AGENT BASED MODELING ARCHITECTURE WITH BPMN AND DEVS NETWORK

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ABSTRACT

The adoption of Business Process (BP) can deal with the (re)development of information process, for instance it can help healthcare providers structuring the way information system and people have to interact. Business Process Management (BPM) is known as a methodology that aims to give a structured way of representing processes of systems. At the same time, the human resources are organized in identified or implicit structures that allows individual to exchange information either related to their work function or not. Nevertheless, the human organizations structure and communication channels are not, up to now, fully captured by the information systems. It may lead to lose part of useful information exchanged by participants. Accordingly, this paper focuses on multi-agent solutions representing social networks in the healthcare domain associated with BPM of patient pathways. The purpose is to combine BP with agent-based models in order to better improve performance and manage resources.

Keywords: Business Process, Business Process Management, multi-agent, performance, resources.

1. INTRODUCTION

Healthcare processes or pathways are typically described informally by text description or by semi-formal languages (Eshuis et al. 2010) . A process is generally defined as a sequence of events that uses inputs to produce outputs. Besides, a business process is an activity or set of activities that will accomplish a specific organizational goal. It is also considered as a sequence of performed steps that drives information to produce goods and/or provides services. The business process needs to be managed and controlled; it attests the need to use a Business Process Management (BPM) methodology. According to (Van Der Aalst, Ter Hofstede, and Weske 2003) the business process management (BPM) includes methods, techniques, and tools to support the design, enactment, management, and analysis of operational business processes. It can be considered as a formalization of classical Workflow Management (WFM) systems and approaches. BPM process solutions enable enterprise to measure and standardize processes and also provide reusable processes that can be networked. In this context, several languages are used for BPM; the most used one nowadays is Business Process Modeling Notation (BPMN). BPMN has been proposed by the Business Process Modelling Initiative (BPMI) and is currently maintained by the Object Management Group (OMG 2003) that provides this standard for IT and business actors. BPMN is an increasingly significant standard for process modeling and has received high attention and uptake in BPM practice (Recker 2008). It is an established standard for business process modelling in industry and economy and frequently supported by a computer program which enables a quite easy graphical description of complex processes (Scheuerlein et al. 2012).

As argued in (Antonacci et al. 2016), the use of BPM in healthcare sector is becoming a key enabler for the improvement of healthcare processes, since the healthcare environment is becoming more dynamic and volatile, and follows more complex processes, the combination of agent based model with business process may be efficient for resolving simulation's limitations in BP in terms of resource allocation, in the other hand, managing the availability of resources in healthcare sector is a very challenging problem with very little research attention. For this reason, the use of business process modeling combined with the adoption of simulation-based analysis provides a cost effective, accurate, and rapid way to evaluate alternatives before committing the required effort and resources (Tumay 1996; Nakatumba, Rozinat, and Russell 2009).

Furthermore, the analysis of performance of BPMN is crucial, it helps Business analysts to predict whether the goal can be achieved or not. For this reason, simulation has been identified as a key technique for BP performance analysis (Antonacci et al. 2016). It can be important for business processes as it helps and supports the decision making process, reduces cost that can occurs in the case wrong decisions haven't been anticipated and as final objective provides a good quality of services.

A viable approach to address the problem of managing the resources allocation is Modeling and Simulation. In this paper we propose a new approach which combines BPMN with agent based model in the case of healthcare systems, the proposed approach adopts DEVS (Discrete

Event System Specification) formalism to analyze the healthcare process behavior. The reminder of this paper is structured as follows first a state of art and background are presented, then we justify our motivation. Section 4 provides the application of the approach in the emergency cases. Finally, conclusions and plans for future works are presented in Section 5.

2. RELATED WORK AND BACKGROUND

BPMN is a graphical notation for drawing business processes (OMG 2003). It provides a standard notation that is easily understandable by all stakeholders; and also bridges the communication gap that frequently occurs between business process design and implementation. Nowadays BPMN becomes widely used by different organizations, as it is simple to learn, but yet powerful enough to depict the potential complexities of business processes. One of the main complexity of BP is the limitation of its simulation, which is due to the following reasons: lack of simulation know-how of BP analysts, costs and difficulties in retrieving and analyzing the data required for simulation model parameterization, large semantic gap between the business process model and the simulation model and finally, the use of models that may be (partially) incorrect or may not be at the right level of abstraction (Bocciarelli, D'Ambrogio, and Paglia 2014). In this context, the use of BPMN models in healthcare sector helps to facilitate the management of complex hospital BPs (Antonacci et al. 2016).

In addition, simulation proved its value in the manufacturing sector and has been used to evaluate process problems in healthcare as well (Harrell and Price 2000). It has been used for over a decade by health services for improving patient care. In this respect, there are a lot of examples in the literature which provide simulation tools for healthcare organization, in (Laskowski and Mukhi 2008), authors have developed a tool for managing emergency department, by planning capacity resources utilization and staff capacity. Moreover, authors in (Norouzzadeh et al. 2015) show how modelling and simulation of internal medicine practice process can help on decision making. The results of simulation, based principally on patient waiting time were able to give an idea about improving resources utilization. Another example is given by Gűnal and Pidd in (Gehlot, Matthew, and Sloane 2016) which describes a model of the process flow of patients, that represents the multitasking behavior of medical staff (doctors and nurses), the only issue is that the ignorance of other possible factors such as: doctors' interactions with patients, other medical staff and their working environment lead to incomplete consideration of the problem (Jain et al. 2011).

Moreover, popular approaches include decision analysis, Markov process, mathematical modeling, systems dynamics and discrete event simulation (Fone et al. 2003) (Kanagarajah et al. 2010). The limitation of these approaches is that they ignore the effect of naturalistic human decision-making and behaviors on the performance of healthcare processes. In order to overcome such limitation the use of Agent Based Modeling (ABM) offers complementary perspectives to model the process of health care domain (Wang 2009). Agent based modeling (ABM) is formed by a set of autonomous agents that interact with their environment and other agents through a set of internal rules to achieve their objectives (Onggo 2010) (Grundspenkis and Pozdnyakov 2006).

The purpose of this paper is to present architecture for modeling and simulation in healthcare domain, the proposed architecture aims to overcome BPMN limitations and drawbacks such as allocation of resources. To this goal, we propose new approach which uses DEVS simulation for emergency department and that considers both healthcare participants and actors.

In this context, there are some studies In the literature using BPMN model with DEVS model, these studies are based on meta-model approach (OMG 2003), which is one of the most used transformation techniques that includes the mapping of BPMN concepts to DEVS concepts. Based on the proposed approach of BPMN to DEVS (Cetinkaya, Verbraeck, and Seck 2012) which presented a Model Driven Development (MDD) framework for modeling and Simulation (MDD4MS), and where a set of transformation rules were defined: some BPMN concepts (Pools, Lane, SubProcess) were mapped to DEVS coupled component while task, event (start, end and intermediate) and Gateway were mapped to DEVS atomic component. This proposal doesn't cover the intervention of different resources like (human resources, devices and/or Software services) which may affect the execution of the task. To overcome such limitations, authors in (D'Ambrogio and Zacharewicz 2016) proposed new approach, by introducing reliability analysis that takes into consideration unexpected failures of the resources that execute the process tasks (unavailability of a resource allocated to task).

Discrete Event system Specification (DEVS) (Zeigler, Praehofer, and Kim 2000) is formalism for modelling Discrete Events Systems. The hierarchical and modular structure of DEVS allows defining multiple models that are coupled to work together in a single and model by connecting their input and output through messages (Wainer 2009). In the same way, the resulting model can also be coupled with others models defining multiple layers in the hierarchical structure. In DEVS, atomic models define the behaviour of the system, and coupled models describe the structure of the system. The DEVS formalism has several advantages. The reason behind using DEVS is that it is based on dynamical systems theory and provides well defined concepts for coupling components, hierarchical and modular model construction, and an object oriented substrate supporting repository reuse. Modular construction is one of the most important characteristics of DEVS because it allows the modeler to design and construct each model independently for optimal efficiency. As long as models adhere to certain protocols, they can interact which each other (Pérez et al. 2010). Accordingly, we use VLE (Virtual Laboratory Environment) for the implementation.VLE is an open source software and API under GPL which supports multi-modeling and simulation by implementing the DEVS abstract simulator(Quesnel, Duboz, and Ramat 2009). It integrates specific models developed in most popular programming languages into one single multi-model. It also proposes several simulators for particular formalisms; for example, cellular automata, ordinary differential equations (ODE), differential equations, various finite state automata (Moore, Mealy, Petri-Nets, etc.) and so on. VLE can be used to model, simulate, analyse and visualize dynamics of complex systems. Its main features are: multi-modeling abilities (coupling heterogeneous models), a general formal basis for modelling dynamic systems and an associated operational semantic, a modular and hierarchical representation of the structure of coupled models with associated coupling and coordination algorithms, distributed simulations, a component based development for the acceptance of new visualization tools, storage formats and experimental frame design tools (Bouanan et al. 2015). In the next sections, we give an overview about the architecture and its application.

3. CONTRIBUTION

3.1. Problem Statement

BPM depends on a very important notion which is a workflow. Workflow can be any business process, which consists of two or more tasks performed in social on concurrently by two or more people. It should assure the right people at the right time. It also provides general information about the business process: individuals and teams needed to complete task, information and resources needed to complete task, finally; Dependencies and deadlines for task completion (Grundspenkis and Pozdnyakov 2006). The use of workflow in healthcare domain is thriving, but since healthcare environment is evolving and complex to manage, it faces some drawbacks including: limited flexibility during process enactment (Bolcer and Taylor 1998), inability to cope with dynamic changes in resource levels and task availability, limited ability to predict changes, due to external events, in both the volume and composition of work, lack of performance, scalability and reliability as well (Pang 2000). For overcoming some of the mentioned limitations, an agent based oriented approach is proposed, this approach aims to involve agent network in coordination of BP. The main idea is to connect only agents who perform required tasks for achieving the goal; this connection is established through the flow information exchanged in the workflow.

3.2. Agent Based Healthcare Process architecture

The proposed architechture aims to combine BPMN with DEVS in ordre to manage resources. Fo this, we classify entities by considering their roles and interactions they have within a multilayer network (Sbayou et al. 2017). This network uses information from both an XML file generated from BPMN diagram and database information for input simulation. Thus, the general model is divided into two parts:

- Coupled model of agents that perform tasks.
- Decisional tasks model to orchestrate network.

This method allows us the integration of different relationships between actors in BPMN that are represented with a node in network representation (Bouanan et al. 2015). Actors are defined as agents, which are represented in the agent based model as individuals or group of individuals. Each agent is described by a set of attributes distinguished into two categories:

- Static attributes i.e., id, gender, and status.
- Dynamic attributes (variables) i.e., availability and state.

Static attributes are intrinsic or unchanged parameters, i.e., time has no effect on them. Dynamic attributes evolve with time or events (Bouanan et al. 2016) (Ruiz-Martin et al. 2016). For instance, doctors can be reached depending on their availability based on worktime and number of patient. The DEVS model is then used for simulation. Final results can be compared to those estimated by experts. We aim also to cover by our architecture various existing situations or structures in healthcare organizations thanks to BPMN and DEVS M&S in order to make it general and not only available for special cases.

In order to apply our approach, at first the user draws a BPMN process of the studied case, in order to clearly represent the role of each agent and to make the process unambiguous. Then the tool generate an XML file which contains information about decisional tasks, these tasks are responsible of the orchestration of the general model. In parallel, it extracts input information required for simulation from a database that contains information about population and healthcare stakeholders.

Once the XML file is generated and data are collected, the DEVS network is created, and it is represented as a multilayer network where each layer describes a level of connection between agents (Sbayou et al. 2017). The DEVS network is created within VLE; which uses the XML file that contains elements which assure connection between represented agents in the network. It also uses R-Studio tool for visualizing results. This method allows us the integration of different relationships between actors in BPMN that are represented with a node in network representation.

We propose an overview picture of our architecture in Figure 1. Actors are defined as BPMN resources (lanes in Figure 1 left part) and then M&S agents (represented by nodes in the figure 1 center part).

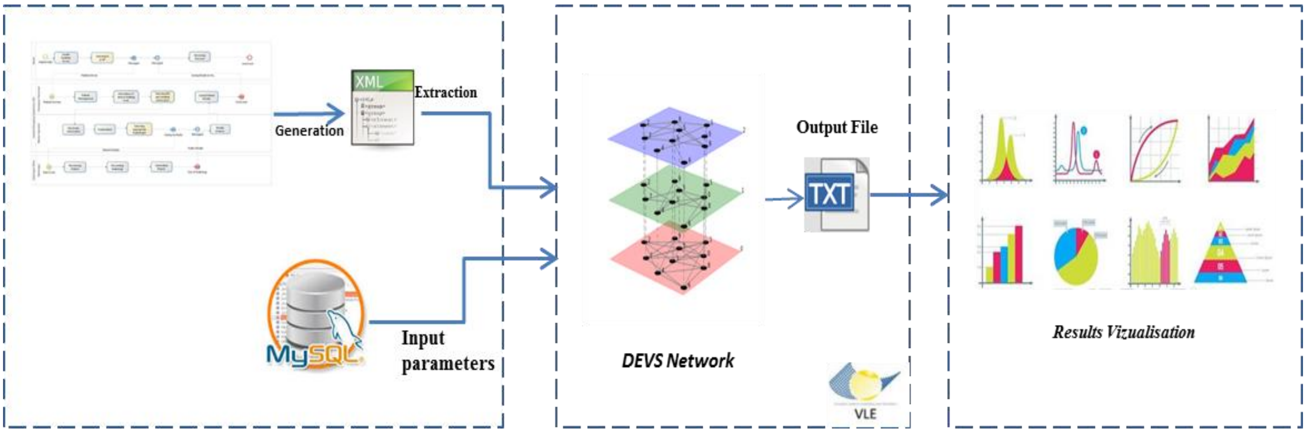

Figure 1: Agent Based Healthcare Process architecture

The BPMN model is describing the medical pathway of patients. It integrates the connection of patient with the different medical resources. Medical resources are including: General Practitioners (GP), Hospital (Fr: CHU) and medical specialists. In some cases, the patient can directly go to specialists without passing through GP. In the study case, these specialists are: gynecologists, ophthalmologists, dentists and psychiatrists (for patients under 26 years old). Then the agent-based model is considering agents as individuals or group of individuals. It represents the social interaction between agents.

3.3. Controller atomic model

In order to implement the architecture, we propose an atomic model as a controller which is based on the XML file generated from the BPMN diagram; it is considered as the dynamic part of our architecture this atomic model is in charge of orchestrating the DEVS network of different agents who performs the process. The proposed model is shown in figure (5), it has input "xml_file", and number of outputs ports which depends on the process, these ports are used to send information to the general model, the general model is a coupled model of atomic models, where each atomic model describes a role in the BPMN process.

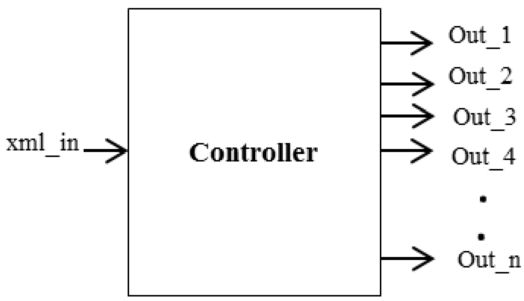

Figure 2: Basic atomic model of controller

3.4. Healthcare system in France

In order to apply our approach we briefly introduce the specific context of health related sector in France. It will permit to understand the process of the healthcare system we describe in our example in France.

The French healthcare system covers both public and private hospitals, doctors and other medical specialists who provide care services to French resident. It is accessible for all residents, independently of their age, income or status. French resident has to register a General Practitioner (GP) "Fr: *Medecin Traitant*", in order to ensure full eligibility to reimbursement of health costs. While following this process, the General Practitioner (GP or G), becomes the principal route which follows the patient care pathways "Fr: *Parcours de soin*". In emergency cases, there is no appointment needed, in addition, Emergency Departments (ED) are the most complex system in healthcare sector. They usually require a lot of resources, at any time.

4. CASE STUDY

4.1. Data Collection

In order to apply our architecture, we have localized the different French hospitals which includes emergency department (Figure 3) according to (CNOM 2017), and we localize them in google maps, also we generate a small population of patient, which is near the hospitals and also those who are living far. In our first study we will only take the case of the patient who are living near to the chosen hospital. We focused our study in the southwest region of France (*Nouvelle Aquitaine*); we consider the case of the University Hospital Center (*CHU of Bordeaux*). Considering the CHU of Bordeaux; we have collected some statistical information about the patients as well as their care in the emergency department. The hospital is visited daily by about 149 patients, the completeness of reception is 100%, the sex ratio representing the number of men and number of women at birth during a given age group is 1,17. 1% of patients visiting the hospital are under one year old, 14% are patients under 18 years of age, patients aged 75 years and over account for 16%, and 7% of patients are not from the region. The average duration of process for each patient is about 4 hours according to ("ORU" 2017). The figure 3 display several Emergency Departments (Green ED Bubbles) of the region of Bordeaux (including CHU of Bordeaux) and the set of Patients (Red P Bubbles).

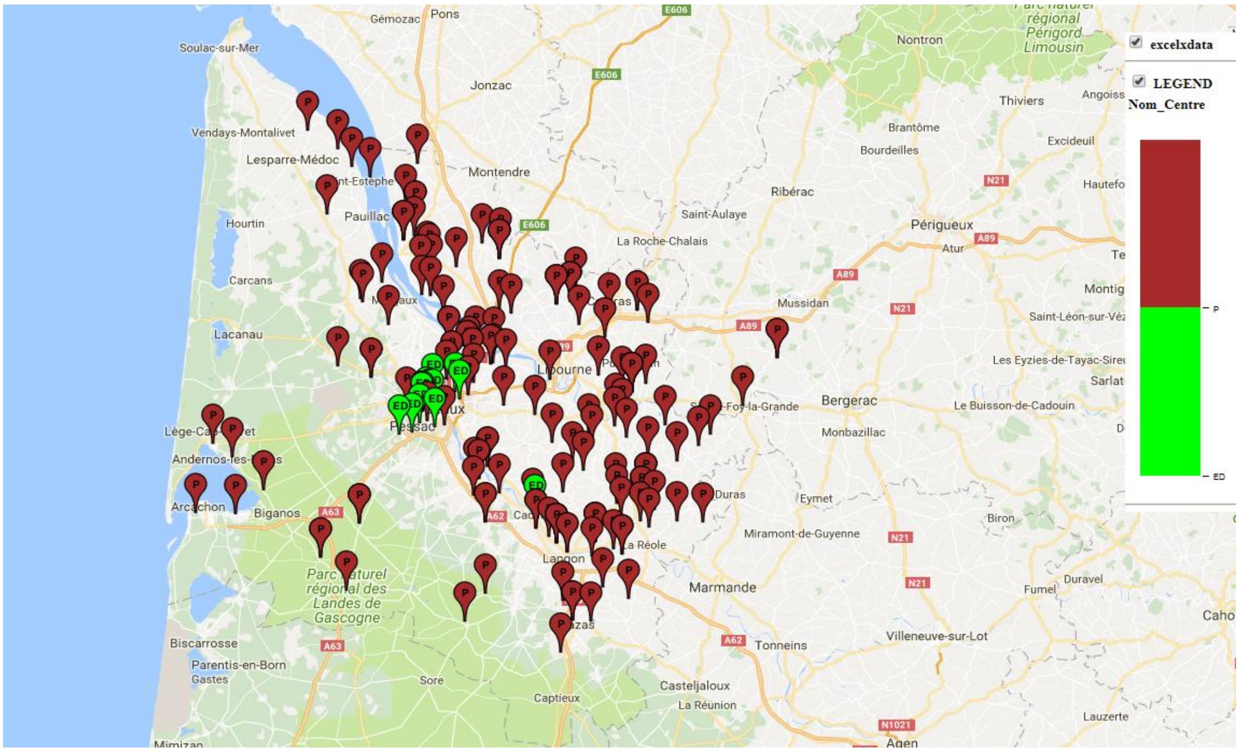

Figure 3: Geographic data in southwest of France

4.2. Emergency Department workflow

In this section we analyze the patient flow in emergency department of CHU of Bordeaux. Figure 4 shows in BPMN a sequence of steps followed by patient and health resources agents in the situation of emergency at ED, the diagram contains agent's roles, and each pool describes tasks to be performed by each agent. The process starts when a health problem occurs, once the patient has a health problem, he has to decide whether to visit his referred GP or to go the hospital. In our case the choice is focused on emergency cases, so the patient selects the hospital and generally the nearest one. Once the patient is received at the hospital, the administrative agent creates admission file for registration, redirects him to the waiting room, then the agent selects the next available practical nurse (Fr: *Infirmier Organisateur de l'Accueil, IOA*). It is described by a BPMN massage flow connection between patient and the CHU.

The priority of patient care is determined by the severity patient's health state. This degree of urgency is evaluated by the practical nurse (IOA) who evaluates the patient state, selects the available emergency physician and then provides him preliminary patient's information. Depending on the patient's health state, the emergency physician orients the patient, who may be referred to resuscitation (case of vital distress), examination boxes (priority patients) or consultations (ambulatory patient). After the installation in boxes, a waiting time of 2 hours minimum is envisaged (surveillance, collection of the results, possibility of recourse to specialist's opinion). In the other hand a hospitalization may be considered (conventional hospitalization, emergency hospitalization (short-term)).

The waiting time is often a source of incomprehension, anxiety and sometimes annoyance. This expectation may depends on number of patients, the arrival of other patients in severe conditions, the availability of resources (practical nurses, physicians and material resources such as beds...) (CHU Bordeaux 2017).

4.3. Operation atomic model for ED controller

In order to capture the detail of the collaboration between agents, the BPMN diagram (Figure 4) described 3 orange tasks (select H or GP; select practical nurse and provide information; select EP and provide information) which we named respectively (T1; T2; T3). These tasks are called decisional tasks, they are used for simulation and are responsible of verifying the availability of resources and connecting them. The operation of the controller in the case of ED has four basic states then set in the DEVS model: «IDLE, "State1", "State2" and "State3" described in Figure 5.

According to the BPMN, the DEVS model (Figure 5) is initialized in "IDLE" state where it reads the XML file and checks for decisional tasks. Then the model can change to the next state according to the convenient task given by the BPMN. The time advance of each tasks depends on the parameters set by the modeler at the BPMN building step at the initialization step. In case described Figure 4, the general model is a coupled model of four atomic models (Patient, Administrative Agent, Nurse and emergency physicians) which can be reused for other case studies, each model is linked with a specific output of the 'Controller' model.

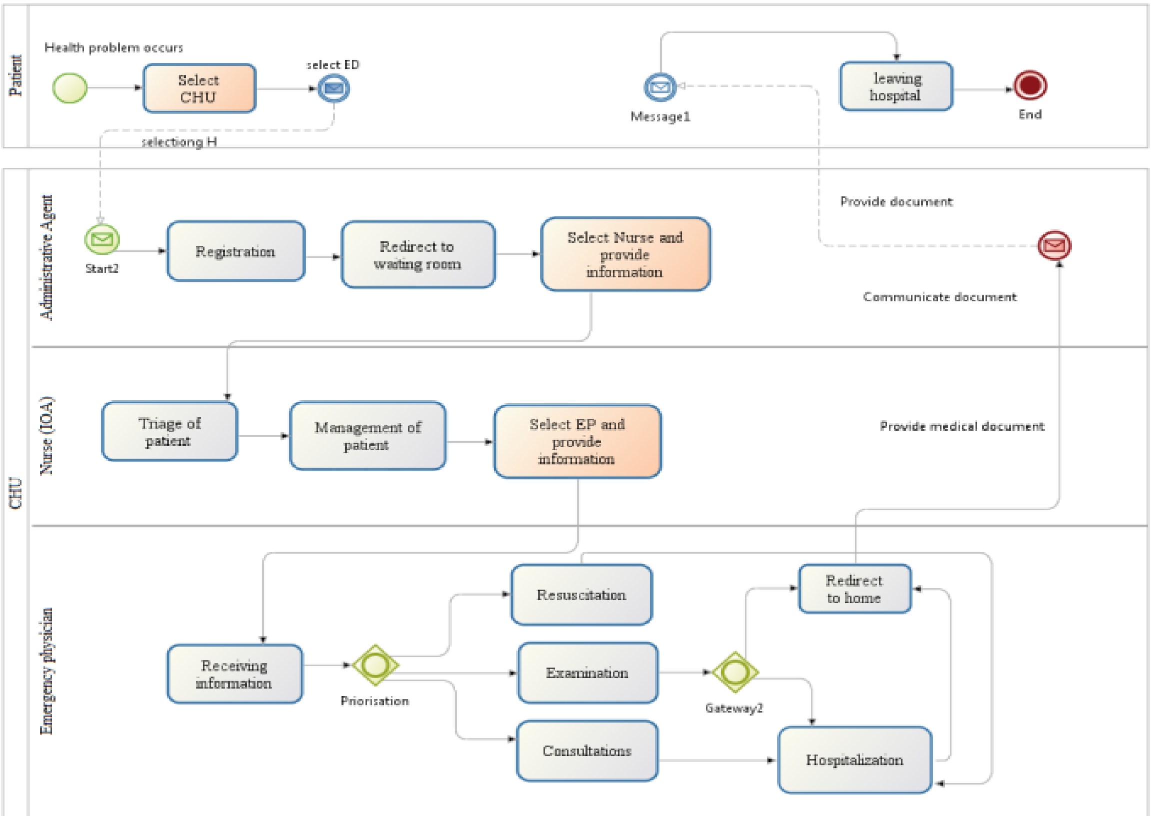

Figure 4: ED patient pathway

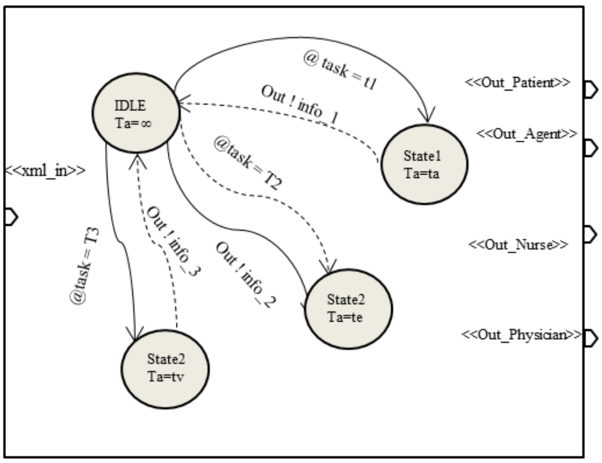

Figure 5: Operation of the controller model

4.4. Results and discussion

In this section we present results based on some data (ORU 2017) (CNOM 2017). Our aim is to simulate the allocation of resources according to some input parameters (number of arrived patient, priority, number of resources and their availability) and also the xml generated file.

For this we take the case of 10 arrived patients, at a specific time, each patient is connected to the administrative agent according to his priority, the arriving of a lot of patient at close time may affect the length of stay (LOS) which we are going to include in the next works. Once the patient is registered, information is sent to the available nurse, the nurse selects the available physician, and affect it the prior patient, and the connection between available resources and seek patient is established.

At the end; each patient has his own health network which includes (administrative agent, nurse, and emergency physician) who participate on performing the patient emergency flow.

In order to apply the approach and ensure its feasibility, we have chosen the case of 1 administrative agent, 3 nurses and 4 emergency physicians. In order to simulate the number of patients who reached the end of the process. The output file of the simulation contains the id of agents and their states, the figure 6 shows simulated DEVS network of one agent (A) connected to several resources (patients (Pi), nurses (Ni) and physicians (Di)). It details all connected resources in the case of arrival of 10 patients at a specific time.

We can observe that some patients are only registered because there is not enough health resources which may take them in charge. We can also observe that that administrative agent is connected to all coming patients that are still waiting for their turn in order to join the network.

This study simulates the allocation of available resources, the main idea is to test and verify the proposed architecture in this paper. In that objective, we use a DEVS network which is helpful in multidimensional structures where interaction between agents is complex.

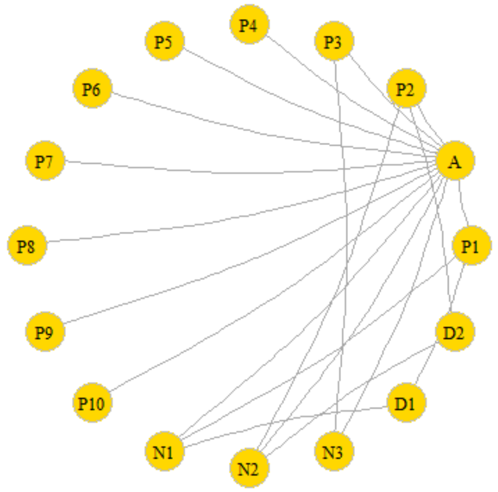

Figure 6: ED department resource network

Our objective in the next work is to play scenarios based on the number of resources and the performed tasks in the BPMN, and also include time parameters in order to improve waiting time in different steps of the process, We are going to focus now on resource allocation time and time to reach the proper resources (so including the geolocation information of agents). In particular we are studying the different time duration of different tasks also integrating performance of different resources depending on their solicitation.

5. CONCLUSION AND PERSPECTIVES

The paper has reported a new approach that combines BPMN with DEVS, applied at first in healthcare modelling sector. The idea presented in this paper was to demonstrate the interest of coupling a health care patient pathway workflows modelled with BPMN with different healthcare resources organized in social networks described with DEVS. Such an approach can be proposed to study a territory in terms of sufficient or insufficient resources available in a specific area. The case study, located in the region of Bordeaux, has been possible thanks to data coming from a national repository that publishes the list of healthcare resources with their geographic location. The presented case study aims to manage resources and shows their impact on the performance of the process. In the coming works we will include new parameters as new resources (equipment) in order to manage the overcrowding of ED. We also want to apply our architecture in other sectors in order to make it functional for different application domain.

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