Efficiency Requirements in PIM to PSM Transformations

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Abstract. In the paper, we provide extensions for MDA (Model Driven Architecture), taking into consideration efficiency requirements. The scope of the proposition is limited to the PIM (Platform-Independent Model) and the PSM (Platform Specific Model) extension. Efficiency requirements are maximal rates of users requests under which the system has to perform. We extend the PIM to the model containing efficiency requirements. We introduce a PSMSpec (PSM Specification) containing a system architecture, platform, efficiency requirements, and a PSMInst (PSM Instance) defining a deployment of the system. The PIM's functional specification and efficiency requirements are transformed to the PSMSpec's system architecture and efficiency requirements. Finally, efficiency characteristics are estimated and verified against the efficiency requirements, the PSMInst is suggested.

1 Introduction

Efficiency requirements shall be handled during development process from the earliest stages [1]. In order to make it possible, we have to specify the requirements with constraints in quantitative way, provide a transformation of the requirements from specification level to design/deployment level, provide verification of the requirements, and introduce changes to design/deployment based on the requirements verification [1], [2].

In the paper, we introduce handling of efficiency requirements in the development process, by extending the MDA (Model Driven Architecture). The MDA is software development approach, which is based on models and the concept of separation of specification from implementation. The concept is applied by transforming platform-independent models (PIMs) into platform specific models (PSMs), which in result are transformed to a system implementation [3].

In the related papers [2], [4], [5] idea of supporting efficiency requirements using MDD (Model Driven Development), in particular MDA, is introduced. Efficiency requirements are not supported by the MDA [2], but are implemented in the MDA by adding new efficiency models at platform independent, platform specific level and by providing transformations of the efficiency models [2], [4], [5]. The efficiency models are resolved and results are used for architecture/design refactoring, if required [2], [4]. In [5], a necessity of differentiating platforms' performance influence to the overall system performance is discussed, e.g. software and hardware platform separation.

The paper is organized in the following way: in Chapter 2, requirements transformation, extension of PIM and PSMs are discussed, in Chapter 3 we introduce behavior metric and discuss a system's efficiency estimation, an example of Payment System is presented in Chapter 4, and the article is summarized in Chapter 5.

2 Extending MDA

In order to introduce efficiency requirements into the MDA, we have to include into MDA models' efficiency requirements, efficiency constraints, and transformations.

The PIM is platform independent model, which defines a software system's *functional requirements* [3]. We add to the PIM *efficiency requirements*. The *functional specification* contains *actors*, *use cases* definition, and *use cases*' scenarios. The *use cases*' specification are defined by UML sequence diagrams in terms of *«boundary»* and *«logic»* classes or *«entity»* classes [6].

The PIM's *efficiency requirements* and *efficiency constraints* are defined for pairs of an *actor* and an *use case*. We specify an *efficiency requirement* by defining a maximal rate of an *use case*'s scenario executions by an *actor*. The *constraints* on the *requirements* indicate most often executed scenarios of the *use case*. For each possible scenario we define a weight, indicating execution rate. The *efficiency requirements* and *constraints* are expressed using MARTE [7].

The PSM is a platform specific model defining a system architecture [3]. We suggest to introduce two PSMs: *PSMSpec* (PSM Specification) and *PSMInst* (PSM Instance). A *PSMSpec* consists of the *software system architecture*, *deployment specification, platform* within the system is developed*, efficiency requirements*, and *efficiency constraints*, required for a total computation effort calculation introduced in Chapter 3. We define *platform* by UML structural elements [6] and *efficiency constraints*, specifying computational complexity of platform's operations. The *deployment specification* defines system deployment on specification level [6] and *efficiency constraints* [7], i.e. defines possible system deployments, e.g. number of *nodes'* instances, *nodes efficiency constraints*.

The *PSMSpec's efficiency requirements* and *efficiency constraints* are mapped from *efficiency requirements* and the *constraints* defined in *PIM*, expressed in terms of the *software system architecture*. An *efficiency requirement* is defined in context of the *actor* and the *use case* from *PIM's use cases*.

A *PSMInst* is a platform-specific model, which contains an instance of the *PSMSpec's deployment specification* [6] with *efficiency characteristics* of *nodes* [7], i.e. computation power of nodes. The *PSMInst* represents a particular deployment of the system.

The *PIM* is transformed into a *PSMSpec*. Two kind of transformation are performed. The first type is a transformation of the *PIM's functional specification* into *PSMSpec's software system architecture* and *deployment specification*, within a *platform*. The second type is a transformation of the *PIM's efficiency requirements* with *constraints* into *PSMSpec's efficiency requirements* with *constraints*.

The *PSMSpec* is transformed into *PSMInst*. A particular deployment of the system is stored in *PSMInst*. During the transformation, instances are created and configurations of the instances are set. The transformation is made with respect to results of the efficiency assessment introduced in Chapter 3.

3 Efficiency Assessment

Fulfilling the efficiency requirements is necessary to find such a system's configuration, i.e. the *PSMInst*, where *computation power provided* by *node* types is more than the *computation power required* by *node* types for the all system *use cases*. Thereby, we have to: assess a *computation effort* for each *use case*'s scenario for each *node's* type, assess the *required computation power* for all system's *use cases* for each *node* type, and check if it is possible to find the system's configuration which *provided computation power that* is sufficient.

In first step, we assess the *use case*'s *computation effort*. We define the behavior metric, which value is used for assessing *computation effort* of a *use case* implemented within a particular *PSMSpec*. The metric is defined in terms of average number of virtual instructions for each *node* type required to execute a *use case*. We assume that each virtual instruction has similar time of execution on a given *node* type. The metric's argument are: the UML sequence diagram representing scenarios of the *use case* and average lengths of scenarios' input and context arguments. Each *occurrence specification* in a UML sequence diagram, e.g. operation invocation, combined fragments, etc. is mapped to a set of virtual instructions. A value of the metric for a given sequence diagram is a collection, in which for each *node* type, a number of virtual instructions corresponding to elements of the sequence diagram executed on the *node* type is given.

The mapping may differ for different platforms, we use herein Java platform, thereby a virtual instruction corresponds to a Java bytecode instruction [8] [9]. Because the virtual instruction is a bytecode, we are able to compute the metric's values for Java platforms' libraries operations and use the values in use case's metric calculation [9]. We assume herein that for all necessary Java's library operations the metric is computed.

We calculate a value of the metric for a given use case's scenarios and attribute values taking into consideration each *node* type on which the scenarios are executed. We calculate the metric according to the following steps:

1. If a given *operation* or an *use case* has already calculated complexity, return the value, taking into consideration *node* type on which *operation* is executed.
   We assume that the value is already given for *operations* of platform's libraries,
2. If a given *operation* or *use case* is defined by an UML sequence diagram than for each *occurrence specification*, taking into consideration *node* type:
   a. Calculate the metric for all called *operations*, i.e. repeat these steps from the beginning for each operation,
   b. If the *occurrence specification* is not inside any *combined fragment* then add the *occurrence specification* metric's value to the given *operation* or *use case* total complexity,
   c. If the *occurrence specification* is inside alternatives, option *combined fragment* then add the *occurrence specification* metric's value to the given

operation or *use case* total complexity multiplying it by weight attached to appropriate *combined fragment's* operand,

d. If the *occurrence specification* is inside loop *combined fragment* then add the *occurrence specification* complexity to the given *operation* or *use case* total complexity multiplying it by number of loop iterations attached to the loop.

In next step, we have to calculate a *required computation power* per *node* type for all the system's use cases taking into consideration the *efficiency requirements*. We calculate it by summing for all pairs of an *actor* and a *use case*, multiplication of each element of a collection of the *use case* metric's value's by a *use case* execution rate

Finally, we have to find a proper system configuration. For each *node* type in the *PSMSpec's deployment specification, efficiency constraints* on a computational power are set. We check for each *node* type whether it is possible to create a proper number of instance where *computational power provided* is more that *computational power required* . If yes, then the condition is fulfilled, otherwise, we have to modify the system architecture, or change the deployment specification constraints.

4 Payment System Example

We present the Payment System as an example of efficiency handling, which provides a money transfer functionality. We present in the paper one use case with efficiency requirements and constraints, which is the money transfer, see Fig. 1. The efficiency requirement, defined by *«gaWorkloadEvent»* and *pattern* tag, is to provide the use case execution's maximal throughput. Weights of each possible scenario are defined by *«paStep»* and a *weight* tag [7], see Fig. 1.

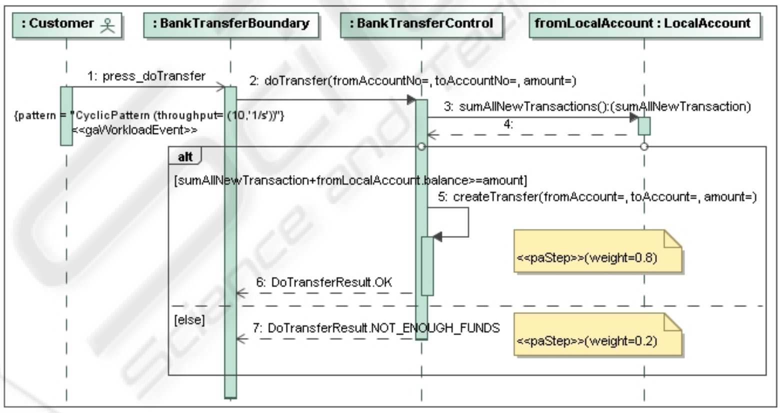
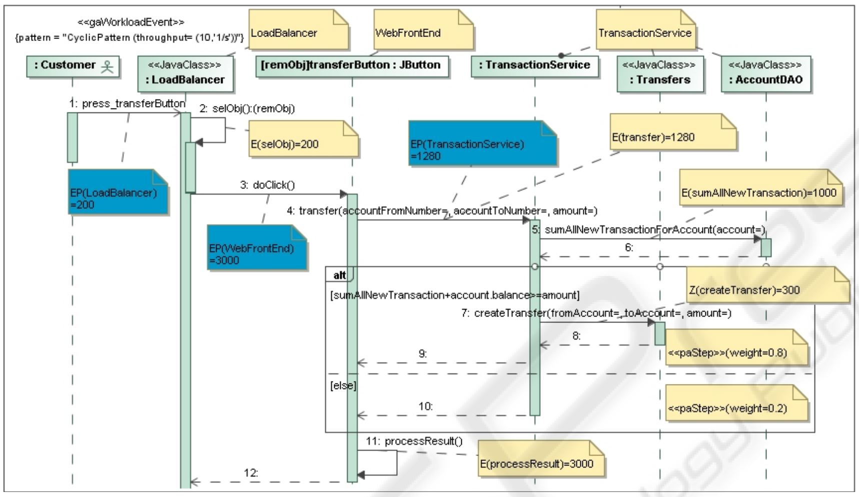

: Customer
: BankTransferBoundary
: BankTransferControl
fromLocalAccount : LocalAccount
1: press_doTransfer
2: doTransfer(fromAccountNo=, toAccountNo=, amount=)
3: sumAllNewTransactions():(sumAllNewTransaction)
4:
{pattern = "CyclicPattern (throughput= (10,'1/s'))"}
<<gaWorkloadEvent>>
alt
[sumAllNewTransaction+fromLocalAccount.balance>=amount]
5: createTransfer(fromAccount=, toAccount=, amount=)
<<paStep>>(weight=0.8)
6: DoTransferResult.OK
[else]
7: DoTransferResult.NOT_ENOUGH_FUNDS
<<paStep>>(weight=0.2)

Fig. 1. PIM - The transfer money use case specification.

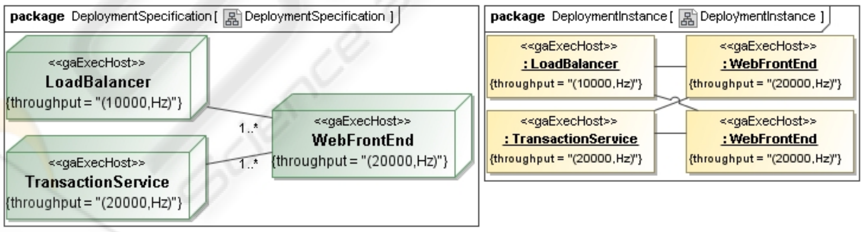
We transfer the PIM's functional requirements to the *PSMSpec*, with respect to client-server architecture pattern, adding the load balancer to provide system scalability [10]. Because of the space limit, we do not present the platform's model in this paper. We present only transformation results in Fig. 2 and Fig. 3: i.e. the sequence diagram of the implementation of *use case*, and deployment diagram with types of *nodes* etc. The Fig. 2 and Fig. 3 already contain efficiency requirements and constraints, however, none of them are added during the *PIM's* functional requirements transformation. The deployment specification diagram is annotated by *efficiency characteristics* of *nodes*, using *«gaExecHost» throughput* tag, see *DeploymentSpecification* in Fig. 3. Next *PIM's efficiency requirement*s and *constraints* are mapped from the *PIM* to the *PSMSpec* with respect to the system's architecture, see Fig. 2.



<<gaWorkloadEvent>>
{pattern = "CyclicPattern (throughput= (10,'1/s'))"}
LoadBalancer
WebFrontEnd
TransactionService
: Customer
<<JavaClass>> : LoadBalancer
[remObj]transferButton : JButton
: TransactionService
<<JavaClass>> : Transfers
<<JavaClass>> : AccountDAO
1: press_transferButton
2: selObj():(remObj)
E(selObj)=200
EP(TransactionService) =1280
E(transfer)=1280
EP(LoadBalancer) =200
3: doClick()
E(sumAllNewTransaction)=1000
4: transfer(accountFromNumber=, accountToNumber=, amount=)
5: sumAllNewTransactionForAccount(account=)
EP(WebFrontEnd) =3000
6:
alt
[sumAllNewTransaction+account.balance>=amount]
Z(createTransfer)=300
7: createTransfer(fromAccount=, toAccount=, amount=)
8:
<<paStep>>(weight=0.8)
9:
[else]
10:
<<paStep>>(weight=0.2)
11: processResult()
E(processResult)=3000
12:

Fig. 2. PSMSpec - The transfer money use case realization.

We assess a *computation effort* of the money transfer *use case*. Each *lifeLine*'s *instance* on Fig. 2 is linked with *comment* pointing out a *node* type. The sequence diagram on Fig. 2, contains the behavior metric's values for *operations*, specified by *E(methodName)*. A *computation effort* per a *node* type for the *use case* is specified by *EP(nodeName)*. These values were calculated with respect to the steps introduced in Chapter 3.



package DeploymentSpecification [DeploymentSpecification]
<<gaExecHost>> LoadBalancer {throughput = "(10000,Hz)"}
1..*
<<gaExecHost>> WebFrontEnd {throughput = "(20000,Hz)"}
1..*
<<gaExecHost>> TransactionService {throughput = "(20000,Hz)"}
package DeploymentInstance [DeploymentInstance]
<<gaExecHost>> : LoadBalancer {throughput = "(10000,Hz)"}
<<gaExecHost>> : WebFrontEnd {throughput = "(20000,Hz)"}
<<gaExecHost>> : TransactionService {throughput = "(20000,Hz)"}
<<gaExecHost>> : WebFrontEnd {throughput = "(20000,Hz)"}

Fig. 3 . PSMSpec deployment specification and PSMInst deployment instance.

We assess the *required computation power*, taking into consideration the efficiency requirement and the results are: *RCP(LoadBalancer)=2000[1/s], RCP(WebFrontEnd)= 30000/n[1/s]* and *RCP(TransactionService)=12800[1/s]*. In next step, we have to find such number of *nodes* instances to fulfill the efficiency requirements. Taking into consideration the *PSMSpec's* deployment specification

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efficiency characteristics, we generate a *PSMInst*, see *deployment instance* on Fig. 3. Sum of nodes' provided computation power for a given type is less than the required computation power for the node type, thereby the efficiency requirements is fulfilled.

5 Conclusions

We provide the MDA models and transformation extensions for handling efficiency requirements in the MDA. The *PIM* is characterized by efficiency requirements and constraints, the *PSMSpec* contains a *software system architecture*, a *deployment specification* and the *efficiency requirements*, and the *PSMInst* represent a instance of the *deployment specification*. In the paper, we provide the *efficiency estimation*, using the behavior metric and illustrate the method with an example.

We only consider the efficiency requirements for the system throughput, however, time constraints are another type of the efficiency requirements to be investigated. We also consider only an "average case", though we should also be able to consider worst case, etc. In the future, it would be advisable to take into consideration several platforms types, e.g. Java, .Net, etc. Moreover, the method provided in the paper does not take into consideration the network communication overhead.

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