A UML Tool for Urbanism and Control Architecture Design Applied to 3GPP Based Architectures

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Abstract: The following paper deals with the design of telecom networks control architectures. It presents a tool named OURDIR that satisfies the need to describe precisely and formally the design of control architectures. Based upon the software architecture design methods and principles, it enables to benefit from the advantages of UML [1] and from the meta-modelling concepts to structure the control architectures domain. Hence, it identifies and associates a set of architectural control elements able to chart and assemble in a methodical mode the functions, functional entities, and organs and the links between. The tool solves the traceability issue and improves the quality of the design process and allows methodical links between the structural elements and constraints via Urbanism, architecture and engineering rules. The paper includes an illustrative example of the tool's usage in the process of describing a 3GPP[2] IMS based architecture.

Keywords: Architecture, Control Functions, UML, Urbanism, 3GPP, meta-modelling.

1 INTRODUCTION

In today's competitive Telecom market, the technological breakthroughs drive major operators to develop the strategy to deliver convergent services. The challenge is to integrate, different mobile and fixed access technologies, already deployed in ad-hoc heterogeneous environments, into a homogeneous architecture. France Telecom defines this process with the term Urbanism.

3GPP-IMS based architectures integrate an IP (Internet Protocol) based multi-services support responding to this convergence need. This architecture contributes to the target retained by France Telecom. Therefore, defining a migration plan to this target is of major importance. This comes to saying that existing and target architectures both need to be considered and represented in a rational formalized manner in order to define a migration plan. Functional modelling is one of the major opportunities for a telecom operator to view its legacy and target control architectures in a simplified but formalized manner. This allows the re-engineering of the control architecture where useful, in order to reach the target. In our paper we study how the architectures can be viewed from a functional perspective. For this purpose we have created a software based architecture tool: "OURDIR". Through this tool we have integrated different functional modelling techniques known to the telecom and IT world, by addressing the problem on a higher level. The difficulty of integrating all these comes from the fact that it is hard to compare them directly.
1.1 The Tool

OURDIR is based on a software approach. Indeed, the same problem was observed in the software industry where applications built in different frameworks were difficult to integrate. The software engineers and researchers have elaborated a solution by defining multiple abstraction levels to be used in the software design and analysis process: "meta-modelling". We have used this technique to elaborate our architecture tool.

In this paper we first list some functional models and design techniques known to the telecom field. Afterwards, an explanation of the meta-modelling technique is given. We then exhibit the tool's principles and associate it with the urbanism process. An outlook of the results the tool's usage in a 3GPP-IMS based architecture project is then given. We finally conclude on the benefits already perceived and discuss the perspectives and future work.

2 LEGACY TELECOM FUNCTIONAL MODELS

The functional models have the objective of managing the complexity of the telecom world by providing a high level view of the details. Here's a list of some of these models:

- ITU-T's "Generic functional Architecture of Transport Networks"(G.805 [3] and G.809 [4]). These recommendations address only the transport domain of the telecommunications network and provide a graphical and logical method for representing and binding a set of identified functional elements.
- TMN (Telecommunications Management Network) is another ITU-T's effort describing a set of functional components (M.3400 [5]) covering some management principles (performance, errors, configuration, accounting and security) in a telecom network.
- ETSI's (European Telecommunications Standards Institute) TISPAN (Telecoms & Internet converged Services & Protocols for Advanced Networks) provides a next generation networks functional architecture [6] from a control point of view and tries to align its recommendations with the 3GPP's technical specifications.
- 3GPP [2] is a major operator and equipment vendor project that aims to define the third generation of mobile communications requirements and architecture and provides a set of specifications with a functional and a technical description.
- GAT [11] (Global Framework for Architecture Analysis in Telecommunications) is a functional classification issued from e-tom (e (Business) Telecom Operation Map) that adds a usage process to the telecommunication business organization map. It is used as a classification tool for control functions. It has been elaborated by France Telecom.

All these models try to approach the functional modelling in a semantic manner. They are not always 100% compatible and interoperable. TINA [8] (Telecommunication Information Networking Architecture) stands at the crossroads of Telecommunication and the IT (Information Technology) industries. The TINA principles offer a complete model and process for designing and analysing telecom and IT services. It can be considered as the first successful marriage between software* and telecommunication principles. The problem with TINA is that it tries to solve all the problems with one single framework and that it isn't flexible enough to include all the control approaches and models. Our tool fills this gap by using the meta-modelling technique.

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* As it is based on OMG's CORBA (Common Object Request Broker Architecture) [9].
3 THE META-MODELLING TECHNIQUE

Meta-modelling is the activity of "creating a model at a higher level of abstraction than the thing being modelled [12]". The meta-modelling technique is very well known by software architects and has driven the OMG to establish the MDA (Model driven Architecture [7]) whose objective was to revolutionize the software design process by creating a PIM (Platform Independent Model) that can be specialized into many Platform Specific Models.

3.1 Benefits of Meta-Modelling in the Software Design Process

The Main benefit of the MDA approach is using different levels of abstractions in order to tailor the same application into different platforms† by injecting for each specification a defined implementation model: the Platform specific information.

Here's a success story of using MDA and model driven engineering. An optical fibre networks operator‡ needed to build an Operations Support System while utilizing numerous existing 3rd party hardware and software systems in order to provide fast on-demand services. Such a system had to communicate automatically and reliably between more than a dozen components and allow for upgrades of new equipment. The OMG's MDA was chosen for the development. It turned out to be more than 50 times as efficient as hand coding [15].

3.2 Using the Meta-Modelling Technique in the Functional Modelling Process

Due to the numerous functional approaches of designing telecom architectures, using the meta-modelling technique seems to be a good idea: We have found it important to elaborate a global model capable of integrating multiple architectures described each in a different approach. In the software industry, UML has become the de-facto modelling formalism. The latest version UML 2.0 integrates more facilities for the modellers providing ways to extend the basic formalism to specific areas of interest and vocabulary. Moreover, some extensions to the UML were encouraged by the OMG like the UML Testing Profile [13] and SysML [14]. They provided an added value to UML for the Testing and System Engineering fields respectively. Following this example we have created a tool including meta-model for control architectures that benefits from the extension possibilities of UML and model driven engineering thus providing a handy tool for the telecom architects.

4 THE TOOL (OURDIR)

OURDIR "A tOol for the URbanism Design of telecommunIcations networks control aRchitectures" is a set of structural control element types logically linked with specific associations. In this section we first outline the urbanism process defined by France Telecom in which OURDIR is used. We then define the main structural elements of OURDIR and how they fit in the urbanism process.

† For example CORBA [9] or JAVA [10]
‡ Looking Glass Networks (http://www.iglass.net)
4.1 The Urbanism Process

OURDIR was designed to respond to the urbanism needs defined in France Telecom. Since urbanism is a large concept. We will only define the urbanism concepts relative to the control architecture of telecommunications network.

Urbanism allows progressive and continuous transformation of services and networks by simplifying and optimizing their added value in order to make them more reactive and flexible following the strategic evolutions defined by the operator. Thus Urbanism consists in defining the target and the associated transitions considered as most favourable for the operator but also to promulgate the rules and to develop the building blocks which will make it possible to produce the target. The Urbanism regarding control architecture is an iterative process of three essential sequential phases: (Figure 1)

1. To chart the existing networks: It consists in first defining the structural elements of the studied telecommunications system. Then it defining in a precise and formalized way the roles and capacities of those elements and there associations and encapsulations. This activity produces cartography of the existing networks.

2. To consolidate the cartography: In this phase, consolidation rules are deduced from the cartography. They make it possible to show the components combined using a particular structure. Hence we are able to validate the coherence of existing architectures by indicating all the reusable and combinable building blocs.

3. To define the evolution rules: The evolution rules aim at approaching a defined target for future Telecom networks. The evolution rules result from the strategy, the re-distribution of business roles and the technological developments defined by the operator. These rules can modify, when applied, the structure of the predefined cartography in order to generate the target cartography and the possible migration paths towards that target.

Finally an additional phase makes it possible to use the cartography to prepare the deployment plan by defining the organs\(^5\) that respond to the required needs using engineering techniques.

4.2 The Tool's Structure

The tool proposes the structure and associations defined using the meta-model in Figure 2 and Figure 3. It contains five categories: Functional Components, Support Functions, Reference Points, Rules, and Interrelations.

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\(^5\) Or equipment types
Functional Components

Functions: The meta-model is centred on functions. A control function carries out a unitary task in a control process by offering interfaces to other functions or functional entities or by using other functions interfaces. For example the function **UserIdentification** (Figure 4) checks the status of a user and gives information on the FN which manages him, using the offered interface "identify".

Functional entities: when a set of functions are always used together, a very strong bond allows them pertinently to be found associated in several control architectures. They are assembled in a one container: a Functional Entity. A functional entity has a number of interfaces offered to other functional entities or functions and can use in the same manner the interfaces offered by others. An illustrative example of a functional entity is shown in Figure 4 where ServiceAccessIdentification provides the functions: UserIdentification, UserAuthentication, TerminalIdentification and LineIdentification.

** Drawn from an ETSI TISPAN draft listing unitary control functions
**Organs**: To prepare a deployment of the functional entities and functions, a definition of an equipment type is given through organs. They give the functional design a technical perspective by integrating the engineering know-how, and technical feasibility: an Organ may implement the functional entities "media gateway controller" and "media gateway" because a lot of equipment vendors propose these functions in the same equipment. **Support Functions**

Support functions are functional information platforms used by functions and functional entities to store control information they may produce or use. Two types of support functions are distinguished: User Information Functions (subscription information, user's identities, Service Level Agreements, etc.) and Network Information Functions (network topology information, resource availability information, etc.)

**Reference Points**

The reference-points define the functional requirements of binding two functions or functional entities to operate properly together. They include the required and offered operations between functions in a binding. Reference Points are also used to define the perimeter of a functional entity by only providing the requirements and offers to the outside. Hence, a Reference Point defines a user/provider relationship between both functions and functional entities. **Figure 5** shows a reference point GateOpeningControl2GateOpening binding functions: GateOpening and GateOpeningControl. The GateOpeningControl requires the operations "openGate" and "closeGate" from gate opening. Section 5.4 shows that the links between Organs are technical instances of the requirements in reference points.

![Figure 4. Examples of functions composing a functional entity](image)

![Figure 5. A reference point example linking the gate opening control to the gate opening](image)

**The Rules**

Given the meta-model in Figure 3 you can notice the presence of 3 entities: UrbanismRules, ControlArchitectureRules and EngineeringRules. The rules guarantee the integrity of the functional design in the urbanism process with respect to the operator's requirements. We will only define those rules (Examples will be given in section 5)

**Urbanism rules** are of two types: Consolidation rules and Evolution rules (see section 4.1). They are associated to the functional entities.

**Control Architecture Rules**: they are associated to the Reference points. They define how a pair of functions is linked.

**Engineering Rules**: are associated with organs (Figure 3). They inject the engineering know how in order to prepare a deployment phase of the functional architecture (see section 4.1).
The Interrelations

A series of interrelations define the nature of the association between the structural elements. They are listed on Figure 2 and defined within the meta-model of Figure 3. They allow us to define the nature, the cardinality and the roles in the relationship between instances of the structural elements. The association "Apply" between organ and engineering rule in Figure 3 indicates that an undetermined number of organs can apply an undetermined number of engineering rules. The organ indicates the rule it applies.

4.3 The Recommended Method for Using the Tool

There is no restriction on how to use the tool in the urbanism process or in any architectural design project related to telecom. However, we implemented the tool in a UML profile, to take full advantage of the offered possibilities.

A UML profile is a set of stereotypes that allow adding specific information to a design element within a UML model. In our case we have defined a control architecture profile that contains stereotypes defined after the structural elements in the meta-model (Figure 6). Thus if we apply the "Function" stereotype of Figure 6 to a model element, it can encapsulate the information contained in the tagged values of the stereotype: the description the GAT classification, the TISPAN classification (Section 2) and the used support functions. So goes for the other stereotypes††

Figure 6. The tool's profile stereotypes

In addition to this we recommend using three types of views (see examples in section 5):

The Composition View shows what component Functions and Functional Entities are within the composite Functional entities (just like in Figure 4). In addition to this, the Urbanism Rules (Consolidation and Evolution) are associated to the composite Functional Entities. Moreover Organs can be associated to the functions and functional entities they implement.

The Architecture View shows how the functions and functional entities are linked by the Reference Points (Figure 5) and what Control architecture Rules they apply.

The Organic View shows the organs as well as the associated engineering rules for a possible implementation of the Architectural and Composition views along with instances of the communication protocols chosen for the overall architecture.

†† For more clarification we have provided enumeration types listing the GAT levels and the TISPAN subsystems in Figure 6
5 AN APPLICATION EXAMPLE IN A 3GPP-IMS ARCHITECTURE

In this section we will give an example using the tool describing some intermediate results for the urbanism process regarding the IMS architecture. Showing the different detailed phases of the urbanism like the elaboration and definition of the urbanism, control architecture and engineering rules is considered to be out of the scope of this paper.

5.1 What is the IMS?

IMS is an essential entity of the 3GPP architecture that contains all core network and access network elements, responsible for the provision of multimedia services. This includes the collection of control signalling and bearer related network elements. IMS is conformant to the IETF (Internet Engineering Task Force) Standards and is based on SIP [16] (Session initiation Protocol). More information about IMS is available on the 3GPP website‡‡ [2].

5.2 A global composition view of the IMS

Figure 7 shows a composition view of the IMS. Hence the functional entities Subscriber Information and Location Handling, Call Session Control Functions (CSCF), External Signalling Control and Media Handling and the function Security Gateway are components of the IMS. The IMS and the functional entity Subscriber Information and Location Handling both apply the Urbanism Rule 1. Following the same reasoning, Call Session Control Functions is composed of: Proxy CSCF, Policy Decision Function, Serving CSCF and Interrogating CSCF. Call Session Control Function applies the Urbanism Rule 2. A series of Organs represent a candidate implementation of the shown architecture: the organ CS Signalling Implementation implements MGCF (Media Gateway Control Function), BGCF (Border Gateway Control Function) and Signalling Gateway. An example urbanism rule is Rule 2: "A single session control is recommended for establishing and handling signalling sessions, it contains all the functions involved in session establishment and related signalling"

‡‡ In the following sections we only describe the structure of the architecture. The use cases that apply can be found in the technical specifications on the 3GPP website.
5.3 An Architectural View of the Functional Entity: Call Session Control Functions

Figure 8 shows the internal architecture of Call Session Control Functions. In this view the 3 components: Proxy CSCF, Serving CSCF and Interrogating CSCF are linked together with the Mw reference point. The Functions Proxy CSCF and Policy Decision Function are linked together using the Gq reference point. All reference points are associated with architecture rules: Mw applies the rule that states "A single and exclusive session control protocol is used is used for communication between session control functions".

5.4 An Organic view of the IMS Architecture

Finally, Figure 9 shows an organic view of a candidate functional implementation of the IMS following some field related engineering rules. Hence you can notice that instantiations of the architectural links between the organs show the specific engineering rules they apply: "SCSCF Implementation", "ICSCF Implementation" and "PCSCF Implementation" are organs linked with an interaction. This interaction is the instance of the link realized by the Mw reference point in Figure 8. Those Organs apply an instance of the Control Architecture Rule 6 related to Mw. This instance is an Engineering Rule (ER1) and it states that "SIP [16] should be used as the communication protocol between the organs".

Figure 8: An architectural view of the Call Session Control Functions showing both internal and external reference points and related Control Architecture Rules.

Figure 9. An organic view showing a candidate functional implementation of the IMS following some field related engineering rules.
6 CONCLUSIONS AND PERSPECTIVES

In this paper we have presented a tool we have created for the architects involved in the urbanism process in France Telecom. We have also showed how it is applied for a 3GPP based architecture. Thus we have proven that this tool is a good way to formally describe existing and target architectures and to integrate and keep track of the requirements. It can also be used for communication between the operator and telecom equipment vendors with the organic view. Thus applying the successful software design approaches to telecom. This tool turns the ad-hoc models of the telecom services and architectures into a higher level well formalized set of views using a standard formalism UML. Thus we have showed that the model driven engineering philosophy is possible in the telecom design field.

In our future work we will try to elaborate dynamic views showing the interactions between control functions in order to complete the static set of views already proposed. We will also try to find a way to formalize the rules related to the components by adapting a UML related standard: OCL (Object Constraint Language).

7 REFERENCES AND LINKS

2. 3GPP website, http://www.3gpp.org
5. ITU-T Recommendation, "TMN Management Functions" (M.3400), July 2004
16. SIP RFC 2543 http://www.ietf.org