A PETRI NET BASED SIMULATOR FOR ACTIVE DATABASE SYSTEMS

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Abstract

Active database systems were introduced to extend the database functionality. As well as a repository of data, active database can detect the occurrence of events in a database system and react automatically to that event occurrence and execute certain actions either inside or outside the database. This behavior is specified by means of ECA (event-condition-action) rules, i.e., when an event has occurred, if the condition is evaluated to true, then an action is executed. The development of a set of ECA rules involve the knowledge of the database structure and the relationships that can exist among the ECA rules, which may produce an inconsistent state in the database. Therefore, it is so important to verify a rule set before its implementation in the active database, and one method to determine if a rule set will produce consistent states of the database is through the simulation of ECA rule firing. In this paper a simulator for active databases, named ECAPNSim, is described. ECAPNSim uses the definition of ECA rules like a structure of an extended Petri net model, the Conditional Colored Petri Net (CCPN). Conditional Colored Petri Net definition involves the knowledge and execution model, which describe the features that an active database system must have. Furthermore, in order to simulate the occurrence of database events, ECAPNSim has been enhanced with the addition of distribution functions for each place that denote events of the ECA rule set. An example has been developed in order to show the ECAPNSim applicability in a certain study area.

Keywords: Petri net, Active Database, ECA rules, Simulation.

Presenting Author's biography

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1 Introduction

Traditional databases (DB) were developed to store a huge amount of information. In this DB type the information only is accessed by insert, delete, update and query algorithms, which were previously programmed in a Data Manipulation Language (DML) by the DB administrator. The set of all this data manipulation programs is the Database Management System (DBMS). However, the execution of those programs is performed only by the request of either a DB user or the DB administrator.

Nevertheless, there are systems that cannot be implemented by using a traditional DB approach. Such systems are those where is well known that if certain events occur in the DB and if the DB state satisfies certain conditions, then an action or procedure is performed in the DB. Therefore, it is necessary to use an approach where a DB could have the ability to react automatically when an event occurs either inside or outside DB environment, after this, it can verify the DB state to evaluate conditions, and if condition is evaluated to true it can execute procedures that modify the DB state. In order to provide of active behavior to traditional DB, Active Databases (ADBs) were introduced. If a human being takes charge to detect the event occurrences, verify conditions, and execute procedures instead an ADB system, then the system may not work well. Thus, it is very important to add enough information to DB about the active behavior and convert a traditional DB into an Active one.

Active behavior of a DB can be defined through a base of active rules, which has the specification of events that will be detected, conditions that will be evaluated, and actions or procedures that will be performed in the DB. The model most widely used is the event-condition-action rule (ECA rule) model, whose general form is as follows [1]:

on event e1

if condition c1

then action a1

ECA rule model works in the following way: when an event e1 that modifies the current DB state occurs, if condition c1 is evaluated to true against DB state, then either an action a1 is executed inside DB or a message is sent outside DB.

An event e1, which can trigger to an ECA rule, can be of two types: primitive event or composite event [2]. A primitive event is generated by the execution of an operation over the DB information (insert, delete, update, or select), a DB transaction, a clock event (which can be absolute, relative, or periodic), or the occurrence of a DB external event. On the other hand, composite events (disjunction, conjunction, sequence, closure, times, negation, last, simultaneous, and any) are formed by the occurrence of a combination of primitive and/or composite events.

Composite events increase the complexity of a base of active rules because composite events are represented by complex structures, which need to be evaluated when a composite event is raised. In the same way that a composite event increases the complexity of a base of active rules, relationships between ECA rules increase the complexity of a base of active rules.

Furthermore, active rules must be validated before its implementation into a real active database system, in order to known its behavior and to verify the presence of situations that may produce an inconsistent state in the database system.

This verification can be performed trough the simulation of the active rules. In this paper an ECA rule simulator is presented, which uses a Petri net model, named Conditional Colored Petri Net (CCPN), to depict ECA rules as a Petri net structure, and with the token game animation the event occurrence and rule triggering are analyzed in order to detect active database problems such as No termination and confluence [2].

The remainder of the paper is organized as follows. Section 2 discusses the related work about active database systems; section 3 gives a general description of the PN model used to depict ECA rules. Section 4 describes a software development named ECAPNSim, which is used to model, simulate and analyze ECA rule sets. Section 5 shows the applicability of ECAPNSim by developing an example of ECA rule set in a bank enterprise. Finally, Section 6 concludes and gives directions for future work.

2 Related work

There are several research studies about active databases and the development of ECA rules. Relational systems, such as starburst [3], Postgres [4], Ariel [5], SYBASE [6], INFORMIX [7], ORACLE [8], among others, provide an active functionality based on triggers, but they cannot handle composite events at all.

Triggers only supports the composite event disjunction, and structure primitive events that are defined over a table, moreover, in the action part of triggers cannot be executed another trigger.

On the other hand, Object Oriented DB systems (such as HiPAC [9], EXACT [2], NAOS [10], Chimera [11], Ode [12], Samos [13]) provide more elements of active systems, like the composite event handling. Nevertheless, because of the different structures and classes used to develop Object Oriented DB systems, there is not a standard model to define ECA rules in these systems.

Few researches have adopted Petri nets as ECA rule specification language [13], [14] [17]. In [17], the

authors proposed an Action Rule Flow Petri Net (ARFPN) model, and a workflow management system was illustrated to verify their ARFPN model. However, their model has much redundant structure because of using many BEGIN OFs, END OFs to describe events, conditions and actions. SAMOS is a successful ADB system, Petri nets is partially used for composite event detection and termination analysis. But, the framework is not Petri-net-based.

Colored Petri Nets (CPN) is a high-level Petri nets which integrates the strength of Petri nets with the strength of programming languages. Petri nets provide the primitives for the description of the synchronization of concurrent processes, while programming languages provide the primitives for the definition of data types and the manipulation of their data values [18]. So it is more suitable for active database than ordinary Petri nets since it can manipulate data values. By using CPN one can not only revealing the interrelation between ECA rules but also capture the operational semantics. For these reasons, CPN is very suitable for modeling and simulation of active rules. References [17] adopted CPN as rule specification language. However, there exists much redundant PN structure for using ”begin of”, ”end of” events, conditions and actions repeatedly. So, Their CPN model is very large even for a small rule set. Therefore, the complexity of CPN management increases. In SAMOS a SAMOS Petri Nets (S-PN) was proposed for modeling and detection of composite events. S-PN is also CPN-like where a different perspective for colors was taken. Colors in S-PN are token types, and one token type is needed for each kind of primitive event.

3 Conditional Colored Petri Net definitions

There are several proposals to support reactive behaviors and mechanisms inside a DBS, which is best known as an ADBS. Nevertheless, these proposals are designed for particular systems, and they cannot be migrated to any other system, moreover, there is not a formal ADBS proposal.

In this paper, a general model to develop ECA rules in an ADBS is proposed, based in PN theory, which can be used as an independent engine in any DBS. An ADBS must offer both a knowledge model and an execution model. Knowledge model specifies the elements of the ECA rule, i.e., the event, condition, and action part. On the other hand, execution model describes the way in that the ECA rule set will be executed.

In knowledge model, each ECA rule element is converted into a CCPN element. The event, which activates the ECA rule, is converted in a CCPN structure that is able to perform the event detection. A Primitive event is depicted by a CCPN place, but if the event rule is composite, then the corresponding CCPN structure is generated. Both types of events finish in a place, which will be used as an input place for a transition.

A CCPN transition holds the next element of an ECA rule, the conditional part. It verifies if there are tokens in its input place and evaluates the conditional part of the ECA rule that is holding. Unlike traditional PN transitions, CCPN transitions have the ability to evaluate boolean expressions.

Finally, the ECA rule element action. When action part is executed in a DBS, it modifies the DB state. This can be viewed as an event that modifies the DB state. Events are represented as CCPN places, thus action part is represented by a place too. The difference between places for events and places for actions is that places for events are input places to transitions, and places for actions are output places from transitions.

CCPN execution model is based in the transition firing rule of PN theory. It provides mechanisms to create tokens with information, or color, about events that are occurring inside the DB. New tokens are placed in the corresponding places for those events. This is the way in that an ECA rule set is processed and both composite and primitive events are detected.

By using Colored Petri Nets (CPN) is possible to depict ECA rules, but only those that have primitive events. ECA rules with composite events cannot be represented efficiently with CPN.

Definition Conditional Colored Petri Net (CCPN) [19] is a Petri net extension, which inherits attributes, and transition firing rule from classical PN [14] [15] [16]. Furthermore, CCPN takes concepts from the CPN, such as data type definition, color (values) assignation to tokens, and data type assignation to places.

In the CPN case, data type assignation is performed for all the places of CPN, on the other hand, in the CCPN case, data type assignation for places is not general, because the CCPN handles a kind of place (virtual place) with the ability to hold different types of tokens.

In order to evaluate conditional part of ECA rule stored inside a CCPN transition, a function is defined to do this task. Evaluation function analyzes the boolean expression and match it with the DB state to determine its boolean value.

Some composite events needs to verify a time interval, hence CCPN provides a function that assigns time intervals to a CCPN transition, which will be the responsible to verify if events are occurring inside time interval defined, likewise the evaluation of ECA rule condition is done. These types of transition are named composite transition.

Each event occurs in a point of time, thus, CCPN provides a functions that assigns a time stamp to every

token created. Time stamp value is the time instant in which the event has occurred. It is useful to verify if an event occurred inside a time interval or to detect composite events such as sequence and simultaneous.

Finally, every time that an event occurs, a token must be created. CCPN has a function to initialize tokens, in other words, when an event occurs in DB, a new token is created by CCPN and its attributes are initialized to the corresponding event values. The new token is put in the place that represents to detected event.

CCPN is an extension of PN that uses CPN concepts [18]. In order to save event information in tokens and to create new tokens with data about the action part of the ECA rule, CCPN uses the concept of "color" taken from CPN. The values stored in tokens are used to evaluate the conditional part of the rule stored in the transition of CCPN. CCPN uses the multi-set concept from CPN, because a CCPN place may have several events at the same time. Unlike CPN, CCPN evaluates conditions inside transitions; meanwhile CPN evaluates conditions in its arcs.

4 ECAPNSim

ECAPNSim is a graphical interface developed as a part of this research, in order to convert automatically ECA rule sets into CCPN structures. Furthermore, ECAPNSim can provide of active functionality to relational databases by establishing communication via ODBC-JDBC drivers. ECAPNSim detects events in the DB, it performs the evaluation of condition, stored in transitions $t \in T_{rule}$, and it executes actions inside the DB, according to the ECA rule set represented as a CCPN. See Fig. 1.

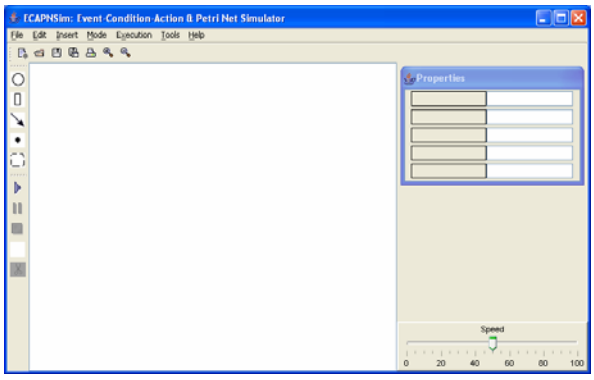

Fig. 1. ECAPNSim environment.

ECAPNSim has two modalities: in the first one, ECAPNSim works as a PN simulator, where the simulation of the ECA rule set behavior is performed; and in the second one, ECAPNSim works as the engine of an active database, in other words, ECAPNSim is placed as an upper layer over a DB system, ECAPNSim "listen" the events that modify the DB state and if there is any event that is in the CCPN as a place, then ECAPNSim takes information about the event and create the token about the event, after that, ECAPNSim places the new token in its corresponding place and starts the token game animation (ECA rule firing).

4.1 Incorporation of distribution functions

ECAPNSim was enhanced with the addition of distribution functions, which are useful to simulate and to analyze the event occurrence in an active rule base.

Distribution functions which are able in ECAPNSim are beta, binomial, Cauchy, chi square, exponential, gamma, geometric, uniform, and weibull, among others. The use of this set of functions depends on the active rule base that will be simulated.

Each place in the CCPN has the property for the definition of a distribution function, according to the frequency of the event occurrence. The values for the functions can be determined by a statistical analysis of the data about the real occurrences of the events that fire ECA rules.

Random values which are generated by distribution functions are used as inter arrival time of events in ECAPNSim. Each time an event occurrence is simulated, a token with information about that event is created, and it is putted into the place that represents the corresponding event. Hence, the token game animation is started and ECA rule developer can detect inconsistencies in ECA rule set.

5 Example

In order to illustrate the applicability of CCPN approach in ECA rule development, an ECA rule base has been implemented. The ECA rule base used is about a bank organization from Mexico, which for security reasons the name is omitted.

Relational model was used to describe the universe of discourse of the DB for this example. Relations and its attributes are listed below:

client (number, name, address, and the beginning date). Stores information about a client of the bank, considering a client's number, name, address, and the date when he began as a client of the bank.

account (number, client number, balance, limit, type {credit, saving, payroll, checks}, state (active, blocked, cancelled)). Holds data about account numbers, such as the account number, the client owner of the account, the current balance of the account, the lower limit of balance, the type of account which could be a credit account, a saving account, a payroll account, or a checking account, moreover, it is necessary to know if an account is active, blocked or cancelled.

outstanding transactions (key, type {deposit, sell}, source account, target account, amount, period). It is used to store transactions that were performed out of office time.

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deposit (deposit date, account number, amount, place {branch, ATM, internet, telephone}, currency). Relation used to store all deposits made in the bank, considering the date and time when the deposit was made, the account were the amount of money was deposited, the place where was performed the transaction, and the currency of transaction.

withdraw (withdraw date, account number, amount, place {branch, ATM, internet, telephone}, location). Has attributes related to transactions to withdraw money accounts. Its attributes are the date of the transaction, the account number where the withdrawn was applied, the amount of money withdrew, the place where the operation was done, and the location, i.e., if the transaction was done in Mexico or abroad.

payment for services (date, source account, target account, access mode, amount, payment concept, location). This relation is used to perform payments for services like telephone, internet, gas, among others. Attributes are date of transaction, the source account where the amount will be withdrawn; the target account where the payment will be applied; the access mode, i.e., the way in that a client perform this service which could be done either by internet or by telephone; the amount of money that will be paid; the concept of the payment; and the location from where the client requests the service.

print a ticket (data transaction). This relation is used to generate tickets about the transactions that are being performed, and only contains the message that will be printed in the ticket. Tickets are printed when a client makes a deposit, a withdraw, or a payment for a service.

report (type of report, description, client, place, state). The attribute type store information about the report, i.e., if the card (either, credit or debit card) of a client was stolen, damaged, or lost; or if the report is about a complaint. In description attribute is described the reason of the report. In a report must be added the client who is doing the report, the place where the client made the report, which could be by Internet, by telephone, or in a branch of the bank; and the state of the report, i.e., if the report invalid, if it is waiting to be checked, if it is being checked, or if it has been resolved.

credit card request (credit card number, account, with photograph, additional credit card). This relation has the attributes credit card number, the account for this credit card, if the credit card is with the client's photography, and if the credit card is an additional one.

In order to control some tasks performed by the bank, an ECA rule set has been developed. These rules automatically will be executed in the DB, providing the active behavior to the DB. The rule set contains seventeen rules, which are described in the following paragraphs.

Rule 0: When a deposit, a withdraw, or a payment for service is made, then a ticket is printed to the client.

Rule 1: When a withdraw is made from a bank account, if the balance of the account is greater than the amount of the withdraw, then the amount is subtracted from the account balance.

Rule 2: When a client performs a payment for a certain service, if the balance of the client's account is greater than the amount of the payment, then a withdraw is performed over the client's account.

Rule 3: When a client makes a deposit inside the office time, i.e., in the labor schedule, then the balance of the client's account is added with the amount of the deposit.

Rule 4: When a client makes a deposit, but he makes it out of office time, then the transaction is deferred and it will be performed the next day.

Rule 5: When a client performs a payment for a service, and if he is accessing by Internet, then the bank charges 25 Mexican pesos to the client's account balance by the internet service.

Rule 6: The same case that previous rule, but now the client is making the transaction by telephone, so, the charges is 20 Mexican pesos.

Rule 7: When the client makes a payment for a service, then the amount paid for the service is charged to the client's account.

Rule 8: When a client makes a withdraw from an ATM and if he has performed more than five withdraws from ATMs, then the bank charges five Mexican pesos from the client account.

Rule 9: When a client makes a deposit, and if the currency is different from Mexican currency and the deposit is made inside the labor schedule, then the currency conversion must be done and the result is added to the client's account.

Rule 10: Similar to previous rule, but if the transaction is made out of labor schedule, then the transaction is deferred to the next labor day.

Rule 11: When a client submit a complaint, but the complaint is rejected, then the bank subtracted from the client account the amount of 200 Mexican pesos.

Rule 12: When a client makes a withdraw from an ATM that belongs to other bank, and if the withdraw was made inside the country, then the commission charged by the bank owner of the ATM is 10 Mexican pesos.

Rule 13: Similar to previous rule, but, in this case, if the withdraw is made abroad, then the commission charged by the bank owner of the ATM is 80 Mexican pesos.

Rule 14: When a credit card is requested by a client, if the client requires his credit card with his photo

included, then the cost of the credit card is increased by 200 pesos.

Rule 15: When a credit card is requested by a client, if the required credit card is an additional one, then the cost of the credit card is increased by 100 pesos.

Rule 16: When a new account number is registered in the bank, if it is a credit account, then the client must pay 350 pesos by the credit service.

For each rule listed above, it is necessary to convert them into its ECA rule description, according to the general model of ECA rules.

rule 000,
on or(insert into deposit, insert into withdraw, insert into payment for service),
if true,
Then insert into print_a_ticket values (’print ticket’);

rule 001,
on insert into withdraw,
if account.balance > withdraw.amount,
Then update account set value balance = balance - withdraw.amount;

rule 002,
on insert into payment_for_service,
if account.balance > payment_for_service.amount,
Then insert into withdraw values (today, account.number, payment_for_service.amount, ’branch’, payment_for_service.location);

rule 003,
on insert into deposit,
if deposit.date < 16:00,
Then update account set value balance = balance + deposit.amount;

rule 004,
on insert_into deposit,
if deposit.date >= 16:00,
Then insert into outstanding_transactions values (account.number, ’deposit’, NULL, deposit.account, deposit.amount, 2);

rule 005,
on insert into payment_for_service,
if payment_for_service.access_mode = ’Internet’,
Then insert into withdraw values (today, account.number, 25.00, ’INTERNET’, payment_for_service.location) ;

rule 006,
on insert into payment_for_service,
if payment_for_service.access_mode = ’Telephone’,
Then insert into withdraw values (today, account.number, 20.00, ’TELEPHONE’, payment_for_service.location) ;

rule 007,
on insert into payment_for_service,
if true,
Then insert into withdraw values (today, account.number, 20.00, ’BRANCH’, payment_for_service.location) ;

rule 008,
on insert into withdraw,
if withdraw.place = ’ATM’ & account.limit > 10,
Then insert into payment_for_service values (Today , account.number, NULL, NULL, 5.00, ’Other services’ , ’Mexico’);

rule 009,
on insert into deposit,
if deposit.currency <> ’PESO’ & deposit.date < 16:00,
Then update account set value amount = amount - deposit.amount + deposit.amount * currency_rate ;

rule 010,
on insert into deposit,
if deposit.currency <> ’PESO’ & deposit.date >= 16:00,
Then insert into outstanding_transactions values (1, ’deposit’, null, deposit.account, deposit.amount, 2));

rule 011,
on update report.state,
if report.type = ’complaint’,
then insert into payment_for_service values (today, NULL, account.number, report.place, 200, ’other services’, ’Mexico’);

rule 012,
on insert into withdraw,
if withdraw.place = ’external ATM’ & withdraw.location = ’Mexico’,
Then insert into payment_for_service values (today, NULL, withdraw.account, ’Automatic’, 10, ’other services’, ’Mexico’);

rule 013,
on insert into withdraw,
if withdraw.place = ’external ATM’ & withdraw.location = ’abroad’,
Then insert into payment_for_service values (today, NULL, withdraw.account, ’Automatic’, 80, ’other services’, ’abroad’);

rule 014,
on insert into credit_card_request,

if credit_card_request.with_photo = 1,
Then insert into payment_for_service values (today, NULL, credit_card_request.account, 'Automatic', 200, 'other services', 'Mexico');

rule 015,
on insert into credit_card_request,
if credit_card_request.additional = 1,
Then insert into payment_for_service values (today, NULL, credit_card_request.account, 'Automatic', 100, 'other services', 'Mexico');

rule 016,
on insert into account,
if account.type = 'Credit' ,
Then insert into payment_for_service values (today, account.number, NULL, 'Automatic', 350.00, 'other services' , 'branch');

The whole CCPN for the ECA rule set described above is showed in Fig. 2.

Correspondences between ECA rule set and CCPN elements are showed in Tab. 1, Tab. 2, and Tab. 3.

Tab1. Event part of ECA rule denoted as CCPN places.

Event	Place	Copy places
insert into deposit, withdraw, or payment for service	p_5	
Insert into withdraw	p_1	p_8, p_{17}, p_{21}, p_{22}
Insert into payment_for_service	p_2	p_{10}, p_{14}, p_{15}, p_{16}
Insert_into deposit	p_0	p_{11}, p_{12}, p_{18}, p_{20}
Insert into credit_card_request	p_7	p_{23}, p_{24}
Insert into account	p_4	
update report.state	p_6	

Tab 2. Action part of ECA rule denoted as CCPN places.

Action	Place
insert into print_a_ticket	p_3
update account set value to balance	p_9
insert into outstanding_transactions	p_{13}
update account set value to amount	p_{19}

Tab. 3. ECA rule elements and its corresponding CCPN elements.

Rule	Event	Transition	Action
000	p_5	t_3	p_3
001	p_8	t_4	p_9
002	p_{10}	t_5	p_1
003	p_{11}	t_6	p_9
004	p_{12}	t_7	p_{13}
005	p_{14}	t_8	p_1
006	p_{15}	t_9	p_1
007	p_{16}	t_{10}	p_1
008	p_{17}	t_{11}	p_2
009	p_{18}	t_{12}	p_{19}
010	p_{20}	t_{13}	p_{13}
011	p_6	t_{14}	p_2
012	p_{21}	t_{15}	p_2
013	p_{22}	t_{16}	p_2
014	p_{23}	t_{17}	p_2
015	p_{24}	t_{18}	p_2
016	p_4	t_{20}	p_2

6 Conclusion

Currently there are database management systems that support ECA rule definition by the use of "triggers", however "triggers" has several restrictions that limits the power that an active database must offer.

On the other side, there are research prototypes that support ECA rule definition, too; and they are more powerful because composite events such as conjunction, disjunction, etc., can de defined. Nevertheless, like database management systems,

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ECA rule definition is performed in the syntax of every active database.

ECAPNSim is an interface that generates a CCPN from an ECA rule definition typed in the on-if-then form. It carries out the simulation of the CCPN behavior according to the event occurrence in a random way, which depends on the distribution function assigned.

ECAPNSim has been improved with the addition of distribution functions in each place that denote an event occurrence.

A study area for active database is computer nets, where active behavior can be implemented in order to monitor traffic of LAN networks; an automatic reaction can be set by an active database system, instead of a human being monitoring. When suspicious events occur in the net, then ECA rules can be triggered and perform the corresponding action to maintain the stability in the net.

Other interesting area of application is in distributed database systems, where the development of ECA rules needs to consider the event occurrence in different servers.

There are several interesting areas where active databases are applied, mainly where systems need an automatic reaction and the response time must be immediate.

Nevertheless, ECA rule development implies that the ECA rule developer must be careful to avoid inconsistency states in the database system.

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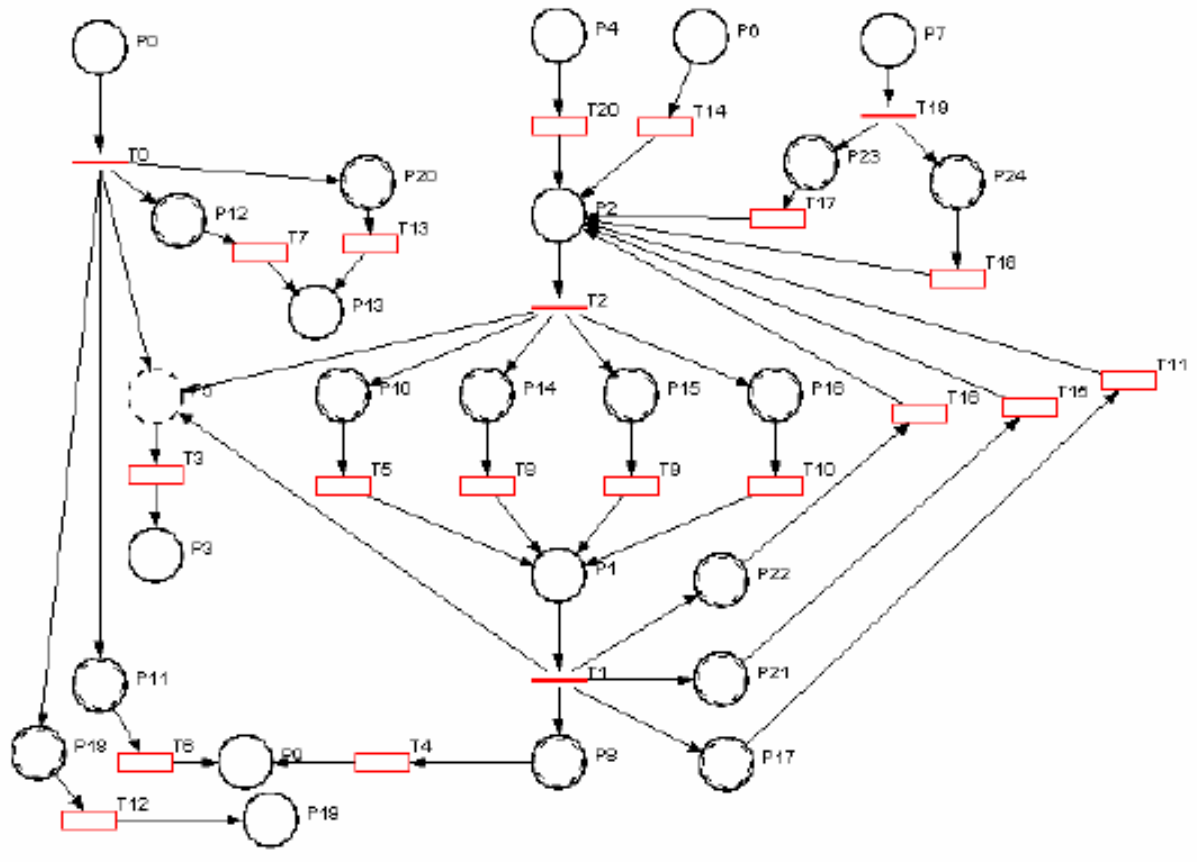

Fig. 2. CCPN structure for the whole ECA rule base.

