RE4DIST: Model-based Elicitation of Functional Requirements for Distributed Systems

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Abstract: Nowadays, software-based systems are often decomposed into several distributed subsystems. The complexity of those systems and the decomposition in different subsystems requires a detailed analysis and documentation of functional requirements. Documenting and managing the functional requirements in a consistent manner is a challenge for software engineers. The requirements for each subsystem cannot be considered in isolation, but it is necessary to state the relations between the functional requirements, too. In this paper, we propose a model-based method to elicit and document functional requirements for distributed systems. Our contribution is two-fold: By providing a requirements model, we first enable consistent documentation of the requirements for the different subsystems and make relations between them explicit. Second, we propose a method to systematically elicit functional requirements of distributed systems. By using the proposed model, we document the results in a consistent manner. Our approach is tool supported, which simplifies its application.

1 INTRODUCTION

Nowadays, software-based systems are often realized as distributed systems. (Tanenbaum and Steen, 2006) define a distributed system as a system whose components are located on different connected computers. Those components communicate via messages to achieve a common goal. Using functional requirements, we describe the functionalities of a distributed system during requirements engineering that are necessary in order to achieve that common goal.

The complexity of distributed systems faces software engineers with new problems during the whole software development process. Especially in one of the earliest phases of software development, namely requirements engineering, it is a challenge for engineers to capture all aspects of a distributed system under development. Although the different components may be deployed independently of each other in different environments, the functionalities of the components highly depend on each other. Thus, it does not suffice to elicit and document requirements for each component independently. In addition, the connection between the components is often remote and hence, is not reliable.

For further analysis, e.g. with regard to privacy or security, it is of essential importance to document the dependencies and interfaces between the subsystems in a consistent and systematic manner. For example, an attacker may inject malicious code on the client side which will then affect stored data on the server side. In addition, the components of distributed systems are often connected via unreliable connections, e.g. via the Internet.

Our aim is to assist software engineers in performing detailed and systematic elicitation and documentation of functional requirements for distributed systems. In this paper, we propose a model-based method called *RE4DIST* (**R**equirements **E**ngineering for **DIST**ributed Systems) which is based on Michael Jackson's problem frames (Jackson, 2001) which allows to model functional requirements in a systematic manner. We first introduce a requirements model based on his terminology, which we extend with regard to distributed systems to make the relations between the different subsystems and their cross-cutting requirements explicit. Based on that model, we provide a method to systematically elicit and document functional requirements and their relations. Our method starts with understanding and documenting the context in which the distributed system shall operate along with the initial set of functional requirements. Next, we identify overlapping functional requirements. We go on with decomposing the over-

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all context into overlapping parts, each describing the concrete context for a subsystem. Last, we use problem diagrams to make dependencies between requirements explicit. For each step of the method, we define validation conditions that ensure detecting errors during the application of the method as early as possible. Using diagrams, we provide a user-friendly view on the elements of the model.

To simplify the application of our method, we provide a tool[1] based on the *Eclipse Modeling Framework* (Steinberg et al., 2009). The tool assists software engineers in instantiating the model using graphical editors and wizards that guide through the method's application. Using the semantics of the models along with OCL (Object Constraint Language), we formalize the validation conditions for automatic evaluation. For the diagrams we use in our method, we provide an intuitive notation based on Google's Material Design[2]. In the present paper, we describe the tool for each step of the method in detail.

The remainder of the paper is the following: In Section 2, we introduce Michael Jackson's problem frames as background knowledge. We introduce our requirements model for distributed systems in Section 3, and we describe our proposed method in Section 4. Using a small case study, we exemplify the application of the method in Section 5. We discuss related work in Section 6 and conclude the paper in Section 7 with a brief summary and an outlook on future research directions.

2 BACKGROUND

To model functional requirements, we make use of the problem frames approach as introduced by Michael Jackson (Jackson, 2001). We consider two types of diagrams, context diagrams and problem diagrams, which both consist of domains, phenomena and interfaces.

Machine domains () represent the piece of software to be developed.

Problem domains represent entities of the real world. There are different types: biddable domains with an unpredictable behavior, e.g. persons (), causal domains () with a predictable behavior, e.g. technical equipment, and lexical domains () for data representation. A domain can take the role of a connection domain (), connecting two other domains, e.g. user interfaces.

[1]RE4DIST - https://swe.uni-due.de (last access: May 16, 2019)

[2]Google Material - https://material.io (last access: March 15, 2019)

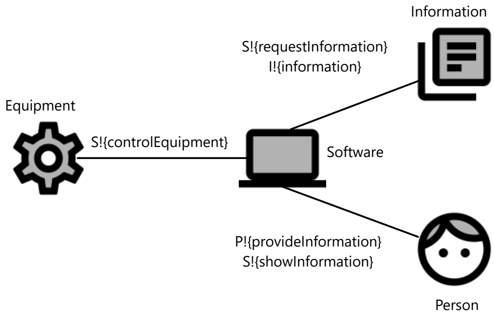


Figure 1: Example for Context Diagram.

Interfaces between domains consists of phenomena. There are symbolic phenomena, representing some kind of information or a state, and causal phenomena, representing events, actions and so on. Each phenomenon is controlled by exactly one domain and can be observed by other domains. A phenomenon controlled by one domain and observed by another is called a shared phenomenon between these two domains. Interfaces (solid lines) contain sets of shared phenomena. Such a set contains phenomena controlled by one domain indicated by *X!*{...}, where *X* stands for an abbreviation of the controlling domain).

A context diagram describes where the problem, i.e. software to be developed, is located and which domains it concerns. It does not contain any requirement. We show an example of such a diagram in Figure 1. It contains four domains and the corresponding interfaces. There are *Software* , *Equipment* , *Information* , and *Person* .

A problem diagram is a projection of the context. It contains a functional requirement (represented by the symbol) describing a specific functionality to be developed. A requirement is an optative statement which describes how the environment should behave when the software is installed.

Some phenomena are *referred to* by a requirement (dashed line to controlling domain), and at least one phenomenon is *constrained* by a requirement (dashed line with arrowhead and italics). The domains and their phenomena that are *referred to* by a requirement are not influenced by the machine, whereas we build the machine to influence the *constrained* domain's phenomena in such a way that the requirement is fulfilled.

In Figure 2, we show a small example describing a functional requirement for updating some information which is a projection of the context given in Figure 1. A *Person* provides information to *Software* to be updated. We make use of a lexical domain *Information* to illustrate a database. The functional requirement *Update* refers to the phenomenon *up-*

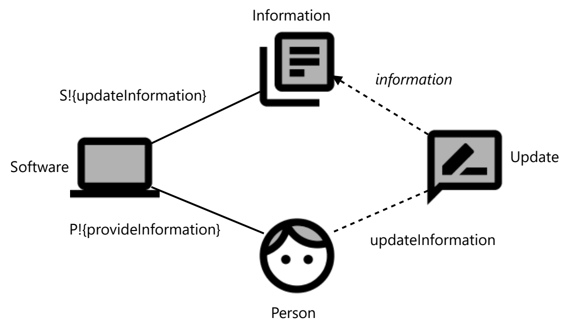


Figure 2: Example for Problem Diagram.

dateInformation and constrains the phenomenon *information*.

The icons we use in our diagrams differ from Jackson's notation. We adopted icons from Google's Material Design[3] to provide intuitive views for the diagrams.

3 REQUIREMENTS MODEL

In the following, we propose a requirements model to document the requirements for a distributed system. In Figure 3, we illustrate the structure and the core elements of that model. We use the problem frames notation as introduced in Section 2 as the basis for it, and we introduce additional elements to describe functional requirements of distributed systems. We highlight newly introduced elements in gray. The root element of the model is the *Requirements Model* itself. It contains two types of *Diagrams*: *Problem Diagrams* and *Context Diagrams*. We introduce two new types of context diagrams. A *Global Context Diagram* describes the overall context of the distributed system. A *Sub Context Diagram* is derived from it and describes the context for a specific subsystem.

The model contains a set of *Domains*, which are contained in at least one diagram. We distinguish four types of domains: (1) *Machine*, (2) Problem Domain, (3) *Remote Machine*, and (4) *Distributed System*. A distributed system consists of at least two machine domains, each representing a subsystem. A remote machine is a problem domain and denotes a machine that is part of the distributed system. Later on, we use the newly introduced problem domain to make the relation between different subsystems explicit. A machine domain represents the part of the distributed system to be developed, and a remote machine represents other subsystems that are related to it. Each domain can control an arbitrary number of *Phenomena*.

An *Interface* contains a set of phenomena, and each diagram contains at least one interface between two domains. We introduce a specialization of an interface called *Remote Interface*. Such an interface connects a machine with a remote machine and makes an unreliable connection explicit. To describe the realization of interfaces in more detail, we adapt the so called attack vector from the *Common Vulnerability Scoring System* (CVSS) (FIRST.org, 2015). An attack vector has predefined values to describe how an attacker accesses a vulnerable component. We introduce an *AccessVector* to describe how domains interact with each other. The vector distinguishes the following four values: *Network (N)* describes remote connections through different networks, e.g. connections via the internet, *adjacent (A)* stands for local network connections, *local (L)* means access to domains not connected to the internet, and *physical (P)* describes physical access to domains.

Requirements are part of a problem diagram and describe the functionalities of the distributed system. We introduce *Distributed Requirements* to describe functional requirements which concern different subsystems.

Tool Support. We decided to build our tool based on the *Eclipse Modeling Framework (EMF)* (Steinberg et al., 2009). EMF is open source and offers a wide range of products for model-based development. For example, we will use Eclipse Sirius[4] to provide a graphical editor for the application of our method.

For our requirements model, we define an Ecore meta-model for the requirements model. The meta-model provides semantic rules, that ensure a consistent and correct instantiation. The notation is similar to UML class diagrams (Object Management Group, 2015) and consists of classes, their attributes, and relations between them. Additionally, we make use of OCL expressions (Object Management Group, 2014) to define further semantic rules and to define formal validation conditions that help to validate instances of the meta-model. In the following, we make use of the model to document the results of our method when using our tool. Due to its complexity, we do not show the Ecore meta-model here.

[3] Google Material - https://material.io (last access: March 15, 2019)

[4] Eclipse Sirius - https://www.eclipse.org/sirius/ (last access: March 12, 2019)

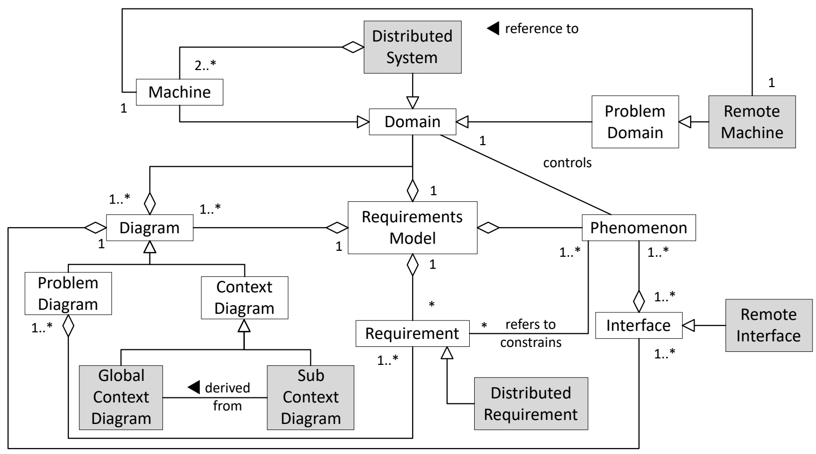


Figure 3: Core Elements of Requirements Model.

4 METHOD

Our method to elicit and document functional requirements for distributed systems (DS) consists of five steps. In Figure 4, we provide an overview of the steps and the corresponding input and output of each step. For each step, we present examples of validation conditions (VC) to ensure that errors occurring during the application of our method can be identified as early as possible. In addition, we briefly describe the tool which supports the application of our method. In Section 5, we provide a case study which exemplifies our method.

4.1 Step 1: Define Global Context & Subsystems

The goal of the first step is to get an understanding of the global context in which the distributed system will operate. We consider an informal scenario description as input. Based on this input, we identify problem domains in the context of the distributed system.

We document the results in a context diagram as described in Section 2. There is exactly one distributed system domain (represented by the symbol) in the context diagram which covers all subsystems that shall be developed. Since existing systems do not need to be developed, we describe them by means of causal domains. Using interfaces, we describe the communication between the distributed system and the environmental domains.

For the distributed system, we identify those subsystems that shall be developed. There are at least two subsystems. The subsystems do not necessarily differ from each other. For example, in a peer-to-peer system, the subsystems realized as peers can have the same functional requirements. We represent the subsystems as machine domains with aggregations to the distributed system in the context diagram.

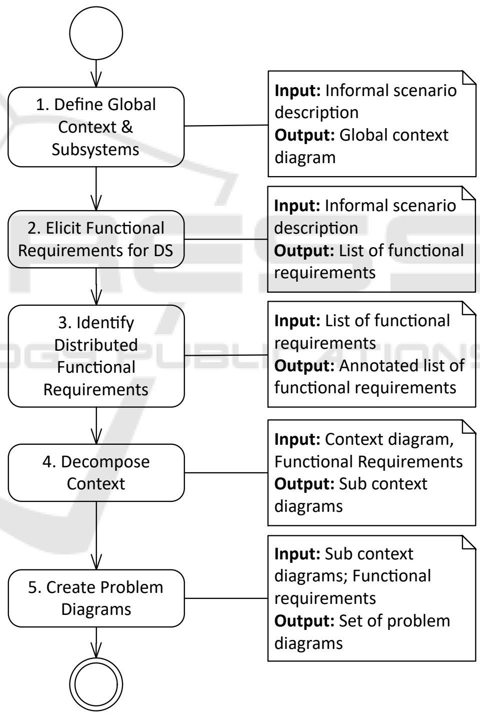


Figure 4: Method Overview.

Validation Conditions. Based on the above-presented description of the step, we define four validation conditions (VC).

VC1 There is exactly one distributed system in the global context diagram.

VC2 A distributed system consists of at least two subsystems.

VC3 All subsystems have been identified and have been documented in the context diagram.

VC4 All problem domains of the context have been identified, e.g. stakeholders and technical equipment.

Tool Support. As mentioned in Section 3, we make use of an Ecore model for our tool. To define the initial context and subsystems, we provide a graphical editor based on *Eclipse Sirius*[5]. The editor assists software engineers in creating the initial context diagram and ensures the semantic rules provided by the model.

Our tool supports the automatic validation of *VC1* and *VC2*. The other two conditions have to be validated manually, but we ask the user of the tool to confirm the validation before proceeding to the next step.

4.2 Step 2: Elicit Functional Requirements for DS

Based on the informal scenario description and the global context diagram, we identify the functional requirements that the distributed system shall satisfy. For each functional requirement, we define a unique name and a proper description of the expected functionality, and we document both textually.

Validation Conditions. For the second step of our method, we define two validation conditions.

VC5 Each functional requirement has a unique name and a valid description.

VC6 Each functional requirement has been identified and has been documented.

Tool Support. Our tool provides a table to list all functional requirements one by one. To this table, one can add new requirements using a wizard, and all requirements will be stored in the model to be reusable in further steps.

The first validation condition can partially be checked via the model, whereas the second one has to be confirmed by the user of our tool before proceeding to the next step.

[5]Eclipse Sirius - https://www.eclipse.org/sirius/ (last access: March 12, 2019)

4.3 Step 3: Identify Distributed Functional Requirements

Due to different environments in which the subsystems may be realized, e.g. a mobile application in contrast to a server application, different teams will be involved in developing a distributed system. Therefore, we distinguish requirements that only concerns a single subsystem, and others requiring the interaction between different subsystems to be satisfied.

In the present step, we make the distinction of types explicit to assign the requirements to the responsible development team. In addition, we document dependencies of subsystems for satisfying requirements. For each requirement, we decide about its type and assign a set of responsible subsystems. A requirement that concerns at least two subsystems has to be considered as distributed, and in a distributed system there is at least one requirement concerning several subsystems.

Validation Conditions. We define two validation conditions for the third step of our method.

VC7 Only requirements concerning at least two subsystems have been classified as distributed.

VC8 At least one requirement has been defined as distributed.

Tool Support. To specify the type of requirement, our tool presents the list of requirements to the user where he/she can select the type. For distributed requirements, we provide a dialog to select the related subsystems. Using references to the corresponding machine domains, our tool documents the results in the model and updates the list of requirements.

Both stated validation conditions can be validated automatically using our tool.

4.4 Step 4: Decompose Context

In the first step of our method, we described the global context of the distributed system. As mentioned earlier, different teams will be involved in developing a distributed system. In the present step, we break down the global context in smaller units, one for each subsystem. Again, we make use of context diagrams which we call *Sub Context Diagram* to document the results, one for each subsystem.

Such a sub context diagram consists of the machine domain for the subsystem and the relevant problem domains. To express the relation between the subsystems, we introduce new elements to the context diagram, namely remote machines (represented by the symbol) and remote interfaces (dotted line). For each related subsystem with which communication exists, we add a remote machine domain and the corresponding remote interface.

The interfaces between machine and problem domains are taken from the global context definition, but the remote interfaces describing the communication between subsystems do not exist there and hence, need to be added.

The set of sub context diagrams help developers in focusing on the context of a concrete subsystem. However, we do not omit the relation to other subsystems.

Validation Conditions. To validate the application of the fourth step, we define the following five conditions:

VC9 There is one context diagram for each subsystem.

VC10 Each domain of the initial context diagram is contained in at least one context diagram of a subsystem.

VC11 Interfaces between machine and remote machine have been marked as *remote*.

VC12 Each context diagram contains all related subsystems represented by means of remote machine domains.

VC13 Only problem domains directly connected to the subsystem or via a connection domain are part of the context diagram.

Tool Support. Our tool automatically creates a sub context diagram for each subsystem. It automatically adds related machines based on the requirement specifications taken from step three and the remote interfaces in-between. We also provide a wizard to select relevant problem domains, phenomena, and interfaces from the initial context. A graphical editor allows adjusting the generated diagrams. To ensure consistency between all steps, we make use of model references to the results of the previous steps.

Except for the last one, our tool allows to automatically evaluate the validation conditions. For the last step, it asks the user to confirm the manual validation.

4.5 Step 5: Create Problem Diagrams

The final step of our method is the creation of problem diagrams for the functional requirements we identified in the second step. For requirements not being classified as distributed, we create problem diagrams as proposed by Michal Jackson (Jackson, 2001) based on the sub context diagram for the responsible subsystem. To specify an interface in more detail, it is possible to add connection domains, e.g. a user interface.

To specify the interfaces in more detail, we annotate the type of connection described with an access vector as introduced in Section 3.

For requirements being classified as distributed, we create one problem diagram per involved subsystem. Those diagrams contain the relevant problem domains taken from the sub context diagram and remote machines for subsystems related to the functional requirement. To connect machine and remote machines, we again make use of remote interfaces.

A distributed requirement is characterized by the communication between machine and remote machine for its satisfaction. Therefore, the requirement *refers to* or *constrains* at least one phenomenon of a remote machine. *Refers to* means that the remote machine triggers an event of the machine to be considered, and *constrains* means that the machine to be considered triggers an event of the remote machine. The annotated phenomenon describes that event.

Validation Conditions. For the final step of our method, we define three validation conditions.

VC14 Each functional requirement is contained in at least one problem diagram.

VC15 For each distributed requirement, there is one problem diagram for each involved subsystem.

VC16 A distributed requirement *refers to* or *constrains* at least one phenomenon of a remote machine.

Tool Support. Using our tool, users can generate problem diagrams for each requirement and each subsystem, respectively. The initial structure of the diagrams can be generated automatically. In addition, we provide a wizard that assists users of the tool in selecting relevant problem domains and interfaces from the model, and in adding connection domains. Again, we use references to existing model elements to ensure consistency between all diagrams.

Our tool can evaluate all validation conditions automatically.

4.6 Final Output

The final output of our method is a set of diagrams for each subsystem. The set consists of a context diagram for the subsystem and problem diagrams which describe the functional requirements to be satisfied by the subsystem. The set allows independent development of each system while still preserving dependencies to other subsystems. Since the output is model-based, changes will be propagated throughout the whole model.

5 CASE STUDY

In the following, we apply our method to a smart grid case study, which is inspired by the *OPEN Meter* project (OPEN meter Consortium, 2009). The diagrams and tables we show in the following have been created with our tool.

5.1 Informal Scenario Description

For the present paper, we focus on a small part of the overall scenario that concerns the customer's home. We provide the initial scenario description in the following: The communication hub is the central gateway, for which software shall be developed. Smart meters measure the customer's power consumption. They transmit the data in given intervals to the communication hub where the data is stored. In addition, a customer can connect to the communication hub using a mobile application on a smartphone or tablet. Customers can configure the mobile application to connect to their communication hub and can then request a list of stored meter data.

5.2 Step 1: Define Global Context & Subsystems

Our distributed system is called *Open Meter*, for which we present the global context diagram in Figure 5a. We identified the stakeholder *Customer*, who is able to enter a *Configuration* for the mobile application and who can request previously stored meter data. We consider a *Smart Meter* as existing technical equipment. Measured data will be stored persistently in the database which we call *Meter Data*.

In Figure 5b, we provide an overview of the different subsystems that shall be developed. Our distributed system consists of two subsystems: The *Communication Hub* will be realized as an embedded system for the gateway at customers' home. The *Mobile App* will be realized as software for smartphones and tablets.

5.3 Step 2: Elicit Functional Requirements for DS

For our scenario, we identify three functional requirements which we document in a table such as shown in Table 1.

Enter Configuration. Customers can configure the mobile application to connect to the communication hub.

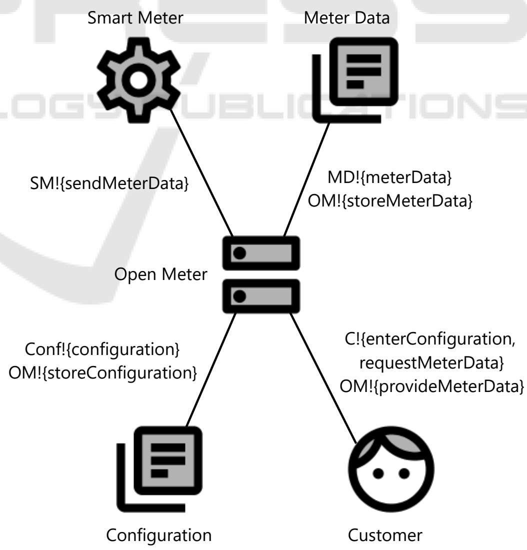
Request Meter Data. Customers can request a list of their meter data via the mobile application.

Store Meter Data. In given intervals, smart meters send the measured data to the communication hub, where it is stored persistently.

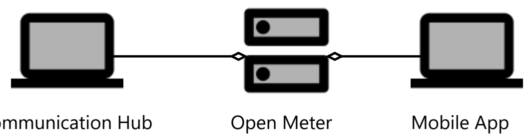
5.4 Step 3: Identify Distributed Functional Requirements

Next, we identify those requirements that concern more than one subsystem.

Enter Configuration. Customers enter the configuration locally in the mobile application. There is no communication with other systems and therefore, the requirement is not considered as distributed.



(a) Context Diagram



(b) Subsystems

Figure 5: Case Study - Global Context Diagram & Subsystems.

Table 1: Case Study - Requirements.

	Description	Is distributed?	Concerned Subsystems
Enter Configuration	Customers can configure the mobile application to connect to the communication hub.	☐ no	[Mobile App]
Request Meter Data	Customers can request a list of their meter data via the mobile application.	☐ yes	[Mobile App, Communication Hub]
Store Meter Data	In given intervals, smart meters send the measured data to the communication hub, wh	☐ no	[Communication Hub]

Request Meter Data. To request the meter data, customers use their mobile application to access the communication hub. The communication hub then returns the stored data. Both subsystems are involved in that process, and therefore we consider the requirement as distributed.

Store Meter Data. Smart meters connect to a communication hub. There is no interaction with other subsystems.

We marked the distributed requirement in the table as shown in Table 1.

5.5 Step 4: Decompose Context

Our scenario contains two subsystems, *Communication Hub* and *Mobile Application*. Hence, it is necessary to define one sub context diagram for each.

Communication Hub. Figure 6 shows the context diagram for the *Communication Hub*. The domain *Meter Data* represents the database where the communication hub stores the measured data persistently, and a *Smart Meter* sends the measured data. Since the *Mobile App* is also part of the distributed system, it is represented as a remote machine. The interface between both subsystems is unreliable and therefore marked as a remote interface.

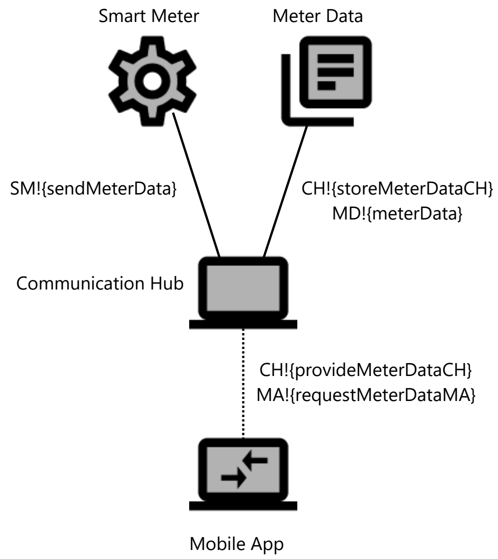


Figure 6: Case Study - Sub Context Diagram for *Communication Hub*.

Mobile Application. For the *Mobile App*, we develop the context diagram in Figure 7. It consists of the *Customer* who uses the application, a *Configuration* and the *Communication Hub*, which is again connected to the machine with a remote connection. There are phenomena to enter the configuration and to request meter data.

5.6 Step 5: Create Problem Diagrams

There are three functional requirements in our scenario for which we present the corresponding problem diagrams in the following.

Enter Configuration. Since the requirement *Enter Configuration* is not a distributed requirement, there is only one problem diagram. It consists of the *Customer*, the *Mobile App* and the *Configuration*. In addition, we decided to make the *User Interface* of the mobile application explicit.

The interface between customer and user interface is physical (P). The interfaces between user interface and mobile application, and between mobile application and configuration are both local (L).

The requirement *Enter Configuration* constrains the phenomenon of the *Configuration* and refers to the phenomenon of the *Customer*. We show the problem diagram in Figure 8.

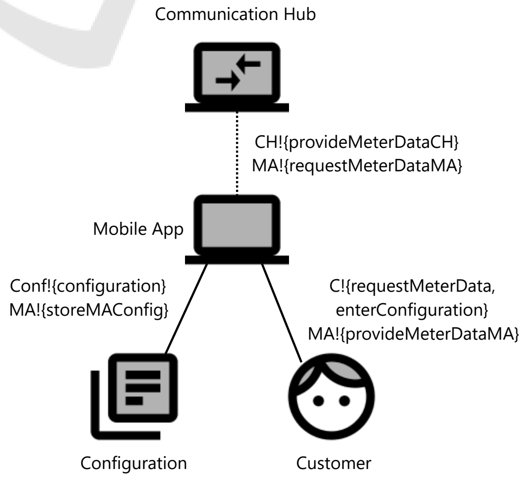


Figure 7: Case Study - Sub Context Diagram for *Mobile Application*.

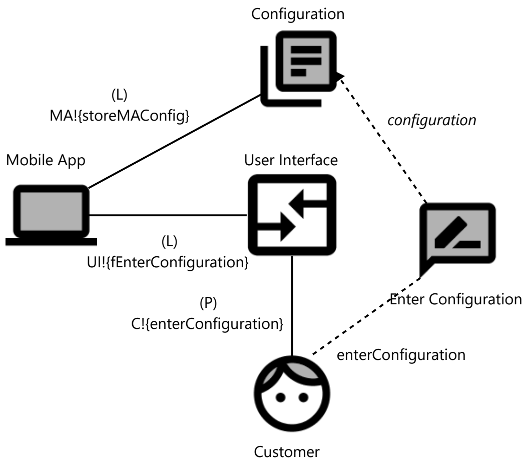


Figure 8: Case Study - Problem Diagram for *Enter Configuration*.

Store Meter Data. We show the problem diagram for the requirement *Store Meter Data* in Figure 9. It consists of the *SmartMeter*, the *Communication Hub* and the *Meter Data*.

Since a smart meter uses the local network to communicate with the communication hub, the interface is classified as adjacent (A). Between communication hub and meter data, there is a local interface.

The requirement constrains the phenomenon of the *Meter Data* and refers to the phenomenon of the *Smart Meter*.

Request Meter Data. We identified the requirement *Request Meter Data* as distributed, because it concerns both subsystems. Therefore, we derive problem diagrams for the *Communication Hub* and for the *Mobile App*. We present both problem diagrams in the following.

Mobile App. In Figure 10, we show the problem diagram for the requirement *Request Meter Data*

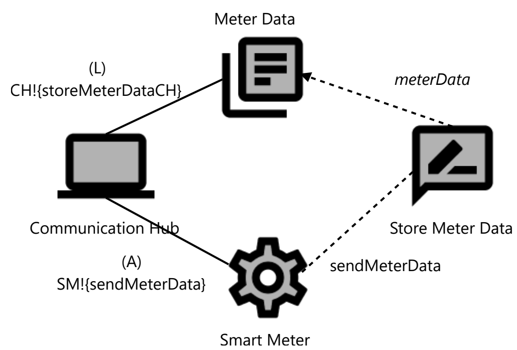


Figure 9: Case Study - Problem Diagram for *Store Meter Data*.

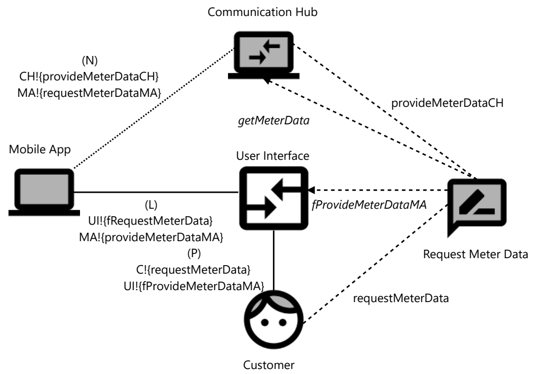


Figure 10: Case Study - Problem Diagram for *Request Meter Data* for *Mobile App*.

with regard to the *Mobile App*. It contains the machine, the *Customer* who initiates the request, the *User Interface*, and the remotely connected *Communication Hub*.

Between customer and user interface, we again consider a physical interface (P), and between user interface and mobile app, there is a local interface (L). Since mobile application and communication hub can communicate remotely via the internet, there is a network interface (N).

The requirement refers to the phenomenon *enterConfiguration* of the *Customer* and to the phenomenon *provideMeterDataCH* of the remote machine. It constrains the phenomenon *getMeterData* representing the event to retrieve the data from the database, and the phenomenon *fProvideMeterDataCH* of the *User Interface* representing the feedback for the customer.

Communication Hub. We show the problem diagram for the *Communication Hub* in Figure 11. It consists of the machine, the *Meter Data* and the remotely connected *Mobile App*.

The types of interfaces are the same as in the previous diagrams.

The requirement refers to the phenomenon of the *Meter Data* and to the phenomenon *requestMeterDataMA* of the *Mobile App*. In addition, the requirement constrains the phenomenon *provideMeterDataMA*, since the *Communication Hub* initiates the event to provide the meter data to the customer.

6 RELATED WORK

(Haley, 2003) argues that the problem frames notation does not allow to specify a *limited to many relation* between interfaces. Therefore, the author suggests using cardinalities on interfaces. Cardinalities

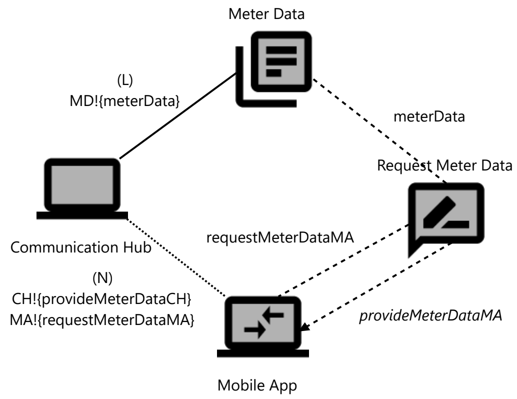


Figure 11: Case Study - Problem Diagram for *Request Meter Data* for *Communication Hub*.

would extend our notation to be more precise in specifying the relations between the different subsystems, e.g. to state the number of concurrent instances.

The same author introduces so called projection domains to document relations between different units of distributed architectures (Haley et al., 2004). The approach does neither provide detailed documentation of the context for each subsystem nor a method to systematically identify overlapping requirements.

(Mohammadi et al., 2013) propose a framework to combine goal-oriented requirements engineering with problem frames. The proposed framework allows extending problem and context modeling approaches with soft-goals, e.g. for security. Using the framework in our method is a promising way to improve the context definition.

(Beckers and Fabender, 2012) describes a pattern-based approach for capturing quality requirements like performance. Since we focus on functional requirements, the proposed pattern and our method can complement each other.

(Ramachandran and Mahmood, 2017) discuss the state of the art in requirements engineering for distributed computing. The authors put a special focus on cloud computing which became very popular in the last years. The presented work can be used to refine our method with a special focus on cloud computing.

(Penzenstadler, 2010) defines a catalogue of criteria to decompose systems and their requirements. There are criteria for context, functionalities and design of software. The presented catalogue may help to further describe the subsystems we identified with our method.

7 CONCLUSION

In this paper, we presented a model-based method to systematically elicit and document functional requirements for distributed systems. Our method requires an informal description as initial input, and the final output is a requirements model that captures functional requirements for each subsystem. To detect errors in the application of our method as early as possible, we state validation conditions for each step. For our requirements model, we extended Michal Jackson's problem frames notation to make the relations between requirements for subsystems explicit. This ensures traceability during the ongoing phases of software development.

To simplify the application of our method, we provide a graphical tool based on an Ecore model. The model-based approach of our tool implements semantic rules to ensure consistent storage of the results. Finally, we formalized as many validation conditions as possible using OCL to automatically validate the resulting model.

During the application of the method on different examples, we observed reoccurring patterns of requirements. Similar to Jackson's problem frames, we plan to develop a catalogue of patterns for characterizing those requirements.

With regard to our tool, we plan to extend the evaluation of validation conditions. Currently, the tool only shows markups for harmed conditions. We plan to add quick fixes and hints to support users in fixing errors as easy as possible.

We also plan to evaluate the usability of our tool and the method itself. To do so, we will perform an experiment for which we provide an informal scenario to test candidates. Using our tool, the test candidates will apply our method, and we will ask for qualitative feedback in the end based on questionnaires. We will use the results to improve our tool and the method.

Due to unreliable connections between the different subsystems and continuous exchange of information, security and privacy are of special importance for distributes systems. With our method, we allow to make those connections explicit. The resulting model can serve as the input for a analysis of possible threats regarding security and privacy. Therefore, we will investigate how our method can improve further analysis, for example by embedding the method in risk management processes such as ProCOR (Wirtz et al., 2018).

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