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Workflow Specification for Interaction Management between Experts in a Cooperative Remote Diagnosis Process

M.A. Laredj and K. Bouamrane

Department of Computer Sciences, Sciences Faculty
University of Oran - (Es-Senia)- Algeria
BP 1524, El M'Naouer, 31000
{lmadnane, kbouamranedz}@yahoo.fr

Abstract. The maintenance became one of the strategic industrial functions. Far from being stabilized today, it progress by introducing the new management methods and the technological development of the production equipments, in particular in the measurement and the control operation. All these factors modify the organization modes of the maintenance function, which converges more and more towards a cooperative approach. It will absorb a big part henceforth, and subsequently, will require a rigorous modeling allowing its future implementation. In this fact, we propose the specification of a workflow model to assist the cooperative maintenance. It main aim, will be to coordinate the interactions between the various intervening actors in the maintenance process.

Key words: E-maintenance, CSCW, Groupware, Workflow, OSSAD, Petri nets.

1. Introduction

Maintenance is today, an activity where collaboration is fundamental. Many actors collaborate to achieve a common purpose: reducing the failure probability or object degradation, each one, having its personal knowledge and practices. Thus, several people of diverse countries and professions, working for distinct companies, can have to work together for the product maintenance, which implies that various cultures must be taken into account in the management of the maintenance process. This is not without causing many problems. It is then necessary to reinvent the organization of the maintenance process and to redefine the relationship between the experts within the cooperative work. The roles and the positions of each actor must be redefined.

In this work we will define in first section the various forms of maintenance in order to put forward in the second part the importance of the cooperation between experts during failure diagnostic. After the description of the various research and platforms, allowing the implementation of a cooperative and collaborative maintenance vision. We will focus ourselves on Proteus platforms [2] and the contribution of Saint Voirin [3][4] which we will improve with “Workflow” approach. We will present in following section the workflow modeling through two steps. The first one based on a systemic language “OSSAD” will be formalized at the second step by the Petri nets that allowing the simulation and validation of our Workflow models thanks to the mathematical properties of the Petri nets.

2. Remote maintenance and diagnosis

It consists to maintain a functional unit, ensured by Internet or a direct telecommunication between this unit and a specialized center. It’s characterized by:

- A remote service to support the diagnosis and repair.
- An expert system to support the failure diagnosis.

The alarms interpretation during monitoring phase can be divided in three parts:

- The filtering limits the alarms information load, and tries to present only “interesting” ones.
- The localization characterizes or identifies the detected dysfunction situation.
- The diagnosis proposes the most credible sources of the observed dysfunction. We often reserve the term of breakdown to the result of the diagnosis. The purpose of the diagnosis phase is to seek the main causes of the observed phenomena. It is thus about a major analysis of the process. The remote diagnosis requires knowing the most possible information on the remote system.

Remote maintenance and e-maintenance can be expensive in terms of costs and quality in some hardware configurations and application fields. In industry, it applies to systems (machines, automats…), connected by Internet or a communication network to the maintenance centers. In the case of systems failures, the maintenance center is automatically informed and can start remote operations. Consequently, we avoid expensive displacements of the supplier specialized technicians for a few minutes of intervention. They allow also rapidity and efficiency of intervention to answer any specific request and in some case, ensures the safety of the expert in dangerous operations as on high lines voltage, or in the nuclear industry.

3. Related works in e-diagnosis and e-maintenance platform

A recent literature review related to this topic with emphasis on Web technology and multi-agent systems has been presented by Campos [19]. Campos et al. concluded that the current developments in these areas are still at the rudimentary stage. For Jardine et al. [20], the reasons that e-maintenance technologies have not been well implemented in industry are :

- lack of data due to incorrect data collecting approach, or even no data collection and/or data storage at all;
- lack of efficient communication between theory developers and practitioners in the area of reliability and maintenance;
- lack of efficient validation approaches; and
- difficulty of implementation due to frequent change of design, technologies, business policies, and management executives

However, there exist considerable incentives in developing tools, methods, or systems for solving these issues, and several e-maintenance platforms have been developed and are in use today, these platforms are a result either of the industrial world or of the academic one. Muller et Al [16] classified them as proprietary platforms (i.e. ICAS [18]), platforms for research and education (i.e. TELMA [1]) or platforms developed within projects (i.e. PROTEUS [2]).

- Muller et Al [16] conclude that among the future common industrial/academic working/research directions, several can be underlined:
- Modelling and implementation of the new processes (e-monitoring, e-prognosis, e-logistics, etc.).
- Need of theory and tools for mastering the behaviour of the interactions of the system–maintenance–economy model, and maintenance decision support system for cost-effective decisions.
- Development of new infotronics-based e-maintenance systems integrating new protocols for collaboration and negotiation, maintenance **workflow**, maintenance Web services, etc.

The PROTEUS platform attempted to correct this needs; it brings a contribution of the vertical integration of applications in the domain of remote maintenance of industrial installations [2]. It provides a unique and coherent description of the equipment (through an ontology description), a generic architecture (based on the **''Web services''** technology) and coherent models of heterogeneous components. However, even if these approaches make it possible to improve the speed and the reliability of the maintenance actions, in fact, it doesn't exploit (or incompletely) cooperation and collaboration between experts, whereas this one can be a decisive element in breakdowns detection and diagnoses. Since these platforms often insist on the system interoperability (GMAO, SCADA…) or the communication between the physical sensors by forsaking the human aspect which is summarized in the form of a pseudo GMAO through request for control generated automatically using an expert system more adapted to the process of preventive maintenance than corrective one.

Saint-Voirin [4] tried to optimize the cooperation activity on the PROTEUS platform. Actually, they have implemented their own conceptual cooperation meta-model on the PROTEUS platform in order to simplify design operations. Their meta-model builds on the use of **multi-agent** systems allowed computer models and simulation of the remote maintenance cooperative system. He called his approach as **Scoop methodology** [3].

3.1. ***S*coop methodology**

This methodology helps to draw structural models of the system. These models are easy to read and their graphical aspects simplify comprehension of the system. The structural modelling is based on a nomenclature of members and interactions. Human members are represented using a square containing basic information. Equipment members are represented using a circle containing the basic information. Interactions are represented using specific nomenclatures, the communication nomenclature and the shared data access nomenclature. In both interaction nomenclatures, the square symbol means that mutual exclusion is required for this type of interaction. The number of arrows is related to the number of members involved in the interaction.

However this nomenclature describes the global structure of the system. It is very useful for specification. However, we cannot verify or simulate anything with this representation. That is why Saint-Voirin [4] developed associated Petri nets for the interactions. Petri nets created are used to verify livingness properties, to find deadlocks and conflicts in the interaction. He also developed an analysis based on stochastic simulations of these Petri nets [4]. Nevertheless, interaction study is just a part of cooperation aspects in cooperative systems. Human cognitive aspects have to be represented. To study this particular point, Saint-Voirin choose to create a multi-agent simulator of cooperative systems. He proposes to define each member of cooperation as an agent. Multi-agent systems allow him to propose a good representation of human entities because of their artificial intelligence abilities. Finally, Saint-Voirin used a XML formalism that allowing description of simple knowledge classified in the identified parts: skills, environment and role and goals.

3.2. Contribution

Saint voirin used in Scoop methodology [3][4] various models (Petri Net, UML, Stochastique Petri net PLOOM-UNITY, Multi-agent, XML…) through several phases (Formal specification, Structural modelling, Interactions modelling, Behavior and knowledge modelling) to define the cooperation and coordination between experts on diagnosis process. In addition he created his own nomenclature that is not well known, so we will try to simplify his approach by using workflow with well know modelling language. This language must be able to generated automatically Petri without human assistance (maintenance experts or technicians) for validation and simulation.

We'll aim to develop an application which assists the cooperative remote maintenance based on workflow architecture **fig (1),** it will build an operational and autonomous system, whose main aim is to coordinate the interactions between the various intervening actors within the maintenance process.

3.3. From Groupware to Workflow

The classification of J. Grudin [7] identified a particular type of groupware, dedicated to the management process (industrial, commercial, administrative, etc) and to the coordination of the various intervening during this same process. This particular type of groupware Known as **"Workflow**" takes care of the good circulation of the documents and information between the various intervening at the key times of a cooperative process such as cooperative maintenance. This is why we choose to use them for implementing our system. We propose a ***Workflow*** system who automates the management and the coordination of the information flow following pre-established models.

The tasks of data processing pass from a person to another according to a well defined conditional circuit. Each actor (technician, expert…) of the circuit carries out its task without needing to be concerned with what was made before and of what should be made afterwards. The application presents to the user the necessary information to carry out his task, before the process does not follow its course towards the next step when the individual makes the task

The possibilities offered by the workflow tools are:

- *Rigorous regulation of the procedures*: the regulation of the task sequencing guarantees the execution of a business in accordance with the workplan.
- *Flow* C*ontrol of the work*: The workflow software makes it possible to follow the progress report of a business step by step and to detect quickly possible bottlenecks corresponding to the accumulation of works at a station.
- M*aximum of automation*: waste of time due to move, seek, photocopy, distribute and classify the documents are decreased considerably

- The workflow software offers also the possibility to automate all the operations for which a human intervention does not bring a real added-value.

3.4. Workflow modeling

The specification of the Workflow applications involves describing precisely in models form, the actors implied in the realization of a cooperative task, the interactions structure that link this actors, the information nature exchanged and the dynamics of the treatments which must be carried out. However, each year, tens of workflow are specified for several companies. In the best cases, the development team bases itself on a rigorous method of specification resulting from the Software engineering. But very often, it bases on a “home made” method resulting from an adaptation of an old method (such as SADT for example) [8].

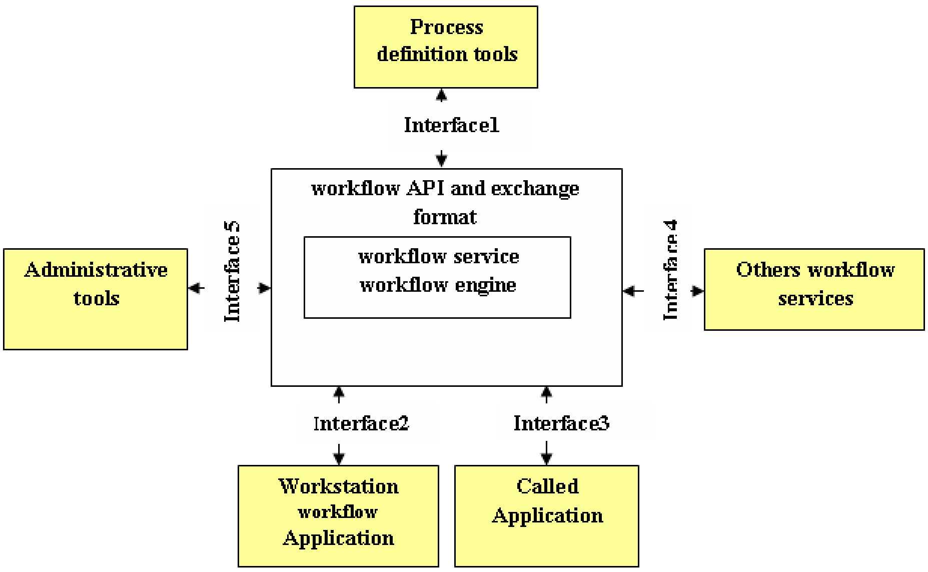


Fig 1. Workflow reference Model **[WfMC]**

It is then frequent to note that the developed interactive systems pose many problems and do not always meet the user's needs, and are often badly adapted to the work organization [8] [9]. This is due to an inadequacy between the methods used and the target aim. The necessity to adapt the methods due to the fact that no uniform method of workflow modeling and specification. The developers which feel a lack during the application of “their” method to a new situation try to improve it, according to their own criteria. It engenders an expansion of personal methods often missing coherence on some aspects.

3.5. Which language for the workflow modeling?

To conclude the modeling and the specification of the remote diagnostic process, it is necessary for us to find the best work organization that permit to provide to each actor the technological tools which assist or automate its individual work and in same time enabling him to communicate with the others in order to coordinate the various activities and thus to achieve the common goals [10]. A complete method would have to:

- Be sufficiently general to allow to model any business process (even if it comprises phases which cannot a priori be implemented by a workflow).
- support the analysis since the identification process until the modeling procedures which will automate the flow .
- Reasoning about the goals and not on the functions performed by different service organization.
- Enable organizations to address complex processes that are not clearly defined. A systemic approach is required in this case [10].

The comparative study of modeling methods, from software engineering (Merise, SADT, SART, OMT, OOM... etc) [10], allowed us to conclude that they are all oriented towards the structuring of data and automated processing, neglecting organizational aspects. This leads us to push our investigations into methods used less or more recent and longer correspond to our expectations. Thus, we have discovered the method OSSAD [11] which is oriented towards the organization of men’s work rather than to the organization of data and automation of treatment.

3.6. The OSSAD Method

The OSSAD Method [11] (Office Support Systems Analysis and Design) was developed during the ESPRIT program (European Strategic Program for Research in Technology Information) from 1985 to 1990 by a multinational team of consultants, academics and Technology Information users. It is about a systemic approach which helps to understand how people work together, by including the users in the conceived system. OSSAD is thus interested above all in organizational operation. It is a method which makes it possible to analyze how various people coordinate their tasks in order to provide a global result. It aims to:

- Provide stakeholders a conceptual framework and organization of work to enable them to lead a project.
- Allow the adaptation of the general framework to each specific situation.
- Provide modeling tools of tertiary or administrative work
- Allow interaction design (and not separately) the sub-technical systems and human

- Propose new opportunities for dialogue between managers, technicians, users of technology.

This method proposes an approach which is done in three stages. Three different levels are thus established: *abstracted*, *descriptive* and *prescriptive*. They meet all needs clearly defined:

Table1. Levels of OSSAD modeling

LEVEL	ROLE	PURPOSE
Abstract	Purpose modelling	What we have to do or to reach?
Descriptive	Ressources modelling	How we realize the purposes? Whith what and who?
Prescriptive	Workflow specification	How did automate the ressources?

4. OSSAD cooperation modeling within a remote diagnosis process

Our modeling is based on a cooperation management algorithm of an expert group suggested by Boussedjra [12] to establish diagnoses and the maintenance of the detected breakdowns. The algorithm manages the group organization, and the communication between experts, it is based for that on the following assumptions:

1. Each grouped together for treatment failure declared by a technician is a group.
2. At any moment, one group member diffuses its data and all other members shall be on standby.
3. Experts are multipurpose or general (they do not know the installations)
4. The site may not be cooperating in the delivery status unless it has been authorized by the coordinator.
5. At any moment one and only one person is authorized to speak or diffusing data.
6. ***The creation of a group*** is initiated by the technician, Fig (2).
7. ***The attribution of sequence number*** is made according to the arrival time of the reply messages. The built group is composed of two sub-groups:
   - The first contains the cooperating experts for the resolution of the breakdown and a coordinator. It under group is active: Exchange of information between the members and a coordinator.

- The second under group is consisted of the members of the active group and the technician (it under group is optional).

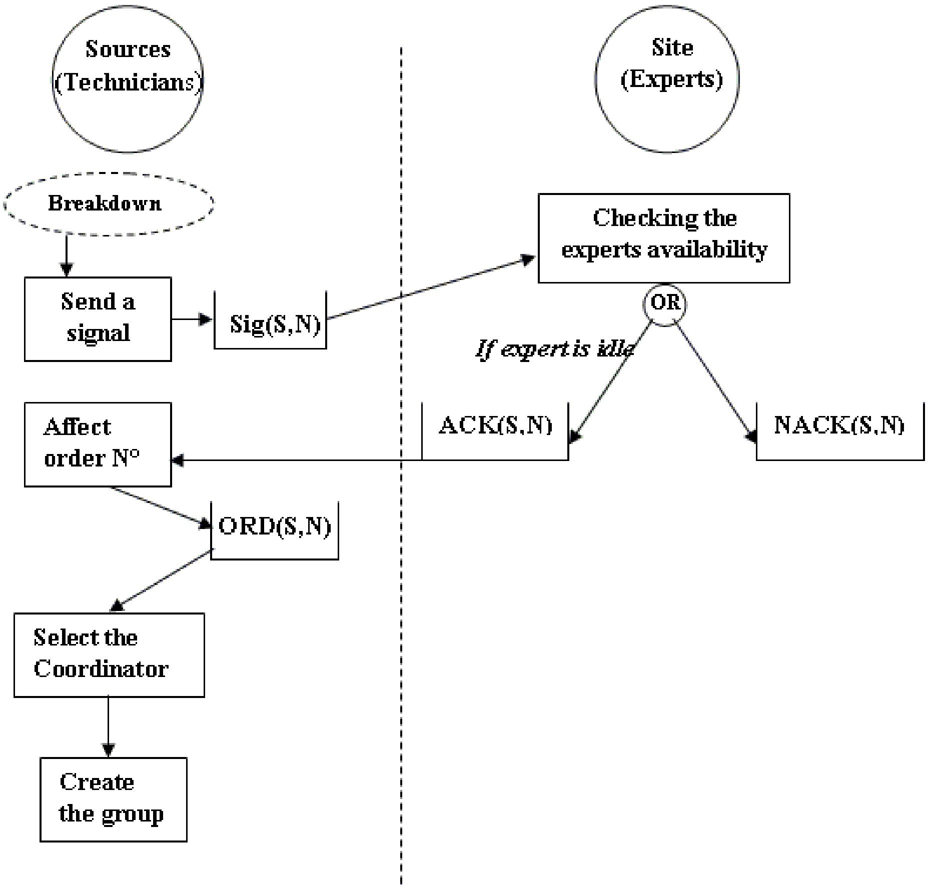


Fig 2. OSSAD operation Model of an expert group building process

8. ***The group coordinator selection*** according to the quality of the network, between him and the breakdown site. The coordinator's role is to act as an interface for communication between group members and the outside world (site failures or other cooperating groups).
9. ***The dissolution of expert group*** can occur in order to answer the set of the breakdowns declared. An expert group can be built by assigning free experts to the declared breakdown.
10. the ***treatment of a new breakdown*** B if all the experts are occupied on a breakdown, will be as follows:
11. If the treatment of a breakdown in progress is completed, then the new breakdown B is treated immediately and the group is rebuild.

12. If the treatment is not finished yet, but an assignment of one or more experts to the declared breakdown B is possible, then two new groups are built, one for the treatment of the breakdown B another for the treatment of the breakdown A.
13. Otherwise, if the declared breakdown B cannot be treated, then it is stored in a queue like a future work.
14. ***The assignment for a new group of expert*** can be done according to the experts sequence numbers (while assigning to the new existing group) or per decision of the each group coordinator.
15. ***The addition of a member*** is done by a call or an invitation of the group via its coordinator, or then by a request from a free site wanting to join the group. As long as the two sites are not agreement (reception of acknowledgment of positive delivery), the member does not enter in the group, fig (3).
16. ***The management of mutual exclusion*** is taken into account thanks to the requests for authorizations managed by the coordinators and the cooperators sequence numbers. The requests classified by importance are sometimes inserted in queues, fig (4).

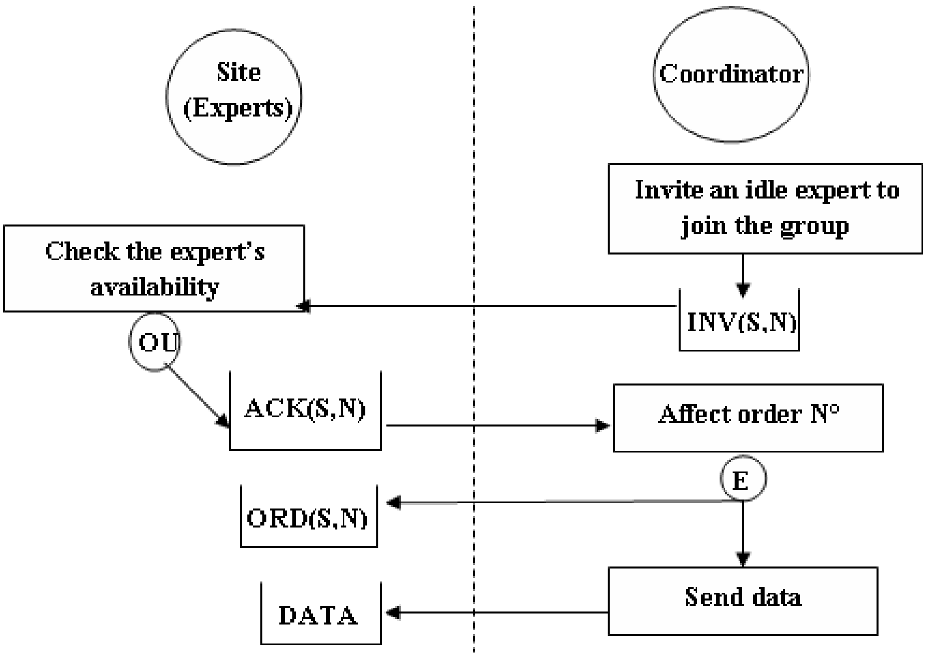


Fig 3. OSSAD operation model of the new member adding process by invitation

4.1. OSSAD prescriptive Model (workflow)

The OSSAD descriptive operation models presented below (*fig 2, 3, 4, 5*) do not constitute (in this form) a specification allowing the workflow applications generation. Chappelet and Legrand [11] introduced a additional *prescriptive* level into OSSAD, this last extends the operations model by the specification of what will be automated in a workflow. This is summarized in the concepts of: *Document*, *State* of document, *Structure* of document, *constraint* of prohibition or obligation, *Completion date* of an operation, *Selection* and *Notification*.

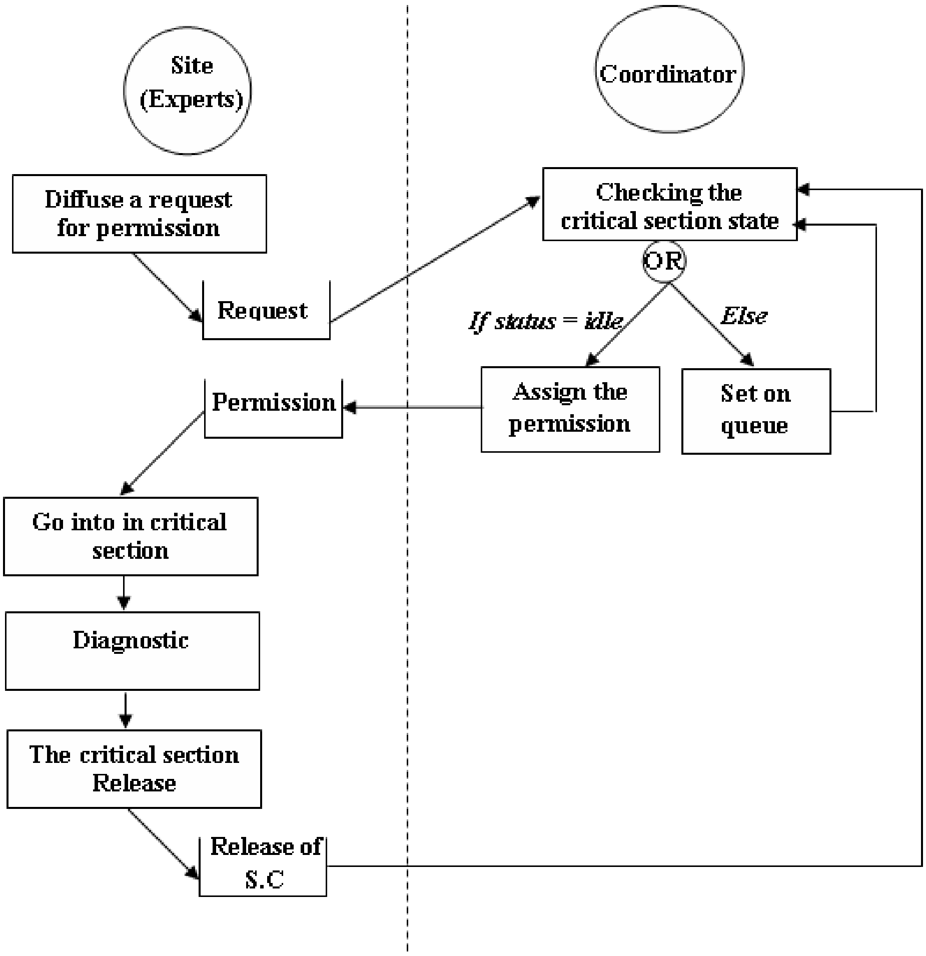


Fig 4. OSSAD operation Model of the mutual Exclusion process

The transformation of a descriptive model into a prescriptive model is done according to the following steps:

- Identify the resources which will be computerized. These resources become documents.
- Specify state changes of these documents in the operating flows (including changes calculated by the workflow management system)
- specify constraints between operations, if necessary,
- Determine the states where it is necessary to select the actor or actors to perform the following operation. This selection can be associated to a notification by email. The notifications are to be recommended for occasional users of an application or for users working on multiple workflow applications.
- Determine the states for which it is necessary to select the actor or the actors having to carry out the following operation. This selection can be associated with an email notification. The notifications are recommended either, for user's occasional application, or for users working on several workflow applications.
- Indicate times of operations, if necessary,
- Specify the structure (sections and fields) documents.

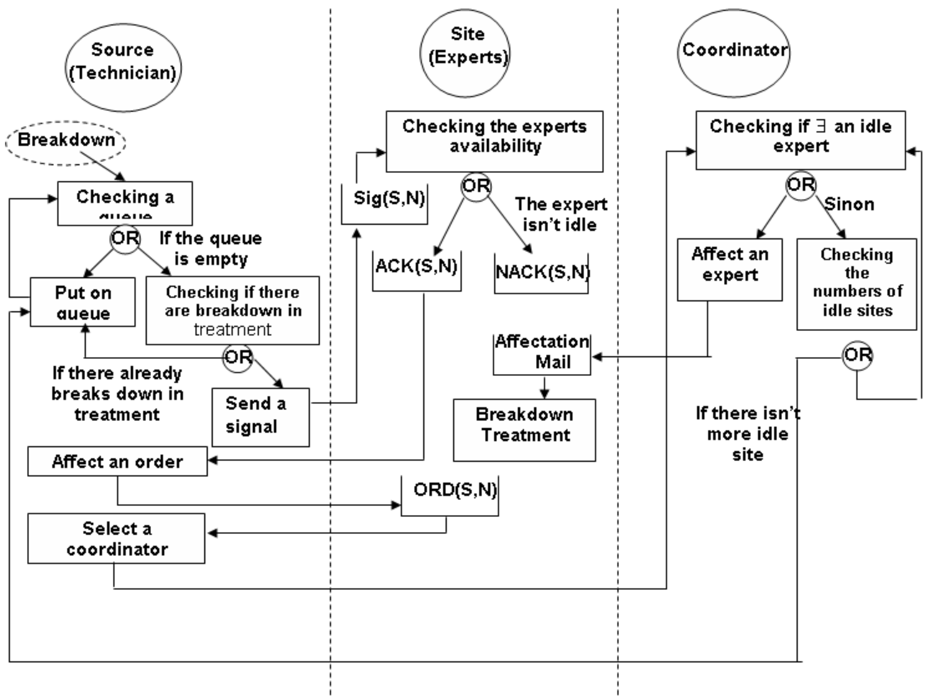
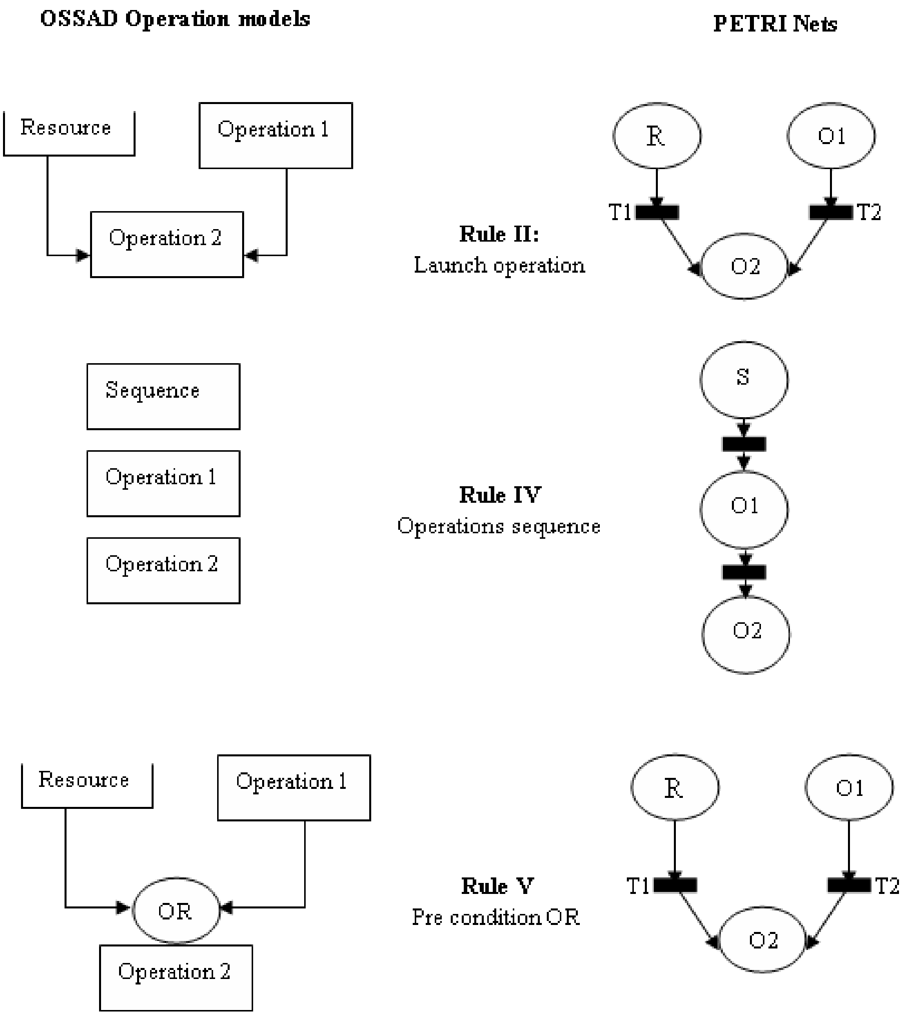


Fig 5. OSSAD operation Model of the group creative process - an expert attribution - additional breakdown treatment

4.2. Generation of the Petri networks from OSSAD models

It was often reproached to workflow models, the absence of possibility of checking and of simulation due mainly to the lack of formalism and the perspective model (workflow) of OSSAD is not safe from these analysis, since, from the motivation of its designers, OSSAD is a relatively simple method, and whose interpretation is little formalized [13]. To overcome these deficiencies, Van Der Aalest [14] introduced the concept of WF NET, the workflows based on a modeling by Petri nets.



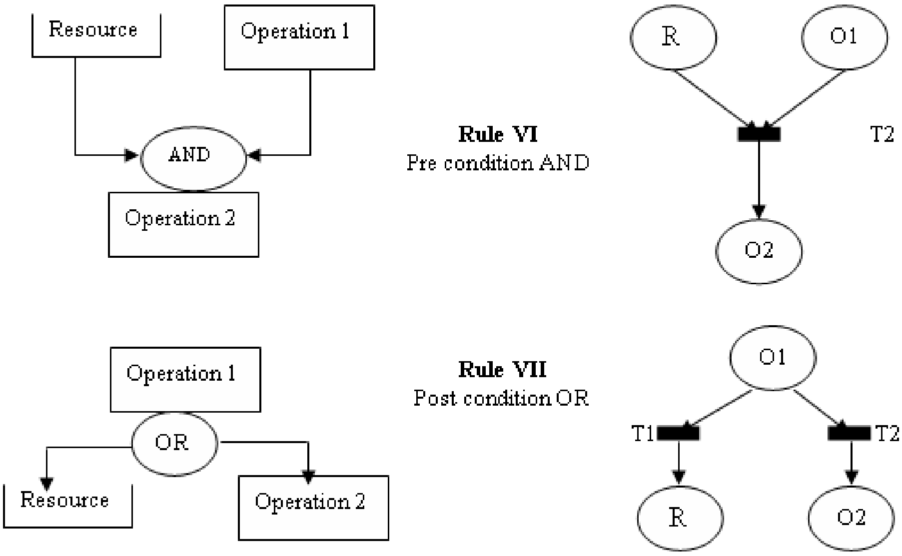


Fig 6. Some transformation rules from OSSAD Models to Petri net [17]

The argumentation of Van Der Aalest was based on the fact that the Petri net are an intuitive graphic language and who led to workflow models whose definition is clear and precise[15]. Moreover, these last years, much of research were carried out on the mathematical properties of the various Petri Net varieties, which has to generate an expansion of methods and techniques for Petri Net analysis which were of a great contribution to modeling workflow. Since these techniques, allows proving the model properties (promptness, conflict, invariant…) and analyzing its performances through various analysis and simulation tools.

However, we cannot allow leave to the end-user the load of Petri nets creating, that are rather the prerogative of expert in the field of data-processing and mathematical modeling. This is why; we will use the theoretical bases of the "OSSAD" formalism and the ten rules defined by Chappelet and Snella [17] for the transformation from OSSAD operation model to Petri Net, in order to generate automatically Petri networks. The **states** (of a Role, a Resource or a Tool) will be interpreted like **"places"** and the **Operations** (of this same model) fig (8), usually represented by squares will be interpreted like **"transitions".** The obtained Petri nets will have a well defined syntax and a logical interpretation. They will make it possible to represent them inter dependences between operations in terms of sequence, availability, parallelism or simultaneity (AND), of conflict or exclusiveness (OR), fig (6).

Note: In certain cases, to simplify, the places (circles) are illustrated only in beginning and end, like for "OR".

4.3. Verification of the Petri Net properties

The evolution of Petri Net is done by crossing of transitions. When during its evolution, certain transitions are never crossed, that indicates that modeled system will not run. There is thus a problem on the systems design level. The idea is to be systematically able to detect this phenomenon, by the Petri Net model properties analysis, in order to have a tool of assistance of the systems design. To check the different properties from our models, and to simulate the circulation of the token in order to detect possible structural conflicts, we chose used PetriParc[1] application, fig (7).

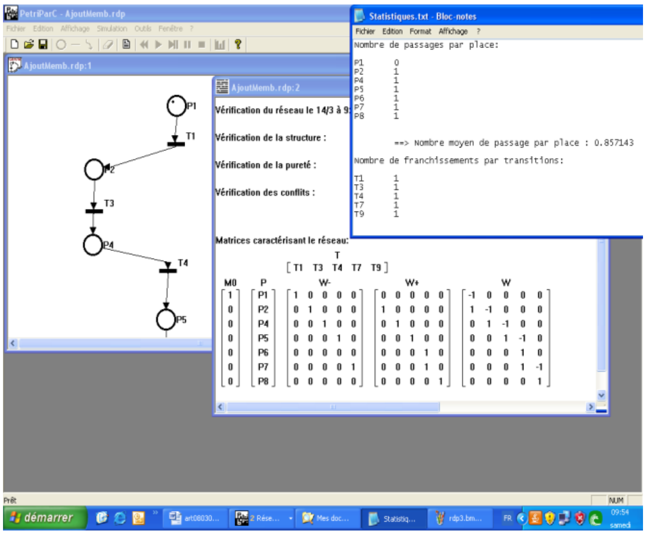


Fig 7. Verification of Petri Net with PetriParc.

[1] www.univ-valenciennes.fr/GDR-MACS/outils.php?id=15

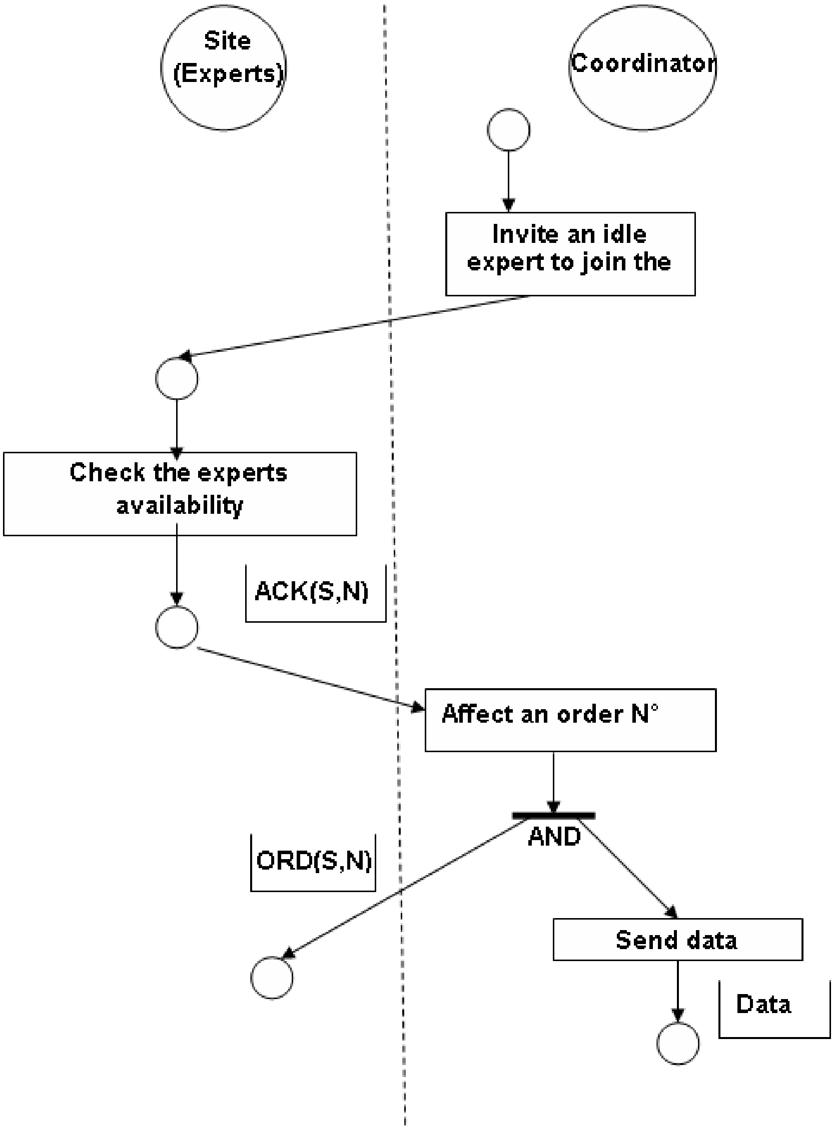


Fig 8. OSSAD Petri net corresponding to the operation model of "joining of a new member by invitation"

5. Conclusion

The Maintenance in general and diagnoses in particular, are processes requiring a great **coordination**, an intense **collaboration** since the actors are divided as well geographically as temporally. It seems to us legitimate then to choose to implement a workflow system to assist the cooperative work of a maintenance team. It is however necessary to take into account that the workflow, contrary to the other traditional computer applications, does not contribute to the computers work automation, but the accomplished human work automation through multiple cooperation and coordination interactions. Beyond the computers treatments, the workflow attempts to assist the man in his interactions with other men via the computers. Data processing for communication (which includes the workflow), is interested in the human interactions and the subjacent behaviors of communication.

The processes profiting the most from these technologies are thus those based on the communication and collaboration for the achievement of the process objective, in our case, maintenance; this nuance led us to choose a double language of modeling OSSAD/Petri Net for the specification of Workflow, thus enabling us to have at the same time a facility of use thanks to the first one, and a precision of formulation as well as opportunity of analysis and simulation from the second one.

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Karim BOUAMRANE was born in Oran (Algeria) in 1968. He graduated in 1991 from Department of Computer Science, Faculty of Sciences, University of Oran, Algeria. He received his PhD degree in computer science in 2006. He is chief of the Research Group in « Diagnosis, Decision Support System and Human interaction" in LIO laboratory. His research interests include Decision support system in transportation system, production system and risk management, also, data warehouse and elearning.

M.A LAREDJ was born in Mostaganem (Algeria) in 1980. He graduated in 2002 from Department of Computer Science, Faculty of Sciences, University of Oran, Algeria. He received his Post graduation degree in computer science in 2005. He prepare his Phd thesis within « Diagnosis, Decision Support System and Human interaction" Research Group in LIO laboratory. His research interests include collaborative work, workflow, BPR and e-maintenance.

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