Transformation BPEL Processes to RECATNet for Analysing Web Services Compositions

Ahmed Kheldoun[1] and Malika Ioualalen[2]
[1]*Computer Science Department, Yahia Fares University, Medea, Algeria*
[2]*Computer Science Department, USTHB University, Algiers, Algeria*

Keywords: RECATNet, BPEL, Conditional Rewriting Logic.

Abstract: One of the most important advantages of Web services technology is the possibility of combining existing services to create a new composite Web process according to the given requirements. BPEL is a promising language which describes web service composition in form of business processes. However, BPEL is an XML-based language and lack of a sound formal semantic, which hinders the formal analysis and verification of business processes specified in it. In this paper, we propose an approach based RECATNet to model and verify BPEL processes. We present some transformation rules of BPEL business processes into RECATNet. Since RECATNets semantics may be defined in terms of the conditional rewriting logic, Maude tools may be used for model-checking the correctness of BPEL processes. A case study is given to show the efficiency of our approach.

1 INTRODUCTION

As a single Web service can provide limited function. It is necessary and feasible to compose functions offered by different individual services into a composite service. Among the results, BPEL (Business Process Execution Language) (A. Alves and al., 2007) is the most popular one that is used to specify business processes for service composition. Nevertheless, BPEL still remains at the descriptive level, without providing any kind of mechanisms or tools support for verifying a composite service.

Therefore, modelling and analysing BPEL business processes with a formal tool becomes critical. This allows designers to detect erroneous properties or verify whether a service process does have certain desired properties (such as reachability, liveness, and so on). This paper presents the mapping of BPEL to RECATNets (Barkaoui and Hicheur, 2007). RECATNets model offers mechanisms for a direct and intuitive support of dynamic creation/suppression of processes at design time. These dynamic mechanisms of RECATNets are adequate to model, in a concise way, the most complex routing construct (flow pattern).

The remainder of this paper is organized as follows. Section 2 discusses related work. Section 3 presents the basic concepts of RECTANets. Section 4 presents transformation rules from BPEL business processes to RECATNet. Section 5 describes a worked example. Section 6 defines the RECATNets semantics in term of conditional rewriting logic. Finally, section 7 concludes the paper and outlines some ideas for future works.

2 RELATED WORKS

The modelling of BPEL processes is addressed in several papers. In this section, we briefly overview some approaches that are closely related to our work.

Aalst et al.(Verbeek and van der Aalst, 2005) propose a method specially towards mapping a BPEL process model onto WF-net in order to use the tool Woflan (Verbeek and van der Aalst, 2000) for their analysis. Hinz et al. (S. Hinz and Stahl, 2005) translate a BPEL process into a pattern based Petri net semantics in order to use the tool LoLA for validating their semantics. CP-nets are used in (Y. Yang and Yu, 2006) to analyse and verify effectively the net to investigate several behavioural properties. Howover, most of these works lack from modularity and they can not allow compact and concise modeling when translating complex construct of BPEL processes.

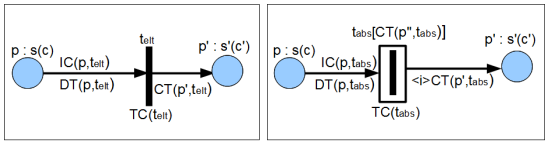
Since RECATNets are a kind of high level algebraic Petri nets combining the expressive power of

Kheldoun A. and Ioualalen M..
Transformation BPEL Processes to RECATNet for Analysing Web Services Compositions.
DOI: 10.5220/0004728004250430
In *Proceedings of the 2nd International Conference on Model-Driven Engineering and Software Development* (MODELSWARD-2014), pages 425-430
ISBN: 978-989-758-007-9

abstract data types and Recursive Petri nets, we claim that using our model based RECATNet to model the BPEL process and its different message types is more natural. The major advatages of the proposed modal is (1) it can model the control flow and data flow in BPEL process; (2) it can model communication, concurrency and synchronisation among processes. These two requirements must be fulffiled by a formal model in order to analyse and verify BPEL processes.

3 RECURSIVE ECATNet REVIEW

Recursive ECATNets (abbreviated RECATNets) (Barkaoui and Hicheur, 2007) are a kind of high level algebraic Petri nets combining the expressive power of abstract data types and Recursive Petri nets (Haddad and Poitrenaud, 2007). Each place in such a net is associated to a sort (i.e. a data type of the underlying algebraic specification associated to this net). The marking of a place is a multiset of algebraic terms (without variables) of the same sort of this place. Moreover, transitions in RECATNet are partitioned into two types (Fig.1): elementary and abstract transitions. Each abstract transition is associated to a starting marking represented graphically in a frame. A capacity associated to a place p specifies the number of algebraic terms which can be contained in this place for each element of the sort associated to p.



(a) Elementary transition (b) Abstract transition

Figure 1: Transition types in RECATNets.

As shown in Fig.1, the places p and p' are respectively associated to the sorts s and s' and to the capacity c and c'. An arc from an input place p to a transition$t$ (elementary or abstract) is labelled by two algebraic expressions $IC(p,t)$ (Input Condition) and $DT(p,t)$ (Destroyed Tokens). The expression $IC(p,t)$ specifies the partial condition on the marking of the place p for the enabling of t (see Table.1).

The expression $DT(p,t)$ specifies the multiset of terms to be removed from the marking of place p when t is fired. Also, each transition t may be labelled by a Boolean expression $TC(t)$ which specifies an additional enabling condition on the values taken by contextual variables of t (i.e. local variables of the expressions IC and DT labelling all the input arcs of t). When the condition $TC(t)$ is omitted, the default value is the term $True$. For an elementary transition t, an output arc (t,p') connecting this transition t to a place p' is labelled by the expression $CT(t,p')$ *(Created Tokens)*. However, for an abstract transition t, an output arc (t,p') is labelled by the expression $ICT(t,p',i)$ *(Indexed Created Tokens)*. These two algebraic expressions specify the multiset of terms to produce in the output place p' when the transition t is fired. In the graphical representation of RECATNets, we note the capacity of a place regarding an element of its sort only if this number is finite. If $IC(p,t) =_{def} DT(p,t)$ on input arc (p,t) (e.g. $IC(p,t) = a^+$ and $DT(p,t) = a$), the expression $DT(p,t)$ is omitted on this arc. In what follows, we note $Spec = (S,E)$ an algebraic specification of an abstract data type associated to a RECATNet, where Σ=(S, OP) is its multi-sort signature (S is a finite set of sort symbols and OP is a finite set operations, such $OP \bigcap S = \phi$). E is the set of equations associated to $Spec$. $X = (X_s)_{s\in S}$ is a set of disjoint variables associated to $Spec$ where $OP \bigcap X = \phi$ and X_s is the set of variables of sort s. We denote by $T_{\Sigma,s}(X)$ the set of S-sorted S-terms with variables in the set X.$[T_\Sigma(X)]_\oplus$ denotes the set of the multisets of the Σ-terms $T_\Sigma(X)$ where the multiset union operator ($\oplus$) is associative, commutative and admits the empty multiset ϕ as the identity element. For a transition t, $X(t)$ denotes the set of the variables of the context of this transition and $Assign(t)$ denotes the set of all the possible affectations of this variables set, i.e.$Assign(t) = \{sub : X(t) \to T_\Sigma(\phi) \mid x_i \in X(t)$ of sort s, $sub(x_i) \in T_{\Sigma,s}(\phi)\}$.

Table 1: Different forms of Input Condition $IC(p,t)$.

$IC(p,t)$	Enabling Condition
a^0	The marking of the place p must be equal to a. (e.g. $IC(p,t) = \phi^0$ means the marking of p must empty)
a^+	The marking of the place p must include a (e.g. $IC(p,t) = \phi^+$ means condition is always satisfied)
a^-	The marking of the place p must not include a, with $a \neq \phi$
$\alpha1 \wedge \alpha2$	Conditions $\alpha1$ and $\alpha2$ are both true
$\alpha1 \vee \alpha2$	$\alpha1$ or $\alpha2$ is true

Definition 1. *A recursive ECATNet is a tuple:* $RECATNet = (Spec, P, T, sort, Cap, IC, DT, CT, TC, I, \Upsilon, ICT)$ *where:*

- $Spec = (\Sigma, E)$ *is a many sorted algebra where the sorts domains are finite (with* $\Sigma = (S, OP)$ *), and* $X = (X_s)_{s\in S}$ *is a set of S-sorted variables*
- P *is a finite set of places.*

- $T = T_{elt} \bigcup T_{abs}$ *is finite set of transitions* ($T \bigcap P = \phi$) *partitioned into abstract and elementary ones.* T_{abs} *and* T_{elt} *denoted the set of abstract and elementary transitions.*
- *sort:* $P \rightarrow S$, *is a mapping called a sort assignment.*
- *Cap: is a P-vector on capacity places:* $p \in P$, *Cap(p):* $T_\Sigma(\phi) \rightarrow N \bigcup \{\infty\}$,
- $IC : PxT \rightarrow [T_\Sigma(X)]^*_\oplus$ *where* $[T_\Sigma(X)]^*_\oplus = \{\alpha^+\} \bigcup \{\alpha^-\} \bigcup \{\alpha^0\}$, *such that* $\alpha \in [T_{\Sigma,sort(p)}(X)]_\oplus$
- $DT : PxT \rightarrow [T_\Sigma(X)]_\oplus$, *such that* $DT(p,t) \in [T_{\Sigma,sort(p)}(X)]_\oplus$,
- $CT : PxT \rightarrow [T_\Sigma(X)]_\oplus$, *such that* $DT(p,t) \in [T_{\Sigma,sort(p)}(X)]_\oplus$,
- $TC : T \rightarrow [T_{\Sigma,bool}(X)]$,
- *I is a finite set of indices, called termination indices,*
- Υ *is a family, indexed by I, of effective representation of semi-linear sets of final markings,*
- $ICT : PxT_{abs}xI \rightarrow [T_\Sigma(X)]_\oplus$, *where* $ICT(p,t,i) \in [T_{\Sigma,sort(p)}(X)]_\oplus$.

Informally, a RECATNet generates during its execution a dynamical tree of marked threads called an extended marking, which reflects the global state of such net. This latter denotes the fatherhood relation between the generated threads (describing the inter-threads calls). Each of these threads has its own execution context. (Barkaoui and Hicheur, 2007) presents more details about RECATNet such firing transitions and generating extended reachability graph.

4 TRANSFORMATION OF BPEL TO RECATNet

The aim of this section is to provide translations from BPEL business processes to RECATNet. We present the semantic representation of BPEL basic and structured activities by RECATNet. The basic idea behind using RECATNets is to allow modeler to construct a large model by using a number of small RECATNets which are related to each other in a well-defined way. The idea behind abstract transition is to allow user to relate a transition to a more complex RECATNet called a subactivity. This subactivity gives more detailes descritpion of the activity represented by the abstract transition.

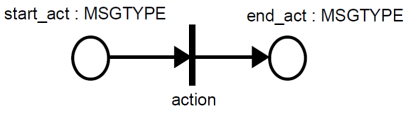


Figure 2: RECATNet construct of basic activities.

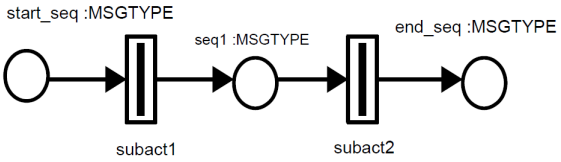


Figure 3: RECATNet construct of Sequence activity.

4.1 Basic Activities Transformation

Basic activities are those which describe atomic steps of a process behaviour like *Receive*, *Invoke*, *Reply*,...etc.

Due to the abstraction from data and message exchanges, all basic activities share the general model shown in Fig.2. Place *start_act* models when the basic activity is ready to start. Place *end_act* indicates that the activity has finished its execution. The transition labelled *action* models the action to be performed.

4.2 Structured Activities Transformation

In order to enable the presentation of complex structures in BPEL, the following structured activities are translated: *sequence*, for defining an execution order; *switch*, for choice routing; *while*, for looping; and *flow* for parallel routing.

4.2.1 Sequence Structure

The sequence construct of BPEL contains one or more activities that are performed sequentially. The RECATNet construct of sequence structure is shown in Fig.3.

Note that each subactivity is modelled by an abstract transition. In fact, firing an abstract transition means that the associate subactivity is invoked. This allows our model be hierarchical and modular and is very clear to understand.

4.2.2 Switch Structure

The switch construct of BPEL supports conditional behaviour. Its RECATNet construct is shown in Fig.4.

Note that all the abstract transitions modelled subactivities are in conflict. The first abstract transition

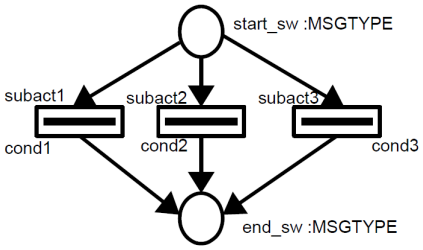


Figure 4: RECATNet construct of Switch activity.

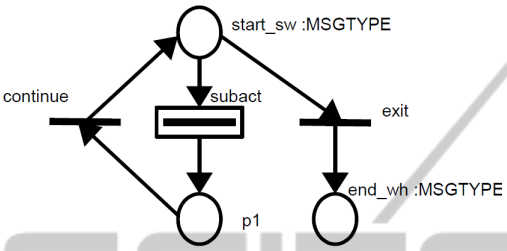


Figure 5: RECATNet construct of While activity.

whose condition holds true is taken and provides the activity performed for the switch. The switch activity is complete when the subactivity of the enabled abstract transition completes.

4.2.3 While Structure

The while construct of BPEL supports repeated performance of a specified iterative activity. Its RECATNet construct is shown in Fig.5. The transition *exit* and *continue* represents empty activities. The abstract transition labelled *subact* models the subactivity to be performed iteratively.

4.2.4 Flow Structure

The flow construct of BPEL allows to specify one or more activities to be performed concurrently. A flow completes when all of the activities in the flow have completed. The RECATNet construct of flow structure is shown in Fig.6. Note that the activity modelled by the abstract transition labelled *subact*3 cannot perform before the activity *subact*2 completes due to control link between them.

5 CASE STUDY

The following example shows how the structure of a BPEL process model is mapped onto a RECATNet. The example is taken from (A. Alves and al., 2007).

In the following example, five basic activities are defined: *getBuyerInfo*, *getSellerInfo*, *settleTrade*, *confirmBuyer* and *confirmSeller*.

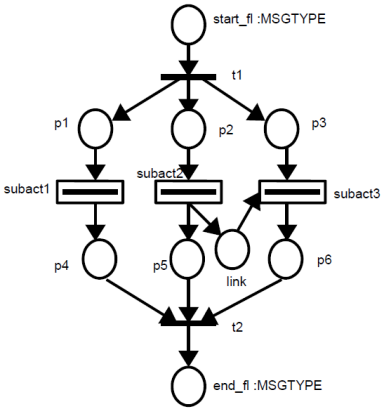


Figure 6: RECATNet construct of Flow activity.

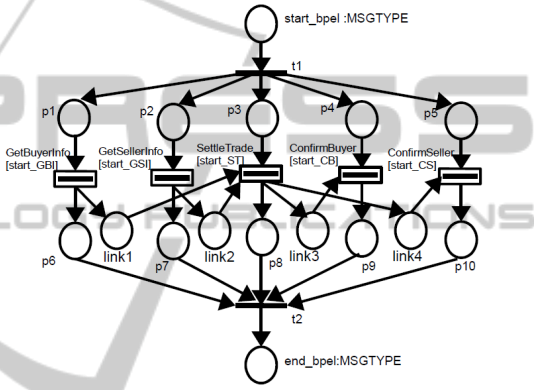


Figure 7: RECATNet construct of the example.

The activities *getBuyerInfo* and *getSellerInfo* can run concurrently. The *settleTrade* activity is not performed before both these activities are completed. After *settleTrade* completes, the two activities *confirmBuyer* and *confirmSeller* are performed concurrently again.

The RECATNet model for this example is shown in Fig.7.

Fig.8 shows a set of simplified RECATNet constructs model the above five activities.

Since our model is modular and hierarchical, it simplifies for designers to add/remove activities in a flexible way.

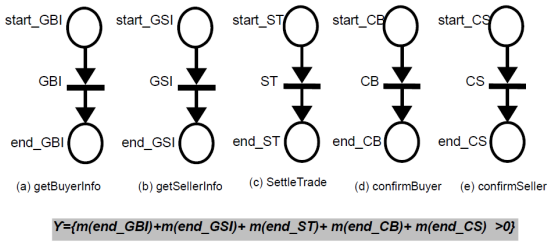


Figure 8: RECATNet construct of basic activities of the example.

6 ANALYSIS METHOD

In order to analyse the soundness and compositionality of services in BPEL, we propose to express the semantic of RECATNet in terms of rewriting logic (Bruni and Meseguer, 2006), the input of model-checker MAUDE.

6.1 RECATNet Semantics in Terms of Rewriting Logic

Since we choose to express the RECATNet semantics in terms of rewriting logic, we define each RECATNet as a conditional theory, where transitions firing and cut step execution are formally expressed by labelled rewrites rules. Each extended marking Tr is expressed, in a recursive way, as a term $[MTh, tabs, ThreadChilds]$, where MTh represents the internal marking of Th, $tabs$ represents the name of the abstract transition whose firing (in its thread father) gave birth to the thread Th. Note that the root thread is not generated by any abstract transition, so the abstract transition which gave birth to it is represented by the constant *nullTrans*. The term $ThreadChilds$ represents a finite multiset of threads generated by the firing of abstract transitions in the thread Th. We denote by the constant *nullThread*, the empty thread.

Consequently, an extended marking Tr is expressed as a general term of sort $Thread$ with the following recursive form: $[MTh_0, nullTrans, [MTh_1, tabs_1, [MTh_{11}, tabs_{11}, ...] ...[MTh_{1n}, tabs_{1n}, ...]]...[MTh_n, tabs_n, [MTh_{n1}, tabs_{n1}, ...]...[MTh_{nn}, tabs_{nn}, ...]]]$ where MTh_0 is the marking of the root thread. In fact, the state space of RECATNet is formalized by the following equational theories.

```
fmod PLACE-MARKING is
sorts Place Multiset Place-marking.
op ems : -> Multiset .
----- The constant implementing the empty
˜marking ems
op _(+)_ : Multiset Multiset -> Multiset
˜[assoc comm id: ems].
op <_;_>: Place Multiset-> Place-marking.
endfm

fmod MARKING is
including PLACE-MARKING .
sort Marking .
subsort Place-marking < Marking .
op em : -> Marking .
----- The constant implementing the empty
marking em
op _(*)_ : Marking Marking -> Marking
[assoc comm id: em] .
endfm

fmod THREAD is
including MARKING .
sorts Thread Trans TransAbs.
subsort TransAbs < Trans.
op nullTrans : -> TransAbs.
op nullThread : -> Thread.
op [_,_,_]:Marking TransAbs Thread->Thread.
op _ _ : Thread Thread -> Thread
[assoc comm id: nullThread] .
endfm
```

Each firing step in a RECATNet is expressed by a rewrite rule of the form $Th => Th' \; if \; C$ which means that a fragment of the RECATNet state fitting pattern Th can change to a new local state fitting pattern Th' if the condition C holds. We give the general form of the rewrite rules describing the behaviour of RECATNets firing steps:

```
---Elementary rules
crl[telt] : <p, mp (+) DT(p, telt)> (*)
<p', mp'> =>  <p, mp> (*)
<p', mp'(+)CT(p',telt)> if (InputCond
and TC(telt) and
 Nbr(mp'(+)CT(p',telt) < Cap(p'))) .
---Abstract rules
crl[tabs] : [M (*)<p, mp (+) DT(p, tabs)>,
T, Th] => [M (*)<p, mp> , T, Th
[<p'', CT(p'',tabs) >, tabs, nullThread]]
if  (InputCond and TC(tabs)) .
---A cut step occuring in a Thread
crl[cut] : <Mf (*) <p', mp'> , T,
mThf [M (*)<pfinal, mpfinal>, tabs, mTh]>
 => [Mf (*)<p', mp' (+) ICT(p', tabs, i),
    T, mThf>]
if  ( ϒ_i   and Nbr(mp'(+)
ICT(p',tabs,i) < Cap(p')) .
```

For instance, if we consider the RECATNet of Fig.7, the rewrite rule describing the elementary transition labelled $t1$ is given as follows:

```
rl[t1] : < start-bpel; token> (*) M =>
[ M (*)<p1 ; token>(*) <p2 ;token>(*)
<p3 ; token>(*)<p4 ; token>(*)<p5 ; token>.
```

Another example, the rewrite rule describing the abstract transition labelled $getBuyerInfo$ is given as follows:

```
rl[getBuyerInfo]: [ M(*) < p1; token >, T,
   Th] => [ M, T, Th [<start-GBI; token>,
   geBuyerInfo, nullThread ]].
```

Figure 9: Execution of the example under Maude environment.

Figure 10: Checking the proper termination property using MAUDE LTL model-checker.

6.2 Implementation using the Maude System

In the framework of this work, we use as platform, the version 2.6 of the Maude system under Windows. One of the main commands of Maude system is *rewrite*. This command rewrites a given expression until no more rules can be applied. An execution for the example is shown in Fig.9.
An important property will be checked called proper termination. This property means that starting from an initial state, every possible execution path properly terminates (evetually). This property is expressed in LTL (Linear Temporal Logic) by the formula : $F\,finalState$ where $finalState$ is a proposition represents the set of final states of the modelled system. The temporal oerator F (Futur) is denoted by $<>$ in MAUDE notation. In Fig.10, we check the validity of this property by applying the LTL model-checker of MAUDE.

7 CONCLUSIONS

In this paper, we present an approach to formalize and analyse BPEL processes based on RECATNet. We present the transformation rules from BPEL business processes to RECATNet. In order to analyse the result model, we define the RECATNets semantics in term of conditional rewriting logic the input of the model-checker Maude (Clavel and al., 2007).

For further research, we will provide more translation rules from BPEL to RECATNet such as scopes, fault handlers and possibly correlations. Also, we plan to finish our tool under construction in order to automate the translation from BPEL to RECATNet.

REFERENCES

A. Alves, A. Arkin, S. A. and al. (April 2007). Web services business process execution language. In *TEMPLATE'06, 1st International Conference on Template Production*. Version 2.0.

Barkaoui, K. and Hicheur, A. (2007). Towards analysis of flexible and collaborative workflow using recursive ecatnets. In *pp.206-217, LNCS 4928 (26-28 2007). Springer Berlin/Heidelberg, Benatallah, B., ter Hofstede, A., Paik, H*. In CBP 2007.

Bruni, R. and Meseguer, J. (2006). Semantic foundations for generalized rewrite theories. In *Theor. Comput. Sci*. 360(1), pp.386-414.

Clavel, M. and al. (2007). Maude manual (version 2.3). In *SRI International and University of Illinois at Urbana-Champaign*. Available at http://maude.cs.uiuc.edu.

Haddad, S. and Poitrenaud, D. (December 2007). Recursive petri nets. theory and application to discrete event systems. In *Acta Informatica*. pp.44-78.

S. Hinz, K. S. and Stahl, C. (Sep 6-9 2005). Transforming bpel to petri nets. In *3rd International Conference on Business Process Management (BPM'05)*. pages 220-235, Nancy, France, Springer-Verlag.

Verbeek, H. M. W. and van der Aalst, W. M. P. (2000). Woflan 2.0: A petri-net-based workflow diagnosis tool. In *21st International Conference of Application and Theory of Petri Nets (ICATPN 2000)*. pages 475-484.

Verbeek, H. M. W. and van der Aalst, W. M. P. (2005). Analyzing bpel processes using petri nets. In *2nd International Workshop on Applications of Petri Nets to Coordination,Workflow and Business Process Management*. pages 59-78.

Y. Yang, Q. Tan, Y. X. F. L. and Yu, J. (2006). Transform bpel workflow into hierarchical cp-nets to make tool support for verification. In *8th Asia-Pacific Web Conference*. pages 275-284.