

Institute of Architecture of Application Systems

University of Stuttgart
Universitätsstraße 38
D-70569 Stuttgart

Bachelorarbeit Nr. 12345

Self-Containment Packager Framework for TOSCA Cloud Service Archives

Yaroslav Nalivayko

Course of Study:	Softwaretechnik
Examiner:	Prof. Dr. Dr. h. c. Frank Leymann
Supervisor:	M.Sc. Michael Zimmermann
Commenced:	10. February 2017
Completed:	10. August 2017
CR-Classification:	I.7.2

Abstract

In recent years, cloud computing is gaining more and more popularity. **Topology and Orchestration Specification for Cloud Application (TOSCA)** provides a whole range of tools for managing and automation of cloud application. The TOSCA standard adds an additional level of abstraction to the cloud applications, in other words, a layer between the external interfaces of cloud application and cloud service provider's API. With the help of TOSCA, it's possible to describe several models of interaction with many different APIs, what allows to automate the rapid redeployment between providers, which are using completely different API. The University of Stuttgart implemented this specification in the runtime environment named **OpenTOSCA**. Description of a cloud application is stored in the **Cloud Service ARchive (CSAR)**, which contains all components necessary for a cloud application life-cycle.

Cloud systems are often described in such way that during they deployment, additional packages and programs need to be downloaded via the Internet. Even with a single server, this can slow down the deployment of cloud application. And if cloud application consists of a large number of servers, each of them downloading a large amount of data during the deployment, this can significantly increase both time and money consumption. During this work a software solution which will eliminate external dependencies in CSAR, resupply them with all packages necessary for deployment and also change the internal structure to display the achieved self-containment will be developed and implemented. For example, all commonly used "apt-get install" commands, which download and install packages, must be removed. Appropriate package must be downloaded and integrated into CSAR structure. Furthermore, all depended packages needed for new packages must also be added recursively.

This Document considers the concept and architecture for mentioned framework. In addition some aspects of implementation will be described.

Contents

1	Introduction	17
2	Basis	21
2.1	Cloud computing and cloud application	21
2.2	Topology and Orchestration Specification for Cloud Applications	23
2.3	OpenTOSCA	25
2.4	Package management	26
2.5	Languages for package management automation	27
3	Requirements	29
4	Concept and Architecture	33
4.1	Concept	33
4.2	Architecture	39
5	Implementation	43
5.1	Global elements	43
5.2	References resolver	44
5.3	Language modules	45
5.4	Package handler modules	47
5.5	Package Handler	48
5.6	Topology handling	49
6	Add new package manager module	51
6.1	Aptitude	51
6.2	Implementing the new package manager module	52
6.3	Integrating Aptitude into the Bash module	53
7	Validation	55
7.1	Input CSAR	55
7.2	Processing	55
7.3	Displaying with the winery	56
7.4	Check artifacts	58

8 Summary	61
Bibliography	69

List of Figures

2.1	TOSCA topology presented by <i>Winery</i>	26
4.1	General description of the software's work flow	33
4.2	An example tree describing how to find Service Templates and Node Templates for a given script	35
4.3	An example scheme representing several language modules containing package manager modules	36
4.4	Preprocessing: decompression, adding files and generating dependencies	40
4.5	The data flow scheme between language modules, package manager modules and the package handler.	41
6.1	A command line visual interface for the <i>aptitude</i> package manager. . . .	51
7.1	Processing by the framework.	56
7.2	Source CSAR represented by <i>Winery</i>	56
7.3	The output CSAR represented by the <i>winery</i>	57
7.4	The output CSAR represented by the <i>winery</i> , some nodes moved manually.	58
7.5	An ansible playbook's execution process	59

List of Tables

List of Listings

4.1	Unreadable bash script	36
5.1	The <i>getPackage</i> definition	49
5.2	Creating of new Node Template	50
6.1	The <i>aptitude</i> inherited from the <i>PackageManager</i> abstract class	52
6.2	The <i>aptitude</i> module with some common elements	52
6.3	The <i>aptitude</i> <i>proceed</i> function	53
6.4	The <i>aptitude</i> line parser	54
7.1	Check bash installation script	58
8.1	Description for the script Artifact Type definition	64
8.2	Abstract language model	65
8.3	Abstract package manager model	66
8.4	Ansible proceeding	67

List of Algorithms

List of Abbreviations

API Application **P**rogramming Interface. 17

CSAR Cloud Service **AR**chive. 24

TOSCA Topology and **O**rchestration **S**pecification for **C**loud **A**pplication. 17

1 Introduction

Cloud Applications Market increases with great speed. Globally annual growth is about 15%. [Sta16] Furthermore observed the growth in the number of firms, which are using Cloud applications. And that are not only some big corporations but also many small companies. [Bun14; Bun17]

One of the most important reasons for the development of cloud applications is the economy of resources. It is much easier and often cheaper to rent a part of another's big mainframe, then to maintain an own server. As well as it is also easier and cheaper to send a small package by mail, than to keep your own car (server) and driver (administrator) for a rare traffic.

The growing popularity of cloud applications makes the automation and the ease of management increasingly important. Under the management is understood the deployment, administration, maintenance and the final roll-off of cloud applications.

The common problem of cloud applications is *affection*. The transfer of a cloud application configured to interact with the **A**pplication **P**rogramming **I**nterface (API) of one provider, to work with another provider and another API is a difficult, but important task. The ability to quickly move a cloud application to the more suitable provider is a key to the development of competition and reducing the cost of maintenance.

Topology and **O**rchestration **S**pecification for **C**loud **A**pplication (TOSCA) [13] provides an opportunity to solve this problem. TOSCA defines the language, which allows describing cloud application and their management portable and interoperable. The use of TOSCA allows to simplify and automate the management of cloud applications by different providers. According to TOSCA standard a cloud application is stored into **C**loud **S**ervice **A**Rchive (CSAR). This archive contains the description of the cloud application, its external functions and internal dependencies, and the data needed for the deployment and operation.

OpenTOSCA [Stu13] is an open source ecosystem (runtime environment) for TOSCA standard developed in University of Stuttgart, which is constantly improved and expanded. OpenTOSCA processes data in CSAR format and performs the actions specified in it. Often these actions contain links to external packages and programs necessary for deployment of the cloud application, which will be subsequently downloaded over the Internet. This downloads can add expenses to the time required to download packages, money spent on rent an idle server and Internet traffic for megabytes of pre-known data. If a cloud application consists of only one deployed server, this may mean a few

seconds of delay. But when an application deploys a large number of linked servers (cloud system), the costs can increase significantly.

Other problems of external dependencies are security and stability. To ensure the security of information, some firms restrict the Internet access. In other networks, the Internet access is extremely limited. (For example, there can be no broadband access, slow communication only over a satellite at certain hours, etc) An attempt to deploy cloud application with external dependencies in such networks may well not succeed.

To solve these problems a software solution for resolving external dependencies in CSARs will be developed and implemented during this work. This software will analyze the CSAR, identify dependencies to external packages and resolve them by downloading the necessary data to install the package (as well as data for all depended packages) and adding them to the CSAR's structure. The simplest example is to find in given CSAR all the commands like "apt-get install package", delete this command, download the package and all depended packages and add them to the CSAR.

This software must be easily expanded (in other words - that will be a framework) since it is impossible to predict and describe all possible types of external dependencies. The output of the framework is a CSAR, which contains additions to original structure, like all the packages necessary for the deployment of the cloud application, with the minimum possible level of access to the Internet during operation.

Structure

The work is structured as follows:

Chapter 2 – Basis: This chapter explains the basic terms of this work. These include definitions and descriptions of cloud applications (section 2.1), TOSCA standard (section 2.2), OpenTOSCA environment (section 2.3) and Packet management (section 2.4).

Chapter 3 – Requirements: Here are clarified requirements for the framework.

Chapter 4 – Concept and Architecture: In chapter 4 the main concepts as well as architecture of the framework are explained and illustrated.

Chapter 5 – Implementation: This chapter contains the description of the implementation. It explains the design and development of individual components of the framework.

Chapter 6 – Add new package manager module: New package manager will be added in this chapter, to proof ease of extensibility.

Chapter 7 – Validation: Output of the framework will be checked here.

Chapter 8 – Summary Summarize the results of the work.

2 Basis

In this chapter, the terms used in this work will be explained. These include definitions for a cloud computing and cloud applications, description of a TOSCA standard and its implementation an OpenTOSCA. At the end, a package management and languages for its automation are described.

2.1 Cloud computing and cloud application

In everyday life, you can often hear the phrase "cloud computing", but what is it? Unfortunately, generally accepted definition of cloud computing that describes all possible situations doesn't exist. But in the scientific community, the definition put forward by National Institute of Standards and Technology (NIST) is commonly used. This definition appropriately describes the concept of cloud computing used in this paper, and therefore this definition will be used.

***Cloud computing** is 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. [Pet11]*

But the computing is to abstract term, for our purpose we need something more practical, like an application. Also, there are no generally accepted definitions of cloud application, but it can be obtained from the definition of cloud computing.

*A **Cloud application** is an application that is executed according to a cloud computing model. [tec]*

In addition, a short definition of the cloud system, a provider, and a user will be provided. Composite cloud applications which consist of multiple small application will be called a **cloud system**. An owner of the physical platform, where cloud computing takes place is called a **provider**. An owner of the cloud application, renting a provider's platform is called a **user**.

Service models

NIST distinguishes between three types of service models.

- **Software as a Service (SaaS).** The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited userspecific application configuration settings.
- **Platform as a Service (PaaS).** The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment.
- **Infrastructure as a Service (IaaS).** The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls).

Usage

Now cloud computing and application can be found everywhere, and they number constantly grows. [Laz16] They are used for test and development, big data analyses, file storage and so on. Cloud computing allows using resources effectively, to distribute the load to a system from several physical servers and to shift the maintenance to the providers. If service uses a single one physical server and this server will be disabled, then entire service will be completely unavailable too. But if cloud application uses a hundred of physical servers, then disabling of one will not carry such serious consequences. In addition, a user doesn't need to maintain a team of administrators for the event of various problems.

Usually, a user doesn't have a direct access to the infrastructure (servers and operating systems), he uses only provided Application Programming Interface (API). An API

provides a set of methods to communicate with provider's infrastructure. Each provider defines his own set of methods, depending on his area of specialization. On the one hand, this specialization makes easier to work with the provider, but on the other hand, it becomes more difficult to redeploy an application to another provider.

2.2 Topology and Orchestration Specification for Cloud Applications

The OASIS [OAS] Topology and Orchestration Specification for Cloud Applications (TOSCA) standard provides a new way to enable portable automated deployment and management of cloud applications. TOSCA describes the structure of an application as a topology containing their components and relationships between them. TOSCA application is a cloud application described according to the TOSCA standard. This standard can be used not only for describing all stages of a cloud application life-cycle but also serve as a layer between the cloud application and provider's API, allowing to implement a single application suitable for working with different providers.

Structure

TOSCA specification provides a language to define services (described in section Service models) and relationships between them using *Service Templates*. In addition it describes the management procedures which create or modify services using orchestration processes. Descriptions of the TOSCA's components used in this work is provided.

Service Template is the main component in TOSCA structure. It contains an information about the structure (Topology Template) and interfaces (Plans) of the service. It can be many Service Templates within one TOSCA application. *Plans* provide interfaces to manage the cloud application. These components combine management capabilities to create higher-level management tasks, which can then be executed fully automated to deploy, configure, manage, and operate the application. Plans are started by external messages and call management operations of the nodes in the topology. *Topology Template* describes the topology of cloud application, defining nodes (Node Templates) and relations between them (Relationship Templates). *Node Template* instantiates a Node Type as a component of a service. *Node Type* defines the properties of such component and the operations available to manipulate the component. *Relationship Template* instantiates a Relationship Type as a relationship between Node Templates in a Topology Template. The Relationship Template indicates that two nodes are connected and define the direction of the connection. *Relationship Type* defines the semantics

and any properties of the relationship. Any Node Types and Relationship Types can be instantiated multiple times. Those types are like abstract classes in high-level programming languages and Templates are objects of those classes.

Artifact represents the content needed for a management such as executables (e.g. a script, an executable program, an image), a configuration file, a data file, or something that might be needed for other executables (e.g. libraries). TOSCA distinguishes two kinds of artifacts: Implementation Artifacts and Deployment Artifacts. *Implementation Artifact* represents the executable of an operation described by a Node Type. *Deployment Artifact* represents the executable for materializing instances of a node. *Artifact Type* describes a common type of an artifact: python script, installation package and so on. *Artifact Templates* represents information about the artifact. The location of the artifact and other attendant data are stored here. Again, types are classes, templates - objects, and artifacts represent a content or a value of an object, but these values of objects can not be changed. *Node Type Implementation* defines the artifacts needed for implementing the corresponding Node Type. For example, if Node Type contains *deploy* and *shutdown* operations, then Node Type Implementation can contain two Implementation Artifacts with scripts for these operations and one Deployment Artifact with data needed for the deployment. Implementations are like final classes between Node Types and Node Templates, but in the TOSCA standard, an Implementation will be chosen only during execution. Types, Templates, and Implementations defining a TOSCA application are stored in definition documents, which have the XML format.

Usage

The combination of topology and orchestration in a Service Template defines what is needed to be preserved across deployments in different environments to enable interoperable deployment of cloud services and their management throughout the complete lifecycle (e.g. scaling, patching, monitoring, etc.). This is useful when an application is ported to alternative cloud environments. [OAS13]

To store the TOSCA application a **Cloud Service ARchive** (CSAR) is used. This is a ZIP-file with ".csar" extension that contains all the data needed for instantiation and management of TOSCA application. These include definition documents, artifacts and so on. In this form, a TOSCA application can be processed by a TOSCA runtime environment.

The root folder of any CSAR must contain a "Definitions" and a "TOSCA-Metadata" folders. The "Definitions" folder contains definition documents and one of them must define Service Template. The "TOSCA-Metadata" folder must contain TOSCA metadata in form of file with the "TOSCA.meta" name. This metafile consists of name/value pairs. One line for each pair. The first set of pairs describes CSAR itself (TOSCA version, CSAR version, creator and so on). All other pairs represent metadata of files in the CSAR. The

metadata is used by TOSCA runtime environment to correctly proceed given files. During this work, the terms an input CSAR and an output CSAR will be used. Input CSAR is a CSAR, which can contain external references and will be processed by the framework. Output CSAR is a CSAR, which was processed by the framework and doesn't contain external references.

2.3 OpenTOSCA

OpenTOSCA provides an open source ecosystem for TOSCA applications. This ecosystem consists of three parts: a TOSCA **runtime environment**, a graphical modeling TOSCA tool **Winery**, and a self-service portal for the applications available in the container **Vinothek**. [Stu13] Descriptions of the runtime environment and the winery will be provided in more details.

Runtime environment

The runtime environment enables a fully automated plan-based deployment and management of cloud applications in the CSAR container. First, the CSAR is unpacked and the files are put into the Files store. Then, the TOSCA definitions documents are loaded, resolved, validated, and processed by the Control component, which calls the Implementation Artifact Engine and the Plan Engine. The Implementation Artifact Engine deploys the referenced Implementation Artifacts and stores their endpoints in the Endpoints database. Finally, the Plan Engine binds and deploys the application's management plans. The endpoints of the management plans are stored in the Plans database. [BBH+13]

Winery

The winery works under a Tomcat server and therefore visual interface is available in a browser. The winery provides a complete set of functions for creating, editing and deleting of elements in the TOSCA topology. An example of the TOSCA topology is presented in the figure 2.1.

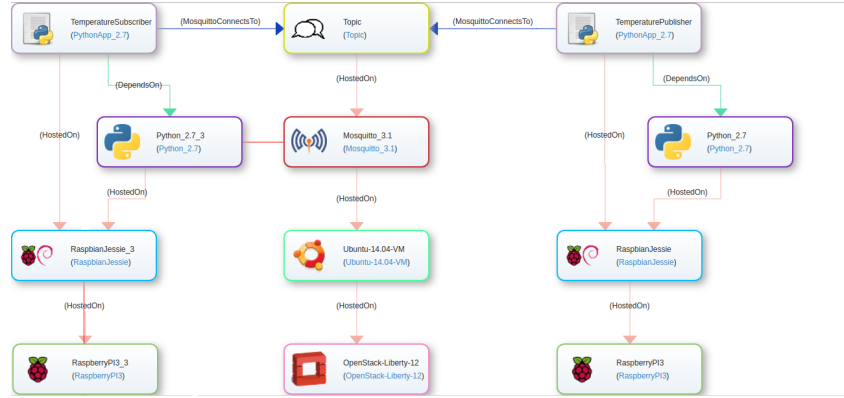


Figure 2.1: TOSCA topology presented by *Winery*.

2.4 Package management

A **package** is an archive file containing both data for installation of the program component and a set of metadata like name, function, version, producer, and a list of dependencies on other packages. Those program components can present not only a single program but also a certain component of a large application. For a user, a **package manager** is a set of software tools that automate the process of installing, updating, configuring and removing of packages. But on operating system site, a package manager is used for managing the database of packages, their dependencies, and versions, to prevent erroneous installation of programs and missing dependencies. This task is especially complex for computer systems which rely on dynamic library linking, which share executable libraries of machine instructions across packages and applications. In these systems, complex relationships between different packages requiring different versions of libraries result in a challenge colloquially known as "dependency hell". Good package management is vital on these systems.

To give users more control over the kinds of software that they are allowing to be installed on their system, software is often downloaded by package managers only from a number of software repositories. By default in Unix systems, a package manager uses official repositories appropriate for the operating system and the device architecture, but it's possible to use additional repositories, like third-party repositories or repositories for another architecture.

Package managers distinguish between two types of dependencies: *required* and *preRequired*. Dependency *package1 required package2* indicates that the *package2* must be installed for a proper **operation** of the *package1*. Dependency *package1 preRequired package2* indicates that the *package2* must be installed for a proper **installation** of the *package1*. In these examples, the *package2* is needed for the *package1*, but the *package2* itself can require additional packages. A structure describing all needed packages and

dependencies between them for given root-package is called a dependency tree. The dependency type *required* can lead to cycles in a dependency tree, which differs them from the normal tree graph structures.

2.5 Languages for package management automation

To automate the package management, various languages are used. Those languages will be described, which will be used in the framework.

Bash

Bash is a Unix command language written as a free software. In addition bash denotes to a command processor that typically runs in a text window, where the user types commands that cause actions. Instead of typing commands direct to a command line, a file containing some commands can be executed. [wikib] This file is called a script. Scripts are often used to automatically install programs.

Ansible

Ansible is an open-source automation engine that automates software provisioning, configuration management, and application deployment. As with most configuration management software, Ansible has two types of servers: controlling machines and nodes. First, there is a single controlling machine which is where orchestration begins. Nodes are managed by a controlling machine over SSH. The controlling machine describes the location of nodes through its inventory. Ansible playbooks express configurations, deployment, and orchestration in Ansible. The playbook format is YAML. Each playbook maps a group of hosts to a set of roles. Each role is represented by calls to Ansible tasks. [wika]

3 Requirements

A new software should be developed, which will resolve external references and complement the TOSCA topology to represent the changes to in a given CSAR file. Since the main purpose of the software is to Resolve References, further the *RR* can be used as an abbreviation. A primary type of external references is an artifact represented by a bash script, which uses an apt-get package manager to install new packages. The exact command for this type of references is "*apt-get install package*". In this example, the *RR* should comment out such commands and add the installation of the **package** and installations of all packages from its dependencies tree as new separate nodes to the TOSCA topology.

To do this a system package manager can be used. An example for the *apt-get* package manager. Using the "*apt-get download package*" command, the installation data for the **package** can be downloaded, and using the "*apt-cache depends package*" command, the list of dependencies for the **package** can be obtained. To install a package from the installation **data** the simple command "*dpkg -i data*" can be used.

An installation data should be integrated into the TOSCA topology. To do this a new node should be created for each package. During this, step a set of definitions will be created. A common description of a new node is provided via a Node Type, which contains the "install" operation. This operation will be implemented by a Node Type Implementation, which uses Artifact Templates. Created nodes should install packages using the same language, as the original node contained the external reference. In the example with the Bash language, the Artifact Templates will be represented by the deployment artifact with the installation data and by the implementation artifact with the script containing the installation command.

Then nodes should be instantiated and referenced. For each Node Template, which uses an artifact with external references to a **package**, a separate Node Template of the **package**'s Node Type should be defined and referenced. Then for each **package**'s Node Template additional Node Templates for packages from its dependencies tree should be defined and referenced. To define a reference between nodes a Relationship Template will be used and to find out which Node Template uses which artifact the CSAR will be preprocessed. During the preprocessing the topology of the SCAR will be analyzed and internal references found.

To distinguish between languages, package managers, and those software handlers, a program component handling a language will be called the language module, and

handling a package manager - the package manager module. The Bash module with the apt-get module will be implemented first. The goal is to develop extendable software, where new modules can be easily added later. This type of a software is called a framework.

After the minimal configuration with the *Bash* and *apt-get* modules will be developed, an *Ansible* module with *apt* package manager module can be added. Ansible scripts are called playbooks. Ansible playbooks and a related data are often packed to a zip archive for encapsulation. That makes the ansible module harder to implement since it should not only parse playbooks but additionally unpack archives. Ansible Node Type Implementations will contain only one artifact. This artifact will be an archive containing both the playbook and the installation data.

Handling

Here an example is provided, representing how the framework should proceed a CSAR. At start an input CSAR will be extracted to a temporary folder, to handle its content. Then the internal structure will be analyzed during the preprocessing. In addition, the common TOSCA definitions not belonging to a specific node (like Artifact Types or Relationship Types) will be added. After that starts the processing. Each file from the input CSAR will be processed by each language module. If a language module accepts a file, then the file is transferred to the package manager modules, belonging to the language module. A package manager module will resolve reference by commenting out the installation command and extracting package names from the command. Using the package name the package installation data will be downloaded, the installation script created, and the TOSCA node defined. To define a new TOSCA node for the package, the definitions for Node Type, Node Type Implementation, and Artifact Templates should be created. A separate Node Template, as well as Relationship Template, should be defined for each depending node. These actions will be recursively repeated for all dependent packages from the package's dependencies tree, which mirrors the tree to the TOSCA topology. At the end, the meta-file should be updated and the data packed back to the SCAR.

These actions will be described in more details the chapter 4 and implemented in the chapter 5.

Result

As a result of the software's work, an output CSAR will be received. This CSAR must have the same functionality as the input CSAR, but all external references to additional packages must be resolved. The output CSAR must be able to be deployed properly without downloading these packages over the Internet. In addition, the dependencies trees for packages from new nodes should be represented in the TOSCA topology.

In order to validate the output CSAR, the TOSCA topology can be checked and represented by the winery and the created artifacts can be checked through those installations on a test machine.

4 Concept and Architecture

In this chapter, the concept and the architecture of the framework, which can satisfy the requirements will be described and substantiated. Solutions to some additional problems will be presented.

4.1 Concept

In this section, the main concept of this work will be described. The general structure of the framework is represented in the block diagram 4.1. In the section 4.1.1, it will be found out how to determine during the preprocessing stage which Node Templates uses the given artifact. Then a functionality of language modules and package manager modules is described. In the section 4.1.3, it will be explained how to create a new node for a TOSCA topology. After that, a problem of the determining the architecture of the final platform will be explained and a solution described. In additional, it will be described, how the results can be validated.

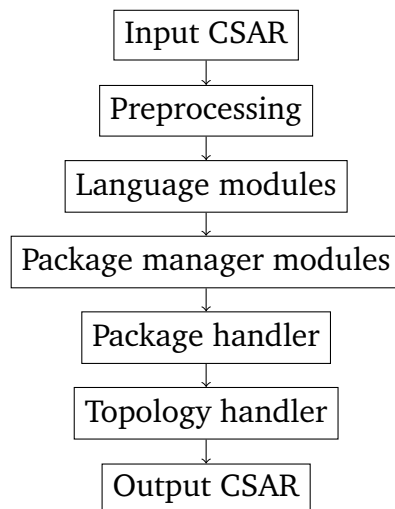


Figure 4.1: General description of the software's work flow

4.1.1 Analysis existing TOSCA-Topology

To properly update the TOSCA topology, it is necessary to add references from the nodes where external references were to newly created nodes, which resolve the external references. According to the TOSCA standard, only references between Node Templates in the same Service Template can be created. That means that each Node Template, which uses artifacts with external references must be found. Furthermore, Service Template where these Node Templates are instantiated must be found to create there a Node Template for the new nodes and reference them to the Node Templates with external references. The Pointers to Artifacts are contained by Artifact Templates, which are used by Node Type Implementations. By composing all the information a simple references chain can be built:

Artifact → *Artifact Template* → *Node Type Implementation* → *Node Type* → *Node Template* → *Service Template*

Now consider the references in more detail.

- *Artifact* → *Artifact Template*
An Artifact can be referenced by several Artifact Templates. (Despite the fact that this is a bad practice.)
- *Artifact Template* → *Node Type Implementation*
The same way an Artifact Template can be used by several Node Type Implementations.
- *Node Type Implementation* → *Node Type*
A Node Type Implementation can describe an implementation of only one Node Type.
- *Node Type* → *Node Template*
Each Node Type can have any number of Node Templates.
- *Node Template* → *Service Template*
But each Node Template is instantiated only once.

Thus structure can be described by a tree with an Artifact as the root, and Service Templates as leaves (The example is on figure 4.2) and will be called the internal dependencies tree.

An additional problem is in the reference between a Node Type and a Node Type Implementation. Node Type can have several implementations, but which one will be used will be determined only during the deployment. The chosen solution to this problem is to use each Node Type Implementation in hope, that they will not conflict. The following steps can be executed during the preprocessing, to build the internal dependencies tree.

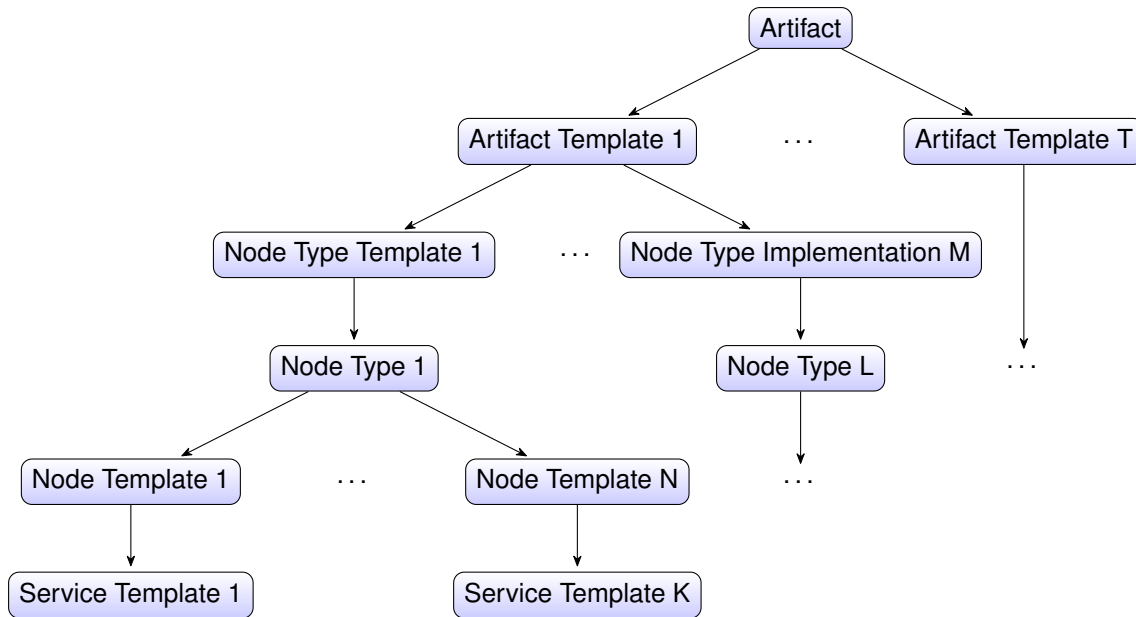


Figure 4.2: An example tree describing how to find Service Templates and Node Templates for a given script

- Find all Artifact Templates to build references from Artifacts to Artifact Templates.
- Find all Node Type Implementations. Because they contain references both to the Node Type and to the Artifact Templates, then the dependency from Artifact to Node Types can be built.
- Find all Service Templates and in them contained Node Templates. Each Node Template contains a reference to Node Type, what is useful for building a dependency from Artifact to Node Template.

In this way, the required internal dependencies tree can be built (with references *Artifact* \rightarrow *Node Template* and *Artifact* \rightarrow *Service Template*).

4.1.2 Modules and extensibility

Unfortunately, it is impossible to identify all types of external references, even when only one language and one package manager are used (an example in the listing 4.1). Since this work is aimed at creating of the easily expanded and supplemented tool, initially only basic usage of package managers will be considered.

The framework should handle different languages, each of them can support various package managers. A language module should filter files not belonging to the language,

Listing 4.1 Unreadable bash script

```
#!/bin/bash
set line = abcdefghijklmnoprst
set word1 = ${line:0:1}${line:14:1}${line:17:1}
set word2 = ${line:6:1}${line:4:1}${line:17:1}
$word1-$word2 install package
```

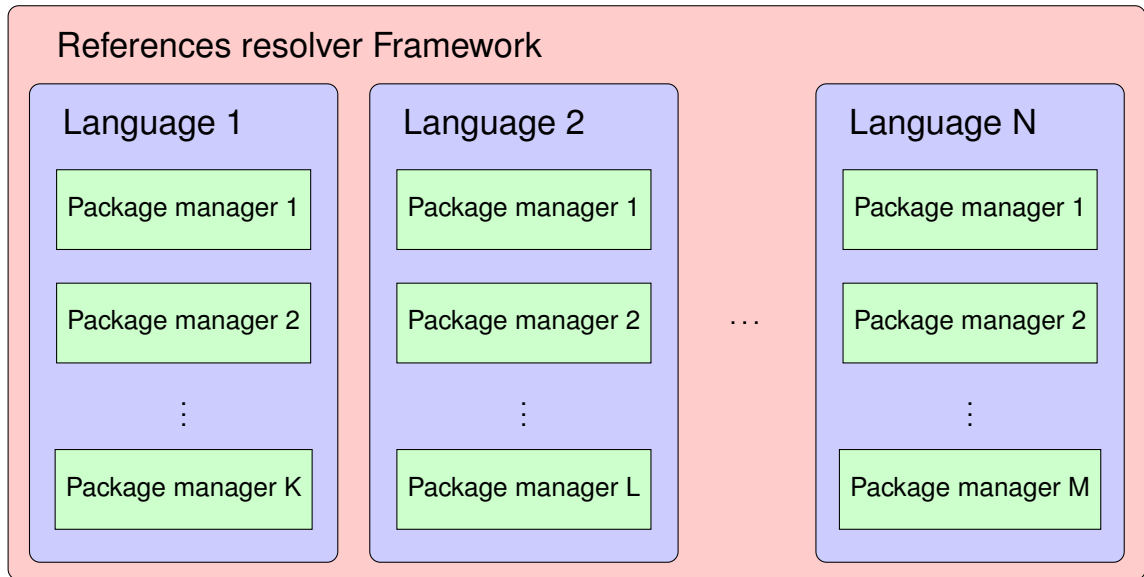


Figure 4.3: An example scheme representing several language modules containing package manager modules

and accepted files will be transmitted to corresponding package manager modules. This principle can be illustrated by a figure 4.3.

A package manager module resolves an external reference and transmits the package name to a package handler, described in section 4.2.5.

The framework will contain a list of all supported language modules, and each language module will contain a list of supported package managers modules. Ease of adding new modules to the framework will proof the correctness of the architecture.

At the beginning, the most popular combination will be implemented: the *bash* language with the *apt-get* package manager. This simple and powerful tool allows to install, delete or update the set of packages in one line. A line-by-line parser should be developed, which analyses scripts and finds the installation commands. After the modules for this combination will be implemented, new language and package manager modules should be added.

4.1.3 Representing downloaded packages in TOSCA-Topology

A package node denotes to the defined and instantiated element of TOSCA topology, the purpose of which is to install the package. The adding of new package nodes to TOSCA topology can be divided into several steps.

- Add definitions for common elements, like Artifact Types or Relationship Types. This can be done once at the preprocessing stage.
- The package node main definition will be represented by a Node Type.
- Artifacts (The downloaded data and the installation script) will be referenced by Artifact Templates.
- Node Type Implementation will combine the artifacts.
- Node Template will instantiate the package node in the corresponding Service Templates. To determine corresponding Service Template the preprocessing described in the section Analysis existing TOSCA-Topology will be used.
- Reference Template will provide topology information, allowing the observer (a user or a runtime environment) to determine, for which nodes the package must be installed. References will be created from the Node Template needing the package to Node Template of created package nodes.

After an execution of those steps, a definition of a package node will be finished and this node can be used.

4.1.4 Determining architecture of a final platform

Another problem appears during choosing the architecture of the device where packages will be installed. Unfortunately, it is impossible to analyze the structure of any CSAR and give an unambiguous answer to the question, on which architecture which node will be deployed. There are many pitfalls here.

A single Service Template can use several physical devices with different architectures. One Implementation Artifacts can be referred by different Node Types and Node Templates, instantiated on different platforms. This way one simple Implementation Artifact with a bash script containing "*apt-get install python*" command can be deployed on different devices within one Service Template (for example with the arm, amd64 and i386 architectures) and will result in the loading and installation of three different packages. For an end user, the ability to use such a simple command is a huge advantage, but for the framework, it can greatly complicate analysis. The following methods of architecture selection were designed.

- *Deployment environment analysis*
The script can analyze the system where it was started (for example using the "uname -a" command) and depending on the result, it will install the package corresponding to the system's architecture.
- *Unified architecture*
The architecture will be defined by the user for a whole CSAR.
- *Artifact specific architecture*
The architecture will be defined separately for each artifact.

Analysis of methods

The *deployment environment analysis*, which at first sight seems to be the most reliable solution, brings many additional problems. Packages for different platforms can differ not only by architecture but also by the version and the list of dependencies. As a consequence, a chaos can be produced by mirroring these different packages with different versions to the TOSCA-topology. The only robust solution seems to be to create for each installed package a set of archives (one archive for one architecture), containing the entire dependency tree for the given package. But this approach contradicts one of the main ideas of this work: the dependencies trees should be mapped to the topology. The *artifact specific architecture* method carries an additional complexity to the user of the framework. It will obligate a user to analyze each artifact and decide on which architecture it will be executed. This can be complicated by the fact that the same artifact can be executed on different architectures.

The method of the *unified architecture* was chosen, as the simplest and easiest to implement. If it will be necessary, this method can be easily expanded to the *artifact specific architectures* method (By removing the user input at start, and choosing an architecture for each artifact separately.) or to *deployment environment analysis* (By downloading packages for all available architectures and adding the architecture determining algorithm to the installation scripts.).

4.1.5 Result's checking

Checking the output of the framework is an important stage in the development of the program. It is necessary to verify both the overall validity of the output CSAR and the possibility to deploy generated package nodes. To test for overall correctness it is possible to use *winery* tool from OpenTOSCA. This tool for creating and editing CSAR archives is also great for visualizing the results. Checking the deployment of the

generated package nodes can be done manually by entering commands starting the implementation artifact's execution.

4.2 Architecture

This section will present the architecture of the framework and the detailed description of its elements. The main elements are a *CSAR handler*, a *references resolver*, *language modules*, *package manager modules*, a *package handler*, and a *topology handler*.

4.2.1 CSAR handler

The CSAR handler provides an access to a CSAR and maintains its consistency. It describes the processes of the adding of new files (to handle the metadata), archiving/unarchiving, and the choosing of a final platform architecture.

4.2.2 References resolver

This is the main element, the execution of which can be divided into the three stages: *preprocessing*, *processing*, *finishing*.

During the *preprocessing* stage, the CSAR will be unarchived, common files added, and internal dependencies trees generated. Figure 4.4 illustrates those steps. During the *processing*, all *language modules* will be activated, which are described in more details in the next section.

To finish the work all results will be packed to the output CSAR during the *finishing* stage.

4.2.3 Language modules

Each *language module* describes a handling of one language and chooses files written in the language. It also contains a list of supported package manager modules. Each language module must provide the capability to generate a TOSCA node for a given package and this node must use the same language to install the package. That means, that a script and definitions for Artifact Templates, a Node Type, and a Node Type Implementation should be created by a language module.

As already mentioned above, during *processing* stage a *language module* analyzes all files one by one and checks their belonging to the language. Any files not belonging

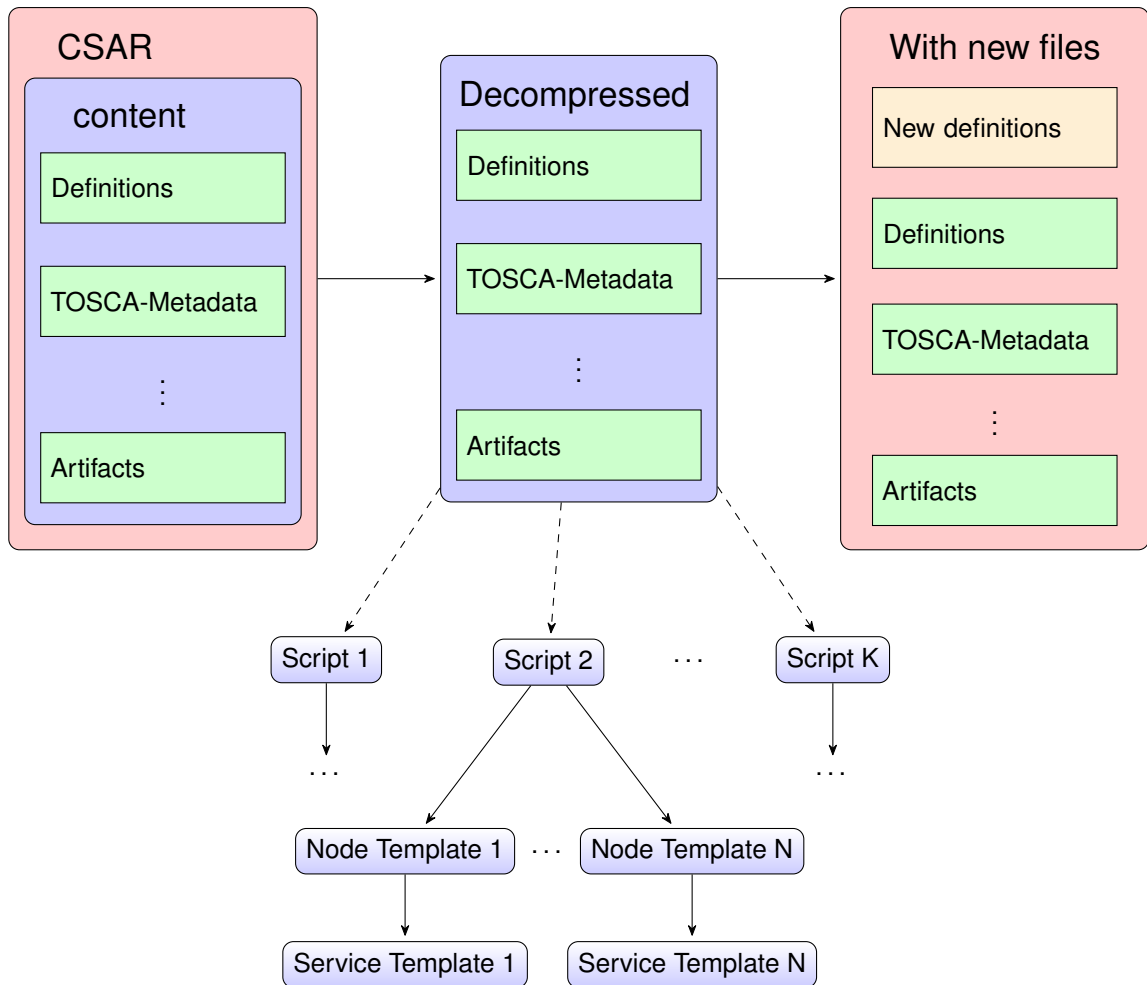


Figure 4.4: Preprocessing: decompression, adding files and generating dependencies

to the described language are filtered out. The remaining files are transferred to the *language module's package manager modules*. For example, a *bash* module will pass only files with `".sh"` extension, which start with the `"#!/bin/bash"` line. An *ansible* module should have an additional functionality to unpack zip archives, where ansible playbooks can be stored. Since ansible playbooks don't contain specific header or marker, the single sign of ansible files is the `".yml"` extension.

4.2.4 Package manager modules

A *package managers module* finds external references, resolves them and transmits the package name to the *package handler*, described in the next section. Figure 4.5 illustrates data flow between language modules, package manager modules, and the

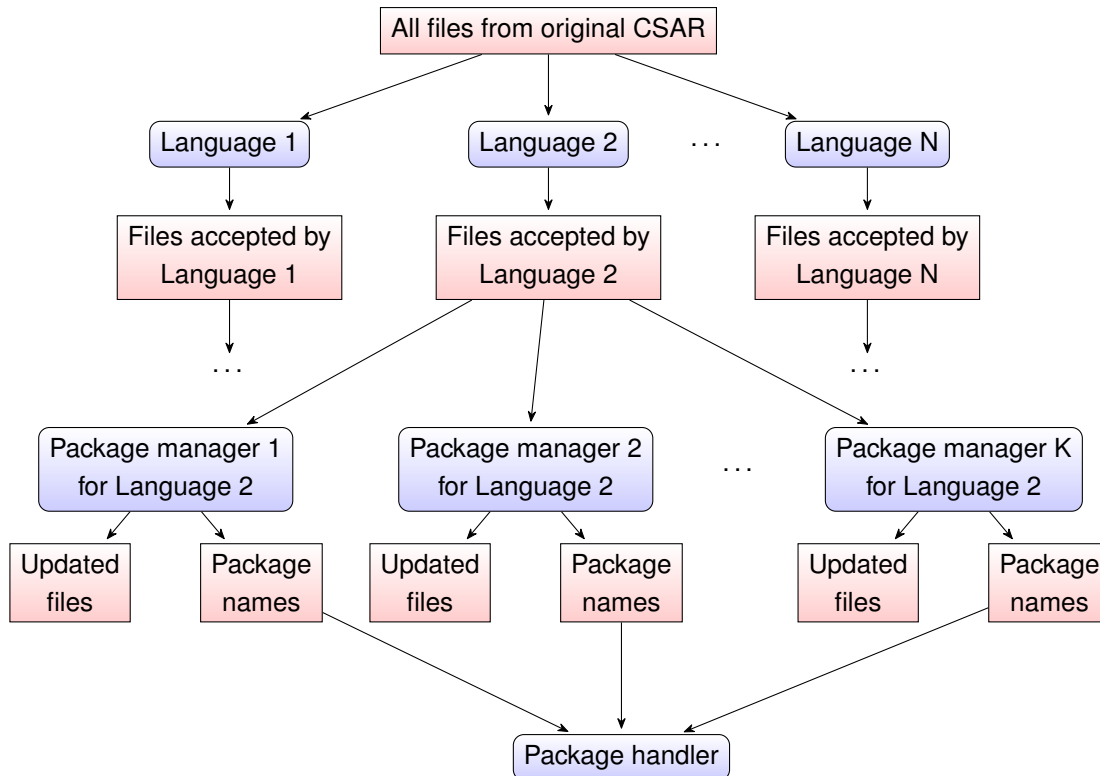


Figure 4.5: The data flow scheme between language modules, package manager modules and the package handler.

package handler.

To resolve an external reference a package manager module will parse a given file. In the case of the apt-get module for bash, the module will read a file line-by-line searching for the strings starting with "apt-get install". Such strings must be commented out and those ends should be divided to separate package names, which will be transferred to the package handler.

4.2.5 Package Handler

The *package handler* becomes a package name, downloads an installation data for an architecture specified by the CSAR handler, transfers the package name to the *topology handler* and recursively repeats the actions for all depended packages. To download an installation data the command "apt-get download **package**" can be used. The architecture can be specified by a ":*architecture*" suffix, for example, a "package:*arm*" mean the package of the *arm* architecture. The list of dependencies will be obtained using the "apt-cache depends **package**" command. The output of such command should

be parsed in order to extract names of depended packages. Of course, in a case of a fault during a download of a package, a user interface should be provided, to find a solution. That can be: retry the download, ignore the package, rename the package, or even break the framework's execution.

4.2.6 Topology Handler

This element should handle the TOSCA topology and has two main tasks: analyze the TOSCA topology during the preprocessing stage to create internal dependencies tries and use those tries to create TOSCA definitions for Node Templates and Relationship Templates in right places for packages provided by the package handler. The analyze of the TOSCA topology was described in the section 4.1.1 and the defining of Node Templates and Relationship Templates in the section 4.1.3.

5 Implementation

This chapter provides the information about the implementation of the framework and his elements, which behavior was described in chapter 4. The Java language was chosen, because of his simplicity and strength. In the Java language, the elements are represented by classes.

5.1 Global elements

This section describes the elements used throughout the whole framework's execution.

CSAR handler

This element provides an interface to access the CSAR content and stores information about files associated with it. The most valuable data are: the name of a temporary extraction folder, the list of files from the CSAR, the meta-file entry, and the architecture of the target platform. All this data are encapsulated into CSAR handler. To operate with the CSAR handler the list with public functions is available.

- *unpack* and *pack* extract the CSAR to the temp folder and pack the temp folder back to the CSAR. These functions use the *ZIP handler* module described below.
- *getFiles* returns the list containing all the files presented in the CSAR.
- *getFolder* returns the path to the folder, where the CSAR was extracted.
- *getArchitecture* returns the architecture used for the CSAR.
- *addFileToMeta* adds an information about the new file to the meta-data.

For example when the CSAR handler extracts the CSAR to the temporary extraction folder using the *unpack* function, it saves the folder's name. Then other elements should use the *getFolder* function to get this name and access the data.

Utils

This class provides methods, used by many other elements.

Using the *createFile* any element can create the file with the given content. This make the code cleaner. In the Java this operation can take more then dozen of strings, but this function makes a creation of files transparent.

The *getPathLength* function returns the deep of the given file's path and is very useful for creating a references between files. For example for a path "*A/B/C/file*" it returns a three and user knows, that he must three time go to the parent directory, to reach the root folder.

The OpenTOSCA uses some limitations to names of TOSCA nodes. Those names can't contain slashes, dots and so on. To obtain an acceptable name from a given name the function *correctName* can be used.

Zip handler

This is a small element with strait functionality. It serves to pack and unpack zip archives, which are used by the CSAR standard. To handle archives it was decided to use the package *java.util.zip*. The functions of archiving and unarchiving are called respectively *zipIt* and *unZipIt*.

5.2 References resolver

This is the main module which starts by framework startup and is executed into three stages: preprocessing, processing and finishing.

Preprocessing

At the preprocessing stage, the CSAR is unpacked, common TOSCA definitions generated and internal dependencies trees build. To unpack the CSAR the function *unpack* from the CSAR handler is used.

Then, common TOSCA definitions will be generated. To do this the *javax.xml.bind* package was chosen. This Java package allows to create a description - Java class describing an xml document. Those documents contain definitions for TOSCA elements, in our case that will be:

- *DependsOn* and *PreDependsOn* describe Relationship Types for the dependency types between packages.
- *Package Artifact* describes a deployment Artifact Type for a package installation data.
- *Script Artifact* describes an implementation Artifact Type for scripts installing packages.
- *Ansible Playbook* describes a deployment Artifact Type for a package installation via Ansible playbook.

An example description of the *Script Artifact* can be found in the listing 8.1. Each description is presented by a separate Java class.

To build internal dependencies trees the topology handler is used. It will be described in the section 5.6. At the preprocessing stage, it will be used to analyze all origin definitions and build internal dependencies trees, as was described in the section 4.1.1. To read original definitions from the XML files the package *org.w3c.dom* was used.

Processing

During this stage, all language modules listed in the *languages* variable are started. For the references resolver element that is only two strings of code, but they start the main functional of the framework.

Finishing

To finish the work the changed data should be packed back to CSAR. The function *pack* from the CSAR handler is used.

5.3 Language modules

This section will describe the language modules. Since the framework is initially oriented to easy extensibility, an abstract model for a Language modules will be defined. New language modules can be added by implementing this model.

Language model

To describe the common functionality and behavior of different language modules, the language model is used. In the Java, this model is described by an abstract class. The abstract class *Language* is presented in the listing 8.2. The common variables for all language modules are: the name of the language, the list with package manager modules, and the extensions of files. And the common functions are:

- *getName* returns the name of this language.
- *getExtensions* returns the list of extensions for this language.
- *proceed* checks all original files. Files written on the language should be transferred to each supported package manager module.
- *getNodeName* returns the name for Node Type, which will install package with this language.
- *createTOSCA_Node* creates the TOSCA definitions for the package. Since the created package nodes must install a package using the same language as the original node, all languages must provide the method for creating the definitions.

New language module must be inherited from the language model and then can be added to the references resolver's *languages* variable.

Bash module implementation

The processing of popular Bash language was implemented. The bash module should accept only files, written on the bash language. To chose such file some signs inherent to all bash scripts can be used. As the signs, the file extension (".sh" and ".bash") and the first line ("#!/bin/bash") are used. Each file, which contains those signs will be passed to supported package managers modules, in our case - to the *apt-get* module described later.

The bash module must provide capability to create definition for TOSCA node, which use the bash language to install a package. A Bash TOSCA node is defined by Package Type, Package Implementation, Package Artifact, and Script Artifact. The Package Type is a simple definition of a Node Type with an "*install*" operation and a name built from the name of the package. The Package Implementation is a Node Type Implementation, which references the Package Artifact and the Script Artifact to implement the Package Type's "*install*" operation. The Package Artifact and the Script Artifact are Artifact Templates referencing the installation data and a bash installation script respectively. The installation script contains the bash header and a installation command, like "*dpkg*

-i **installation_data**". This package node will be instantiated with a Node Template later by the topology handler. Those definitions and the installation command are created by the *createTOSCA_Node* function.

Ansible implementation

To test the extensibility of the framework, the Ansible language was added. Since ansible playbooks are often packed to archives, therefore it may be necessary to unpack them first and then analyze the content. Thus, the files are either immediately transferred to package handlers, or they are unzipped first. Listing 8.4 presents these operations. As a sign of the ansible language, the ".yml" extension is used, since its playbooks don't contain any specific header.

Creating an ansible TOSCA node for a package is a complicated operation. As a first step the original files should be analyzed to determine the configuration (the set of options like a username or a proxyserver). When implementer analyzer is unable to set all necessary options, a user interface will be provided to fulfill any missing parameters. Having all those options a playbook and a configuration file can be created in a temporary folder. After adding the installation data to the folder, it can be packed to a zip archive. This archive is a implementation artifact, for which the Artifact Template should be created. A Node Type with an "*install*" operation and a name built from the name of the package should be defined. And finally a Node Type Implementation linking the operation and the Artifact Templates should be defined. A Node Template will be added by the topology handler.

5.4 Package handler modules

and Package manager modules

Package handler model

Like to languages, an abstract class for package handlers is defined at first. His description contains only one function *proceed* (In the listing 8.3), that finds and eliminates external references, as well as passes the found package names to the package handler.

Apt-get Bash implementation

The apt-get package manager module is a simple line-by-line file parser which searches for the lines starting with the "*apt-get install*", comments them out and passes this command's arguments to package handler's public function *getPackage*. The code can be found in the listing ??.

Apt implementation

Since the package installation written in the *ansible* language with the *apt* package manager can be described in many different ways, then the processing will be a complicated task too. It's worth mentioning that the processing uses a simple state machine and regular expression from the *java.util.regex* package.

5.5 Package Handler

Package handler provides an interface for interaction with the package manager of the operating system. It allows to load packages and to determine the type of dependencies between them.

Package downloading

This operation is performed using one recursive function *getPacket* defined in the listing 5.1. This function downloads packages for the dependency three, calls the language's function *createTOSCA_Node* to create package nodes and the topology handler's functions *addDependencyToPacket* or *addDependencyToArtifact* to update the topology.

The Arguments of the *getPacket* function will be described shortly.

- *language* is used to call the right *createTOSCA_Node* function.
- *packet* is a package name to be downloaded.
- *listed* holds a list with packages already presented in the dependency tree. No need to download them again, but new dependencies will be created.
- *source* defines the parent element in the dependency tree. For the root package that will be the original artifact file, for other packages - the depending package.

Listing 5.1 The *getPackage* definition

```

/**
 * Download package and check its dependency
 *
 * @param language, language name
 * @param packet, package name
 * @param listed, list with already included packages
 * @param source, name of package or file depending on the package
 * @param sourcefile, name of original file contained external reference.
 * @throws JAXBException
 * @throws IOException
 */
public void getPacket(Language language, String packet, List<String> listed, String
    source, String sourcefile)

```

- *sourcefile* is the name of the original artifact with external dependencies. This name will be used by the *language* to generate package node and by topology handler to create the dependency.

For downloading the command *apt-get download package* is used. If a download fails then the user input is used to solve the problem.

Dependencies

To determine the dependency type the command *apt-cache depends package* is used. Example output was presented in section ??.

5.6 Topology handling

Topology handler serves to update the TOSCA topology. For this purpose the ?? is executed during preprocessing stage.

Update Service Templates

To update Service Templates two functions are provided.

- *addDependencyToPacket(sourcePacket, targetPacket, dependencyType)* generates dependency between two package nodes.

Listing 5.2 Creating of new Node Template

```
Element template = document.createElement("tosca_ns:NodeTemplate");
template.setAttribute("xmlns:RRnt",
    RR_NodeType.Definitions.NodeType.targetNamespace);
template.setAttribute("id", getID(package));
template.setAttribute("name", package);
template.setAttribute("type", "RRnt:" + RR_NodeType.getTypeName(package));
topology.appendChild(template);
```

- *addDependencyToArtifact(sourceArtifact, targetPacket)* generates dependency between original node and package node.

The both functions finds all Node Templates and Service Templates for the given *sourcePacket* or *sourceArtifact* using the internal dependencies trees. For each found Node Templates a package node for the *targetPacket* package is instantiated by creating new Node Template. Then the dependencies between found Node Templates and new Node Templates is created by instantiating Relationship Templates. The type of dependency is the value of the *dependencyType* for *addDependencyToPacket* and always the *preDependsOn* for *addDependencyToArtifact*.

To update existing TOSCA definition the *org.w3c.dom* and *org.xml.sax* packages are used. Creating of new Node Template is presented in the listing 5.2.

6 Add new package manager module

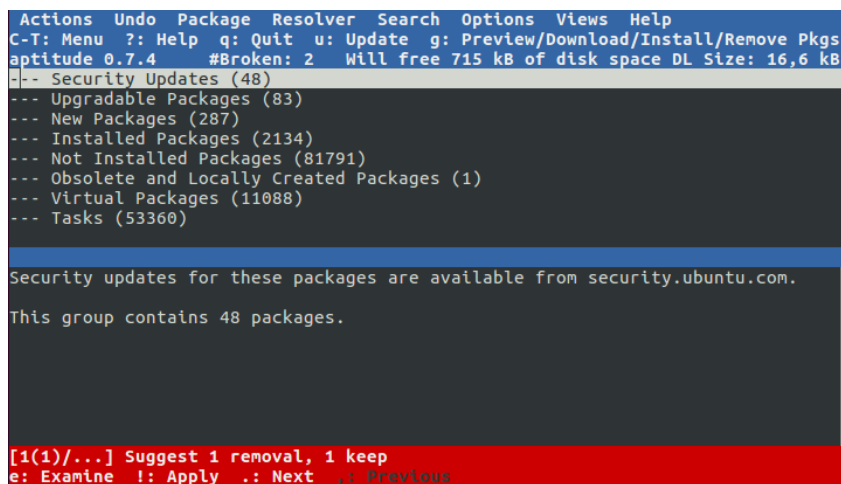
This chapter shows the extensibility of the framework by adding a new package manager module for the *bash* the *aptitude*.

Section 6.1 provides a common information about the *aptitude*.

In section 6.2 the module is implemented and in section 6.3 is integrated into the *bash* language module.

6.1 Aptitude

This section describes the *aptitude* package manager. Like to the *apt-get*, the *aptitude* is a command line program, where a package can be installed using the *aptitude install package* command. In additional, it can be started in a pseudo-graphical mode to provide a visual interface (An example in figure 6.1). An another advantage compared to the



```
Actions Undo Package Resolver Search Options Views Help
C-T: Menu ? : Help q: Quit u: Update g: Preview/Download/Install/Remove Pkgs
aptitude 0.7.4 #Broken: 2 Will free 715 kB of disk space DL Size: 16,6 kB
-- Security Updates (48)
-- Upgradable Packages (83)
-- New Packages (287)
-- Installed Packages (2134)
-- Not Installed Packages (81791)
-- Obsolete and Locally Created Packages (1)
-- Virtual Packages (11088)
-- Tasks (53360)

Security updates for these packages are available from security.ubuntu.com.
This group contains 48 packages.

[1(1)/...] Suggest 1 removal, 1 keep
e: Examine !: Apply .: Next <: Previous
```

Figure 6.1: A command line visual interface for the *aptitude* package manager.

apt-get is the capability to search for packages by a part of the name (or by any other attributes) using the *aptitude search text* command.

6 Add new package manager module

Listing 6.1 The *aptitude* inherited from the *PackageManager* abstract class

```
public final class PM_aptitude extends PackageManager {
    @Override
    public void proceed(String filename, String source)
        throws FileNotFoundException, IOException, JAXBException {
        // TODO Auto-generated method stub
    }
}
```

Listing 6.2 The *aptitude* module with some common elements

```
public final class PM_aptitude extends PackageManager {

    // name of the package manager
    static public final String Name = "aptitude";

    /**
     * Constructor
     */
    public PM_aptitude(Language language, CSAR_handler ch) {
        this.language = language;
        this.ch = ch;
    }

    @Override
    public void proceed(String filename, String source)
        throws FileNotFoundException, IOException, JAXBException {
        // TODO Auto-generated method stub
    }
}
```

6.2 Implementing the new package manager module

The process of the implementing of the *aptitude* module will be described here. At first, the *aptitude* class will be inherited from the abstract class *PackageManager*. This is presented in the listing 6.1.

After that, the *aptitude* class can be used as a regular package manager module (but it lacking functionality). Need to add the common code, like the constructor and the manager's name. After these operations, the *ansible* module can be presented in the listing 6.2.

Since the package manager will read files, the CSAR handler is stored by the constructor to the *ch* variable for a further use. In addition, the language (*bash* in this case) is stored too, to be propagated later to the package handler.

Now focus on the *proceed* function. A line-by-line file analyzer is needed, which can modify the data and in the case of a modification, the entire file should be rewritten.

Listing 6.3 The aptitude *proceed* function

```
@Override
public void proceed(String filename, String source)
    throws FileNotFoundException, IOException, JAXBException {
    if (ch == null)
        throw new NullPointerException();
    System.out.println(Name + " proceed " + filename);
    BufferedReader br = new BufferedReader(new FileReader(filename));
    boolean isChanged = false;
    String line = null;
    String newFile = "";
    while ((line = br.readLine()) != null) {
        // TODO parsing will be done here
    }
    br.close();

    if (isChanged)
        Utils.createFile(filename, newFile);
}
```

The *isChanged* value indicates that the file must be rewritten with the new content from the *newFile* variable. Now an *aptitude* line parser will be implemented, which reads a line from the *line* variable and stores it or its changed version to the *newFile* variable. If the data is changed, then the *isChanged* variable must be set to true. Any *ansible* package installation calls should be detected, commented out and its arguments (package names) should be propagated one by one to the Package Handler's function *getPackage*. For the parsing, the line is divided into words. The packet handler's *getPackage* function takes the language, the package name, and the source artifact name as the arguments.

6.3 Integrating Aptitude into the Bash module

Now the *aptitude* module can be added to the bash module. The only thing to do is to add the *aptitude* to the bash's list of package manager modules. This is done by the bash's constructor with the sting: `"packetManagers.add(new PM_aptitude(this, ch));"`. The new package manager module is ready to work.

6 Add new package manager module

Listing 6.4 The aptitude line parser

```
String[] words = line.replaceAll("[:&]", "").split("\\s+");
// skip spaces at the beginning of string
int i = 0;
if (words[i].equals(""))
    i = 1;
// looking for aptitude
if (words.length >= 1 + i && words[i].equals("aptitude")) {
    // aptitude found
    if (words.length >= 3 + i && words[1 + i].equals("install")) {
        System.out.println("aptitude found:" + line);
        isChanged = true;
        for (int packet = 2 + i; packet < words.length; packet++) {
            System.out.println("package: " + words[packet]);
            ch.getPackage(language, words[packet], source);
        }
    }
    newFile += "##References resolver//" + line + '\n';
}
else
    newFile += line + '\n';
```

7 Validation

In this chapter, the developed framework will be tested. An input CSAR will be described in the section 7.1. The processing by the framework is described in the section 7.2. The output CSAR will be added to and displayed by Winery in the section 7.3. Generated Artifacts will be tested in the section 7.4.

7.1 Input CSAR

In this test an CSAR from the OpenTOSCA Demos is used. The CSAR provides a service for Automating the Provisioning of Analytics Tools based on Apache Flink. [16] The structure of the service is provided in the figure 7.2. The service uses a server virtualization environment named *vSphere* (The *VSphere_5.5* node from the structure.). In the environment works the *Ubuntu* virtual server (The *Ubuntu – 14.04 – VM* node). *Ubuntu* hosts two applications: the *Python* (*Python2.7*) and the *Flink Simple* (*Flink_Simple_1.0.3*). An analyze shows the external references here: the *Python* node installs the python package and *Flink Simple* node - the Java package. The CSAR has a two submodules: a Data Prediction and a Data Delivery, both a hosted on the *Flink Simple* node and require the Python node.

7.2 Processing

Since the framework is written in the Java, to start it an Java jdk (version 1.8 or above) is necessary. Additionally an operating system must contain an apt-get program. For Linux systems it can be easily installed. To start the framework an Java environment is used. After the start, user should enter the input CSAR name, the output CSAR name, and the architecture. After that, the framework should work fully automatically, analyzing the artifacts and resolving any external references. Figure 7.1 provides an example.

```

jerry@jerry-note:~/TOSCA$ java -jar RR.jar
enter the input CSAR name: FlinkApp_Demo_Small_On_VSphere.csar
enter the output CSAR name: output.csar
source: FlinkApp_Demo_Small_On_VSphere.csar
target: output.csar
Proceeding file FlinkApp_Demo_Small_On_VSphere.csar
Please enter the architecture.
Example: i386, amd64, arm, noarch.
architecture: amd64
Parse Artifacts
Parse Implementations
Parse ServiceTemplates
RefToNodeType
artifacttemplates_httpP3AP2FP2Fopentosca_orgP2Fartifacttemplates_VSphere_5_5_Clo
udProviderInterface_IA_files_org_opentosca_nodetypes_VMWare5_5__CloudProviderInt
erface_war : [VSphere_5.5]
artifacttemplates_httpP3AP2FP2Fopentosca_orgP2Fartifacttemplates_FlinkApp_IA_fil
es_start_sh : [FlinkApp]
artifacttemplates_httpP3AP2FP2Fopentosca_orgP2Fartifacttemplates_Python_2_7_Impl
_InstallIA_files_install_sh : [Python_2.7]
artifacttemplates_httpP3AP2FP2Fopentosca_orgP2Fnodetypes_Ubuntu-14_04-VM_Operati
ngSystemInterface_IA_files_org_opentosca_NodeTypes_Ubuntu-14_04-VM__OperatingSys
temInterface_war : [Ubuntu-14.04-VM]
artifacttemplates_httpP3AP2FP2Fopentosca_orgP2Fartifacttemplates_Flink_Simple_1_

```

Figure 7.1: Processing by the framework.

7.3 Displaying with the winery

The Winery was installed to test the correctness of the output CSAR. This is an environ-
ment for the development of TOSCA systems and is useful for checking the results.
The CSAR's representation by the winery is displayed in the figure 7.2. Those exter-

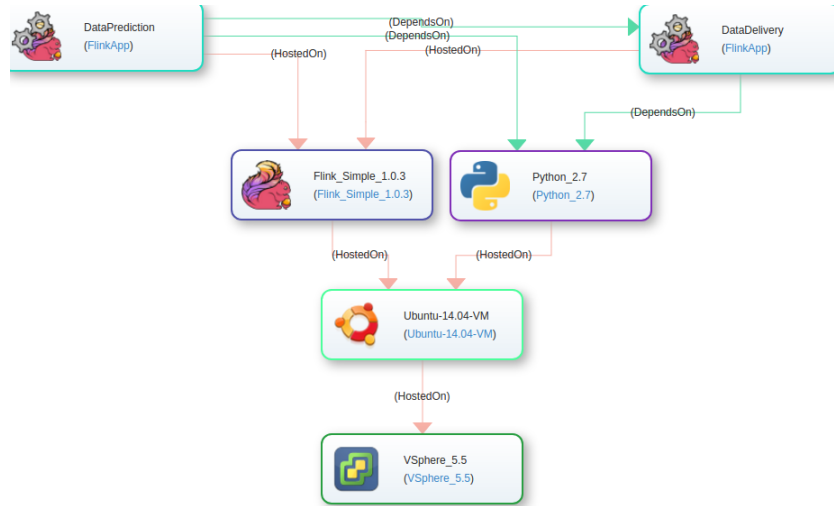


Figure 7.2: Source CSAR represented by Winery.

nal references are resolved by the framework and exchanged by new nodes in output CSAR.

7.3.1 Add to winery

This output CSAR will be added to Winery. Due to significant increase in size, this can be a fairly lengthy procedure. There were only six nodes in the input CSAR, but after the processing, it contains more than 100 of nodes. During the addition to the winery, the CSAR's syntax is tested. In case of errors, messages will be displayed.

7.3.2 Display by winery

The output CSAR will be displayed. Again, due to the high number of nodes, the processing can take a long time. At the time, the correctness of the internal references will be checked. If something was defined not properly, these erroneous nodes or links between them will not be displayed. The representation of the output CSAR by the winery is shown on the figure 7.3 (Only the part of the CSAR is visible). It seems

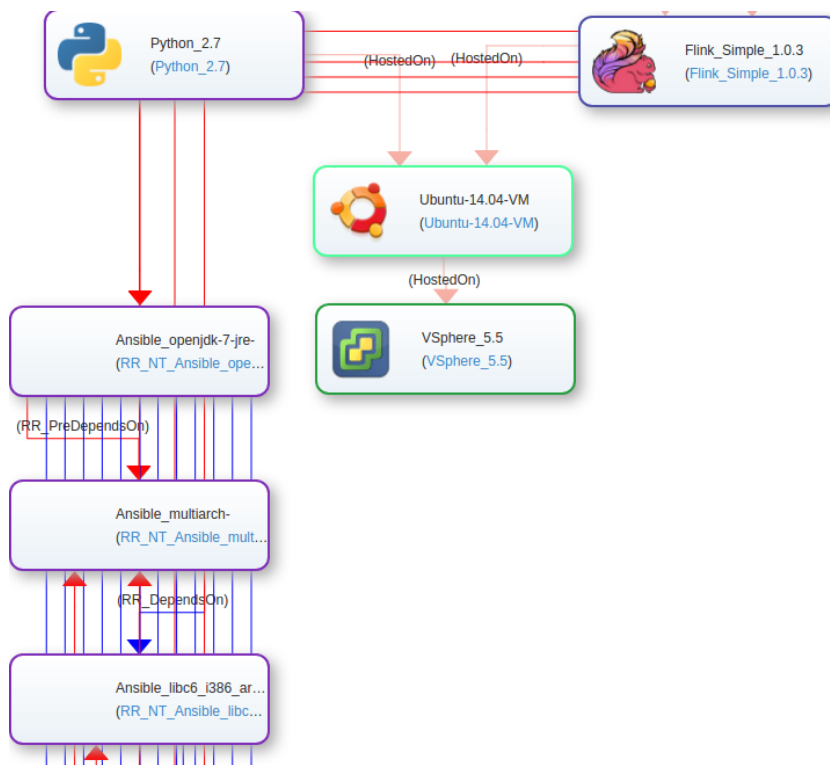


Figure 7.3: The output CSAR represented by the *winery*.

pretty beloved. To verify the TOSCA's structure some nodes were moved manually (figure 7.4). By checking several nodes with `apt-cache depends` command, the correctness of dependencies was verified. By opening the content of the new nodes, it was verified, that there are artifacts.

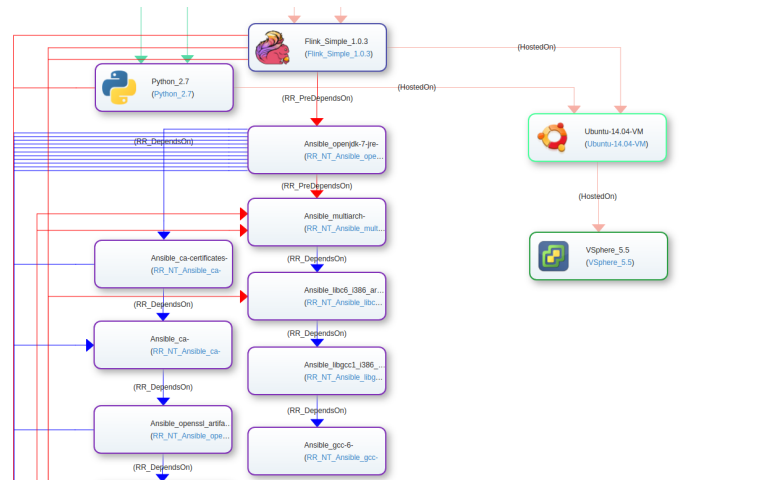


Figure 7.4: The output CSAR represented by the *winery*, some nodes moved manually.

Listing 7.1 Check bash installation script

```
user@user:~$ sudo RR_python2.7-minimal.sh
(Reading database ... 286091 files and directories currently installed.)
Preparing to unpack python2.7-minimal.deb ...
Unpacking python2.7-minimal (2.7.12-1ubuntu0~16.04.1) over (2.7.12-1ubuntu0~16.04.1) ...
Setting up python2.7-minimal (2.7.12-1ubuntu0~16.04.1) ...
Processing triggers for man-db (2.7.5-1) ...
```

7.4 Check artifacts

Also it is necessary to check whether it is possible to install new packages using the generated Artifacts. At first bash scripts will be tested, then ansible playbooks.

7.4.1 Check bash scripts

Since the bash is used in the Linux's command line, it will be pretty easy to check bash installation scripts by starting them (of course that must be done with the necessary privileges). An example of the *python2.7* installation is presented in the listing 7.1.

Since the process ended without any warnings or errors, it was completed successfully. This way any bash installation script can be checked.

7.4.2 Check ansible playbooks

To check an ansible playbook manually we need to extract the zip file containing the playbook. During the regular execution this work will be done by the runtime environment. The call of the ansible runtime to proceed the playbook is a simple procedure too. Example is provided on figure 7.5.

Ok signals that the installation was completed successfully.

```
jery@jery-note:~/TOSCA/temp$ sudo ansible-playbook ./main.yml
[WARNING]: provided hosts list is empty, only localhost is available

PLAY [install package] *****
TASK [setup] *****
ok: [localhost]
TASK [install task] *****
changed: [localhost]
PLAY RECAP *****
localhost                : ok=2    changed=1    unreachable=0    failed=0
```

Figure 7.5: An ansible playbook's execution process

8 Summary

Listings

Listing 8.1 Description for the script Artifact Type definition

```
public class RR_ScriptArtifactType {

    @XmlElement(name = "tosca:Definitions")
    @XmlAccessorType(XmlAccessType.PUBLIC_MEMBER)
    public static class Definitions {

        @XmlElement(name = "tosca:ArtifactType", required = true)
        public ArtifactType artifactType;

        @XmlAttribute(name = "xmlns:tosca", required = true)
        public static final String toska="http://docs.oasis-open.org/tosca/ns/2011/12";
        @XmlAttribute(name = "xmlns:winery", required = true)
        public static final String
            winery="http://www.opentosca.org/winery/extensions/tosca/2013/02/12";
        @XmlAttribute(name = "xmlns:ns0", required = true)
        public static final String ns0="http://www.eclipse.org/winery/model/selfservice";
        @XmlAttribute(name = "id", required = true)
        public static final String id="winery-defs-for_tbt-RR_ScriptArtifact";
        @XmlAttribute(name = "targetNamespace", required = true)
        public static final String
            targetNamespace="http://docs.oasis-open.org/tosca/ns/2011/12/ToscaBaseTypes";

        public Definitions() {
            artifactType = new ArtifactType();
        }

        public static class ArtifactType {
            @XmlAttribute(name = "name", required = true)
            public static final String name = "RR_ScriptArtifact";
            @XmlAttribute(name = "targetNamespace", required = true)
            public static final String
                targetNamespace="http://docs.oasis-open.org/tosca/ns/2011/12/ToscaBaseTypes";
            ArtifactType() {}
        }
    }

}
```

Listing 8.2 Abstract language model

```
public abstract class Language {

    // List of package managers supported by language
    protected List<PackageManager> packetManagers;

    // Extensions for this language
    protected List<String> extensions;

    // Language Name
    protected String Name;

    // To access package topology
    protected Control_references cr;

    // List with already created packages
    protected List <String> created_packages;

    /**   Generate node name for specific packages
     * @param packet
     * @param source
     * @return
     */
    public abstract String getNodeName(String packet, String source);

    /**   Generate Node for TOSCA Topology
     * @param packet
     * @param source
     * @return
     * @throws IOException
     * @throws JAXBException
     */
    public abstract String createTOSCA_Node(String packet, String source) throws
        IOException, JAXBException;
}
```

8 Summary

Listing 8.3 Abstract package manager model

```
public abstract class PackageManager {

    // Name of manager
    static public String Name;

    protected Language language;

    protected Control_references cr;

    /**
     * Proceed given file with different source (like archive)
     *
     * @param filename
     * @param cr
     * @param source
     * @throws FileNotFoundException
     * @throws IOException
     * @throws JAXBException
     */
    public abstract void proceed(String filename, String source) throws
        FileNotFoundException, IOException,
        JAXBException;
}
```

Listing 8.4 Ansible proceeding

```
public void proceed() throws FileNotFoundException,
    IOException, JAXBException {
    if (ch == null)
        throw new NullPointerException();
    for (String f : cr.GetFiles())
        for (String suf : extensions)
            if (f.toLowerCase().endsWith(suf.toLowerCase())) {
                if (suf.equals(".zip")) {
                    proceedZIP(f);
                } else
                    proceed(f, f);
            }
}

public void proceed(String filename, String source)
    throws FileNotFoundException, IOException, JAXBException {
    for (PacketManager pm : packetManagers)
        pm.proceed(filename, source);
}

private void proceedZIP(String zipfile) throws FileNotFoundException,
    IOException, JAXBException {
    boolean isChanged = false;
    String folder = new File(cr.getFolder() + zipfile).getParent()
        + File.separator + "temp_RR_ansible_folder" + File.separator;
    List<String> files = zip.unZipIt(cr.getFolder() + zipfile, folder);
    for (String file : files)
        if (file.toLowerCase().endsWith(".yaml"))
            proceed(folder + file, zipfile);
    if (isChanged) {
        new File(cr.getFolder() + zipfile).delete();
        zip.zipIt(cr.getFolder() + zipfile, folder);
    }
    zip.delete(new File(folder));
}
```

Bibliography

- [13] OASIS Standard. *Topology and Orchestration Specification for Cloud Applications Version 1.0*. Nov. 25, 2013. URL: <http://docs.oasis-open.org/tosca/TOSCA/v1.0/TOSCA-v1.0.html> (cit. on p. 17).
- [16] *OpenTOSCA for the 4th Industrial Revolution*. University of Stuttgart. 2016. URL: <http://www.opentosca.org/demos/smart-prediction-demo/index.htm> (cit. on p. 55).
- [BBH+13] T. Binz, U. Breitenbücher, F. Haupt, O. Kopp, F. Leymann, A. Nowak, S. Wagner. “OpenTOSCA - A Runtime for TOSCA-based Cloud Applications.” English. In: *Proceedings of 11th International Conference on Service-Oriented Computing (ICSOC’13)*. Vol. 8274. LNCS. Springer Berlin Heidelberg, Dec. 2013, pp. 692–695. DOI: 10.1007/978-3-642-45005-1_62. URL: http://www2.informatik.uni-stuttgart.de/cgi-bin/NCSTRL/NCSTRL_view.pl?id=INPROC-2013-45&engl=1 (cit. on p. 25).
- [Bun14] S. Bundesamt. *12 % der Unternehmen setzen auf Cloud Computing*. Dec. 19, 2014. URL: https://www.destatis.de/DE/PresseService/Presse/Pressemitteilungen/2014/12/PD14_467_52911.html (cit. on p. 17).
- [Bun17] S. Bundesamt. *17 % der Unternehmen nutzten 2016 Cloud Computing*. Mar. 20, 2017. URL: https://www.destatis.de/DE/PresseService/Presse/Pressemitteilungen/2017/03/PD17_102_52911.html (cit. on p. 17).
- [Laz16] M. Lazar. *Current Cloud Computing Statistics Send Strong Signal of What’s Ahead*. Nov. 3, 2016. URL: https://www.insight.com/en_US/learn/content/2016/11032016-current-cloud-computing-statistics.html (cit. on p. 22).
- [OAS] OASIS. *Organization for the Advancement of Structured Information Standards*. URL: <https://www.oasis-open.org/> (cit. on p. 23).
- [OAS13] OASIS. “Topology and Orchestration Specification for Cloud Applications Version 1.0.” In: *OASIS Committee Specification 01*. <http://docs.oasis-open.org/tosca/TOSCA/v1.0/cs01/TOSCA-v1.0-cs01.html>. Mar. 18, 2013 (cit. on p. 24).

- [Pet11] T. G. Peter Mell. *The NIST Definition of Cloud Computing*. Recommendations of the National Institute of Standards and Technology, Special Publication 800-145. National Institute of Standards and Technology, Sept. 2011 (cit. on p. 21).
- [Sta16] Statista. *Umsatz mit Cloud Computing** weltweit von 2009 bis 2016 und Prognose bis 2020 (in Milliarden US-Dollar)*. 2016. URL: <https://de.statista.com/statistik/daten/studie/195760/umfrage/umsatz-mit-cloud-computing-weltweit-seit-2009/> (cit. on p. 17).
- [Stu13] I. U. Stuttgart. *OpenTOSCA - Open Source TOSCA Ecosystem*. 2013. URL: <http://www.iaas.uni-stuttgart.de/OpenTOSCA/> (cit. on pp. 17, 25).
- [tec] techopedia. *Definition - What does Cloud App mean?* URL: <https://www.techopedia.com/definition/26517/cloud-app> (cit. on p. 21).
- [wika] wikipedia. *Ansible (software)*. URL: [https://en.wikipedia.org/wiki/Ansible_\(software\)](https://en.wikipedia.org/wiki/Ansible_(software)) (cit. on p. 27).
- [wikb] wikipedia. *Bash (Unix shell)*. URL: [https://en.wikipedia.org/wiki/Bash_\(Unix_shell\)](https://en.wikipedia.org/wiki/Bash_(Unix_shell)) (cit. on p. 27).

All links were last followed on July 30, 2017.

Declaration

I hereby declare that the work presented in this thesis is entirely my own and that I did not use any other sources and references than the listed ones. I have marked all direct or indirect statements from other sources contained therein as quotations. Neither this work nor significant parts of it were part of another examination procedure. I have not published this work in whole or in part before. The electronic copy is consistent with all submitted copies.

place, date, signature