Model-Driven New Generation Telecommunication Services Modeling Framework

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Abstract: This paper presents an innovative model-driven new generation telecommunication services modeling framework (for short, MdTSMF). A methodology applying MDA (Model Driven Architecture) to new generation telecommunication services creation within web service based Service-oriented Architecture (SoA) environment is proposed. According to telecommunication services characteristics, MdTSMF extends the CIM (Computation Independent Model) of MDA. In PIM (Platform Independent Model) phase, UML Profile is used to abstract service related meta-model, including telecommunication services meta-model, SLA based QoS meta-model and service supporting function meta-model. A method for transformation rules from PIM to Web Service PSM (Platform Specific Model) is discussed. At last, MdTSMF presents two possible approaches to validate UML based service models.

Key words: MDA, NGN, Service Modeling Framework, UML

1 Introduction

New generation telecommunication networks (3G/4G, NGN) present openness, distributed, heterogeneous, convergent development trend. The telecom domain has a general consensus that the new generation networks consist of an underlying Network Architecture (NA) and an up-layer Service Architecture (SA) (BAR Jagot & al., 2002). It is considered that the NA will be a packet-based, QoS-enabled network, SA will be a flexible, openness service enabling environment to support easier service creation and service management. The success key of new generation telecom networks is to provide divergent, personalized services or applications. Currently, the main efforts of telecom field are to open up the underlying network resources through the opening API technologies, such as Parlay/OSA (Parlay 2004, OSA 2003) specified by Parlay Group, 3GPP and ETSI, as well as JAIN of SUN MicroSystem. The approach of opening API enhances the reusability of network service capabilities, but there is little support for reuse at the application modeling level (Babak A & al., 2002). Old service creation methods are unable to meet the current open service environment requirements. However, the new methodology of rapidly creating valued-added services in an economical manner is very scarce. This paper attempts to apply MDA to new generation telecommunication services development to resolve this problem.

MDA (MDA Guide 2003) has been declared by OMG (Object Management Group) as the next strategic direction in software development field. The foundations of MDA are UML (Unified Modeling Language), XMI (XML Metadata Interchange), MOF (Meta Object Facility), CWM (Common Warehouse Metadata) standards. MDA attempts to enhance the abstraction level of software development by separating system business function from platform-specific implementation technology. The core of MDA is its conceptual models, includes CIM (Computation Independent Model), PIM (Platform Independent Model), PSM (Platform Specific Model), and model transformation rules. CIM mainly describes the domain and requirements of system, capturing the requirement information; PIM is a model of system that has not any technology-specific implementation information. PSM describes the model of system that uses one or more specific platform implementation technology. Based on standards already supported by a large segment of the software engineering industry, MDA promises fully automatic model transformation from PIM to PSM, and automatic PSM to code generation.
Applying MDA method to telecommunication services development will result in following advantages. Firstly, service development progress is speeded up and development cost is decreased effectively (Eurescom P1149 project 2002). MDA heightens the abstraction level of service creation, so service developers only need design PIM according to CIM regardless of underlying implementation technology details. Secondly, the application reusability is enhanced and service portability across different platforms is improved. PIM specifying business function could be transformed to one or more platform PSMs based on specific transformation rules. When the underlying platform technology is evolved, PIM can be transformed to new PSM smoothly according to new transformation rules.

The objective of this paper is to present a model-driven telecommunication service modeling framework to instruct the new generation services development process. The remainder of this paper is structured as follows: section 2 describes the openness, distributed, heterogeneous service architecture and service creation environment; section 3 presents the architecture overview of MdTSMF; section 4 proposes the extension methodology of CIM, describes the service requirements capture and analysis model; section 5 discusses platform independent service model, analyzes the telecommunication service related meta-models abstraction at PIM level; section 6 introduces platform specific service model, including web service based service-oriented architecture PSM and QoS-supported BPEL4WS modeling method; section 7 specifies the model transformation rules; section 8 presents the validation method of UML based service model and section 9 gives some conclusions and future research work.

2 Service Architecture and Service Creation Environment

The new generation telecommunication network is generally separated two parts: NA (Network Architecture) and SA (service architecture). NA consists of all kinds of access networks (such as Circuit Switched Domain, Packet Switched Domain, IP multimedia subsystem and other wireless local area networks) and transport networks (ATM+IP+GMPLS). This paper focuses on SA and divides SA into four parts: user terminal application environment which is hosting on user terminal, service enabling architecture, application servers and service creation environment. Service enabling architecture is an openness, distributed middleware processing environment, including service management platform, opening network resource access platform and various service enablers. Service management platform takes charge of service provider management, service lifecycle management and service roaming, etc. Opening network resource access platform indicates the gateway providing standard API, such as Parlay/OSA gateway. Service enablers refer to all kinds of service capability servers, such as call control server, message service server, location service server and so on. Application servers provide service logic execution environment. Service can be deployed on different application servers based on different implementation technology platforms. Service creation environment provides telecom domain related metamodels, service creation methodology and supporting tools. Service developers are able to create new value-added services easily and quickly through service creation environment. This paper focuses service creation related method and technology. Figure 1 depicts the relationship of these elements of service architecture.

![Figure 1. Service Architecture and Service Creation Environment](image)

3 MdTSMF Architecture Overview

MDA is a common software development architecture, whose focus is laid on all kinds of related standard specification and does not concern any methodology and guidelines aiming at a specific domain (such as telecom service creation). This paper, according to the idea of MDA, presents a concrete model-driven telecom service creation approach within service-oriented architecture based on web service--MdTSMF (Model-driven Telecommunication Services Modeling Framework) (Figure 2). The goal of this approach is to provide a plug and play, new telecom service creation approach, which obviously separates service function specification from specific APIs and implementation techniques, supports the domain models shared. In conclusion, in the open service-oriented architecture, MOF (Meta Object Facility) (MOF 2.0 Core Proposal 2002) is used to model, integrate and manage domain meta-data; XMI (XML Metadata Interchange) (XML Metadata Interchange version 1.1 2002) is used to storage and access to MOF-compliant domain models. Consequently, the same service model can be "imported and exported" by different modeling tools, realizing the “Plug and Play” mode of models and enabling the service models not to be confined by the specific modeling tools. Besides, service function model is independent of interface technique and implementation technique, the same PIM can be mapped to different PSM with different model transformation engine. Accordingly, the model transformation engine plays a “Plug and Play” role.
Therefore, the flexibility, reusability and portability of telecom service software are all improved greatly, and the software lifecycle is prolonged accordingly.

The model-driven telecom service creation environment faces to 2 kinds of developers. One is domain meta-model designer, whose main responsibility is to abstract and construct kinds of telecom service-related meta-models and implement meta-models using UML Profile extension mechanism. Besides, they are also responsible for design of model transformation rules. The other is general service developer, who makes use of all kinds of meta-models to design service function logic and then apply model transformation rules to service models to accomplish the transformation from PIM to PSM or PSM to code.

Figure 2. OSA/Parlay Web Service application development approach based on MDA

Figure 2 depicts the MDA-based telecom service development approach within Parlay Web Service environment, which includes 5 steps:

1) Service requirement analysis model: mainly includes service definition, service function description, analysis of service value chain relationship, accounting and benefit distribution mode, specifying appropriate under-layer network type, demand to network and terminal facilities, target customers, standard and specification abided by service, demarcating the boundary of service system and network environment, specifying the roles participated in the service activity, requirements for software and hardware, and so on.

2) PIM is divided into 2 abstraction levels—service analysis model and service design model. First, by refining the requirement analysis model, service developers make use of telecom service-related domain meta-models to construct the platform independent service analysis model. This model doesn’t concern any API technique and implementation details, but only concentrate on service function logic and non-function constraints. Then, by adding platform independent software design pattern, the transformation from platform independent service analysis model to platform independent service design model is completed. The software design pattern adopted above is Enterprise Collaboration Architecture (ECA) of Enterprise Distributed Object Computing (EDOC) (UML Profile for EDOC 2002) set down by OMG. ECA is independent of any implementation platform technique, which can map to different implementation platforms, such as Component Collaboration Model (CCM) of CORBA. In this model, the platform independent Enterprise Collaboration Architecture (ECA) model is mapped to web service specific model in the light of Web Service for Enterprise Collaboration (WSEC) (WSEC RFP, 2002).

3) Platform specific service model is also abstracted to 2 levels: one is the open API technique specific model, and the other is the implementation platform technique specific model. Within the web service environment, the main interface includes Parlay API and Parlay X API (Parlay X specification 1.0, 2004). In order to map the telecom service-related meta-model used at PIM level to concrete interface technique model, it is necessary to abstract the meta-models of these 2 API specifications. The unified API technique model encapsulates the differences of under-layer concrete network interfaces. And the implementation platform technique specific model refers to the implementation manner of a specific interface. For example, the same interface can be implemented by CORBA technique or by Web Service technique. In this paper, we adopt web service as distributed object computing technology. Web service can host on several concrete platforms, such as Java, EJB, .NET and so on. Therefore, the layer of implementation platform technique specific model is mainly composed of Web Service hosting platform model and Web Service technique related model. The former mostly describes the information related to web service implementation platform technique, and the latter depicts Web Service itself, such as WSDL (Web Service Description Language) model, SOAP (Simple Object Access Protocol) model and so on.

4) Through model transformation engine, platform specific service model can generate implementation code and configuration files automatically or semi-automatically. Web service hosting platform model is responsible for generating source code of hosting platform, as well as related configuration and deployment files. Whereas the web service technique specific model is used to generate web service technique related files, such as SOAP, UDDI (Universal Description, Discovery, and Integration), WSDL, BPEL4WS (Business Process Execution Language for Web Services) and so on. Lastly, the compiled executable program can be deployed on application server to run.
5) The function of model transformation. Just as showed in Figure 2, model transformation plays a role in 3 aspects. Firstly, the transformation from PIM to PSM, that is, from telecom service related model to concrete interface technique model, such as mapping to Parlay or Parlay X API. Secondly, the transformation from the platform independent software design architecture (ECA) to the Web Service related design architecture (WSEC). Lastly, in the process of PSM to code, concrete implementation platform technique specific models are transformed to code.

According to telecom domain peculiar characteristics, MdTSMF couples MDA methods of software engineering field with telecom domain existing service specifications, modeling languages and methods. The following sections will illustrate the methodology of MdTSMF in details.

4 Service Requirements Capture and Analysis Model

The concrete guidelines of CIM still have not been specified by OMG MDA Group. But the service requirements play an important role in telecommunication service development. So MdTSMF puts forward some concrete, practical approaches to service requirement capture and analysis.

4.1 Multiple Views and Multiple Angles Modeling

Different stakeholders of telecommunication services have different requirements. In service requirement analysis phase, MdTSMF defines three views for telecommunication services, including service user view, service provider view and telecom operator view. Every view consists of some “care” points. For example, service user cares the service price policy, using manner, user terminal configuration requirements, etc. However, service users do not care the implementing technology of service. On the other hand, telecom operator cares service deployment, service data and user data management, service access control and authorization, underlying network resource requirements, and so on.

4.2 Functional and non-Functional requirements Modeling

Telecom operator need to provide quality of service guaranteed service for users. Moreover, different services require different service quality. So the telecommunication service requirement analysis must concern about both functional requirements and non-functional requirements. For instance, message service (Short Message Service, Multimedia Message Service) requires transportation reliability and message integrity, insensitive to delay time. The voice service, however, requires low delay time. MdTSMF emphasizes not only functional requirements, but also non-functional requirements. Different services have different QoS parameters set.

5 Platform Independent Service Model

The function of service platform independent model is to maintain service logic function separately from underlying implementation technology. As MDA is a UML based universal software development approach, there are no telecom domain related metamodels to support service modeling. In order to support new generation QoS-guaranteed service modeling, MdTSMF abstracts three kinds of metamodels using UML Profile extension mechanism (Unified Modeling Language Specification, 2002), including telecommunication services meta-models, SLA based QoS meta-models, service supporting function meta-models. The following part will discuss these meta-models respectively.

5.1 Telecommunication Services meta-models

Through analyzing the services development trends and characteristics of new generation telecommunication networks(3G/4G, NGN), MdTSMF specifies the class of services and abstracts the various service meta-models, mainly including call service, message service, location service, user interaction service, information content service, presence & availability service. Every service consists of some sub-services, for instance, call service comprises general call, multiparty call and multimedia call. MdTSMF creates <<Service>> stereotype to support service meta-model abstraction using UML extension mechanism. The Figure 3 depicts part structure of service meta-models.

5.2 SLA Based QoS meta-models

In distributed, heterogeneous service environment, for new generation multimedia services, especially composite services, quality of service need to be guaranteed. In order to resolve this problem, service user and service provider subscribe SLA (Service Level Agreement). SLA specifies the quality of service parameters, such as bandwidth, response time, service availability, pricing policy, etc. However, current service development methods hardly support QoS requirements modeling. In order to satisfy the provisions of SLA, MdTSMF provides SLA based QoS meta-models for service modeling. Service QoS model will be mapped to corresponding QoS processing mechanism of PSM under the help of
specific transformation rules. The following Figure 4
introduces the QoS concept model. Every customer
subscribes a SLA which comprises all user subscribed
service contracts. Every service contract corresponds
to a service QoS profile described by one or more QoS
statements. QoS statement comprises QoS constraint
which uses QoS parameters.

Service developer uses this QoS meta-model to
specify non-functional requirement and then bind it to
concrete functional element.

![Figure 4. SLA Based QoS Concept Model](image)

5.3 Service Supporting Function meta-models

Telecommunication network resources need to be
accessed by the third party application programs in a
security, authorized manner. On the other hand,
personalized services need a personalized service
enabling environment to provide customization
configuration mechanism. On this analysis base,
MdTSMF abstracts some necessary service
supporting function meta-models comprising access
control model, billing model, service discovery
model, service profile model and user preference
profile model.

![Figure 5. Service Supporting Function Concept Model](image)

6 Platform Specific Service Model

PSM depicts the specific implementation platform
related system behaviors. One PIM can be mapped to
different PSMs. For example, one service PIM can be
mapped to CORBA PSM or Web Service PSM, and so
on. As web service technologies can resolve the
seamless communication problem in distributed,
heterogeneous network environment, international
standard organizations (such as 3GPP, Parlay, ETSI,
OMA) attempt to apply web service technologies to
new generation service network. Parlay Group and
3GPP have published higher abstraction level Parlay
X Web Service. Currently they are jointly trying to
specify Parlay Web Service specification. Otherwise,
web service technologies are integrated with other
Internet technologies, such as Grid technology,
Semantic Web. Some promising technologies, for
instance, Semantic Web Service (Peer, J. 2002) and
OGSA (Open Grid Service Architecture), are
emerging. Considering web service technologies
enabling to integrate telecom network with Internet,
MdTSMF focuses on web service technologies
specific design model. The foundational research
comprises two parts: web service based SoA (Service-
Oriented Architecture) (M. P. Papazoglou & al. 2003)
meta-model abstraction, QoS-supported web service
workflow modeling mechanism.

6.1 Web Service based Service-oriented
Architecture Modeling

Web service is one rapidly evolving middleware
technology. Its standards, such as WSDL, SOAP,
UDDI, are constantly revised. In order to protect the
investments on web service based applications,
MdTSMF adopts UML Profile to create the platform
independent conceptual architecture model of web
service based SOA. This conceptual model mainly
describes the static aspects of web service, including
SoA roles, such as service registry agency, service
provider, service requester, as well as operations and
messages, for instance, publish, find and bind.
Through applying MDA to modeling web service
technologies, MdTSMF increases the resilience of
service as web service technologies evolve. Figure 6
depicts the components and interfaces of SoA.

![Figure 6. Web Service based Service-oriented Architecture](image)

Figure 7 describes find operation dependencies
relationship. Service requester represents requested
service description through a stereotype
<<RequestDescription>>. Service provider specifies its
service through a stereotype
<<ServiceDescription>>, and then registers to service
registry agency. When service requester uses find
interface to discover the needed service, service
registry agency will look up satisfied service to
respond. Then service requester uses bind interface to
utilize service.
6.2 QoS-supported Web Service Workflow Modeling

The conceptual model of SOA describes static aspects and basic web service behaviors. However, new generation telecommunication services will always be complex and need compose some web services to complete the special function. Web service workflow languages, such as WSFL (Web Service Flow Language) (F. Leymann 2001), WSCI (Web Service Choreography Interface) (Web Service Choreography Interface 1.0. 2002), BPEL4WS (Business Process Execution Language for Web Services, for short, BPEL) (Business Process Execution Language for Web Services, version 1.1. 2003), are used to specify the collaborations and interactions of web services. MdTSMF adopts UML extension mechanism to model BPEL (Marlon Dumas & al., 2001). BPEL provides an XML notation and semantics for specifying business process behavior based on web services. A BPEL4WS process is defined in terms of its interactions with partners. A partner may provide services to the process, require services from the process, or participate in a two-way interaction with the process. Thus BPEL orchestrates web services by specifying the order in which it is meaningful to call a collection of services, and assigns responsibilities for each of the services to partners. Currently, IBM declared that its Rational XDE has implemented the mapping from UML 1.4 to BPEL 1.1. (Gardner & al., 2003) Table 1 shows the mapping relationship.

Table1. UML to BPEL mapping overview

<table>
<thead>
<tr>
<th>UML Construct</th>
<th>Profile Construct</th>
<th>BPEL4WS Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;&lt;Process&gt;&gt;</td>
<td>&lt;&lt;class&gt;&gt;</td>
<td>BPEL process definition</td>
</tr>
<tr>
<td>Activity graph on a &lt;&lt;Process&gt;&gt;</td>
<td>&lt;&lt;class&gt;&gt;</td>
<td>BPEL activity hierarchy</td>
</tr>
<tr>
<td>Hierarchical structure and control flow</td>
<td>&lt;&lt;receive&gt;&gt;, &lt;&lt;reply&gt;&gt;, &lt;invoke&gt;&gt;</td>
<td>BPEL variables</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BPEL sequence and flow activities</td>
</tr>
</tbody>
</table>

Currently, however, there are no suitable QoS processing models to deal with the performance of web services collaborations in distributed environment (Cardoso, J. 2002. Daniel A. Menasce 2003). The technical route of MdTSMF is to establish one UML based QoS processing mechanism models at web service PSM level in order to correspond to QoS models at PIM level. One composite task can be decoupled with several basic subtasks. At the same time, maybe multiple web services can implement the same subtask. So we need to select the suitable web service according to QoS requirements. MdTSMF’s QoS processing mechanism model comprises dynamic service selection, QoS performance prediction, fuzzy evaluation rule repository, knowledge repository. Dynamic service selection model is used to select some suitable web services from service registry agency. QoS performance prediction model utilizes the rules of fuzzy evaluation rule repository and information of knowledge repository to predict the QoS of composite web service. As different telecommunication services require different quality of service. MdTSMF assigns different value weight to QoS parameters of specific service. For example, voice service requires low delay, narrow band; but multimedia video service specially requires broad band transportation guarantee. SMS requires reliable service. The value weights of QoS parameters for every service are stored in fuzzy evaluation rule repository. QoS performance prediction model will use these value weights to compute the suitability degree of each web service, and then select the best one. In order to reduce the selection time of services, some suitable web services are kept in knowledge repository and updated real time.

7 Model Transformation

Model Transformation (J. Whittle 2002) comprises two parts: On the one hand, model static structures, such as service related meta-models (namely business meta-models) mapping to web service based platform meta-models. On the other hand, model dynamic behaviors transformation, for example, service logic execution process mapping to BPEL4WS execution process. Model transformation rules play an important role in MDA model transformation. Through the further refined marking, PIM source model can be mapped to PSM target model. The following Figure 8 depicts the model transformation process.
related constrained rules. One PIM model can be marked in different way, and then can be mapped to different PSM models. Telecom domain service related constrained rules mainly consist of service invocation rules, data access and store rules, resource allocation rules and exception process rules.

8 Model Verification Methods

As MdTSMF adopts the model based programming patterns, the verification of service model is very important before model transformation and code generation. The verification of service model can check the deadlock, or other state errors. There two possible approaches to model verification.

8.1 Executable UML Model

This is the ideal approach to MDA model verification. The United Modeling Language provides modeling foundations for both the structural and behavioral parts of a system. However, as UML 1.x lacks the capability of precise and formal action semantics description, UML 1.x based models are not executable. Now OMG are adding action semantics to UML 2.0 standards. The integration of the Action Semantics into UML will support the executable UML model verification, which uses SDL formal semantics and integration with MSC to enhance the simulation and validation capabilities of UML.

In conclusion, when UML 2.0 is not supported by modeling tools, MdTSMF will adopt approach 2. Once UML 2.0 is mature, approach 1 is proposed.

8.2 Mapping UML-based Model to SDL

In the telecommunication domain, ITU-T has specified the Specification and Description Language (SDL) (SDL 1999). Originally SDL has been developed to support the specification of telecommunications systems, especially communication protocols. Now SDL has been extended to a specification language for distributed real-time interactive systems. SDL has formal semantics and is well integrated with Message Sequence Chart (MSC) (Message Sequence Charts, 2000) which is suitable for verification of simulation or testing. Currently, ITU-T and OMG have started to jointly address the SDL combined with UML. So MdTSMF provides another SDL approach to UML model verification, which uses SDL formal semantics and integration with MSC to enhance the simulation and validation capabilities of UML.

In conclusion, when UML 2.0 is not supported by modeling tools, MdTSMF will adopt approach 2. Once UML 2.0 is mature, approach 1 is proposed.

9 Conclusions and Future Research

This paper mainly presents an innovative model-driven approach to telecommunication services modeling framework. Applying MDA to telecommunication service development is confronted with many challenges, for example, the establishment of standard UML Profile for new generation telecommunication services modeling, the model transformation rules, the MDA supporting tools, etc.

At present, we are doing some research on the prototype system of the model-driven service creation environment with the MDA tool— ArcStyler4.0 (ArcStyler 4.0 2004) of IO-Software company. And according to the features of ArcStyler4.0, the approach presented in this paper is adjusted to implement the code generation. The concrete adaptation is: PSM and specific transformation rules are integrated into one Cartridge which is responsible for model transformation. Some platform specific information items are defined to Marks in Cartridge. Once created, service PIM is then marked by the defined Marks. At last, the marked PIM is transformed to generate code directly by Cartridge. Now, we have implemented the third party call application within Parlay X environment in this way.

As the function of ArcStyler4.0 supporting model to model transformation is not mature, the Cartridge of prototype system is relatively complex. But the service development productivity has been enhanced. With the advancing of MDA standards and supporting tools, the advantages of the model-driven service creation approach presented in this paper will be completely manifested. It is really one expecting approach to implement telecom value-added service development with MDA-based service creation methodology and technique. Based on the completed research work, we will lay emphasis on further extension of telecom service meta-model, and the study of model to model transformation rules and its implementation engine in future.

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