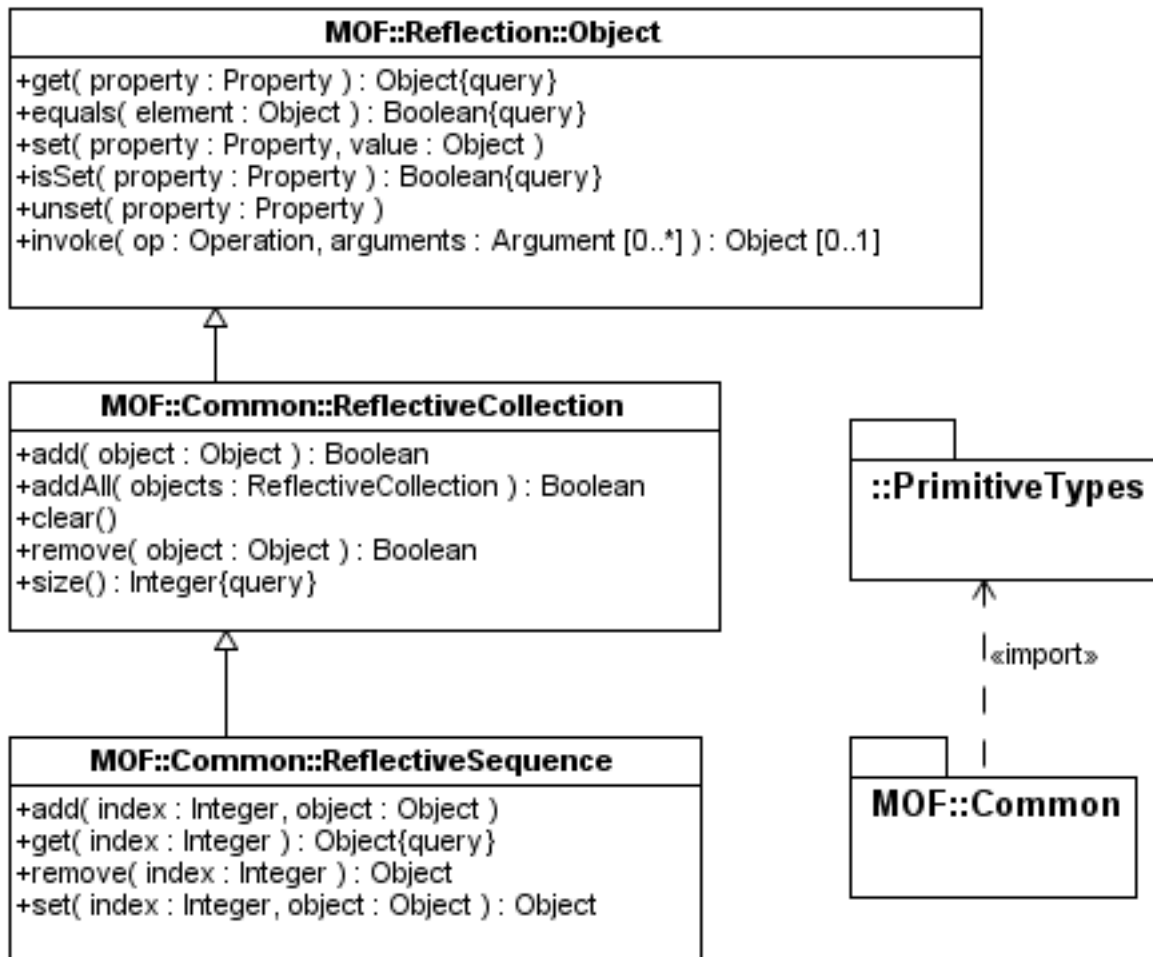
Figure 10.2 – The Common package

10.6 ReflectiveCollection

ReflectiveCollection is a reflective class for accessing properties with more than one possible value. It is defined in package MOF::Common in order to facilitate reuse in many other MOF capabilities.

For ordered properties, ReflectiveSequence (see below) must be returned.

Modifications made to the ReflectiveCollection update the Object's values for that property atomically.

Exception: throws ClassCastException if the Property's type isInstance(Element) returns false.

add(object: Object): Boolean

Adds object to the last position in the collection. Returns true if the object was added.

addAll(elements: ReflectiveSequence): Boolean

Adds the objects to the end of the collection. Returns true if any elements were added.

clear()

Removes all objects from the collection.

remove(object: Object): Object

Removes the specified object from the collection. Returns true if the object was removed.

size(): Integer

Returns the number of objects in the colleciton.

10.7 ReflectiveSequence

ReflectiveSequence is a subclass of ReflectiveCollection that is used for accessing ordered properties with more than one possible value. Modifications made to the ReflectiveSequence update the Element's values for that property atomically.

Exception: throws IllegalArgumentException if a duplicate would be added to the collection and Property.isUnique()==true.

Exception: throws IndexOutOfBoundsException if an index out of the range of 0 <= index < size() is used.

Exception: throws IllegalArgumentException if a duplicate would be added to the list and Property is of type Class or Property.isUnique()==true.

add(index: Integer, object: Object)

Adds object to the specified index in the sequence, shifting later objects.

get(index: Integer): Object

Returns the object at the given index in the sequence.

remove(index: Integer): Object

Removes the object at the specified index from the sequence. Returns the object removed.

set(index: Integer, object: Object): Object

Replaces the object at the specified index with the new object. The removed object is returned. Behavior of particular operations defined in ReflectiveCollection is the following when applied to a ReflectiveSequence:

add(object: Object): Boolean

Adds object to the end of the sequence. Returns true if the object was added.

Issue 6910: change type of parameter

addAll(objects: ~~ReflectiveSequence~~ReflectiveCollection): Boolean

issue 6907: clarify behavior

Adds any objects from the parameter collection to the end of the target sequence:
- in the same order if parameter is unordered then the ordering is random.
- if the target is a unique sequence then only if they are not already present, this includes objects already added from the parameter which has the effect of removing duplicates from the parameter collection if not unique.

Returns true if any objects were added.

~~Adds the object to the end of the sequence. Returns true if any objects were added.~~

remove(object: Object): Boolean

Removes the first occurrence of the specified object from the sequence.

11 Extension

MOF models provide the ability to define metamodel elements like classes that have properties and operations. However, it is sometimes necessary to dynamically annotate model elements with additional, perhaps unanticipated, information. This information could include information missing from the model, or data required by a particular tool. The MOF Extension capability provides a simple mechanism to associate a collection of name-value pairs with model elements in order to address this need.

Issue 6905: Add tag ownership

Issue 15824: Fix imports/merges and make certain operations {query}

Issue 15827: Updated figure, superseding that from 6905
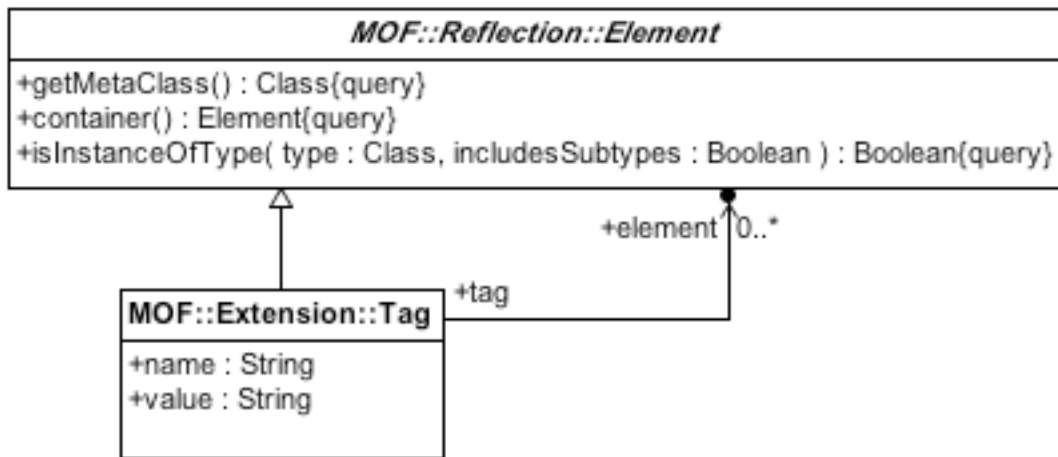
Figure 11.1 – The Extension package

11.1 Tag

A Tag represents a single piece of information that can be associated with any number of model elements. A model element can be associated with many Tags, and the same Tag can be associated with many model elements.

Properties

- name: String - The name used to distinguish Tags associated with a model element.

- value: String - The value of the Tag. MOF places no meaning on these values.

- elements: Element [0..*] - The elements that tag is applied to.

Issue 6905: Add ownership

- owner:Element [0..1] – The element that owns the tag (for management purposes)

Operations

No additional operations.

Constraints

No additional constraints.

Semantics

A Tag represents a named value that can be associated with zero or more model elements. A model element cannot have more than one tag with the same name. How tags for a model element are located is not specified by MOF.

Issue 6905: Add tag ownership

A Tag may be owned by another element. This might be a Package, where the tags have been applied externally to the model, or one of the Elements to which the Tag has been applied.

Rationale

Simple string name-value pairs provide extensibility for MOF models that cover a broad range of requirements. They are included to reduce the need to redefine metamodels in order to provide simple, dynamic extensions.

Part III - The MOF Model

A metamodel is a model used to model modeling itself. The MOF 2 Model is used to model itself as well as other models and other metamodels (such as UML 2 and CWM 2 etc.). A metamodel is also used to model arbitrary metadata (for example software configuration or requirements metadata).

Metamodels provide a platform independent mechanism to specify the following:

- The shared structure, syntax, and semantics of technology and tool frameworks as metamodels.

- A shared programming model for any resultant metadata (using Java, IDL, etc.).

- A shared interchange format (using XML).

The shared programming model and interchange formats can be generated using standardized mappings such as XMI and JMI which are transformations (mappings) of metamodels to specific technologies/languages, etc. The use of metamodels in combination with reflection enables generative modeling and programming.

The MOF 2 Model builds on a subset of UML 2.0 Infrastructure which provides concepts and graphical notation for the MOF Model. The MOF 2 Model is made up of two main packages, Essential MOF (EMOF) and Complete MOF (CMOF), which are described in subsequent chapters. The MOF Model also includes additional capabilities defined in separate packages including support for, identifiers, additional primitive types, reflection, and simple extensibility through name-value pairs.

To simplify the MOF so as to facilitate ease of implementation and conformance while maximizing interoperability and convenient interchange, MOF 2 defines EMOF as a kernel metamodeling capability defined as a limited conformance level. For the purposes of this specification, the MOF 2 model refers to Complete MOF, the CMOF model. References to EMOF are always explicit.

The following chapters describe the:

- Model Packages Essential MOF (EMOF) and Complete MOF (CMOF),

- MOF Model's requirements and use of the UML 2 Infrastructure, and migration from MOF1.4 to MOF2.

Gagagaga

12 The Essential MOF (EMOF) Model

12.1 Introduction

Issue 15398: update for direct use of UML2 Superstructure

This chapter defines Essential MOF, which is the subset of MOF that closely corresponds to the facilities found in OOPLs and XML. The value of Essential MOF is that it provides a straightforward framework for mapping MOF models to implementations such as JMI and XMI for simple metamodels. A primary goal of EMOF is to allow simple metamodels to be defined using simple concepts while supporting extensions (by the usual class extension mechanism in MOF) for more sophisticated metamodeling using CMOF. Both EMOF and CMOF (defined in the next chapter) reuse the UML2 ~~InfrastructureLibrary~~. The motivation behind this goal is to lower the barrier to entry for model driven tool development and tool integration.

The EMOF Model ~~merges~~ uses constrained UML2 class models ~~the Basic package from UML2~~ and includes additional language capabilities defined in this specification. The EMOF model merges the Reflection, Identifiers, and Extension capability packages to provide services for discovering, manipulating, identifying, and extending metadata.

EMOF, like all metamodels in the MOF 2 and UML 2 family, is described as a ~~CMOF~~ UML model. However, full support of EMOF requires it to be specified in itself, removing any package merge and redefinitions that may have been specified in the ~~CMOF~~ UML model. This chapter provides the ~~CMOF~~ UML model of EMOF, and the complete, merged EMOF model. This results in a complete, standalone model of EMOF that has no dependencies on any other packages, or metamodeling capabilities that are not supported by EMOF itself.

Note – The abstract semantics specified in "CMOF Abstract Semantics" on page 53 are optional for EMOF.

The relationship between EMOF and InfrastructureLibrary::Core::Basic requires further explanation. EMOF merges Basic with the MOF capabilities and a few extensions of its own that are described below. Ideally, EMOF would just extend Basic using subclasses that provide additional properties and operations. Then EMOF could be formally specified in EMOF without requiring package merge. However, this is not sufficient because Reflection has to introduce Object in the class hierarchy as a new superclass of Basic::Element which requires the merge. As a result of the merge, EMOF is a separate model that merges Basic, but does not inherit from it.

By using PackageMerge, EMOF is directly compatible with Basic XMI files. Defining EMOF using package merge also ensures EMOF will get updated with any changes to Basic. The reason for specifying the complete, merged EMOF model in this chapter is to provide a metamodel that can be used to bootstrap metamodel tools rooted in EMOF without requiring an implementation of CMOF and package merge semantics.
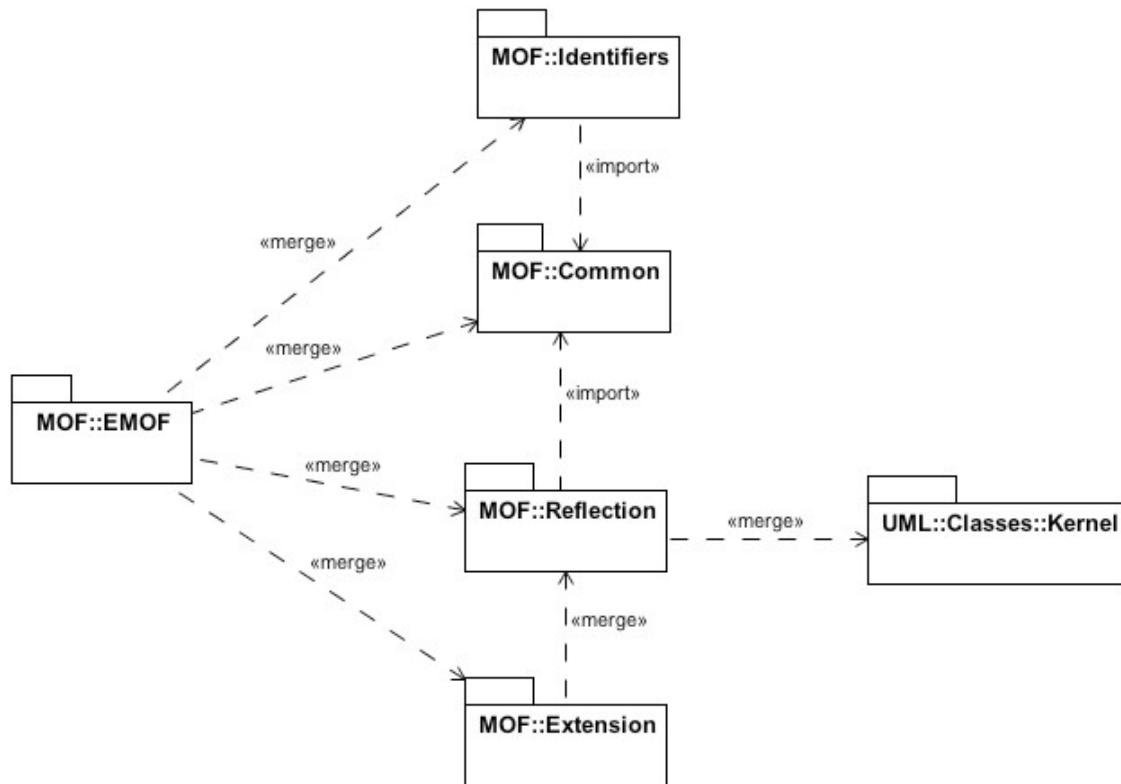
Figure 12.1 – EMOF Model- Overview

Issue 15398: Update for use of UML Superstructure

~~The~~ EMOF ~~model provides~~makes use of the minimal set of elements required to model object-oriented systems. EMOF reuses the ~~Basic~~ Kernel package from UML 2.~~0 Infrastructure~~Library as is for metamodel structure without any extensions, although it does introduce some constraints.

12.2 EMOF Merged Model

Issue 15398: Update for use of UML Superstructure

This section provides the equivalent EMOF model, obtained by merge with UML~~complete EMOF model merged with Basic and~~ the MOF capabilities and omitting those classes and properties excluded, or required to be empty, by EMOF constraints. Thus it represents those parts of UML that can be used to specify EMOF metamodels. ~~~~It is completely specified in EMOF itself after applying the package merge semantics ~~described in Infrastructure~~. The description of the model elements is identical to that found in UML ~~2.0 Infrastructure~~ and is not repeated here.

~~Basic~~

~~EMOF merges InfrastructureLibrary::Core::Basic from UML 2.0 Infrastructure. The results of the merge are given in the following diagrams.~~ The results of merging the capabilities described in the next section are also shown in some of the diagrams.
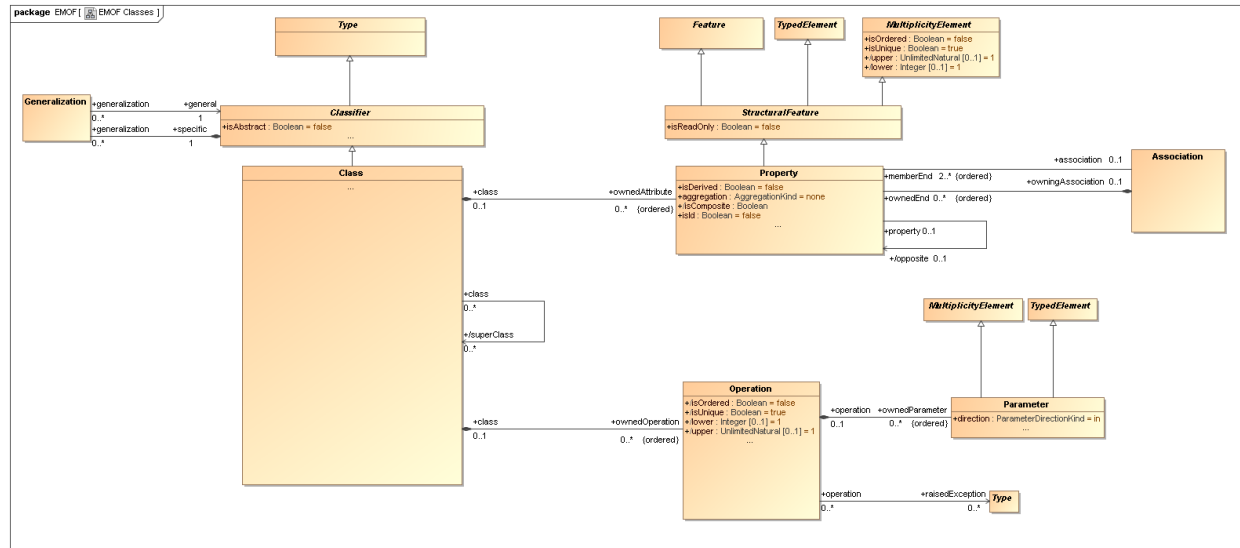
Figure 12.2 – EMOF Classes
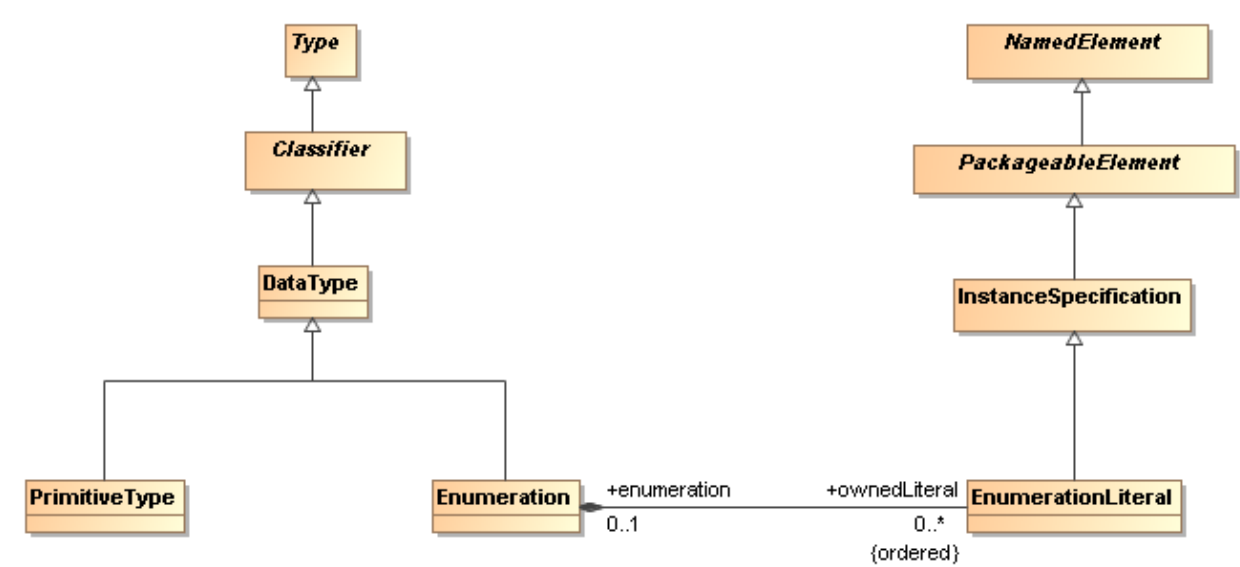
Figure 12.3 – EMOF Data Types
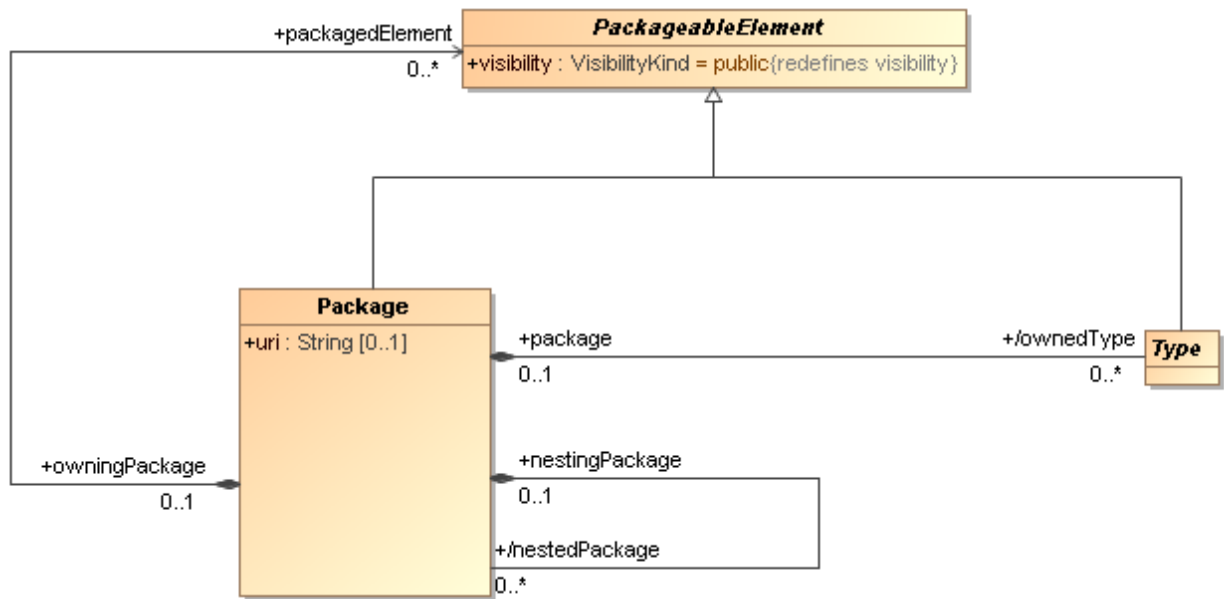
Figure 12.4 – EMOF packages
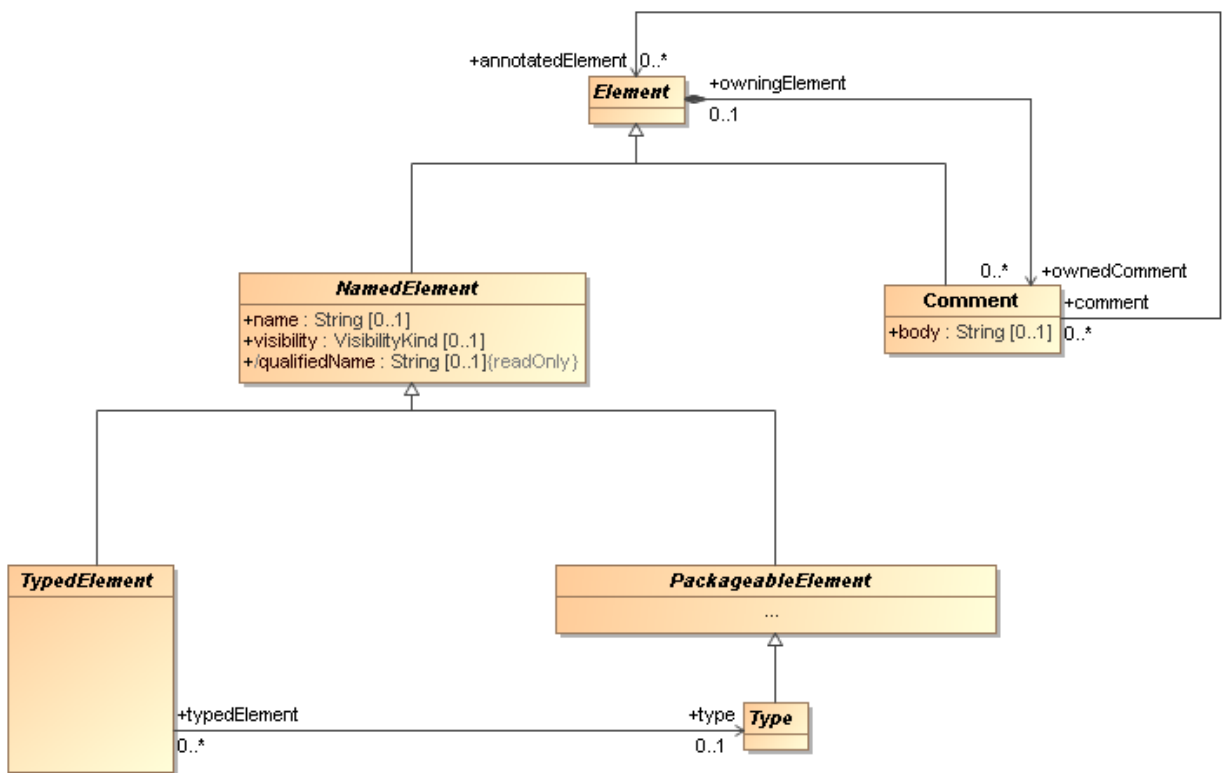
Figure 12.5 – EMOF Types

12.3 Merged Elements from MOF

The EMOF Model merges the following packages from MOF. See the capabilities chapters (9 through 11) for diagrams of the EMOF capabilities.

- Identifiers

- Reflection

- PrimitiveTypes

- Extensions

12.4 EMOF Constraints

Issue 15820: reference the OCL

These constraints have a formal representation in executable OCL, as referenced from Annex B.

[1] The type of Operation::raisedException is limited to be Class rather than Type.

[2] Notationally, the option is disallowed of suppressing navigation arrows such that bidirectional associations are indistinguishable from non-navigable associations.

Issue 15820: Reword constraint for use with UML

[3] Names are required for all Names are required for all NamedElements except for ValueSpecifications. Types and Properties (though there is nothing to prevent these names being automatically generated by a tool).

Issue 15820: Reword constraint for use with UML

[4] Core::Basic and EMOF does not support visibilities. All property visibilities expressed in the UML MOF model will be ignored (and everything assumed to must be explicitly set to public where applicable be public, that is for all NamedElements, ElementImports and PackageImports. Furthermore, no alias is allowed for any ElementImport.) Name clashes through names thus exposed should be avoided.

[5] The definitions of Boolean, Integer, and String are consistent with the following implementation definitions: • Boolean: http://www.w3.org/TR/xmlschema-2/#boolean • Integer: http://www.w3.org/TR/xmlschema-2/#integer • String: http://www.w3.org/TR/xmlschema-2/#string

[6] All the abstract semantics specified in the Chapter 15, "CMOF Abstract Semantics" are optional for EMOF.

Issue 15830: Delete unenforceable constraint

[7] X is an object and therefore supports reflection if MOF::Object.isInstance(X)==true.

Issue 15397: Add constraint

[7] Property.isID can only be true for one Property of a Class

Issue 15398: Add constraints on UML

Issue 15820: Replace this constraint on UML introduced by 15398

[8] An EMOF metamodel is restricted to use the following concrete metaclasses from UML's Kernel:
- Association
- Class
- Comment
- DataType
- Enumeration

- EnumerationLiteral
- Generalization
- InstanceValue
- LiteralBoolean
- LiteralInteger
- LiteralNull
- LiteralReal
- LiteralString
- LiteralUnlimitedNatural
- Operation
- Package
- Parameter
- PrimitiveType
- Property

Issue 15820: Add navigableOwnedEnd to constraints from 15398

[9] The following properties must be empty:
- Association::navigableOwnedEnd
- Class::nestedClassifier
- Classifier::/general for instances of Datatype
- Operation::bodyCondition
- Operation::postcondition
- Operation::precondition
- Operation::redefinedOperation
- Parameter::defaultValue
- Property::qualifier
- Property::redefinedProperty
- Property::subsettedProperty

Issue 15820: Remove ownedNavigableEnd, and add isQuery=true to constraints from 15398

[10] The following properties must be false:
- Association::isDerived
- Classifier::isFinalSpecialization
- Feature::isStatic
- Property::isDerivedUnion
- RedefinableElement::isLeaf

[11] Generalization::isSubstitutable must be true

Issue 15820: Update constraint from 15398 to fix typo in property name

[12] An Association has exactly 2 memberEnds, may never have a navigableOwnedEnd (they will always be owned by Classes) and may have at most one ownedEnd

Issue 15820: Update constraint from 15398

[13] An Operation can have up to one Parameter whose direction is 'return'; furthermore, an Operation cannot have any ParameterSet per constraint [8].
[14] Comments may only annotate instances of NamedElement
[15] Only one member attribute of a Class may have isId=true.

Issue 15820: Update constraint from 15398 and add new constraints from [17]

[16] Property::aggregation must be either 'none' or 'composite'.

[17] Enumerations may not have attributes or operations
[18] BehavioralFeature must be sequential.
[19] Class must not be active.
[20] An EnumerationLiteral must not have a ValueSpecification.
[21] An Operation Parameter must have no effect, exception or streaming characteristics.
[22] A TypedElement cannot be typed by an Association.
[23] A TypedElement other than a LiteralSpecification or an OpaqueExpression must have a Type.
[24] A TypedElement that is a kind of Parameter or Property typed by a Class cannot have a default value.
[25] For a TypedElement that is a kind of Parameter or Property typed by an Enumeration, the defaultValue, if any, must be a kind of InstanceValue.
[26] For a TypedElement that is a kind of Parameter or Property typed by an PrimitiveType, the defaultValue, if any, must be a kind of LiteralSpecification.
[27] A composite subsetting Property with mandatory multiplicity cannot subset another composite Property with mandatory multiplicity.
[28] A Property typed by a kind of DataType must have aggregation = none.
[29] A Property owned by a DataType can only be typed by a DataType.
[30] Each Association memberEnd Property must be typed by a Class.
[31] A multi-valued Property or Parameter cannot have a default value.
[31] The values of MultiplicityElement::lowerValue and upperValue must be of kind LiteralInteger and LiteralUnlimitedNatural respectively.

12.5 EMOF Definitions and Usage Guidelines for the ~~Basic~~ UML Model~~s~~

When the EMOF package is used for metadata management the following usage rules apply.

Package

- Although EMOF defines Package and nested packages, EMOF always refers to model elements by direct object reference. EMOF never uses any of the names of the elements. There are no operations to access anything by NamedElement::name. Instances of EMOF models may provide additional namespace semantics to nested packages as needed.

Properties

- All properties are modified atomically.

- When a value is updated, the old value is no longer referred to.

- Derived properties are updated when accessed or when their derived source changes as determined by the implementation. They may also be updated specifically using set() if they are updateable

Type==DataType

- The value of a Property is the default when an object is created or when the property is unset.

- Properties of multiplicity upper bound > 1 have empty lists to indicate no values are set. Values of the list are unique if Property.isUnique==true.

- "Identifier" properties are properties having property.idID==true.

Type==Class

- Properties of multiplicity upper bound == 1 have value null to indicate no object is referenced.

- Properties of multiplicity upper bound > 1 have empty lists to indicate no objects are referenced. Null is not a valid value within the list.

- EMOF does not use the names of the properties, the access is by the Property argument of the reflective interfaces. It does not matter what the names of the Properties are, the names are never used in EMOF. There is no special meaning for having similar names. The same is true for operations, there is no use of the names, and there is no name collision, override, or redefinition semantics. EMOF does not have an invoke method as part of the reflective interface, so there are no semantics for calling an EMOF operation. The names and types of parameters are never compared and there is no restriction on what they can have singly or in combination. Other instances of EMOF metamodels, or language mappings, such as JMI2, may have additional semantics or find that there are practical restrictions requiring more specific definitions of the meaning of inheritance.

Property::isComposite==true

- An object may have only one container. • Container properties are always multiplicity upper bound 1.

- Only one container property may be non-null.

- Cyclic containment is invalid.

- If an object has an existing container and a new container is to be set, the object is removed from the old container before the new container is set.

- Adding a container updates both the container and containment properties on the contained and containing objects, respectively. The opposite end is updated first.

- The new value is added to this property.

Property::isComposite==false, Bidirectional

- The object is first removed from the opposite end of the property.

- If the new value's opposite property is of multiplicity upper bound == 1, its old value is removed.

- This object is added to the new value's opposite property.

- The new value is added to this property.

Object

- Everything that may be accessed by MOF is an Object.

- An Object that is not also an Element may be an instance of one DataType.

Issue 12800: Add new section

12.6 Predefined Tags

This Section defines a predefined Tag whose name is "org.omg.emof.oppositeRoleName" which can be applied to instances of Property within instances of the EMOF model.

Constraints

context Tag inv:

--The predefined Tag can only be applied to instances of Property whose "opposite" Property is empty

  name = "org.omg.emof.oppositeRoleName" implies

   element.oclIsKindOf(Property) and element.oclAsType(Property).opposite->isEmpty()

Semantics

If an instance of a Tag has "org.omg.emof.oppositeRoleName" as its "name", then its "value" specifies a role name that expressions can use to traverse in the opposite direction of the Property, such as OCL expressions and QVT expressions.

If an expression uses a role name specified using a Tag with "name" "org.omg.emof.oppositeRoleName", and more than one Property has such a Tag with that role name, then it is up to the expression language to decide whether this is an error condition or represents a reverse navigation across all those Properties. An expression language should not choose to pick one such Property at random in case of ambiguity.

Rationale

Use of this Tag is lighter weight than using Property's "opposite" Property. Use of the "opposite" Property in all cases where what is required is only the ability for expressions to traverse in the opposite direction would have the following negative consequences:

- It would result in tighter coupling among Classes

- It would add to the runtime burden that instances of the model place upon the underlying infrastructure that manages them, by: 1) increasing the overall footprint, since the opposite Property adds substantially to the contract of the Class that owns the additional Property designated as the opposite of the original Property; 2) requiring that storage be allocated for instances of the additional Property; and 3) requiring that referential integrity be maintained in storage among instances of the original Property and instances of the additional Property.

It is beyond the scope of MOF Core to specify the concrete syntax that expressions use for traversal via the org.omg.emof.oppositeRoleName in languages such as OCL and QVT.

13 CMOF Reflection

CMOF Reflection provides extended capabilities over the EMOF Reflection package. The relationships are as follows:

Issue 15824: Fix imports/merges
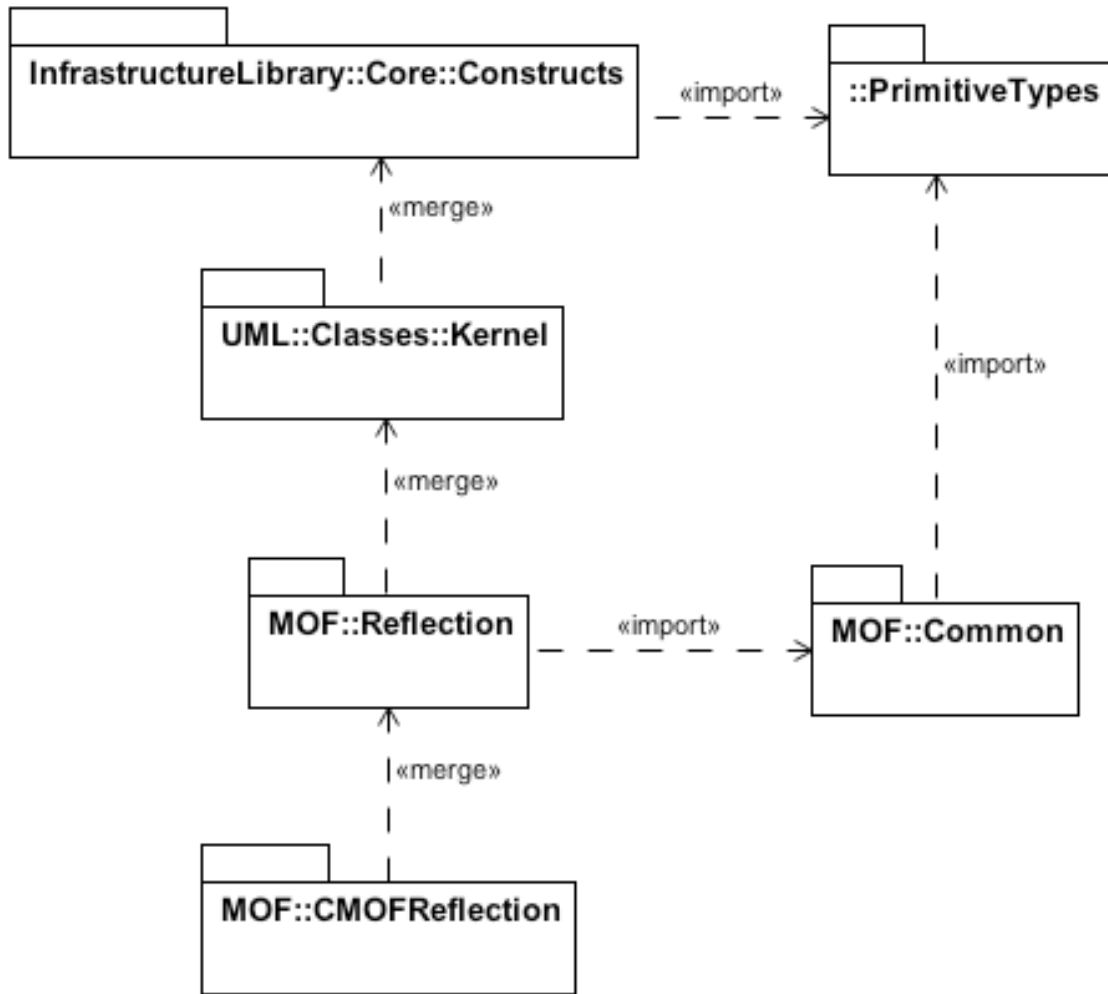
Figure 13.1 – CMOF Reflection

Note that CMOF Reflection merges operations into the existing Object, Extent, and Factory classes, and adds a Link class and an Argument datatype. The additions in CMOF Reflection are as follows:

Issue 15831: Delete operation verify() from the figure

Issue 15832: Move 4 operations from Element to Object

Issue 15859: Update operations

Issue 15824: Fix imports/merges
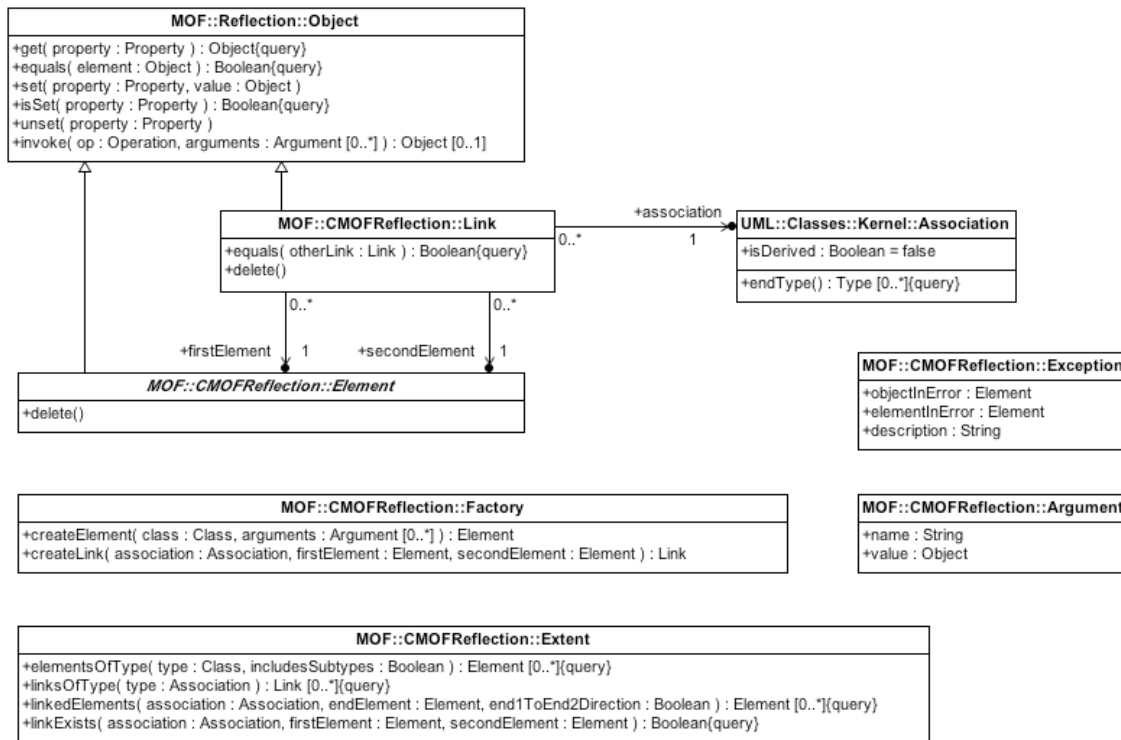
Figure 13.2 – CMOF Reflection package

13.1 Link

This is a new class that represents an instance of an Association, in the same way that Element represents an instance of a Class.

Properties

association: Association - This is the Association of which the Link is an instance.

firstElement: Element - This is the Element associated with the first end of the Association.

secondElement: Element - This is the Element associated with the second end of the Association.

Operations

equals(otherLink:Link): Boolean

Returns True if the otherLink has association, firstElement, secondElement all equal to those on this Link.

delete()

Deletes the Link. This may leave the same elements associated by other links for this Association.

Constraints

The firstElement must conform to the type of the first memberEnd of the association.

The secondElement must conform to the type of the second memberEnd of the association.

The set of Links as a whole must not break the multiplicity constraints of the association member ends.

Semantics

When the link is created, it is not assigned to any Extent.

Rationale

Since MOF 2.0 allows the same pair of elements to be linked more than once in the same Association (if isUnique=false for the association ends), then Link needs to be more a simple tuple value, though not as heavyweight as a first class Element.

Changes from MOF 1.4

None. The MOF 1.4 navigation capabilities are retained.

13.2 Argument

This is a new datatype that is used to represent named arguments to open-ended reflective operations. It is open-ended and allows both Elements and data values to be supplied.

Properties

name: String - The name of the argument. value: Object - The value of the argument.

Constraints

None: constraints will be dependent on the context of where the Argument is supplied.

Semantics

None.

Rationale

Since MOF 2.0 allows Operation parameters and Properties to have defaults, it is necessary to explicitly identify the values supplied.

Changes from MOF 1.4

Values supplied to constructors are now identified rather than being deduced through the ordering.

13.3 Object

CMOF Reflection adds the following extra operations.

Operations

Issue 15859: Delete delete() and isInstanceofType, and update definition of invoke()

~~delete()~~

~~Deletes the Object.~~

invoke(op:Operation, arguments : Argument[0..*]) : ~~Element~~Object[0..~~*~~1]
      Calls the supplied Operation on the object, passing the supplied Arguments and returning the result. If the operation produces more than one result value, then the result of the invoke operation is a kind of ReflectiveCollection containing all of the result values produced.

The Operation must be defined on the Class of the Object, and the arguments must refer to Parameters of the Operation. If an Argument is not supplied for a Parameter, its default value, if any, will be used.

~~isInstanceOfType(type : Class, includeSubtypes : Boolean) : Boolean~~

~~Returns true if this object is an instance of the supplied Class, or if includeSubtypes is true, any of its subclasses.~~

Rationale Adds the equivalent of MOF 1.4 capabilities.

Changes from MOF 1.4

Parameters to operations are now identified by name.

13.4 Element

CMOF Reflection adds the following extra operations.

Operations

delete()

Deletes the Element.

Issue 15859: Delete invoke() and correct typo in name of isInstanceofType

~~**invoke(op: Operation, arguments: Argument[0..*]): Object[0..*]**~~

~~Calls the supplied Operation on the element, passing the supplied arguments and returning the result. The Operation must be defined on the Class of the Element, and the arguments must refer to Parameters of the Operation. If an Argument is not supplied for a Parameter, its default value, if any, will be used.~~

isInstanceOfType(type: Class, includeSubtypes: Boolean): Boolean

Returns true if this element is an instance of the specified Class, or if the includeSubtypes is true, any of its subclasses.

Rationale

Adds the equivalent of MOF 1.4 capabilities.

Changes from MOF 1.4

Parameters to operations are now identified by name.

13.5 Factory

CMOF Reflection adds two extra operations.

Operations

createElement(class:Class, arguments : Argument[0..*]) : Element

Unlike the simple create() operation this allows arguments to be provided for use as the initial values of properties.

The arguments must refer to DataType Properties of the Class. If an Argument is not supplied for a Property its default value, if any, will be used.

createLink(association : Association, firstElement : Object, secondElement : Object) : Link

This creates a Link from 2 supplied Elements that is an instance of the supplied Association. The firstElement is associated with the first end (the properties comprising the association ends are ordered) and must conform to its type. And correspondingly for the secondElement.

Rationale

Adds the equivalent of MOF 1.4 capabilities.

Changes from MOF 1.4

Names have changed.

13.6 Extent

CMOF Reflection adds four extra operations.

Operations elementsOfType(type : Class, includeSubtypes : Boolean) : Element[0..*]

This returns those elements in the extent that are instances of the supplied Class. If includeSubtypes is true, then instances of any subclasses are also returned.

linksOfType(type : Association) : Link[0..*]

This returns those links in the extent that are instances of the supplied Association.

Issue 15824: Fix typo in operation name

linkedElementss(association : Association, endElement : Element, end1ToEnd2Direction : Boolean) : Element[0..*]

This navigates the supplied Association from the supplied Element. The direction of navigation is given by the end1ToEnd2Direction parameter: if true, then the supplied Element is treated as the first end of the Association.

linkExists(association : Association, firstElement : Element, secondElement : Element): Boolean

This returns true if there exists at least one link for the association between the supplied elements at their respective ends.

Rationale

Adds the equivalent of MOF 1.4 capabilities.

Changes from MOF 1.4

Names have changed.

14 The Complete MOF (CMOF) Model

The CMOF Model is the metamodel used to specify other metamodels such as UML2. It is built from EMOF and the Core::Constructs of UML 2. The Model package does not define any classes of its own. Rather, it merges packages with its extensions that together define basic metamodeling capabilities.

Issue 15824: Update figure
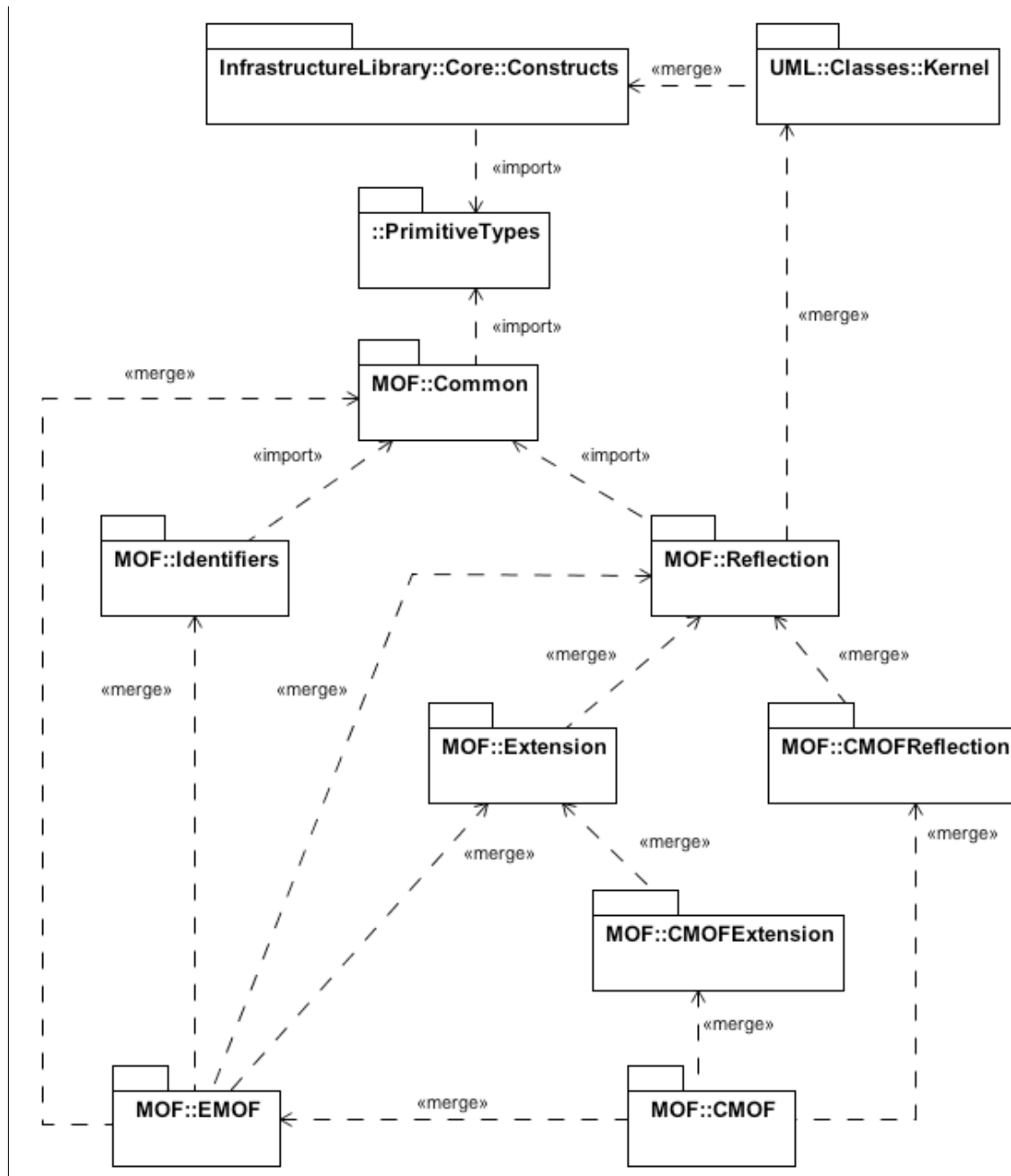
Figure 14.1 – CMOF Packages

14.1 ~~Imported~~ Elements <u>used</u> from UML 2 ~~Core~~

~~By merging the Constructs package from the UML 2 Core, the CMOF Model's members include the following packages from Abstractions as well as Basic, as listed below.~~

~~Abstractions~~

- ~~Namespaces~~
- ~~Classifiers~~
- ~~Comments~~
- ~~Constraints~~
- ~~Ownerships~~
- ~~Multiplicities~~
- ~~Relationships~~
- ~~StructuralFeatures~~
- ~~BehavioralFeatures~~
- ~~Visibilities~~
- ~~Super~~
- ~~Changeabilities~~
- ~~Redefinitions~~
- ~~Expressions~~
- ~~TypedElements~~

Figure 14.2 shows some of the key concrete classes and associations of ~~the~~ UML 2 ~~Core~~ <u>that are used to specify CMOF metamodels</u>~~imported by MOF Model~~. There are many other important elements ~~in the Core~~<u>that are used from UML</u>, but these provide the structure of class modeling. <u>See the UML specification for full details.</u>
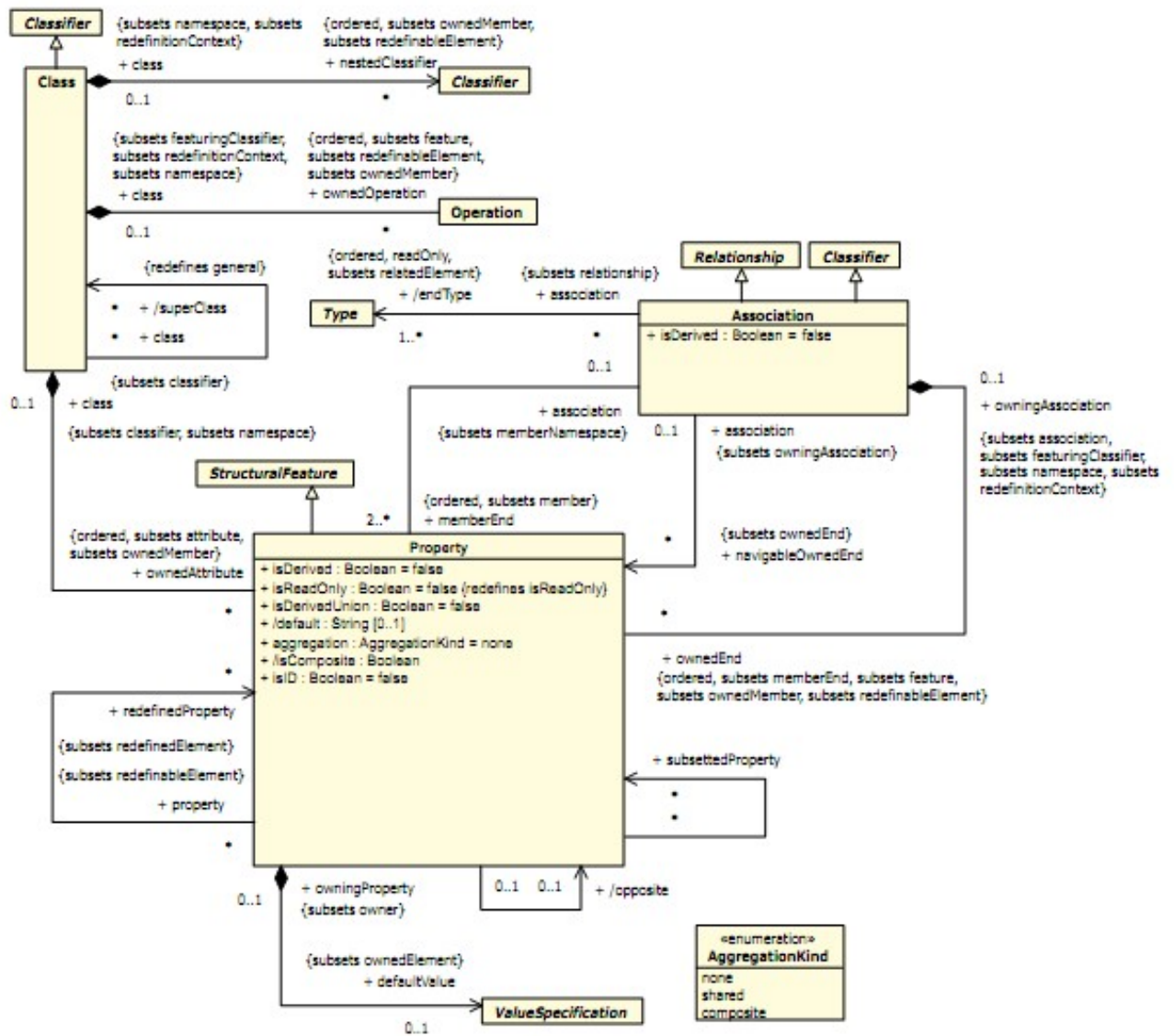
Figure 14.2 – Key concrete classes from UML2 Kernel package

14.2 Imported Elements from MOF

The CMOF Model merges package EMOF from MOF which includes MOF capabilities packages:

- Identifiers

- Reflection

- Extension

14.3 CMOF Constraints

This section details ~~additional~~ the constraints owned by the CMOF package that are applied to metamodels to be processed by a CMOF implementation. These constraints supersede the EMOF constraints from clause 12.4; that is, validating a CMOF metamodel should be done with respect to all the CMOF constraints defined in this clause ignoring all the constraint definitions from clause 12.4.

The CMOF metamodel, other MOF packages, and UML itself conform to all of these.

These constraints have a formal representation in executable OCL, as referenced from Annex B.

[1] The multiplicity of Association::memberEnd is limited to 2 rather than 2..* (i.e., n-ary Associations are not supported)~~.~~; unlike EMOF, CMOF associations can have navigable association-owned ends.

~~context Association inv: memberEnd->size() = 2~~

[2] The type of Operation::raisedException is limited to be Class rather than Type. ~~context Operation inv: raisedException.oclIsType(Class)~~

[3] In order to support limited implementations of the Integer class, each instance of Integer occurring as an attribute value of an element is in the range of integers that can be represented using a 32-bit two's complement format. In other words, each integer used is in the range from -2^{31} through $2^{31} - 1$. ~~context Integer inv: value >= -2³¹ and value <= 2³¹ - 1~~

[4] In order to support limited implementations of the String class, each instance of String occurring as an attribute value of an element has a length that does not exceed 65535 characters.

[5] Notationally, the option is disallowed of suppressing navigation arrows such that bidirectional associations are indistinguishable from non-navigable associations.

[6] Names are required for all ~~classifiers and features~~NamedElements except for ValueSpecifications ~~(though there is nothing to prevent these names being automatically generated by a tool). context Classifier inv: not(name = OclUndefined) context StructuralFeature inv: not(name = OclUndefined)~~

[7] CMOF does not support visibilities. All property visibilities must be explicitly set to public where applicable, that is for all NamedElements, ElementImports and PackageImports. Furthermore, no alias is allowed for any ElementImport.~~Visibilities will be ignored (and everything assumed to be public). Name clashes through names thus exposed should be avoided.~~

[8] Enumerations may not have attributes or operations. ~~context Enumeration inv: isEmpty(feature)~~

[9] Property.isID can only be true for one Property of a Class

[10] A CMOF metamodel is restricted to use the following concrete metaclasses from UML's Kernel:
- Association
- Class

- Comment
- Constraint
- DataType
- ElementImport
- Enumeration
- EnumerationLiteral
- Generalization
- InstanceValue
- LiteralBoolean
- LiteralInteger
- LiteralNull
- LiteralReal
- LiteralString
- LiteralUnlimitedNatural
- OpaqueExpression
- Operation
- Package
- PackageImport
- PackageMerge
- Parameter
- PrimitiveType
- Property

[11] The following properties must be empty

- Class::nestedClassifier
- Property::qualifier

[12] The value of Feature::isStatic must be false

Issue 15820: Replace the constraint from 15398

[13] A multi-valued Property or Parameter cannot have a default value. The default value of a Property or Parameter typed by a PrimitiveType must be a kind of LiteralSpecification. The default value of a Property or Parameter typed by an Enumeration must be a kind of InstanceValue. A Property or Parameter typed by a Class cannot have a default value.

[14] The values of MultiplicityElement::lowerValue and upperValue must be of kind LiteralInteger and LiteralUnlimitedNatural respectively

Issue 15820: Delete the constraint on Dependency being ignored from 15398

[15] Generalization::isSubstitutable must be true

[16] Only one member attribute of a Class may have isId=true. Any others (e.g. those inherited) must be redefined: either made unavailable or redefined to change isId = false.

Issue 15820: Update the constraint [17] from 15398 and add new constraints from [18]

[17] Property::aggregation must be either 'none' or 'composite'
[18] BehavioralFeature must be sequential.
[19] Class must not be active.
[20] An EnumerationLiteral must not have a ValueSpecification.

[21] An Operation Parameter must have no effect, exception or streaming characteristics.
[22] A TypedElement cannot be typed by an Association.
[23] A TypedElement other than a LiteralSpecification or an OpaqueExpression must have a Type.
[24] A TypedElement that is a kind of Parameter or Property typed by a Class cannot have a default value.
[25] For a TypedElement that is a kind of Parameter or Property typed by an Enumeration, the defaultValue, if any, must be a kind of InstanceValue.
[26] For a TypedElement that is a kind of Parameter or Property typed by an PrimitiveType, the defaultValue, if any, must be a kind of LiteralSpecification.
[27] A composite subsetting Property with mandatory multiplicity cannot subset another composite Property with mandatory multiplicity.
[28] A Property typed by a kind of DataType must have aggregation = none.
[29] A Property owned by a DataType can only be typed by a DataType.
[30] Each Association memberEnd Property must be typed by a Class.
[31] A Constraint must constrain at least one element and must be specified via an OpaqueExpression.
[32] The body of an OpaqueExpression must not be empty.

14.4 CMOF Extensions to Capabilities

This section details CMOF extensions to the MOF2 capabilities.

Reflection

[1] CMOF extends Factory to allow the format of the string argument of Factory::createFromString and the result of Factory::convertToString to be specified as defined in "Meta Object Facility (MOF) 2.0 XMI Mapping" in order to support default values for structured data types.

Issue 15826: Delete redundant paragraph

~~**Extension**~~

~~[1] CMOF extends package Extension with role name "tag" for the non-navigable end on the association between Tag and Element.~~

Issue 15827: Replacement text and diagram

Extension

[1] CMOF extends package Extension with an association between Element with role tagOwner and Tag with a navigable association-owned end role ownedTag.

Associations:

tagOwner : Element[0..1] {subsets Element::owner}

> Note: Although the ownedTag end is owned by the association, it must be navigable to support retrieving the Tags that an object owns using UML's ReadLinkAction (see UML2.4, clause 11.3.33). Additionally, OCL provides the capability to retrieve the Tags that an Element, e, owns, with the expression: e.ownedTag (see OCL2.2 clause 7.5.3). That is, the following invariant follows from figure 11.1:

```
context Element
inv CMOF_ElementTag: ownedTag->forAll(tagOwner = self)
```
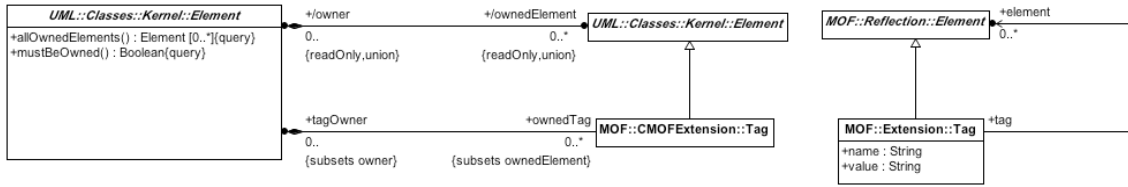
Figure 14.3 – CMOF Extension Package

Table1 Part IV - Abstract Semantics

This part of the MOF 2 specification addresses abstract mappings from the MOF model: This forms the foundation for defining concrete mappings to various technologies such as XMI and JMI.

15 CMOF Abstract Semantics

This chapter describes the semantics of CMOF by describing the functional capabilities of a modeled system and how those capabilities are related to elements in the model. These capabilities are independent of any mapping to implementation technology, so their descriptions are abstract.

Note that all of these capabilities are limited by the types, multiplicities, constraints, visibility, setability, etc. imposed by the model, and are possibly further constrained by other considerations such as access control security, immutability of historical versions of data, etc. Therefore, use of these capabilities can fail in specific situations - a failure results in an exception being raised (see Exceptions package).

15.1 Approach

MOF is a platform-independent metadata management framework that involves creating, manipulating, finding, changing, and destroying objects and relationships between those objects as prescribed by metamodels. This section describes the Core capabilities that MOF provides, and the semantics and behaviors of those activities. These capabilities may be extended or refined in the further specifications in the MOF 2.0 series. It is not the intention of this section to mandate that all MOF implementations need to support all of these capabilities: more to define what the capabilities mean when they are provided. Compliance points are described separately. For example, this section defines the semantics of Reflection: this constrains those implementations that provide Reflection but does not require all implementations to provide it.

For these capabilities to be well-defined, well-behaved, and understandable, some of these capabilities are described with respect to a lightweight notion of logical "extents" of model elements that provide some abstract notion of location and context. These will be more fully defined as part of the MOF 2.0 Facility and Object Lifecycle specification.

The goal of defining these capabilities is that they provide a single platform-independent definition that can be used as the basis of the language bindings in order to gain some level of consistency and interoperability. It also allows the semantics and constraints resulting from metamodeling decisions to be defined: increasing the level of semantic definition.

This section takes MOF from being a meta-metamodel to being a modeled system specification (a Platform Independent Model). This of necessity introduces more detail and constraints than present in the UML2 Infrastructure on which it's based. In particular it has been necessary to extend the UML2 Instances model to achieve this.

Though the approach is described in terms of the instances model (e.g., Slots) it is important to stress that this is a specification model and does not determine an implementation approach. Instances classes such as Slot do not appear in the operations specified: implementations should behave as if they were implemented using Slots but will in general be implemented using far more efficient mechanisms.

The specification is in terms of the reflective interface but it is intended that there be specific interfaces generated for specific metamodels.

15.2 MOF Instances Model

Principles

This semantic domain just covers the Classes Diagram from Constructs.

In general the approach is to avoid redundancy and only to have Slots where needed (e.g., not for derived attributes). This is to simplify specification of update behavior (not attempted here) and potentially the specification of XMI serialization.

The exception is that association instances are represented both as AssociationInstances and via Slots on the linked objects (for navigable association ends only). In theory the navigable end values could be derived via queries over the AssociationInstances but this was not done:

- for simplicity of explanation.

- to retain the 'illusion' that these properties are true attributes.

- to provide for greater consistency with Basic.

Datavalues act as both Instances (since they may have slots) and as ValueSpecifications: since datavalues are always considered directly stored in a slot rather than being referred to (which would require some sort of identity).

The following represents the Semantic Domain model for Constructs. It extends the abstract syntax for Instances.
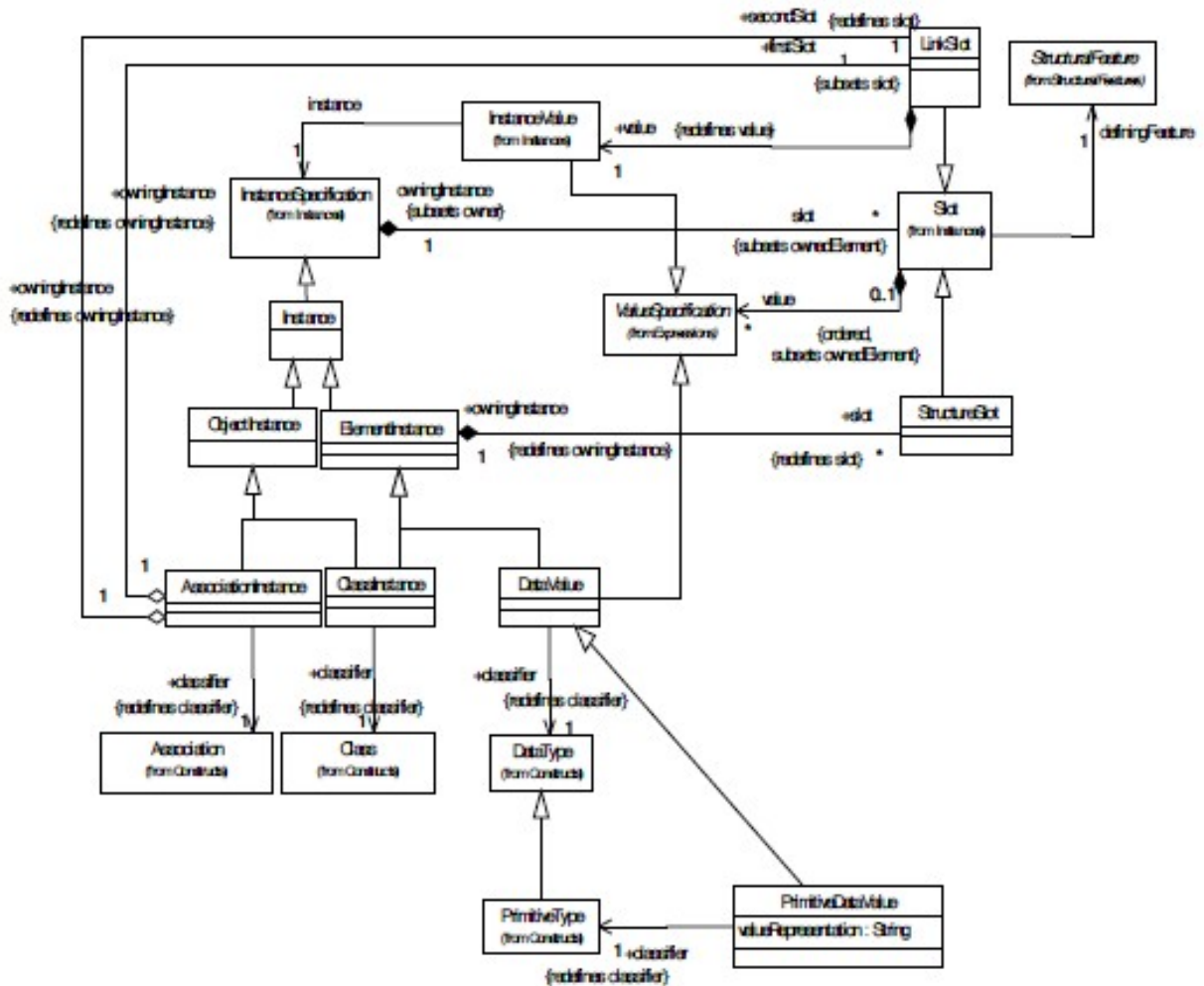
Figure 15.1 – Semantic Domain Model for Constructs

The following represent constraints on the classes introduced.

ObjectInstance (applies to both ClassInstances and AssociationInstances)

1. There is exactly one slot for each stored StructuralFeature and no further slots. The storedStructuralFeatures include inherited ones but exclude:

- Derived properties (including derived unions).

- Properties that have been redefined (there exists a property that is a member of the classifier that has redefinedProperty= this).

2. The classifier is not abstract.

3. The instance obeys Constraints that have its classifier as context.

ClassInstance

1. An instance is owned via at most one composition.

2. At most one Slot for an isComposite property may have a value. (This needs more work if the owner reference is not navigable).

3. Compositions are not cyclic. **Slot**1. Each value is compatible with the type of the definingFeature.

StructureSlot

1. The number of values corresponds with the multiplicity (upper and lower) of its definingFeature.

2. If the feature isUnique, then no 2 values are equal.

3. Slots for opposite properties tie up. For all values in slot the referenced objects do refer back via the opposite property; moreover no Slot of the opposite property in other objects refers to the owner of this Slot.

4. The slot's values are a subset of those for each slot it subsets.

LinkSlot

1. Where the feature is a navigable end, then the ClassInstance Slot is consistent with the Link slot.

2. The number of links is consistent with the multiplicity and uniqueness of the ends.

PrimitiveDataValue

1. If classifier is an Enumeration, then the valueRepresentation is the name of a valid EnumerationLiteral.

Further constraints on Abstract Syntax

The following represent new constraints that should be introduced.

Datatype

For all properties, isReadOnly is true, isComposite is false, isDerivedUnion is false. Datatypes may not participate in Associations.

PrimitiveType

For all properties, isDerived is true.

Enumeration For all properties, isDerived is true.

Property

If one of a pair of opposites isUnique, then so must the other be. At most one of redefinedProperty and subsettedProperty may be set.

Association

An Association is derived if all its Properties are derived.

15.3 Notes

This section models the reflective capabilities in terms of the Instances model above: so each Reflective signature is interpreted/modeled as the equivalent operation on the Instances model above.

The implementation for derived properties and operations is opaque: inbuild function *extInvoke* is used to call the implementation-supplied code. No slots are allocated for derived properties.

Similarly the evaluation of constraints is deferred to an inbuilt operation *evaluateConstraint*.

An extra function *extent()* is used to represent the current extent or extents of an Object. Its value is context dependent. Moreover it is expected that a Factory will be associated with at least one Extent (this is properly in scope of MOF 2 Facility RFP).

No distinction is made between slots based on multiplicity: it assumed that a slot can hold a collection; also that a collection can be a valid instance of DataValue. In most language bindings it is expected that for a multivalued property (upper bound > 1) that an empty collection will be returned instead of null: for simplicity of specification this is not done here.

Convenience/helper OCL operations are used.

For clarity a distinguished value '*null*' is used here for Property values to indicate they are empty.

15.4 Object Capabilities

Object::getType(): Type modeled as **ObjectInstance::getType(): Type**

post: result = self.classifier

Object::container(): Object modeled as **Instance::container(): ClassInstance**

post: result = self.get(self.owningProperty())

Object::get(Property p): Element modeled as **ObjectInstance::get(Property p): ElementInstance**

-- If a foreign association end then navigate link, else access slot or derive the value

post: (p.namespace.isOclType(Association) and result = navigate(p)) or
   self.propertySlot(p) <> null and (
     (self.propertySlot(p).value <> null and result = self.propertySlot(p).value) or
     result = p.default) or
   (p.isDerivedUnion and result = unionedProperties(p)->union(s| s = self.get(s)) or
   (p.isDerived and result = self.extInvoke('get', p))

Object::set(Property p, Element v) modeled as **ObjectInstance::set(Property p, ElementInstance v)**

pre: not(p.isReadOnly)
post: internalSet(p, v)

Object::isSet(Property p): Boolean modeled as **ObjectInstance::isSet(Property p): Boolean**

post: result = (self.propertySlot(p).value = null)

Object::unset(Property p) modeled as **ObjectInstance::unset(Property p)**

pre: not(p.isReadOnly)
-- Set to property default - this will have desired effect even if the default is not set (null)
post: internalUnset(p)

Object::delete() modeled as **ObjectInstance::delete()**

-- Delete all composite objects and all slots
post: (self.allProperties->select(p| isComposite(p), delete(self.get(p))) and
    self.allSlottableProperties->forAll(p| destroyed(self.propertySlot(p))) and
    extent().removeObject(self) not(extent().objects() includes self) and
    destroyed(self)

Issue 15831: Delete operation verify()

~~**Object::verify()** modeled as **ObjectInstance::verify()**~~

~~-- Check all cardinalities and constraints (for CMOF classes only)~~
~~post: (self.allProperties->forAll(p | let v = self.get(p) and~~
~~   (p.lower <> null implies v.size() >= p.lower) and~~
~~   (p.upper <> null implies v.size() <= p.upper) and~~
~~   (p.isUnique implies v.size() = asSet(v).size) and~~
~~   (self.classifier.container = EMOF implies~~
~~   (p.isReadOnly implies not(self.isSet(p)))~~
~~ and~~
~~ (self.classifier.container = CMOF implies~~
~~   self.classifier.allConstraints->forAll(c| self.evaluateConstraint(c))~~

Object::invoke(Operation op, Set{Tuple{Parameter p, ValueSpecification v}} args):Element modeled as
ClassInstance::invoke(Operation op, Set{Tuple{Parameter p, ValueSpecification v}} args):Element

-- Ensure all supplied parameters are for this operation and the values are of the correct type and all mandatory parameters are supplied

pre: args->forAll(Tuple{p, v}| op.parameter includes p and conformsTo(p.type, v)) and
    op.parameter->select(p| p.lower > 1, args includes Tuple{p, x})
-- Issue: should defaults be substituted for the parameters before extInvoke? - probably yes
post: result = extInvoke(op, args)

Object::isInstanceOfType(type: Class, includeSubclasses: Boolean): Boolean modeled as
ClassInstance::isInstanceOfType(type: Class, includeSubclasses: Boolean): Boolean

post: result = (self.classifier = type or
    includeSubclasses and self.classifier.allParents() includes type)

15.5 Link Capabilities

Link:equals(otherLink:Link): Boolean modeled as
AssociationInstance:equals(otherLink:AssociationInstance): Boolean

post: result = (self.association = otherLink.association and
    self.firstSlot.value = otherLink.firstSlot.value and
    self.secondSlot.value = otherLink.secondSlot.value)

Link:delete() modeled as **AssociationInstance:delete()**

post: destroyed(self.firstSlot) and destroyed(self.secondSlot) and
    extent().removeObject(self) not(extent().objects() includes self) and
    destroyed(self)

15.6 Factory Capabilities

The following are defined on the class Factory:

Factory::createObject(Type t, Set{Tuple{Property p, ValueSpecification v}} args): Object

-- Create the object and slots for properties (including inherited ones) which are not derived and not the redefinition or subset of another; assign the supplied values or default values if any

pre:

-- Check the arguments are valid properties of the correct type and that values are supplied for all mandatory properties with no default

not(isAbstract(t)) and
args->forAll(Tuple{p, v}| t.allProperties includes p and conformsTo(p.type, v)) and
   op.parameter->select(p| p.lower > 1 and p.default = null and args includes Tuple{p, x})
-- Create the slots and then set the values from arguments or defaults
post: oclIsNew(result) and
   extent().addObject(result)
   extent().objects includes result and
   result.classifier = c and
   t.allSlottableProperties->forAll(a | exists(s:StructureSlot | oclIsNew(s) and
     s.definingFeature = a and
     s.owningInstance = result) and
   t.allProperties->forAll(p| (exists(v | args includes [p,v] and internalSet(p,v))) or
     (self.internalUnset(p))
-- also need to cater for setting properties using constraints(?)

Factory::createFromString(dataType: DataType, string: String) : Element modeled as
Factory::createFromString(dataType: DataType, string: String): DataValue

-- issue: requires a set of syntax rules for literals
pre: self.package.member includes dataType

Factory::convertToString(dataType: DataType, element: Element) : String modeled as
Factory::createFromString(dataType: DataType, element: DataValue): String

-- issue: requires a set of syntax rules for literals
pre: self.package.member includes dataType
post: createFromString(dataType, result) = element
-- the string produced should parse to the same value!

15.7 Extent Capabilities

This section describes minimal capabilities for MOF Core. It does not address issues such as extent creation that are in scope of MOF 2.0 Facility and Object Lifecycle RFP. Neither does it yet cover the use of 'exclusive' and 'useContainment' attributes: it is assumed that all objects are directly contained in one extent.

As an abstract model of behavior extents are implemented using the following Instance model:
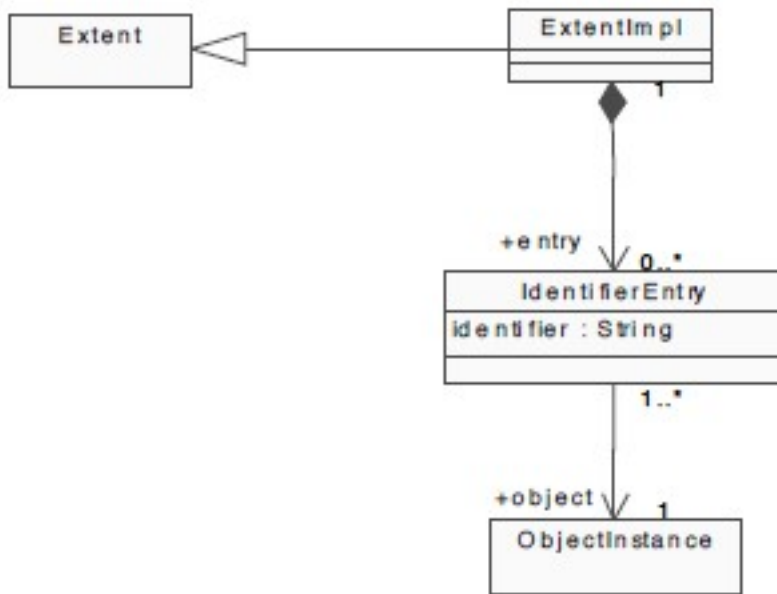
Extent::objects(): Object modeled as **ExtentImpl:objects(): ObjectInstance**

post: result = entry->object

Extent::objectsOfType(type: Class, includeSubtypes: Boolean): Object modeled as
ExtentImpl:objectsOfType(type:Class, includeSubtypes: Boolean): ObjectInstance

post:
result = self.entry->object->select(o| o.classifier = type or
   (includeSubtypes and o.classifier.allParents includes type)

Extent::linksOfType(type: Association): Link modeled as **linksOfType(type: Association): AssociationInstance**
post:
result = self.entry->object->select(o| o.classifier = type)

**Extent::linkedObjects(association : Association, endObject : Object, end1ToEnd2Direction : Boolean) :
Object** modeled as **ExtentImpl:linkedObjects(association : Association, endObject : Object,
end1ToEnd2Direction : Boolean) : ObjectInstance**

post: result = self.entry->object->select(o, r| o.classifier = association and (
   (end1ToEnd2Direction and o.firstObject = endObject and r = o.secondObject) or
   o.secondObject = endObject and r = o.firstObject))

Extent::linkExists(association : Association, firstObject : Object, secondObject : Object) : Boolean modeled as
Extent::linkExists(association : Association, firstObject : Object, secondObject : Object) : Boolean

result = self.entry->object->exists(o| o.classifier = association and
   o.firstSlot.value = firstObject and
   o.secondSlot.value = secondObject)

Extent::identifier(o: Object): String modeled as **ExtentImpl::identifier(o: ObjectInstance): String**

post:
result = self.entry->object->select(eo| eo = o).identifier

Extent::object(id: String): Object modeled as **ExtentImpl::object(id: String): ObjectInstance**

post:
result = self.entry->select(i| i = id).object

15.8 Additional Operations

[1] This gives all of the properties in the namespace of the class (including inherited) that require a slot: it excludes properties owned by Associations, derived properties and those that subset or redefine another property (in which case that property will provide the slot and the redefinition will just restrict the values)

Class::allSlottableProperties(): Set(Property);
allSlottableProperties = member->select(p| p.oclIsKindOf(Property) and
   not (self.allParents() includes p.namespace)
   -- excludes foreign association ends
   not(p.isDerived) and
   isEmpty(p.redefinedProperty) and
   isEmpty(p.subsettedProperty))

[2] This returns the slot corresponding to the supplied property. For redefining properties it will be the redefined one. Note that derived properties will only have slots if the redefine a non-derived one so the result may be null.

Instance::propertySlot(Property p): Slot
propertySlot = self.slot->select(definingFeature = p.originalDefinition))

[3] This returns the original definition of a Property through any number of redefinitions and subsetting.

Property::originalDefinition(): Property
post: (isEmpty(redefinedProperty) and isEmpty(subsettedProperty) and result = self) or
(notEmpty(redefinedProperty) and result = redefinedProperty.originalDefinition()) or
(notEmpty(subsettedProperty) and result = subsettedProperty.originalDefinition())

[4] This returns the single Property that represents the current owner of the Object based on current instance values; may be null for top level objects
Object::owningProperty(): Property

Issue 9147: Correct constraint

post: result = self.allProperties->select(op| op.opposite <> null and op.opposite.isComposite and self.get(op)<> null)

~~post: result = self.allProperties->select(op| op.isComposite and self.get(op) <> null)~~

[5] This returns the Properties that subset a derived union

Object::unionedProperties(p: Property): Set(Property)
pre: p.isDerivedUnion
post:
result = self.allProperties->select(sp| sp.subsettedProperty includes p)

[6] This returns all the Constraints for a classifier

CMOF::Classifier::allConstraints(): Set(Constraint)
post:
result = extent().objectsOfType(Constraint)->select(c | c.context = self)

[7] This sets a property value regardless of whether read only (used for initialization)

ObjectInstance::internalSet(Property p, ElementInstance v)
post: (self.propertySlot(p) <> null and self.propertySlot(p).value = v) or
   (p.namespace (self.p.namespace.isOclType(Association) and

not (self.allParents() includes p.namespace) and -- allow access to own assoc ends
    setLink(p, v)) or
(p.isDerived and result = self.extInvoke('set', p, v))

[8] This unsets a property value regardless of whether read only (used for initialization)

 ObjectInstance::internalUnset(Property p)
post: (self.propertySlot(p) <> null and self.propertySlot(p).value = null) or
   (p.isDerived and result = self.extInvoke('unset', p, v))

[9] This adds an object to an Extent - only on creation

ExtentImpl::addObject(ObjectInstance o, String suppliedId [0..1]): String
pre: not(self.entry.identifier includes suppliedId)
post: oclIsNew(e) and oclType(e) = IdentifierEntry and
   e.object = o and
   self.entry includes e
   self.entry->select(ex | ex.identifier = e.identifier)->size() = 1 -- the new id is unique and
   (suppliedId <> null implies e.identifier = suppliedId)

[10] This removes an object from an extent - only on destruction

ExtentImpl::removeObject(ObjectInstance o)
pre: self.objects includes o
post: let e = self@pre.entry->select(ex|ex.object = o) and
   destroyed(e) and not(self.entry includes e)

[11] This navigates an association end from an object ObjectInstance::navigate(Property p): Set(ObjectInstance)
pre: p.namespace.isOclType(Association)
post: -- Find the relevant Links by querying the Extent
-- Issue - need to deal with subsets/unions
let values= extent().objectsOfType(p.namespace)->select(link| link.get(p.opposite) = self)->get(p) and
   (p.isUnique implies result = oclAsSet(values))
   and not(p.isUnique implies result = values)

[12] Sets an association end

ObjectInstance::setLink(Property p, Element v)
-- If the property is multivalued then break it into individual elements and create links
-- In either case delete existing links
pre: p.namespace.isOclType(Association)
post: let oldValues= extent@pre().objectsOfType(p.namespace)->select(link| link.get(p.opposite) = self)->get(p) and
   values->forAll(v| v.delete()) and (p.upper = 1 implies self.createLink(p, v)) and
   (p.upper > 1 implies v->forAll(o| createLink(p, o))

[13] creates an individual link

ObjectInstance::createLink(Property p, ObjectInstance v)
-- Use normal object creation. Assume the existence of the Factory
post: factory.create(p.namespace, Set{ Tuple{p, v}, Tuple{p.opposite, self}})

16 Migration from MOF, v1.4

This chapter addresses the migration of existing MOF 1.4 metamodels to MOF 2.0 Complete. MOF 1.4 metamodels can be translated to MOF 2.0 models based on a straightforward mapping that can be fully automated as described below. Note that attributes that have an obvious direct mapping (e.g., MOF 1.4 ModelElement::name to MOF 2.0 NamedElement::name) are not listed here.

16.1 Metamodel Migration

A valid MOF 1.4 metamodel can be translated to a MOF 2.0 model. Translation is based on a straightforward mapping that can be fully automated.

MOF 1.4	MOF 2 Mapping
ModelElement::annotation	New instance of Comments::Comment class linked to a corresponding Element via annotatedElement attribute and Comment::body attribute set to the value of the annotation and Comment::usage attribute set to "documentation."
ModelElement::container	NamedElement::namespace (Note that this is abstract, so appropriate specializations must be used.)
ModelElement::constraints	The association between constraint and constrained element is navigable only from constraint to constrained element, not vice versa. To constrain an element, the element needs to be added to Constraint::contextₜ attribute of a given constraint.
Namespace::contents	Namespace::ownedMember (Note that this is abstract, so appropriate specializations must be used.)
GeneralizableElement::isLeaf	Not supported. This attribute can be ignored without losing any information as the attribute constrains the model and not the objects being modeled.
ModelElement::container	NamedElement::namespace (Note that this is abstract, so appropriate specializations must be used.)
ModelElement::constraints	The association between constraint and constrained element is navigable only from constraint to constrained element, not vice versa. To constrain an element, the element needs to be added to Constraint::contextₜ attribute of a given constraint.
Namespace::contents	Namespace::ownedMember (Note that this is abstract, so appropriate specializations must be used.)
GeneralizableElement::isLeaf	Not supported. This attribute can be ignored without losing any information as the attribute constrains the model and not the objects being modeled.
GeneralizableElement::isRoot	Not supported. This attribute can be ignored without losing any information as the attribute constrains the model and not the objects being modeled.
GeneralizableElement::supertypes	Classifier::general
Class::isSingleton	MOF 1.4 Class with isSingleton = true is no longer directly supported. It can be simulated by inserting a Constraint on the class: self.metaobject.allInstances.size = 1.
CollectionType	Not directly supported. Can be substituted by an instance of DataType class with one attribute (called 'value') of the same type and multiplicity as the CollectionType.
EnumerationType	Mapped to Enumeration, where strings in the value of the MOF 1.4 EnumerationType::labels attribute are mapped to instances of EnumerationLiteral class with the label string as the name and the same ordering. The enumeration literals are linked to an enumeration via the

	Enumeration::ownedLiteral attribute.
AliasType	Not supported. Map to a subtype of the concrete data type corresponding to the type that the AliasType points to. Attach any constraints from the AliasType to the subtype.
StructureType	Maps to DataType.
StructureField	Maps to Property owned by a DataType corresponding to the parent StructureType.
Feature::scope	Not supported – all the features in MOF 2.0 are instance-level.
StructuralFeature::isChangeable	Maps to Property::isReadOnly which has the opposite meaning (i.e., isReadOnly = not isChangeable).
Reference	Redundant as a separate element from the referenced AssociationEnd (which is now a Property). The fact that the AssociationEnd had a Reference means that the new Property corresponding to the AssociationEnd should be owned by the Class not the Association.
Reference::referencedEnd	The Property representing the association itself. Redundant as above.
Reference::exposedEnd	Property::opposite. Redundant as above.
Operation::exceptions	Operation::raisedException.
Exception	An Exception can be any desired subclass of Classifier. By default it should be a Class with the same name as the Exception.
AssociationEnd	Property associated with an Association via memberEnd attribute. To make the Property (i.e., the AssociationEnd) exposed in a class (similarly to using a reference in MOF 1.4), it needs to be owned by the class (while still being a memberEnd of the association).
AssociationEnd::isNavigable	Not supported as defined in MOF 1.4. In MOF 2.0 all the ends are navigable in terms of MOF 1.4 navigability. MOF 2.0 defines navigability in terms of being able to navigate to the end directly from a type – this is analogous to having a reference in MOF 1.4.
AssociationEnd::aggregation	Property::isComposite (composite maps to true, none maps to false, shared was underspecified in MOF 1.4 –maps to false).
AssociationEnd::isChangeable	See mapping of StructuralFeature::isChangeable.
Import	PackageImport, PackageMerge or ElementImport classes. If the imported elements are whole packages, then Import maps to PackageImport in case of isClustered=false and PackageMerge in case of isClustered=true (this may need to be revisited in conjunction with the MOF 2.0 Facility RFP Note: For importing individual elements inside packages Import maps to ElementImport. Note that in MOF 2.0, an import makes names within imported packages visible without qualification.
Import::importedNamespace	PackageImport::importedPackage, PackageMerge::mergedPackage, ElementImport::importedElement Note that in MOF 2.0, an import makes names within imported packages visible without qualification.
Tag	Extension::Tag

16.2 API Migration

This section summarizes the API equivalents between the MOF 1.4 Reflective API, the JMI API and the proposed MOF 2.0 Core API. Class names are in bold and italics.

Note that many of the gaps for MOF 2.0 are where the previous APIs have operations specific to the language binding (e.g., related to class proxies) or are convenience operations.

Issue 15831: Delete operation verify() from the table

MOF 1.4	JMI	MOF 2
RefBaseObject	RefBaseObject	Object
refMofId	refMofId	Extent::identifier
refMetaObject	refMetaObject	getMetaclass
refImmediatePackage	refImmediatePackage	
refOutermostPackage	refOutermostPackage	
refItself	Java Object.equals	Element::equals
refVerifyConstraints	refVerifyConstraints	~~verify~~
refDelete	RefObject::refDelete	delete
RefObjec	RefFeatured	
refValue	refGetValue	get
refSetValue	refSetValue	set
refUnsetValue	Set value to null	unset
refAddValueBefore	Use of live collections	
refAddValueAt	*ditto*	
refModifyValue	*ditto*	
refModifyValueAt	*ditto*	
refRemoveValue	*ditto*	
refRemoveValueAt	*ditto*	
refInvokeOperation	refInvokeOperation	invoke
Test for value = null	Test for value = null	isSet
	RefObject	
refIsInstanceOf	refIsInstanceOf	isInstanceOfType
	refClass (gets proxy)	
refImmediateComposite	refImmediateComposite	container

refOutermostComposite	refOutermostComposite	
RefBaseObject::refDelete	refDelete	delete
RefClass	RefClass	
refCreateInstance	refCreateInstance	Factory::create
refAllObjects (includeSubtypes=true)	refAllOfType	Extent::elementsOfType (includeSubtypes=true)
refAllObjects (includeSubtypes=false)	refAllOfClass	Extent::objectsOfType (includeSubtypes=false)
	refCreateStruct	Factory::createFromString
	refGetEnum	Factory::createFromString
refAssociation	refAssociation	
refAllLinks	refAllLinks	Extent::linksOfType
refLinkExists	refLinkExists	Extent::linkExists
refQuery	refQuery	Extent::linkedElements
refAddLink	refAddLink	Factory::create
refAddLinkBefore	Use live collections	
refModifyLink	*ditto*	
refRemoveLink	refRemoveLink	delete
	refAssociationLink (datatype – tuple)	
RefPackage	RefPackage	Extent
refMofId (inherited)	refMofId (inherited)	
refMetaObject(inherited)	refMetaObject(inherited)	
refImmediatePackage(inherited)	refImmediatePackage(inherited)	
refOutermostPackage(inherited)	refOutermostPackage(inherited)	
refItself(inherited)	Java Object.equals	
refClassRef	refClass	
refAssociation	refAssociation	
refPackage	refPackage	
	refAllPackages	
	refAllAssociations	
	refCreateStruct	
	refGetEnum	

RefBaseObject::refDelete	refDelete	
		useContainment (attribute)
		elements
		identifier
		element

Part V - Annexes

This section includes the following annexes:

A - XSD and XMI for MOF 2

Issue 9802: Remove Annex B

B - JMI Java Language Mapping

Annex A
~~XSD and~~ XMI for MOF 2.~~0~~ Core

(normative)

Issue 1344: Provide XMI file

Issue 10698: Update URIs

Issue 15398: Replace by reuse of UML2.4 Superstructure
The Package::URI for EMOF is:
> http://www.omg.org/spec/MOF/20100901/emof.xmi

And for CMOF is:
> http://www.omg.org/spec/MOF/20100901/cmof.xmi

MOF 2 Core directly reuses UML2 Superstructure L3 for metamodel representation.
Hence, though EMOF and CMOF have their own package URI, they do not define their own XMI namespace or prefix (which override the Package URI via the org.omg.xmi.nsURI tag).

MOF 2.4 uses UML 2.4 and so:

> The namespace uri is: http://www.omg.org/spec/UML/20100901
> The namespace prefix is: uml

The exception to the above is the MOF Extension package, for MOF Tags, which is not covered by UML and has namespace as follows:
> The namespace uri is: http://www.omg.org/spec/MOF/20100901
> The namespace prefix is: mofext

Note: for transition purposes it is possible to transform in both directions between MOF 2.0 EMOF and CMOF metamodels and compliant metamodels represented in UML 2.4 without loss.

~~The Meta Object Facility (MOF) 2.0 XMI Mapping Specification defines extensions to XMI 2.0. Document ptc/04-10-17 contains the XSD and XMI files for MOF 2.0.~~

~~XMI allows the use of tags to tailor the schemas and documents that are produced using XMI. The following have been explicitly set for EMOF; the others are left at their default values:~~

~~• tag nsURI set to "http://schema.omg.orb/spec/MOF/2.0/emof.xml"~~

~~• tag nsPrefix set to "emof"~~

Issue 7548: Add new tag on EMOF Element

> • tag contentType set to "any" for Element

~~The following have been explicitly set for CMOF; the others are left at their default values:~~

~~• tag nsURI set to "http://schema.omg.orb/spec/MOF/2.0/cmof.xml"~~

~~• tag nsPrefix set to "emof"~~

Issue 9802: Remove Annex B

~~Annex B~~
~~(normative)~~

~~JMI Java Language Mapping~~

~~The Java language mapping for MOF 1.4 defined by the JSR-40 Java Metadata Interface (JMI) Specification expert group as part of the Java Community Process will require revision to support MOF 2. The Java language mapping for MOF 2.0 will be defined using a new JSR under the Java Community Process.~~

Issue 15820: Add new Annex

Annex B
Metamodel Constraints in OCL

(Informative)

The constraints to be applied to a UML model to validate whether it is a valid metamodel are provided in accompanying files as referenced below. They are executable in the Eclipse OCL environment.

The constraints for EMOF are in: CMOFConstraints.ocl

The constraints for CMOF are in: EMOFConstraints.ocl