MOSQUITO 1.6
User Manual

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1 Mosquito versioning

The MOSQUITO evolution across the different releases is shown in Figure 1.

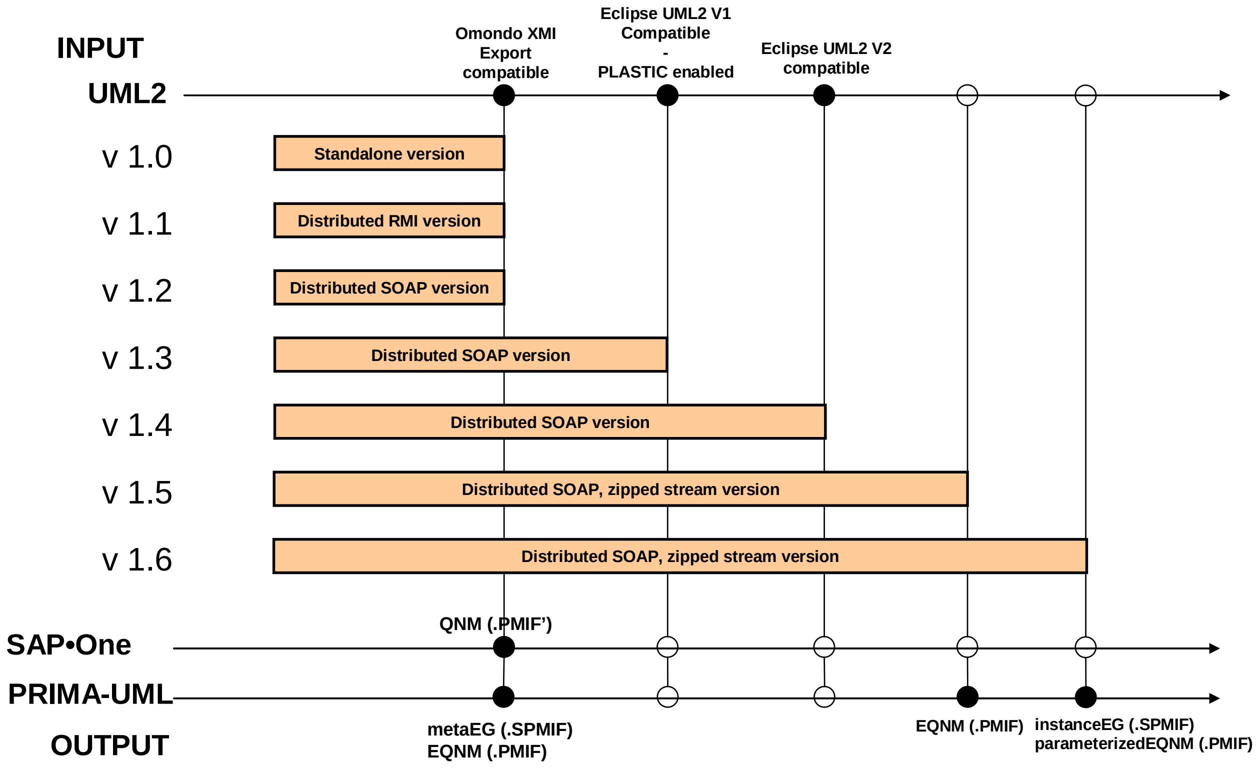


Figure 1: Mosquito versioning.

The MOSQUITO 1.6 release provides new features that have been added to the previous version. Now MOSQUITO 1.6 fully support the SAP·One and PRIMA-UML methodologies: it is now able to build all the analysis models required by these methodologies:

SAP·ONE: Queuing Network Model (QNM);
PRIMA-UML: Extended Queuing Network Model (EQNM);
PRIMA-UML: meta Execution Graph (metaEG);
PRIMA-UML: instance Execution Graph (instanceEG); **(new)**
PRIMA-UML: parameterized Extended Queuing Network (pEQNM); **(new)**

2 Getting Started

MOSQUITO (MOdel driven conStruction of QUeuIng neTwOrks) is a tool developed in JAVA language as plug-in for the Eclipse Platform. To use it you need to install a Java Virtual Machine and the Eclipse Platform with a compatible Eclipse UML SDK.

2.1 Installation Requirements

Server Side

Operating System:	Independent
Web Application Container:	Apache Tomcat 6.0 with Axis2 1.4
JDK version:	1.5

Client Side

Eclipse:	3.2 or higher
Eclipse EMF SDK:	2.2.x
Eclipse UML2 SDK:	2.x
JDK version:	1.5

2.2 Getting Eclipse with Eclipse UML

The main Web site for Eclipse is www.eclipse.org. On that page, you can see the latest Eclipse news and links to a variety of online resources, including articles, newsgroups, bug tracking, and mailing lists.

The latest version of Eclipse can be downloaded from the main download page at www.eclipse.org/downloads (if this site is unavailable, a number of mirror sites around the world are available). Go ahead and download the latest release or stable build.

The download page for each release includes various notes concerning that release as well as links to every platform version. Eclipse supports a large number of platforms, including Windows, Linux, Solaris, HP, Mac OSX, and others. Choose the Eclipse SDK download link corresponding to your platform and save the Eclipse zip file to your computer's hard drive. This will generally be a very large file (>105 MB), so be patient unless you have sufficient bandwidth available to quickly download the file.

Once the Eclipse zip file has been successfully downloaded, unzip it to your hard drive. Eclipse does not modify the Windows registry, so it does not matter where it is installed.

MOSQUITO was developed with Eclipse 3.2 and subsequently tested with Eclipse 3.2 and higher versions.

It is very important to download a version of Eclipse equipped with the EclipseUML SDK plug-in to manage the UML models that represent the input to MOSQUITO. However, if you already have an Eclipse installation without EclipseUML, you can update your platform with the update manager selecting Help --> Software Updates --> Find and Install --> Search for New features to Install.

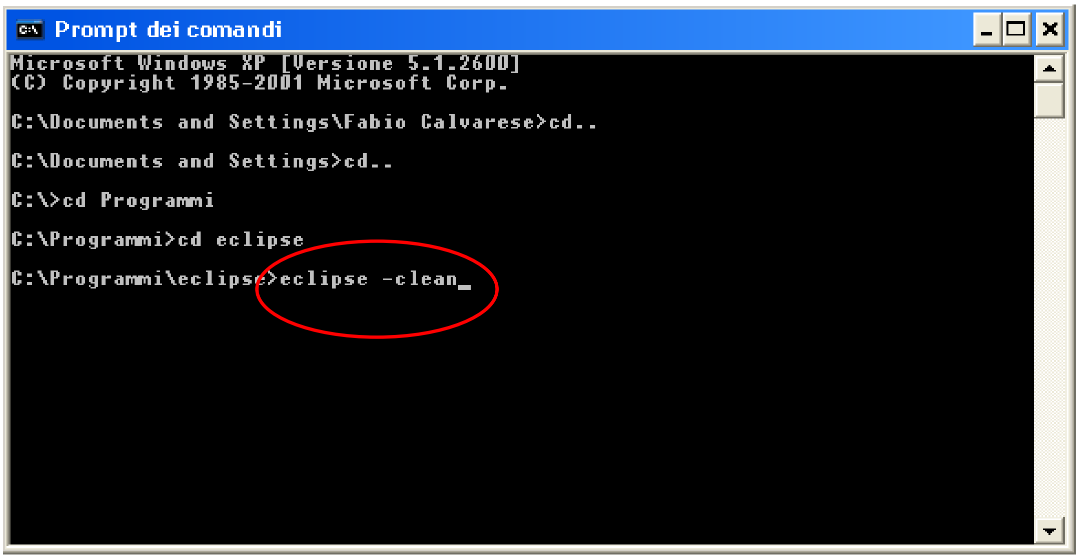
2.3 Installing MOSQUITO

You can download MOSQUITO client from the following web page
http://sealabTools.di.univaq.it/SeaLab/MosquitoDownload.html.

MOSQUITO is a plug-in for the Eclipse platform, and its installation (like every other Eclipse plug-in) is very simple. It is sufficient to unzip the zip file di.univaq.MOSQUITO in the main folder of Eclipse (e.g., c:/eclipse). After this step verify if the plug-in jar file appears in the plug-in directory (e.g., c:/eclipse/plugins/di.univaq.MOSQUITO_x.x.x.jar). Take care to remove all the previous versions of MOSQUITO.

Eclipse caches plug-ins information in a configuration directory. For this reason, the first launching of Eclipse with the installed MOSQUITO plug-in must be performed using the –clean command-line option so that the cached plug-ins information will be rebuilt.

To do this you must use the prompt to launch Eclipse. If you are in the directory of Eclipse installation them you must type the "Eclipse –clean" command as reported in Figure 2.



```
Microsoft Windows XP [Versione 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

C:\Documents and Settings\Fabio Calvarese>cd..

C:\Documents and Settings>cd..

C:\>cd Programmi

C:\Programmi>cd eclipse

C:\Programmi\eclipse>eclipse -clean_
```

Figure 2 Eclipse refresh procedure

After started the Eclipse platform, you can verify the correct MOSQUITO installation by inspecting the plug-in details under Help -> About Eclipse SDK -> Plug-in Detail. The MOSQUITO plug-in must appear in the list of the currently installed plug-ins.

This step can be also performed once and for all by modifying the eclipse.ini configuration file by adding the "-clean" option on the top of this file.

For example

```
-clean
-showsplash
org.eclipse.platform
…
```

3 MOSQUITO and the supported model-based methodologies

The shows the MOSQUITO model generation processes (Ax and Bx paths) illustrated in the previous sections

The two methodologies will be briefly explained in the following two sections.

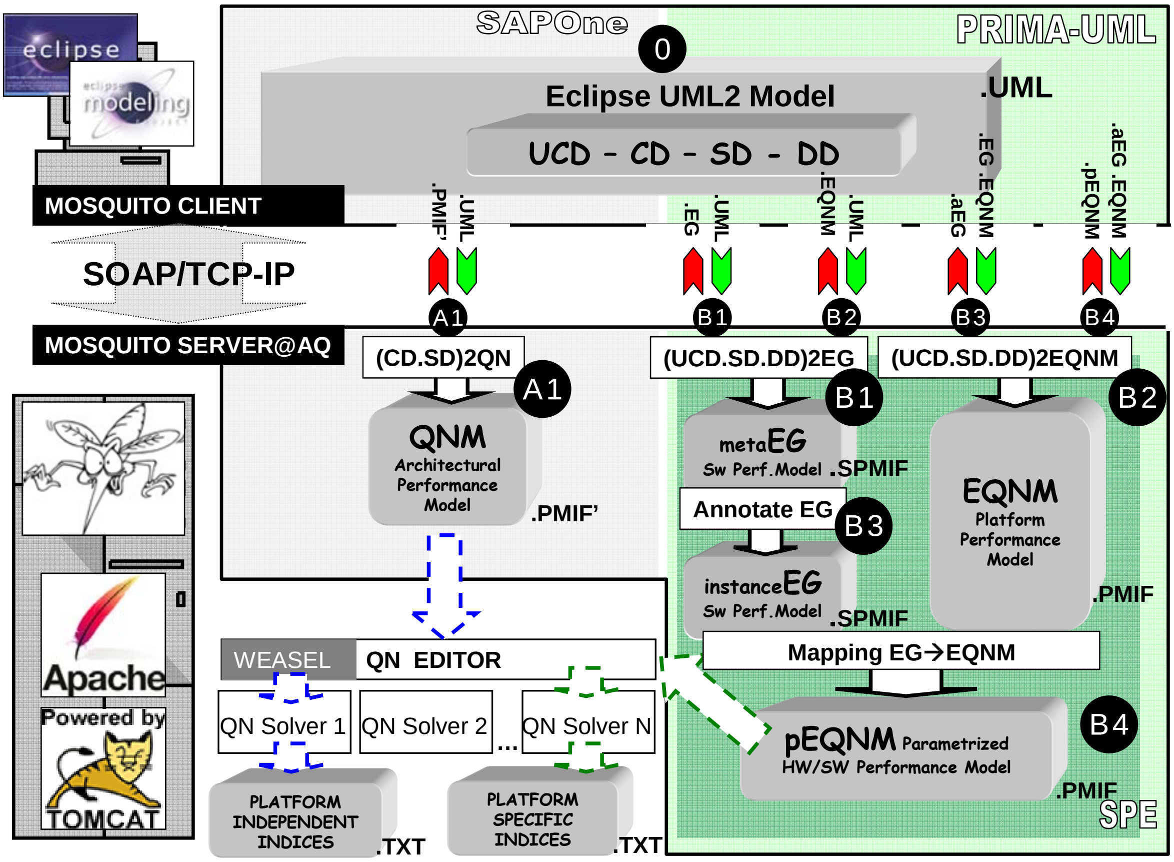


Figure 3: The performance analysis model generation carried out by Mosquito.

3.1 The SAP·One methodology

SAP·One [1] is a methodology for the performance modelling of a software system. It consists essentially in the generation of a queuing network from an UML architectural model.

SAP·One has been conceived to be applied in the first phases of the software process to reveal architectural flaws as soon as possible, so the developer will be able to modify the system architecture.

The UML architectural model (step 0) is formed by a static and dynamic view of the system provided by a Component Diagram (CD) and a Sequence Diagram (SD), respectively. These diagrams are enriched with additional information about the system performance from the SPT [4] profile, such as scheduling policies and service times of software components (on CD) and workloads on interaction between component instances (on SD).

In this approach the service centers of the QNM don't represent hardware resources (such as disks or processors) rather they represent the software components of the system architecture.

The UML model represents therefore a platform-independent model (PIM), and the performance indices that can be obtained are "somehow" parametric. This is because the assumption underlying the methodology is that every software component will be placed on a logical device, and that all

the devices will have the same “speed” but they can manage requests through queues of different capacity and different scheduling policy
In practice, the SAP·One analysis is comparative, in that the obtained performance values are useful to reveal bad architectural choices, but they are of little value as absolute performance indices.

3.2 The PRIMA-UML methodology

PRIMA-UML [3] is a methodology for the performance modelling of a hw/sw model: starting from properly annotated UML2 diagrams, generates a sw/hw performance model. PRIMA-UML is based on the Software Performance Engineering (SPE) methodology.
The UML software/hardware model contains two *viewpoints:* the static view shows which components instances are executed on which hardware hosts (DD) while the dynamic view define the operational profile (i.e. frequencies of use of the system functionalities by the users, depicted on the UCD) and the interactions (i.e. invocation messages) between software components (SD). From a source UML sw/hw model in these settings, two different kind of performance models (defined in SPE) are obtained:

(i) a software performance model represented as Execution Graph (EG): a graph of processing steps (i.e operation invocations) that perform a function of the software system and where arcs represent the order of execution (very similar to UML Activity Diagram). PRIMA-UML splits the EG generation in two phases:
   a) first, a metaEG is generated representing a generic topology (just node and arcs)
   b) then an instanceEG is generated on the base of the metaEG that contains a matrix of values (*overhead matrix*) representing the software resource (i.e. n# of CPU instructions or number of messages exchanged or n# of database accesses) required by each processing steps and how these software resource requirements are translated in terms of hardware resource requirements.

   Different execution paths with different execution probabilities are determined by he operational profile on the UCD and by the message exchanged by component instances on the SD.

(ii) a platform performance model represented as an Extended Queuing Network Model (EQNM). It shows which are the execution environment of each components in terms of available hardware resource (CPUs and DISKs) and possible DELAYs due to different configurations (e.g. interactions between components deployed on different networked nodes are “delayed”). PRIMA-UML splits the EQNM generation in two phases:
   a) first, a EQNM is generated representing a generic topology with featured service centers (e.g. with scheduling policies) of different type (CPU, DISK or DELAY) and arcs connecting them;
   b) a parameterized EQNM resulting from the merging of an already existing instance EG (i.b) and EQNM (ii.a). The merging of the instance EG and the EQNM models ends the model analysis generation phase.

This type of system analysis is better suited when the developers have already some ideas on the potential target platforms because EQNM service centers, in PRIMA-UML, represent hw resources.

4 MOSQUITO implementation technologies

MOSQUITO is a client/server application. The plug-in di.univaq.MOSQUITO implements the client side that provides the functionality to invoke the operations (i.e. model2model transformations) exposed by the MOSQUITO Web Service installed on a server running at University of L'Aquila.
The system architecture is shown in Figure 4.

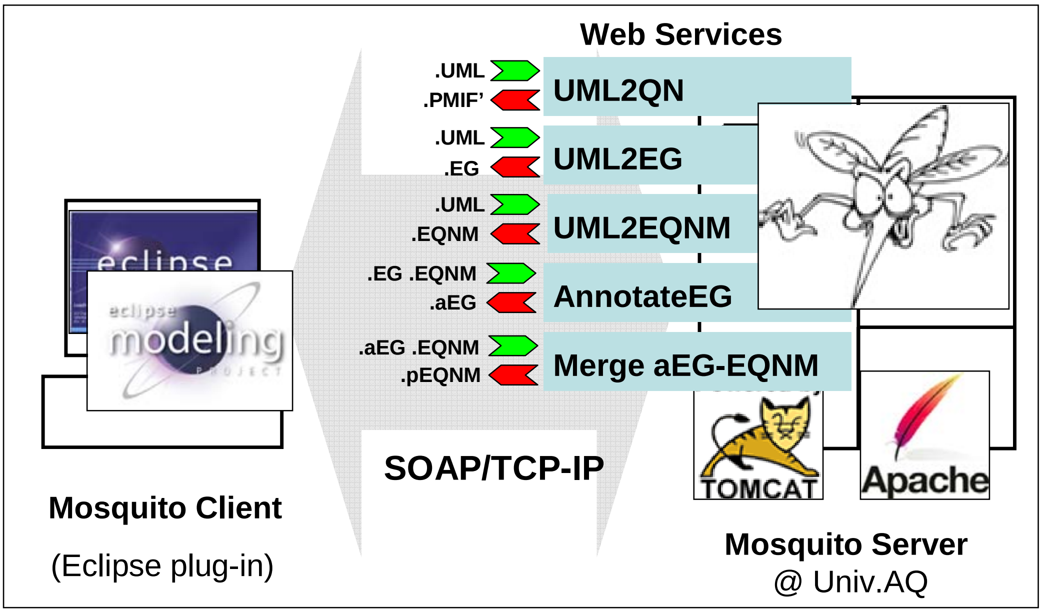
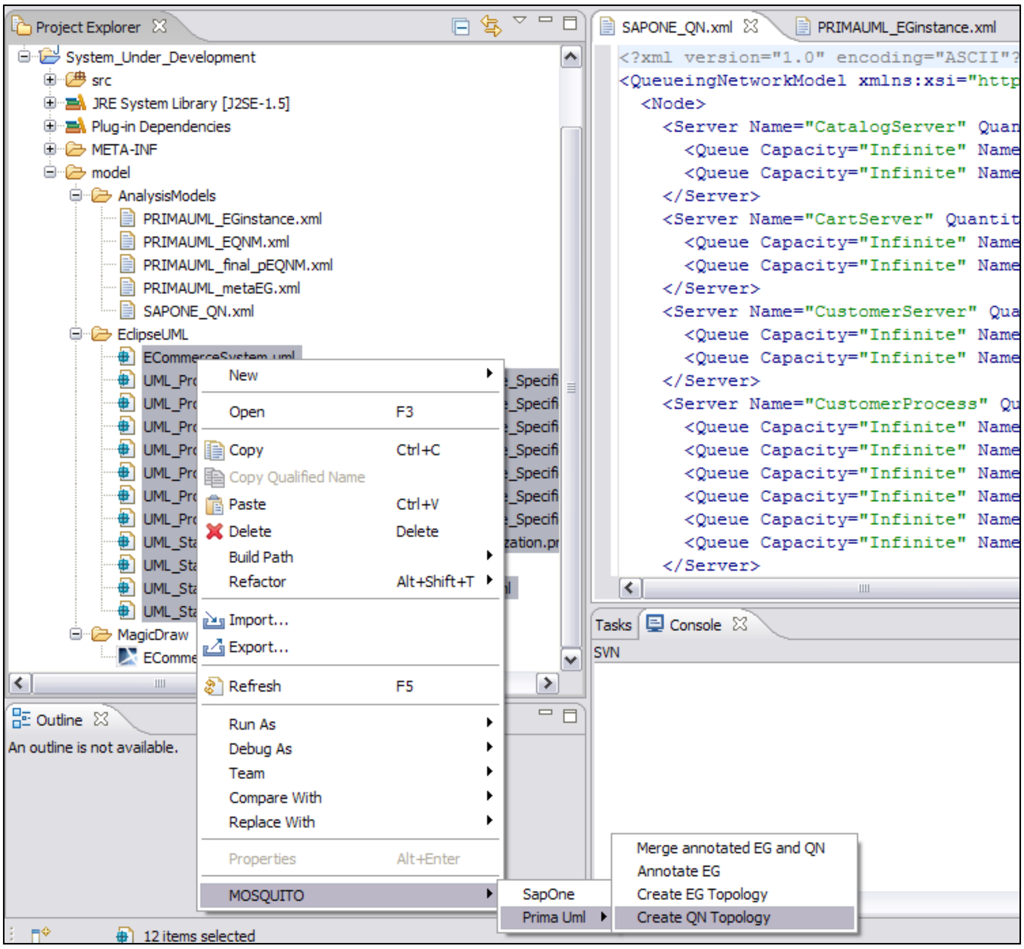


Figure 4: Mosquito client-server architecture.

In particular MOSQUITO is exposed as a Web Service: This will allow any user to implement an alternative client, using the preferred languages and technologies, to use the services of MOSQUITO server placed at di.univaq.it domain.

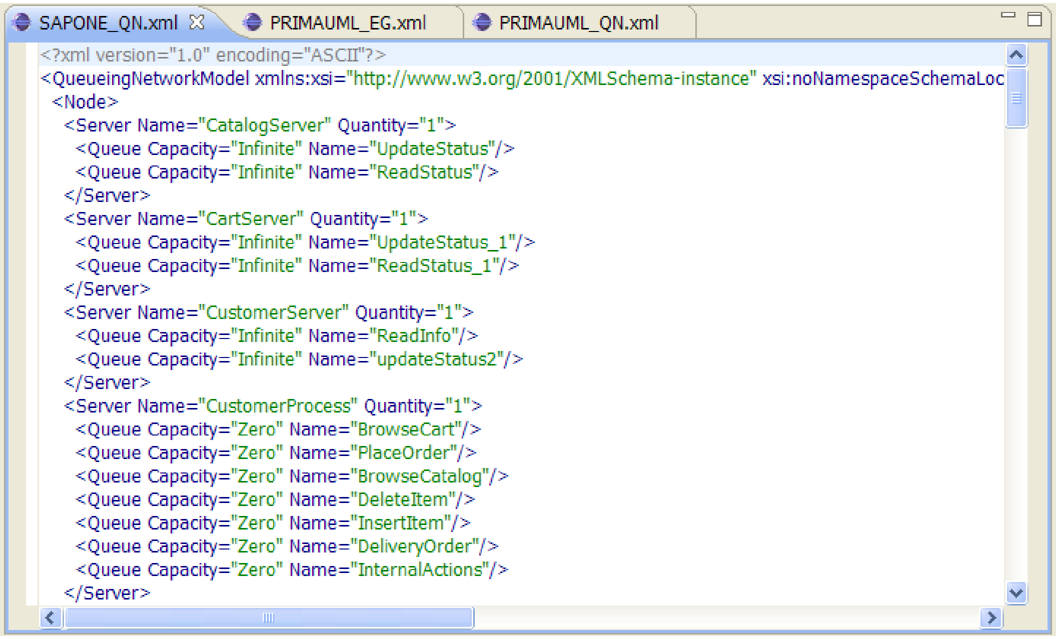
The MOSQUITO client that we provide is an Eclipse plug-in that allows an entirely automated process. The user must only properly create and annotate UML models according to the selected methodology (i.e SAP·One or PRIMA-UML).
The extension point used for the MOSQUITO interface is the Eclipse popup menu. After the creation of a model the user must only select the correct source models (see Figure 3) and activate the desired transformation, as shown in the following Figure 5.



```
<?xml version="1.0" encoding="ASCII"?
<QueueingNetworkModel xmlns:xsi="http
  <Node>
    <Server Name="CatalogServer" Quan
      <Queue Capacity="Infinite" Name
      <Queue Capacity="Infinite" Name
    </Server>
    <Server Name="CartServer" Quantit
      <Queue Capacity="Infinite" Name
      <Queue Capacity="Infinite" Name
    </Server>
    <Server Name="CustomerServer" Qua
      <Queue Capacity="Infinite" Name
      <Queue Capacity="Infinite" Name
    </Server>
    <Server Name="CustomerProcess" Qu
      <Queue Capacity="Infinite" Name
      <Queue Capacity="Infinite" Name
      <Queue Capacity="Infinite" Name
      <Queue Capacity="Infinite" Name
      <Queue Capacity="Infinite" Name
      <Queue Capacity="Infinite" Name
    </Server>
```

Figure 5. Invoking Mosquito transformations from Eclipse Platform.

The result of the transformation will be showed in the Eclipse XML editor as follows: eventually, a WARNING or ERROR tabs will be displayed containing the warnings or errors about input model, respectively (Figure 6).



```
<?xml version="1.0" encoding="ASCII"?>
<QueueingNetworkModel xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLoc
 <Node>
  <Server Name="CatalogServer" Quantity="1">
   <Queue Capacity="Infinite" Name="UpdateStatus"/>
   <Queue Capacity="Infinite" Name="ReadStatus"/>
  </Server>
  <Server Name="CartServer" Quantity="1">
   <Queue Capacity="Infinite" Name="UpdateStatus_1"/>
   <Queue Capacity="Infinite" Name="ReadStatus_1"/>
  </Server>
  <Server Name="CustomerServer" Quantity="1">
   <Queue Capacity="Infinite" Name="ReadInfo"/>
   <Queue Capacity="Infinite" Name="updateStatus2"/>
  </Server>
  <Server Name="CustomerProcess" Quantity="1">
   <Queue Capacity="Zero" Name="BrowseCart"/>
   <Queue Capacity="Zero" Name="PlaceOrder"/>
   <Queue Capacity="Zero" Name="BrowseCatalog"/>
   <Queue Capacity="Zero" Name="DeleteItem"/>
   <Queue Capacity="Zero" Name="InsertItem"/>
   <Queue Capacity="Zero" Name="DeliveryOrder"/>
   <Queue Capacity="Zero" Name="InternalActions"/>
  </Server>
```

Figure 6: Mosquito output models are displayed as xml-based files.

5 MOSQUITO at work

In this section we explain how to introduce the SAP·One and PRIMA-UML annotations in the Eclipse UML models[1]. The presentation is driven by the eCommerce System example.

5.1 eCommerce System Specification

In the electronic commerce system, there is a supplier that publishes his catalogue on the web. The catalogue can be visioned by registered and unregistered users. Registered users become customers for the supplier. The supplier accepts customer orders and delivers the ordered items maintaining all the relevant data. He needs to maintain information on data, on the catalogue and on the orders purchased by his customers. Each registered customer has a cart where he/she can insert or delete items. The customer can order only if the cart is not empty. The system also allows the customer to monitor the order status and to confirm the delivery in order to permit the payment.

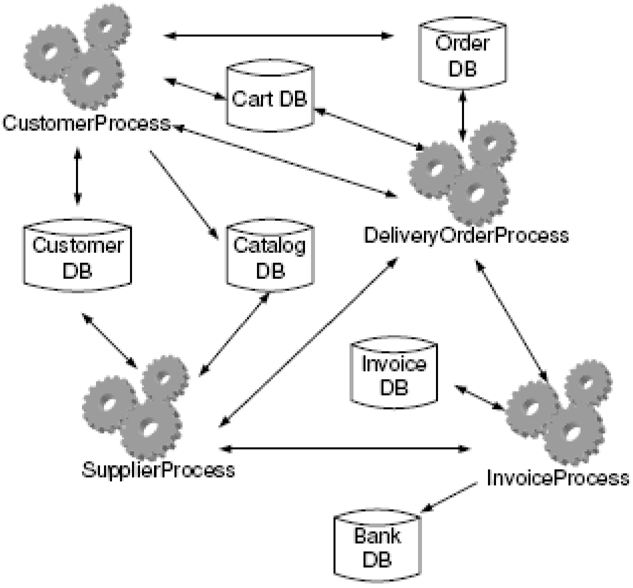


Figure 7: Overview of the eCommerce System

Figure 7 shows the system structure at a high level of details. In a first analysis, some databases (Customer DB, Cart DB, Order DB,etc.) and four process type (CustomerProcess, SupplierProcess, etc.) are identified. For each involved database, there is a server that permits to communicate with it. The interactions with these servers are asynchronous. Each customer has associated a (individual) CustomerProcess. If the customer is not registered, the process allows the browsing of the catalogue only, whereas if he is a registered one, the process activates all the functionalities the system provides him (cart managing, order placement, etc.). All the functionalities provided by the system to the supplier, instead, are coded in the SupplierProcess. The DeliveryOrderProcess and InvoiceProcess are processes that manage the activities to be executed to dispatch an order and to produce the corresponding invoice. In the system one DeliveryOrderProcess instance and one

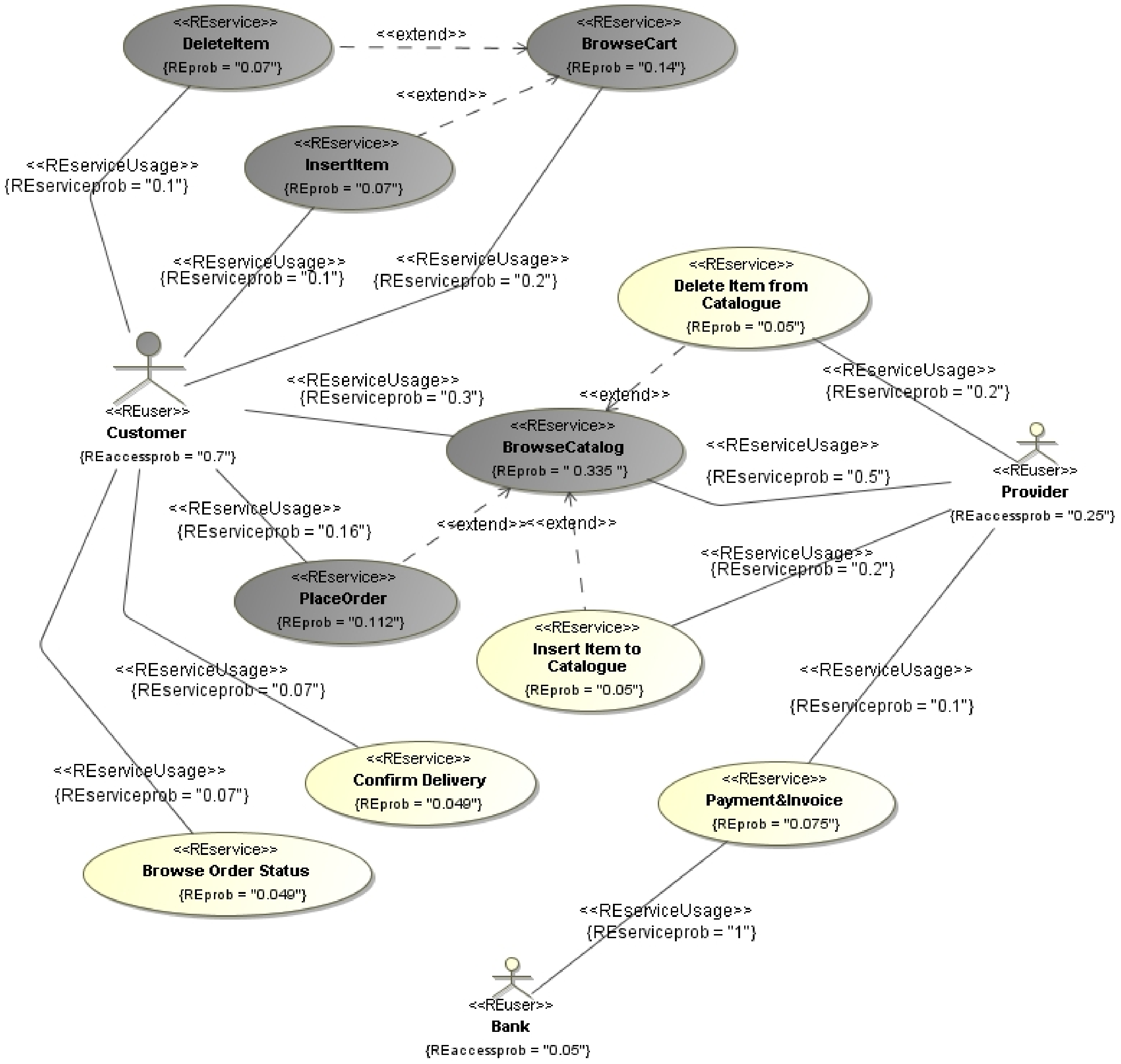
[1] Generating an Eclipse UML2 model (.uml) as input to Mosquito implies a more detailed description using the *terms* used by the OMG UML 2.1 Superstructure specification (e.g the names used for metaclasses and their tags) and by an UML2 SPT profile (e.g. names used for stereotypes and their tags). That kind of detailed and precise should allow a tighter mapping between the Import/Export API code and its textual description: Eclipse UML uses the official OMG UML 2.1 Superstructure specification to define its own API.

Invoice Process instance are running, any time, for each order and for each invoice in process, respectively.

For the sake of presentation, a simplified version of this system is considered. The focus is on a subset of customer functionalities. In particular, only catalogue browsing, cart browsing, item insertion and deletion to/from the cart, order placement functionalities will be considered.

5.2 Use Case Diagram

Figure 8 shows the use case diagram (UCD) for the e-commerce system. Three actors are in the system: Customer, Supplier and Bank. The e-commerce customer can browse both the cart (BrowseCart) and the catalogue (BrowseCatalog), she/he can insert and delete items to/from the cart (InsertItem and DeleteItem, respectively). She/He can place an order and check its status (PlaceOrder and BrowseOrderStatus), and finally she/he can confirm the delivery (ConfirmDelivery) of the items ordered. The use case diagram also specifies that both InsertItem and DeleteItem functionalities use the BrowseCart in their execution.



<<REservice>> DeleteItem {REprob = "0.07"}
<<extend>>
<<REservice>> BrowseCart {REprob = "0.14"}
<<extend>>
<<REservice>> InsertItem {REprob = "0.07"}
<<REserviceUsage>> {REserviceprob = "0.1"}
<<REserviceUsage>> {REserviceprob = "0.1"}
<<REserviceUsage>> {REserviceprob = "0.2"}
<<REservice>> Delete Item from Catalogue {REprob = "0.05"}
<<REuser>> Customer {REaccessprob = "0.7"}
<<REserviceUsage>> {REserviceprob = "0.3"}
<<extend>>
<<REserviceUsage>> {REserviceprob = "0.2"}
<<REservice>> BrowseCatalog {REprob = " 0.335 "}
<<REserviceUsage>> {REserviceprob = "0.5"}
<<REuser>> Provider {REaccessprob = "0.25"}
<<REserviceUsage>> {REserviceprob = "0.16"}
<<extend>>
<<extend>>
<<REserviceUsage>> {REserviceprob = "0.2"}
<<REservice>> PlaceOrder {REprob = "0.112"}
<<REservice>> Insert Item to Catalogue {REprob = "0.05"}
<<REserviceUsage>> {REserviceprob = "0.07"}
<<REserviceUsage>> {REserviceprob = "0.1"}
<<REserviceUsage>> {REserviceprob = "0.07"}
<<REservice>> Confirm Delivery {REprob = "0.049"}
<<REservice>> Payment&Invoice {REprob = "0.075"}
<<REservice>> Browse Order Status {REprob = "0.049"}
<<REserviceUsage>> {REserviceprob = "1"}
<<REuser>> Bank {REaccessprob = "0.05"}

Figure 8: UCD of the eCommerce System with the operational profile.

The supplier maintains the catalogue by inserting new items from the catalogue (InsertNewItemInCatalogue) and deleting from it the items no more available (DeleteItemFromCatalogue). Moreover, she/he processes the orders by delivering the items sold (DeliveryOrder) and producing the invoice after the customer has payed (Payment&Invoice). In this last use case, the bank actor is in charge for the money transfer from the customer bank account to the supplier one. Again, the use case diagram specifies that both InsertNewItemInCatalogue and DeleteItemFromCatalogue functionalities use the BrowseCatalogue in their execution.

For the sake of presentation, in this document a simplified version of this system is considered. The focus is on the customer view by considering only the software system functionalities reported on the figure. The choice has been driven by the fact that the focus is on performance aspects hence the customers are the system actors producing more workload to the system. Thus, the use cases critical from performance perspective are those accessed from them.

5.2.1 Sap·One annotations

No Sap•One annotations are required on the Use Case Diagram.

5.2.2 PRIMA-UML annotations

PRIMA-UML annotates and makes use of the Use Case Diagram (UCD) to take into account the operational profile.

The UCD must be annotated with information regarding the probability of a user to access the system, as well as the probabilities to invoke different use cases.

This information is introduced with the **stereotype «REuser»**[2] associated to an Actor and on the Actor-Use Case association, respectively, through the *ReAccessProb* and *ReService* tags.

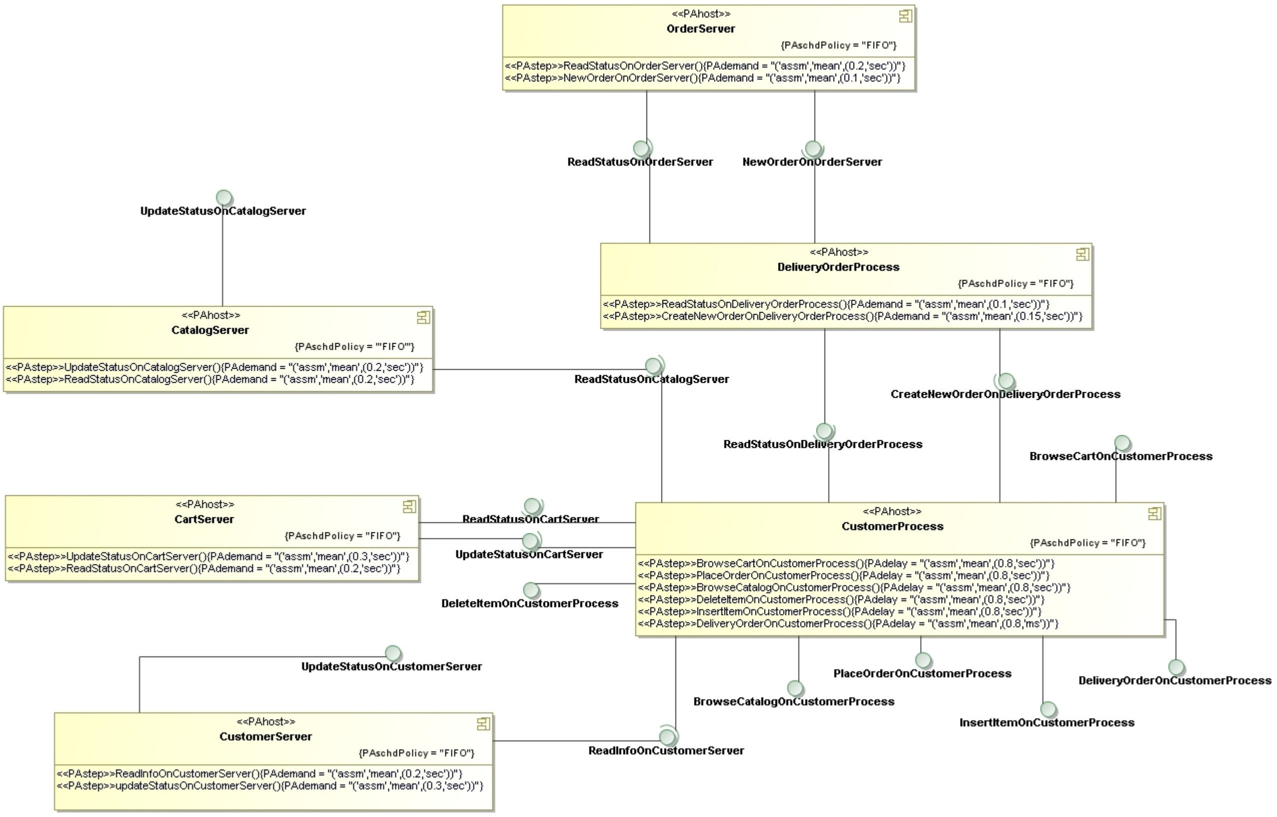
The probabilities of the Use Case Diagram will be used to partially parameterize the performance model.

Stereotype Syntax	Apply Stereotype on (UML metaclasses)	Semantic
<<REuser>> {REaccessprob = value}	On the uml.**Actor**	It denotes the probability that an user accesses the system
<<REservice>> {REprob = value}	On the uml.**UseCase**	It denotes the probability that a provided system functionality can be accessed by all possible users.
<<REserviceUsage>> {REserviceprob = value}	On the uml.**Association** between **<<REuser>>** and **<<REservice>>**	It denotes the probability for the user to invoke a particular use case.

Table 1: PRIMA-UML Stereotypes used on UCD.

[2] UML SPT profile doesn’t provide stereotypes to model the operational profile on the Use Case Diagram. We extend UML SPT with the <<REuser>> stereotype. Its name comes from another profile introduced for reliability purposes.

5.3 Component Diagram



<<PAhost>>
OrderServer
{PAschdPolicy = "FIFO"}
<<PAstep>>ReadStatusOnOrderServer(){PAdemand = "('assm','mean',(0.2,'sec'))"}
<<PAstep>>NewOrderOnOrderServer(){PAdemand = "('assm','mean',(0.1,'sec'))"}
ReadStatusOnOrderServer
NewOrderOnOrderServer
UpdateStatusOnCatalogServer
<<PAhost>>
DeliveryOrderProcess
{PAschdPolicy = "FIFO"}
<<PAstep>>ReadStatusOnDeliveryOrderProcess(){PAdemand = "('assm','mean',(0.1,'sec'))"}
<<PAstep>>CreateNewOrderOnDeliveryOrderProcess(){PAdemand = "('assm','mean',(0.15,'sec'))"}
<<PAhost>>
CatalogServer
{PAschdPolicy = "'FIFO'"}
<<PAstep>>UpdateStatusOnCatalogServer(){PAdemand = "('assm','mean',(0.2,'sec'))"}
<<PAstep>>ReadStatusOnCatalogServer(){PAdemand = "('assm','mean',(0.2,'sec'))"}
ReadStatusOnCatalogServer
CreateNewOrderOnDeliveryOrderProcess
ReadStatusOnDeliveryOrderProcess
BrowseCartOnCustomerProcess
<<PAhost>>
CartServer
{PAschdPolicy = "FIFO"}
<<PAstep>>UpdateStatusOnCartServer(){PAdemand = "('assm','mean',(0.3,'sec'))"}
<<PAstep>>ReadStatusOnCartServer(){PAdemand = "('assm','mean',(0.2,'sec'))"}
ReadStatusOnCartServer
UpdateStatusOnCartServer
DeleteItemOnCustomerProcess
<<PAhost>>
CustomerProcess
{PAschdPolicy = "FIFO"}
<<PAstep>>BrowseCartOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'sec'))"}
<<PAstep>>PlaceOrderOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'sec'))"}
<<PAstep>>BrowseCatalogOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'sec'))"}
<<PAstep>>DeleteItemOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'sec'))"}
<<PAstep>>InsertItemOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'sec'))"}
<<PAstep>>DeliveryOrderOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'ms'))"}
UpdateStatusOnCustomerServer
PlaceOrderOnCustomerProcess
DeliveryOrderOnCustomerProcess
BrowseCatalogOnCustomerProcess
InsertItemOnCustomerProcess
<<PAhost>>
CustomerServer
{PAschdPolicy = "FIFO"}
<<PAstep>>ReadInfoOnCustomerServer(){PAdemand = "('assm','mean',(0.2,'sec'))"}
<<PAstep>>updateStatusOnCustomerServer(){PAdemand = "('assm','mean',(0.3,'sec'))"}
ReadInfoOnCustomerServer

Figure 9: Component Diagram

In Figure 9 we present the UML 2.0 Component Diagram (CD) for the portion of the e-commerce system we consider. This diagram highlights the software components and their required and provided interfaces. The provided interfaces are represented by a circle whereas the required ones are represented by a semicircle.

In general, an interface is composed by a set of operations provided or required by a software component. Here, to simplify the presentation of the parameterization phase, we assume that an uml.Interface represents uml.Operation of the uml.Component. Then each uml.Operation is annotated, according to the UML SPT profile[3], in order to introduce performance aspects of software components. All the values for the execution times of the uml.Operation are assumed (see the *assm* keyword in the tag value), as our intent is to carry on a performance analysis at the software architecture level when such information is not available, whereas it can be guessed by the designers on the basis of their experience or on the basis of previous releases of the same software system.

The considered (sub)system is composed by six components. Four of them (OrderServer, CatalogServer, CartServer, CustomerServer) interact with the corresponding databases by easying the insertion, deletion, reading and updating of data. These components allow asynchronous communications, hence all the interfaces they provide contain asynchronous operations. The remaining two components, namely CustomerProcess and DeliveryOrderProcess, provide the GUI to interact with the system, the back end process that manages all her/his request (as made through the GUI) and the business process to manage the order delivery, respectively. These components

[3] Note that we *extend* the <<PAstep>> stereotype with the *Operation metaclass* in order to allow the annotation of the component Operation.

interact asynchronously with the DB servers and synchronously among them. Thus the interfaces they provide respect such properties.

Finally, since the component diagram in the figure only describes the portion of the e-commerce system considered, it does not contains the components and the interfaces that are not involved in the use cases considered. For example the component that allows the Supplier to delete or insert an item in the catalogue is missing, as well as the corresponding CatalogServer provided interfaces that manage such operations on the corresponding database.

5.3.1 Sap˙One annotations

The Component Diagram (CD) is annotated with parameters related to the components, as **each component is transformed into a Queueing Network server center**. Example paramters are: the kind of center (i.e. waiting or delay), and the scheduling policy that it uses to extract requests from its queue (e.g. FIFO, IS etc).

Stereotype Syntax	Apply Stereotype on (UML metaclasses)	Semantic
<<PAhost>> {PAschdPolicy='type'}	On the uml.**Component**	If a component is extended with this stereotype its queue has a *type.* If a component is not extended, then it corresponds to a delay resource without queue and with an infinite number of instances.

<<PAstep>>
{ PAdemand = ('assm','mean',(*value,'unit* time'))}
XOR
{ PAdelay = ('assm','mean',(*value,'unit* time'))}
	On the component uml.**Operation** implementing the homonymous provided uml.**Interface**.	The execution time to satisfy each services request. PAdemand must to be used for active components whereas PAdelay must be used for passive ones. PAdemand and PAdelay tags are mutually exclusive because a component can't be active and passive at the same time.

Table 2: Sap•One Stereotypes used on CD.

Each software component is annotated with the **<<PAhost>> stereotype** , and the methodology works under the hypothesis that every component is allocated on a different active resource.

The tag value *PAschdPolicy* denotes the scheduling policy of the component queue.

The **«PAstep» stereotype** is associated to the component operation implementing the homonymous interface: both tag values *PAdemand* (for active components) and *PAdelay* (for passive components) model the component execution time to satisfy a request exposed by the interface.

In particular the syntax to use within the CD is summarized in Table 2.

5.3.2 PRIMA-UML annotations

No PRIMA-UML annotations are required on the Component Diagram.

5.4 Sequence Diagram

Interaction diagrams are a common mechanism for describing systems, at varying levels of detail, in a way comprehensible by both software designers and potential end users and stakeholders of the system. Typically the interaction diagrams do not describe the whole system behavior but selected execution traces. There are normally other legal and possible interactions that are not contained within the drawn diagrams. Originally, **interaction diagrams represent system objects and how they interact**. In the new conception (UML 2.0), such diagrams describe the system by means of participants (that can be system modules at a different level of abstraction such as subsystem or component instances, objects and so on) and how they interacts each other to accomplish a task. In the UML terminology, interactions are units of behavior that focus on the observable exchange of information between elements (such as objects) in form of messages. UML 2.0 defines four different interaction diagrams: sequence diagram, communication diagram, interaction overview diagram and timing diagram. Among these diagrams both **Sap•One and PRIMAUML methodologies** use Sequence Diagrams: they specify **messages that are exchanged between component instances** (whose types are depicted on Component Diagram) that are in charge to provide the system functionalities (i.e. the use cases depicted on Use Case Diagram).

As example scenario the **PlaceOrder sequence diagram** is presented in Figure 10. The Sequence Diagram is composed by several (nested) combined fragments and their operands. In particular, it shows an example of two alternative behaviors specified by means of an alt operator with two InteractionOperand. A Customer asks for an order placing through his own CustomerInterface and, first of all, the CustomerProcess reads the cart status on the CartServer. If the cart is empty the order cannot be placed (see the second interaction operand in the alt combined fragment). Otherwise the CustomerProcess proceeds in collecting the customer information (such as for example his mail address) and creates a new order in the Order DB. Finally it empties the customer cart. In this scenario it is assumed that all the information the customer must provide to place an order is collected before and the PlaceOrder request corresponds to the final submission from the customer. Moreover, the payment procedure is encompassed in a different use case. For example, if the customer decided to pay by a credit card, the Payment&Invoice use case (see Figure 8) will be in charge to manage the bank transfer.

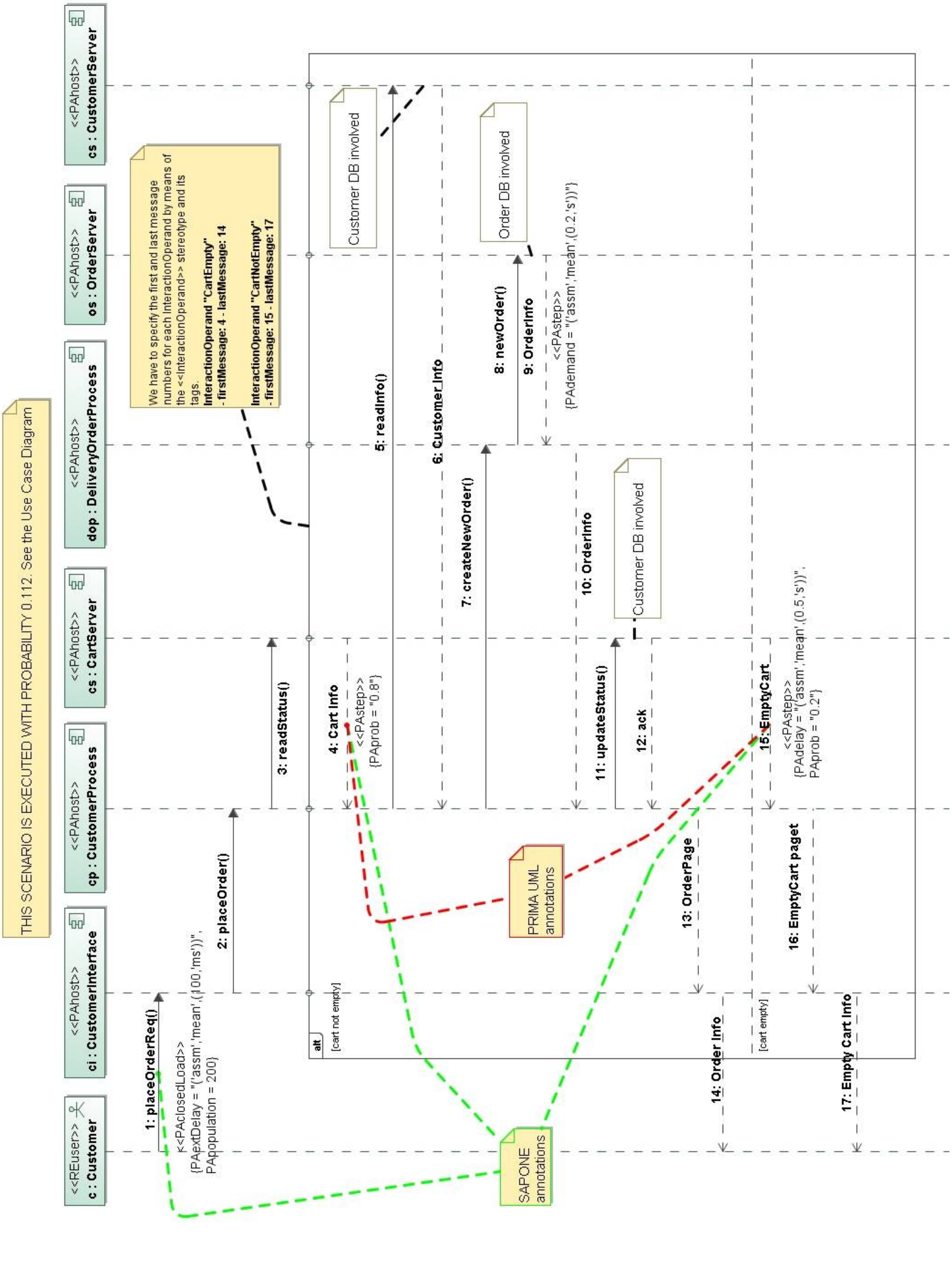

THIS SCENARIO IS EXECUTED WITH PROBABILITY 0.112. See the Use Case Diagram
<<REuser>> c : Customer
<<PAhost>> ci : CustomerInterface
<<PAhost>> cp : CustomerProcess
<<PAhost>> cs : CartServer
<<PAhost>> dop : DeliveryOrderProcess
<<PAhost>> os : OrderServer
<<PAhost>> cs : CustomerServer
We have to specify the first and last message numbers for each InteractionOperand by means of the <<InteractionOperand>> stereotype and its tags.
InteractionOperand "CartEmpty"
- firstMessage: 4 - lastMessage: 14
InteractionOperand "CartNotEmpty"
- firstMessage: 15 - lastMessage: 17
1: placeOrderReq()
<<PAclosedLoad>>
{PAextDelay = "('assm','mean',(100,'ms'))",
PApopulation = 200}
2: placeOrder()
3: readStatus()
alt
[cart not empty]
4: Cart Info
<<PAstep>>
{PAprob = "0.8"}
5: readInfo()
Customer DB involved
6: Customer Info
7: createNewOrder()
8: newOrder()
9: OrderInfo
<<PAstep>>
{PAdemand = "('assm','mean',(0.2,'s'))"}
Order DB involved
10: OrderInfo
11: updateStatus()
Customer DB involved
12: ack
13: OrderPage
14: Order Info
PRIMA UML annotations
SAPONE annotations
[cart empty]
15: EmptyCart
<<PAstep>>
{PAdelay = "('assm','mean',(0.5,'s'))",
PAprob = "0.2"}
16: EmptyCart paget
17: Empty Cart Info

Figure 10: the Sequence Diagram

5.4.1 Sap˙One annotations

The **Sequence Diagram (SD)** must be enriched with the information in the following table.

Stereotype Syntax	Apply Stereotype on (UML metaclasses)	Semantic
<<PAclosedLoad>> {PApopulation=population quantity, PAextDelay=(‘assm', 'mean' ,(30,’ms’))}	On the first uml.**Message** of the Sequence Diagram	This stereotype denotes the closed workload of the scenario depicted on the Sequence Diagram, in particular its population and the think time.
<<PAstep>> {PAprob = value}	On the first uml.**Message** used on the two uml.**InteractionOperand** **(**i.e. *if* and *then* operands**)**of the **Alt** uml.**CombinedFragment**	It denotes the probability to activate the message in the uml.**CombinedFragment**. With probability 1-value the control is given to the first message following the alt compartment.

Table 3: Sap•One Stereotypes used on SD.

The **stereotype «PAclosedLoad»** specifies the closed workload intensity and it is used to annotate the first message of every Sequence Diagram, where the used tag values are: *PApopulation* (i.e. number of user) and *PAextDelay* (i.e. required time to execute a request). Possible alternative behaviors in the UML interaction fragments are annotated with the **<<PAstep>> stereotype.** The *PAprob* tag value specifies the execution probability of each behavior.

5.4.2 PRIMA-UML annotations

The Sequence Diagram must be enriched with the information in the following table.

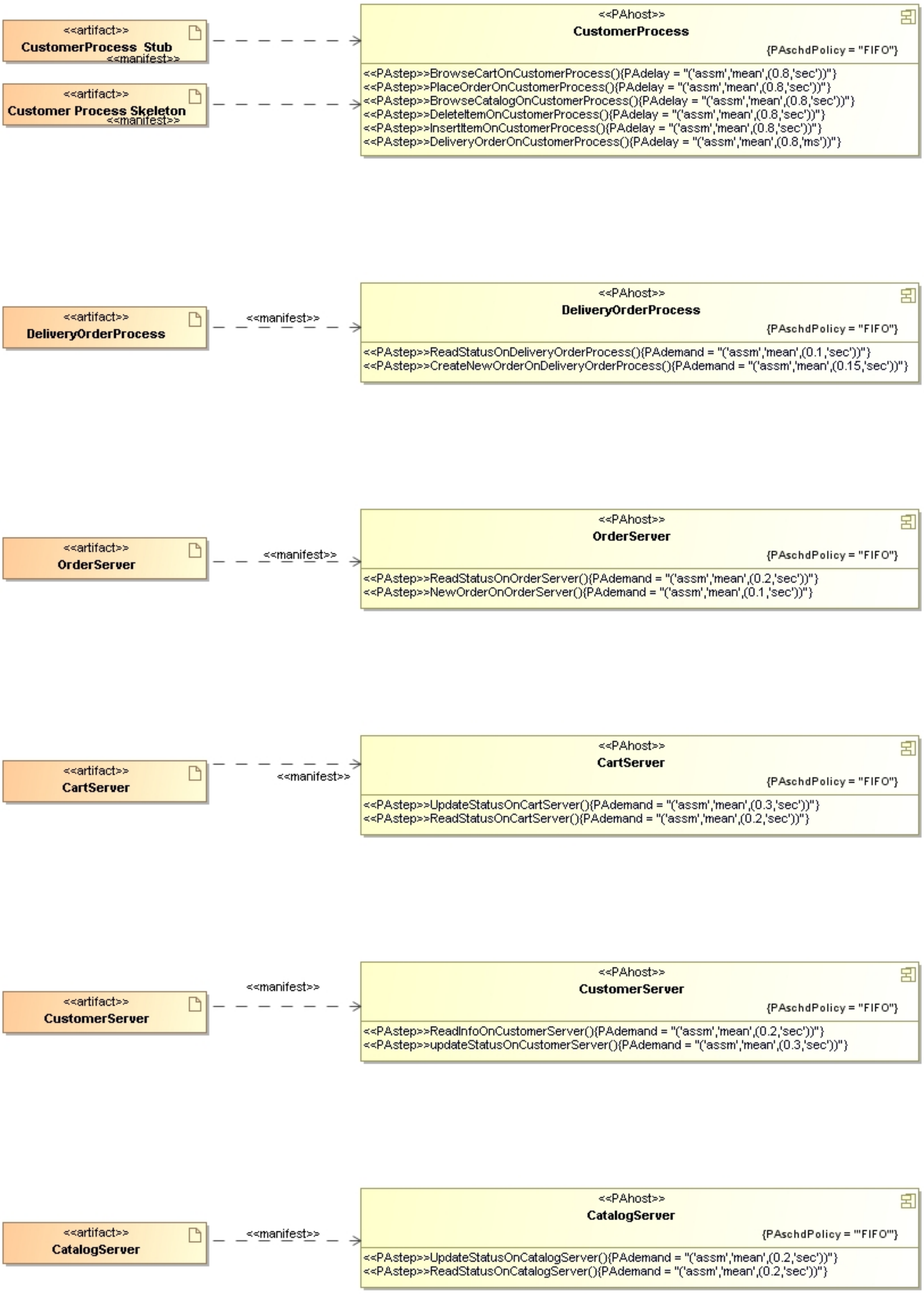
Stereotype Syntax	Apply Stereotype on (UML metaclasses)	Semantic
<<PAstep>> {PAprob = value}	On the first uml.**Message** used on the two uml.**InteractionOperand** **(**i.e. *if* and *then* operands**)**of the **Alt** uml.**CombinedFragment**	It denotes the probability to activate the message in the uml.**CombinedFragment**. With probability 1-value the control is given to the first message following the alt compartment.
<<PAstep>> {PArepetitionFactor = value}	On the first uml.**Message** exchanged in the **Loop** uml.CombinedFragment	It denotes the number of the iterations in the loop fragment.

Table 4: PRIMA-UML Stereotypes used on SD.

It is worth to note that the <<PAstep>> stereotype is applied on the first message of the Alt uml.CombinedFragment in the same manner as the Sap•One methodology.

5.5 Deployment Diagram

A **Deployment Diagram** shows the configuration of run-time processing elements and the software components that live on them. It is a graph where nodes (i.e., the processing elements, uml.Node) are connected by communication path (i.e. uml.CommunicationPath). **Nodes can contain artifacts (uml.Artifact) that manifest components** (see Figure 11). Therefore a DD shows the mapping of components on processing elements (see Figure 12).



<<artifact>>
CustomerProcess Stub
<<manifest>>
<<artifact>>
Customer Process Skeleton
<<manifest>>
<<PAhost>>
CustomerProcess
{PAschdPolicy = "FIFO"}
<<PAstep>>BrowseCartOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'sec'))"}
<<PAstep>>PlaceOrderOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'sec'))"}
<<PAstep>>BrowseCatalogOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'sec'))"}
<<PAstep>>DeleteItemOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'sec'))"}
<<PAstep>>InsertItemOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'sec'))"}
<<PAstep>>DeliveryOrderOnCustomerProcess(){PAdelay = "('assm','mean',(0.8,'ms'))"}
<<artifact>>
DeliveryOrderProcess
<<manifest>>
<<PAhost>>
DeliveryOrderProcess
{PAschdPolicy = "FIFO"}
<<PAstep>>ReadStatusOnDeliveryOrderProcess(){PAdemand = "('assm','mean',(0.1,'sec'))"}
<<PAstep>>CreateNewOrderOnDeliveryOrderProcess(){PAdemand = "('assm','mean',(0.15,'sec'))"}
<<artifact>>
OrderServer
<<manifest>>
<<PAhost>>
OrderServer
{PAschdPolicy = "FIFO"}
<<PAstep>>ReadStatusOnOrderServer(){PAdemand = "('assm','mean',(0.2,'sec'))"}
<<PAstep>>NewOrderOnOrderServer(){PAdemand = "('assm','mean',(0.1,'sec'))"}
<<artifact>>
CartServer
<<manifest>>
<<PAhost>>
CartServer
{PAschdPolicy = "FIFO"}
<<PAstep>>UpdateStatusOnCartServer(){PAdemand = "('assm','mean',(0.3,'sec'))"}
<<PAstep>>ReadStatusOnCartServer(){PAdemand = "('assm','mean',(0.2,'sec'))"}
<<artifact>>
CustomerServer
<<manifest>>
<<PAhost>>
CustomerServer
{PAschdPolicy = "FIFO"}
<<PAstep>>ReadInfoOnCustomerServer(){PAdemand = "('assm','mean',(0.2,'sec'))"}
<<PAstep>>updateStatusOnCustomerServer(){PAdemand = "('assm','mean',(0.3,'sec'))"}
<<artifact>>
CatalogServer
<<manifest>>
<<PAhost>>
CatalogServer
{PAschdPolicy = "'FIFO'"}
<<PAstep>>UpdateStatusOnCatalogServer(){PAdemand = "('assm','mean',(0.2,'sec'))"}
<<PAstep>>ReadStatusOnCatalogServer(){PAdemand = "('assm','mean',(0.2,'sec'))"}

Figure 11: The artifacts that manifest each component

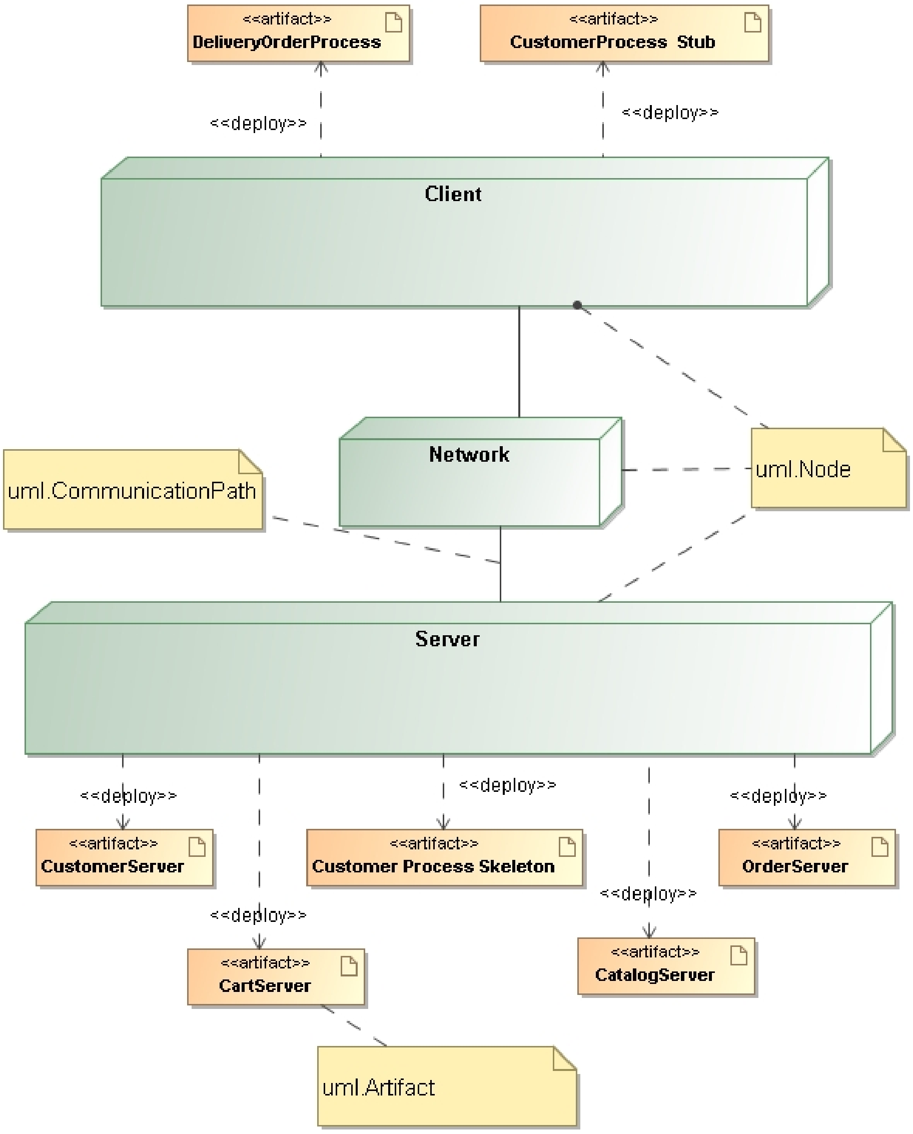


Figure 12: Deployment Diagram

Figure 11 shows the uml.Artifacts that manifests uml.Components (see the <<manifest>> stereotyped dependency between the uml.Component and its own uml.Artifacts), whereas Figure 12 shows uml.Artifacts deployed on uml.Nodes.

5.5.1 Sap•One annotations

No Sap•One annotations are required on the Deployment Diagram.

5.5.2 PRIMA-UML annotations

The QNM topology (see **Errore. L'origine riferimento non è stata trovata.**) is derived from the annotated DD: the interacting component instances depicted on the SDs (as uml.Lifelines) are deployed (by means of uml.Artifacts, see Figure 11) on a node equipped with a suitable set of hardware resources. Such hardware resources are shown on the deployment diagram in Figure 13.

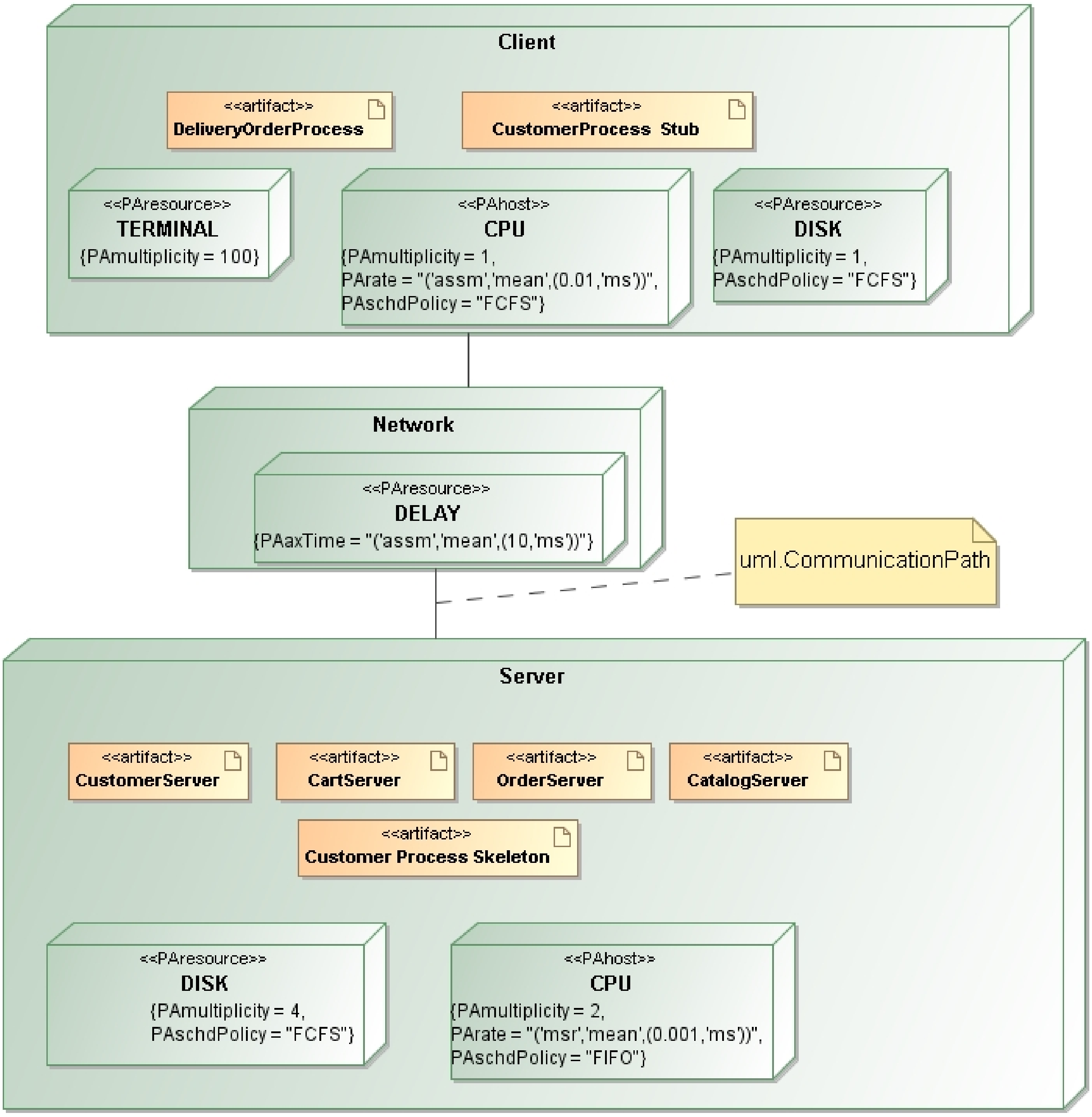


Figure 13: Annotated Deployment Diagram for the PRIMA-UML methodology.

Hardware resources are distinguished in active and passive ones by means the <<PAhost>> and <<PAresource>> stereotypes, respectively [3]. The PRIMA-UML methodology makes use of three different kind of resources over a uml.Node:

- CPU, as the name itself suggests, is a (active <<PAhost>>) resource representing CPUs;
- DISK that represents a storage (passive[4] <<PAresource>>) resource;
- TERMINAL[5] that represents users/jobs that access the container node.

Table 5 specifies the additional information that has to be specified for such kind of resources.

[4] A **processing resource** (i.e. PAhost) is a device which has processing steps allocated to it. A **passive resource** (i.e. PAresource) represents a resource protected by an access mechanism (e.g., a semaphore), which is accessed during the execution of an operation.

[5] CPU, DISK and TERMINAL are reserved words.

Stereotype Syntax	Apply Stereotype on (UML metaclasses)	Semantic
<<PAhost>> **CPU** {PAschdPolicy = value, PArate = value, PAmultiplicity = value}	On **uml.Node**.	A **processing resource** is a device which has processing steps allocated to it. *PAmultiplicity* defines how many instances of the CPU resource are available on the containing uml.Node.
<<PAresource>> **DISK** {PAmultiplicity = value}	On **uml.Node**.	A **passive resource** represents a resource protected by an access mechanism (e.g., a semaphore), which is accessed during the execution of an operation. *PAmultiplicity* defines how many instances of the DISK resource are available on the containing uml.Node.
<<PAresource>> **TERMINAL** {PAmultiplicity = value}	On **uml.Node**.	It represents users/jobs that access the containing node. *PAmultiplicity* defines how many users/jobs access the containing uml.Node.
<<PAresource>> **DELAY** {PAaxTime = value}	On **uml.Node**.	It represents a network (i.e. LAN, WAN) connecting two Node. *PAaxTime* specifies the delay introduced by the network communication.

Table 5: PRIMA-UML Stereotypes used on DD.

5.6 Generating Analysis Models

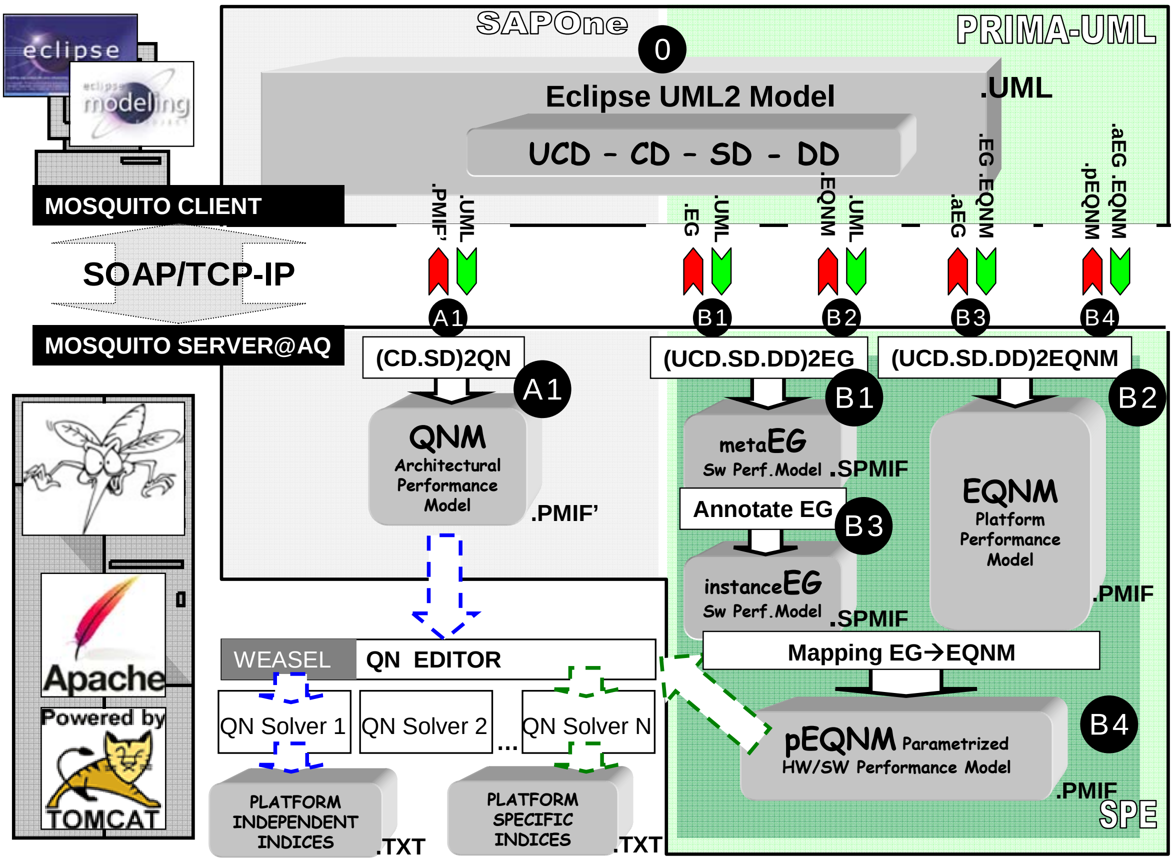
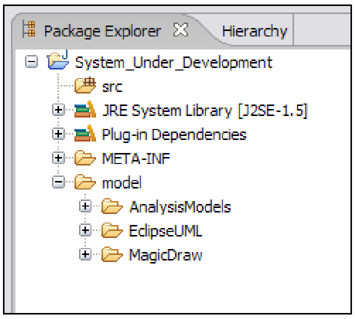


Figure 14: Analysis Models generation steps.

This section shows how to generate all the analysis models (step Ax and Bx, see Figure 14):

1. Open your Eclipse Platform;
2. Create a Simple Project. You can also use the Empty EMF Project that is better organized.

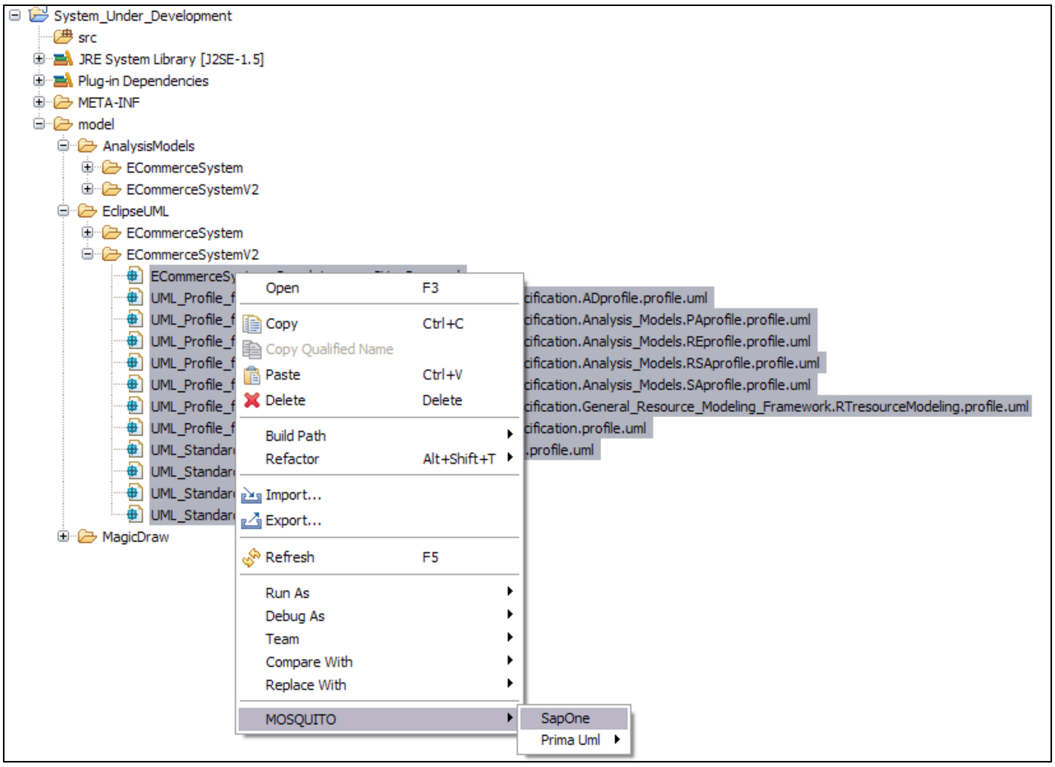


3. You can organize your models as (i) EclipseUML2-compliant modeling tool format (e.g. MagicDraw®) (ii) Eclipse UML model exported from the previous tool, (iii) Analysis Models

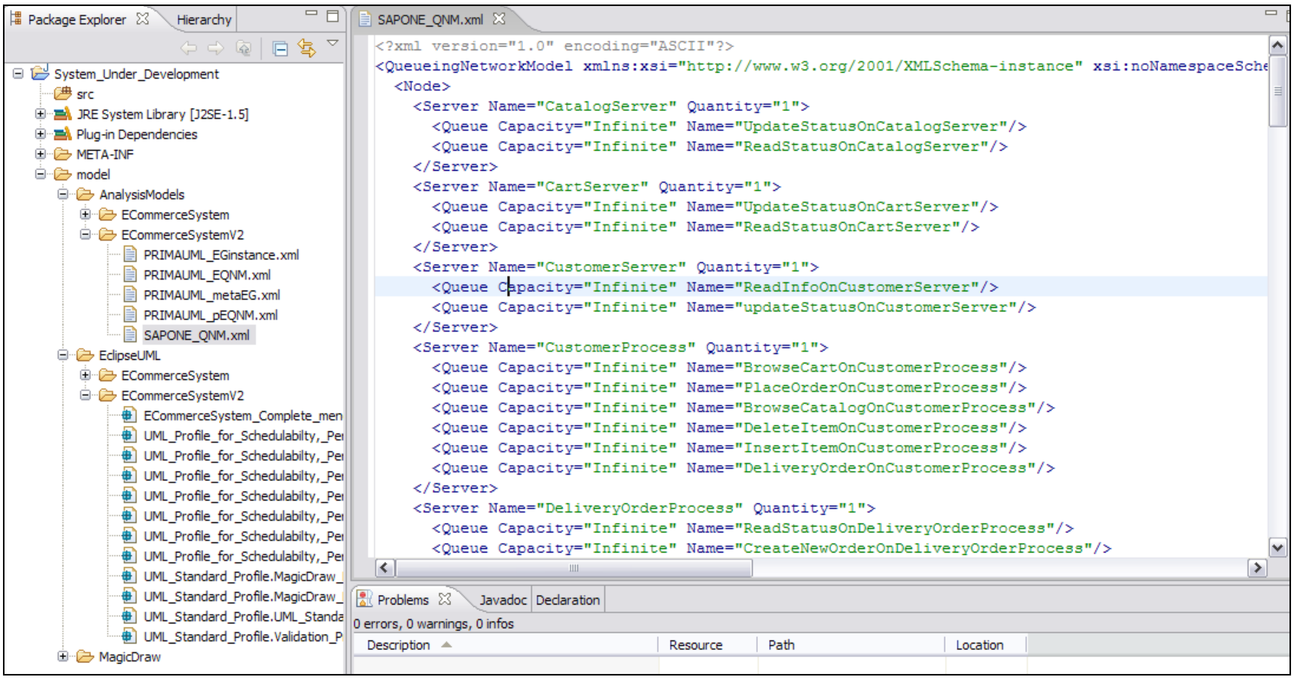
5.6.1 Sap•One QNM

This section shows how to generate the QNM model (step A1, see Figure 14):

4. Select **all** the *.uml file within the EclipseUML folder;
5. Right click to show the contextual menu. Select MOSQUITO>Sap•One. You need a working internet connection to invoke the MOSQUITO Web Service at University of L'Aquila.



6. If the source model (*.uml) is correct you obtain the target analysis model, the QNM (a valid PMIF' xml model).
7. You can visually check the QNM on the Eclipse XML Editor;



Package Explorer
Hierarchy
System_Under_Development
src
JRE System Library [J2SE-1.5]
Plug-in Dependencies
META-INF
model
AnalysisModels
ECommerceSystem
ECommerceSystemV2
PRIMAUML_EGinstance.xml
PRIMAUML_EQNM.xml
PRIMAUML_metaEG.xml
PRIMAUML_pEQNM.xml
SAPONE_QNM.xml
EclipseUML
ECommerceSystem
ECommerceSystemV2
ECommerceSystem_Complete_men
UML_Profile_for_Schedulabilty,_Pei
UML_Profile_for_Schedulabilty,_Pei
UML_Profile_for_Schedulabilty,_Pei
UML_Profile_for_Schedulabilty,_Pei
UML_Profile_for_Schedulabilty,_Pei
UML_Profile_for_Schedulabilty,_Pei
UML_Profile_for_Schedulabilty,_Pei
UML_Standard_Profile.MagicDraw_
UML_Standard_Profile.MagicDraw_
UML_Standard_Profile.UML_Standa
UML_Standard_Profile.Validation_P
MagicDraw
SAPONE_QNM.xml
Problems
Javadoc
Declaration
Description
Resource
Path
Location

```
<?xml version="1.0" encoding="ASCII"?>
<QueueingNetworkModel xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSche
  <Node>
    <Server Name="CatalogServer" Quantity="1">
      <Queue Capacity="Infinite" Name="UpdateStatusOnCatalogServer"/>
      <Queue Capacity="Infinite" Name="ReadStatusOnCatalogServer"/>
    </Server>
    <Server Name="CartServer" Quantity="1">
      <Queue Capacity="Infinite" Name="UpdateStatusOnCartServer"/>
      <Queue Capacity="Infinite" Name="ReadStatusOnCartServer"/>
    </Server>
    <Server Name="CustomerServer" Quantity="1">
      <Queue Capacity="Infinite" Name="ReadInfoOnCustomerServer"/>
      <Queue Capacity="Infinite" Name="updateStatusOnCustomerServer"/>
    </Server>
    <Server Name="CustomerProcess" Quantity="1">
      <Queue Capacity="Infinite" Name="BrowseCartOnCustomerProcess"/>
      <Queue Capacity="Infinite" Name="PlaceOrderOnCustomerProcess"/>
      <Queue Capacity="Infinite" Name="BrowseCatalogOnCustomerProcess"/>
      <Queue Capacity="Infinite" Name="DeleteItemOnCustomerProcess"/>
      <Queue Capacity="Infinite" Name="InsertItemOnCustomerProcess"/>
      <Queue Capacity="Infinite" Name="DeliveryOrderOnCustomerProcess"/>
    </Server>
    <Server Name="DeliveryOrderProcess" Quantity="1">
      <Queue Capacity="Infinite" Name="ReadStatusOnDeliveryOrderProcess"/>
      <Queue Capacity="Infinite" Name="CreateNewOrderOnDeliveryOrderProcess"/>
```

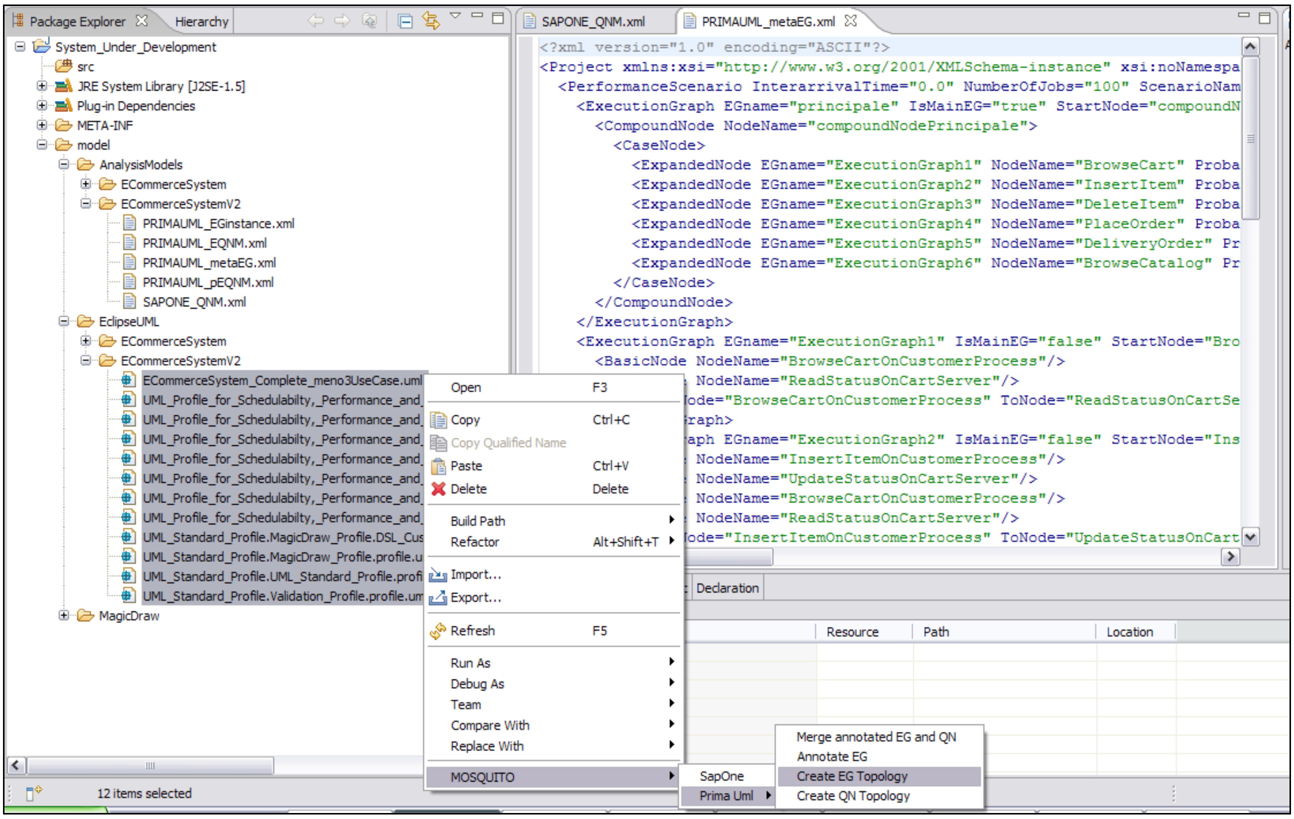
0 errors, 0 warnings, 0 infos

8. Save the QNM in Analysis Model.

5.6.2 PRIMA UML Meta EG

This section shows how to generate the QNM model (step B1, see Figure 14):

9. Select **all** the *.uml file within the EclipseUML folder;
10. Right click to show the contextual menu. Select MOSQUITO>PRIMAUML>create EG Topology[6]. You need a working internet connection to invoke the MOSQUITO Web Service at University of L'Aquila.
11. If the source model (*.uml) is correct you obtain the target analysis model, the meta EG (a valid SPMIF xml model).
12. You can visually check the meta EG on the Eclipse XML Editor;
13. Save the meta EG in Analysis Model.



```
<?xml version="1.0" encoding="ASCII"?>
<Project xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespa
  <PerformanceScenario InterarrivalTime="0.0" NumberOfJobs="100" ScenarioNam
    <ExecutionGraph EGname="principale" IsMainEG="true" StartNode="compoundN
      <CompoundNode NodeName="compoundNodePrincipale">
        <CaseNode>
          <ExpandedNode EGname="ExecutionGraph1" NodeName="BrowseCart" Proba
          <ExpandedNode EGname="ExecutionGraph2" NodeName="InsertItem" Proba
          <ExpandedNode EGname="ExecutionGraph3" NodeName="DeleteItem" Proba
          <ExpandedNode EGname="ExecutionGraph4" NodeName="PlaceOrder" Proba
          <ExpandedNode EGname="ExecutionGraph5" NodeName="DeliveryOrder" Pr
          <ExpandedNode EGname="ExecutionGraph6" NodeName="BrowseCatalog" Pr
        </CaseNode>
      </CompoundNode>
    </ExecutionGraph>
    <ExecutionGraph EGname="ExecutionGraph1" IsMainEG="false" StartNode="Bro
      <BasicNode NodeName="BrowseCartOnCustomerProcess"/>
                 NodeName="ReadStatusOnCartServer"/>
               ode="BrowseCartOnCustomerProcess" ToNode="ReadStatusOnCartSe
               raph>
               aph EGname="ExecutionGraph2" IsMainEG="false" StartNode="Ins
                 NodeName="InsertItemOnCustomerProcess"/>
                 NodeName="UpdateStatusOnCartServer"/>
                 NodeName="BrowseCartOnCustomerProcess"/>
                 NodeName="ReadStatusOnCartServer"/>
               ode="InsertItemOnCustomerProcess" ToNode="UpdateStatusOnCart
```

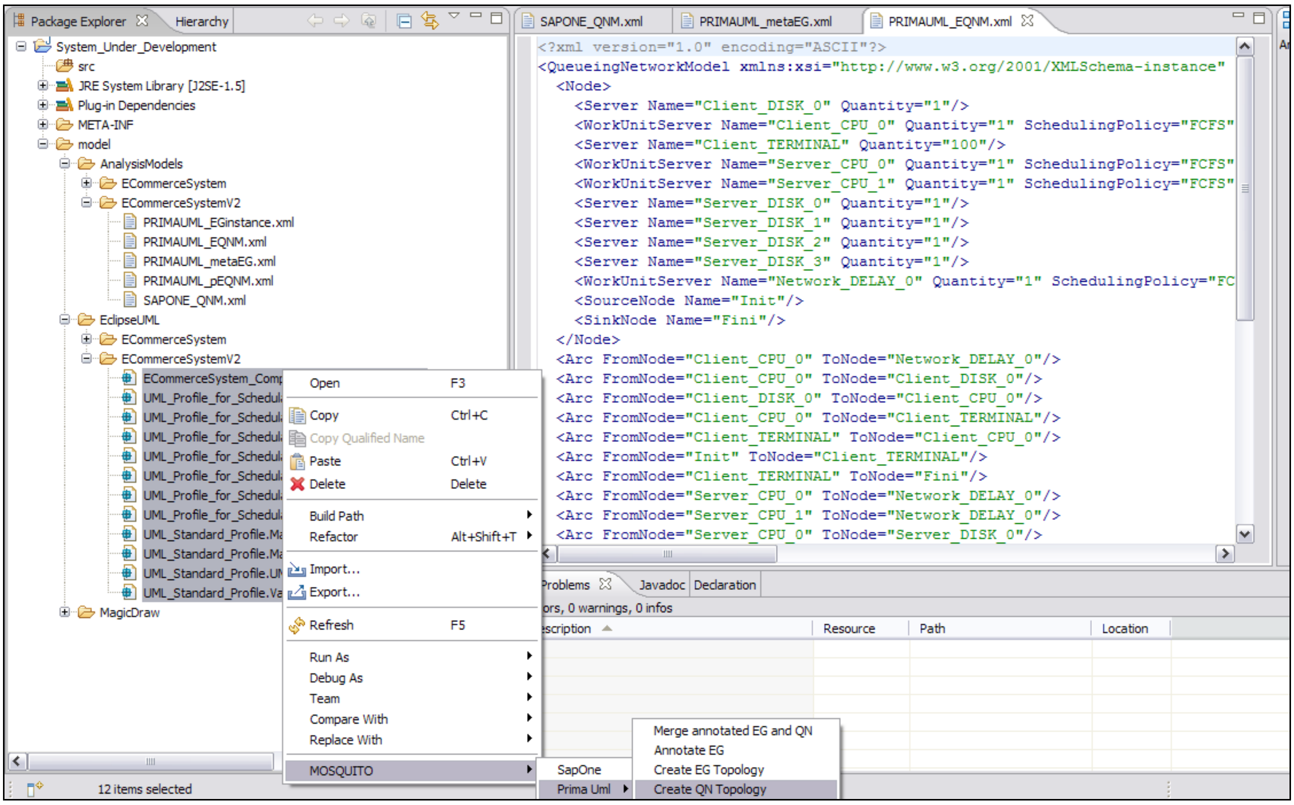
Package Explorer
Hierarchy
System_Under_Development
src
JRE System Library [J2SE-1.5]
Plug-in Dependencies
META-INF
model
AnalysisModels
ECommerceSystem
ECommerceSystemV2
PRIMAUML_EGinstance.xml
PRIMAUML_EQNM.xml
PRIMAUML_metaEG.xml
PRIMAUML_pEQNM.xml
SAPONE_QNM.xml
EclipseUML
ECommerceSystem
ECommerceSystemV2
ECommerceSystem_Complete_meno3UseCase.uml
UML_Profile_for_Schedulabilty,_Performance_and_
UML_Profile_for_Schedulabilty,_Performance_and_
UML_Profile_for_Schedulabilty,_Performance_and_
UML_Profile_for_Schedulabilty,_Performance_and_
UML_Profile_for_Schedulabilty,_Performance_and_
UML_Profile_for_Schedulabilty,_Performance_and_
UML_Profile_for_Schedulabilty,_Performance_and_
UML_Standard_Profile.MagicDraw_Profile.DSL_Cus
UML_Standard_Profile.MagicDraw_Profile.profile.u
UML_Standard_Profile.UML_Standard_Profile.profi
UML_Standard_Profile.Validation_Profile.profile.um
MagicDraw
12 items selected
SAPONE_QNM.xml
PRIMAUML_metaEG.xml
Open F3
Copy Ctrl+C
Copy Qualified Name
Paste Ctrl+V
Delete Delete
Build Path
Refactor Alt+Shift+T
Import...
Export...
Refresh F5
Run As
Debug As
Team
Compare With
Replace With
MOSQUITO
SapOne
Prima Uml
Merge annotated EG and QN
Annotate EG
Create EG Topology
Create QN Topology
Declaration
Resource
Path
Location

5.6.3 PRIMA UML EQNM

This section shows how to generate the EQNM model (step B2, see Figure 14):

14. Select **all** the *.uml file within the EclipseUML folder;
15. Right click to show the contextual menu. Select MOSQUITO>PRIMAUML>create QN Topology. You need a working internet connection to invoke the MOSQUITO Web Service at University of L'Aquila.
16. If the source model (*.uml) is correct you obtain the target analysis model, the EQNM (a valid PMIF xml model).
17. You can visually check the EQNM on the Eclipse XML Editor;
18. Save the EQNM in Analysis Model.

[6] A meta Execution Graph is also called EG Topology because it contains only a graph of node representing operation invocations and arcs connecting them.

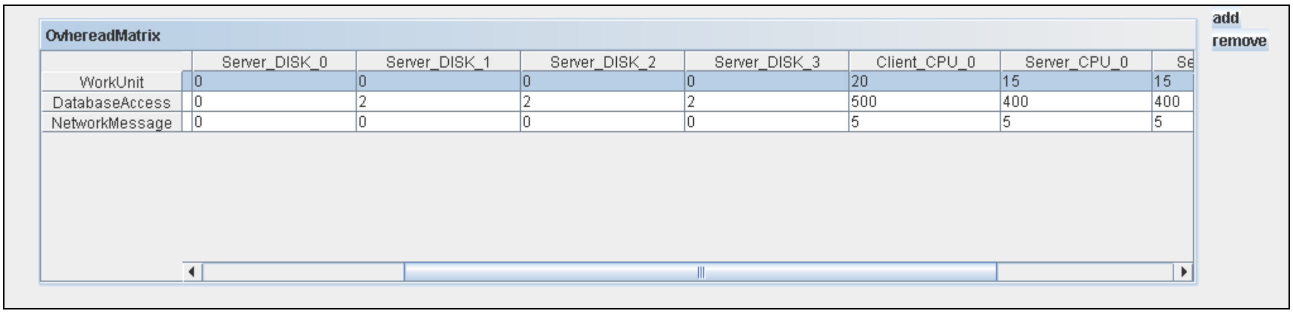


```
<?xml version="1.0" encoding="ASCII"?>
<QueueingNetworkModel xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  <Node>
    <Server Name="Client_DISK_0" Quantity="1"/>
    <WorkUnitServer Name="Client_CPU_0" Quantity="1" SchedulingPolicy="FCFS"
    <Server Name="Client_TERMINAL" Quantity="100"/>
    <WorkUnitServer Name="Server_CPU_0" Quantity="1" SchedulingPolicy="FCFS"
    <WorkUnitServer Name="Server_CPU_1" Quantity="1" SchedulingPolicy="FCFS"
    <Server Name="Server_DISK_0" Quantity="1"/>
    <Server Name="Server_DISK_1" Quantity="1"/>
    <Server Name="Server_DISK_2" Quantity="1"/>
    <Server Name="Server_DISK_3" Quantity="1"/>
    <WorkUnitServer Name="Network_DELAY_0" Quantity="1" SchedulingPolicy="FC
    <SourceNode Name="Init"/>
    <SinkNode Name="Fini"/>
  </Node>
  <Arc FromNode="Client_CPU_0" ToNode="Network_DELAY_0"/>
  <Arc FromNode="Client_CPU_0" ToNode="Client_DISK_0"/>
  <Arc FromNode="Client_DISK_0" ToNode="Client_CPU_0"/>
  <Arc FromNode="Client_CPU_0" ToNode="Client_TERMINAL"/>
  <Arc FromNode="Client_TERMINAL" ToNode="Client_CPU_0"/>
  <Arc FromNode="Init" ToNode="Client_TERMINAL"/>
  <Arc FromNode="Client_TERMINAL" ToNode="Fini"/>
  <Arc FromNode="Server_CPU_0" ToNode="Network_DELAY_0"/>
  <Arc FromNode="Server_CPU_1" ToNode="Network_DELAY_0"/>
  <Arc FromNode="Server_CPU_0" ToNode="Server_DISK_0"/>
```

5.6.4 PRIMA UML EG instance

This section shows how to generate the EG instance (step B3, see Figure 14):

19. **Select the meta EG and the EQNM from the Analysis Model folder;**
20. Right click to show the contextual menu. Select MOSQUITO>PRIMAUML>Annotate EG. You need a working internet connection to invoke the MOSQUITO Web Service at University of L'Aquila.
21. If the source models (the EQNM and the meta EG) are correct a wizard will be shown to fill in information about software and hardware resource consumption by means of an *overheadmatrix*.

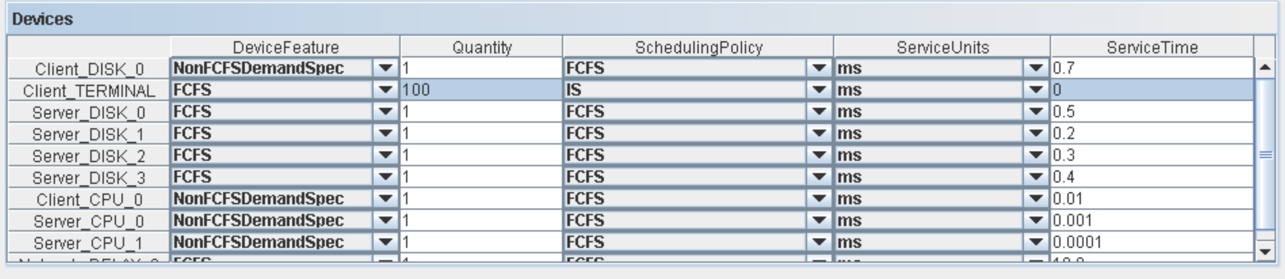


OvhereadMatrix

	Server_DISK_0	Server_DISK_1	Server_DISK_2	Server_DISK_3	Client_CPU_0	Server_CPU_0	Se
WorkUnit	0	0	0	0	20	15	15
DatabaseAccess	0	2	2	2	500	400	400
NetworkMessage	0	0	0	0	5	5	5

The rows represent the software resource available. You can or remove them pressing the Add and Remove buttons, respectively. Once the software resources have been defined you need to fill in the columns. Each column represent an hardware resource: they have been specified on the Deployment Diagram (static view of the UML source model) using the CPU DISK TERMINAL and DELAY "special" inner uml.Nodes. The number of columns depends also by the "PAmultiplicity" attribute assigned to the aforementioned node. If you

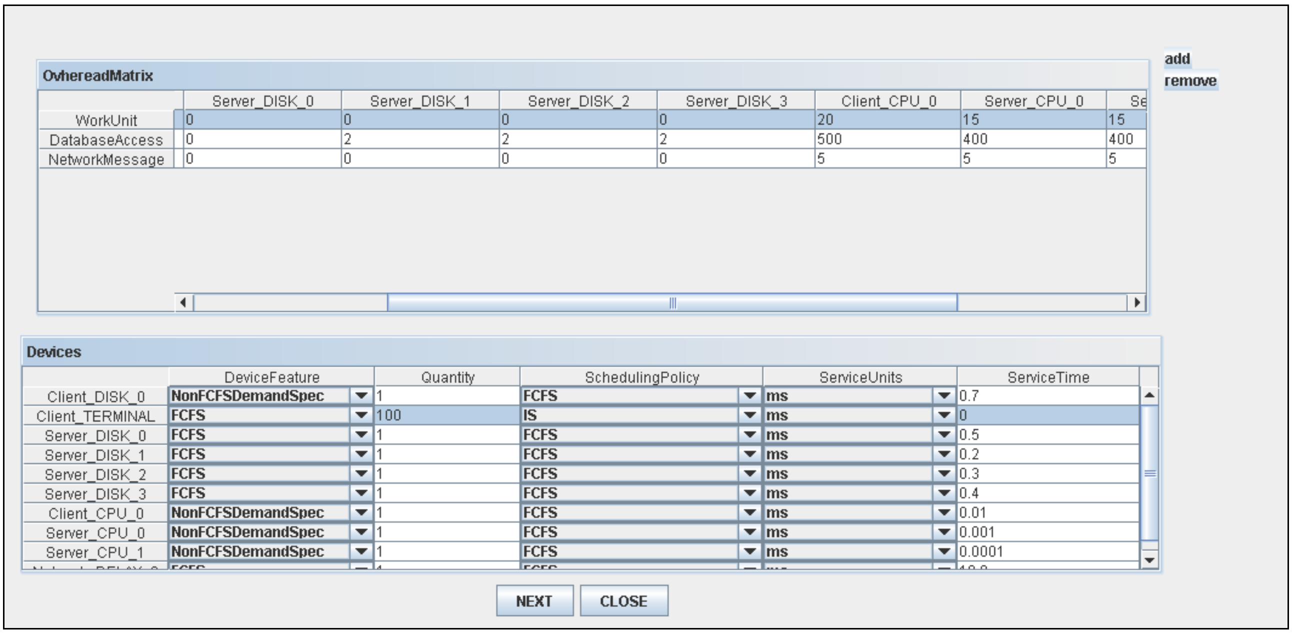
specify “PAmultiplicity = 3” for the DISK node within a Server node you obtain Server_DISK_x where x varies from 0 to 2 (as in the shown overhead matrix).
The cell value represent a “consumption link” between software and hardware resources: (WorkUnit,Client_CPU_0) = 20 means that one workunit corresponds to 20 units of time at hardware level.
On the second matrix here below, the user can check if the additional information introduced on th UML Model have been suitably reported. The “ServiceTime” column contains the “multiplier” for the cell value of overhead matrix.
Then *(WorkUnit,Client_CPU_0) = 20 * (Client_CPU_0, ServiceTime)* corresponds to the amount (in terms of “time”) of hardware resource required by one “WorkUnit” of software resource.



Devices

	DeviceFeature	Quantity	SchedulingPolicy	ServiceUnits	ServiceTime
Client_DISK_0	NonFCFSDemandSpec	1	FCFS	ms	0.7
Client_TERMINAL	FCFS	100	IS	ms	0
Server_DISK_0	FCFS	1	FCFS	ms	0.5
Server_DISK_1	FCFS	1	FCFS	ms	0.2
Server_DISK_2	FCFS	1	FCFS	ms	0.3
Server_DISK_3	FCFS	1	FCFS	ms	0.4
Client_CPU_0	NonFCFSDemandSpec	1	FCFS	ms	0.01
Server_CPU_0	NonFCFSDemandSpec	1	FCFS	ms	0.001
Server_CPU_1	NonFCFSDemandSpec	1	FCFS	ms	0.0001

22. Click the Next Button;



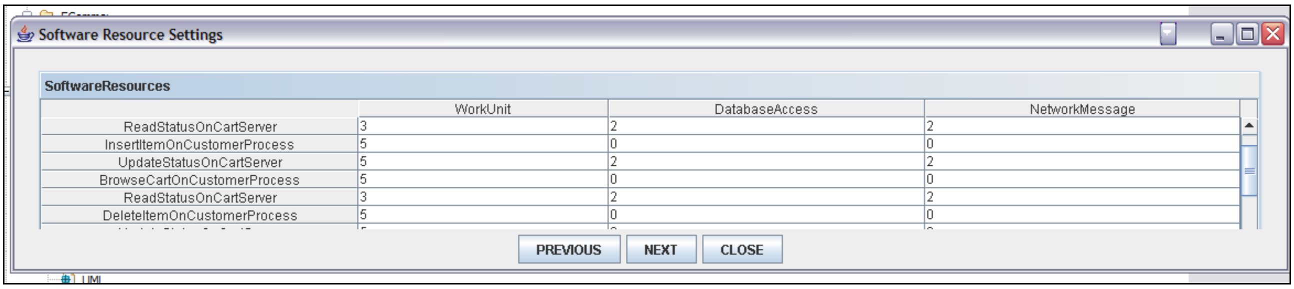
OvhereadMatrix

	Server_DISK_0	Server_DISK_1	Server_DISK_2	Server_DISK_3	Client_CPU_0	Server_CPU_0	Se
WorkUnit	0	0	0	0	20	15	15
DatabaseAccess	0	2	2	2	500	400	400
NetworkMessage	0	0	0	0	5	5	5

Devices

	DeviceFeature	Quantity	SchedulingPolicy	ServiceUnits	ServiceTime
Client_DISK_0	NonFCFSDemandSpec	1	FCFS	ms	0.7
Client_TERMINAL	FCFS	100	IS	ms	0
Server_DISK_0	FCFS	1	FCFS	ms	0.5
Server_DISK_1	FCFS	1	FCFS	ms	0.2
Server_DISK_2	FCFS	1	FCFS	ms	0.3
Server_DISK_3	FCFS	1	FCFS	ms	0.4
Client_CPU_0	NonFCFSDemandSpec	1	FCFS	ms	0.01
Server_CPU_0	NonFCFSDemandSpec	1	FCFS	ms	0.001
Server_CPU_1	NonFCFSDemandSpec	1	FCFS	ms	0.0001

23. Fill in the Software Resource Demand Vector for each metaEG node that represents a system operation invocation. Obviously you can “guess” some values and try different solutions creating different EG instance model. You have to fill in all the fields.



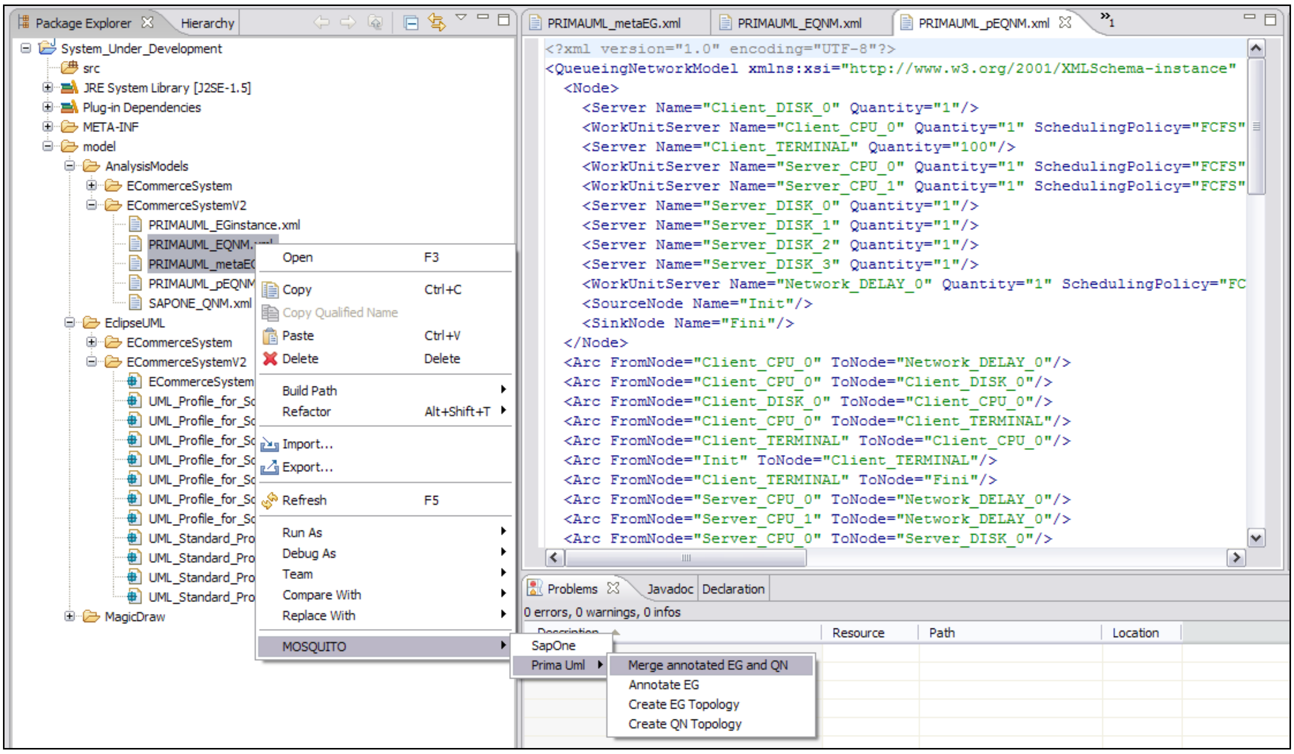
	WorkUnit	DatabaseAccess	NetworkMessage
ReadStatusOnCartServer	3	2	2
InsertItemOnCustomerProcess	5	0	0
UpdateStatusOnCartServer	5	2	2
BrowseCartOnCustomerProcess	5	0	0
ReadStatusOnCartServer	3	2	2
DeleteItemOnCustomerProcess	5	0	0

24. Press the Next button and the resulting EG instance model will be displayed on the Eclipse XML editor;
25. Save the EG instance in Analysis Model.

5.6.5 PRIMA UML parameterized EQNM

This section shows how to generate the parameterized EQNM model (step B4, see Figure 14):

26. Select the EQNM model obtained at step B2 and the EG instance obtained at step B3;
27. Right click to show the contextual menu. Select MOSQUITO>PRIMAUML>Merge Annotated EG and QN. You need a working internet connection to invoke the MOSQUITO Web Service at University of L'Aquila.
28. If the source models are correct you obtain the target analysis model, the parameterized EQNM (a valid PMIF xml model).
29. You can visually check the parameterized EQNM on the Eclipse XML Editor;
30. Save the parameterized EQNM in Analysis Model.



```
<?xml version="1.0" encoding="UTF-8"?>
<QueueingNetworkModel xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  <Node>
    <Server Name="Client_DISK_0" Quantity="1"/>
    <WorkUnitServer Name="Client_CPU_0" Quantity="1" SchedulingPolicy="FCFS"
    <Server Name="Client_TERMINAL" Quantity="100"/>
    <WorkUnitServer Name="Server_CPU_0" Quantity="1" SchedulingPolicy="FCFS"
    <WorkUnitServer Name="Server_CPU_1" Quantity="1" SchedulingPolicy="FCFS"
    <Server Name="Server_DISK_0" Quantity="1"/>
    <Server Name="Server_DISK_1" Quantity="1"/>
    <Server Name="Server_DISK_2" Quantity="1"/>
    <Server Name="Server_DISK_3" Quantity="1"/>
    <WorkUnitServer Name="Network_DELAY_0" Quantity="1" SchedulingPolicy="FC
    <SourceNode Name="Init"/>
    <SinkNode Name="Fini"/>
  </Node>
  <Arc FromNode="Client_CPU_0" ToNode="Network_DELAY_0"/>
  <Arc FromNode="Client_CPU_0" ToNode="Client_DISK_0"/>
  <Arc FromNode="Client_DISK_0" ToNode="Client_CPU_0"/>
  <Arc FromNode="Client_CPU_0" ToNode="Client_TERMINAL"/>
  <Arc FromNode="Client_TERMINAL" ToNode="Client_CPU_0"/>
  <Arc FromNode="Init" ToNode="Client_TERMINAL"/>
  <Arc FromNode="Client_TERMINAL" ToNode="Fini"/>
  <Arc FromNode="Server_CPU_0" ToNode="Network_DELAY_0"/>
  <Arc FromNode="Server_CPU_1" ToNode="Network_DELAY_0"/>
  <Arc FromNode="Server_CPU_0" ToNode="Server_DISK_0"/>
```

0 errors, 0 warnings, 0 infos

5.6.6 Analysis of Performance Model

The target performance models, Sap•One QNM and PRIMA-UML parameterized EQNM, can be sent to any PMIF' and PMIF compliant QN solver. In Figure 3 we report the WEASEL*MOSQUITO. http://sealabtools.di.univaq.it/SeaLab/MosquitoHome.html.*[6] tool we are developing within the Department of Computer Science at University of L'Aquila.

6 References

[1] A. Di Marco, P. Inverardi "Compositional generation of Software Architecture Performance QN Models". Proc. 4th Working IEEE/IFIP Conference on Software Architecture (WICSA'04)*, 2004.*

[2] A.Di Marco. Model-based Performance Analysis of Software Architectures. PhD thesis, '05.

[3] V. Cortellessa, R.Mirandola "PRIMA-UML: a Performance Validation Incremental Methodology on Early UML Diagrams", Science of Computer Programming , 44 (2002), no.1, pagg.101-129.

[4] OMG, UML Profile, for Schedulability, Performance, and Time, Version 1.1, formal/05-01-02.

[5] C. Smith, L.G.Williams. Performance Solutions, Addison Wesley, 2002.

[6] MOSQUITO. http://sealabtools.di.univaq.it/SeaLab/MosquitoHome.html.

7 Appendix

In this appendix we report details of the methodology mechanisms.

7.1 Queuing Network process creation (SAP·One methodology)

The creation process of the queuing network through the SAP·One methodology can be summarized in two steps:

- *Identification of the service centers and their carachteristics:* A delay or waiting service center is associated to every component of the Component Diagram. An offered service that corresponds, in practice, to every interface of the component, indicates what job classes are managed by each server.
  Service center characteristics (e.g. time service, kind of center and scheduling policy) are defined from the associated tag values.

- *Classes chain and workload definition*: The Sequence Diagrams (with the annotated information) represent the workload intensity, while the net topology is defined analysing the dynamics of communication between components. The idea is to associate a connection in the queuing network from each sender component (i.e. a component that sends a messages in some Sequence Diagrams) to each receiving component. The receiving component will have infinite queue if the interaction is asynchronous, whereas a null queue if synchronous.

SAP·One defines a set of translation rules combined to various architectural patterns corresponding to at interaction fragment of UML Sequence Diagrams. In this way it is possible to generate the complete architectural topology stepwise while parsing the UML diagrams [1].

7.2 Execution Graph creation (PRIMA-UML methodology)

The translation rules used from the PRIMA-UML methodology can be summarized in the following steps.

Estimation of scenarios execution probability:
In Figure 15 an annotated UCD is shown: users and arcs are annotated with weights that lead to compute the probability that each use case is expected to occur. Note that, early in the lifecycle, these weights come out from designer's guesses on the operational profile, whereas later they can be obtained from actual measures.

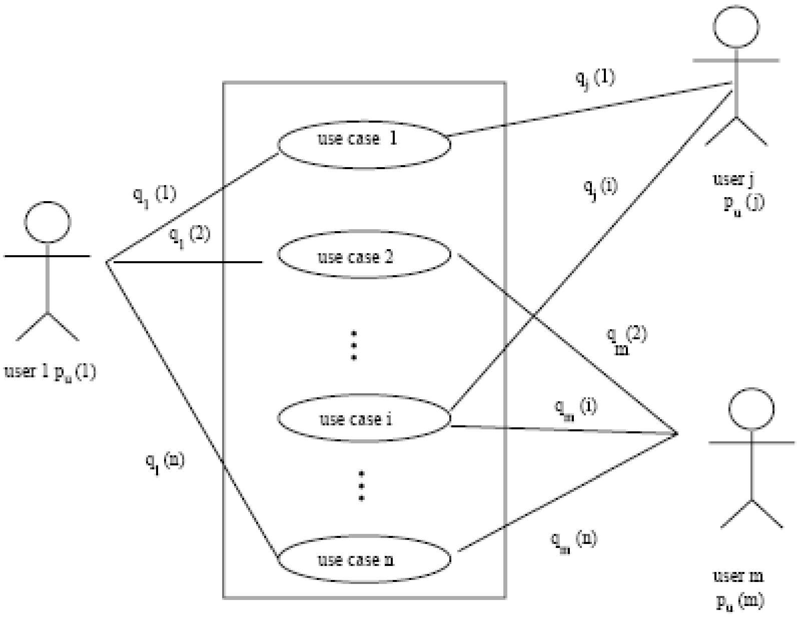


Figure 15: Generically annotated UCD

Let us suppose to have a UCD with *m* types of users and n use cases. Let $p_u(i)$ (*i*=1,…,m) be the *i*th user type probability of usage of the software system (i.e. *<<REuser>> REaccessprob*) . We have that:

$$\sum_{i=1}^{m} p_u(i) = 1$$

Let $q_i(j)$ (*j*=1,…,n) be the probability that the *i*th user makes use of the software system by executing the use case *j* (i.e. *<<REserviceUsage>> REserviceprob*). We have that:

$$\sum_{j=1}^{n} q_i(j) = 1$$

The probability for whatever scenario *j* (described by means of a Sequence Diagram (SD) associated to the UseCase *j*) to be executed is then given by

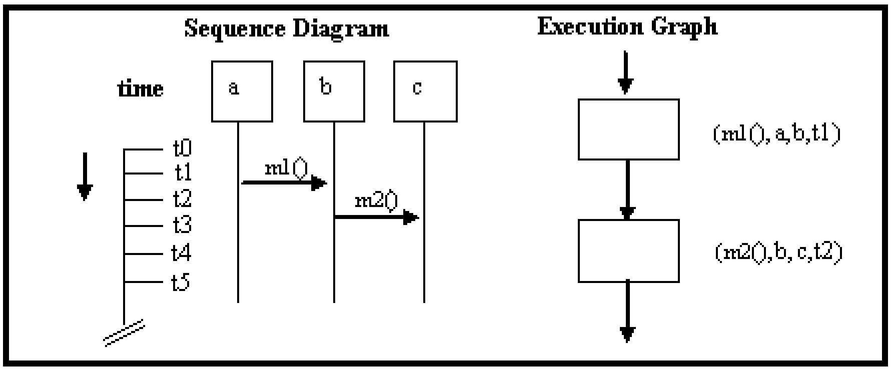
$$P(j) = \sum_{i=1}^{m} p_u(i) q_i(j) = 1$$

This can be equivalently expressed as:

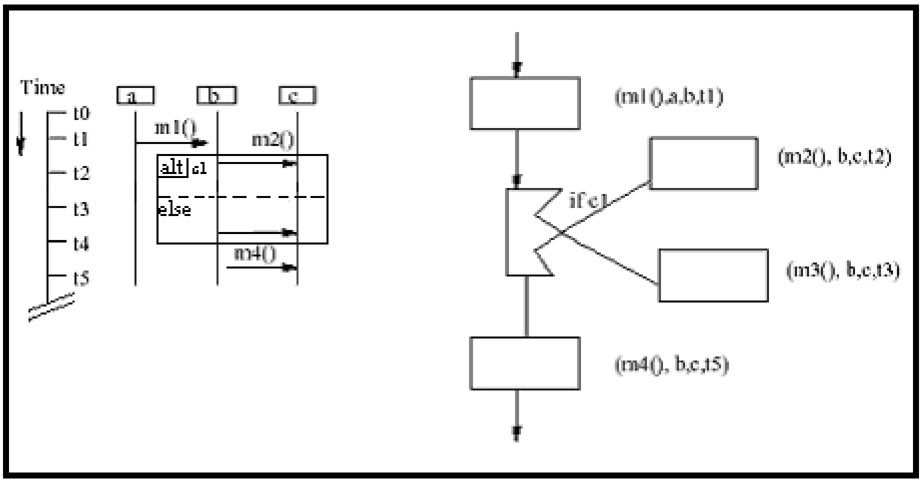
$$REprob_{REservice_j} = \sum_{i=1}^{m} REaccessprob_{REuser_i} \cdot REserviceprob_{REuser_i\ REservice_j} = 1$$

Sequence Diagram processing and meta-Eg building:

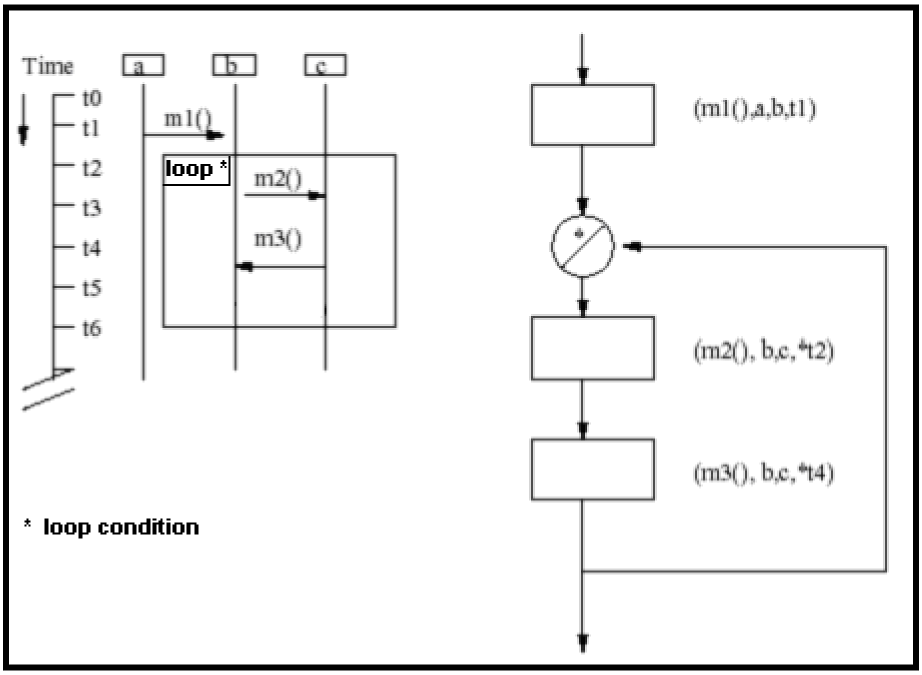
In this step an algorithm is used to transform all the Sequence Diagrams in an Execution Graph that is called a meta-EG [2]. The meta-EG is a platform independent annotated Execution Graph. The idea of the algorithm it is to apply the following translating rules for Sequence Diagram patterns.



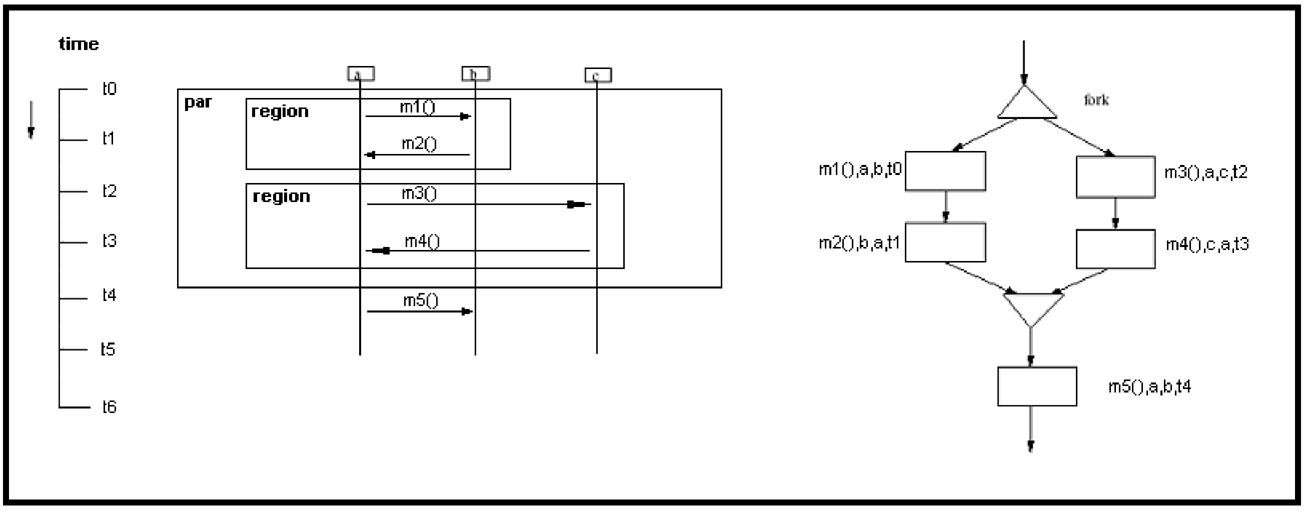
Translation rule for the sequential steps.



Translation rules for the alternative fragmetn.



Translation rule for the loop fragments.



Translation rule for the parallel fragments.

For what concerns Sequence Diagram fragments, the following mapping is adopted.
The Reference operator, corresponding at the key word R*ef*, denotes that a Sequence Diagram includes a defined behaviour in another Sequence Diagram. This is translated so that the queuing network corresponding to the first diagram merges the sub-net corresponding to the second diagram.
The alternative operator, corresponding at the key word *Alt*, denotes the presence, in the diagram, of a choice between two behaviours, or more simply the choice to execute or not a specific behaviour. The methodology translates the operator as a net branching point with probabilities associated to the matching patterns.
The Parallel operator, corresponding at the key word *Par*, denotes two or more different patterns to be executed in parallel. It is translated with a pair of fork/join nodes in the network.

The methodology is able also to translate other operators, as described in [1],that are not yet implemented in MOSQUITO.