Workflow Modeling for Virtual Enterprise: 
a Petri Net Based Process-View Approach

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Abstract

At present, the research of workflow modeling has been extended to the context of virtual enterprise in order to realize business process integration among member enterprises. Petri net and its extensions are classic modeling methods in workflow modeling, while the process-view is a promising approach used in workflow composition. This paper proposes a novel Petri net based process-view method to model workflow for virtual enterprise and concentrates on the mapping from the Petri net based base workflow model to its corresponding process-views, which incorporates the coordination of control flow and data flow. During the mapping process, abstract place and logical transition are proposed and added in order to abstract information from the base workflow model and also to ensure that the process-views are complete Petri net workflow models. At last, an integrated workflow model can be obtained by integrating the process-views, which is the interface to realize cross-organizational business process integration.

Keywords: Virtual Enterprise, Workflow Modeling, Process-View, Petri Net, Business Process Integration.

1. Introduction

In the increasingly intensive competition environment, enterprises have to enhance their collaboration ability in order to survive, so a new collaborative alliance is forming, namely virtual enterprise (VE). The core idea of VE is that each member enterprise exerts its core competency and cooperates with other enterprises efficiently to make the whole alliance competent. Therefore, the integration of cross-organizational business process is one of the key points of VE.

Workflow is the automation of business process (WFMC, 1998), and the automation of workflow is realized through workflow management system (WMS). The WMS is always a focus for research and development in the wave of enterprise informationization. Up to now, WMS applied within an organization or enterprise is relatively mature. In contrast to this, integration of cross-organizational business process is a new but attractive research topic. Each member enterprise in VE is an independent economic entity and has its own WMS. For safety, they must hide some details of their internal business processes when participating in the integrated process. At the same time, it is critical to provide various participants with adequate process information for the effective management of workflow [1]. The most promising way is to realize the integration of cross-organizational business process without changing the existing private processes [2].

Motivated by the notion of views in databases, process-view is proposed to support the integration of cross-organizational business process. A process-view is an abstract process derived from an implemented base process [1]. In the process-view approach, a company can realize the business process integration with various partners using different process-views derived from the same base process, which is very suitable for workflow modeling within a VE. Petri net and its extensions are powerful modeling methods which are used extensively in workflow modeling. Strong mathematical foundation and availability of a wide range of supporting tools have made Petri nets popular among academic researchers [3]. This paper proposes a novel Petri net based process-view approach to model workflow for VE.

The remainder of this paper is organized as follows. Section 2 states background and related works. Section 3 describes workflow model based on Petri net. Section 4 details the mapping process from base workflow model to its corresponding process-views. Section 5 presents how to apply the Petri net based process-view approach to VE. We conclude the paper with discussions of the benefits of our approach and works in the future.

2. Background and related works

VE is a hot research area owing to the rapid progress of Internet and communication technology in recent years. Weixuan Xu et al. [4] exposed systematically the concept of VE and methodology for its intelligentized management. Jyhjong Lin and Tsui-e Lin [5] proposed an object-oriented modeling approach that addresses the management of collaboration on the Internet between
enterprises. H.T. Goranson [6] described the new agenda, the key technical challenges and the concurrent required innovations in business practice. The ECOLEAD project [7] [8] aimed to create strong foundations and mechanisms needed to establish the most advanced collaborative and network-based industry society in Europe.

Workflow modeling for VE is an important research topic. Many researchers are trying to find a suitable way for workflow modeling, and Petri nets based methods have been used. WfMC has developed specifications to enable interoperability between heterogeneous workflow systems. W.M.P. van der Aalst [9] reviewed new and existing architectures to enable interorganizational workflow and verified the correctness of the interorganizational workflow. Khodakaram Salimifard et al. [3] gave a summarization about Petri nets based modeling of workflow systems. Dongsheng Liu et al. [10] adopted colored Petri nets to model workflow processes for VE, and proposed an extension workflow-net based on colored Petri nets (WFCP-net), an expanding suite of tools were also developed. Song Huang et al. [11] proposed a timed colored Petri nets based approach to model distributed manufacturing processes and interaction relations among them, and established a workflow based manufacturing process execution environment.

On the other hand, process-view based workflow modeling has also obtained more and more attention. Duen-Ren Liu et al. [1] [12] proposed an order-preserving process-view approach to model workflow for virtual processes, and established a method to map the base process to its process-views. Karsten A. Schulz et al. [13] proposed a workflow view approach to facilitate cross-organizational workflow, and discussed particularly on state dependency between the base process and its workflow views. Dickson K.W. Chiu et al. [2] [14] discussed workflow view driven cross-organizational interoperability in a Web Service environment, and formulated an interoperation model of workflow views and its consistency criteria.

However, few works concerned with the synthesization of the Petri net and the process-view workflow modeling methods, so we concentrate on the mapping from the Petri net based base workflow model to its process-views which incorporates the coordination of control flow and data flow, and an integrated workflow model can be obtained by integrating the process-views as the interface to realize cross-organizational business process integration.

3. Workflow model based on Petri net

Petri net and its extensions are graphic symbol-based modeling method which can be systematically analyzed by simulation, meanwhile there exists much mathematical theory foundation making Petri net with its extensions popular among researchers.

This paper utilizes the basic Petri net (PN) to model workflow. A basic Petri net is a bipartite graph with two nodes P (places) and T (transitions), which are connected via directed F (arcs). In graphic representation, places are represented as circles, transitions as rectangles or bars, and arcs as directed arrows. Places can hold tokens represented as dots in circles, and the distribution of tokens is called a marking which represents a system state.

Definition 1 A basic Petri net can be defined as a 5-tuple PN = (P, T, F, W, M0), where P is a finite set of places, T is a finite set of transitions, P ∩ T = ∅ and P ∪ T ≠ ∅. F ∈ (P × T) ∪ (T × P) is a finite set of directed arcs, W is the weight function on arcs, W → {0,1,2,...}, M0 is an initial marking.

A PN workflow model is activity-based. Generally, activities and their dependencies are used to describe a process. Dependencies describe the ordering relationships between activities within a process [1]. In a PN workflow model, the state of a system is represented by the markings, the condition is illustrated by place and the activity is illustrated by transition. The execution of an activity can change the state from M to M'.

Figure 1 describes the workflow models of enterprise A and enterprise B in a VE. Figure 1.(a) represents the design-manufacture process of a product in enterprise A, this product makes up of three parts, part1 and part2 are manufactured within enterprise A, and part3 is outsourcing from its partner enterprise B. Figure 1.(b) represents the design-manufacture process of the part3 in enterprise B.

4. Mapping a workflow model based on Petri net to its process-views

4.1. Workflow model based on Process-view approach in VE

A process-view is an external accessible subset of a workflow model [2], and a workflow model may have different process-views due to different requirements of various partner enterprises. In fact, member enterprises possess different needs and levels of authority to get information from workflow models [1]. In order to keep privacy and to realize collaboration between member enterprises, process-views can selectively hide certain details from workflow models and also abstract some activities from workflow models.

Definition 2 A process-view based on basic Petri net can be also defined as a 5-tuple PV = (P', T', F, W, M0), where

1. P' = (BP, AP) is a finite set of places, BP are base places which are the same as places in PN, AP are abstract places which used to hide details from PN.
2. T'=(BT, LT) is a finite set of transitions, BT are base transitions which are the same as transitions in PN, LT are logical transitions which only used as logical control, and P ∩ T = φ, P ∪ T ≠ φ.

3. The definitions of F, W and M₀ are the same as the ones in PN.

Definition 3 An abstract place is a sub-model of the base workflow model. A sub-model is a part of the base workflow model. The definition of the sub-model is the same as PN.

Figure 3 describes an abstract place (P2, P3, T2) described by the rectangle. Adopting abstract places to hide details is inspired by object-oriented Petri nets (OOPN).

Definition 4 A logical transition does not represent a real activity, and is just used as logic control. It doesn’t consume and produce tokens.

Due to the abstract places may damage the integrality of a process-view as a PN workflow model, the logical transition is proposed to ensure the process-view is a complete PN workflow model, and keep consistent of the control flow and data flow between the base workflow model and its process-views.

As to the workflow model of enterprise A described in figure 1.(a), enterprise B can get a process-view from enterprise A based on the cooperative contracts established by enterprises A and B. The contracts may be in the form of Sequence Diagram of UML. Figure 2.(a) describes the process-view provided by enterprise A to B, meanwhile enterprise A can get a process-view from B described in figure 2.(b). In figure 2, base places (transitions) are illustrated by real line, abstract places and logical transitions are illustrated by dashed line. In figure 2.(a), abstract place Part12 is used to hide the manufacturing processes of part1 and part2. In figure 2.(b), abstract place Part312 is used to hide the manufacturing processes of part31 and part32.

4.2. Control flow in the mapping process

Control flow is the ordering relationships between activities. In WfMC specification [15], there are six ordering structures in business process, which are Sequence, And-Split, Or-Split, And-Join, Or-Join and Loop. In a PN workflow model, a transition only has one subsequent transition is Sequence, a transition with two or more output/input places is And-Split/And-Join, a place with two or more output/input transitions is Or-Split/Or-Join, while Loop corresponds the repeated execution of a
set of transitions and places. Figure 4 represents And-Split, Or-Split, And-Join and Or-Join ordering structures by PN.

![Figure 4. Four ordering structures modeled by PN](image)

In order to describe the interoperation relationship in obtaining the integrated workflow model by integrating the process-views, two kinds of interoperable relationships of Nested and Synchronized (WfMC, 1996) are modeled in process-view approach illustrated in figure 5. In this figure, places may be the base places or abstract places, and transitions may be the base transitions or logical transitions.

![Figure 5. The interoperable models in process-view approach](image)

**4.3. Data flow in the mapping process**

Data flow is an essential part of workflow execution in conjunction with control flow [16]. The data flow of a base workflow model is not the same as the data flow of process-views derived from the base workflow model, since a process-view hides information from the base workflow model.

We use abstract places to abstract data flow. It divides the data flow into three categories (internal common, internal privacy and external data flow). Internal common data flow (ICD) is internal data flow which can be accessible to outside. Internal privacy data flow (IPD) is internal data flow which must be hidden to outside. External data flow (ED) is data flow which can be passed between partner enterprises.

Figure 6 shows the abstracting process of data flow from the base workflow model to its process-view. In the base workflow model illustrated in figure 6.(a), data flow A and C are internal privacy data flow represented by real thick line, data flow B and E are internal common data flow represented by thin dashed and data flow D is external data flow represented by thick dashed. Place P6 is an interface to link to external workflow model. In the process-view illustrated in figure 6. (c), the abstract place P134 replaces sub-workflow model \{P1, T1, P3, T2, P4\}, data flow A and C are hidden by P134. Logical transitions T4 and T5 are added in order to ensure the process-view is a complete PN workflow model.

![Figure 6. (a) The base workflow model; (b) The middle model; (c) The process-view](image)

**4.4. Obtaining the integrated model by integrating the process-views**

After getting the process-views between A and B, the integrated workflow model can be obtained by integrating the process-views described in figure 2.(c). In this model, the two process-views are integrated into a workflow model. Like the figure 2.(c), the outsourcing transition in workflow model of enterprise A is replaced by the process-view provided by enterprise B to A. The integrated workflow model is the interoperation interface between enterprise A and B, its implementation can realize the workflow composition in VE.

**5. Applying the process-view approach based on Petri net to VE**

VE is a high dynamic enterprises alliance, and member enterprises can join or leave the VE frequently depending on the commerce opportunity. The process-view approach based on Petri net is a promising workflow modeling method for VE. In process-view approach, the member enterprises can quickly realize the workflow composition without changing their own base workflow model, while this approach can save cost for enterprises and make the VE competent in dynamic competition environment.

Figure 7 illustrates the collaboration among member enterprises in a VE, which adopts the process-view approach based on Petri net in the process of workflow
composition. The VE has three member enterprises A, B and C.

Figure 7. The collaboration of member enterprises in process-view approach

The steps of applying the process-view approach to VE are:

**Step 1** Finish the workflow modeling based on PN in each enterprise.

**Step 2** Establish the cooperation relationship among member enterprises by subscribing the collaboration contracts.

In a VE, the collaborative relationship among member enterprises can be treated as service consumer and service provider. The contracts define all details of service provision including the identification of the service and all parameters required to execute the service [17]. The Sequence Diagram of UML is one of the forms to describe the contracts.

**Step 3** Map the base PN workflow model to its process-views according to the contracts, which incorporates the control flow and data flow.

**Step 4** Obtain the integrated model by integrating the process-views.

Member enterprises can interact with others through the integrated models after finishing these steps.

### 6. Conclusion and future works

In this paper, we propose a novel Petri net based process-view approach to model workflow for VE. This approach synthesizes the merits of Petri net and process-view. The main focus concerned is the mapping from a base Petri net based workflow model to its process-views, which incorporates the control flow and data flow coordination, and an integrated workflow model can be obtained by integrating the process-views as the interface to realize cross-organizational business process integration. Abstract place and logical transition are used in the mapping process. In this approach, the base workflow models in enterprises need not to change when integrating with the workflow models in other enterprises which is a promising way in workflow modeling for VE.

There are still some works need to be done in the future, such as to further complete the modeling approach, to design the algorithm of automating the mapping process and to develop a suitable workflow management system.

### Acknowledgement

This research has been supported by the National Basic Research Program (973 Program) of China under grant No. 2004CB719405. The authors would like to acknowledge the valuable comments given by Dr. Peigen Li and Chi Zhou.

### References


