Using Assertions to Enhance the Correctness of Kmelia Components and their Assemblies

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Abstract

The Kmelia component model is an abstract formal component model based on services. It is dedicated to the specification and development of correct components. This work enriches the Kmelia language to allow the description of data, expressions and assertions when specifying components and services. The objective is to enable the use of assertions in Kmelia in order to support expressive service descriptions, to support client/supplier contracts with pre/post-conditions, and to enhance formal analysis of component-based system. Assertions are used to perfom analysis of services, component assemblies and service compositions. We illustrate the work with the verification of consistency properties involving data at component and assembly levels.

Keywords: Component, Assembly, Datatype, Assertions, Property Verification

1 Introduction

The Kmelia component model [7] is an abstract formal component model dedicated to the specification and development of correct components. A formal component model is mandatory to check various kind of properties for component-based software systems: correctness, liveness, safety; to find components and services in libraries according to their formal requirements; to refine models or to generate code. The key concepts of Kmelia are component, service, assembly and composition. One important feature is the use of services as first class entities. A service has a state, a dynamic behaviour which may include communication actions, an interface made of required and provided subservices. The composition of components is based on the interaction between their linked services. Linking components by their services in component assemblies establishes a bridge to service oriented abstract models.

In [7] we introduced the syntax and semantics for the core model and language. It has been incrementally enriched later. We mainly focused on the dynamic aspects of composition: interaction compatibility in [7] and component protocols with service composition in [6]. Following this incremental approach, we consider in this article

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an enrichment of the data and expressions in the kmelia model and its impact on the language syntax, its semantics and the verification of properties. Our guiding objective is twofold: 1) enable the definition of assertions (with invariant, pre/post conditions, and properties of services, components, and compositions), 2) increase the expressiveness of the action statements so as to deal with real size case studies.

Assertions are useful (i) to define *contracts* [1] on services; contracts increase the confidence in assembly correctness and they are a pertinent information when looking for candidates for a required service, (ii) to ensure the consistency of components respecting the invariant. The actions implement a functional part of the services which should then be proved to be consistent with the contracts. Therefore the correctness verification aspects of the Kmelia model is enhanced.

Motivations. Modelling real life systems requires the use of data types to handle states, actions and property descriptions. The state of the art shows that most of the abstract components models [4,13,24,12]. They enable various verifications of the interaction correctness but they lack expressiveness on the data types and do not provide assertions mechanisms and the related verification rules. As an example, in Wright the dynamic part based on CSP is largely detailed (specification and verification) while the data part is minor [4]. In the proposal of [22] the data types are defined using algebraic specifications, which are convenient to marry with the symbolic model checking of state transition systems but this proposal does not deal with contracts and assertions.

Contribution. In this work, we enrich the Kmelia model with data and assertions at the service and composition levels in order to deal with safe services, component consistency and assembly contracts. *First*, the Kmelia language is enriched with data and assertions so as to cover in an homogeneous way structural, dynamic and functional correctness with respect to assertions. *Second*, we deal with state space visibility and access through different levels of nested components; in addition to service promotion we define variable promotions and the related *access rules* from component state in *component compositions*. *Last*, feasibility of proving component correctness using the assertions is presented. We show how structural correctness is verified and how the associated properties are expressed with the new data language.

To design it , we have established a trade off [2] between the desired expressiveness of our language and the verification concerns. To avoid the separation of analysis tools and to work on the same abstract model, we advocate for an approach where both data and dynamic part are integrated in a unique Kmelia language.

The article is structured as follows. Section 2 gives an overview of the Kmelia abstract model and introduces its new features. In Section 3 a working example is introduced to illustrate the use of data and assertions. The formal analysis issue is treated in Section 4; we present various analysis to be performed and we focus on component consistency and on checking assembly links. The formal analysis are based on the formal descriptions of Section 2 also many details are omitted in this paper. Section 5 concludes the article and draws some discussions and perspectives.

[1] Our contract definitions are related to classical results of works such as *design-by-contracts* [20].

[2] We thought to encapsulate statements from other formal data languages such as Z, B, OCL or CASL, with the idea to reuse existing tool supports for checking syntax and properties. That approach was not convincing due to a lack of expressiveness, or a weak tool support or integration problems.

2 The Kmelia Model and its new Features

We enriched the Kmelia language of [7] to allow the description of datatypes, expressions and first order logic predicates. This section revisits the Kmelia model, focusing on its new features.

2.1 Data types and expressions

We enrich the Kmelia language by designing a small but expressive data language. This enables us to deal homogeneously with the expression of the properties related to the component level and to the composition level.

Basic types such as Integer, Boolean, Char, String with their usual operators and semantics are permitted. Abstract data types like record, enumeration, range, arrays and sets are allowed in Kmelia. User-defined record types are built over the above *basic* types. Specific types and functions may be defined and imported from libraries. A Kmelia *expression* is built with constants, variables and elementary expressions built with standard arithmetic and logical operators. An assignment is made of a variable at the left hand side and an expression at the right hand side.

Assertions (pre-/post-conditions and invariants) are first order logic *predicates*. In a post-condition of a service, the keyword old is used to distinguish the before and after variable states. This is close to OCL's **pre** or Eiffel's **old** keywords. Guards in the service behaviour are also predicates. All the assertions must conform to an observability policy described in Section 2.3.

2.2 Components

A **component** is one element of a component type. A component is referenced with a variable typed using the component type; for example c:C where c is a variable and C a component type. The access to a state variable v of c is denoted c:v.

A **component type** C is a 8-tuple $\langle \mathcal{W}; \mathcal{A}; \mathcal{N}; \mathcal{M}; \mathcal{I}; \mathcal{D};\ ; \mathcal{CS} \rangle$ with:

- $\mathcal{W} = \langle T; V; type; Inv; Init \rangle$ the state space where T is a set of types, V a set of variables, $type : V \rightarrow T$ the function that map variables to types, Inv an invariant defined on V and $Init$ the initialisation of the variables of V.
- $\mathcal{A}$ a finite set of elementary actions (based on the expressions).
- $\mathcal{N}$ a finite set of service names with $\mathcal{N}^P$ (provided services) and $\mathcal{N}^R$ (required services) two disjoint finite sets of names[3]: $\mathcal{N} = \mathcal{N}^P \uplus \mathcal{N}^R$.
- $\mathcal{M}$ a finite set of message names.
- $\mathcal{I} = \mathcal{I}^P \uplus \mathcal{I}^R$ the component interface which is the union of two disjoint finite sets of names $\mathcal{I}^P$ and $\mathcal{I}^R$ such that $\mathcal{I}^P \subseteq \mathcal{N}^P \wedge \mathcal{I}^R \subseteq \mathcal{N}^R$.
- $\mathcal{D}$ is the set of service descriptions with the disjoint provided services ($\mathcal{D}^P$) and required services ($\mathcal{D}^R$) sets: $\mathcal{D} = \mathcal{D}^P \uplus \mathcal{D}^R$.
- $: \mathcal{N} \rightarrow \mathcal{D}$ is the function mapping service names to service descriptions. Moreover there is a projection of the $\mathcal{N}$ partition on its image by $:$ $s \in \mathcal{N}^P \Rightarrow (s) \in \mathcal{D}^P \wedge s \in \mathcal{N}^R \Rightarrow (s) \in \mathcal{D}^R$

[3] $\uplus$ denotes the disjoint union of sets

- $\mathcal{CS}$ is a set of constraints related to the services of the interface of C in order to control the usage of the services.

Observability of the component state. To preserve the abstraction and encapsulation of components, the state of a component is accessed only through its provided services. Nevertheless to understand the specification of a service (i.e. its contract) we need to *observe* its context (an exposed part of its component state space). Similarly a composite component requires observable informations from its components. Therefore we define V^O as the subset of the **observable** variables of V. Consequently the state invariant Inv is composed of an observable (Inv^O defined on V^O) and a non-observable part. The notion of observability is also applied to service pre/post conditions with the specific rules described in section 2.3. Observability is a kind of visibility related to contracts.

2.3 Services

The behaviour of a component relies on the behaviours of its services which are a kind of concurrent processes. A service models a functionality *activated* by a call. An activated service runs its behaviour and shares the component state with other activated services of the same component. During its evolution a service may activate other services by calling them or communicate with them by messages. Due to dependencies and interactions between services, the actions of several activated services may interleave or synchronise. Only one action of an activated service may be observed at time. Formally a *service* s of a component with type C [4] is defined by a 3-tuple $\langle \mathcal{IS}; \mathcal{IW}; \mathcal{B} \rangle$ with:

- The service interface $\mathcal{IS}$ is defined by a 6-tuple $\langle \ ; \ ; vW; Pre; Post; \mathcal{DI} \rangle$ where
  - is the service signature $\langle name; param; ptype; Tres \rangle$ with $name \in \mathcal{N}$, $param$ a set of parameters, $ptype : param \rightarrow T$ the function mapping parameters to types and $Tres \in T$ the service result type;
  - $vW = \langle vT; vV; vtype; vInv; vInit \rangle$ is a *virtual state space* with vT a set of types, vV a set of variables, $vtype : vV \rightarrow vT$ the function mapping context variables to types and $vInv$ an invariant defined on vV and $vInit$ the optional initialisation of the variables of vV;
  - is a set of message signatures $\langle mname; mparam; mptype \rangle$ where $mname \in \mathcal{M}$, $mparam$ and $mptype$ are similar to those of the service signature;
  - Pre is a pre-condition defined on the union of the variables in V; vV; and $param$: $V \cup vV \cup param$;
  - $Post$ is a post-condition defined on $V \cup vV \cup param \cup \{ \text{result} \}$, where the predefined result variable of type $Tres$ denotes the service result;
  - $\mathcal{DI}$ is the *service dependency*; it is composed by services on which the current service depends. $\mathcal{DI}$ is a 4-tuple $\langle sub; cal; req; int \rangle$ of disjoint sets where $sub \subseteq \mathcal{N}^P$ (resp. $cal \subseteq \mathcal{N}^R$, $req \subseteq \mathcal{N}^R$, $int \subseteq \mathcal{N}^P$) contains the provided services names (resp. the ones required from the caller, from any component or from the component itself) in the scope of s.

[4] and by extension a service of a component $c : C$

- $\mathit{IW} = \langle \mathit{IT}; \mathit{IV}; \mathit{Itype}; \mathit{IInv}; \mathit{IInit} \rangle$ is the local state space where IT is a set of types, IV a set of local variables, $\mathit{Itype} : \mathit{IV} \rightarrow \mathit{IT}$ the function mapping local variables to types, IInv a local state invariant defined on IV (mostly $\mathit{IInv} = \mathit{true}$) and IInit the initialisation of the variables of IV.
- The behaviour $\mathcal{B}$ of a service s is an *extended labelled transition system* (eLTS) with state and transitions. The necessary details are given on the example of Section 3. The full background is provided online in references [7,6].

The state space IW local to a service is used only in the service behaviour $\mathcal{B}$ but not used in the assertions.

Virtual state spaces. A required service is an abstraction of a service provided by another component. Since that component is unknown when specifying the required service, it may be necessary to describe this "imaginary" component. We introduce the notion of a *virtual state space* vW in order to abstract the service context. For a *provided* service this virtual context is always empty.

Observability vs. service state space. Let s be a service of a component type C. The distinction between observable and non-observable variables of the component state space is revisited [5] according to the following table:

Service state space	Variables		Invariant	
	Observable part	Non-observable part	Observable part	Non-observable part
`Provided` s	V^O	V	Inv^O	Inv
`Required` s	vV	V	$vInv$	Inv

The pre-/post-conditions of s must respect the well-formedness rules related to the observable, non-observable and virtual contexts according to the following table:

Service Assertions scope	pre-condition		post-condition	
	Observable Pre^O	Non-observable Pre^{NO}	Observable $Post^O$	Non-observable $Post^{NO}$
`Provided` s	$V^O \cup param$	none	$V^O \cup param \cup \{$ result $\}$	$V \cup param \cup \{$ result $\}$
`Required` s	$vV \cup param$	$V \cup param$	$vV \cup param \cup \{$ result $\}$	none

Figure 1 summarises (in the context of a composition as described in Section 2.4) the relations between state spaces, observability and contracts. The boxes denote components (a, b) and compositions (c). The grey (resp. white) "funnel" denote provided (resp. required) services.

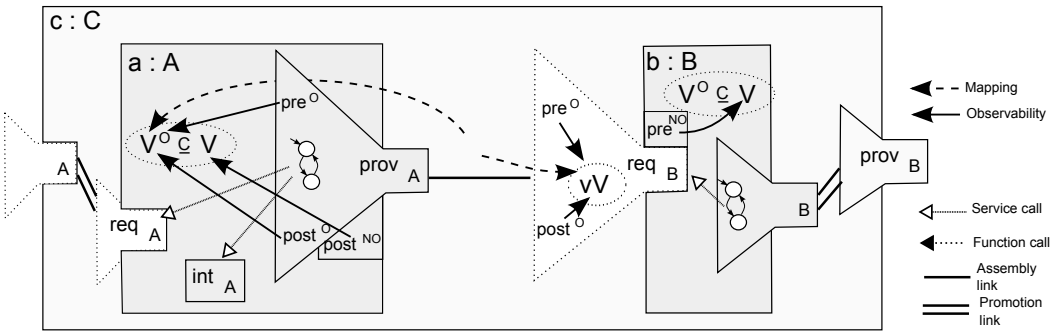

Fig. 1. State variables scope and assertion scope

[5] it is not a partition here because of the supplementary variables in *param* and *result*

The observable pre-/post-conditions of service $prov_A$ (resp. req_B) refer to the observable state V^O of a (resp. the virtual state vV of req_B). These conditions will be used to check the contracts implicitly supported by the assembly links and the composition links. In particular the virtual state vV of req_B should map with a subset of V of a. Non-observable pre-conditions (resp. post-conditions) are meaningless for a provided service (resp. required service) because they prevent safe assembly and promotion contracts. The non-observable pre-condition of service req_B gives call conditions on the (caller) component state variables$V$ of b. The non-observable post-condition of service $prov_A$ refer locally to the whole state V of a and should establish the non-observable part of the invariant of a.

2.4 Assembly and Composition

An *assembly* is a set of components that are linked (*horizontal composition*) through their services. An assembly is one element of an *assembly type*. An *assembly link* associates a required service to a provided one. Considering the rich interface of a Kmelia service (see 2.3), we need an explicit matching mechanism, to link properly the 6-tuples defining given service interfaces; therefore, additionally to signatures and dependency (via sublinks) mapping we now define *context* and *message mappings*. When needed, message or service parameters re-ordering must be handled through adaptation mechanisms [5].

Assembly context and message mapping. Consider a required service sr of a component cr of type CR linked to a provided service sp of another component cp of type CP. The virtual state space variables (vV_{sr}) of sr must be "instantiated" using the *observable* variables of sp (V^O_{CP}) by a mapping (total) function $vmap : vV_{sr} \rightarrow exp(V^O_{CP})$ where $exp(X)$ denotes an expression over the variables of X.
Each message name of sr is mapped to a message name of sp by a mapping (total) function $mmap : mname_{sr} \rightarrow mname_{sp}$.

A *composition* is the encapsulation of an assembly into a component (the composite) where some features (variables and services) of the nested components can be promoted at the composite level. *Promotion links* are used to promote services. The mappings and rules are similar to the ones of assembly, they are not detailed here.

State variables promotion. An observable variable $vo \in V^O_C$ from a component $c : C$ can be promoted as a variable $vp \in V_{CP}$ of a composite component $cp : CP$. Formally, there are a function $prom : V_{CP} \rightarrow V^O_C$ which establishes the *variable promotion*, i.e. a bridge between the variable names. In the Kmelia syntax, $(vp; vo) \in prom$, is written vp FROM c:vo. The promoted variables retain their types ($type(vp) = type(vo)$) and are accessed (*read-only* at the composite level) in their effective contexts using a service of the sub-component that defines the variables. This guarantees the encapsulation principle.

Now Kmelia services are equipped with expressive means (pre-/post-conditions, observability, virtual context) to describe contracts. Section 3 illustrates them on a working example. They are used to check services and assemblies correctness as described in Section 4.

3 A Working Example

The example is a simplified *Stock Management* application including a *vending* main service. This process manages product references (catalog) and product storage (stock). Administrators have specific rights, they can add or remove references under some consistency business rules such as: *a new reference must not be in the catalog* or *a removable reference must have an empty stock level.*

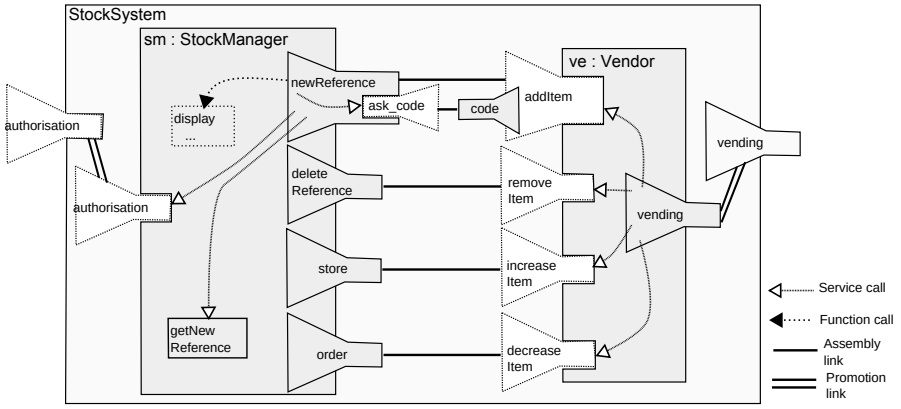

Fig. 2. Simplified Assembly of the Stock Case Study

The system is designed as a reusable component type StockSystem. It encapsulates an assembly of two components: sm:StockManager and ve:Vendor. The former is the core business component to manage references and storage. The latter is the system access interface. The main vending service is promoted at the StockSystem level. In this paper we focus only on the addItem and newReference services. According to the vending service, a user may add a new item in the stock management using the required service addItem of the Vendor component.

```
required addItem () : Integer
Interface
  subprovides : {code}
  Virtual Variables
     catalogFull : Boolean;
     catalogEmpty : Boolean     //possibly catalogSize
  Virtual Invariant not(catalogEmpty and catalogFull)
  Pre not catalogFull
  //No LTS
  Post (Result <> noReference) implies (not catalogEmpty)
End
```

The required service addItem is fulfilled with the provided service newReference which gets a new reference and performs the update of the system if there is an available new reference (see the listing 2). The links and sublinks are explicitly defined in the composition part of a composite component, as detailed in the listing 3.

The nested services represent the *service dependency* $\mathcal{DI}$. For example, the required service addItem provides a special code subservice[6]. Similarly the provided service newReference requires a ask_code service from its caller (see the ***calrequires*** declaration in the interface of newReference in the listing 1).

Inside the components, the different arrows represent various kind of calls: function call (with no side effects), service call (according to the service dependency).

[6] In Kmelia, a subservice of a service s, is a service that belongs to the interface (*subprovides*) of s.

The newReference service calls the display function (declared in the predefined Kmelia library), a service getNewReference required internally (from the same component) and the ask_code service required to its caller.

Data types in Kmelia. The data types are explicitly defined in a **TYPES** clause or in the shared libraries (predefined or user-defined). As an example, the following library (named Stocklib) declares some specific types, functions and constants.

```
TYPES
    ProductItem :: struct {id: Integer; desc: String; quantity: Integer} ;
CONSTANTS
    maxRef : Integer := 100;
    emptyString : String := "" ;
    noReference : Integer := -1;
    noQuantity : Integer := -1
```

These data types in this part are quite concrete; more abstract data types are in the process to be included in the predefined library.

A Kmelia component and observable state. The listing 1 is an extract from the Kmelia specification of the StockManager component. The state of StockManager declares among the other variables, the *observable* variable catalog which can be used for context mapping in the assembly links but also in promoted variables for composite components. Two arrays (plabels and pstock) are used to stock the labels of current references and their available quantity. The invariant states that: the catalog has an upper bound; all references in the catalog have a label and a quantity; the unknown references have no entries in the two arrays pstock and plabels. The assertions in Kmelia are possibly named predicates; the labels in front of the invariant lines are names used in this specification.

Listing 1: Kmelia specification StockManager State

```
COMPONENT StockManager
INTERFACE
   provides : {newReference, removeReference, storeItem, orderItem}
   requires : {authorisation}
USES {STOCKLIB}
TYPES
   Reference :: range 1..maxRef
VARIABLES
   vendorCodes : setOf Integer; //authorised administrators
   obs catalog : setOf Reference; // product id = index of the arrays
   plabels : array [Reference] of String; //product description
   pstock : array [Reference] of Integer //product quantity
INVARIANT
   obs @borned: size(catalog) <= maxRef,
   @referenced: forall ref : Reference | includes(catalog,ref) implies
      (plabels[ref] <> emptyString and pstock[ref] <> noQuantity),
   @notreferenced: forall ref : Reference | excludes(catalog,ref) implies
      (plabels[ref] = emptyString and pstock[ref] = noQuantity)
INITIALIZATION
   catalog := emptySet;
   vendorCodes := emptySet;     //filled by a required service
   plabels:= arrayInit(plabels,emptyString); //consistent with ..
   pstock := arrayInit(pstock,noQuantity);  //..empty catalog
```

A Kmelia service with its assertions. The listing 2 gives the specification of the provided service newReference. It provides a new reference if its running goes well. The pre-condition is that the catalog does not reach its maximal size. The post-condition is decomposed into several observable/non-observable named parts.

It states that we may have a result ranging in 1..maxRef or no reference at all, in the latter case the catalog remains unchanged.

Listing 2: Kmelia specification Provided Service with assertions

```
provided newReference () : Integer  //Result = ProductId or noReference
Interface
   calrequires : {ask_code} #required from the caller
   intrequires : {getNewReference}
Pre
   obs size(catalog) < maxRef #the catalog is not full
Variables # local to the service
  c : Integer;      # c : input code given by the user
  res:Reference;
  d : String;           # product description
Initialization
  res := noQuantity;
Behavior
Init i # the initial state
Final f # a final state
{  i -- c := __CALLER!!ask_code() --> e1,
       # gets the password on the ask_code (service) channel
  e1 -- [not(c in vendorCodes)]
        display("adding a reference is not allowed") --> end,
  e1 -- [c in vendorCodes] __CALLER?msg(d) --> e2,
       # gets the product description
  e2 -- [d = emptyString]
        display("adding an EmptySet description is not allowed") --> end,
  e2 -- [d <> emptyString] res := __SELF!!getNewReference() --> e4,
  e4 -- {catalog := including(catalog,res); //add new reference
         pstock[res] := 0; //default stock is null
         plabels[res] := d //product description is the one provided
        }--> end,
  end -- __CALLER!!newReference(res) --> f
       # the caller is informed from the Result and the service ends.
}
Post
 obs @resultRange:((Result >= 1 and Result <= maxRef) or (Result = noReference)),
 obs @resultValue:(Result <> noReference) implies (notIn(old(catalog),Result)
                    and catalog = add(old(catalog),Result)),
 obs @noresultValue:(Result = noReference) implies Unchanged{catalog},
 @refAndQuantity: (Result <> noReference) implies
          (pstock[Result] = 0 and plabels[Result] <> emptyString and
          (forall i : Reference | (i <> Result) implies
             (pstock[i] = old(pstock)[i] and plabels[i] = old(plabels)[i] ))),
 @NorefAndQuantity: (Result = noReference) implies Unchanged{pstock,plabels}
```

The behaviour of a service defines a list of transitions e1 −−label−−> e2 where e1 and e2 are state names. A transition label is a guarded combination of actions [guard] action∗. An action is either an *elementary action* from $\mathcal{A}$ (expression) or a *communication action* (service interaction). The syntax of a communication action is channel(! | ? | ⁇ | ‼) message(param∗) where the channel denotes a reference in the service dependency $\mathcal{DI}$, the single char operators are message interactions (send/receive) and the double char operators are service interactions (call, result). The channel **_CALLER** stands for the caller service, **_SELF** stands for a service of the same component (internal call), _rs stands for a required service. In this article we will not consider further the behaviour.

Context and message mappings. The context and message mappings (see 2.4) are specified in assembly links. In the listing 3, variables of the virtual context of addItem are associated with an expression on the variables of the context of newReference i.e. the observable state variables of the component sm. In this example, there are no message mapping because only the standard msg message (declared in the predefined Kmelia library) is used.

Listing 3: Kmelia specification StockSystem

```
COMPONENT StockSystem
INTERFACE
  provides : {vending}
  requires : {authorisation}
COMPOSITION
  Assembly
    Components
      sm : StockManager;
      ve : Vendor
    Links ////////////assembly links/////////
      lref: p-r sm.newReference, ve.addItem
          context mapping
            ve.catalogEmpty == empty(sm.catalog),
            ve.catalogFull == size(sm.catalog) = MaxInt
          sublinks : {lcode}
      lcode: r-p sm.ask_code, ve.code
      ...
  End // assembly
  Promotion
    Links ////////////promotion links/////////
      lvend: p-p ve.vending, SELF.vending
      laut: r-r sm.authorisation, SELF.authorisation
END_COMPOSITION
```

In the next section, we show how this Kmelia specification is analysed using our COSTO [7] tool and a specific verification approach using the B method and tools.

4 Formal Analysis and Experimentations

Components, assemblies and compositions should be analysed according to various facets. Tables 1 and 2 give an overview of the verification requirements that we consider to validate a Kmelia specification. Some of them were achieved before, in particular the behavioural compatibility of services and components, treated in [7]: it was achieved using model-checking techniques provided by existing tools (Lotos/CADP [8] and MEC [9]); the involved parts of the Kmelia specifications were automatically translated into the input languages of these tools and checked.

In this section, we address aspects related to data type checking and assertion checking; the main goal is to analyse parts of a Kmelia specification using its new features such as the assertions. Formal verification tools are necessary to check assertions consistency. Our approach consists in reusing existing tools such as the B tools and especially the Rodin [10] framework. We design a systematic verification method that enables us to reuse the proof obligations generated by the B tools for our specific purpose.

Event-B and Rodin framework. Rodin is a framework made of several tools dedicated to the specification and proof of Event-B models. Event-B [1] extends the classical B method [2] with specific constructions and usage; it is intended to the modelling of general purpose systems and for reasoning on them. Proof obligations (POs) are generated to ensure the consistency of the considered model, i.e. the preservation of the **INVARIANT** by the **EVENTS**. Other POs ensure that a *refined* model is consistent, i.e. the abstract **INVARIANT** is preserved and the refined events

[7] COmponent Study TOolkit dedicated to the Kmelia language
[8] http://www.inrialpes.fr/vasy/cadp/
[9] http://altarica.labri.fr/wiki/tools:mec_4
[10] http://rodin-b-sharp.sourceforge.net

Analysis	**Status**
Static rules: Scope + name resolution + type-checking	done
Observability rules	in progress (see 2.3)
Component interface consistency	done
Services dependency consistency: $\mathcal{DI}$ well-formed vs. $\mathcal{I}$ and $\mathcal{D}$ (component) $\mathcal{DI}$ vs. $\mathcal{B}$ (eLTS)	done
Simple constraint checking (parameters, query, protocol, ...)	in progress
Local eLTS checking (deadlocks, guard, subprovides, ...)	in progress
Invariant consistency vs. pre/post conditions: provided services : $Inv^O \wedge Pre^O \Rightarrow Post^O \wedge Inv^O$ $Inv \wedge Pre \Rightarrow Post^{NO} \wedge Inv$ required services : $vInv \wedge Pre^O \Rightarrow Post^O \wedge vInv$	 experimental (a) experimental (b) experimental (c)
Consistency between service assertions and eLTS: eLTS vs. $Post$ the post condition should be established required service R calls vs. Pre_R the context must ensure the precondition (local+virtual) eLTS vs. subprovided service SP annotations Pre_{SP} the context must ensure the precondition (local)	not yet

Table 1
Formal analysis of a simple Kmelia component

Analysis	State
Static rules: Scope + name resolution + type-checking	done
Observability rules: promoted variables	done
Link/sublink consistency: assembly and composition signature matching service dependency matching (subprovides, callrequires)	done [7]
context mapping (cm function) and observability rules message mapping	
Assembly Link Contract correctness: $cm(Pre^O_R) \Rightarrow Pre^O_P$ $Post^O_P \Rightarrow cm(Post^O_R)$	 experimental (d) experimental (e)
Provided Promotion Link Contract correctness: PP is at the composite level $cm(Pre^O_P P) \Rightarrow Pre^O_P$ $Post^O_P \Rightarrow cm(Post^O_{PP})$	 experimental (f) experimental (g)
Required Promotion Link Contract correctness: RR is at the composite level $cm(Pre^O_R) \Rightarrow Pre^O_{RR}$ $Post^O_{RR} \Rightarrow cm(Post^O_R)$	 experimental (h) experimental (i)
eLTS (behaviour) compatibility	done [7]

Table 2
Formal analysis of a Kmelia assembly and compositions

do not contradict their abstract counterparts.

POs can be discharged automatically or interactively, using the Rodin provers.

Verifying Kmelia specifications using Event-B. The main idea is, first to consider a part of the Kmelia specification involved in the property to be verified (a service, a component, a link of an assembly, an assembly, etc), then to build from this part of the specification, a set of (Event-)B models in such a way that the POs generated for them correspond to the specific obligations we needed to check the Kmelia specification assertions. Using B to validate components assembly contracts

has been investigated in [15,18].

We systematically [11] build some Event-B models, with an appropriate structure as explained below, to check some of the proof obligations presented in Tables 1 and 2. The Event-B models are currently built by hand.

(i) For each component and its provided services, we generate an Event-B model. The proof of the consistency of this model ensures the proof of the rules (a) and (b) for the invariant consistency at the Kmelia level.

(ii) For each required service (and its "virtual context") we have to generate an Event-B model. Its B consistency establishes the rule (c).

(iii) For each assembly link between a required service req and a provided one prov, we give an Event-B model of the observable part of prov, which *refines* the Event-B model of the required service req previously checked.
- the consistency proof of the Event-B model ensures the rule (a) for the invariant consistency at the Kmelia level;
- the refinement proof establishes both the rules (d) and (e) for the Kmelia assembly correctness.

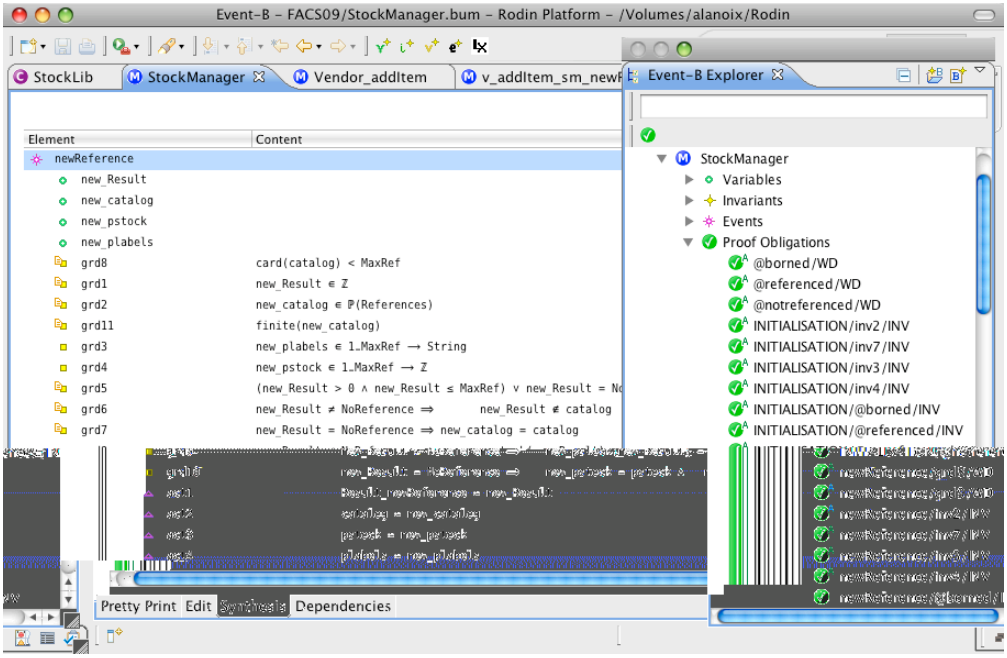

Fig. 3. Rodin

We are not going to deal in this article with the details of the translation procedure [12]. Kmelia invariant and pre-condition translations are quite systematic, whereas the post-condition concept does not exist into the B language. Therefore we abstract the post-condition by using an **ANY** substitution that satisfies the post-condition (once translated) as proposed in the context of UML/OCL to B

[11] applying defined rules which are not yet fully automatised

[12] The specifications and results are available in http://www.lina.sciences.univ-nantes.fr/coloss/projects/kmelia/index_en.php

translations [19]. Figure 3

Discussion. Our work is more related to abstract and formal component models like SOFA or Wright, rather than to the concrete models like CORBA, EJB or .NET. The Java/A [9] or ArchJava [3] models do not allow the use of contracts. We have already emphasized (see Section 1) the fact that most of the abstract models deal mainly with the dynamic part of the components. Some of them [16,23] take datatypes and contracts into account but not the dynamic aspects. Some other ones [11,13] delay the data part to the implementation level.

In [14] *may/must* constraints are associated to the interactions defined in the component interfaces to define behavioural contracts between client and suppliers. In Kmelia, the distinction between a supplier constraint and the client is done from a methodological point of view rather than a syntactic rule. The use of B to check component contracts has been studied in [15,18] in the context of UML components.

Fractal [17] proposes different approaches based on the separation of concerns: the common structural features are defined in Fractal ADL [21] ; dynamic behaviours are implemented by Vercors [8] or Fractal/SOFA [12] and the use of assertions are studied in ConFract [16]. In ConFract contracts are independent entities which are associated to several participants, not to services and links as in our case; their contracts support a rely/guarantee mechanism with respect to the (vertical) composition of components.

In [10] a component (a component type in Kmelia) is a model in the sense of the algebraic specifications. Dynamic behaviours are associated to components but not to services, which are simple operations. The component provided and required interfaces are type specifications and composing component is based on interface (or type) refinement. In Kmelia components are assembled on their services; therefore the main issue is not to refine types as in [10] but rather to check contracts as in [25]. More specifically our case is more related to the *plugin matching* of [25].

Perspectives. Several aspects remain to be dealt with regarding assertions and the related properties, composition and correctness of component assemblies. First, we need to implement the full chain of assertion verification especially the translation *KmlToB* which is necessary to automatically derive the necessary Event-B models to check the assertions and the assemblies. Second, we will integrate high level concepts and relations for data types. In particular, we plan to integrate some kind of objects and inheritance in the type system but also component types. Assertions in this context are more difficult to specify and to verify.

Another challenging point is the support for interoperability with other component models. We assume that in real component applications, a component assembly is built on components written in various specification languages. When connecting services (or operations) we can at least check the matching of signatures. If the specification language of the corresponding services or components accepts contracts (resp. service composition, service behaviour) we can provide corresponding verification means.

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