Process-based E-Service-Logistics for Healthcare Networks

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Abstract: Coordination in healthcare networks becomes increasingly important to enable integrated care scenarios, to enhance patient satisfaction and to reduce costs of the treatment processes. A process-oriented approach for coordination in healthcare networks is introduced. It shows how interorganizational treatment processes can be supported by the concept of process-based e-service-logistics. The allocation of e-services is based on a model describing services and coordination tasks between roles in a healthcare network. The underlying systems architecture is presented. A solution for the (semi-) automated individualization of process-based e-service-logistics based on Case Based Reasoning (CBR) technology is discussed.

1 Introduction

1.1 Motivation

The healthcare industry is one of the most important economic sectors in Germany causing annual expenses of about 230 billion euros (over 10 percent of the gross domestic product of Germany) and employing more than 4.2 million people. An empirical study[1] reveals that 81 percent of the respondents expect that networking in the healthcare industry will increase in the next three to five years [SKB06, S. 21]. Moreover 88 percent of the survey participants (fully) agree that the demand for coordination and IT-support in healthcare networks is going to rise in the future. There are several reasons for an increasing demand for networking and coordination:

- Regulations enforcing cross-sectoral work: In Germany the law "GKV-Modernisierungsgesetz" (SGB V (§§ 140a-h) enacted in 2003 improves the possibilities to realize integrated care mechanisms especially establishing cross-sectoral healthcare networks.

[1] The study initiated at the Department of Information Sciences II at the University Erlangen-Nuremberg adressed german and suisse ambulant healthcare networks (healthcare network managers as well as physicians). The survey investigated the maturity of healthcare network organizations regarding strategy, processes, and information technology.

- Concentration on core competencies: To realize both high quality standards and efficient operations the concentration of healthcare providers on core competencies (e.g. cardiologists, radiologists, physical therapists) will continue to grow in the years to come. To cover complex customer processes numerous specialists have to cooperate more closely resulting in more coordination efforts and increased communication and information needs.
- Search for new sources of revenue: In the future new service offerings will be designed by interweaving activities of different business fields (e.g. healthy nutrition and clothes, wellness services) with traditional care processes to expand the providers' services and increase customer satisfaction.

1.2 Research Project

The research project focuses on the IT-driven management of healthcare networks. Whereas many research projects deal with the integration of health data (e.g. electronic health records) this project concentrates on the coordination of interorganizational processes within healthcare networks. Goal of the project is to support coordination and control of healthcare network processes by providing patients and healthcare suppliers with a customized set of electronic services. Process portals (see figure 1) enable the interaction between users (e.g. patients, physicians) and the use of e-services provided by the system [for details see SB05]. A process integration platform is realized enabling the design and runtime execution of a process-based e-service-logistics.

Figure 1: Process portal providing e-services

To analyze requirements and design innovative concepts for network coordination the research project cooperates with the healthcare network "Qualitäts- und Effizienzgemeinschaft Nürnberg-Nord (QuE)" which is organized as a gatekeeper system [WLF05].

2 Coordination in Healthcare Networks

The concept of process-based e-service-logistics is based on the interdisciplinary coordination theory. „Coordination is managing dependencies between activities performed to achieve a goal" [MC90, S. 361]. Whereas this definition is widely accepted coordination theory deals with many different means of coordination (e.g. based on forms, conversation structure or information sharing). This project argues for a process-oriented approach of coordination supported by process models as a special kind of plan in the terminology of coordination theory. But coordination based on process models faces important challenges to cope with. Therefore the characteristics of healthcare network processes and their requirements will be discussed next. To transfer the general tasks and principles of coordination to the healthcare domain we have to analyze which processes and coordination tasks exist within healthcare networks. Table 1 shows some examples:

Healthcare Network Processes	Coordination tasks	E-Services
management processes: needed to control the healthcare network	goal adjustment, network monitoring and reporting, planning, guideline implementation	healthcare performance cockpit (balanced scorecard, stakeholder-specific reports)
medical treatment processes[2]: adding value to patients and resulting in revenue for healthcare providers	controlling health status of patients, exchange and adjustment of medical reports, discharge letters or prescriptions	patient monitoring service (e.g. bluetooth scale), electronic prescriptions, electronic discharge notes
support processes: enabling processes laying the foundation to run the business	absorption of costs, accounting, billing and payment, master data management	web service orchestrated workflows for cost absorption, e-billing, patient master index

Table 1: Processes, tasks, e-services

Treatment processes are often documented in process modelling tools (e.g. ARIS, VISIO), domain-specific tools[3] or proprietary files (e.g. Excel, Word). They represent guidelines and process instructions and ensure transparency for medical staff. They normally represent standard process models for dealing with activity flows from a service provider´s point of view (e.g. hospital) and are often supported by case management or workflow management systems. But standardized process models do not represent the real-life characteristics interorganizational treatment processes are facing:

• unique • requiring intensive coordination and information • long-lasting and complex	• stepwise changing and volatile • requiring in-depth knowledge	• involving numerous participants • important and risky • cross-sectoral

Table 2: Characteristics of interorganizational treatment processes

The research project focuses on the treatment process from a cooperative view regarding the patients way throughout the whole healthcare network.

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[2] In literature view terms are used for medical treatment processes (e.g. guidelines, clinical-/ critical pathways, interdisciplinary care paths) pointing out different origins, goals and perspectives [GSS04, GMW03, Jo02].
[3] c.f. for example www.clinpath.de

The individual characteristics of each patient, the high degree of volatility during the real-time execution of the process instance and its complexity are big challenges when supporting the execution of individual processes by information technology:

- Individualization: Standard process models based on guidelines (e.g. for treating chronic heart failure) can´t reflect the complexity of real-life treatment processes. Therefore process models should be adapted to individual patient´s needs. To avoid modelling efforts a new way of (semi-)automated process design is needed.
- Adaptability: Members of the healthcare network (especially gatekeepers) should be able to modify the individual process model easily as soon as new information about the state of treatment or illness exists.
- Flexibility: E-services (e.g. information and application services) must be linked to individual process activities in a flexible way.

3 Process-based E-Service-Logistics

The concept of process-based e-service-logistics aims to support the coordination of healthcare network processes by providing patients and healthcare suppliers with a customized set of electronic services. Electronic services are software components which encapsulate functions (e.g. application or data centric services) in a coarse-grained manner e.g. using web services as technical representation [KBS05]. The e-service requirements regarding information and coordination in healthcare networks are derived from semi-automatically customized process models. They result in a process-based e-service-logistics model executed by the architecture described below.

3.1 Architecture Overview

An Individual Value Web System (IVWS) is a process management platform supporting the coordination of individual treatment processes by providing network participants with e-services. At the level of individual patient instances treatment processes and the flow of activities throughout the network are coordinated by a gatekeeper model. The gatekeeper system aims to improve the quality of care and to realize synergies during the treatment process e.g. by avoiding unnecessary medical examinations. One person is the contact person (gatekeeper) collecting all information about the patient and coordinating his treatment. The system architecture has to support this gatekeeper concept which defines the business architecture within the healthcare network [AD05]. Hence, the central execution of web service-based workflows [Bu03] is the basic technical principle ensuring a high degree of structural analogy of business and systems architecture. To achieve this the research project uses web service technology and the concept of service oriented architecture as technical basis. The process and e-service scheme instantiated at the first stop of the patient in the healthcare network is executed by the IVWS.

The system controls and distributes e-services to roles across the network and informs the gatekeeper about the patient status. Thus the gatekeeper gets transparency concerning the treatment process giving him the possibility to intervene if necessary. The research work is based on the concept of a process-enabled service-oriented architecture (SOA). It enables "lightweight" application frontends which are only responsible for interacting with system users (dialog control). Moreover the concept argues for the encapsulation of processes within process centric (web) services. The complexity of backend systems is encapsulated within intermediary services. As a result the separation of process logic (within a process layer) and business logic (within a basic services layer) is assured [KBS04].

3.2 Architecture Components

The system architecture follows a 4-tier approach (see figure 2):

Presentation layer: Application frontends initiate and control all activities of the IVWS. Typically application frontends are graphical user interfaces enabling direct interaction of users with the system (WebParts implemented with C# using the MS Sharepoint Portal Server). Within the research project role-specific process portals for patients, service providers and network managers are implemented [SB05].

Customization and flow control layer: This layer consists of three components – the process and e-service customization, meta orchestration and service bus including features for orchestrating and executing web services.

Service bus and web service orchestration: A core component of the IVWS is a service bus connecting all participants within the network. It ensures any kind of communication between application frontends and e-services. MS Biztalk Server delivers the functionality to provide the following characteristics of the service bus [KBS04, S. 65]:

- Connectivity: The service bus connects network participants delivering e-services.
- Integration services: The service bus is able to cope with heterogeneous technologies providing features to integrate different programming languages, operating systems, runtime engines, middleware products and communication protocols (e.g. data mapping tables).
- Communication: The service bus deals with different kinds of communication concepts (e.g. synchronous and asynchronous).
- Technical services: The service bus is primarily responsible for communication within the network but also provides technical services for operating a SOA (e.g. logging, auditing, security, message transformation, transactions).
- Process orchestration and execution: The service bus helps to orchestrate and execute web service-oriented workflows. Programs or long-lasting processes evoke e-services periodically or event-triggered. E.g. a recall web service for examinations is executed by MS Biztalk Server based on an orchestrated process scheme.

To provide e-service support along processes a lot of technical concepts and solutions already exist [Ja05, BCS05]. Shortfalls of commercial web service concepts are:

- Lack of flexibility: Web service orchestrations can only represent processes which are defined at design time. Variants and paths can only be executed being defined beforehand.
- No individualization: The orchestrated pathways are predetermined for all instances using the same patterns (e.g. activities, coordination tasks, e-services). Therefore they only allow the use of decisions or business rules for dealing with different cases. Individualization of the required treatment process and e-service flow for one patient instance is not possible [BCS05, S. 94].
- Lack of usability: Today, tools for enabling the orchestration and executing of web services (e.g. MS Biztalk Server) are not designed to directly support end users. They help application developers realizing solutions on a very technical level (e.g. definition of port types, message transformation, data mapping).

Process and e-service customization: For customizing treatment processes and their e-service-logistics specification Case Based Reasoning (CBR) technology is used (for details see 3.3).

Meta orchestration: Today´s approaches for defining and executing web service-oriented process models are not able to cope with semi-structured or even individual processes. To exploit the advantages of web service technology but overcome the deficits mentioned above the concept of meta orchestration was developed (see figure 2). The meta orchestration server (MOS) operates as an intermediate interconnecting the customization component (CBR system), the network participant (user interface) and a commercial web service orchestration and runtime engine (MS Biztalk Server). Service providers (e.g. gatekeeper) are able to instantiate and modify one patient´s treatment process and e-service-logistics blueprint which is suggested and transferred by the CBR system (see 3.3). For example the solution enables gatekeepers to activate or disable health-related e-services by using a defined and pre-configured set of e-services. Afterwards web services will automatically be evoked along the individual process. Commercial service bus technology is used to execute the process-based e-service-logistics at runtime. Subtasks and orchestrations will be triggered and results are sent back to the MOS.

Application layer: E-services of a SOA are software components encapsulating business functions in a coarse-grained manner. E-services consist of a service contract, service interfaces and implementation. The implementation is the physical representation of the required business logic and the relevant data (programs, configuration data, data base) [KBS04]. Besides their, the IVWS-specific services (e.g. the customization component described below) and all kinds of existing (third party) web services delivering value can be easily evoked by the service bus using SOAP and WSDL.

Data layer: An MS SQL-based process and e-service repository provides features and information for searching and utilizing process models (see 3.3) and e-services, e.g. physical location, service provider, contact, charge fee, technical constraints, security data, service level agreements.

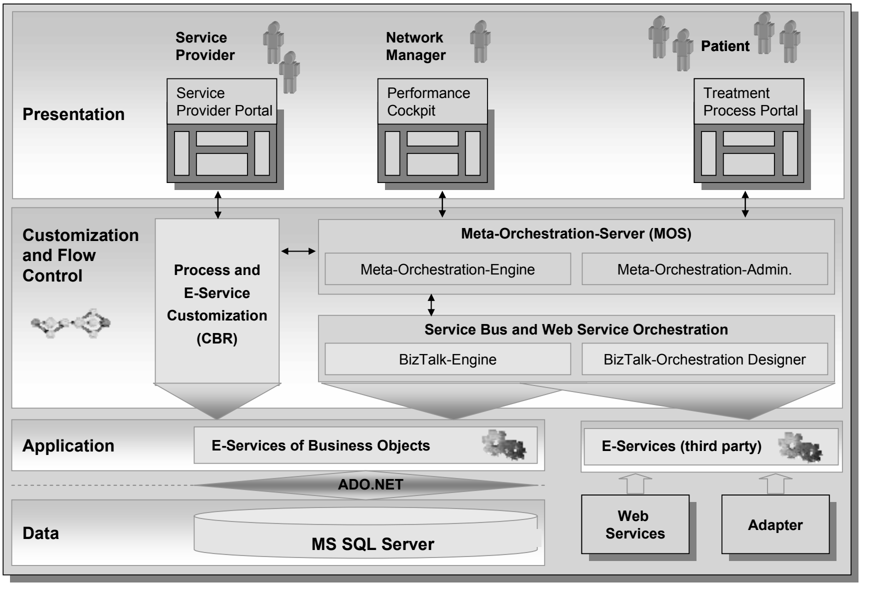

Figure 2: Architecture – Individual Value Web System (IVWS)

3.3 Process and E-Service Customization

Traditional methods for process individualization are:

- Classic approach: Each process is individually modelled from scratch for a distinct context (disadvantages: time-consuming, no reuse) [Ru02, S. 2; La97, S. 2].
- Recomposition approach: Copying and recomposition of existing process segments (re-)using process-specific know-how (disadvantage: time-consuming search and composition of process segments) [Ru02, S. 2].
- Reference modelling approach: process-specific know-how is provided by reference models (disadvantage: in case of numerous models time-consuming search, high effort for adaptation) [Ru02, S. 2; La97 S. 2f; Br03, S. 31].
- Skeleton approach: storing and reusing process-specific know-how by use of abstract process structures with placeholders. The placeholders are filled with distinct data in case of usage (disadvantage: time-consuming search, high specification effort) [Re97, S. 114; La97, S.4].
- Process module approach: preserving and utilization of know-how using process modules (disadvantage: high search and assembly effort) [Ru02, S. 2; La97, S. 4f].

There is one goal that all approaches have in common: to provide an adequate method for generating a process specification tailored to a distinct individual context. Innovative approaches of process individualization deal with intelligent concepts for automated search and adaptation [WWT97, S. 3ff; WW97, S. 52f; RPR99, S. 230ff; Ru02, S. 67ff].

For customizing treatment processes and their e-service-logistics specification a component uses an intelligent algorithm based on Case Based Reasoning (CBR) (see figure 3). CBR enables the solution of problems using existing know-how and experience. That CBR approach shows several advantages [MDS01, S. 13ff]:

- It fulfils the basic requirements for automated selection and adaptation.
- Existing problem solutions can be reused (no effort for configuring from scratch).
- CBR helps in complex and partially unknown domains (also unidentified correlations of problems and solutions can be stored and reused).
- Based on psychological insights CBR is similar to human means of problem solving providing a powerful methodological background (user acceptance).
- It provides a simple mechanism for acquisition of knowledge (know-how has not to be decomposed and formalized but can be used in its natural representation).
- Adaptation and changes within the knowledge base can be realized easily by deleting old cases and adding new cases.

Case representation: Process-specific knowledge is stored in a case database. Each case consists of a patient context (problem description), a corresponding treatment process, and an e-service-logistics specification (solution). Attribute-value-vectors are used to represent the process context describing the patient and their current clinical picture. As medical indications have specific factors influencing the treatment process indication-specific attributes have to be defined for each disease (see table 3). To represent the process and the corresponding e-service-logistics specification (solution) a more expressive type of representation is needed. Therefore, an object-oriented model describes the processes and its elements by classes. One process consists of several object instances of this classes.

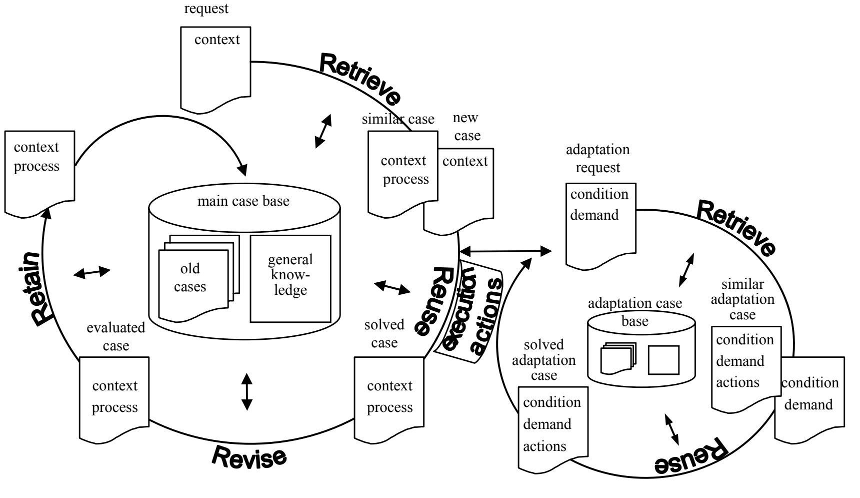

Figure 3: CBR systems for customization of treatment process and e-service logistics

Retrieve: The CBR cycle starts with a new request from a service provider describing the process context of one patient´s clinical picture. In order to solve the new problem a similar case already stored in the database is searched. Local and global similarity measures are defined to find similar cases in the main case base. The prototype deals with cases of chronic heart failure (see table 3).

attribute	**patient request**	**patient from case base**	**local similarity**	**weight** (normed)	**global similarity**
age	63	72	0,89	0,06	$\sum_{i=1}^{23} g_i \cdot sim_i = 0,78$
gender	male	male	1	0,07	
compliance	sufficient	good	0,55	0,03	
dyspnea	yes	yes	1	0,03	
oedemas	no	no	0	0,05	
heart rhythm	regular	regular	1	0,04	
NYHA classification	III	II	0,75	0,07	
...					

Table 3: Example of global similarity measurement

Reuse: If a treatment process is in progress and a new case request already includes a process and e-service specification a new specification is composed (compositional adaptation). Afterwards old attributes of the case will be updated (substitutional adaptation) and the process structure of the copied process and e-service elements are modified (structural adaptation). To reduce the effort for adaptation cases for adaptation are automatically derived from the main CBR cycle. Therefore mechanisms based on a second CBR system are deployed to find similar adaptation cases resulting in applicable actions to modify the old case.

Within the *revise* stage the consistency of the new case is tested and executed. After execution the case will be evaluated and stored in the case base (*retain*).

4 Conclusion

Networking and the demand for coordination within healthcare networks will increase. Here, a process-oriented coordination approach is proposed. Process-based e-service-logistics and the underlying service-oriented architecture supports coordination by delivering relevant e-services to network participants. The allocation of e-services is based on a model describing services and coordination tasks between network participants within interorganizational treatment processes. As a result e-services will be provided in the right sequence at the right time for all relevant network participants working on a patient´s individual process instance. To reduce effort for modelling, searching and adapting processes an approach for (semi-) automated individualization of process-based e-service-logistics based on Case Based Reasoning (CBR) technology is used. In order to provide a flexible solution for the runtime execution of e-services the concept of meta orchestration is suggested. The use of runtime information to enrich existing controlling systems and evaluation of the concept are still necessary. Research is in progress. Preliminary results show that a flexible and user-friendly way of delivering e-services supporting process-based coordination in healthcare networks is feasible and operational.

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