EXE-SPEM: Towards Cloud-Based Executable Software Process Models

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Abstract: Executing software processes in the cloud can bring several benefits to software development. In this paper, we discuss the benefits and considerations of cloud-based software processes. EXE-SPEM is our extension of the Software and Systems Process Engineering (SPEM2.0) Meta-model to support creating cloud-based executable software process models. Since SPEM2.0 is a visual modelling language, we introduce an XML notation meta-model and mapping rules from EXE-SPEM to this notation which can be executed in a workflow engine. We demonstrate our approach by modelling an example software process using EXE-SPEM and mapping it to the XML notation.

1 INTRODUCTION

The Model Driven Engineering (MDE) vision is based on putting higher emphasis on models to increase both abstraction level and automation. This brings several benefits such as: reduced development cost, increased quality and reduction of maintenance costs. In the context of software processes, modelling software processes have been influenced by two major groups: a) a group of tool developers interested in process automation (focusing on models for machines). And b) a group that is interested in modelling software processes to understand and improve them (focusing on models for humans) (Mnch et al., 2012).

The Software and Systems Process Engineering Meta-model (SPEM2.0) (OMG, 2008) became an Object Management Group (OMG) standard for software process modelling. However, SPEM2.0 lacks support for model execution and fits in the "models for humans" category. Such languages have been made for process documentation and exchange (Bendraou et al., 2006).

Today, machine-executable models are crucial as companies are seeking increased automation in their software processes. Increased automation means faster development and less cost.

The rise of cloud computing has changed the way software is consumed and delivered. It is also changing the way software is developed with development tools and environments moving to the cloud (e.g. Codenvy [1], Jazz [2]). As a result, gradually -but surely- the entire software development process will be taking place in the cloud in a "as a Service" fashion (e.g. (Schmidberger and Schmidberger, 2012)). Executing software processes in the cloud will bring several benefits such as saving resources (money, time and effort) and increasing the development speed. However, there are issues that need to be considered such as confidentiality and privacy of artefacts and processes, and utilization of elastic cloud resources.

To support software process models execution in the cloud, we introduce EXE-SPEM which is an extension of the SPEM2.0 meta-model to enable capturing the information needed for cloud-based software process execution. Since SPEM2.0 is a visual (non-executable) language, we also introduce an executable XML notation that can be executed in a workflow engine. We define the rules for model transformation between EXE-SPEM and the executable XML notation.

This paper is structured as follows, Section 2 provides a brief background on model driven engineering, cloud and SPEM2.0 enactment. Section 3 discusses the potential of having cloud-based executable software process models. A set of required features for cloud-based software process models is established in Section 4. Section 5 introduces EXE-SPEM and Section 6 introduces the XML notation. Sec-

[1]https://codenvy.com/
[2]https://jazz.net/

tion 7 provides a demonstrating example of a software development process modelled in EXE-SPEM and mapped to an executable XML model. Finally, conclusions are discussed in Section 8.

2 BACKGROUND

In this section, we present background information and discussion about the potentials and challenges of Model Driven Engineering (Section 2.1). The concepts of Software and Systems Process Engineering Meta-model (SPEM2.0) are briefly presented (Section 2.2). Related work on SPEM2.0 enactment is reviewed (Section 2.3). Finally, cloud computing and its service and deployment models are described (Section 2.4).

2.1 Model Driven Engineering (MDE)

Today, software systems are more complex than ever. They consist of large number of subsystems or components possibly written in several programming languages and run on different platforms. Over the years, the complexity of software systems kept growing and the development paradigms kept evolving to address this continuous growth of complexity. However, as Fred Brooks put it (Brooks, 1987): "There is no silver bullet" as he argues that all what new methods can do is to eliminate accidental difficulties in software development but essential difficulties are inherent and will continue to exist.

The evolution of development paradigms has focused on increasing the level of abstraction and automation in software development to enable developers to focus on the core business logic. And this is the aim of Model Driven Engineering (MDE). The concept of MDE is to use models for abstraction of program specification. These models can then be transformed into an executable format which leads to automation. MDE is centred around two enabling technologies (Schmidt, 2006):

- Domain Specific Languages (DSLs): which are modelling languages defined to capture models for a particular domain such as: avionics or financial services. DSLs are better than general purpose languages as the latter fail to capture the essential details of all domains.
- Model Transformation and code generation: models can be transformed between different modelling languages in order to provide platform independence and interoperability. In addition, code for a specific platform can be generated from the models which reduces the cost and time-to-market and increases the quality of the overall system (Azoff, 2008). The generated code ideally should be of good quality and conform to the best practice of the target platform (depending on the quality of the code generator).

One of the popular MDE approaches is the Object Management Group (OMG) standard: Model Driven Architecture (MDA) (OMG, 2003). MDA was driven by the diversity of systems and programming languages and frameworks which led to various compatibility and interoperability issues (Haan, 2008b). As the standard document states: "We have to agree to coexist by translation, by agreeing on models and how to translate between them" (OMG, 2003).

As a result of the increased automation and abstraction, MDE brings in several benefits including: faster development cycles, more flexibility towards platform and staff changes, reduced development and maintenance costs and increased quality. However, MDE still faces some challenges which restrict its wide industrial adoption. Tooling support for MDE approaches is weak compared to the tooling support of current programming languages. This is because the big vendors are not backing MDE tools (Azoff, 2008). In addition, developers tend to like coding more than modelling and this hinders their acceptance of MDE approaches. Furthermore, undertaking MDE projects comes with several risks. Using a general purpose language or having too many domain specific languages for modelling is one of the main risks as it may lead to badly formed models (Haan, 2008a). Some MDE approaches like MDA form just a part of the development life-cycle which means companies would need to spare extra effort/cost to support the rest of the life-cycle (Azoff, 2008). In the context of software processes, several software process modelling approaches existed (e.g. Rule-based (Peuschel and Schäfer, 1992), Petri-net based (Emmerich and Gruhn, 1996) and Programming language-based (Conradi et al., 1992)). Today, there are standards for modelling software processes such as: SPEM2.0 (OMG, 2008), Essence (OMG, 2014) and ISO/IEC 24744 (ISO, 2014).

2.2 SPEM2.0

SPEM2.0 was developed by the Object Management Group (OMG) for defining software and system development processes and their components. With the aim of accommodating large range of development methods and processes, SPEM2.0 was designed to be generic without adding domain-specific elements to its core structure. SPEM2.0 is defined as an MOFbased meta-model and a UML 2 profile (OMG, 2008). It is based on the concept of interaction between *Roles* that perform *Activities* which consume (and produce) *Work Products* (Combemale et al., 2006). SPEM2.0 is structured into seven meta-model packages which contain its modelling elements.

2.3 SPEM2.0 Enactment

One of the problems with SPEM2.0 is its lack of explicit enactment support. In section 16 of its standard (OMG, 2008), it is stated that there are two common ways for enacting SPEM2.0 process: a) mapping the process model into project plans and enact them using project planning tools. And b) mapping the process model to a business flow or execution language then enact it in a workflow engine.

As a result of the lack of enactment support, several researchers have proposed different approaches and extensions to support process enactment. In (Yuan et al., 2006), the authors propose mapping rules to map SPEM2.0 models into XML Process Description Language (XPDL) which then can be enacted in XPDL-based engines. In (Portela et al., 2012), authors propose xSPIDER_ML (a software process enactment language based on SPEM 2.0 concepts). Although xSPIDER_ML is supported with a modelling tool and an enactment environment, the notion of enactment is limited to process monitoring since developers are supposed to perform their tasks off-line and report their progress to the enactment environment. The authors in (Ellner et al., 2010) introduce eSPEM which is a SPEM extension to allow describing fine-grained behaviour models that facilitate process enactment. They implement a distributed process execution environment (Ellner et al., 2011) based on the Foundational subset for Executable UML Models (FUML [3]) standard with emphasis on supporting the ability to share process state on different nodes, suspend and resume process execution, interact with humans, and adapt to different organizations. However, the notion of process enactment in that execution environment also assumes that developers carry out their tasks outside the execution environment and return control back to it once they finish. There are SPEM2.0 extensions which address specific domains' needs. For instance, S-TunExSPEM (Gallina et al., 2014) is allow modelling, simulation and execution of safety-oriented processes based on safety standards (e.g. DO-178B). To support executability, the authors define mapping rules between S-TunExSPEM and XPDL2.2 (WFMC, 2012).

[3] http://www.omg.org/spec/FUML/

In general, we found that all those extensions have one or more of the following weaknesses:

- They did not have any available tool support.
- Their notion of enactment is limited to monitoring the process while the process itself is performed completely outside the enactment environment.
- They did not have explicit support for cloud-based enactment.

The question about enacting SPEM2.0 processes is yet to be answered (possibly in the next version(s) of the standard). However, to the best of our knowledge, the concept of cloud-based enactment of SPEM2.0 models has not been mentioned in the literature.

2.4 Cloud Computing

Cloud computing is defined as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell and Grance, 2011). There are three cloud service models:

- Infrastructure as a Service (IaaS): computing infrastructure (hardware and network) is provided as a service. This model gives the greatest flexibility to customers as they control the OS, software stacks and some limited networking configurations. On the other hand, this means more maintenance effort from the customer side.
- Platform as a Service (PaaS): this model gives less control and requires less effort from the customer's side. The computing infrastructure, OS and the software stack is managed by the cloud provider. Customers can only deploy applications created using the libraries, tools and programming languages supported by the provider and may not be able to deploy the same application on another PaaS provider.
- Software as a Service (SaaS): providers offer software applications to customers as a service and take control of all the application and software stack as well as the underlying infrastructure. The customer's control in this model is very limited and cannot exceed some specific application settings.

Depending on who has control on the cloud resources, deployment models can be categorized into four types (Mell and Grance, 2011): public, private, hybrid and community clouds. Cloud gained vast popularity due to the benefits it brings. It reduces capital expenditure, operational costs and up-front investments needed by companies to get into the market. Cloud also offer elastic resources that can be scaled up and down on demand. In addition, cloud services are offered on pay-as-you-go model which means customers pay only for what they use.

However, there are also risks associated with cloud computing. The main risk comes from multi-tenancy -where computing resources are shared between multiple tenants-. Multi-tenancy is a core characteristic of cloud which allows for efficient use of resources. But it also impose security risks from potential adversary cloud neighbours. As a result of the security risks, lack of trust and control in the cloud has been one of the main risks for cloud adopters.

3 MOTIVATION

Cloud computing is changing the way software systems are delivered as we are entering the POST-PC era (Maximilien and Campos, 2012; Lawler, 2014). This change is taking place due to the compelling characteristics of the cloud such as: accessibility, availability, elasticity and the pay-as-you-go pricing model. MDE can benefit from these characteristics. Bruneliere et al (Brunelière et al., 2010) proposed the term Modelling as a Service (MaaS) where they highlighted the potential for integrating the MDE and the cloud domains. They argue that cloud's availability would facilitate model execution and evolution by allowing designers to rely on the cloud for infrastructure and deployment. They also argue that model transformation engines and MDE tools' bridges can be made available as an on-demand services in the cloud which would ease interoperability problems. In addition, the cloud accessibility makes it easier to collaborate and have distributed models repository.

Models are the core artefact in MDE. The longer a software artefact remains of value, the greater the return from creating it (Haan, 2008a). Therefore, having an executable model that remains of value throughout the development cycle will have higher return on productivity and quality than modelling for the purpose of documentation or communication only. And with software development moving to the cloud (e.g. project Eclipse Orion [4] -the cloud-based counterpart of the Eclipse IDE-), software process models should be executable in the cloud. For a model to be executable, it means that the model can be passed (either directly or after being transformed) to a process enactment engine which can execute it. Execution in the cloud requires the model to incorporate cloud-specific execution requirements as well as control flow information to guide the execution. These requirements are discussed in Section 4.

[4] https://orionhub.org/

In this paper, we reuse a subset of the SPEM2.0 meta-model and extend it to meet the requirements established in Section 4. We follow a different approach from our previous work (Alajrami et al., 2014) where we defined a custom domain specific language for modelling cloud-based software processes. Researchers have proposed various extensions to SPEM2.0 to support domain specific features (e.g. (Gallina et al., 2014; Ellner et al., 2010)). However, non of those extensions support cloud-based execution of software processes. Reusing the existing process elements from SPEM2.0 saves us from reinventing the wheel. To support executablility, we map the software process models to an XML model. Other executable languages such as: XML Process Definition Language (XPDL) (WFMC, 2012) or Business Process Execution Language (BPEL) (OASIS, 2007) were not used as they do not capture fine grained execution details of individual activities within a process. In addition, the available workflow engines for those languages are not cloud-based and do not provide fine-grained execution control. Providing fine grained executability controls in the software process model allows for facing the cloud risks. For instance, a sensitive activity in a process can be configured to run on a private infrastructure.

4 REQUIREMENTS FOR CLOUD-BASED SOFTWARE PROCESS MODELS

In this section, we define what information a cloud-based software process model should contain to enable cloud-based model execution. The following requirements are not satisfied by SPEM2.0 specification. Therefore, we extend SPEM2.0 to satisfy these requirements in Section 5. The requirements are:

- **R1- Allow defining the required cloud resources for an activity.**
  Software process activities are diverse and they use different tooling support. While some activities in a process might be as simple as editing a textual file, other activities could involve more complex computational tasks (e.g. testing or model checking). Such computing intensive tasks need to be allocated appropriate computing resources. With the elasticity of cloud computing,

it is possible to allocate an initial set of resources and scale it up and down as needed. A cloud-based software process model needs to capture the initial set of resources needed to start model execution. It also needs to capture the resource scaling mechanism if needed. To cater for different activities' needs, the model should allow having different execution settings/configurations for each activity.

- **R2- Allow defining security and privacy measures.**
  Security has been the main concern for using cloud computing. Many enterprises and officials are sceptical about using public clouds based on their fear of data loss or leakage. Although cloud computing relieves enterprises from infrastructure management and maintenance, this comes with the disadvantage of cloud's opacity. Users do not know where their data is actually located and which other users may have access to it. Private clouds came to address those concerns by giving full control of the infrastructure to the user. In a software process model, some artefacts or activities may use confidential or sensitive data. Therefore, process designers should be able to define whether an activity (and its artefacts) should be undertaken in a private cloud (for security reasons) or in a public cloud.

- **R3- Define basic human-machine runtime interactions.**
  Software process are very complex and involve many stakeholders (e.g. designers, developers, project managers, business analysts, customers). While in some cases the process activities can be repetitive and automated (with no or little human interactions), many activities would require human interactions during the process execution. We envision to support two types of basic human-machine interactions:
  - Decision making: where a human would guide the executing process at runtime by specifying a particular branch the execution should follow, or by deciding to repeat a particular activity with different settings. This kind of interaction should be defined in the process model in order to be supported at runtime.
  - Parameter passing: in some cases, it might be difficult to set some execution parameters for an activity at the modelling stage. In such cases, a simple interaction is needed to pass those parameters at runtime. This allows activities to have a simple interaction with users in the form of questions (asking for parameters) and answers (passing parameters by users).

- **R4- Allow defining control-flow semantics.**
  Software processes are control-flow processes. Software process models need the flexibility of expressing control flow semantics such as: loops, forks and joins. SPEM2.0 does not provide explicit control flow elements.

- **R5- Allow defining the required tool support.**
  Activities in software processes are usually supported by some tools. In this context, the execution of software process models means orchestrating the supporting tools for process activities in a workflow style. Therefore, the model need to incorporate the tool details such as: version and compatible inputs and outputs.

5 EXE-SPEM

As described in Section 2.3, SPEM2.0 does not have explicit support for process execution. We extend the SPEM2.0 meta-model to address the requirements established in Section 4. The extended model is called EXE-SPEM.

Out of the seven SPEM2.0 meta-model packages, the *Process Structure* meta-model contains the structural elements for process definition. EXE-SPEM extends *Process Structure* meta-model with two new meta-classes, one enumeration and added attributes to existing meta-classes. Figure 1 illustrates the extended meta-model where classes with dark grey background are new and classes with light grey background have new attributes. To keep the figure clear, some classes (not affected by the extension) have been omitted.

The extension is summarized in the following points:

- The *CloudPrivacyKind* enumeration is added to define types of cloud deployment where an activity will be executed. It is used as an attribute in the *Activity* meta-class.
- The *Activity* meta-class is extended with attributes that will be used to guide execution in the cloud. The added attributes specify the version of the activity (the supporting tool) to be used, the type of cloud deployment (private or public) and the type and number of machines and a time out for executing the activity in the cloud. This meets the requirements R1 and R5. The use of *CloudPrivacyKind* here satisfies requirement R2.
- Two subtypes of *Activity* are introduced to provide control flow semantics:

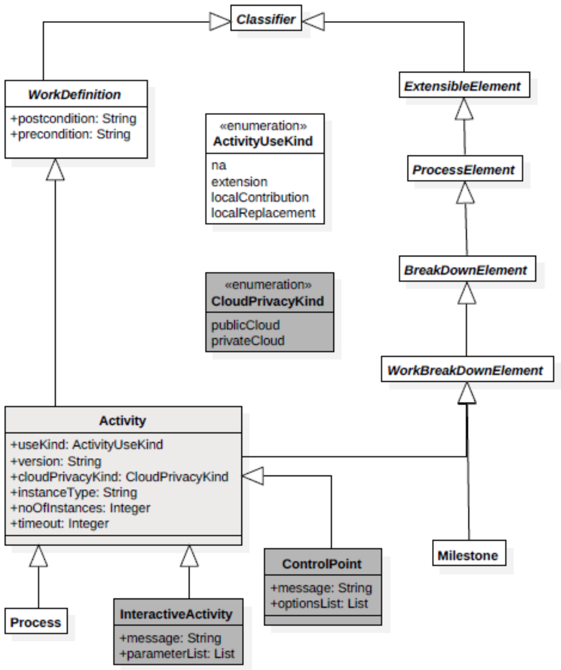


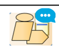
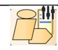
Figure 1: The meta-model of the extended SPEM 2.0 process structure.

– The *Control Point* provides the semantics of control flow in the process model. Control points in the process model give the user executing the process control on deciding which branch the execution should follow next. A branch can be: a loop (referring to the same activity), a fork or a join. The control point interaction is simply done by providing options (pre-defined in the model) and asking the user to make a decision on which option to follow. This meets requirement R4 and the decision making interaction part of requirement R3.

– *Interactive Activity* which can be used to model an activity that involves simple interactions with stakeholders. This meets the parameter passing type of interactions in requirement R3.

Icons for the EXE-SPEM elements are provided in Table 1. It is worth noting that EXE-SPEM reuses some of the SPEM2.0 elements (Role Use, Guidance, Process Parameter and Work Sequence) with the same icons. Furthermore, the difference between a *Task* and *Activity* in EXE-SPEM is that the task is not supported by a tool while the activity is.

Table 1: Graphical Icons of EXE-SPEM elements.

Element	Icon	Element	Icon
Process		Activity	
Interactive Activity		Control Activity	
Task Use		Work Product Use	

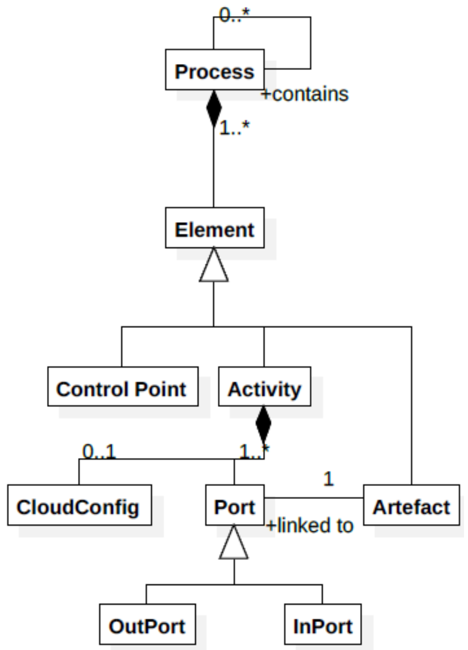


Figure 2: The meta-model of the XML schema.

6 XML NOTATION

In order to enact the EXE-SPEM model, we map it to an executable XML format following the XML schema in the Appendix. The meta-model of the schema is described in Figure 2. The XML schema captures a process consisting of the following elements:

- **Process:** this is the software development cycle. A process is usually created by an actor but might be performed by multiple actors.
- **Actor:** a person who is involved in the process such as: process managers, software engineers, testers, etc. A process will involve one or more actors. Although a team of actors might collaborate off-line on performing an activity, the activity will be assigned to a single actor who takes the responsibility for this activity.
- **Artefacts:** items produced or needed by the activities of the software development process (e.g. code, executables, models, documents, etc.).

- **Activities:** Activities represent the smallest unit of execution. They represent the different steps in a software production life cycle. Those steps usually involve the use of tools and/or actor interaction to be completed. Activities can be:
  - *Concrete activities:* are executable blocks of code. This type of activities is the tool support that is used for process execution. For instance, a verification activity will be supported by a verification tool (e.g. a model checker) which will be executed.
  - *Control points:* a type of activities which allows actors to guide the execution of the process in one of multiple defined directions. This allows for supporting loops, if conditions, and forks.
- **Cloud configuration:** represents cloud-related configurations such as: cloud deployment type, machine type, machine image, number of machines to be used, etc.
- **Ports:** Each activity can have zero or more input ports and zero or more output ports. Ports provide the means to connect activities and direct the process execution flow. They define both the consumed and produced artefacts by an activity. In addition, input ports act as preconditions that need to be satisfied so that the activity can start executing.

Table 2 shows the rules to map an EXE-SPEM model into the XML format described above. The mapping include some SPEM2.0 elements which are reused in EXE-SPEM. These elements are denoted with *.

7 EXAMPLE PROCESS

In this section, we model parts of the software process documentation example adopted from Shell Method process repository [5]. Shell Method is an integrated software development methodology designed for business and operations-oriented database systems that must pass audit. The example describes in detail the life-cycle of an order entry and shipping operations database application project [6].

We modelled the high level stages of the project as shown in Figure 3. In this model, a *Control Point* is introduced after the Integration and Testing phase to provide control flow in the process. Figure 4 shows the Integration and Testing stage of the life-cycle modelled in EXE-SPEM. This process uses an *Interactive Activity* to allow the user to provide parameters to run the integration tests. The Integration and Testing activity takes four artefacts as an input (generated from the Development stage) and produces six outcome artefacts.

[5] http://www.shellmethod.com/
[6] http://shellmethod.com/refs/SDLC.pdf

Table 2: Mapping rules between EXE-SPEM and our XML notation.

EXE-SPEM cloud-specific process	XML Process
Process	Process
Phase	(Sub) Process
Activity	Activity
Control Point	Control Point
Interactive Activity	Interactive Activity
Activity (execution -related) attributes	Cloud Configuration (of an activity)
Task (supported by a tool)	Activity
Task (Not supported by a tool)	Activity description attribute
Work Product Use	Artefact
Role Use*	Activity actor attribute
Guidance*	Activity description attribute
Process Parameter*	Port
Work Sequence*	Port attributes

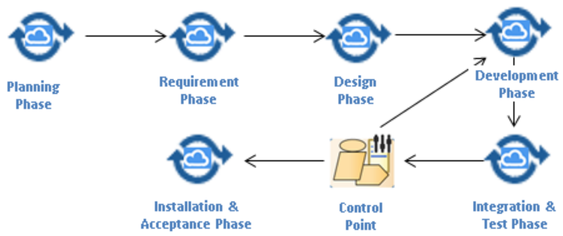


Figure 3: High level life-cycle process model in EXE-SPEM.

The life-cycle process model is mapped to an XML model following the mapping rules in Table 2. The following is a snippet of the XML model :

```
<Process>
<Elements>
......
<Process>
<Elements>
<Activity ID="560d33bce4v02180e944k921">
<Name>Integration</Name>
<Description>
Integration and Testing stage
</Description>
<Interactive>true</Interactive>
<No_of_input_ports>4</No_of_input_ports>
<No_of_output_ports>6</No_of_output_ports>
<Wait_for_input>false</Wait_for_input>
<Responsible_role>
```

```
Integration Engineer
</Responsible_role>
<Version>1</Version>
<In_ports>
<In_port>
<From_activity>560d33bbe4b02110e7</From_activity>
<Artefact ID="560d33bbe4b02110e944c806">
......
</Artefact>
</In_port>
<In_port>
<From_activity>560d33bbe4b02110e8</From_activity>
<Artefact ID="560d33bbe4b02110e944c842">
......
</Artefact>
</In_port>
......
</In_ports>
<Out_ports>
<Out_port>
<Next_activity>560d33bbe4b02110e8</Next_activity>
<Artefact ID="560d33bbe4b02110e944b5j2">
......
</Artefact>
</Out_port>
......
</Out_ports>
<Cloud_config>
<Cloud_deployment_model>public
</Cloud_deployment_model>
<Cloud_provider>AWS</Cloud_provider>
<Instance_type>m3.xlarge</Instance_type>
<No_of_instances>2</No_of_instances>
<Timeout>2</Timeout>
</Cloud_config>
</Activity>
</Elements>
</Process>
<Control_Point ID="560d33bbe4b02110e8jm2n16">
<Message>Choose the next branch.</Message>
<Options>
<Option> <!--  Development-->
<ActivityID>560d33bbe4b02110e8</ActivityID>
</Option>
<Option> <!--  Installation & Acceptance-->
<ActivityID>560d33bbe4b02110e8</ActivityID>
</Option>
</Options>
</Control_Point>
</Elements>
</Process>
```

In contrast to SPEM2.0, using EXE-SPEM in the above model has allowed to model interaction and control flow semantics. In addition, the textual model (XML) contains configurations that will used for enactment.

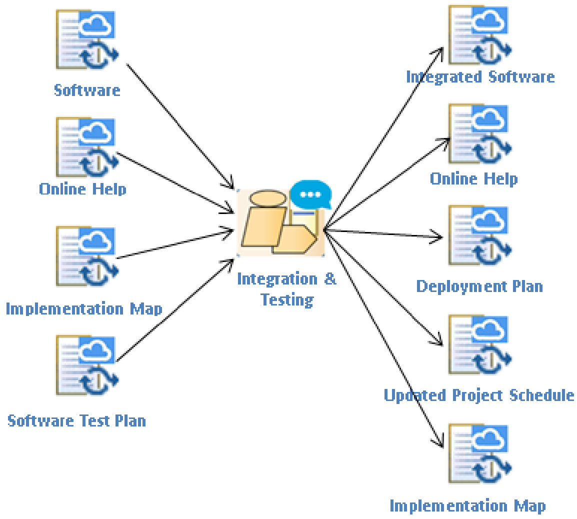


Figure 4: Integration and Testing process model in EXE-SPEM.

8 CONCLUSIONS

Cloud computing is becoming the norm for computing resources delivery. However, its potential for software processes has not been fully harnessed yet. In this paper, we highlighted the potentials and concerns of moving software processes to the cloud. We argued that executable cloud-based software process models can help with further adoption of the MDE approach for software development. This will leverage the benefits of both the cloud and MDE for software development.

We introduced EXE-SPEM which is an extension of the SPEM2.0 meta-model to capture cloud-based execution information in software process models. To demonstrate the use of EXE-SPEM, we used it to model an example software process for database application development. Currently, we are working on developing a cloud-based enactment platform to execute EXE-SPEM models. The new platform will support integrating tools as services and execution of software process models on a hybrid cloud. In addition, algorithms to automate the mapping between the EXE-SPEM and the XML notation.

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APPENDIX: XML SCHEMA FOR EXECUTABLE SOFTWARE PROCESS MODELS