From Educational modelling languages
to Stochastic Petri Net modelling for E-learning technologies analysis

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From Educational modelling languages to Stochastic Petri Net modelling for E-learning technologies analysis

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Abstract. Training and learning methods have been greatly improved thanks to the use of E-learning technologies, and have reached a large public including companies' staff, remote and foreign students. Many works have been proposed in the literature in the field of E-learning research so that to allow actors to work with more efficiency and more effectiveness. These recent works focus more and more on educational modelling languages and object learning modelling languages. Among these languages, EML language (Educational Modelling Language) has been introduced for modelling learning processes, and on the other hand, the LOM (Learning Object Metadata) and IMS (Instructional Management Systems) specifications have been defined for modelling teaching resources (objects).
In this article, we will present an approach for the design and performance evaluation of an e-learning platform, by first using a mixture of the two languages LOM and EML, then, modelling the platform with Stochastic Petri Net models. The modelling is proposed in order to analyse learning processes of the platform. We will see that this Petri net model can provide an efficient way to evaluate an e-learning platform.
Keywords. E-learning, educational resources, educational processes, LOM, IMS content packaging, EML, modelling and analysis, Stochastic Petri net modelling.

1. Introduction

Over the last decade, the introduction of computer technologies in the learning field has become more and more important. These technologies favoured learner activities and developed assistance functions. Later, communication technologies and web services have enlarged possibilities of interactions and made learning methods more flexible. All these technologies are offered to the learner as **E-learning** technologies.

So, E-learning is defined as the training by using new information and communication technologies, such as multimedia resources, Internet and so on intranet enterprises. The multiple communication ways integrated to E-learning environment permit the cooperation between peers for remote supervision of learner's work.

As the use of such technologies becomes more and more complex and widespread, this requires standardization and organization of learning methods. For that purpose, two aspects have been studied:

- The first aspect concerns educational resources management, which can be of any type: text, bitmap, animations, simulations, forms, and specialized applications. Educational resources (courses, exercises, home works…) must be organized so that to make easy access and reuse of objects in large contexts. So, standards have been developed, for defining technical specifications and establishing educational applications and services interoperability. Among these standards, there are the "**IMS-Content Packaging**" specification and **LOM** (Learning Object Metadata) model. The **IMS-Content Packaging** [IMS03] describes the structure and organization of learning objects as a set of files grouped into a package, in order to facilitate exchange of these objects. On the other hand, the LOM model [7], [4] characterizes and indexes educational objects by using metadata.
- The second aspect concerns organization of activities done by e-learning actors. The formalization of educational activities has led to another initiative: the EML language (Educational Modelling Language) [3], [5], which describes the characterization elements of educational processes.

This paper summarizes the most suitable approach to build the design of an e-learning platform, and then proposes a model based on Stochastic Petri Nets (SPN) to analyse learning processes of the platform.

For that goal, first, we present each of the languages LOM and EML. Then, we propose using these modelling languages for conceiving an elearning platform. Finally, we provide the SPN model which permits analysis of the platform.

2. Specifications LOM and IMS-Content Packaging [7]

Educational documents or objects are the kernel of knowledge in E-learning platforms. Indeed, the different actors, creators of educational contents, courses editors work independently and often without knowing each other. So, they need to rely on common standards to guaranty correct operating with educational resources in a large number of contexts.

Consequently, standards have been defined for characterization of numerical educational documents, so that to allow exchange, sharing and reuse of these documents. These ones are seen as a grouping of elementary elements which can be decomposed and recomposed in different manners in order to be reused in different environments [6]. Among these standards, we find the IMS and LOM specifications.

2.1. IMS-Content Packaging

The Instructional Management Systems **(**IMS) Consortium is a grouping of 250 educational establishments and companies like IBM and Apple whose goals are to define technical specifications for interoperability of educational applications and services. Among these specifications, we find the **IMS-Content Packaging.** This specification organizes educational resources according to a model: The ***Content Framework*** which splits resources into:

a. « *The Content packaging* »: groups together physical resources and data necessary to their description into an entity said **package**. A package represents a reusable resource incorporable into an educational platform, and comprises two elements: an XML file (said **Manifest**) which describes content organization and educational **resources** [4], and physical files (physical resources) given into the Manifest.

b. « *The content management* » : organizes system management data. It comprises didactic intelligent resources. As an example, we can say that the content management put courses, users and groups into a database to allow the system to load a course or initialize a group. The organization is done through two elements:

- **The data source:** organizes data on users (learners, schools, enterprises).
- **The run-time environment:** organizes learning and interaction rules, where abilities and objectives are programmed.

2.2. LOM Model

This model was introduced by the Learning Technology Standards Committee (LTSC), for the description of educational objects (resources). It is considered as a common characterization system in the educational information domain. To describe an educational object, LOM uses a standard for metadata presentation, which can consist of several optional elements: title, author, description, editor, collaborator, date, resource type, source, language, relation, scope and rights management [4]. It defines nine categories, each one giving a certain aspect of the object: the general description, the life cycle, the metametadata, the technical information, the educational part, the rights, the relational aspect, the annotation and classification.

3. EML Language [KOP 01]

EML (Educational Modelling Language) is a new model for the standardization of electronic learning system. It was developed by the OUNL (Open University of the Netherlands) at the end of the nineteenth, and was available in December 2000. It integrates metadata not only on educational resources and their contents, but also on roles, links, learners' interactions and activities. It also models learning processes.

The modelling language EML is based on two notions which form the kernel of an educational meta-model:

3.1. Unit of study

It is the smallest unit which gives learning events to the learner, by satisfying one or several related objectives. It consists of series of activities which can be without content (like a conversation between a learner and his teacher), or the result of the unit (like producing a report after a research activity).

3.2. Pedagogies

EML is also based on the notion of pedagogy and "teaching objects" like: Learning tasks, educational objectives, pre-requisites, roles, files and learning environment.

In brief, to model in EML, we create units of study. This creation follows the steps below:
- Definition of the pre-requisites and educational objectives.
- Definition of a scenario which specifies how activities must be done.
- Definition of the activities referenced in the scenario.
- Definition of activities environment.
- Assignment of activities to actors' roles.
- Specification of learning development conditions.
- Definition of meta-data.

Once defined the specifications we will use later, we present in the following a methodology to build the design of an e-learning platform.

4. Design of the E-learning platform

In order to build an e-learning platform, we proceed as follows:
- We first study the information system, and deduce classes of objects handled by the system, following a standard methodology like MERISE, UML, OMT …etc.
- Then, to consider E-learning particularities, we model educational documents (objects) by using the IMS and LOM specifications, and deduce classes associated to these objects.
- Finally, we model educational processes (activities) by using EML language, and deduce classes associated to these activities.

4.1. Information system

In the information system corresponding to the e-learning platform, three actors' types are handled: the learner, the teacher and the administrator. In order to identify object classes of the system, we model the functioning of the system. For that objective, we have structured the study into six aspects:
- User management.
- Formation management.
- Educational documents management.
- Educational follow-up.
- Communication.
- Events history.

For each aspect, we describe the actions representing all possible behaviours of the system following a methodology. Then, we identify classes associated to the platform objects.

4.2. LOM modeling

In order to complete the information system's study and consider E-learning specificities, it is necessary to study educational documents or objects and metadata characterizing them. We eventually modify or extend the definition of objects classes obtained in the fist step.

To achieve this goal, we describe our organizing model of educational objects by giving the content packaging proposed by the *IMS.* This model allows resources reuse thanks to metadata which characterize the different documents, and is easily integrated into the platform.

Educational numerical objects of the platform are enumerated below depending on their educational objectives:

1. Comprehension.
2. Practicing exercises and tests.
3. Evaluation.
4. Documentation.

In fact, each subject teached into the platform has a set of educational objects, satisfying the precedent objectives in order to provide the teaching and to reach goals fixed by the subject.

So, to study educational objects, we follow the principle of organizing with packages. This principle consists of grouping in a directory peculiar to each subject:

- The set of physical files or « resources » necessary to the building of an educational document.
- The set of subdirectories of each document type, which contain :

- The manifest files written in XML, which describe the hierarchical structure of the educational documents presentation.
- The meta description files using LOM model.
- Style sheets which permit to do a personal make up depending on the user profile.

Consequently, by following the LOM method, two files are associated to each educational document: the manifest file, and the meta description file which describes document's content by several elements (general, life cycle, technical, educational, relation, classification, ..).

Once each document studied, we refine definition of corresponding objects obtained in the first step of the platform design.

We notice that, in this step, we haven't taken into account educational activities' specificities. So, the next and final step is to study activities by EML.

4.3. EML modeling

The e-learning platform is considered as a learning environment, which offers a set of tools and functionalities for learners and teachers. It permits also to conceptors or educational responsible persons to realize learning processes into several phases, which constitute educational activities.

In this step, we first describe educational activities which are specific to each actor. This description must consider several parameters like teaching conditions, pre-requisites, educational objectives, required resources and learners' supervision. We distinguish two types of activities:

- learning activities, and
- Supervision activities.

a. Learning activities: are defined on the basis of successive logical steps of the learning process. These steps are themselves defined by identifying logic parts (chapters) constituting each course of each subject. These activities pass know ledges to learners, apply these know ledges and evaluate them to validate the learning process. So, we rely on three basic activities:

- Course activity,
- Exercise activity, and
- Evaluation activity.

Each activity in accordance with EML is characterized by objectives, prerequisites, environment, resources and support tools.

b. Supervision activities: They are done by tutors who assist and guide learners during the learning process by helping them. This support consists of replying to their questions, taking part into forums, enriching the FAQ lists and correcting evaluation documents of the learners (paper exams, homeworks …etc).

Summarizing the activities description, we define first what are the activities studied, and define their characterization. Finally, we identify object classes which define the activities, and we enrich our modelling of the information system.

Once this study done, the designer can carry out an E-learning platform, by adopting the appropriate physical resources such as the suitable database management system, web services …etc.

Once the design achieved, we can perform an analysis of the platform with the help of a Petri net modelling.

5. SPN Modelling of the Platform

Stochastic Petri Nets (SPN) [2], [1] have been widely used in the last years for performance analysis of parallel and complex systems, especially in telecommunications, production and information systems. They are considered as a powerful model which expresses the most important characteristics and permits, thanks to its probabilistic nature, to perform a numerical performance evaluation. In fact, they have proved their efficiency with analytical results, inspired from stochastic processes, especially Markov chains. A Stochastic Petri Net (SPN) is defined as follows:

Definition: A Stochastic Petri Net (SPN) is a couple S=<N,W> where:

- N is a marked Petri net, N= (P, T, Pre, Post, Inh, M_0) :
  - P, T are two finite disjoint sets called respectively places and transitions.
  - Pre, Post and Inh : PxT $\rightarrow$ Bag(P) are arc functions :
  - Pre, Post are resp. the backward and forward incidence functions,
  - Inh is the inhibition function, and
  - Bag(P) is the set of multisets on P : $Bag(P)=\{x=(x(p))_{p\in P}/\forall p\in P, x(p)\in IN\}$.
  - M_0 is a function from P to N called the initial marking.
- $W=(\lambda_1,...,\lambda_n)$: vector of transition rates.

So, to analyze E-learning processes and verify their correctness, we propose to model activities of the platform with an SPN model. For that goal, we opt for modelling separately activities related to each management aspect of the platform, as we have proposed for studying the information systemg. The advantage behind this method is to build SPN models of acceptable size. This makes possible the analysis of the resulted models by SPN tools, which often cannot operate with large models.

Furthermore, we can say that, when making the SPN modelling, we feel the necessity to identify objects (tokens) represented in places, and sometimes use guards on transitions. Consequently, the most suitable model is the Stochastic Well-formed net (SWN) which is an SPN with a structured type of objects, defined as follows:

In the following, we give first our SPN modelling. The resulted models can be turned into SWN models by defining colours classes of places and transitions and arc functions.

To illustrate the SPN modelling, we present for each management aspect one or more SPN models.

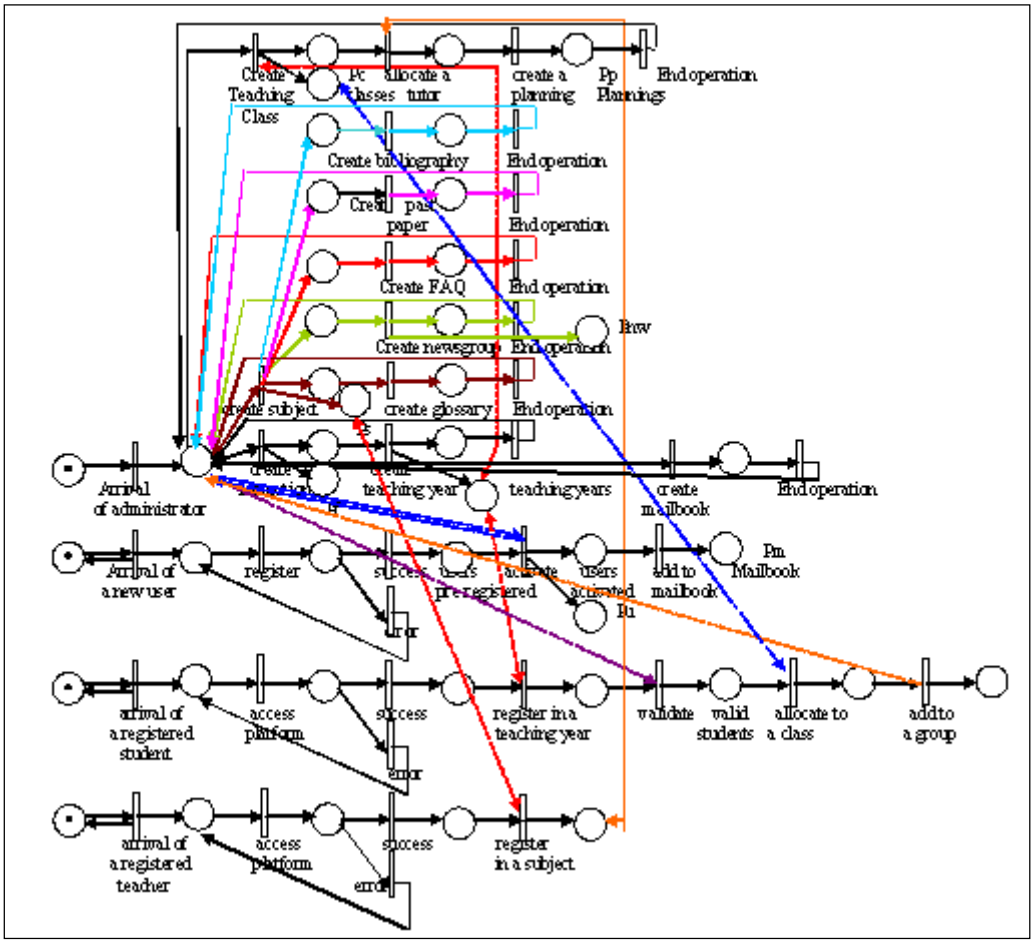

Fig.1. SPN models for user management

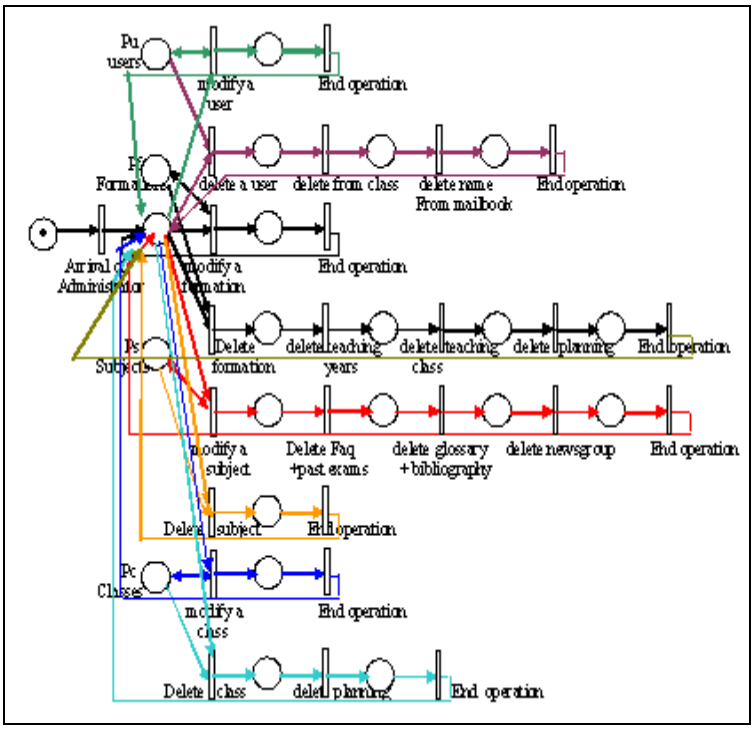

Fig.2. SPN models for formation management

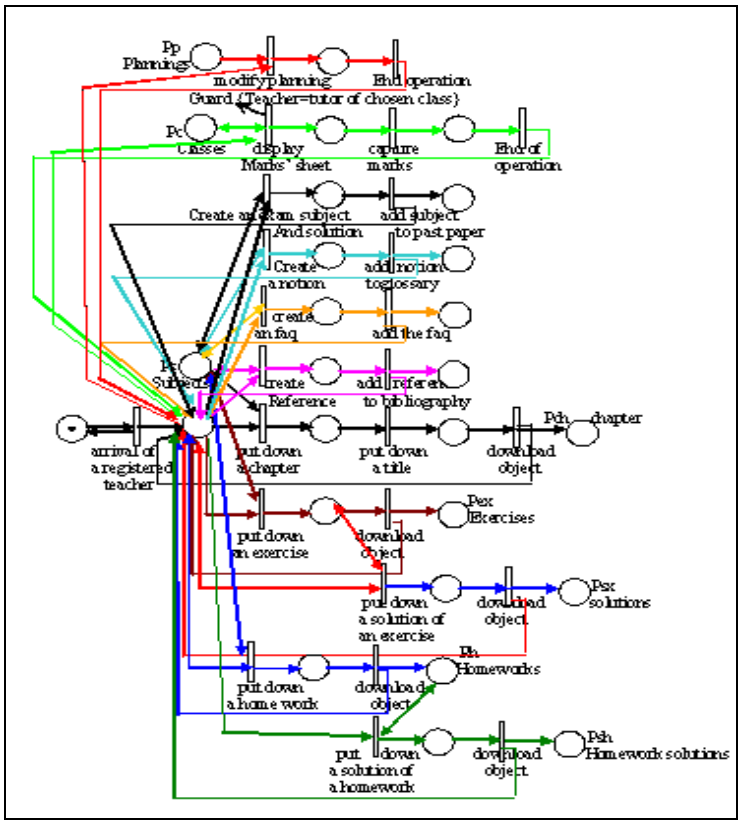

Fig.3. SPN models for educational resources' management

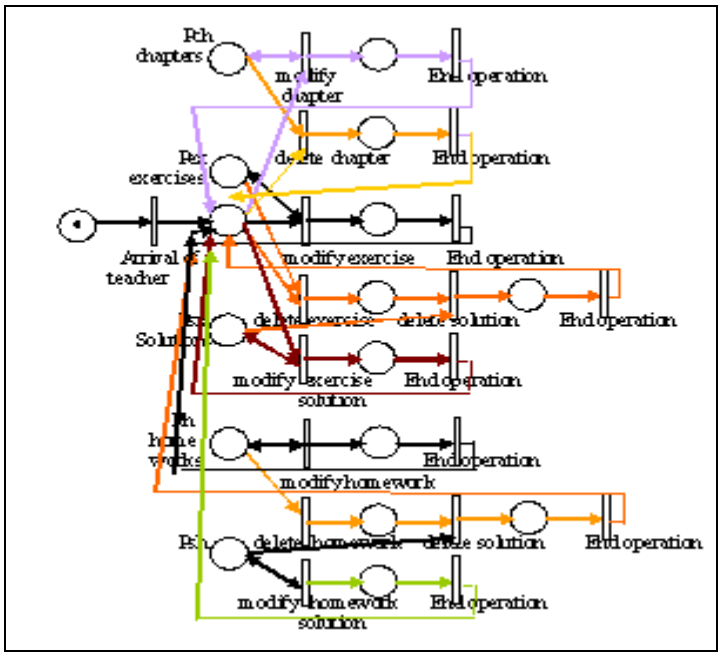

Fig.4. SPN models for educational resources' management (following)

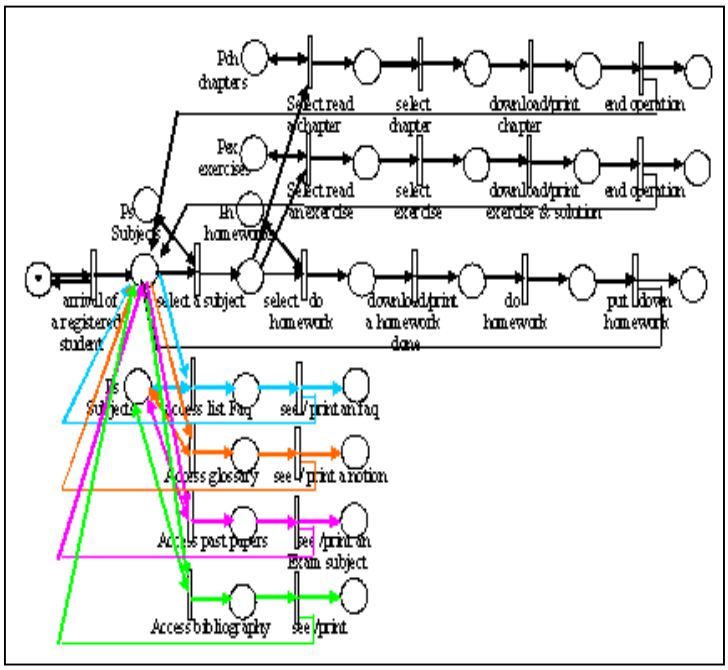

Fig.5. SPN model for educational resources use

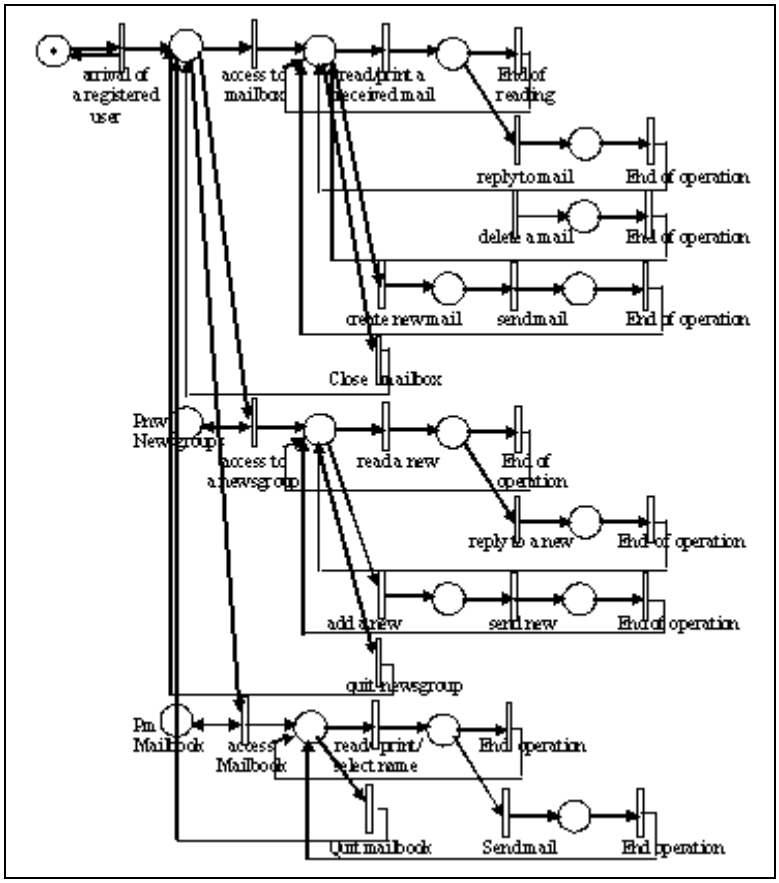

Fig.6. SPN model for communication aspect

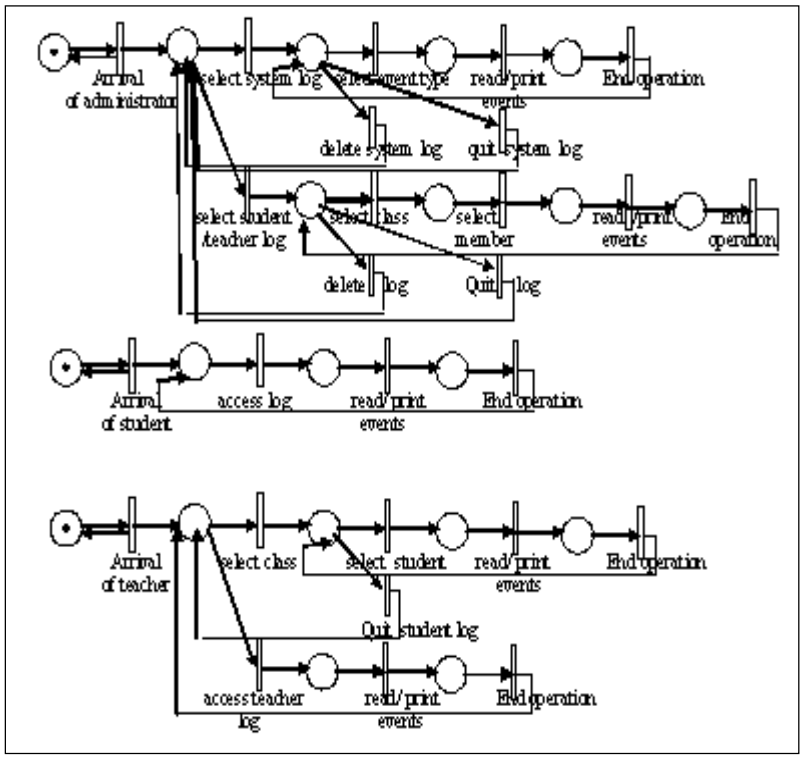

Fig.7. SPN model for history management

We notice that rates of transitions are not given in the model, but are necessary for numerical analysis.

The models that were built can be analyzed by using SPN tools. Among available developed tools, we can use the GreatSPN package which has proved its efficiency in performance evaluation of systems.

6. Conclusion

In this work, our interest was focused on formalizing the design of an E-learning platform on one hand, by performing a modelling of the information system, completed by a LOM and EML modelling of educational objects and activities. On the other hand, we proposed an SPN modelling which can help to do an analysis and evaluation of the platform processes. We can say that LOM and IMS specifications, and so on EML language, give powerful tools to include the most e-learning specificities, but also we need a formal methodology such as UML to cope with static and dynamic description of the information system. This work has been implemented into a prototype of an E-learning platform at the University. This prototype has shown the flexibility of the platform, interoperability and possibility of reusing educational objects.

The design of the platform must also be completed by verification, analysis and even a numerical evaluation phase, during which we can compute several performance indices. As examples of these ndics, we can give the average number of learners following a course, the throughput of an activity, the average time response for correcting and marking home works, …etc. The most suitable model to perform this numerical analysis is the SPN one. What remains to do is to effectively exploit the SPN model given in the paper to perform a qualitative and quantitative analysis of the platform.

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