Configuration of Telecommunication Systems in KIKon

Werner Emde+, Christian Beilken+, Josef Börding+, Wolfgang Orth*, Ulrike Petersen+, Jörg Rahmer*, Michael Spenke+, Angi Voss+, Stefan Wrobel+

+ GMD, FIT
Schloß Birlinghoven
D-53754 Sankt Augustin
Germany

* GMD, TKT
Rheinstr. 75
D-64295 Darmstadt
Germany

<surname>.<lastname>@gmd.de

Abstract

In this paper we present an overview of a project concerned with the configuration of telecommunication systems. The long term goal of this project is a fielded knowledge-based configuration system to support the work of consultants of the Deutsche Telekom AG. In this paper we analyze how and why the configuration of telecommunication systems differs from the configuration of other technical systems like cars and airplanes. We will present the design rationales and the architecture of a new prototypical system and describe some of its components and their interaction.

Introduction

Casual users of telecommunication systems are usually aware of only a few different types of telecommunication services (e.g. phone and email services) and components (phones, fax-machines, modems). A closer look at telecommunication systems of modern companies reveals that the world of telecommunication is enormously complex with thousands of different components and hundreds of services. The structure of telecommunication systems can be arbitrarily complex including different types of networks and various network transitions.

The configuration of telecommunication systems for private customers typically consists of a careful selection of a few components only. Configuring the telecommunication system of a company can require a complex iterative process including the analysis of customer needs, the development of a concept, the selection of technical components and services, the implementation and commissioning of the system - until the customers specific requirements are met. Examples of very complex telecommunication systems are call centers designed to integrate information processing and telecommunication.

In 1994 Deutsche Telekom AG started a research project (KIKon) to analyse configuration problems in the telecommunication domain and to evaluate techniques able to support the work of customer advisers (Böhm & Uellner 1996). A first prototypical knowledge-based consultation system dealing with the telecommunication domain of private customers was realized in 1995 (Beilken *et al.* 1995). The system was implemented using the configuration system shell COSMOS (Heinrich & Jüngst 1991). Although we achieved promising results with regard to the restricted application area, we realized that existing configuration system shells are only partially suited to deal with the telecommunication systems domain in general. Hence, as we are now investigating the telecommunication domain of middle-sized companies, we have redesigned our system and reimplemented it from scratch.

In this paper we explain how and why configuration of telecomminication systems differs from the configuration of other technical systems like cars, airplanes, or other machines. We present the design rationales and the architecture of a new prototypical system and describe some of its components and their interaction.

Telecommunication systems domain

During the last decade the world of telecommunication has changed dramatically. New services like mobile communication, and ISDN (integrated service digital network), internet became very popular even for private use. The number of offered telecommunication components and communication related computer components (hardware/software) is still growing. Therefore, configuring a telecommunication system requires to make a large number of decisions. Very often a customer does not only need some advice to select the "best" component among many similar ones, but also requires support in choosing among different services. The later is usually connected with a decision for or against a particular telecommunication system structure. Even for private customers there are often many possibilities to satisfy their requirements. For example, the requirement to send and receive faxes can be realized with a fax-machine, with multifunctional phone/fax-components, with a personal computer including a modem and fax-software.

With respect to the number of components that have to be considered to find an acceptable configuration, the telecommunication systems domain is very similar to many other technical domains. Nevertheless, some important differences exist. First of all, configuration of telecommunication systems takes a special position, because a telecommunication system is able determine how people can communicate and interact, which kind of information flow will be used, and which kind of work flow can be realized. One crucial point is that the communication relation may have to be taken into account.

Therefore, it is unrealistic to expect that a knowledge-based system is able to configure an optimal system in one shot given a set of requirements stated by the customer. It is also not appropriate to expect that a customer is able to answer questions during the configuration process if the answer will be handled as a definite (hardly revisable) decision for or against a particular telecommunication system structure.

Instead, configuration in the telecommunication domain should be viewed as a design or *modeling* activity with crucial effects on communication and information processing. In order to support the configuration of telecommunication systems it is necessary to meet requirements known to be crucial from work on knowledge acquistion — an activity that also can be viewed as modeling activity[1]: The consultant should be supported by a system that ((Wrobel 1988),(Morik *et al.* 1993, p. 60ff)):

- allows the consultant to control the order in which the "modeling" sub-tasks are solved,
- supplies immediate feedback about the consequences of "modeling" decisions,
- offers operators for the refinement and the revision of the "model", and
- allows to inspect and to compare alternatives.

Typically the requirements of customers in the telecommunication domain are incomplete or possibly contradictory when they meet the first time with a consultant. Neither the desired functionality of a new or extended telecommunication system will be known completely, nor has the customer clear and reliable ideas about what types of new components and new services are necessary. Furthermore, simple evaluation criteria to choose among different configuration alternatives are usually not applicable. The price of new components and the fixed and variable costs of using telecommunication services might be important, but depending on the customer demands other criteria have to be taken into account as well (e.g., the robustness or extendibility of a system).

Closely related to these observations is the fact that supporting configuration at the level of concrete components is not enough. A consultant should be able to start at an abstract level, because in the beginning of a consultation about a complex communication system it is usually necessary to develop a *conceptual* solution first.

There are two reasons why discussions between consultant and customer at an abstract level are useful. First, they may be neccessary for the consultant to understand or identify the problems of the customer. Secondly, they are sometimes useful to *convince* the customer and to *explain* advantages and disadvantages of radically different solutions. Due to their experience consultants often "know" the best solution soon after the beginning of the consultation. This indicates that human experts may utilize case-based reasoning methods during configuration (Rahmer & Voß 1996; Voß 1995; 1996).

The following conclusions can be drawn from this short description of the telecommunication system domain. A useful consultant support system

- must support interactive configuration (by delivering feedback, offering revision operators, etc.),
- must be able to construct alternative solutions for the customer problems,
- must be easily maintainable,
- should support configuration at different levels of abstraction.

Design Rationales of KIKon

Having described the peculiarities of the telecommunication systems domain, we now discuss how we deal with them in the KIKon project. The rough architecture of our prototypical consultation support system is shown in figure 1.

The system offers a domain-dependent graphical user interface that can best be described as a configuration editor. The editor can be used to configure telecommunication systems manually at different levels of abstractions. It includes an advanced table mechanism (Spenke, Beilken, & Berlage 1996) for comparing and selecting components. Each input to the editor is passed to the configurator and checked for consistency with previous specifications. The configurator can also be used to complete a configuration. In this case, the output may consist of several, differently structured alternatives. They are presented by the configuration editor using the same representation offered for manual configuration. Any descision of the user or advice given by the configurator can be revised at any point in the configuration process.

The elicitation of the requirements of a customer is supported by a case base of customer descriptions (lawyers, travel agencies etc.). A case base containing descriptions of previously configured systems can be used by the consultant to quickly construct a "solution" manually. In the future, such cases will also be used by a case-based reasoning mechanism. The current version of the configurator is based on a purely resource-oriented approach.

[1] For a detailed discussion of the relation between knowledge acquisition and modeling see (Morik 1991), (Morik *et al.* 1993, p. 12ff).

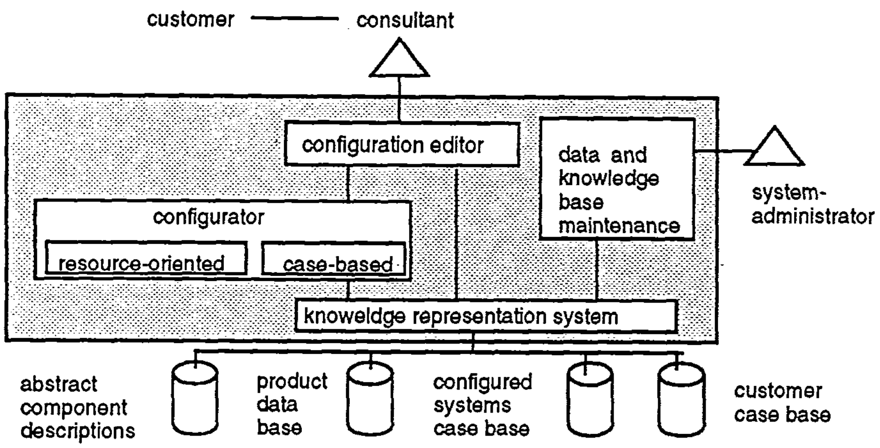


Figure 1: Rough architecture of the KIKon system

In the following we describe how the requirements discussed in the previous section are fulfilled by explaining features of the configuration editor and of the configurator. Furthermore, we describe the interaction of both components.

Configuration editor

The design of the user interface is influenced by the following requirements:

- The specification of requirements should be possible at the level of concrete telecomunication services and components (e.g., a fax-machine of type AF302) as well as at abstract levels (e.g, a component that allows to send faxes),
- the interface should support the inspection of configuration alternatives,
- the interface should be able to present different views on a configuration, e.g., structural views, zoom out/zoom-in, and surveys of composite parts,
- previously constructed configurations (standard solutions) should be accessible to support the elicitation of customer requirements, and
- the interface must support the interactive modeling of the customer requirements/target system.

In general the consultant uses the consultation system to configure a telecommunication system of a company with one or several branches, each with one or several working places. We assume that the system is used during the consultation. So the output of the system should also be comprehensible to the customer.

While selecting components and services, the consultant/customer should be supported by allowing him or her to gradually specify features of components and services. At some point, the customer typically needs to get an overview about remaining choice points. Presentation of devices using tables has proven worth for this kind of tasks. Such tables do not need to be static as in printed documents, but columns and rows can be added and deleted dynamically. Furthermore, it is useful to group related features, because this allows to apply techniques like hiding sub-menus[2].

The current version of KIKon's configuration editor supports the configurations of a telecommunication system for a company with several working places and a central service station offering services to the working places (private branch exchange (PBX), computer network server). A graphical interface allows to edit the structure of the telecommunication system (e.g., creation of new working places, adding a new component to a working place). In figure 2 an example of the structural view on a working place is shown. The working place includes a manually selected telephone ACTRON AB. Its access to the analogue telephone system is delivered by a NFN-connection box. As the connection box offers three slots, it can also be used to supply (shared) access to the telephone system for one of five fax-machines already included as third component of the working place. With respect to this fax-machine the customer has still to select one using the table mechanism.

By double-clicking on a component in the structural view, a table is opened that presents the features (attribute values) of concrete components and allows to specify open feature values. For example, the table shown in figure 3 is displayed by double-click on the icon representing the fax-machine in figure 2[3] The col-

[2]For a recent overview about the use of tables (also called cases-by attribute table or relational tables) in man-machine communication see (Spenke, Beilken, & Berlage 1996).

[3]The figure contains only a part of the actual table displayed by the configuration editor. The complete table presents the attribute values of all five fax-machines among the user has to choose.

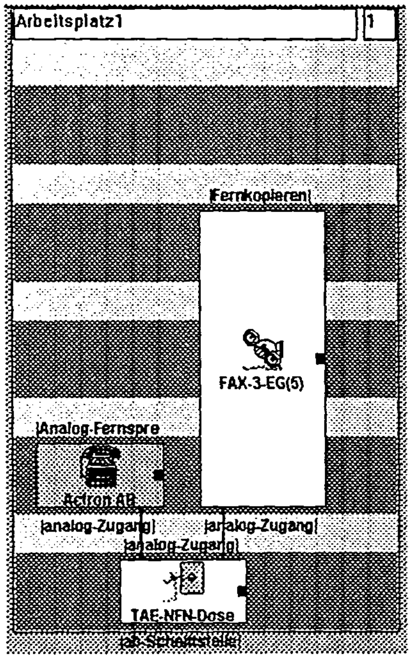
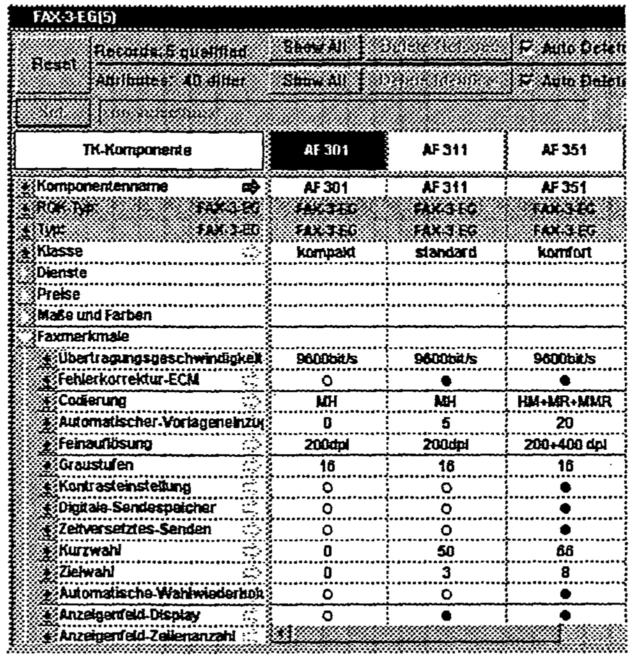


Figure 2: Example of a configured working place



TK-Komponente	AF 301	AF 311	AF 351
Komponentenname	AF 301	AF 311	AF 351
ROK-Typ FAX-3-EG	FAX-3-EG	FAX-3-EG	FAX-3-EG
Typ FAX-3-EG	FAX-3-EG	FAX-3-EG	FAX-3-EG
Klasse	kompakt	standard	komfort
Dienste			
Preise			
Maße und Farben			
Faxmerkmale			
Übertragungsgeschwindigkeit	9600bit/s	9600bit/s	9600bit/s
Fehlerkorrektur-ECM	o	●	●
Codierung	MH	MH	HM+MR+MMR
Automatischer-Vorlageneinzug	0	5	20
Feinauflösung	200dpi	200dpi	200+400 dpi
Graustufen	16	16	16
Kontrasteinstellung	o	o	●
Digitale-Sendespeicher	o	o	●
Zeitversetztes-Senden	o	o	●
Kurzwahl	0	50	66
Zielwahl	0	3	8
Automatische-Wahlwiederholung	o	o	●
Anzeigenfeld-Display	o	●	●
Anzeigenfeld-Zeilenanzahl			

Figure 3: Example of a table with fax-machines

umn entitled with "Typ" (in German: type (of component) appears in grey, because the user restricted the set of components to analogue fax-machines in a previous step. The free 'N'-slots of the connection-box would also be able to satisfy the requiements of an answering machine.

Three sets of features are attached to each component: features to describe the component (e.g., the name, price, colour, baud-rate, etc.), features to describe the functionality of a component (e.g., baud-rate is a feature of the functionality analogue fax), and features describing what is required by the component (e.g., a fax-machine requires a slot with certain features). If the customer/consultant is not yet able to select an appropriate attribute value, the choice can be postponed. In this case, the specification result is a disjunction of all remaining possible components. For example, the customer may specify a hardware component that should supply a fax-service, but nothing else. In this case, the corresponding icon in the structural view represents the set of all fax-machines including digital and analogue ones.

Instead of choosing components manually, the consultant can invoke the configurator to propose components that are able to satisfy requirements of already selected components (including those requirements added by newly introduced components).

Resource-oriented configurator

By now the reader should have gained an intuitive understanding of how we intend to meet the requirements related to the user interface. Next, we turn our attention to the configurator of the KIKon system. The following requirements must be fulfilled by this component:

- The knowledge base of the configurator must be easly to maintain.
- The configurator should be able to check the consistency of manually configured systems.
- As it is not possible to specify strict evaluation critera and as a specification may be incomplete, the configurator should deliver configuration alternatives. Furthermore, it must be possible to restrict the number of configuration steps that ahve to be solved automatically.
- As we intend to support the conceptual phase in the beginning of a consultation, the configurator should be capable of configuring at an abstract level.
- As case-based reasoning seems to play an important role in configuration by human experts, the configurator should be able to utilize information about previously solved tasks (Rahmer & Voß 1996).

After we had studied the advantages and disadvantages of different approaches to knowledge-based configuration like

- rule-based configuration approaches,
- structure-oriented approaches as they are used in PLAKON and PROKON (Cunis, Günter, & Strecker 1991),
- constraint-based approaches (see, e.g., (Faltings & Weigel 1994)),

- resource-oriented approaches as used in the systems COSMOS (Heinrich & Jüngst 1991) and MOKON (Kleine-Büning & Stein 1994) (see also (Schwanke & Benert 1990)), and
- case based reasoning (Kolodner 1993),

we decided to develop a new approach that combines resource-oriented configuration and case-based reasoning (Rahmer & Voß 1996).

In our view, the resource-oriented approach best achieves an easily maintainable system for domains where the structure of configurations is extremely variable (Rahmer & Sprenger 1996).

The basic idea of resource-oriented configuration is as follows: Each component (phones, fax-machines, computers, modems) in the domain is described by the set of resources it supplies and the set of resources it consumes. Given a set of open resource requirements (specifying the needs of a customer), the configurator adds components to the configuration until all requests of a resource are satisfied.

```
component 'analogue-telephone'
 {super 'telephone';
  consumes
     {'analogue-telephone-system-access' 1
          {'TAE-Slot' 'F';};};
  supplies
     {'analogue-telephone-service' 1;};
  attributes
     {'display';};
  constraints
   {supplies.'analogue-telephone-service'.
         'telephone-charges-info' = 'Takt' ->
   attributes.'display' = 'yes';
   };
}
```

Figure 4: Definition of analogue telephone

An example of the description of an analogue telephone processed by KIKons configurator is shown in figure 4. An analogue telephone is described as subcomponent of telephone. It requires a slot of type 'F' delivering access to the analogue telephone system. The phone is able to supply an analogue telephone service. A constraint will require a telephone with display if the add-on service telephone charging information is required with the analogue telephone service. The description of a connection-box able to deliver access to the analogue telephone system is shown in figure 5.

In addition to the definition of (atomic) components, the knowledge base contains definition of complex components (e.g., "working place") and the definition of resources (e.g., analogue-telephone-service"). Resource definitions describe how resources offerings and requirements have to be balanced.

```
component 'TAE-NFN-connection-box'
 {super 'connection box';
  clevel inf;
  consumes
   {'ab-connection' 1;};
  supplies
   {'analogue-telephone-system-access' 2
            {'TAE-Slot' 'N';};
    'analogue-telephone-system-access' 1
            {'TAE-Slot' 'F';};};
  constraints
   {};
}
```

Figure 5: Definition of 'TAE-NFN-connection-box'

Up to now, we have implemented a first version of the configurator that works purely resource oriented[4]. This resource-oriented configurator is implemented by a set of domain-independent logical constraints and rules. Utilizing the backtracking mechanism of Prolog, the configurator delivers alternative solutions of configuration tasks. In contrast to other systems like COSMOS or MOKON our system is not designed to find the "best" solution.

Configuration tasks are specified by the configuration editor. For each component added to the structural view of a configuration, the configuration editor generates a corresponding abstract component. If the user has not specified enough attributes of a component such that the abstract type of the component is not unambiguously defined, the configurator has to solve more than one configuration task. This may happen, e.g., when the user has not specified if a analogue or digital fax-machine should be a component in the configuration. In this case the results of the configurator are either merged or presented as configuration alternatives (if the structure of the solutions differs).

Discussion

In this paper we have described some characteristics of the interactive configuration system KIKon supporting the manual as well as the semi-automatic configuration of telecommunication systems. In contrast to the interactive configuration approach described by (Gelle & Weigel 1996), our configuration approach deals with the problem of selecting the right set of components and connections among them, while Gelle and Weigel deal with the problem of determing the values of discrete and continous variables describing a a fixed set of components.

The graphical user interface includes a dynamic table mechanism to support the comparision and selec-

[4] For a discussion how to integrate resource-oriented configuration with case-based reasoning see (Rahmer & Voß 1996).

tion of components. While the configuration editor deals with sets of concrete components, the resource-oriented configurator deals with (abstract) component types. Relying on the resource-oriented configuration approach the knowledge base is easy to maintain.

The current domain model includes descriptions of various component classes (phones, fax-machines, modems communication software, PBXs, and computer equipment related to communication and information transfer issues) and services (different phone services, add-on services, communication services and data-transfer services).

So far we have dealt with the configuration of new telecommunication systems. In the future, we will incorporate methods to improve or extend the functionality of existing systems. Furthermore, we will integrate resource-oriented configuration and case-based reasoning to take advantage of knowledge implicitly contained in descriptions of previously configured systems. Future work includes also the evaluation of our system by Telekom consultants.

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