Organization of Distributed Learning Environment Modeling by using Petri Nets

Radi Romansky, Elena Parvanova

Abstract: *The distributed learning is a model that permits to the different components of the learning process to be situated in the different places of the Internet based educational environment. This assumes distributed access to remote learning resources and using different information blocks from the nodes. In this reason the architectural design of such distributed learning environment (DLE) requires to build an adequate conceptual model and to organize an investigation of the information service by using formalization and modeling. The paper presents the initial phases in a DLE investigation by using the deterministic apparatus of Petri Nets. The modelling organization includes a resources and processes formalization and designing of basic model primitives for a DLE general model realization.*

Key words: *e-Learning, Distributed Learning, Distributed Information Servicing, Formalization, Discrete Model, Petri Nets.*

1. INTRODUCTION

The global Information Society is organized by different information resources and activities and the e-learning (as a part of the European e-governance) is an important component [1]. In this reason the distributed learning (DL) unites the principles of e-learning and networking and M. Bowman write in [2]: "Distributed learning is not just a new term to replace the other 'DL', distance learning… Distributed learning is an instructional model that allows instructor, students, and content to be located in different, noncentralized locations so that instruction and learning occurs independent of time and place." The distributed approach permits to use the contemporary concepts for semantic Web as ontology in the e-learning scenarios, building the networks for educational media exchange, personalized access to the distributed information resources, intelligent systems, etc.

The model of DL is connected with the concept of distributed and common-used informational resources in a heterogeneous environment with local management. In this reason the design of such distributed learning environment (DLE) requires to build an adequate conceptual model [3] and previously investigation based on formalization and modeling of the processes of information servicing. This will increase the effectiveness of the architectural and software design [4, 5] and it has different methods and tools for modeling and investigation of information processes. The information servicing in the DLE could be regarded as a sequence of events that each of them could be realized if a set of conditions is executed. This approach permits to use the discrete apparatus of the Petri Nets (PNs) [5, 6].

The paper presents the initial phases in a DLE investigation by PN model connected with modeling organization. In this reason a formalization of DLE components and processes of the information servicing is given. This formalization is based on proposed conceptual model and is used as a basis for model primitives designing. These basic models permit to build a general PN model of DLE for its deterministic investigation.

2. FORMALIZATION OF INFORMATION SERVICING BY USING PETRI NETS

A conceptual model for organization of DLE is proposed in [3] and a generalized scheme is shown in fig. 1. DLE is planned as a multi-user and interactive environment for knowledge presentation in the area of 3D simulation and virtual reality organization. Each 3D simulation will be executed on the server and will be visualised by the client browser. The access to the learning resources could be realized from different remote nodes by communication resources of Internet. The main components defined in this conceptual model are users, information learning resources and communication

medium. All these components could be described as discrete independent units with internal structure and own functionality. This permits to use the deterministic apparatus of Petri Nets for organization of DLE modeling and previous formalization.

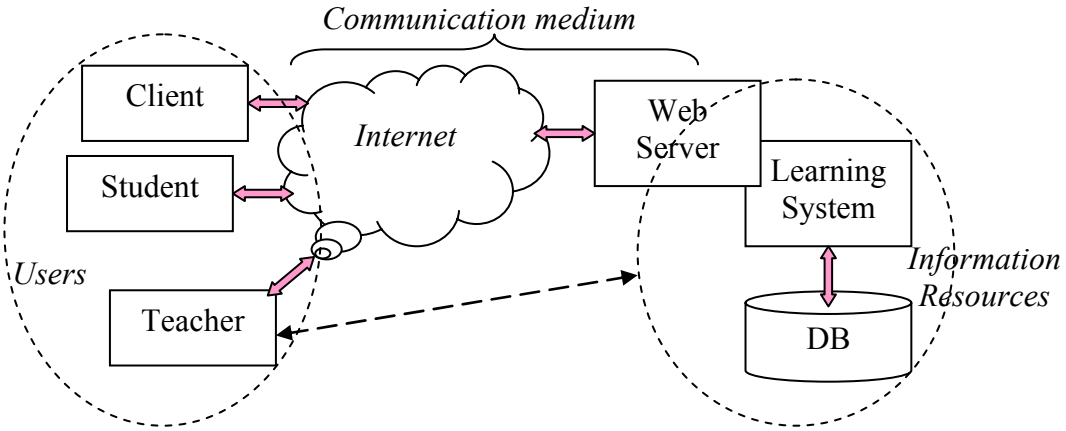

Fig.1. Generalized scheme of DLE

The modeling by using PNs is connected with presentation of the investigated process or object as a sequence of events, named transactions that could be activated if connected conditions (presented by marked places) are realized. Each PN-model could be defined as an ordered triple $PN = (P, T, F)$, where: $P = \{p_1, p_2, \ldots, p_m\}$ – set of places; $T = \{t_1, t_2, \ldots, t_n\}$ – set of transactions; $F \subseteq (P \times T) \cup (T \times P)$ – set of relations (set of arcs). The sets P and T are final sets ($m \geq 0$, $n \geq 0$, $P \cap T = \varnothing$). The set F includes ordered couples (p_i, t_j) that define relations $P \rightarrow T$ and $T \rightarrow P$, and two functions are constructed – $I,O \in \mathbf{N}^{|P| \times |T|}$, named input and output functions.

The extended PN definition $PN = (P, T, F, W, \mu_0)$ includes two additional elements: $W:F \rightarrow \{1,2,3,\ldots\}$ – weight function for each arc and $\mu_0:P \rightarrow \{0,1,2,3,\ldots\}$ – initial marking for PN execution starting.

The matrix approach permits to define the PN by using two matrix: $\mathbf{D}^-$ – input matrix (present the input places for each transaction) and $\mathbf{D}^+$ – output matrix (present the output places for the each transaction): $\mathbf{D}^-[j, i] = \eta(p_i, I(t_j))$; $\forall\ p_i \in P$; $j = 1 \div m$ and $\mathbf{D}^+[j, i] = \eta(p_i, O(t_j))$; $\forall\ p_i \in P$; $j = 1 \div n$. The definition $PN = (P, T, \mathbf{D}^-, \mathbf{D}^+)$ permits to present each transaction t_j as a vector $e[j]$ with n elements that all of them are 0, but only element „j" is 1.

The defined PN could be described as a directed multi-graph that functions I and O are presented by arcs between places (rings) and transactions (rectangle or segment). The modeling by using PN is based on execution of marked net that each position has an integer count of marks $k \geq 0$ that could be changed during the PN evolution $\mu_0 \rightarrow \mu_1 \rightarrow \mu_2 \rightarrow \ldots$.

The main information processes in DLE are connected with remote access to the distributed learning resources, transmission of these informational objects through the network medium and using the information by active users. In this reason, the following groups of basic component are defined after the formalization:

- ✓ $U = \{U_i / i = 1 \div N\}$, $U \neq \varnothing$ (Users) – realize a remote access to learning contents in different DLE nodes by requests to the information resources $req : U_i \xrightarrow{T_q} R_j$, for $\forall U_i \in U; \forall R_j \in R$;
- ✓ $R = \{R_j / j = 1 \div M\}$, $R \neq \varnothing$ (Resources) – present the learning contents as an information objects (blocks) $Inf : R_j \xrightarrow{T_q} U_i$ (for $\forall U_i \in U; \forall R_j \in R$) and/or other means, situated in the separate nodes of the DLE permitting multi-user access.

✓ $T = \{T_q / q = 1 \div K\}$, $T \neq \varnothing$ (Transmitters) – network technical and technological tools for information object transmission trough the communication medium of the DLE;

✓ Distributor (D) – it distributes and routs all requests $req : U_i \xrightarrow{T_q} R_j$ and information objects $Inf : R_j \xrightarrow{T_q} U_i$ and unite the algorithms, protocols and other means for connection between DLE components.

Finally, the formalization permits to describe the environment as an ordered structure $DLE = \{U, R, T, D\}$ with two types of relations between its components: $req : U_i \xrightarrow{T_q} R_j$ and $Inf : R_j \xrightarrow{T_q} U_i$, and this is illustrated in fig. 2.

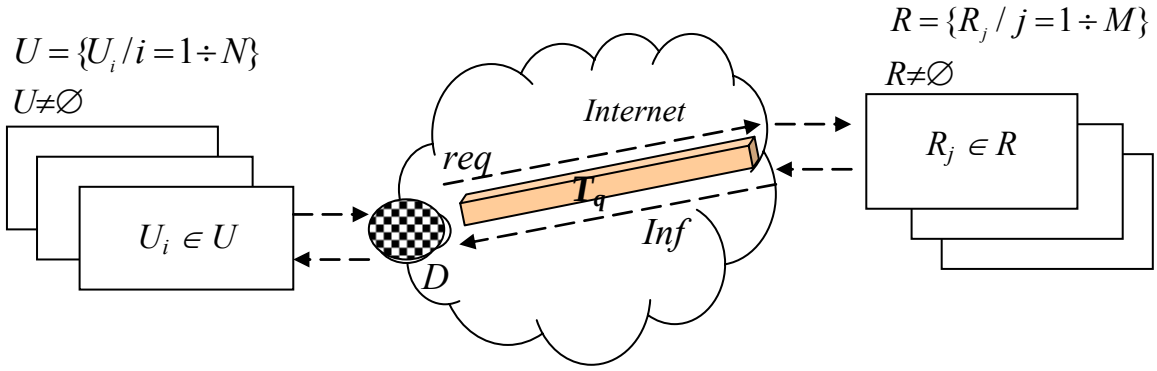

Fig.2. Abstract model of DLE

3. DEFINITION OF BASIC MODELS

Three basic models (primitives) are defined for the purpose of the modelling. They are built on the base of the segment shown in fig. 3 (abstract presentation of the one-user access to the information learning resource) and they are described below.

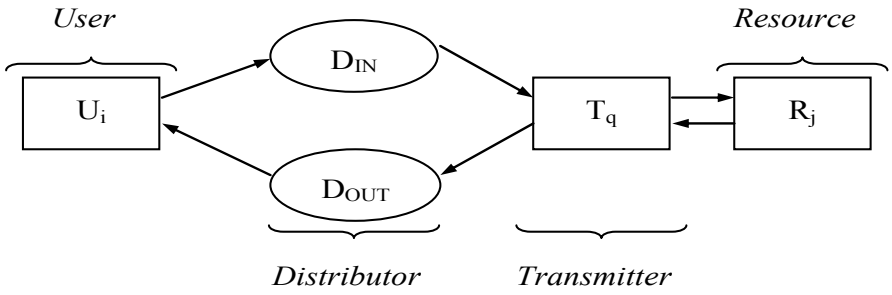

Fig.3. Basic DLE Segment for one-user access modeling

3.1. Basic model for "User"

The following formal objects for the PN-model building are defined and its graph presentation is shown in fig. 4:

Events:

t_1 – generation of a request for access to distributed learning (information) resource;

t_2 – entered information block processing;

t_3 – sending a request to the distributed medium for routing;

t_4 – an information block enters into the input buffer from the distributed medium.

Conditions:

p_1 – availability of the user to work with the distributed learning resource;

p_2 – presence of a request in the input buffer;

p_3 – presence of information block in the output buffer.

$$P=\{p_1,p_2,p_3\} \Rightarrow |P|=3 \qquad T=\{t_1,t_2,t_3,t_4\} \Rightarrow |T|=4$$
$$I(t_1)=\{p_1,p_1\} \qquad O(t_1)=\{p_1,p_2\}$$
$$I(t_2)=\{p_3\} \qquad O(t_2)=\{p_1\}$$
$$I(t_3)=\{p_2\} \qquad O(t_3)=\{Out\_U \equiv D_{IN}\}$$
$$I(t_4)=\{In\_U \equiv D_{OUT}\} \qquad O(t_4)=\{p_3\}$$

Input and output matrixes:

D⁻	p_1	p_2	p_3	D_{IN}	D_{OUT}
t_1	2	0	0	0	0
t_2	0	0	1	0	0
t_3	0	1	0	0	0
t_4	0	0	0	0	1

D⁺	p_1	p_2	p_3	D_{IN}	D_{OUT}
t_1	1	1	0	0	0
t_2	1	0	0	0	0
t_3	0	0	0	1	0
t_4	0	0	0	0	1

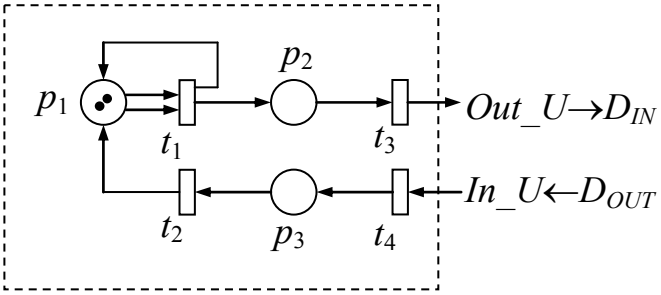

Fig.4. Basic PN-model for "User" with initial marking μ_0=(2,0,0)

3.2. Basic model for "Resource"

The following formal objects for the PN-model building are defined and its graph presentation is shown in fig. 5:

Events:

t_R – processing of an entered request for access to the information learning resource;

t_S – giving the access to the learning resource (an information block sending).

Conditions:

p_A – presence of entered in the input buffer request for access and using of distributed learning resource;

p_B – readiness to give of a distributed learning resource;

p_C – presence of processed request;

p_D – the access to the distributed learning resource is given and the information block is directed to the network medium.

$$P=\{p_A,p_B,p_C,p_D\} \Rightarrow |P|=4 \qquad T=\{t_R,t_S\} \Rightarrow |T|=2$$
$$I(t_R)=\{p_A,p_B\} \qquad O(t_R)=\{p_C,p_C\}$$
$$I(t_S)=\{p_C,p_C\} \qquad O(t_S)=\{p_B,p_D\}$$

Input and output matrixes:

D⁻	p_A	p_B	p_C	p_D
t_R	1	1	0	0
t_S	0	0	2	0

D⁺	p_A	p_B	p_C	p_D
t_R	0	0	2	0
t_S	0	1	0	1

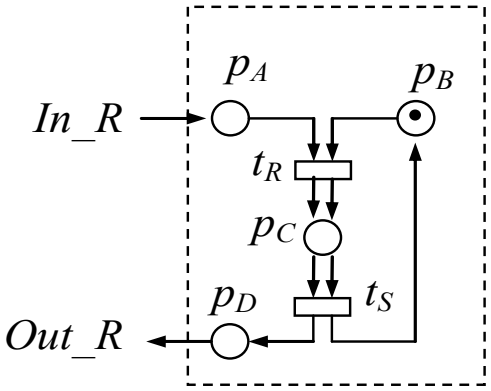

Fig.5. Basic PN-model for "Resource" with initial marking μ_0=(0,1,0,0)

3.3. Basic model for "Transmitter"

The following formal objects for the PN-model building are defined and its graph presentation is shown in fig. 6:

Events:

t_{T1} – request transmission trough the distributed (network) medium based on the routing algorithm;

t_{T2} – information block (learning contents) transmission through the distributed medium to the user (respond returning).

Conditions:

p_{T1} – readiness to transmit a request to node (distributed learning resource) in the DLE (availability of rout and communication resource);

p_{T2} – readiness to transmit information block to the user (availability of free communication resource on the rout).

$$P=\{p_{T1},p_{T2}\} \Rightarrow |P|=2 \qquad T=\{t_{T1},t_{T2}\} \Rightarrow |T|=2$$
$$I(t_{T1})=\{D_{IN},p_{T1}\} \qquad O(t_{T1})=\{In\_R,p_{T2}\}$$
$$I(t_{T2})=\{Out\_R,p_{T2}\} \qquad O(t_{T2})=\{D_{OUT},p_{T1}\}$$

Input and output matrixes:

$\mathbf{D^-}$	D_{IN}	D_{OUT}	p_{T1}	p_{T2}	In_R	Out_R
t_{T1}	1	0	1	0	0	0
t_{T2}	0	0	0	1	0	1

$\mathbf{D^+}$	D_{IN}	D_{OUT}	p_{T1}	p_{T2}	In_R	Out_R
t_{T1}	0	0	0	1	1	0
t_{T2}	0	1	1	0	0	0

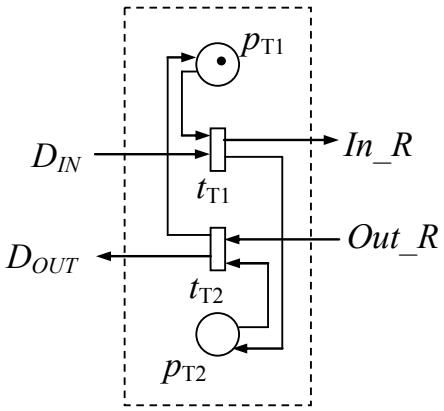

Fig.6. Basic PN-model for "Transmitter" with initial marking μ_0=(1,0)

5. CONCLUSION

The model for distributed learning is connected with the concept of distributed and shared information resources in a heterogeneous environment with local management. On the side of the information process the d-learning permits to all basic learning participants (teachers, students, informational resources) to be placed in different territorial distributed places (different nodes of the DLE). This provides multi-user access supporting and personalization of resources use.

The presented formalization and designed model primitives determine the base for carrying out an investigation of the learning and information processes in the DLE. In this connection the next investigation phase is a generalized Petri net model constructing and its execution. In order to obtain a good result is necessary to make a previous verification of the designed primitives.

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