The modeling of flow of IT equipment to a unit of services IT by Coloured Petri Net

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Abstract: - This paper presents the use of coloured Petri nets to model economical, social systems, political systems. It concerns the flow computing equipment in a unit profile. The network which models the system is described in detail. CPN-Tools is used to draw a coloured Petri network to obtain the coverage graph (that appears following evolution of a network, starting from a certain state of the system) and a report that provides information about boundedness, liveness and fairness properties of the modeling network .

Key-Words: - coloured network, location, transition, multiset, marking trap, liveness, fairness.

1 Introduction

The model is represented by "Unit Services" IT (US abbreviation). A company producing electronic equipment for computers has offices scattered in several continents. In Europe it has branch with many work centers, one of which being geo-strategically positioned in Romania to serve Central and Eastern Europe.

Unit of Services (U.S.) located in Romania offers maintenance of the equipment produced by "Parent Firm" at the clients locations.

To streamline the activities the "Parent Firm" is interested in many aspects of the activity of the establishment Service (US.), with priority to:

- The number of interventions - function of which the equipment reliability can be observed.
- The number of equipment with defects which can not be repaired. This type of equipment is not sent to the branch in order to avoid the costs (transportation, testing etc.).
- The number of equipment with defects that can be repaired. This type of equipment is sent to the branch, increasing the costs.

Such analysis of activities highlights that the company should develop a strategy on short and medium term, for the manufacturing as well as for sufficient supply of equipment Unity Service (US.).

2 The model description

To model the system we use the following locations and transitions:

- Locations

- US – services unit;
- FIRM – branch that supplies the equipment “US”;
- MAG – warehouse, where "FIRM" bring new equipment or equipment that was faulty but have been repaired. From here the equipments to services unit are supplied;
- CL – clients (the recipients of the services supplied of “US”);
- CR – location where customers requests for re-supplying with equipment at needed are included;
- ED – location where the debuggers bring the defects equipments and selects the equipments that can be repaired;
- OA – location where the activities are ordered;
- NEDR, NEDN and NINT – locations where the number of defects equipments that can be repaired, defects equipments that can not be repaired and which must be removed from the circuit and respective the number of interventions to clients are included.

- Transitions.

- t_1 – Demand of supply, at the storeroom "MAG" with a "p" set of equipments (p = 10 in the example shown) new or repaired from the "FIRM";
- t_2 – demand for re-supply to the unit of services (US) with a "q" set of equipments from the storeroom MAG (q = 10 in the example shown);
- t_3 – demand from a client for an intervention;
- t_4 - extraction of a defect equipment from the customer and of registration of an intervention made at client in "NINT”;
- t_5 – decision, if the defect equipment from the location ED can be repaired or not, troubleshooting if is possible to send it to "FIRM" to reintroduce it in circuit, and the record in NEDR as repaired equipment. If an equipment can not be repaired it will be register as an equipment which can not be repaired in NEDN.

Initially we assume that "FIRM" has a number "n" of new equipment (n = 100 in the example shown) and that the unit of services (US.) has "m" functional equipment (m = 10 in the example shown).

Network uses the following functions of colors, $\mathscr{F}$= { A, H, R, N} where :

- A = {b, c, d, dn, dr}, H = {db, dp},
- R = {inter} and N = {n},

with the following meanings:

- b – the functional equipments (new or repaired);
- c – the customer demands for intervention;
- d – the faulty equipments;
- dn – defects equipments which can not be repair;
- dr – defects equipments repaired;
- db – defect equipment that can be fixed;
- dp – defect equipment that can be not repaired, or out of warranty;
- n – black token;
- inter – interventions of (US) team to clients.

We also use the variable x $\in$ H to decide, at the transition level t_5, if a defect equipment taken from a location ED can be repaired or not.

Staining by A all the network locations, staining by R the location "NINT", and by N the location "OA".

Weights on the arcs (the expressions on the arcs) are:

- multisets over the sets of colours with which the locations are coloured, that are incidents to those arcs;
- decision instructions, depending on the value of a variable (x, in this) by the possible values of its set (H, in our case) associated with the incident transition of these arcs (t_5, in our case), that assign the arcs multisets, over sets of colours attached to the locations incident to those arcs.

3. Description of network evolution

If we consider the locations in the order given by the vector:

- (NEDR, FIRM, CR, ED, MAG, US, CL, NINT, NEDN, OA)

and starting from the initial seting:

$$\mu_0 = (0,\ 100`b,\ 0,\ 0,\ 0,\ 10`b,\ 0,\ 0,\ 0,\ 1`dn)^t$$

it is observed that the unique transition possible is t_3, which announces a client's demand for an intervention.

As consequence, a service engineer takes functional equipment, goes to the client and announces that there was a call for an intervention. It is obtained by he marking:

$$\mu_1 = (0,\ 100`b,\ 1`c,\ 0,\ 0,\ 9`b,\ 1`b+1`d,\ 0,\ 0,\ 0)^t$$

in which, the functional equipment reach the client, and the service engineer has a broken equipment.

Still, the unique transition allowed is the transition t_4, by which faulty equipment is taken and deposited in the ED location, a token is deposited in the location OA to allow a new request for intervention by another client and an intervention that has took place is registered in the NINT location. Thus the following marking appears:

$$\mu_2 = (0,\ 100`b,\ 1`c,\ 1`d,\ 0,\ 9`b,\ 1`b,\ 1`inter,\ 0,\ 1`n)^t$$

Now, a new request from a client may appears because the T_3 is currently allowed and at the same time we can decide if faulty equipment introduced in ED can be repaired or not, by producing t_5 transition, which is allowed at this moment.

If the transition t_5 is produced and it is decided, that the equipment can not be fixed, for example, (t_5: n = dp) the following marking appears:

$$\mu_3 = (0,\ 100`b,\ 1`c,\ 0,\ 0,\ 9`b,\ 1`b,\ 1`inter,\ 1`dn,\ 1`n)^t$$

If, at the transition t_5, the decision that the equipment can be repaired is taken, i.e. (t_5: n = db) is produced, the following marking appears:

$$\mu_4 = (1`dr,\ 101`b,\ 1`c,\ 0,\ 0,\ 9`b,\ 1`b,\ 1`inter,\ 0,\ 1`n)^t$$

If, at the moment μ_2 a new service request appears, then the T_3 transition is produced and the following marking appears:

$$\mu_5 = (0,\ 100`b,\ 2`c,\ 1`d,\ 0,\ 8`b,\ 1`d+2`b,\ 1`inter,\ 0,\ 0)^t.$$

Continuing in the same way, a digraph of partial coverage is obtained. It has a fixed number of markings nodes (500 in the example shown).

If we are interested on the system' state after a fixed number of nodes, we can study the markings of terminal nodes of the digraph.

If we want to know the system' state at some point, we will study the proper marking of a certain node of the digraph.

We can require the coverage graph, following a number of transitions before established or after the expiry of a certain time expressed in seconds. All these requirements can be done using the following path, from the CPN-Tools:

Tool Box → State Space → CalcSS,

where the variables nodestop, arcstop or seccstop are set to the desired values.

In the next example, the settings are: nodestop: 500 and seccstop: 10.

The coverage graph is built With CPN - Tools until the 500 nodes are found or the working time of 10 seconds expires.

The CPN - Tools were also used to design the network which models our system. The network obtained is given in Fig 1.

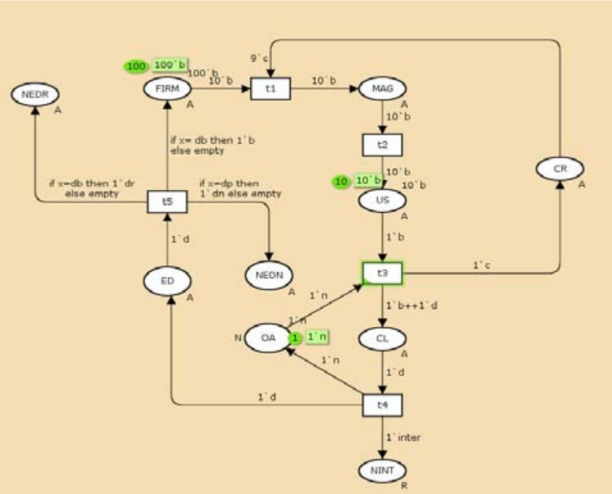

Fig. 1. Network

4 Modeling results

The coverage graph with 501 nodes whose first part it is shown in Fig. 2 was generated by CPN - Tools.

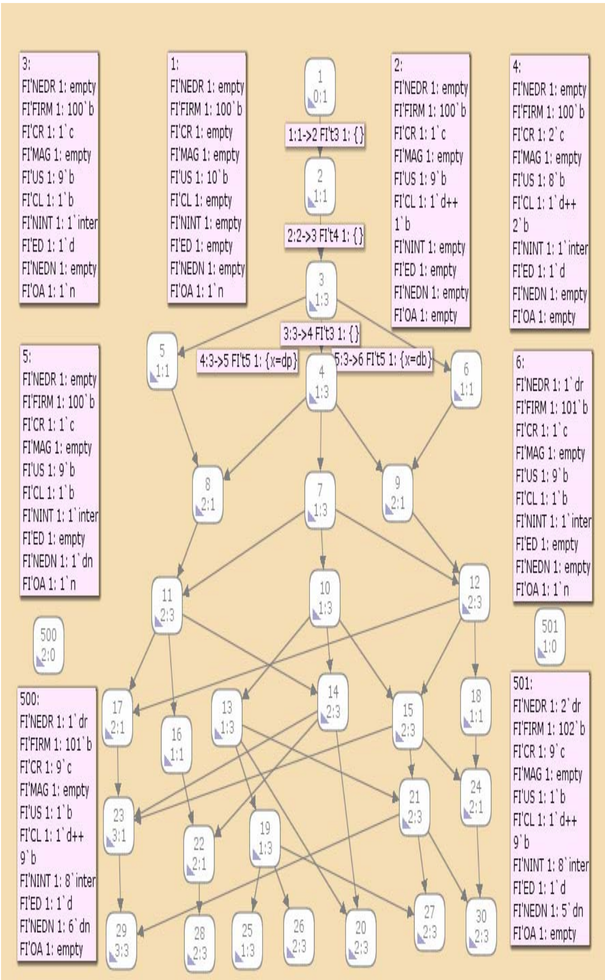

Fig 2. Coverage graph

By CPN-Tools a report was also obtained. It provides information about:

- The number of nodes and arcs of the coverage graph and his state (complete or partial);
- The number of nodes and arcs of the reduced digraph associated to is;
- Minimum and maximum values obtained by the evolution of network in the locations;
- The markings on which are made, the lower and upper edges;
- The markings trap of the network;
- Dead markings and their number;
- Dead transitions;
- Liveness transitions;
- Information on the transitions fairness.

The report is given in the Fig. 3.

```
CPN Tools state space report for:
[redacted]
Report generated: Tue Mar 02 10:06:57 2010
 Statistics
------------------------------------------------------------------------
  State Space                                    Scc Graph
     Nodes:  501                                      Nodes:  501
     Arcs:   1233                                     Arcs:   1233
     Secs:   0                                Secs:   0
     Status: Partial

  Boundedness Properties
------------------------------------------------------------------------
  Best Integer Bounds
                          Upper       Lower
     FI'CL 1               12           0
     FI'CR 1               10           0
     FI'ED 1               11           0
     FI'FIRM 1             107          90
     FI'MAG 1              10           0
     FI'NEDN 1             7            0
     FI'NEDR 1             7            0
     FI'NINT 1             11           0
     FI'OA 1               1            0
     FI'US 1               11           0

  Best Upper Multi-set Bounds                    Best Lower Multi-set Bounds
     FI'CL 1         1`d++11`b                     FI'CL 1          empty
     FI'CR 1              10`c                     FI'CR 1          empty
     FI'ED 1              11`d                     FI'ED 1          empty
     FI'FIRM 1            107`b                    FI'FIRM 1        90`b
     FI'MAG 1             10`b                     FI'MAG 1         empty
     FI'NEDN 1            7`dn                     FI'NEDN 1        empty
     FI'NEDR 1            7`dr                     FI'NEDR 1        empty
     FI'NINT 1            11`inter                 FI'NINT 1        empty
     FI'OA 1              1`n                      FI'OA 1          empty
     FI'US 1              11`b                     FI'US 1          empty

 Home Properties
------------------------------------------------------------------------
  Home Markings
     None
 Liveness Properties
------------------------------------------------------------------------
  Dead Markings
     77 [501,500,499,498,497,...]
  Dead Transition Instances
     None
  Live Transition Instances
     None
 Fairness Properties
------------------------------------------------------------------------
     No infinite occurrence sequences.
```

Fig 3. Report

We observe that the coverage graph has 501 nodes and 1233 arcs, and it is incomplete (partial).

The maximum values of the locations are given in the vector following vector:

$$(7, 107, 10, 11, 10, 11, 12, 11, 7, 1)^t.$$

The minimum values of the locations are given in the following vector:

$$(0, 90, 0, 0, 0, 0, 0, 0, 0, 0)^t.$$

Concerning the marking corresponding to the maximum values of locations we remark that:

- There are not markings trap. There are 77 markings dead of which the last are:

501, 500, 499, 498, 497 etc.

- There are liveness transitions and infinite sequences in producing transitions, so correct information about fairness of transitions can not be supplied.

- The marking 501 corresponds to the following state of system :

$$\mu_{501} = (2`dr,\ 102`b,\ 9`c,\ 1`d,\ 0,\ 1`b,\ 1`d+9`b,\ 8`inter,\ 5`dn,\ 0)^t .$$

Hence it can be concluded that 8 interventions were performed:

- a demand from a client, that is in solving process - a defect equipment was replaced by a functional one,
- 9 requests for interventions,
- two equipment were repaired and returned to the circuit,
- 5 equipment present defects, and can not be repaired,
- a functional equipment remains at US,
- a broken equipment is in ED location, but no decision has been taken (if it can be repaired or not).

This way, by studying proper marking, the system state can determined any time.

5. Conclusion

The model presented in this article emphasizes the modeling power of colored Petri networks. With its help we can know the system state each moment and the statistics on the number of interventions, the number of equipments faulty that can be repaired and the number of equipment that can be not repaired, which give information on the fiability of IT equipment used.

In this paper I assumed that functional IT equipment is supplied at the company.

The model can be extended with a component for testing the batch of equipments incoming from companies producing equipment, so the company will accepted only those batches that have, to example, 95% functional equipment (less than 5% of them to be defects manufacturing equipment. If the percentage would be higher, the batch is going to be refused).

References:

[1] K. Jensen, *Coloured Petri Nets*, Vols. 1-3, Spinger-Verlag Berlin Heidelberg, 1992.

[2] K. Jensen, L. M. Kristensen, *Coloured Petri Nets-Modelling and Validation of Concurrent Systems*, Spinger-Verlag Berlin Heidelberg, 2009.

[3] G.W. Brams, *Reseaux de Petri : Theorie et pratique*, Vols. 1 , 2, Masson, Paris, 1983.

[4] F. Blaga, I. Stanasel, A. V. Pele, Evaluarea performantelor de fabricatie flexibila CFF-2R-2002 utilizand retele Petri temporizate, *Fascicle of Management and Tehnological Engineering* 1563-1570, *Annals – Oradea University*, 2008.

[5] http://www.cs.au.dk/CPnets/CPN-Tools, 2009.