19 WORKFLOW HISTORY MANAGEMENT IN VIRTUAL HEALTHCARE ENTERPRISE

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There are various applications of workflow history information maintained by Workflow Management System in the organizations. Most of such applications are also relevant and required in the context of a Virtual Enterprise. To make these applications of workflow history information feasible, sharing of geographically distributed history information among participating organizations of a virtual enterprise is vital. Such sharing requires a common systematic way of identification of history information. As a part of development of research project HISFlow, we develop a simple and generic scheme to identify history information of workflows across a Virtual Healthcare Enterprise. This scheme provides a robust foundation for more sophisticated Workflow History Management of a Virtual Enterprise. The scheme also caters the concept of partial view of a virtual process i.e. a view of virtual process seen by a participating organization. We use an example to demonstrate the working of the scheme for the identification of workflow history information.

1. INTRODUCTION

An integrated health care service built upon partnerships, alliances, and relationships with physicians, polyclinics, laboratories, pharmacies, hospitals and payers is emerging as the operating model for health care organizations (Horsch, 1999). The concept of a Virtual Enterprise is the solution to establish such integrated health care. As defined in the literature, virtual enterprise is a consortium of autonomous, diverse, geographically dispersed organizations that accumulates resources to achieve common objectives efficiently. The interaction of processes of the participating organizations is essential to build such a Virtual Healthcare Enterprise.

Workflow Management System has been widely conceived as principal supporting technology for automation of business processes and interaction with other organizations. Consequently, it provides a basic framework for the Virtual Enterprise paradigm. As mentioned in (Amin, 2002), such a framework is a set of WfMSs that are collaborating in a loosely coupled way to achieve automation of business processes of the Virtual Healthcare Enterprises. As the workflow technology is approaching first level of maturity, new strengths of it have been discovered. One of them is exploitation of history of workflow processes for various different purposes.

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The rest of this section presents background and the problem to be solved in the paper. Section 2 elaborates the identification scheme for history information and also proposes two models to conceptualize the history information space. The Section 3 presents an example to demonstrate the working of proposed scheme. Section 4 talks about different workflow history applications and their relevance to a Virtual Enterprise. Conclusion is given in the Section 5.

1.1 Background

From WFMS viewpoint (Amin, 2002), a Virtual Enterprise is defined as an enterprise whose processes are virtual in the sense that they consist of geographically distributed processes. In other words, a Virtual Process is a set of processes that are connected with each other to fulfill a bigger goal of the Virtual Enterprise. Each of such processes runs on different autonomous WfMSs of respective organizations. As these processes are executed locally, the history information of the processes is stored in and maintained by the respective WfMSs. Such history information of the local process is only accessible to local WfMS and hence it can only be used by the respective organization. As the local process is part of the virtual process, related portion of the history of the process should also be shared with relevant organizations. Such sharing of history of local processes with the other participating organizations produce three complex problems. Firstly, we need a systematic mechanism to let the organization identify interested history information residing on other organizations. (Tagg, 2001) also raises the same problem and names it the workflow case identifier problem. Secondly, not all the history information is meant to be shared with or accessed by other organizations and this accessibility varies from organization to organization. So we need a way to abstract history information for sake of sharing. Thirdly, we need to have an application level communication protocol for WfMSs to communicate history information among the participating organizations. In this paper we only discuss first problem.

1.2 Problem Statement

A Workflow Management System of a participating organization handles its own process instances and instance related data autonomously. Hence every WfMS has its own identification of its workflow history information. Such identification is only valid inside the organization. But for different applications of history information, one organization has to refer to the workflow history information of peer organizations. Therefore, to let the organization identify workflow history information of a peer organization is the problem that has to be solved for making use of workflow history information of a Virtual Enterprise.

To further explain the problem, suppose two clinical processes X and Y are part of one Virtual Process but running on different hospitals. In the definition of X, we want to have a workflow branching condition based on the history of instances of Y. We have to put this as an expression in the definition of X so that when an instance of X is running, this expression is resolved to get the data of required instances of Y.

Such expressions require two things: identification of workflow history information and some operators. The operators are beyond the scope of this paper. We only propose the identification scheme. This scheme would provide a base not only for such expressions, but also for different kinds of analysis and monitoring.

2. STRUCTURE OF HISTORY INFORMATION

2.1 Instance Identification Scheme

Both Workflow Relevant Data and Workflow Internal Data are tied to the process instances. Once the process instance is identified, all the information attached to it can be obtained. So the first step of identification of history information is identification of process instances. Taking this observation into consideration, we define a process instance the first basic unit of workflow history information of a Virtual Enterprise. In this paper, we only propose the identification scheme of process instances across the organizations. This scheme needs to be further enhanced to have workable identification of workflow history information.

There are two levels of identification scheme: definition level and instance level. Definition level identification involves only process definitions of participating organizations. It is a step towards achieving instance level identification which involves process instances of the participating organizations. The approach of instance level identification scheme is based on the fact that a virtual process instance is a logical container that contains process instances of participating organizations. Being participants of such a logical container, process instances belonging to different organizations have same context. This same context along with definition level identification provides necessary information to identify the process instances of the peer organizations. In the following part of the paper, we develop this identification scheme by using Set theory and mathematical notations.

The participating organizations of the given Virtual Enterprise VE can be presented as

$O(VE) = \{o_1, o_2, o_3, ...o_i\}$ Where $o_1, o_2, o_3, ...o_i$ stand for the identification of organizations. And i is the total number of organizations in the Virtual Enterprise

Definition: Following the modeling approach of (Amin, 2002), Virtual Process is defined by two things: participating process definitions and peer to peer link among them. Hence, Definition of Virtual Process VP can be represented as

$VP = \{P(VP), \|(VP)\}$ Where $P(VP)$ means all the process definitions participating in Virtual Process Definition VP and $\|(VP)$ means all the peer to peer relations of the participating process definitions of VP.

All the process definitions belonging to organization O_1 are represented as

$P(O_1) = \{p_1, p_2, p_3, \ldots\ldots p_{k_1}\}$ Where $p_1, p_2, p_3, \ldots\ldots p_{k_1}$ are identifiers of process definitions of organization O_1 which are unique within the organization. And k_1 is the total number of process definitions in organization O_1.

Please note that $P(O_1)$ should be read as P of O_1 meaning the processes of O_1.

Similarly for organization O_i, its process definitions can be represented as

$P(O_i) = \{p_1, p_2, p_3 \ldots\ldots p_{k_i}\}$ Where $p_1, p_2, p_3 \ldots\ldots p_{k_i}$ are identifiers of process definitions of organization O_i which are unique within the organization. And k_i is the total number of process definitions in organization O_i.

The participating organizations of Virtual Process Definition VP can be represented as

$O(VP) = \{o_1, o_2, o_3, \ldots\ldots o_j\}$ Where $O(VP) \subseteq O(VE)$ and j is the total number of organizations participating in Virtual Process Definition VP.

A process definition can uniquely and globally be identified with the combination of two identifiers: the locally unique process definition identifier and its organization identifier, provided the organization identifier is globally unique. For example process definition $p_{(a,b)}$ is globally unique, where 'a' stands for process definition identifier and 'b' stands for organization identifier. For sake of simplicity we assume that only one process definition of the organization participates in the Virtual Process Definition VP. In terms of globally unique identifiers, the participating process definitions in Virtual Process Definition VP can be represented as

$$P(VP) = \{p_{(m_1,o_1)}, p_{(m_2,o_2)}, p_{(m_3,o_3)}, \ldots\ldots\ldots p_{(m_j,o_j)}\}$$

Where $m_1, m_2, m_3, \ldots\ldots m_j \in P(O_1), P(O_2), P(O_3), \ldots\ldots\ldots P(O_j)$

respectively and $o_1, o_2, o_3, \ldots\ldots o_j \in O(VP)$

For nth Virtual Process Definition

$$P(VP_n) = \{p_{(m_j^n,o_j)}\} \quad \ldots\ldots\ldots\ldots\ldots \text{(A)}$$

We represent peer to peer relations of processes definition p_1 with other process definitions, say p_2 and p_3, as $p_1 \| (p_2, p_3)$.

Therefore all the peer to peer relations of $P(VP)$ in the Virtual Process Definition VP can be represented as

$$\|(VP) = \{p_{(m_1,o_1)} \| (p_{(r_1,q_1)}), p_{(m_2,o_2)} \| (p_{(r_2,q_2)}), \ldots\ldots p_{(m_j,o_j)} \| (p_{(r_j,q_j)})\} \ldots\ldots \text{(B)}$$

Where $q_j \subseteq O(VP)$ and $m_j \notin r_j$ and

$$(r_j, q_j) = \{(\Phi_1, \lambda_1), (\Phi_2, \lambda_2), (\Phi_3, \lambda_3), \ldots\ldots\ldots (\Phi_h, \lambda_h)\}$$

Where $h = card(q_j)$ and $\lambda_h \in q_j$ and $\Phi_h \in P(\lambda_h)$

and $\lambda_a \neq \lambda_b$ if $a = b$

After having expressions (A) and (B), we apply above identification scheme on the Partial View concept of (Amin, 2002).

Definition: As defined in (Amin, 2002), a Virtual Process Definition is a set of Partial Views seen by individual participating organizations.

$$VP = \{PV_1VP, PV_2VP, PV_3VP, \ldots\ldots\ldots PV_jVP\}$$

Where PV_1VP, PV_2VP, PV_3VP and PV_jVP are Partial Views of VP seen by the organizations o_1, o_2, o_3 and o_j respectively.

Definition: To an organization, Partial View of a Virtual Process Definition is a set of its local process definition and peer to peer relations with other participating process definitions of the same Virtual Process Definition.

Following above definition of Partial View, PV_1VP can be represented as

$$PV_1VP = \left\{\left(p_{(m_1,o_1)}\right), \left(p_{(m_1,o_1)} \middle\| p_{(r_1,q_1)}\right)\right\}$$

Similarly

$$PV_jVP = \left\{\left(p_{(m_j,o_j)}\right), \left(p_{(m_j,o_j)} \middle\| p_{(r_j,q_j)}\right)\right\}$$

For jth Partial View of nth VP

$$PV_jVP_n = \left\{\left(p_{(m_j^n,j)}\right), \left(p_{(m_j^n,j)} \middle\| p_{(r_j^n,q_j^n)}\right)\right\} \ldots\ldots\ldots\ldots \text{(C)}$$

With the help of above expression definition of local process and its relations can be identified. Please note that Proxy Process of Meta Model of Partial View given in (Amin, 2002) is just a way of implementation of relation of local process with other processes.

As mentioned above, notion of Virtual Process Instance provides a context that logically connects all the participating process instances belonging to different organizations. All the instances of Virtual Processes Definition VP can be represented as

$I(VP) = \{I_1VP, I_2VP, I_3VP, \ldots\ldots\ldots I_gVP\}$ Where I_gVP is the identifier of gth instance of Virtual Process Definition VP.

Following the expression (A)

$I_gVP = \{I_g p_{(m_j,o_j)}\}$ Where $I_g p_{(m_j,o_j)}$ are all the process instances of participating organizations that belong to Virtual Process Instance I_gVP.

Similarly, for the gth instance of Partial View PV_jVP of Virtual Process Definition VP can be represented as

$$I_g PV_j VP = \left\{ I_g p_{(m_j,j)}, I_g \left(p_{(m_j,j)} \middle\| p_{(r_j,q_j)} \right) \right\} \text{ ..... (D)}$$

Where $I_g \left(p_{(m_j,j)} \middle\| p_{(r_j,q_j)} \right)$ is the *gth* instance of relations between local process definition $p_{(m_j,j)}$ and $p_{(r_j,q_j)}$. Remember $p_{(r_j,q_j)}$ are process definitions of peer organizations with which local process definition is connected.

The semantic of instance of relation, say $I_a \left(p_b \| p_c \right)$, is one complete interaction between two process instances $I_a p_b$ and $I_a p_c$. Where $I_a p_b$ and $I_a p_c$ are *ath* instances of process definitions p_b and p_c respectively. Process instance $I_a p_b$ is a local process instance and $I_a p_c$ is a process instance of a peer organization. The expression (D) let the organization know which process instances of peer organizations are interacting with which local process instances. In simpler words, the relationship of local process instances and process instances of peer organizations is captured in expression (D). And this relationship helps the organization identify process instances of peer organizations.

2.2 Workflow History Space

2.2.1 Process/Place/Time Model

We conceptualize Workflow History Information as three co-ordinate space, axes of which are Process, Place and Time. "Process" and "Place" symbolize Virtual Process Definition and Organization respectively. A single point in this space is a set of instances of a process definition belonging to an organization. For example, a point $\left(VP_1, O_2, T_6 \right)$ shown in "Figure 1 (a)" gives us a set of all instance identifiers of a local process definition $p_{(m_2^1,O_2)}$ that exist at time T_6. And as we know from expression (A), $p_{(m_2^1,O_2)}$ is a participating process definition of VP_1 and belongs to the organization O_2. This set of instances includes both the instances that are currently active and the instances that have been executed by the time T_6. In this view of the workflow history information space, we only consider to identify the instances, not the internal details of the instances.

2.2.2 Instance/Place/Time Model

This model gives another view of the workflow history that can be used to have internal detail of a process instance. Axes of this space are Instance, Place and Time. The "Instance" symbolizes a Virtual Process Instance. A single point in this space is

a snap shot of a local process instance belonging to an organization at given time. For example, a point (I_3VP_1, O_1, T_4) shown in "Figure 1 (b)" gives a snap shot of a local process instance $I_3 p_{(m_1^1, O_1)}$ of organization O_1 at time T_4 that belongs to I_3VP_1. By snap shot we mean the values of all kind of data attached to the process instance at given point of time. This includes the data and the states of both finished and active activities, the relevant data, and the instance internal run-time data.

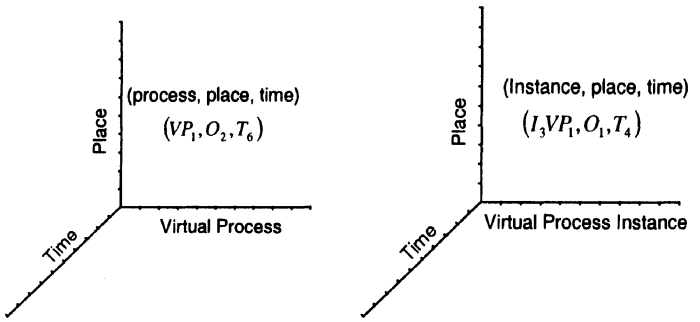

Figure 1 – (a) Virtual Process Space (b) Virtual Process Instance Space

3. APPLICATION OF INSTANCE IDENTIFICATION SCHEME

A simplified form of the example given in (Amin, 2002) is used to demonstrate the application of proposed instance identification scheme. We ignore the internal details of the process definitions as we are not concerned with it. We also add few extra process definitions into picture to make it more suitable for the current purpose. Four organizations, the Police, the Community Pediatrics, the Examination Room Provider and the Post AFE Care Provider, are collaborating to form a Virtual Enterprise. A child rape case is reported to the Police and it asks the Community Pediatrics to do AFE examination. The Community Pediatrics requires an examination room from nearby hospital, the Examination Room Provider. After the initial AFE examination, the patient is admitted to the Post AFE Care Provider for further treatment. All the four participating organizations have their own processes that interact with each other to form a Virtual Process to achieve the bigger goal.

As shown in the "Figure 2", the process definition P2 of The Police is participating in the Virtual Process Definition VP_1, and linked with one of the process definition P3 of The Community Pediatrics. Similarly process definition P3 of Community Pediatrics is further interacting with process definitions P1 and P4 of Post AFE Provider and Room Provider respectively.

Suppose VP_1 denotes the virtual process given in the example. By using equation (A), all the participating process definitions of VP_1 are presented in terms of globally unique identifiers as

$$P(VP_1) = \{p_{(p_2,o_1)}, p_{(p_4,o_2)}, p_{(p_1,o_3)}, p_{(p_3,o_4)}\}$$

By using equation (B), all the relations among the local process definitions of VP_1 are presented as

$$\|(VP_1) = \begin{Bmatrix} p_{(p_2,o_1)} \| (p_{(p_4,o_2)}), p_{(p_4,o_2)} \| (p_{(p_2,o_1)}, p_{(p_1,o_3)}, p_{(p_3,o_4)}), \\ p_{(p_1,o_3)} \| (p_{(p_4,o_2)}), p_{(p_3,o_4)} \| (p_{(p_4,o_2)}) \end{Bmatrix}$$

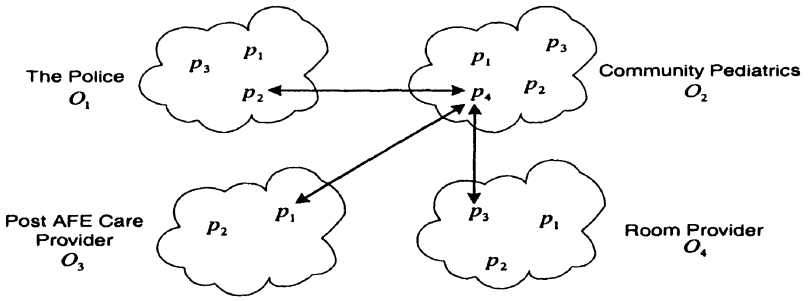

Figure 2 – Interaction of participating processes of a Virtual Process

For the Partial View of VP_1 seen by the Police in terms of global identifiers can be represented as

$$PV_1VP_1 = \{(p_{(p_2,o_1)}), (p_{(p_2,o_1)} \| (p_{(p_4,o_2)}))\}$$

Similarly for the Partial View seen by Community Pediatrics

$$PV_2VP_1 = \{(p_{(p_4,o_2)}), (p_{(p_4,o_2)} \| (p_{(p_2,o_1)}, p_{(p_1,o_3)}, p_{(p_3,o_4)}))\}$$

For the Partial View seen by Post AFE Care Provider

$$PV_3VP_1 = \{(p_{(p_1,o_3)}), (p_{(p_1,o_3)} \| (p_{(p_4,o_2)}))\}$$

For the Partial View seen by Room Provider

$$PV_4VP_1 = \{(p_{(p_3,o_4)}), (p_{(p_3,o_4)} \| (p_{(p_4,o_2)}))\}$$

Now lets take an example of one instance of the partial view seen by Community Pediatrics, say $I_3PV_2VP_1$. Following expression (D), Community Pediatrics can identify process instance $I_3 p_{(p_2,o_1)}$ belonging to the police. Similarly other process instances can also be identified.

4. APPLICATIONS OF WORKFLOW HISTORY IN A VIRTUAL ENTERPRISE

We have observed that the applications of workflow history information is generally scattered in the literature. Every work tries to focus on one or a few applications of

workflow history information. As a part of the contribution of this paper, we first consolidate all the applications of workflow history information and then discuss their relevance in a Virtual Enterprise.

The applications of workflow history are generally divided into two broad categories: Monitoring and Controlling. Monitoring deals with the history of currently running process instances. Controlling deals with the history of already finished process instances over a longer period of time. (Muehlen, 2000) and (Muehlen, 2001) further categorize monitoring into two categories based on the purposes of the monitoring. There are two types of purposes: technical and business oriented. As the framework of a Virtual Enterprise is a set of loosely-coupled WfMS, the technical monitoring is less relevant for the virtual enterprises. For example, an organization is not concerned with the system load, response time and license management of the WfMSs of its peer organizations. But it is very much concerned to know the business states of the process instances of the peer organizations.

As one of the facets of controlling, an important application of workflow history is to do analysis of it over a very long period of time for business process re-engineering. Workflow history is analyzed to improve accuracy, efficiency and timeliness of the processes. Beate in (List, 2000) proposes a separate read-only analytical repository of history information for this purpose. This kind of analysis has new aspects in the case of Virtual Enterprise. The analysis can help the organizations to refine the current arrangements of the virtual enterprise. It can also set the guidelines for creating new virtual enterprises.

Application of the history information for sake of History-dependant Authorization (Casati, 1999) has larger scope in a Virtual Enterprise. The criteria of authorization of tasks to the users could be based on the workflow history of current instance or past instances of the peer organizations. For example, whenever user 'Y' of the peer organization executes some activity 'A', only user 'X' of this organization will execute the particular activity 'B'. Similarly workflow branching logic can also be based on the workflow history of the peer organization. In some domains like medical, workflow history serves for legal purposes as well. Future of an instance can be predicted based on the projection of the workflow history. Other applications of workflow history information include finding of workflow exception patterns to have guidelines for handling them (Sadiq, 2000) and helping the organizations maintain an Organizational Memory discussed in (Kaathoven, 1999) and (Wargetitsch, 1997). Knowledge Management is another emerging area where benefits of workflow history are yet to be discovered fully. (Zhao, 1998) and (List, 2001) bring some of such benefits to light.

In short, not many published works talk about Workflow History Management. Even fewer touch this issue in the context of Inter-organizational Workflows or Virtual Enterprises. Peter in (Muth, 1999) discusses it as part of research project Mentor, but the focus is on architectural aspects of it. Querying of History Information and its optimization are the main topics of (Koksal, Mar 1998) and (Koksal, Oct 1998).

5. CONCLUSION

Although we refer to some particular process model, in this paper we try to keep our discussion and solution at abstract level and independent of details of any process model. This makes the approach equally useful for any process model. But on the other hand, because of being primitive, the solution is not complete enough to be practical unless it is enhanced to cover detailed data of process instances The main focus is to solve the problem of identification and linking of the processes of a Virtual Enterprise for sake of history information. We believe that the approach can be useful in any form of process automation that involves geographically distributed processes.

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