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Process-oriented Integration and Coordination of Healthcare Services across Organizational Boundaries

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Abstract

To achieve an integration and coordination healthcare services among organizations through inter-organizational processes to enable organizations to provide high quality healthcare integrated services and continuous process improvements, this paper proposes a methodology that follows a top-down approach based on a Model-Driven Architecture. It provides a modeling language that enables organizations conceptualizing an integration agreement, and identifying and designing cross-organizational process models. These models are used for the automatic generation of: process models representing the private view each organization requires to perform the role it fulfills in cross-organizational processes, and Colored Petri Net (CP-Net) specifications to implement these processes. A multi-agent system platform provides agents that interpret CP-Nets and enable the communication between the Healthcare Information Systems of the organizations for executing the cross-organizational processes. Clinical documents are defined using the HL7 Clinical Document Architecture. This methodology guarantees that important requirements for healthcare services integration and coordination are fulfilled: interoperability between heterogeneous Healthcare Information Systems; ability to cope with changes in cross-organizational processes; guarantee of alignment between the integrated healthcare service solution defined at the organizational level and the solution defined at technological level; and the distributed execution of cross-organizational processes keeping the organizations autonomy.

Key words: process-oriented integration cross-organizational process healthcare processes clinical document architecture model-driven architecture healthcare information systems

1 Introduction

Global healthcare can involve many organizations that have to coordinate their efforts for providing quality and efficient services. This requires integrating and coordinating healthcare services across organizational boundaries based on integration agreements among healthcare organizations.

A process-oriented integration and coordination of healthcare services could fulfill this requirement. Healthcare organizations can achieve this by implementing cross-organizational processes. A cross-organizational process defines the global view of interactions between the organizations to achieve a common

goal [1, 2]. Clinical documents (such as referral letters, diagnostic results and discharge summaries), which contain the information needed to perform the healthcare services, are exchanged through these processes.

From an organizational viewpoint, cross-organizational processes enable the organizations focus on the required document interchange and the coordination of activities to improve the management of resources and services. From a technological viewpoint, they enable to derive the interfaces the Healthcare Information Systems (HISs) of the organizations require to interoperate for exchanging clinical documents and executing the processes.

Current approaches handle the integration of healthcare services only from a technological viewpoint. They are mainly focused on the information interchange through electronic documents and technical communication issues, but outside the framework of healthcare processes that cross the boundaries of several organizations [3]. Other approaches consider healthcare processes, but they were limited to an intra-organizational scope [4].

A process-oriented integration and coordination requires an appropriate deployment of integration agreements healthcare organizations celebrate. The difficulty is to determine what cross-organizational processes should be carried out, what aspects of them should be considered and how they can be catered for from a technological standpoint. This implies to elicit the requirements from an integration agreement, design a healthcare solution defining processes and clinical documents to exchange, and define a technological solution on an IT-platform for implementing and executing these processes.

This paper proposes healthcare organizations integrate and coordinate healthcare services through cross-organizational processes. For this purpose, a methodology for process-oriented integrated healthcare services is presented. This methodology encourages separating the organizational level from the technological level in order to allow both creating abstraction layers to easy the design of the integrated healthcare service solution and the cross-organizational processes in an independent way of the technology [5], and from them generating the technological solution. To guarantee the alignment between the integrated healthcare service solution and its technological solution, the methodology is based on a Model-Driven Architecture [6]. To interchange clinical documents, the Health Level Seven Clinical Document Architecture is used [7]. A multi-agent software platform for implementing and executing cross-organizational processes among healthcare organizations is also presented. The proposed methodology allows automatically generating the logic and components the software agents require to execute cross-organizational processes and interoperate the HISs of the organizations.

The structure of the paper is as follows. Section 2 discusses related work. Section 3 describes the methodology for designing and implementing cross-organizational healthcare processes. Section 4 presents the multi-agent platform to implement and execute these processes. Section 5 presents a relevant scenario of the referral process which demonstrates the use of methodology and software agents platform proposed. Moreover, an analysis of the results obtained and challenges encountered in implementing of this methodology. Finally the Conclusions section is presented.

2 Related work

In [26], a methodology based on workflow management technologies to support the automation of workflows involved into healthcare processes was proposed. The approach focuses on process modeling without considering the clinical documents involved in it, and it is limited to an intra-organizational scope.

In [3], an approach to support the cross-institutional data exchange using the CDA was proposed. Scenarios identified in this approach: send discharge letters from a HIS to the office system of the physician through encrypted and signed emails, deliver discharge letters from a HIS to an electronic health record using secure HTTPS; and exchange laboratory results or any other clinical document between a HIS and the electronic health record. The approach is focused on both the information interchange through electronic documents and technical communication issues, but without regards the cross-organizational healthcare processes.

3 Methodology for process-oriented integrated healthcare services

3.1 Background

3.1.1 Modeling healthcare processes

The design of cross-organizational healthcare processes requires a modeling language that meets the features of process-oriented integration, such as representation of: organizations' autonomy, the global view of peer-to-peer interactions between the organizations, negotiations, and complementary and integrated views of the aspects of cross-organizational processes. To fulfill these features, the UML Profile for Collaborative Business Processes based on Interaction Protocols (UP-ColBPIP) was proposed [1, 8]. This language extends the semantics of UML2 to model cross-organizational processes by means of different views. In particular, the behavior and control flow of cross-organizational processes is modeled in terms of interaction protocols by reusing the notation of UML2 Sequence Diagrams.

In addition, the execution of cross-organizational processes in a decentralized way requires organizations to define their private integration processes. An integration process supports the role an organization fulfills in a cross-organizational process. It contains the public and private activities that an organization requires to support the role the organization fulfills in a cross-organization process [9]. The Business Process Modeling Notation (BPMN) can be used to model these processes [10]. This language provides a simple notation to represent private business processes through diagrams that describe the process flow by using flowchart techniques.

3.1.2 Model-Driven Architecture

Model-driven architecture (MDA) is based on the use of models in the software development process to simulate, estimate, understand, communicate, and produce code [5]. An MDA-based approach allows a better way of addressing and solving the problems of interoperability, heterogeneity, organization autonomy and alignment between the organizational and technological solutions involved in an cross-organizational setting by separating the development into different abstraction levels [1].

3.1.3 Health Level Seven Clinical Document Architecture

Health Level Seven (HL7) provides frameworks and standards for exchange, integration and retrieval of electronic health information [11]. The HL7 Clinical Documents Architecture (CDA) has proved to be a valuable and powerful standard for a structured exchange of clinical documents between heterogeneous software systems. The CDA is part of the HL7 version 3 family of standards, which derive their semantic content from the shared HL7 Reference Information Model (RIM) and is implemented in the Extensible Markup Language (XML) [12]. The HL7 CDA document is comprised of two parts: the header and the body. The header contains meta-information about the document, the encounter data, the service actors like document originators, document recipients, healthcare providers and the service tags like the patient or family members. The body contains the actual medical records in form of a report or a structured text [7]. According to the complexity of the document structure, CDA documents can be classified into three levels: level 1 documents have structured header and structured body with limited coding capacity, level 2 documents encompass all the constraints of level 1 and support free text representation of section contents, and level 3 documents support the codification of section contents with controlled or external vocabulary [7].

3.2 Methodology

The proposed methodology applies a top-down approach based on a model-driven architecture and consists of three phases: Definition of an Integration Agreement, Design of the Integrated Healthcare Service Solution, and Generation of the Technological Solution (Fig. 1). The focus of effort goes from the definition of models at higher levels of abstraction to the use of these models to directly generate the specifications of the implementation. In the next subsections the phases, models and languages involved in the methodology are

described. Also, a set of tools that support the methodology are explained. Details of its application are presented in Section 5.

3.2.1 Phase 1: Definition of the Integration Agreement

In this phase, the requirements of the integration agreement are jointly elicited by the involved healthcare organizations and defined in a healthcare integration agreement model. The definition of the integration agreement implies: the definition of requirements and goals, identification of cross-organizational processes, and identification of clinical documents.

The definition of requirements and goals are represented with the UP-ColBPIP language by defining the cross-organizational integration view. This view defines the integrated healthcare service and encloses the healthcare organizations involved, the role they fulfill in the integration and their communication relationships. Also, the common organizational goals to be fulfilled are captured. These goals allow the healthcare organizations evaluating the performance of the integrated healthcare service.

Afterwards, the identification of the cross-organizational processes needed to achieve the organizational goals is performed. The cross-organizational processes are agreed by the involved healthcare organizations. Also, the clinical documents that will be interchanged through the execution of these processes are identified. Both the cross-organizational processes and the clinical documents that were identified are represented with the UP-ColBPIP language by defining the cross-organizational process view.

3.2.2 Phase 2: Design of the Integrated Healthcare Service Solution

The integrated healthcare service solution implies: the design of the cross-organizational processes required to carry out an integration agreement; the definition of the clinical documents to be exchanged; and the design of the private integration processes of each organization according to the role it performs in cross-organizational processes (Fig. 1).
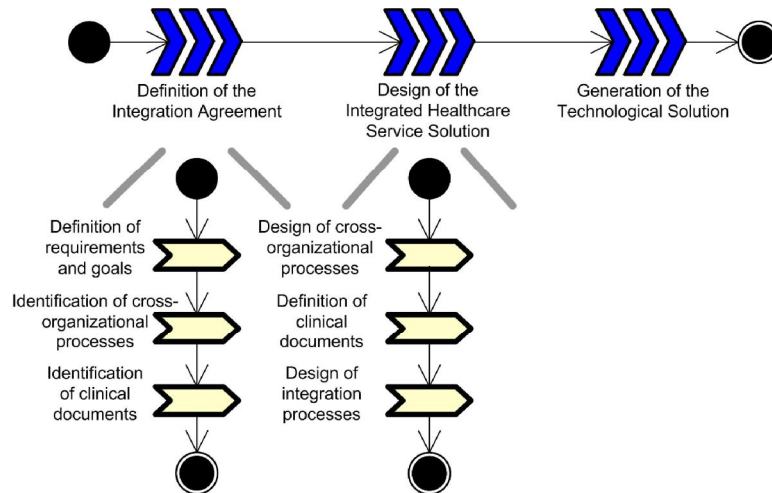

Figure 1: Phases of the process-oriented integrated healthcare services methodology

Design of cross-organizational processes

The UPColBPIP language is used to define the behavior of cross-organizational processes through interaction protocols [1, 8]. An interaction protocol describes a high-level communication pattern through a choreography of messages between healthcare organizations playing different roles. The representation of a cross-organizational process through an interaction protocol describes the interactions between organizations from a global viewpoint [1]. Thus, the focus is on modeling the control flow of the messages that represent the interchange of documents between the organizations. A message contains a clinical document and it is described by a speech act, which allows to describe the intention the message sender has with respect to the document that is sent.

The cross-organizational processes models should be verified. This can be performed applying a MDA-based method for verification of cross-organizational processes. Interaction protocols are formalized, transformed and mapped into CP-Net specifications, which then can be used to determine the correctness of a process, such as it is free of deadlocks and live-locks [18]. In this way, cross-organizational processes may be verified at an early stage of the development, when most of the fundamental decisions are carried out, previous to the generation of the technological solution.

Definition of clinical documents to exchange

The clinical documents to be exchanged in the cross-organizational processes are defined. Clinical documents and their types are represented in class diagrams and referenced in the cross-organizational process view and interaction protocol view. The HL7 CDA is used to define the syntactic and semantics structure of clinical documents [7]. In this work, the CDA header is extended including information about organization role, clinical document name, and clinical document type. The organization role defines the role a healthcare organization plays in the cross-organizational process. The clinical document name indicates the name of the document. The clinical document is the patient clinical data to be interchanged.

Design of integration processes

The private view each healthcare organization requires to perform its role in cross-organizational processes is expressed through integration processes. The design of an integration process implies to define, from the viewpoint of an organization, both: the public activities that support the receiving of messages from and the sending of messages to other organizations, and the private activities that process the documents to be received in messages and generate the documents to be sent. The BPMN language is used to represent integration process models. They are derived by applying the method for generating integration process models from cross-organizational process models proposed in [9]. A UP-ColBPIP interaction protocol representing a cross-organizational process is transformed into BPMN process diagrams (one for each organization involved in the cross-organizational process). The transformation rules add the public activities from the interaction protocol messages and the private activities that support the message exchange.

3.2.3 Phase 3: Generation of the Technological Solution

This phase implies defining the technological solution to support the decentralized execution of cross-organizational processes (Fig. 1). Each organization has to generate XML-based specifications of its integration processes in the target technology selected to implement the processes. As it is discussed in Section 4, in this work software agent technology is used. Software agents that execute the processes require a CP-Net model expressed in an XML-based format. A CP-Net model is an executable and formal specification of an integration process model and contains the activities and functions to be performed by an agent to interoperate with another agent for executing a cross-organizational process. To generate a CP-Net from a BPMN integration process model, transformation rules based on the approach proposed in [13] are applied.

3.2.4 Tools for the methodology

A set of tools were developed in order to aid organizations to apply this methodology. They are built on the Eclipse open development platform [19] in order to take advantage of a well-known development environment and its extension mechanisms. The tools were implemented as Eclipse plug-ins (Fig. 2) and consist of: editor plug-ins for the UP-ColBPIP language that allow modeling an integration agreement and the cross-organizational processes; a plug-in for BPMN that allows editing integration process models; a plug-in for CP-Nets that allows editing CP-Nets models; a transformation engine for BPMN that implements the rules of the method for generating BPMN integration process models from UP-ColBPIP interaction protocols; and a transformation engine for CP-Net that generates a CP-Net in an XML format from a BPMN integration process model.

The editor plug-ins are based on Graphical Modeling Framework and manipulates and store models based on the Eclipse Modeling Framework. The rules of the transformation engine for BPMN were implemented with the Eclipse Query-View-Transformation tool. The rules of the transformation engine for CP-Net were implemented by using the JET2 model-to-code transformation tool.
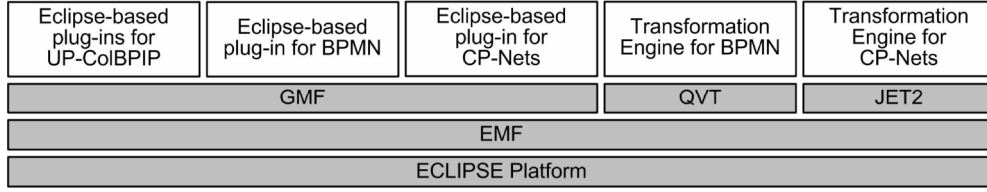
Eclipse-based plug-ins for UP-ColBPIP	Eclipse-based plug-in for BPMN	Eclipse-based plug-in for CP-Nets	Transformation Engine for BPMN	Transformation Engine for CP-Nets
GMF			QVT	JET2
EMF				
ECLIPSE Platform				

Figure 2: Eclipse-based tools for the proposed methodology

4 Multi-agent platform for implementing cross-organizational healthcare processes

4.1 Background

4.1.1 Colored Petri Nets

Colored Petri Nets (CP-Nets) are suited to model the behavior of concurrent systems in terms of the flow of control or flow of objects or information [13]. Some advantages of preferring CP-Nets for executing processes are: CP-Nets have formal semantics that enables unambiguous execution and simulation of process models; unlike some event-based process modeling notations as dataflow diagrams, CP-Nets can model both states, events and the information conveyed in tokens; there are many analysis techniques for Petri Nets that make it possible to identify deadlocks, proper completion, absence of dead tasks, and safety issues [14].

4.1.2 Software Agent Technology

Software Agents are considered one of the most important paradigms that on the one hand may improve on current methods for conceptualizing, designing and implementing software systems, and on the other hand may be the solution to the legacy software integration problem [15]. An agent is essentially a special software component that has autonomy that provides an interoperable interface to an arbitrary system and can behave like a human agent, working for some clients in pursuit of its own agenda [15]. Software agents exhibit features like autonomy, heterogeneity, decentralization, coordination and social interactions, which are also desirable features for cross-organizational settings [1, 16]. Multi-agent systems are applications in which many autonomous software agents are combined to solve large problems [17].

4.2 Multi-agent platform

A software platform is required to support the execution of cross-organizational processes. To this aim, software technology as Multi-Agents Systems (MAS), Service Oriented Architectures (SOA) and Web Services can be used. In this work a multi-agent software platform is proposed that enables healthcare organizations to carry out a decentralized execution of cross-organizational processes. Software agent technology is seen as a potentially robust and scalable approach to meet the challenges of complex negotiations in healthcare environments [17]. The software agents that compose the platform are:

- Model Administrator Agent (MAA) is responsible for managing a repository of process models of an organization corresponding to integrated healthcare service solutions. This contains interaction protocols models representing the cross-organizational processes that an organization have agreed on executing with other organizations. Along with each protocol, CP-Net models corresponding to the role the organization fulfills in the protocols are stored. This agent accesses the repository to retrieve models (e.g., CP-Nets models), upon requests from AMA agents.

- Access Manager Agent (AMA) represents an organization that participates in an integration agreement of healthcare service. It is responsible for establishing communication with AMAs of the other organizations in order to agree, in a dynamic way, on the execution of cross-organizational processes defined in a integrated healthcare service solution. This agreement is achieved by the execution

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between the AMAs of the predefined protocol called request for collaboration, which was proposed in [16]. This agent instantiates the CAAs and DAAs.

- Collaboration Administrator Agent (CAA) is responsible for performing the role a healthcare organization fulfills for executing a cross-organizational process. To this aim, a CAA uses a CP-Net model containing the behavior of the organization's role and executes a cross-organizational process jointly with the other CAAs of the organizations involved in the process. This is instantiated by an AMA when organizations agree on the execution of a new instance of a cross-organizational process.

- Data Administrator Agent (DAA) is in charge of retrieving and storing clinical documents in the HIS of an organization. This is instantiated by an AMA when a CAA is instantiated.

The platform was built by using the Java Agent DEvelopment Framework (JADE) [15], which is a physical multi-agent development framework and platform that complies with Foundations of Intelligent Physical Agents (FIPA) specifications and aims at simplifying the development and implementation of multi-agent systems [15]. The process machine component embedded into the CAA agents, which is in charge of interpreting CP-Net models and execute the processes, was implemented by using the Java-based Petri Net framework (JFern). JFern provides an object-oriented Petri Net engine that provides methods to store and execute Petri Nets in real-time, and for simulation [20]. JFern supports an XML based persistent storage of Petri Nets. The tokens of a CP-Net contain XML formatted clinical documents, which are parts of the content of FIPA ACL [21] messages that the agents exchange.

5 Results

To provide a better understanding of how methodology works, in this section we present a hypothetical, yet realistic, scenario of a referral process between hospitals, setting and explain how methodology and the agents act, how they cooperate, what information they use and what results they generate.

The scenario consisted of a project for integrating and coordinating healthcare services between a General Hospital and a Specialist Hospital located in the North of Mexico. The General Hospital is 25 years old. Each year approximately 22,000 inpatients and approximately 200,000 outpatients receive medical treatments in it. The Specialist Hospital is a new public hospital outfitted with the latest high-tech hospital equipments. The patients are referred from the General Hospital to the Specialist Hospital when they require medical care for a disease such as cancer, heart and vascular, or neurologic.

Both hospitals establish an integration agreement for developing an integrated healthcare service. The purpose is to decrease the management time and improve the quality of the medical referrals between the involved hospitals through the implementation of cross-organizational processes that define electronic interchange of standard documents with clinical data. It allows physicians making better decisions about the patient healthcare. Data about processes and information required for integrating and coordinating healthcare services were collected through interviews to the clinicians, nurses, managers and other stakeholders of each hospital.In this case, clinicians play the more important role in the referral process.

5.1 Design and Implementation

5.1.1 Definition of the integration agreement

Figure 3 shows the cross-organizational integration view defined with the UP-ColBPIP language that contains the integrated healthcare service of Patient Referral. This service involves to the General Hospital that performs the Primary Care Provider (PCP) role and to the Specialist Hospital that performs the Specialist Care Provider (SCP) role; both related through a cross-organizational link with their corresponding interfaces.
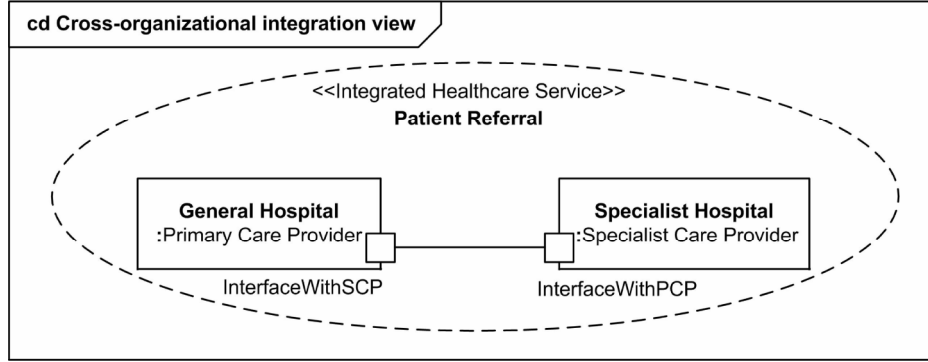
Figure 3: Cross-organizational integration view

Figure 4 shows the cross-organizational process view. To achieve the goal of improving the quality of the patient care, the Patient Referral Process was defined. The purpose of this process is to manage a patient referral between the involved hospitals. The processing of a patient referral implies the negotiation of a patient transfer order and then the management of the medical referral. Therefore, the Patient Referral Process is composed of two sub-process: the Patient Transfer Order process and the Medical Referral Management process. The former has as goal to decrease the management time of the patient admission and the later has as goal to obtain reliable clinical information about the patients. The common organizational goals can be quantified for evaluation through indicators such as the management time of patient referrals, number of transfer orders of patients successfully completed, amount of patient transfer orders rejected and accuracy of the patient clinical information exchanged.
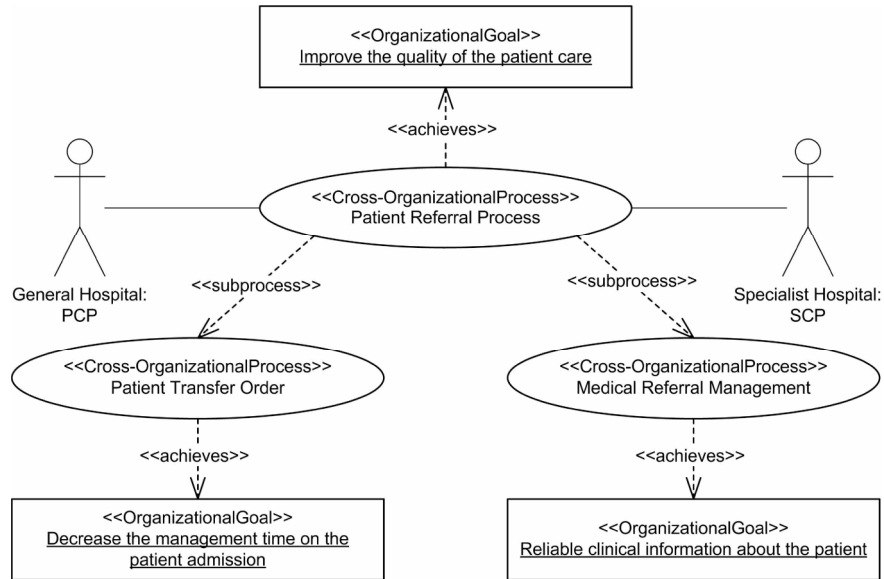

Figure 4: Cross-organizational process view

5.1.2 Design of the Integrated Healthcare Service Solution

The behavior of the cross-organizational processes was defined by using the UP-ColBPIP language. The protocol representing the patient referral process has only two subprotocols, Patient Transfer Order and Medical Referral Management that are executed in that order. Figure 5 shows the interaction protocol that represents the Patient Transfer Order sub-process. This protocol supports a negotiation process between a PCP (The General Hospital) and a SCP (The Specialist Hospital) to agree on a patient referral. The process

begins with the PCP sending a propose message to the SCP. This message has attached the Patient Transfer Order (PTO) document with the data about the reason for referral, as diagnosis, severity or aspect of medical treatment for which the patient is being referred. The SCP evaluates the proposal and responds with either a successful accept-proposal message or a reject-proposal message. This is indicated by a control flow segment with the XOR operator and with the two paths containing each message. If the SCP sends an accept-proposal message, it then creates a referral number and then sends an inform message with the referral number.

If the SCP sends a reject-proposal message, this message must contain a document with the reasons for rejecting the proposal. When the PCP receives the reject-proposal message evaluates it and responds with either an inform message or a confirm message (see second XOR control flow segment of Figure 5). In the last case, the confirm message indicates that the SCP's rejection is accepted by the PCP and the protocol finishes. Otherwise, the PCP sends an inform message with a PTO Change clinical document, which indicates changes to the initial PTO clinical document about the priority of the patient care. The SCP must accept the changes and create and send the referral number attached to an inform message.
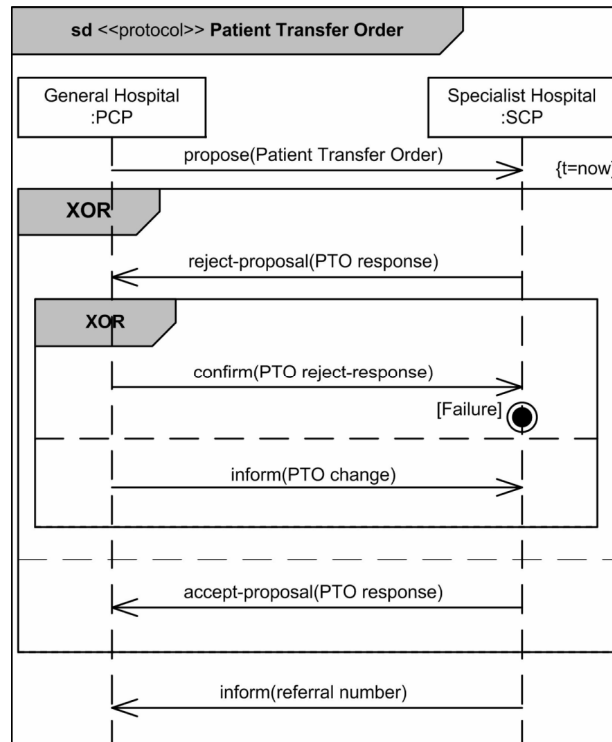

Figure 5: Patient transfer order interaction protocol

When the Patient Transfer Order interaction protocol finishes successfully, the Medical Referral Management interaction protocol continues (Fig. 6). This protocol defines the interchange of clinical documents required for a patient's medical treatment. The process begins with the PCP sending an inform message with the patient referral letter attached containing data about the required medical treatment. After the SCP receives this message, it responds with a confirm message that with a document containing a digital certificate of a SCP's authority and a receipt acknowledgment of the patient referral letter. In addition another confirm message is sent when the patient was received by the SCP. Both messages can be done in parallel, as it is expressed by the AND control flow segment. Then, a treatment is carried out by the SCP and when is completed, the SCP sends both (see second AND control flow segment) an inform message with a medical summary attached and an inform message with a discharge note attached. Then, the process ends.
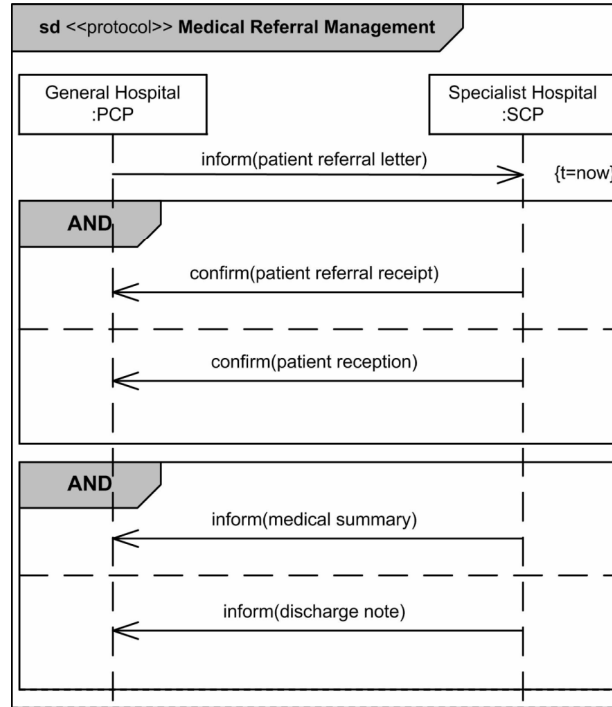
Figure 6: Medical referral management interaction protocol

In addition, the structure of several clinical documents were defined according to the CDA standard. The patient referral letter document is used by the General Hospital to inform the Specialist Hospital the health services the patient needs. The medical summary document contains the treatment information and recommendations the Specialist Hospital generates. Both documents are based on the CDA discharge summarization note document type. The discharge note document, which is based on the CDA discharge note document type, contains basic information about the patient care and the hospital authorization to transport the patient to the General Hospital. Each clinical document includes in the header the organization role element that indicates the role of the organization that sends the document. The header also contains the document name which is placed in the title element. Both elements are used to reference the clinical documents in the interaction protocols. The structure of the other documents used in the processes was defined without following a standard of clinical documents, because of the needs of exchanging administrative information between the hospitals.

Once defined the cross-organizational processes and the clinical documents, the next task is the design of integration processes. The cross-organizational processes defined with the UP-ColBPIP language were transformed into BPMN process diagrams representing the integration processes of each hospital. This was performed by using the transformation engine for BPMN implemented described en Section 3. The model of each integration process was generated with the public and the private activities of the corresponding hospital required to support the message exchange of the cross-organizational processes.

Figure 7 shows the integration process model of the Patient Transfer Order process for the General Hospital. In this BPMN process diagram three public send activities for sending messages and three receive message event for receiving messages were included. Furthermore, the following private activities were added in automatic way: generate patient transfer order, generate patient transfer order change, generate patient transfer order reject-response, and store referral number. Also, it was necessary to apply a refinement to the evaluate patient transfer order response task that was automatically generated in order to express an evaluation task. The diagram also shows the control flow that is defined according with the flow defined in the protocol.
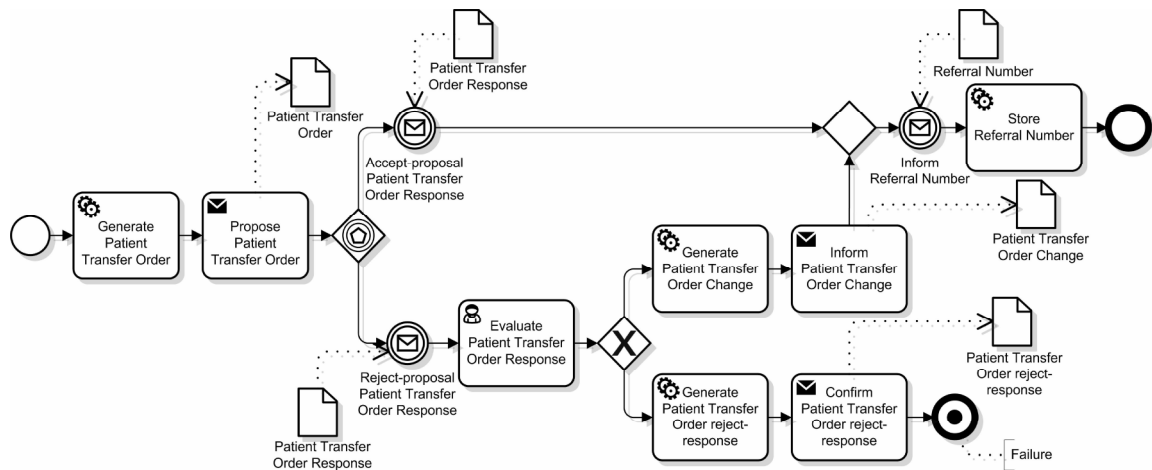
Figure 7: BPMN integration process (patient transfer order) for the General Hospital

Figure 8 depicts the integration process model of the Patient Transfer Order process for the Specialist Hospital. In addition to the public activities for sending messages and the events for receiving messages, the private activities added to this process are: evaluate patient transfer order, verify patient transfer order change, and generate referral number.
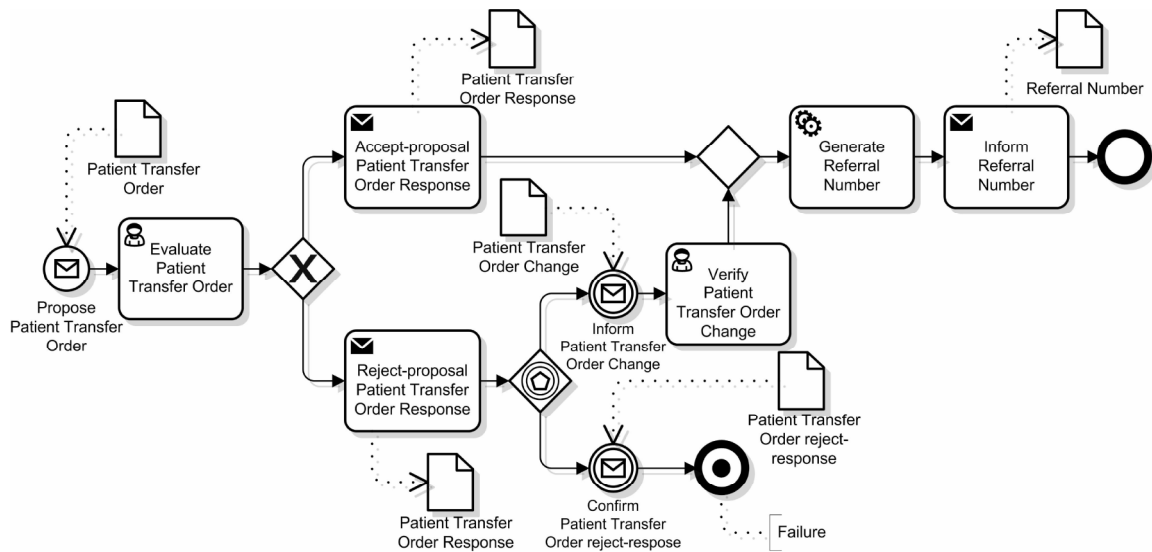

Figure 8: BPMN integration process (patient transfer order) for the Specialist Hospital

The BPMN process diagram representing the integration process model of the Medical Referral Management process for the General Hospital is shown in Figure 9. In this diagram a public send activity for sending message and four receive message events for receiving messages were included. Besides, the following private activities were added in automatic way: generate patient referral letter, store patient referral receipt, store patient reception, store medical summary, and store discharge note.
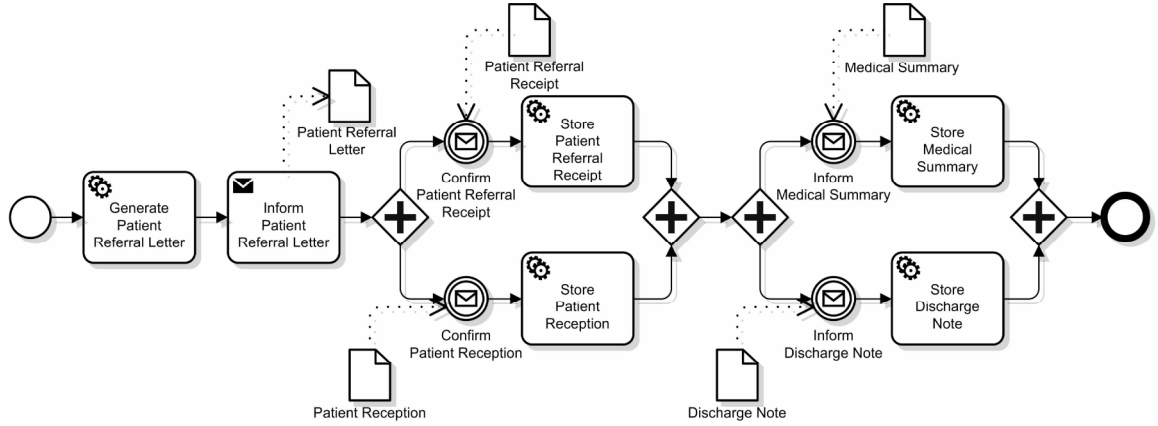
Figure 9: BPMN integration process (medical referral management) for the General Hospital

Figure 10 shows the integration process model of the Medical Referral Management process for the Specialist Hospital. In addition to the public activities for sending messages and the events for receiving message, the following private activities added are: evaluate patient referral letter, generate patient referral receipt, generate patient reception, generate medical summary, and generate discharge note.
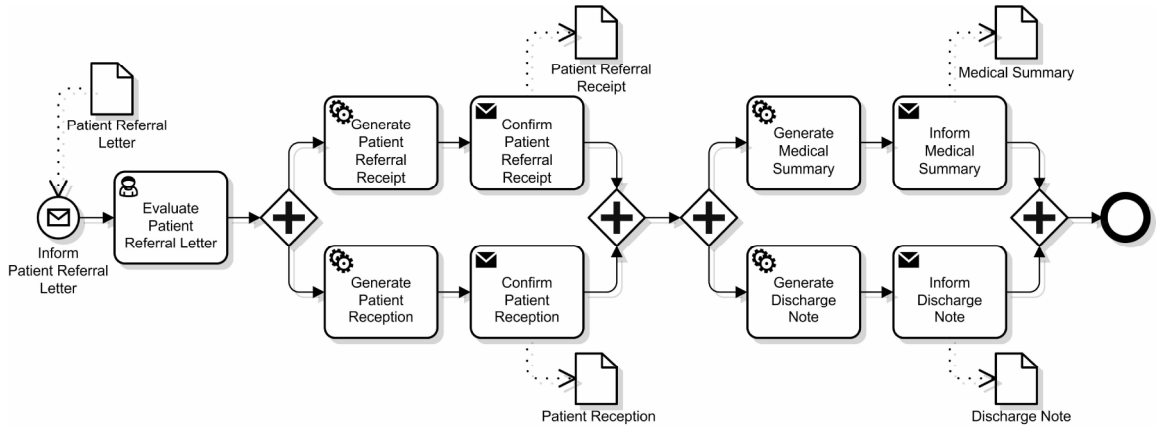

Figure 10: BPMN integration process (medical referral management) for the Specialist Hospital

5.1.3 Generation and implementation of the technological solution

To generate the technological solution, the BPMN-based integration process models of each hospital were transformed into CP-Net models using the transformation engine for CP-Nets mentioned in Section 3. As an example, Figure 11 shows the CP-Net model of the General Hospital. The diagram depicts the behavior of the hospitals involved in the Patient Transfer Order process in terms of CP-Nets. The public and private activities of an integration process, as well as the receive message events, are expressed by transitions in the CP-Nets. These CP-Net models are stored in XML format and they serve as input to the agent-based platform.
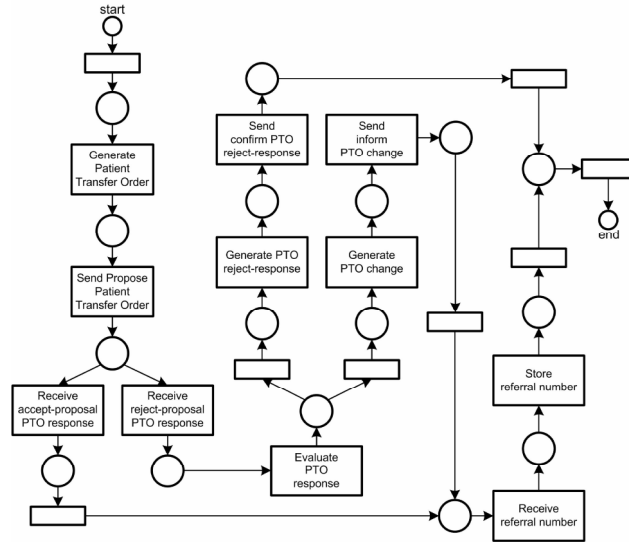
Figure 11: CP-Net diagram (patient transfer order) for the General Hospital

For implementing and executing the cross-organizational processes, the multi-agent software platform described in Section 4 is used. Figure 12 shows the agents that compose the implementation for the processes of the defined in the integrated healthcare service solution. Each hospital has a HIS that can generate the information to be sent in electronic clinical documents and process and store the information received in the documents. Also, each hospital has a process model repository that is managed by a Model Administrator Agent (MAA). The repository contains the interaction protocol models defined in Section 5.1.2 as well as the CP-Net models corresponding to the organization that is owner of the repository.
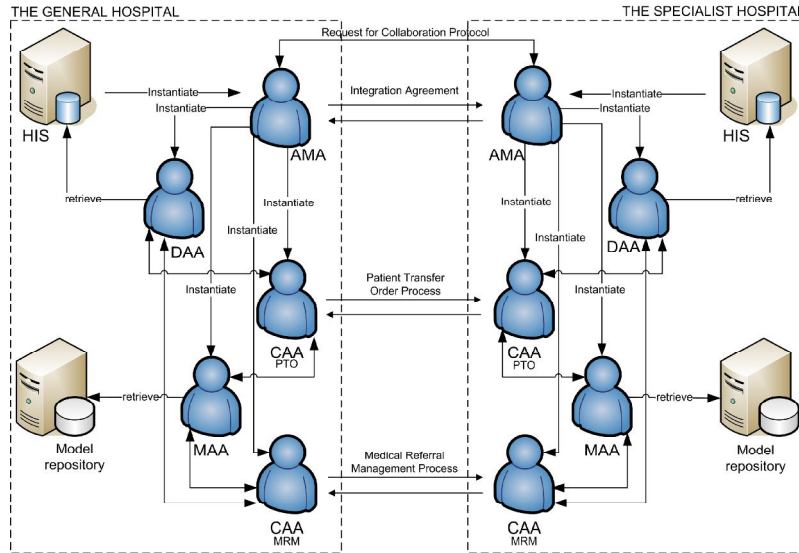

Figure 12: Multi-agent software platform developed for implementing and executing cross-organizational processes

An Access Manager Agent (AMA) is instantiated for each hospital. AMAs are always active and there is one representing the General Hospital and another one representing the Specialist Hospital. When the hospitals want to execute a cross-organizational process defined in their repositories, first the AMAs of the hospitals execute the request for collaboration protocol in order to retrieve the CP-Net model that corresponds to each

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part and instantiates a Collaboration Administrator Agent (CAA). Second, the retrieval of a CP-Net model of an organization is done by a request from the AMA to the MAA. Third, with this model, the AMA of each hospital instantiates a CAA that will perform the role the organization fulfills in the cross-organizational process.

In addition, when a CAA is instantiated, the AMA instantiates a Document Administrator Agent (DAA) if it is not on execution. For each organization, there will be a number of CAAs as instances of cross-organizational processes have. As an example, Figure 12 shows the AMA of each organization has instantiated two CAAs, one for executing an instance of the PTO protocol and the another one for executing an instance of the MRM protocol. The PTO protocol is executed by the respective CAAs of the organizations and the MRM protocol is also executed by the respective CAAs of the organizations. They interoperate by exchanging the messages defined in the protocol. The messages convey the electronic clinical documents. These documents are stored in the HISs of the organizations or retrieved from the HIS of the organizations. In this way, the interoperation and integration of the HISs of the organizations is carried by the agents.

5.2 Results analysis

The integration of healthcare services between the General Hospital and the Specialist Hospital has been carried out through a paper-based interchange of clinical documents as referral letters, diagnostic results or discharge summaries and the ad-hoc coordination of activities carried out by telephone. This way of communicating medical documents among healthcare providers is deficient in quality, as well as error prone and often too slows [24, 25].

The developed approach allows the General Hospital and the Specialist Hospital to integrate and coordinate healthcare service about Patient Referral by executing cross-organizational processes. The main benefits of this approach for these hospitals are:

- The interactions between the hospitals and the interchange of clinical documents required to carry out the patient referral healthcare service are explicitly defined in the interaction protocols representing the cross-organizational processes.

- Hospitals can interchange documents based on a well-known standard such as HL7 CDA, which provides a common syntactic and semantics of the interchanged information.

- Quality of the integrated healthcare service can be improved by evaluating the performance of the cross-organizational processes against their associated common goals such as quality of the patient referral, decrease of the management time of referrals, reliable information about medical referrals.

- The patient transfer order protocol allows to the hospitals the execution of a negotiation to agree on a referral of a patient. This improves the coordination for referrals among the hospitals.

- The medical referral management protocol allows the management of the referral of a patient in a coordinated way. Parallel interactions improve the performance between the hospitals.

- The rapid generation of integration processes required by the hospitals to know, from a conceptual viewpoint, the public and private activities that they have to implement and perform for executing the cross-organizational processes.

- The automatic and transparent generation of the technological solution by generating the CP-Net models from the integration process models.

- The integration and interoperation of the HIS of the hospitals through a software agent platform, which deals with and hides the conversion issues of data between the HISs.

- AMA agents allows to the hospitals automate the agreement on the execution of a patient referral by generating the CAA agents that executes the corresponding cross-organizational processes.

In this way, the hospitals can deliver an efficient healthcare service in quality and response time due to an effective communication based on cross-organizational processes.

In healthcare organizations, there are a variety of processes, such as hospital administration by managers, registration for treatment by patients, test report generation by technicians, and diagnosis decision making by

clinicians. Furthermore, within the challenges encountered in the process modeling in healthcare organizations is the complexity of these processes. The healthcare processes represent complex routine work, that involve many activities (performed either concurrently or sequentially), that engage many persons, and that are in general frequently performed. There is a trend to view healthcare in a multidisciplinary perspective, as numerous interactions and cooperation take place across different functional units in terms of information sharing, consultation, and combined treatments. These interactive and collaborative activities should be well organized and managed, without which the efficiency of healthcare service cannot be easily guaranteed.

6 Conclusions

This work proposed a contribution to show healthcare organizations can achieve high quality and improve the communication in the integration and coordination of healthcare services when they focus on cross-organizational processes. This work presented a methodology that provides guidelines for the organizations can define an integration agreement identify and design the cross-organizational processes required and the clinical documents to be exchanged in them. From each cross-organizational process each organization can also automatically generate the logic required to execute it through a multi-agent system platform. This platform provides agents that enables to the organizations to manage and monitor the processes as well as enables the interoperation and integration of the Healthcare Information Systems (HISs) of the organizations.

Important requirements for service integration among healthcare organizations are fulfilled: support to celebrate integration agreements; interoperability between heterogeneous HIS by using standards for clinical document exchange; ability to cope with changes in cross-organizational processes for establishing a continuous improvement strategy; the alignment between the healthcare integrated service solution defined at the organizational level and the solution defined at technological level to guarantee the technological solution provides a full support to the cross-organizational processes; and the distributed execution of cross-organizational processes that allows each organization keeping its execution autonomy.

The scenario that was used to validate the methodology allowed illustrating details of its application. The information system generated allows the General Hospital and the Specialist Hospital coordinating their efforts for providing quality and efficient services.

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