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RSCM technology for developing runtime-reconfigurable telecommunication applications

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ABSTRACT

Runtime reconfiguration is a fundamental requirement of many telecommunication applications which also has been addressed by management standards like CMIP, 3GPP TS 32.602, and NETCONF. Two basic commands considered by these standards are CREATE and DELETE which operate on managed objects inside an application. The available configuration management technologies, like JMX, OSGi, and Fractal, do not support the CREATE and DELETE reconfiguration commands of the telecommunication standards. In this paper, we introduce a novel technology, called RSCM, for development of runtime reconfigurable applications complying with the telecommunication standards. The RSCM subagent takes the responsibility of loading the application from the configuration file, executing the runtime reconfiguration commands (including CREATE and DELETE), enforcing validity of the configuration state, and updating the configuration file according to the latest reconfiguration commands. We exploit the modular and object oriented features of the XML technology for storing the configuration state of a program in a configuration file. The software development process is tailored such that the design of XML schemas of managed classes is performed parallel to the design of software classes. In addition, a novel programming approach based on indirect referencing is proposed which allows safe and almost immediate deletion of managed objects at runtime. This indirect referencing mechanism affects the implementation of associations in class diagrams and prevents methods of a class to use the "this" pointer freely. The RSCM technology has been successfully used in several commercial telecommunication applications; including an SMS service center, an SMS gateway, and an SMS hub.

1. Introduction

MANY telecommunication applications, e.g. routers, gateways, and hubs, provide such critical services where it is completely unacceptable to stop them for reconfiguration; so they demand runtime reconfiguration. Several management standards, e.g. CMIP [1], 3GPP TS 32.602 [2],and NETCONF [3], have been proposed for the runtime reconfiguration of the network and telecommunication applications. These standards assume that an application consists of a set of managed objects which are organized as a tree called MIB (Management Information Base). The common runtime reconfiguration commands specified by these standards are: GET, SET, CREATE, and DELETE. The GET command gets the values of the configuration parameters, the SET command updates the configuration parameters, the CREATE command creates a new managed object, and the DELETE command deletes a managed object.

Among these runtime reconfiguration commands, the CREATE and DELETE commands are much more difficult to implement. At execution of the CREATE command, the new managed object must be completely initialized: the configuration variables, references from this object to other objects, and references from other objects to this object, all should be initialized with appropriate values. Since a managed object may contain several other managed objects, the implementation of the CREATE command should also take the responsibility of creating and initializing the subtree of the contained managed objects as well. Furthermore, for the CREATE command to be meaningful, one should specify what types of managed objects can be created and where these managed objects can be added to the MIB tree. The difficulty of implementing the DELETE command lies in the fact that there may be many references to the deleting managed object. On the one hand, deleting an object, while being referenced by other objects, leads to dangling pointers and consequently segmentation fault errors. On the other hand, postponing the deletion of a managed object until the references are released may delay the execution of the DELETE

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Table 1
Feature-based comparison between RSCM and related methods.

Feature	Technology/standard implementation				
	JMX [5]	**Work of Menten** [8]	**Fractal** [7]	**libnetconf** [4]	**RSCM**
Accepting CREATE/DELETE reconfiguration commands from managers.	No	Yes	No	Yes	Yes
CREATE/DELETE reconfiguration commands are handled automatically by subagent	No	No	No	No	Yes
Mapping the name of a managed object to a reference to the actual entity	Yes	Yes	Yes	No	Yes
Automatic handling of the configuration file	No	Yes	Yes	Yes	Yes
Distributed specification of validation constraints	No	Yes	Yes	No	Yes
Supporting inheritance relation among Managed Objects in the configuration file	No	No	No	No	Yes
Appropriate programming interfaces for CREATE/DELETE runtime reconfiguration commands.	No	No	Yes	No	Yes
Provisioning the development of manageable software libraries with built-in CREATE/DELETE runtime-reconfigurability.	No	No	Yes	No	Yes
Providing a mechanism for [safe and]almost immediate deletion of managed objects	No	No	No	No	Yes
Object Oriented Design	Yes	No	Yes	No	Yes
Supporting both C++ and Java programming languages	No	Yes	Yes	No	Yes

command for an unlimited time.

The task of executing the runtime reconfiguration commands includes many application-independent subtasks such as communicating management packets over the network, validating the reconfiguration commands, mapping the name of an object to its reference within the application, calling methods of managed objects (instead of calling a global function), and updating the configuration file according to the latest configuration state. Implementations of telecommunication standards like 3GPP TS 32.602 or NETCONF (e.g. libnetconf [4]) solely invoke a callback function, asking the application developer to perform the CREATE and DELETE commands. Various technologies have been developed that encapsulate some/all of these subtasks in a reusable software library called the subagent. The JMX technology [5], the OSGi configuration admin service [6], and the Fractal framework [7] propose the most important general purpose subagents for configuration management. The JMX and OSGi technologies are confined to the java programming language, but the Fractal framework is available both in java and C programming languages. Menten [8] developed a subagent specifically designed for management of network devices with limited resources that is specially powerful in representing and validating the configuration state using the XML technology.

However, none of these subagents support the CREATE and DELETE reconfiguration commands as specified by the telecommunication standards. While the JMX technology has provisioned mechanisms for setting and getting configuration variables and performing operations on managed objects, it does not provide any mechanism for creating or deleting managed objects at all. The OSGi configuration admin service introduces a special kind of component, called Managed Service Factory, instances of which can be used for creating and deleting managed objects of a specific managed class. However, since the OSGi configuration admin service does not support the tree structure of MIB for managed objects, the supported CREATE and DELETE operations differ considerably from those specified by the telecommunication standards. The Fractal programming framework defines a well-designed set of interfaces for Fractal components, but its subagent does not exploit these interfaces for implementing the CREATE and DELETE commands. Menten's subagent [8] finds the parent object and sends it an XML fragment containing the necessary information for creating the child object. However, it leaves the task of creating the subtree of objects, as specified by the XML fragment, to the parent object. In addition, none of these technologies address the issue of how a managed object can be deleted in a safe and immediate way.

In this paper, we introduce the RSCM (Runtime Software Component Management) technology which performs the complete DELETE and CREATE operations as specified by the standards with a minimum intervention from application programmer. The RSCM subagent exploits some simple programming interfaces, implemented by the managed objects, to fulfill the CREATE and DELETE reconfiguration commands. In addition, the proposed technology guarantees the safe and almost immediate deletion of managed objects. Since the proposed technology is targeted for the telecommunication applications, we assume that, as specified by the telecommunication standards, the relationships between managed objects can be represented as a MIB tree. We store the configuration state of the application in an XML document and use XML Schema to validate the integrity of the configuration state. In addition, the RSCM technology provides programming interfaces which can be used for defining arbitrarily complex validation rules. The RSCM subagent also takes the responsibility of updating the configuration file according to the latest reconfiguration commands.

We also pay special attention to the software engineering issues [9] of developing runtime reconfigurable applications. Specifically, we address the issue of how the proposed technology can be used in developing reusable software libraries with built-in runtime reconfigurability. Another novelty of the proposed technology is making connections between the object oriented design in the programming language and the XML Schema of the configuration file.

We have implemented the RSCM subagent in C++ and java programming languages. A CLI (Command Line Interface) complying with ITU-T Z.315 [10] standard and a web-based interface complying with the 3GPP TS 32.603 [11] standard have been developed for management of the applications developed by the RSCM technology. Table 1 compares the RSCM technology with JMX [5], work of Menten [8], Fractal [7] and libnetconf [4].

The rest of the paper proceeds as follows. In section II, we introduce the RSCM technology and explain how it addresses the key issues of developing runtime reconfigurable applications. In Section III, we report some experiments on development of real-world telecommunication applications with the RSCM technology. We conclude the paper in Section 4.

2. The proposed technology

2.1. Subagent's management operations

After studying various network and telecommunication management standards, we concluded that the subagent should support the following basic management operations:

2.1.1. Operations for investigating the MIB tree

2.1.1.1. ListChildren. This operation takes the name of a parent