Modeling Interactions between Web Applications and Third Party Systems

Nathalie Moreno and Antonio Vallecillo
Dpto. de Lenguajes y Ciencias de la Computación
Universidad de Málaga, Spain
{vergara,av}@lcc.uma.es

Abstract

Web-based applications are no longer isolated systems. Now they need to interoperate with external service providers and legacy systems, which are available in a wide range of different platforms, and may follow disparate communication mechanisms. Modeling the interactions between these systems is not simple, and needs to be properly addressed within any model-driven development scenario. Many of the existing Web Engineering proposals do not take this fact into account, or else they address it in a very simplistic way. In this work we use an MDA approach for encapsulating the different interaction abstractions and mechanisms into a separate platform-independent level, and show the transformations required to produce platform-specific models depending on the particular details and interaction mechanisms of each technology platform and middleware.

1 Introduction

As the demand and the number of available distributed Web applications grows, so does the need to easily design, deploy, maintain, *integrate* and *interconnect* such Web applications in heterogeneous environments. MDA [17, 5] seems to be one of the most promising approaches for addressing these issues: it provides the right kinds of abstractions and mechanisms for improving the way applications are integrated and interconnected nowadays.

A proper integration approach requires a structured and efficient way to assist software architects and developers achieve such integration not only at implementation level, but also during all phases of the development process. In this regard, any integration with legacy data and external services at the PIM level requires modeling them, too (their structural features, behavioral descriptions, etc.)—allowing the manipulation of the external entities of such systems like native elements of our models. Special care should be taken in this case with the bridges that connect the system with its external partners applications, for which transformations are also needed, as mentioned in [10].

Although a priori there are no major problems with this approach, we may face different kinds of incompatibility issues when trying to integrate external pieces into the system (e.g., external services or legacy applications). For instance, the interface of the services required by our application (as specified in one of the PIMs) may not match the interface of the actual service, as provided by the external service provider. There is no problem if these incompatibilities are explicit because they can be easily detected and corrected—as happens with signature incompatibilities, for example. These situations can be treated with the use of adaptors, wrappers, or any kind of adaptation technique.

The major problem appears in the cases of implicit assumptions on the interaction models and mechanisms followed by clients and servers. Normally, these assumptions are implicitly made by software developers with previous knowledge about how the target platform(s) work. Whenever all of the application is generated from the initial PIMs using a single platform technology, and therefore all parts follow the same interaction models and patterns, this problem does not arise. However, when we need to work with external entities, the interactions models of each party should be made explicit so as to be able to detect and resolve potential inconsistencies and conflicts at design level.

This work presents an approach for modeling the communication mechanisms between a Web application and its related external systems. It makes explicit both the programming abstractions through which the client and service provider perceive and use the communication, and certain implementation choices about the selected target platform that are generally implicit. This is specially relevant in those contexts in which several platform technologies may be simultaneously used.

In general, there is no standard way of describing implementation decisions such as concurrence, security or transaction, in order to get computationally complete PIMS, i.e., PIMs that contain all the information required to produce real program code. Several approaches address this issue by identifying these concerns at different levels of abstraction. For instance, Almeida et al. [1, 2] introduce the *abstract platform* concept, which defines the characteristics required for the mappings onto the set of concrete target platforms, which are considered in an MDA design process. Following a different approach (that uses a UML profile) Witthawaskul and Johnson [21] define the *unit of work* concept which can be applied to a UML operation to support platform independent transaction modeling. Similarly, our work follows an approach based on marks (using a UML metamodel) that guide both the PIM to PSM transformation, and also the PSM to the Implementation Model transformation. They represent interaction model capabilities and services provided by potential target platforms abstracted away and specified in a platform-independent way.

Another controversial issue is to do with the place where implementation decisions are expected to be specified: (i) directly in the PIM; (ii) in the target platform model, or; (iii) in the transformation model. The MDA community still struggles to deal with this issue, as a quick look at the discussions happening in the MDA mailing lists clearly reveals.

The structure of this document is as follows. After this introduction, Section 2 provides a brief description of the interaction styles supported by technologies like CORBA, Enterprise Java Beans, J2EE, Web Services or .NET. After that, Section 3 derives a UML metamodel based on existing similarities found among the previous interaction models. Using this metamodel, Sections 4, 5 and 6 show how to apply it in a service-oriented scenario. Finally, Section 7 draws some conclusions and outlines some future research activities.

2 Interaction Models for Web Applications

Currently, Web applications need to interoperate with third party systems (external portlets, Web services or legacy applications) in a variety of ways—interaction models—which reflect the heterogeneity of applications built upon disparate implementation technologies such as J2EE, CORBA or .NET. Generally, each middleware technology has its own interaction model, although traditional client-server interaction patterns are likely to be common.

A Web application may be required to communicate with a great variety of systems in different address spaces and running on heterogeneous platforms—which use different communication abstractions and interaction models. Here we will briefly describe the interaction styles of the most commonly used technologies, which are able to connect applications implemented using heterogeneous technologies.

Three main technologies support nowadays communication between modules of disparate systems, hiding platform and language specific details: CORBA, Enterprise Java Beans, J2EE and Web Services and .NET.

CORBA Service Provider. To request a CORBA service provider, the client may follow one of two approaches [8, 15, 19]: (i) a static invocation method or (ii) a dynamic invocation method. In the former, the client has to acquire an object reference to the CORBA object at compile-time. This reference is used to initiate a proxy object that represents the remote object in the client's address space. For generating the proxy implementation, an IDL specification of the CORBA object is required and compiled into the client program. IDL specifications can define both synchronous (request/reply) operations and asynchronous (one-way) messages.

For dynamic invocations there is no information about the types and interface specifications of the required CORBA service. The client can look this information up by querying an Interface Repository (a service that provides IDL definitions at run-time). In consequence, a client request consists of operations for setting the name and parameters of the request and retrieving the returned values or an exception at run-time. Once the client has acquired a valid remote object reference to the CORBA server object, it can call the server object's methods as if the server object resided in the client's address space. The mapping of the object name to its implementation is handled by the Implementation Repository.

Enterprise Java Beans/J2EE Provider. For a client to call a business method, it needs to go via an EJB object (a generated Java class based on the Component Interface). This means that a client never accesses an enterprise bean directly [4, 20]. Firstly, the client has to call a factory object (which is the EJB Home Object) to either locate an existing EJB object or create a new one EJB object. Once generated during compile or deployment time, EJB objects act as bridges between the client and the bean instances [18].

There are several types of EJBs: *session beans, entity beans and message-driven beans*. The two former kinds of beans provide their interfaces to allow remote clients to invoke them. However, message-driven beans do no make their interfaces public. On the contrary, a message-driven bean listens for messages that are sent using *Java Message Service* and processes them anonymously (asynchronous invocations).

An XML file describes how an Enterprise Java Bean should be assembled and deployed, its name, and other external dependencies of the bean.

Java/RMI. This mechanism is tied to the Java programming language and virtual machines [9]. RMI allows operations on Java objects to be invoked. The client should first contact an RMI registry, and request the name of the service. RMI URLs identify services, including the hostname on which the service is located, and the logical name of the service. Then, the registry will point the client in the direction of the service it wants to call. The mapping of Object Name to its Implementation is handled by the RMI Registry.

RMI generates proxies and stubs from Java interface definitions. Furthermore, RMI uses Java's capabilities for dynamic linking to load the classes of parameters or returned objects over the network, allowing clients or servers to receive objects of classes unknown at compile time.

Web Services & .NET Provider. In order for a client to be able to employ a Web service, the client should know where the Web service resides and how to invoke its methods (that is, how to serialize the call to the Web service and how to deserialize received messages from the Web service). This information is provided by the WSDL specification of the Web service [22]—an XML document that specifies the data types of the messages, the protocols that are accepted, the Web service's endpoint, and the bindings.

Since the notions involved in creating the SOAP message to be sent to the Web service, making the actual HTTP request, deserializing the HTTP response, etc. could be complex, they are abstracted using a proxy class. Such a class encapsulates the complexity of calling a Web service and reveals a simplified interface [11]. From the client application's perspective, the Web service is simply a local component—the client doesn't have to worry about the specifics of how to serialize a SOAP message, or how to make a HTTP request.

3 Modeling interactions

3.1 Basic Interactions

The basic interaction model works according to the three-step process shown in Figure 1, being different interaction models supported by combinations of this configuration—mainly combinations of the second and third steps.

Step 1. A service provider publishes a description of their services in a publicly accessible registry.

Step 2. A service requestor discovers those services by querying the registry and binds to the selected service. (Note that we will call the service requester a *client*)

Step 3. The client interacts with service provider.

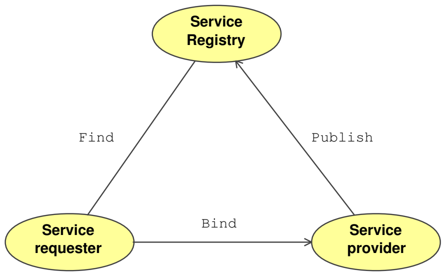

Figure 1. Basic Interaction Model

According to Figure 1, an interaction between two endpoints can be defined in terms of:

- The set of messages accepted by the service provider (*Provided Interface*)
- The set of messages required by the client (*Required Interface*)
- A protocol that defines the partial order between the exchanged messages.
- The programming abstractions through which the client and server view the protocol (*the client-side and server-side programming interfaces*). This is important, because these programming abstractions encapsulate the agreement between both parties on the data format, the mechanism for transforming and reconstructing the object state into this format, the transport protocol, etc.

Most approaches just focus on the first three points. However, the fourth one is not explicitly stated or modeled anywhere; instead, it is usually implicitly assumed by both the client and the server, and therefore hard-wired into their models, transformation rules, and code. This is not flexible and does not provide the platform-independence required in a true MDA approach. Besides, these assumptions are usually made separately, which may cause other contradictory choices. Thus, being able to express this kind of information—particulary the last point—in a Platform-Independent way is a step forward to achieving abstracts models established in more detail that allow code-generation MDA tools to obtain real implementations.

3.2 Identifying Model Elements and their Relationships

In our proposal we have tried to use existing UML elements as much as possible, in particular UML 2.0 elements because they provide some useful architectural concepts

UML Base Element	Stereotype
Port	≪ServerPort≫
Port	≪ClientPort≫
Port	≪StubClient≫
Port	≪ProxyClient≫
Port	≪DynamicClient≫
Interface	≪InterfaceSignature≫
Interface	≪ProvidedInterface≫
Interface	≪RequiredInterface≫
Assembly Adaptor	≪Interaction≫

Table 1. Summary of the stereotypes used

and mechanisms for our purposes. Table 1 shows a summary of the profile we have defined for representing these concepts. In particular, we consider each system as a UML 2.0 *Component*, which represents "a modular part of a system that encapsulates its contents, designs as well as implementations features, without losing the ability to describe deployment information and being replaceable within its environment" [16].

Component interactions are carried out through a layer of abstraction that allows clients to instantiate and access the methods of the external services provider. In this sense, we can define one or more *Ports* through which a *component* invokes and receives method calls.

Since each endpoint can act as either a *provider* or a *client* in each of the Web interactions in which it plays a role, we have modeled causality by a *Port* stereotyped as *ClientPort* or *ServerPort*.

The interaction between a *ServerPort* and a *ClientPort* falls into one of the following categories:

- Synchronous invocation. The *ClientPort* invokes a remote procedure and blocks it until a response or an exception is received from the *ServerPort*.
- Asynchronous invocation. The *ClientPort* invokes a remote procedure and continues processing without waiting for a return, although the returned value will be received at any moment.
- One-way invocation. The *ClientPort* invokes a remote procedure but does not block or wait to receive a return since it will not receive a return value.

Initially we will consider that each *Port* is associated with only one *Interface*. More precisely, a *ClientPort* is associated with a *RequiredInterface* and a *ServerPort* is associated with a *ProvidedInterface*. A *ProvidedInterface* specifies public operations that are remotely available. On the other hand, *RequiredInterfaces* complement *ProvidedInterfaces* and describe those external features on which a system depends to implement its functionality.

Ports describe how a *System* interacts with its environment. They are different to *Interfaces* because *Interfaces* contain just syntactic information about the methods provided by a *System*, while *Ports* encapsulate the required business logic that allows a *Requirer* to interact with a *Provider*, tying that business logic with a concrete "implementation choice". Note that in many cases some implementation choices will only be supported by certain target platforms.

Each *Port* has an associated a *Protocol* that defines the partial order in which the post owner object expects its methods to be called, and the order in which it invokes another object's methods. *Port's Protocols* show a global perspective over its constituent external applications protocol descriptions. For simplicity we have supposed that each *Port* is associated with only one *Interface*, and hence *Port's protocols* will coincide with *Interface's protocols*.

ServerPort's Protocol can be describe as text files using BPEL4WS or WS-CDL specifications, for example. *ClientPorts* interfaces can be augmented with behavioral descriptions based on *protocol state machines* that define usage constraints among features of the associated interface. Many aspects of the *ClientPort* are determined by the external system which the client connects to. In consequence, the *ClientPort* can be classified into three main categories based on the third party system that they can interact with:

(*i*) *Stub Clients* are never required to be downloaded or distributed to clients and they are specific to a certain protocol, transport option and server requirer (accorded at compile time). The client must obtain a reference to the *Stub* before using it, which represents an instance of the server provider. In order to obtain it, both the remote interface and its implementation have to be available so the client relies on an implementation-specific class.

(*ii*) *Proxy Clients*, as *Stub Clients*, refer to static invocation of server provider methods. They are not portable across implementations either—in this case, the code for the *Proxy Client* is created during runtime, but the reference to the interface specification of the external provider is obtained at compile-time.

(*iii*) *Dynamic Clients* can access a service discovering its interface description dynamically. In the same way, they can invoke server provider methods at runtime. This implies an extra work at runtime to fetch and process the server interface.

At this point, a benefit of using *Ports* is that the constraints and requirements on the communications between applications can be modeled without forcing software developers to take into account the platform specific notions in their designs. In this way, the designs can be reused to be run on different platforms (hence following the platform-independence philosophy dictated by MDA).

The kind of *Client Port* to be used is important, and strongly influences the kinds of client-side artifacts that need to be generated at development-time. Both *Stub* and *proxy* clients require the complete interface specification of the external services. That is, the client does not need to discover the required service but instead it has, at development-time, to know the external system's details (location, configuration file, WSDL or IDL URL, namespace, etc.). In contrast, *Dynamic Clients* must dynamically discover and invoke an external system without any prior knowledge of its details (signature of the remote procedure or the name of the service). For a *Dynamic Client*, there is no coupling between the service interface and the client. This makes the client code easy to modify if the external systems specifications change.

On the other hand, one of the most significant differences between *Stub Clients* and *Proxy Clients* is how external functionality is invoked. For the former, the client-side programming interface is embedded inside the client business logic. On the contrary, for *Proxy Client* and *Dynamic Client*, the client-side code is packaged apart from the client application.

Please note that the selection of these *Ports* only affects the client side. From the server perspective, it only receives and returns messages which are identical for all client types.

3.3 Adaptors

In case there is a strong requirement of using an external service provider (e.g., for *Stub Clients*), the software designer can specify what should be done if the behavior/specification of both parties is incompatible. Since we have the interface of the required external systems (*provided interfaces*) available, we can carry out static checking for comparing them and determining whether they fulfil our requirements (*required interfaces*).

If not, the designer can decide at designing-time to implement an intermediate business logic (*adaptors*) that conforms to a given interface or employs a required external system. *Adaptors* mediates between the *ClientPort* and *ServerPort* interactions, resolving *service provider* and *service requester* differences at interface and protocol levels.

4 Example: The Travel Agency

In order to illustrate the use of interaction patterns in the definition of Platform Independent and Platform Specific Models, let us consider a Travel Agency service that sells vacation packages to its customers. The packages include flights, hotel rooms, car rentals, and combinations of these. External service providers include transportation companies (airlines, hotels and car rentals) and financial organizations (credit companies and banks).

To book a vacation package, the customer will provide details about his preferred dates, destinations, and accommodation options to the Travel Agency System (TAS). Based on this information, the TAS will request its service providers for offers that fulfill the user's requirements, and will then present the list of offers to the customer. At this point, the customer may either select one of the offered packages, reject them all and quit, or refine his requirements and start the process again. If the customer selects one of the packages, the TAS will book the individual services to the corresponding transportation companies, and charge the customer.

The straightforward application of MDA to develop a system is based on the following steps:

Step 1 Create class diagram (PIM) describing object model.

Step 2 Mark PIM elements with stereotypes.

Step 3 Customize the marked PIM with annotations.

Step 4 Specify the target platform.

Step 5 Generate a PSM.

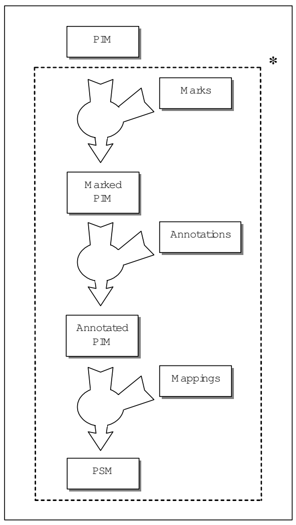

Figure 2. The PIM to PSM iterative process

In general, the MDA software development process becomes an iterative model transformation process where each step transforms one (or more) PIM of the system at one level into one (or more) PSM at the next level until a final implementation model is reached (see Figure 2). Here, an implementation model is just another PSM, which provides all the information needed to construct a system and to put it into operation).

Note that we will call the last platform *technology platform* (i.e., the one that provides the executable PSM, or *implementation*). The intermediate platforms that transform PIMs into PSMs that will be used as PIMs in the next step are considered as *abstract platforms*.

Given that an element of the PIM may be marked several times with marks that come from different metamodels, it will be transformed according to each of the mappings. The semantic of the resulting marked element is given by the gathered features through the MDA model transformation process.

In our approach we need to go though two main phases. Firstly, we need to identify the system scope and boundaries, i.e, which services will be provided by our system, and which ones will be externally required. The result of this phase is a high-level architectural view of the services and components of our global system. In the second phase, we need to determine the concrete platforms and communication mechanisms between our application and the external systems identified previously.

5 Identifying the scope and boundaries of our system

In our previous work [14], we presented a model-based framework that allows the high-level integration of Web applications with third party systems aligned with the MDA principles. It enables the manipulation of the external entities and systems as native elements of our models.

At design level, software developers are able to specify/mark: the system elements that require code generation; the system elements that will be remotely accessed using its provided interface specifications and implementations; the system elements that need to interact with others; and the system properties that are used for identifying them. All this is done in this first phase in a platform-independent manner, i.e., independently from the communication asbtractions and mechanisms used, and the platforms in which our system and the external services are implemented. These details will be added in the second phase.

In the first place we need to create the PIM of the system, which in our case is shown in Figure 3. It focuses just on the operations of the system, while abstracting away the rest of the details (software architecture, distribution, system boundaries, communication protocols, implementation platforms, etc.). This solution is specified in terms of UML packages and their interconnections in a platform independent manner, where no implementation decisions have been explicitly stated (this greatly simplifies the PIM of the application making it reusable across different target platform environments).

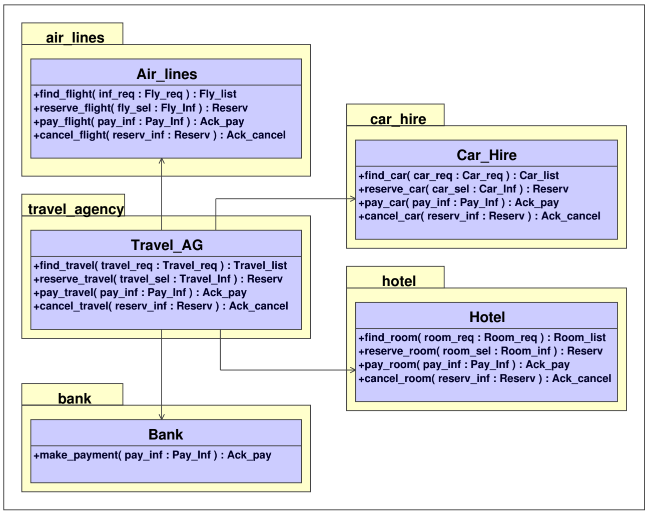

Figure 3. The TAS PIM

As previously mentioned, any integration to legacy data and services may require that the interfaces to those elements are also modeled. The kind of information that is available from them will allow us to check whether they match our requirements or not, as described by the system model [13]. More precisely, this information should be able to allow us to:

(*a*) model the component or legacy system (e.g., by describing its structure, behavior, and choreography);

(*b*) check whether it matches the system requirements (this is also known as the *gap analysis* problem [7]);

(*c*) evaluate the changes and adaptation effort required to make it match the system requirements (i.e., evaluate the *distance* between the models of the "required" and the "actual" services, see e.g., [12]); and

(*d*) ideally, provide the specification of an adaptor that resolves these possible mismatches and differences (see e.g., [6]).

The integration of third party systems with a Web application should be addressed at three levels of abstractions (namely, *presentation*, *business process* and *data level*) [14]. For the sake of simplicity, in this paper we will only consider the business process level.

Once the high-level PIM is described, we need to identify the system scope and boundaries, and then build a model of the system with this information. That target model (PSM) will be built by transforming the original PIM using marks. To identify the elements in the TAS PIM that should be transformed in a particular way, we will use the stereotypes ≪ExternalSystem≫ and ≪ExternalAssociation≫. An ≪ExternalSystem≫ defines any other external system interacting with the system under consideration. In the same way, an ≪ExternalAssociation≫ defines an interaction between the system under deployment and an ≪ExternalSystem≫.

Implicitly, each type of model element in the PIM is only suitable for certain marks, which indicate what type of model element will be generated in the PSM.

Marks are not a part of the platform independent model although they appear on the marked PIM (see Figure 4).

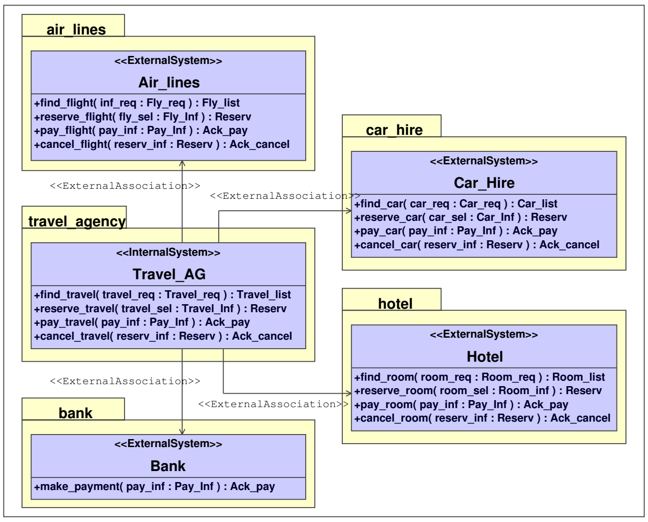

Figure 4. The marked TAS PIM

Note that the marked PIM is, by definition technology independent. In consequence, the prefix "External" used by the stereotypes ≪ExternalSystem≫ and ≪ExternalAssociation≫ in Figure 4 does not imply any implementation decisions. Instead, it is only used to limit the system scope that has to be development.

Once we have the marked PIM, we need to transform it into a PSM that can be translated into a target implementation code. As "platform" we will use here the UML 2.0 constructs and infrastructure for describing software architectures, because what we want to build in this phase is the software architectural description (i.e., model) of the system. This transformation will be guided by the following mapping rules:

- **Packages transformation.** Each UML package is mapped to a UML ≪Component≫ initialized with the same as its corresponding UML package.
- **Classes transformation.** The UML class stereotyped as ≪InternalSystem≫ or ≪ExternalSystem≫ is mapped to a UML ≪Class≫ holding the same characteristics as its original (name, attributes and operations).
- **Associations transformation.** For each UML association stereotyped as ≪ExternalAssociation≫ two component ports will be generated, each one as Association ends of that relationship. Ports will be associated to the UML ≪Component≫ derived in the previous step. Its behavior is defined in terms of an interface associated with that port, which specifies the nature of the interactions that may occur over that port. Thus, the port interface's name is given the value of the UML class name from which it derives and its operations correspond to its UML class operations.
- **Transformation of Association's ends.** For the endpoint of an ≪ExternalAssociation≫ stereotyped as ≪InternalSystem≫, a usage dependency from the port to the interface is generated, showing how the ≪InternalSystem≫ provides a set of services.

  For the endpoint of an ≪ExternalAssociation≫ stereotyped as ≪ExternalSystem≫, an implementation dependency from the port to the interface is generated, showing the services required by the ≪ExternalSystem≫.
- Finally, assembly connectors are defined from required Interfaces to the corresponding provided Interfaces.

Applying these mapping rules on the PIM in Figure 4, the PSM shown in Figure 5 is obtained.

As previously mentioned, the MDA software development process is an iterative model transformation process whereby a PIM is transformed into a PSM, which in turn becomes the PIM for the next transformation—until a final PSM (the system *implementation*) is reached. What counts as a platform depends on the level of abstraction, and the kind of system being developed.

6 A Platform Specific Interaction-Model

Once we have the (UML 2.0) architectural description of the system, that identifies its scope and interactions with external services, the next phase focuses on the specification of such external interactions using the particular platforms and communication mechanisms of the required services. By adopting an MDA transformation process based on marks and annotations, we have to define the marks and transformations required.

Basically the information that the transformation process has to generate from the marked PIM is: the communication mechanisms between the *Components*; how the communications will be carried out; and the information that

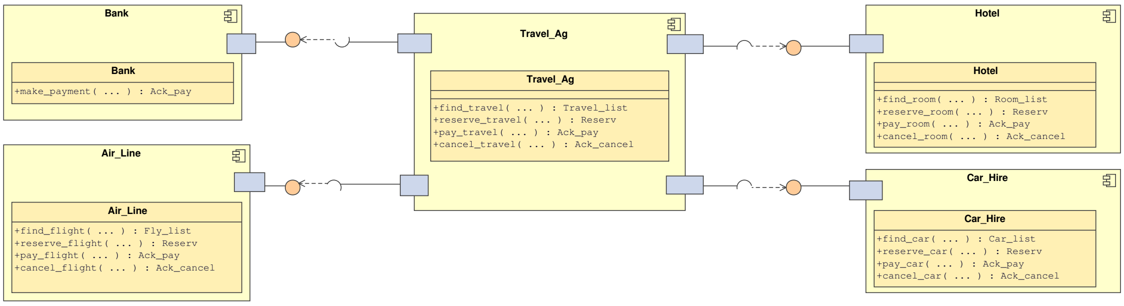

Figure 5. The PSM after applying the MDA transformation

describes the architecture of the Web application. Therefore, the model shown in Figure 5 has to be marked again to specify that information.

Once we have applied previous transformation rules on the PIM, the resulting PSM is also platform-independent. We will mark them with decisions which are considered and taken in the context of a specific implementation design based on the concepts discussed in Section 3:

- Ports that specify services provided by external entities are stereotyped as ≪ServerPorts≫
- Ports that specify required services are stereotyped as ≪ClientPorts≫.
- Finally, assembly adaptors connecting interfaces have been stereotyped as ≪Interactions≫.

The resulting model is shown in Figure 6.

Now it is time to include information about the technologies used to interact with the external services.

In the particular case of the Travel Agency System, we are going to make use of external service providers which include transportation companies (airlines, hotels and car rentals) and financial organizations (credit companies and banks). For illustration purposes we have selected different technologies for each external service. More precisely:

- A CORBA implementation of the Hotel Service. As previously mentioned, in order to participate in an interaction with a CORBA server application, the client (that is, our Travel Agency Service) must be able to get an object reference for a CORBA object and invoke operations on the object. To accomplish this, the client needs information about references to the environmental objects that provide services for the CORBA application we plan to use and the IDL specification for implementing a stub-style invocation. Figure 7 shows how this information is specified using notes associated to its corresponding stereotypes.
- Another CORBA implementation of the CarHire Service. In this case, we plan to implement a dynamic interaction pattern so the IDL file will be looked up in an Interface Repository where it must be stored. In that sense, no IDL file has to be provided by the external server provider.

  The exact steps taken to access the Interface Repository depend on whether the client is seeking information about a specific object, or browsing the Interface Repository to find an interface. In both cases, before a dynamic client can browse the Interface Repository, it needs to obtain the object reference of the Interface Repository to start the search. Once the client has the object reference, it can navigate the Interface Repository, starting at the root.
- The two other external services are supposed to be available as external Web services. Their respective WSDL interface descriptions are required as illustrated in Figure 7. Additionally, the code for the interaction with the Airline Web service relies on an implementation-specific class since it uses an stub-style. This means that its implementation should also be available.

At this point, we also need to decide on the implementation technologies and platforms of our own system. Imagine that we decide to implement the Travel Agency using Java and Web Services technologies.

In this case we could use the transformation rules of any of the existing approaches for converting our marked and annotated PIM (in Fig. 7) to the corresponding PSM (shown in Fig. 8). For instance, we could follow the approach by Bezivin et al. [3], and then proceed according to the following steps:

1. Code each service endpoint interface and its implementation class. A service endpoint interface declares the methods that a remote client may invoke on the service. In this case, each UML class is mapped to

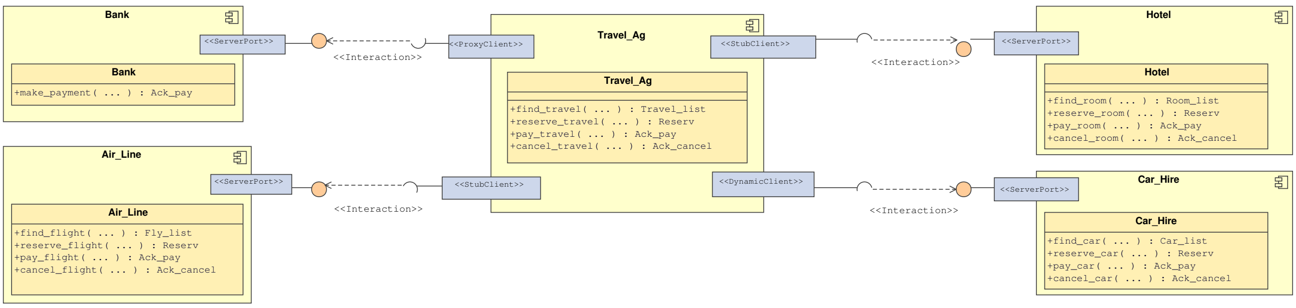

Figure 6. Marked PIM

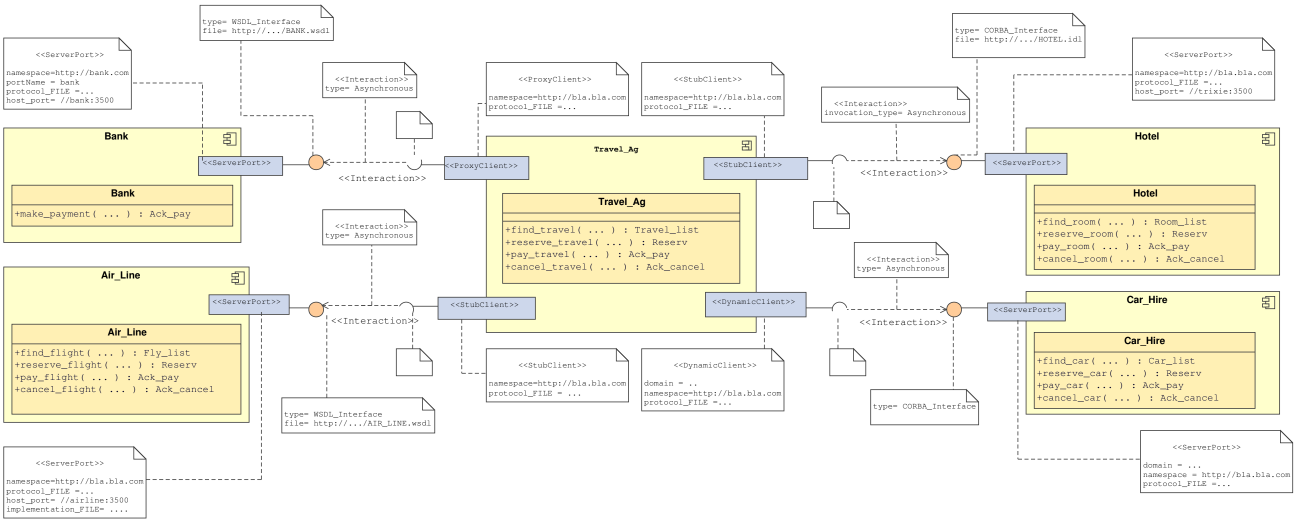

Figure 7. The Annotated TAS PIM

a ≪JavaClass≫ initialized with the same characteristics of its corresponding UML class. Based on this, the ≪JavaInterface≫ is also derived.

2. Build, generate, and package the files required by the service. In this case, each UML class is also mapped to a ≪WSDL Specifications≫: ≪WSDL types≫, ≪WSDL operations≫, ≪WSDL bindings≫ and ≪WSDL services≫.

3. Deploy the service. Four deployment files are required in our case: web.xml, jaxrpc-ri.xml, config-wsdl and config-interface. Thus, the ≪JavaClass≫ is mapped to a ≪JWSDPweb.xml≫, ≪JWSDPjaxrpc-ri.xml≫, ≪JWSDPconfig-wsdl≫ and ≪JWSDPconfig-interface≫ files.

4. Generate client-side abstractions for consuming external services. For the CORBA services, we will add: the client stubs for each interface (interfaceStub.java), the CORBA helper class (interfaceHelper.java) and the CORBA holder class (interfaceHolder.java) that describe everything needed to use the client stub from the Java programming language. For the rest of the services, no more classes are generated (the code is embedded in the ≪JavaClass≫ implementation).

The PSM obtained, shown in Figure 8, includes all the details required to build the final implementation.

7 Conclusions and Future Works

In this paper we have discussed some of the (many) problems that may happen when integrating Web-based applications with external systems. In particular, we have concentrated on the interaction issues due to potential incompatibilities between clients and servers of different implementation platforms and middlewares. Our main contribution is

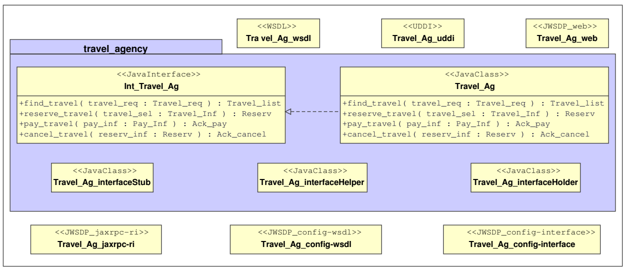

Figure 8. The final TAS PSM

to make such interaction models and mechanisms explicit, so incompatibilities can be detected, and bridges or adapters can be easily built. Besides, we have done it according to the MDA principles, encapsulating those interaction concepts and mechanisms in a platform-independent manner, and then providing transformation rules to the different implementations available of these concepts in the most commonly used platforms and middelwares.

Now that the interaction issues can be solved at this level, we plan to move forward, trying to address two other major issues. Firstly, the (semi-)automatic derivation of adaptors in case of incompatibilities are detected at this level. Secondly, the description of some behavioral and QoS information in the models, in order to deal with these kinds of aspects.

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