Deterministic Investigation of Distributed Learning Environment by using Petri Nets Model

Radi Romansky, Elena Parvanova

Abstract: *The distributed learning is organized on the base of distributed access to remote learning resources, communication medium for transmission of user requests and learning objects (information resources, 3D components, multimedia, etc.), participation of different users (teachers, students, clients, etc.) and mechanisms of education. All these components organize a common Distributed Learning Environment (DLE) and for its architecture designing an adequate investigation is needed. The paper presents an investigation of DLE by using the deterministic apparatus of Petri Nets. The main goal is to build a model as an asynchronous Petri net completed by previously defined basic model primitives. In this reason a verification of these primitives is made and a global model is presented. The model execution is made and some analytical results are discussed.*

Key words: *e-Learning, Distributed Information Resources, Petri Nets, Discrete Modeling.*

1. INTRODUCTION

The contemporary Information Society permits to introduce the 3D modeling possibilities in the www environment. By joining the principles of e-learning, 3D modelling and communication medium of the global network is possible to realize a Distributed Learning Environment (DLE) that offers a set of knowledge in the area of 3D simulation and virtual reality. During the last years 3D virtual environments represent a new form of learning environment that can involve synchronous and asynchronous learning opportunities that provide a three-dimensional simulated learning situation, rather than replicating a traditional classroom, laboratory and university [1, 2]. In addition, the combination of X3D modeling language and Adaptive Hypermedia Architecture (AHA) is possible to represent 3D educational virtual environments [3]. All these prerequisites give a real possibility to make a DLE in the field of 3D simulation and virtual reality.

The paper presents a possibility for DLE architecture investigation by using the deterministic apparatus of Petri Nets [4, 5]. The main goal is to build a model as an asynchronous Petri net (PN) completed by previously defined basic model primitives for main participants in the processes of information servicing [6]. In this reason a verification of these primitives is made and a global model is presented. The model execution is made and some analytical results are discussed.

2. DLE ABSTRACT DESCRIBING AND BASIC MODELS VERIFICATION

A basic general abstract model of the learning interactions in the DLE is designed and is shown in fig. 1. The connection path between a user and an information resource is marked and basic participants in the distributed learning process are defined:

- ✓ Set of users $U = \{U_i / i = 1 \div N\}$, $U \neq \varnothing$;
- ✓ Set of learning resources $R = \{R_j / j = 1 \div M\}$, $R \neq \varnothing$;
- ✓ Set of transmitters $T = \{T_q / q = 1 \div K\}$, $T \neq \varnothing$;
- ✓ Distributor (D) that routs all information objects in the communication medium.

The basic models (primitives) describing these DLE components by using PN are presented in [6]. Two different interactions between nodes are defined:

- ✓ requesting a learning resource initialized by user $req : U_i \xrightarrow{T_q} R_j$ (for $\forall U_i \in U; \forall R_j \in R$);

✓ responding by sending the requested learning object (information block) $Inf : R_j \xrightarrow{T_q} U_i$ (for $\forall U_i \in U; \forall R_j \in R$).

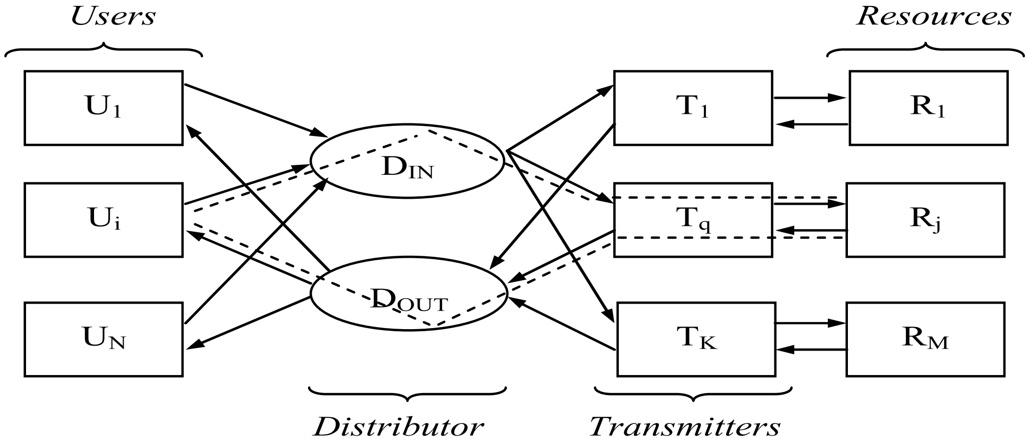
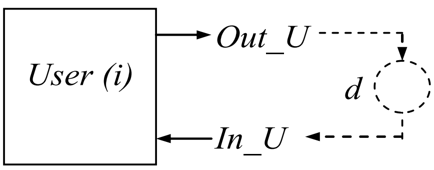


Fig.1. General abstract model of the DLE

A verification of the designed primitives should be made before the DLE construction. The goal is to detect the primitives' functionality and blocking absence.

• **User**

The testing of the model primitive "User" is made on the base of the modified abstract model presented in the fig. 2 where an additional passive place *d* is introduced.



D^-	p_1	p_2	p_3	d
t_1	2	0	0	0
t_2	0	0	1	0
t_3	0	1	0	0
t_4	0	0	0	1

D^+	p_1	p_2	p_3	d
t_1	1	1	0	0
t_2	1	0	0	0
t_3	0	0	0	1
t_4	0	0	1	0

Fig.2. Modified abstract model of the component "User" – initial marking $\mu_0 = (2,0,0,0)$

✓ Permitted transaction(s) defining – calculation by using $\mu_0 \geq e[j].D^-$ at μ_0:

t_1 ⇨ $\mu_0 = (2,0,0,0) \geq (1,0,0,0).D^- = (2,0,0,0)$ Permitted

t_2 ⇨ $\mu_0 = (2,0,0,0) \geq (0,1,0,0).D^- = (0,0,1,0)$ Not permitted

t_3 ⇨ $\mu_0 = (2,0,0,0) \geq (0,0,1,0).D^- = (0,1,0,0)$ Not permitted

t_4 ⇨ $\mu_0 = (2,0,0,0) \geq (0,0,0,1).D^- = (0,0,0,1)$ Not permitted

✓ Next marking(s) defining – if the transaction t_j is permitted for the next marking μ* defining should be used the equation $\mu^* = \mu + e[j].D$, where $D = D^+ - D^-$ is incident matrix:

$$D = D^+ - D^- = \begin{bmatrix} -1, +1, & 0, & 0 \\ +1, & 0, -1, & 0 \\ 0, -1, & 0, & +1 \\ 0, & 0, & +1, -1 \end{bmatrix}$$

The model primitive execution is the following:

$\mu_0 = (2,0,0,0)$ ⇨ $\mu_1 = (2,0,0,0) + (1,0,0,0).D = (2,0,0,0) + (-1,+1,0,0) = (1,1,0,0)$

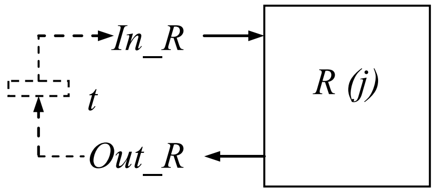
$\mu_1 = (1,1,0,0)$ ⇨ $\mu_2 = (1,1,0,0) + (0,0,1,0).D = (1,1,0,0) + (0,-1,0,+1) = (1,0,0,1)$

$\mu_2 = (1,0,0,1)$ ⇨ $\mu_3 = (1,0,0,1) + (0,0,0,1).D = (1,0,0,1) + (0,0,+1-1) = (1,0,1,0)$

$\mu_3 = (1,0,1,0)$ ⇨ $\mu_4 = (1,0,1,0) + (0,1,0,0).D = (1,0,1,0) + (1,0,-1,0) = (2,0,0,0) \equiv \mu_0$

• **Resource**

Modified model primitive (t is an introduced passive transaction) for the verification purpose is shown in fig. 3.



D^-	p_A	p_B	p_C	p_D
t_R	1	1	0	0
t_S	0	0	2	0
t	0	0	0	1

D^+	p_A	p_B	p_C	p_D
t_1	0	0	2	0
t_2	0	1	0	1
t_3	1	0	0	0

Fig.3. Modified abstract model of the "Resource" – initial marking $\mu_0 = (1,1,0,0)$

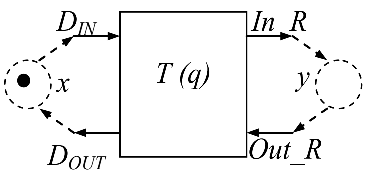
✓ Defining of the permitted transaction at $\mu_0 = (1,1,0,0)$ ⇨ t_R;

✓ Calculating of the incident matrix: $D = D^+ - D^- = \begin{bmatrix} -1,-1,+2,\ 0 \\ 0,+1,-2,+1 \\ +1,\ 0,\ \ 0,-1 \end{bmatrix}$;

✓ Model execution (PN evolution): $\mu_0 = (1,1,0,0) \xrightarrow{t_R} (0,0,2,0) \xrightarrow{t_S} (0,1,0,1) \xrightarrow{t} \mu_0$.

• **Transmitter**

Modified model primitive is shown in fig.4 and two additional passive positions (x, y) are added.



D^-	p_{T1}	p_{T2}	x	y
t_{T1}	1	0	1	0
t_{T2}	0	1	0	1

D^+	p_{T1}	p_{T2}	x	y
t_{T1}	0	1	0	1
t_{T2}	1	0	1	0

Fig.4. Modified abstract model of the "Transmitter"
(initial marking $\mu_0 = (1,0,1,0)$ and permitted transaction t_{T1})

✓ Incident matrix: $D = D^+ - D^- = \begin{bmatrix} -1,+1,-1,+1 \\ +1,-1,+1,-1 \end{bmatrix}$

✓ Evolution of the primitive's PN:

$\mu_0 = (1,0,1,0) \rightarrow \mu_1 = (0,1,0,1) \rightarrow \mu_2 = (1,0,1,0) \equiv \mu_0$

Conclusion: the evolution of all primitives is cyclic and without blocking.

3. GENERAL DLE-MODEL DEFINING

The modeling of the DLE is realized by using the verified primitives based on the infrastructure shown in fig. 5. The general formal PN-model of this network medium is defined below (for j = 1, 2, …, K):

$$P = \{D_{IN}, D_{OUT}, \{p_{T1j}, p_{T2j} / j = 1 \div K\}\} \qquad T = \{t_{T1j}, t_{T2j} / j = 1 \div K\}$$

$$I(t_{T1j}) = \{D_{IN}, p_{T1j}\}$$

$$O(t_{T1j}) = \{In\_R_j, p_{T2j}\}$$

$$I(t_{T2j}) = \{Out\_R_j, p_{T2j}\}$$

$$O(t_{T2j}) = \{D_{OUT}, p_{T1j}\}$$

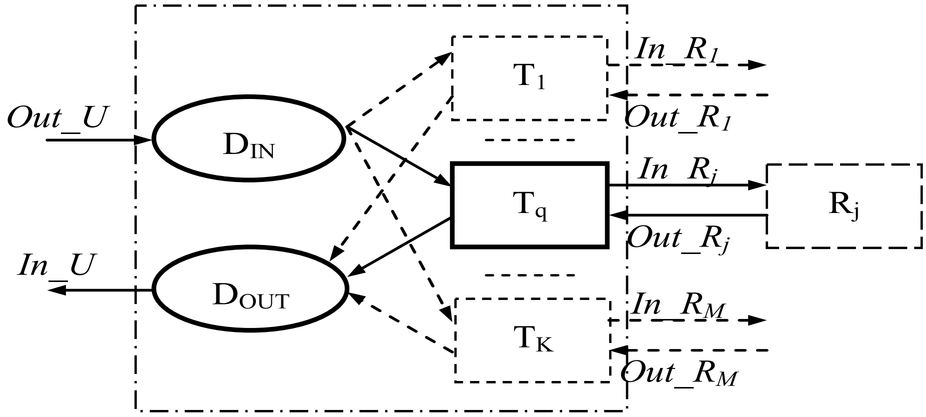


Fig.5. Abstract model of the network infrastructure

The graph presentation of a separate segment of the general DLE-model as a PN is presented in fig.6.

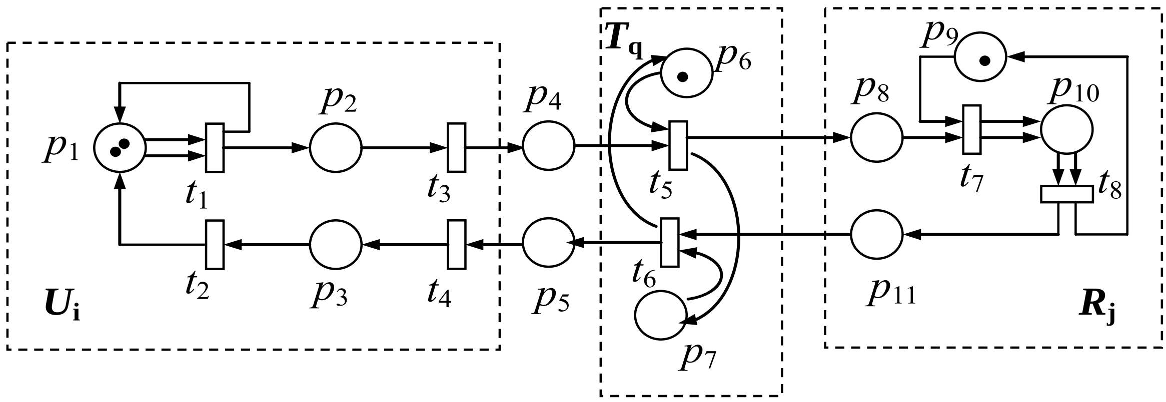


Fig.6. PN-model of the information servicing for a DLE-segment – initial marking μ_0= (2,0,0,0,0,1,0,0,1,0,0)

The matrix definition of the segment from fig. 6 is the following:

$$D^- = \begin{vmatrix} 2&0&0&0&0&0&0&0&0&0&0\\ 0&0&1&0&0&0&0&0&0&0&0\\ 0&1&0&0&0&0&0&0&0&0&0\\ 0&0&0&0&1&0&0&0&0&0&0\\ 0&0&0&1&0&1&0&0&0&0&0\\ 0&0&0&0&0&0&1&0&0&0&1\\ 0&0&0&0&0&0&0&1&1&0&0\\ 0&0&0&0&0&0&0&0&0&1&0 \end{vmatrix} \qquad D^+ = \begin{vmatrix} 1&1&0&0&0&0&0&0&0&0&0\\ 1&0&0&0&0&0&0&0&0&0&0\\ 0&0&0&1&0&0&0&0&0&0&0\\ 0&0&1&0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&1&1&0&0&0\\ 0&0&0&0&1&1&0&0&0&0&0\\ 0&0&0&0&0&0&0&0&0&1&0\\ 0&0&0&0&0&0&0&0&1&0&1 \end{vmatrix}$$

4. EXECUTION OF THE DLE-MODEL AND INVESTIGATION

✓ *Permitted transaction(s) defining* – at the defined initial marking μ_0 only the transaction t_1 is permitted. This fact is defined by the checking of the condition (matrix approach): $\mu_0 \geq e[1].D^-$. It is realized because $e[1] = (1,0,0,0,0,0,0,0)$ and $e[1].D^- = (1,0,0,0,0,0,0,0).D^- = (2,0,0,0,0,0,0,0)$.

✓ *Calculating of the incident matrix:*

$$D = D^{+} - D^{-} = \begin{bmatrix} -1,+1,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0 \\ +1,\ 0,-1,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0 \\ 0,-1,\ 0,+1,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0 \\ 0,\ 0,+1,\ 0,-1,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0 \\ 0,\ 0,\ 0,-1,\ 0,-1,+1,+1,\ 0,\ 0,\ 0 \\ 0,\ 0,\ 0,\ 0,+1,+1,-1,\ 0,\ 0,\ 0,-1 \\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,-1,-1,+1,\ 0 \\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,+1,-1,+1 \end{bmatrix}$$

✓ *Next marking defining* – for the presented μ_0 the next marking will be defined as follows:

$$\mu_1 = \mu_0 + e[t_1].D = \mu_0 + e[1].D = (2,0,0,0,0,1,0,0,1,0,0) + (1,0,0,0,0,0,0,0,0).D =$$
$$= (2,0,0,0,0,1,0,0,1,0,0) + (-1,+1,0,0,0,0,0,0,0,0,0) = (1,1,0,0,0,1,0,0,1,0,0) = \mu_1$$

The model evolution for a single time execution is presented in Table 1. Fig. 7 shows the general scheme of the model evolution (the tree of the reachability).

Table 1.

t	***μ***	***Places and marks***										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
	μ_0	2	0	0	0	0	1	0	0	1	0	0
t_1	μ_1	1	1	0	0	0	1	0	0	1	0	0
t_3	μ_2	1	0	0	1	0	1	0	0	1	0	0
t_5	μ_3	1	0	0	0	0	0	1	1	1	0	0
t_7	μ_4	1	0	0	0	0	0	1	0	0	2	0
t_8	μ_5	1	0	0	0	0	0	1	0	1	0	1
t_6	μ_6	1	0	0	0	1	1	0	0	1	0	0
t_4	μ_7	1	0	1	0	0	1	0	1	0	0	0
t_2	μ_2	2	0	0	0	0	1	0	0	0	0	1

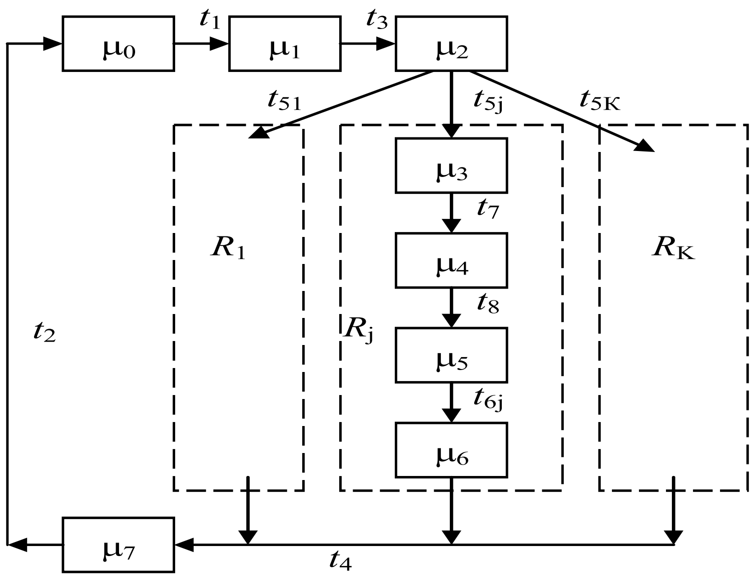


Fig.7. General scheme (tree of reachability) of the model evolution

The model investigation is realized by the analysis of the tree of the reachability and of the basic model conditions. The main results are generalized below.

✓ *Reachability* – the model allows cyclic execution of the basic phase of transactions fairing.
✓ *Liveliness* – the model is alive because the evolution permits at each step to fire (activate) at least one transaction (see Table 1).
✓ *Blocking* – no situation during the evolution can block the model execution at the one-user access to the learning resource.
✓ *Boundness* – the model is 2-bounded because $\Sigma\mu(p_i)\leq 2$ (see Table 1).
✓ *Safety* – it may be accepted that the model is safe because for all transactions the number of input arcs is equal to the number of output arcs.
✓ *Persistence* – the total number of marks in the model is the same during each execution step.
✓ *Conservativeness* – yes, based on the same reason.

5. CONCLUSION AND FUTURE WORK

The discrete modelling and investigation presented in the paper will help to define the most important points of the DLE architecture and the main problems connected to the organization of processes for information servicing. As a next phase in our work we plan to design suitable DLE architectural model and to realize 3D prototypes as a distributed information objects in DLE.

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REFERENCES

[1] Bischoff, A. Bandwidth saving synchronous collaboration environment for virtual universities. Proceedings of Virtual University, Bratislava, Slovakia*, Dec. 2004, pp. 44-48.*

[2] Bouras, C., T. Tsiatsos. Distributed virtual reality: building a multi-user layer for the EVE Platrorm. Journal of Network and Computer Applications, 27, 2004, pp.91–11.

[3] Chittaro, L., R. Ranon. Adaptive Hypermedia Techniques for 3D Educational Virtual Environments. IEEE Computer Society, July/August, 2007, pp.31-36.

[4] Hein, James L., Discrete Mathematics (2nd ed.), Jones and Bartlett Publishers, Sudbury, Massachusetts, ISBN 0-763-72210-3, 2003 (731 p.).

[5] Girault, Caude, Rudiger Valk. Petri Nets for Systems Engineering (A Guide to Modeling, Verification, and Applications), ISBN 3-54041-217-4, Springer-Verlag, Berlin, Heidelberg, 2003 (608 p.).

[6] Romansky, R., E. Parvanova. Organization of Distributed Learning Environment Modeling by using Petri Nets. Proc. of the 5th Int'l Conf. on e-Learning and the Knowledge Society, Berlin, Germany, 31.08-01.09.2009.

ABOUT THE AUTHORS

Assoc. Prof. Radi Romansky, PhD, Department of Computer Systems, Technical University - Sofia, Phone: +359 2 965 32 95, e-mail: rrom@tu-sofia.bg

Elena Parvanova, PhD Student in Computer Systems Dept., Technical University – Sofia, e-mail: e_parvanova@abv.bg