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A Framework based on Workflow and Multi-agent Supportimg Virtual Enterprise Dynamic Formation

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Abstract: The virtual enterprise constructing process was completed with the help of an intelligent facilitate component. For the current requirements of modern enterprises, this study propose a framework supporting Virtual Enterprise dynamic formation based on workflow and multi-agents technologies. Four components are defined in this framework: Global Workflow Engine (GWE), Outsourcing Process Center (OPC), Collaboration Knowledge Base (CKB) and XML-Bridge and every component are described exactly in the article. The computation models and algorithm are also put forward to help realizing intelligent decisions of Multi-Agent System (MAS). Furthermore, a simple example is given to validity the proposed framework and the problems that remain to be tackle in future are also pointed out at the end.

Key words: Workflow, models, algorithm, dynamic, intelligent

INTRODUCTION

Virtual Enterprise (VE) is a concept that was introduced in 1991 under the background of economic globalization, marketization and informationize. VE is a temporal union that formed for certain business opportunities; every member devotes its core technologies, core capabilities and resources with the supporting of information technology (Gao *et al*., 2006). The VE is a new enterprise operating mode that enterprises compete in developed countries and advanced companies in 21st century and it is also a hot topic in both academic community and industry community. The rapid changing markets opportunities and growing personalization requirements make the demands of collaboration between Workflow Management Systems (WFMS) increased. Especially in B2B electronic commerce, the requirements are more impending because most of the E-commerce processes related to many other companies workflow systems, any single enterprise or individual workflow system could not complete the business process independently (Kwak *et al*., 2002; Yang *et al*., 2010).

VE is a dynamic enterprises union with the characteristics that dynamic organization structure, distributive physical scope, reconfigurability of structure and rapid reaction for market opportunities. There are one leader and a number of members in the union and the founder of the union is leader and service providers of the leader are members. WFMS of every member is developed with different technology and located at different regions even countries and profit autonomous entity as well.

Researches about VE in information technology field mainly concentrate on the collaboration work of distributed enterprises application systems, research works can be divided into three stages roughly: early on the appearance of VE concept, researches mainly focus on Enterprises Application Integration (EAI), they just integrate members' application systems for certain task mechanically and the cooperative relationships are relative stable (Kwak *et al*., 2002; Huang, 2002; Song *et al*., 2010). With the deepening of research and the fast changing business environments, just pursuit the systems integration cannot satisfy the demand of rapid virtual enterprise formation, simultaneously, web services was put forwarded as a new service mode, academic researches shift to how to combine Web service technology into enterprises dynamic collaboration in virtual enterprise (Grefen *et al*., 2009; Zhang and Du, 2009; Hu and Paul, 2003) in recent years,

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the intelligent requirements for VE dynamic formation growing rapidly, researchers tries to combine Artificial Intelligence technology into enterprises collaboration, such as semantic enhanced Web service, Web services composition with rule driven, Multi-Agent negotiation mechanism in VE dynamic formation, etc. (Ren *et al*., 2008; Shi and Zhang, 2003; Gao *et al*., 2006; Ricci *et al*., 2002).

Collaborations between WFMSs should be scalable, flexible and intelligent. To this end, we propose a framework based on workflow and multi-Agent supporting Virtual Enterprise dynamic formation. Four main components are defined for the proposed framework: Global Workflow Engine (GWE), Outsourcing Process Center (OPC), Collaboration Knowledge Base (CKB) and XML-Bridge. GWE controls the whole process of leader enterprises' workflow, including send out external collaboration request, monitor cooperate process, affirm users, etc. OPC is the core component of the proposed framework, it responds to the request from GWE and to seek the best partners for the leader according to the outsourcing contents; it also has to help tackling the exceptions in systems collaboration, etc. CKB is a data base that facilitates OPC works more intelligently. XML-Bridge is middleware for information exchange between heterogeneous systems.

Many WFMSs have been designed and implemented to support the dynamic collaboration in a distributed heterogeneous environment. Researches about Virtual Enterprise have also acquired many achievements; scholars are making efforts in this field. Kwak *et al.* (2002) proposed a framework supporting dynamic workflow interoperation and enterprise application integration and defined four components workflow engine, adapter, service interface repository and XML messages to help realizing the framework. Ren *et al.* (2008) introduced semantic enhanced rule driven workflow execution in collaborative Virtual Enterprise, On the one hand, having semantic support, OWL-Sis used in dynamic service discovery and composition at high level. On the other hand, at the concrete level, industry-based BPEL is exploited in service execution. In order to realize interoperability in OWL-S and BPEL without loss of semantic information, this paper further proposed an OWLS2BPEL Mapper to facilitate the workflow robustness and support rule evaluation to increase responsiveness to customers. Grefen *et al.* (2009) proposed a Internet-Based support for process oriented Instant Virtual Enterprise (IVE) and developed a prototype system named crosswork, the system is formed with the agent-oriented front end and the service-oriented back end and it helps distributed organizations efficiently create and operate IVEs by providing automated, Internet-based support for the composition, setup and execution of global business processes.

Many national funding projects have also made great achievements. Shi and Zhang (2003) proposed an Agent-based framework for cross-domain cooperation of Virtual Enterprise, In this framework, there is a service-information Supply-Demand Center (SDC) serving as a service information medium and agents are responsible for cooperative partner selecting before cooperation and interaction during cooperation. Allocation strategy, negotiation strategy and basic interaction models are also presented. Gao *et al.* (2006) introduced a multi-agents cooperate production management model and develop a prototype system, the main contents of this work contains cooperate production plan between VE members and tasks dispatch and conflict resolution, etc. Multi-agents negotiation, systems integration and network communication technologies are used to tackle the problems that encounter in VE members' collaboration. Tan and Yushun (2007) proposed a dynamic workflow model fragmentation for distributed execution method, workflow models are divided into fragments that could be executed on multiple distributed sub-workflow engines; based on the well-known Petri net formalism, a designed algorithm partitioned the centralized process model into fragments step by step while the process is executed, the fragments created can migrate to proper severs, where tasks are performed and new fragments are created and forwarded to other servers to be executed in succession (Tan and Yushun, 2007).

REQUIREMENTS OF FRAMEWORK FOR VIRTUAL ENTERPRISE COLLABORATION

In the union of Virtual Enterprise, the leader enterprise in charge of the global business processes; it set a goal according to certain market opportunity, then decomposition the goal into amount of sub-tasks and design the whole business process with these sub-tasks. Sub-tasks can be divided into two groups roughly, one group includes all tasks that the leader enterprises can complete them itself and another includes all activities that should be outsourcing. In other words, all sub-tasks can be distinguished with internal activity and external activity.

Internal activities: The leader enterprises have core capability in finishing these activities and the executing details of these activities are clear from the beginning of a workflow process. When the workflow moves to activities of this kind, leader's internal departments start to do relevant works.

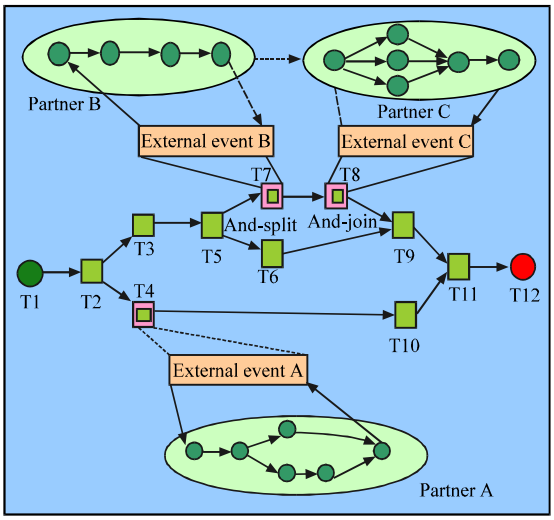

Fig. 1: A virtual enterprise with four members

External activities: The leader enterprises do not have core capabilities in finishing these activities or even cannot complete them. These activities should be outsourced for better partners who have core capability in doing these works. The leader enterprises do not clear the executing details of these activities while designing the global workflow process and when the workflows moves to these activities, leader's workflow engine will start relevant programs, then sending out requests, to seek optimal partners and formed a VE.

In order to lower the burden of leader enterprises' workflow systems when handling external activities, there need a special component responding to the leader's requirements requests and service providers' registry. This component seeks best partners for leader enterprise intelligently and also tackles various possible exceptions during the collaboration of multiple workflow systems. Intelligent seeking partners need the support of historical data information, market information, etc., thus a collaboration knowledge base is required to facilitate the intelligent and automatic process of constructing a Virtual Enterprise. Members' workflow systems of a VE located at different places and these systems are heterogeneous mostly, a middleware is needed to shield the heterogeneous between systems for convenient information exchanges.

Figure 1 shows a business process that needs collaboration of multiple workflow systems. The leader enterprise receive an order and then its' research department decompose the business into activities T_1, T_2, T_3 ... T_{12} and T_4, T_7, T_8 are external activities, others are internal activities. When the workflow comes to T_4 or T_7, the leader will call for external collaboration. T_7 and T_8 are adjacent external activities and they could be outsourced at the same time for reducing overall time of the whole workflow. There are three external activities in Fig. 1 and Partner A, Partner B and Partner C are proper collaborators for each activity. The three partners together with leader enterprise formed a Virtual Enterprise that has four members.

FRAMEWORK SUPPORTING VE DYNAMIC FORMATION

Design principle: The goal of this paper is to propose a framework of virtual enterprises system. In this framework, the service requester (leader's workflow system) needs not care about the way that external activities are carried out and even not know how to select service providers (collaboration partners). The VE constructing process was completed with the help of virtual enterprises collaboration platform. In achieving the goal we propose a framework based on dynamic workflow and Multi-Agent System (MAS). This framework utilizes the business process flexible management feature of dynamic workflow and intelligent ability of MAS and it can well done the dynamic constructing process of Virtual Enterprises.

For the convenient of problems description, the following parts define the concepts of Dynamic Workflow and Multi-Agent System.

Definition 1: A dynamic workflow is a four-tuple: W≤ID, M, Q, S>, where, ID is the sole identifier of a workflow; M is the general information of a workflow and M≤Founder, Date, Version, Info>is a four-tuple, where four parameters represent the following information respectively: the founder, the issue date, the model version and the descriptive information of an instance; Q = (N; F) where, N is the set of all activities appearing in the workflow model, including internal activities and external activities; F is the set of flow relations between activities, including the relations between internal activities and also the relations between internal activities and external activities and $F \subseteq N \times N$; S is the state of a workflow instance (Li and Du, 2009).

Definition 2: Multi-Agent System (MAS) is that multiple Agents accomplish certain tasks with mutual cooperation and mutual support; it has rich knowledge and powerful functions of its own. Activities between Agents are autonomy and independent. The behaviors and goals of one Agent are not limited by other Agents. They complete system target through consultation, cooperation and competition between them.

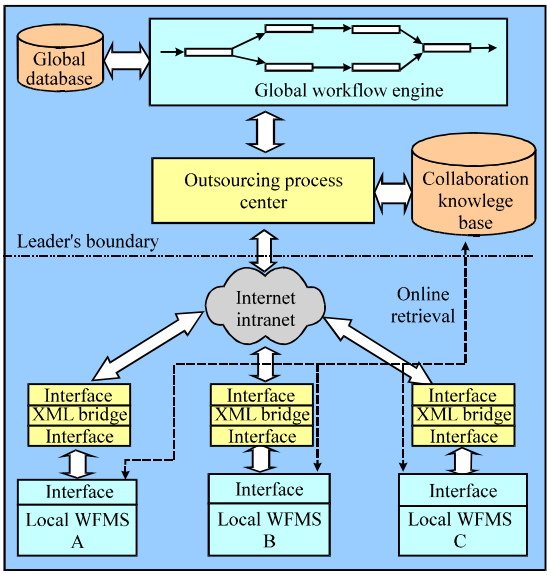

Fig. 2: Overall architecture of the framework

Overall architecture of framework: The proposed framework supports the leader enterprises' workflow seeking partners at run time in distributed heterogeneous and Internet environments; meanwhile, the seeking process are intelligent and automatic. In this framework, four features serve important roles: Global Workflow Engine (GWE), Outsourcing Process Center (OPC), Collaboration Knowledge Base (CKB) and XML-Bridge. The leader enterprise of VE in charge of GWE, OPC and CKB; and XML-Bridge is invoked by workflow systems that want to register their services. Figure 2 shows the overall architecture of framework.

Figure 2 shows the overall structure of the framework. Service provider (Local WFMS A, B, C), which want to announce their services, can access the CKB of leader enterprises online to get more information about leader enterprises and then invoke the middleware XML-Bridge. Service providers send XML messages to OPC with this middleware and registry their services in OPC.

If the leader enterprises of VE want to outsource some sub-tasks at run time, its' WFMS must sending out request messages to leader's OPC forwardly. This requires the GWE should be flexible and scalable for proper selecting external partners' workflow systems.

OPC is a core component of the proposed framework, it mainly undertakes the management of service requests information from the leader enterprises and service provides information from external enterprises. Meanwhile, OPC seeks best partners for outsourcing tasks and tackles collaboration exceptions between workflow systems. It is a hinge between leader enterprises and external partners.

CKB is a facilitate component in the framework and it mainly stores the historical information of past transactions between leader and partners, such as reputation, service quality, efficiency, etc. Meanwhile, the business terminology mapping sets between the leader and partners and the valuable information gathered by leader's business intelligence departments are also stored in CKB.

XML-Bridge is a bridge between heterogeneous workflow systems. It can not only transfer various data information into XML documents, but also work in the opposite direction. Detail descriptions about the four components in Fig. 2.

DETAIL DESCRIPTIONS OF FRAMEWORK

This part mainly introduces the detail descriptions of the four components shown in Fig. 2. The working principles and internal structures of each component are defined.

Global Workflow Engine (GWE): GWE plays an important role in this framework, it could identify the activities that the leader cannot complete and sends out outsourcing requests to OPC forwardly. Meanwhile, it is in charge of the global control of leader's workflow processes.

Key classes of GWE: The Global Workflow Engine consists of six key classes. Among the six classes, workflow creator, global manager and task list manager are instantiated at system set up time; External Invoker, Communication Trigger and Exception Handler are instantiated at run time of a workflow process. The functionalities of each class are as follows:

- Workflow Creator (WC) is a user interface of the workflow engine, it is used to create a workflow instance
- Global Manager (GM) controls the work of engine, it determines the start time of classes such as External Invoker, Communication Trigger and Exception Handler
- Task List Manager (TLM) manages the instances lists of workflow engine, because there may be amounts of instances in one workflow engine
- External Invoker (EI) sends out outsourcing requests to OPC when the workflow comes to external activities
- Communication Trigger (CT) sends out trigger information for instant communication, to impart user the collaboration state of affairs between systems

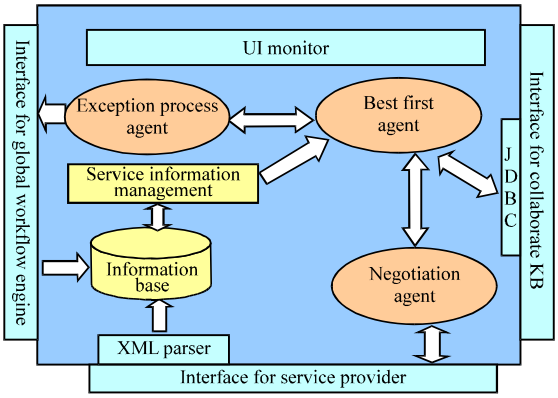

Fig. 3: Internal structures of OPC

- Exception Handler (EH) tackles the collaboration exceptions during the run time of workflow instances, improving the robust of VE collaborate

Control flow of GWE: First the user crates a workflow instance with class WC and transfers the creation information to GM, then GM in charge of global control of this instance and TLM's task list increase a work item. When the workflow instance comes to external activities, GM sends messages to EI and EI sends out outsourcing information requests to OPC. If GM receives the feedback information from OPC, then it will activate CI for instant communication with the user. If exceptions occur during the instance execution process, EH will be activated for exceptions handling.

Outsourcing Process Center (OPC): OPC is a core component of the proposed framework and it mainly manages the information from service requester (leader enterprise) and service providers (candidate enterprises). It seeks best partners for outsourcing tasks and tackles collaboration exceptions between workflow systems intelligently. OPC mainly contains two parts, one is a multi-agent system composed of three agents (exception process agent, best first agent and negotiation agent), the other is supply-demand management module composed of Information base and service information management parts. There are also many facilitate parts in OPC, such as XML Parser, external interfaces, etc. Figure 3 shows the internal structures of OPC.

Multi-Agent System (MAS): The MAS in OPC is composed of three agents: Exception process agent, best first agent and negotiation agent. Each agent is self-governing and independent and these agents collaborate to complete certain tasks.

Best first agent is responsible for seeking best partners for leader enterprise and it have the following behaviors: (1) send the bidding request, best first agent release the bidding news for every outsourcing tasks, (2) receive the bidding message, possible enterprises send bidding documents to tenderee, (3) set the evaluation criterion, the agent set evaluation rules according the requirements of leader enterprise and (4) assess enterprises' capability, electing qualified enterprises as optional partners.

Negotiation Agent negotiates specific cooperation issues with service providers that chosen by Best First Agent and it have the following behaviors: (1) complete the bidding process, (2) negotiate the exact finishing time of every outsourcing activities, (3) cooperative behavior, realizing the communication process between host enterprises and partners and (4) supervision behavior, the Agent monitors the executing state of every outsourcing activities.

Exception Process Agent tackles various exceptions during the cooperation processes (e.g., tasks cannot be finished on time, service providers encounter accidents, etc.).

Agents communicate with each other and cooperate for the system goals, moreover, the intelligent level increased dynamically along with the growth of system run time. The working processes of MAS are roughly as follows: first MAS received the requests information from the leader and then best first agent goes to seek partners in service information management part. If best first agent cannot find proper partners for the leader, exception process agent will start to work; if best first agent finds only one proper partner, negotiation agent will start to negotiate the specific cooperation issues with the partner; if best first agent finds more than one proper partners, it will start the evaluation programs to evaluate the quality of partners according to the computation model designed in section 6 and chooses the best one for leader enterprises, then Negotiation Agent starts to negotiate the specific cooperation issues with the partner.

Supply and demand management module: Supply and demand management module in OPC is composed of two features: Information Base and Service Information Manager. Information Base is a database for the storage of supply and demand information, mainly including the information such as service type, service name, service description, service life circle and service providers' information, etc. Service Information Manager mainly in charge of the management of the information in Information Base, such as service information registry, service information classification and service information maintenance, etc.

Collaboration Knowledge Base (CKB): CKB is a facilitate feature of the virtual enterprise framework, it provides data information for MAS making intelligent decisions and provides convenience for mutual understanding between partners and leader in a VE. All data information in CKB can be divided into four classes:

- Business terminology mapping sets between the leader and partners. Data of this kind is used to provide convenience for mutual understanding between partners and leader in a VE and also helps new members that want to join in the VE knowing more about the leader. These data is visible to all external enterprises
- Basic information of partners that ever collaborated with the leader. These data include information such as partners' name, social honor, credit rating, registry capital, location, etc. and they are references when Best First Agent chooses the best partner from multiple candidates. Meanwhile, these data just be used by the leader enterprise in VE and they are invisible and secretive to other members in VE
- Business information of partners that ever collaborated with the leader. These data include information such as service name, service quality, reputation, efficiency, etc. and they are also references when Best First Agent chooses the best partner from multiple candidates. And their visibilities are invisible to other members in VE
- Valuable information gathered by leader's business intelligence departments. These data include information such as new partners that might collaborate in future, peer review about new partners, aptitude of about these enterprises and even negative information about them. These are business secretes of leader enterprise, so they are invisible to other enterprises

The data amounts in CKB will increase along with the growth of system's run time and this makes the decision making processes of MAS more intelligent. But huge amount of data will lower the searching efficiency of best first agent, thus data updating strategies need to be designed for CKB.

XML-bridge: XML-Bridge is a middleware between heterogeneous workflow systems' communication. It is a bridge for information exchanges and used to shield the isomerism between workflow systems. If one enterprise wants to join into a virtual enterprise, it should invoke this middleware firstly. XML-Bridge can not only transfer various data information into XML documents, but also can transfer XML documents into the required form of certain workflow systems.

COMPUTATION MODELS AND ALGORITHM OF MAS

Multi-Agent System is a core feature in OPC and it seeks best partners for leader enterprise of VE. As is discussed eariler if the best first agent found more than one proper candidates, it will start to evaluate every candidate and then chose the best one. This section will introduce the computation modules of MAS when evaluates candidates, moreover, intelligent seeking algorithm is also put forward.

The evaluation of service providers mainly via the observation of their historical behaviors or appraise information and then derive the expectation for providers' future behaviors. Viewing from another aspect, it is trust worthiness for partners and also a reflection of Agent's social characteristic. Best First Agent might encounter three situations when evaluates a partner: the first one, this partner is a new comer and there is no information about it in CKB; the second one, this partner is a new comer and there is much information that gathered by intelligence departments of leader enterprise about it in CKB; the third one, this partner is not a new comer, there are historical business information about it in CKB. For the first situation, MAS will affirm users and then start manual evaluation processes; for the last two situations, MAS will evaluate the partners according certain computation modules and chose the best one.

Evaluation model for familiar partners: The evaluation of familiar partners mainly refers to the historical behavior information and this information was stored in CKB. In order to reflect the dynamic and cumulative characteristics of the evaluation model, the following five important parameters were introduced into this model:

- **Cooperation time:** If the leader cooperates more with the partner, it is more familiar with this partner and is easier to set up mutual trust, the evaluation result is more precise as well
- **business money amount:** The money amount of one business deal directly reflects importance degree of that transaction
- **Service quality:** Service quality reflects leader's satisfaction degree of that cooperation.
- **Cost performance:** It reflects the cost-effective ratio of that cooperation.
- **Deal time:** It is the time when that cooperation finished and it can reflect the partner more precise if the deal time is closer

The evaluation module for MAS evaluates familiar partner i at current time t as follows:

$$Eva(name_i,t)=\sum_{k=1}^{T(k)}\frac{Satis(name_i,t_k)*Money(name_i,t_k)*Decay(t)*CPer(name_i,t_k)}{GMoney(name_i,t)} \quad (1)$$

T (k) is the times of transactions between the leader and partner i.

Satis ($name_i$, t_k) is the satisfaction degree of the kth transaction between the leader and partner i and its data scope is (-1, 1) and better service get higher marks.

Money ($name_i$, t_k) is the money amount of the kth transaction between the leader and partner i and it directly reflects the importance degree of that transaction;

CPer ($name_i$, t_k) is the cost performance of the kth transaction between the leader and partner i and its data scope is (0, 1); the higher the cost-effective ratio was the better marks it got.

Decay (t) is a decay function; it reflects the weight of the kth transaction at current time t and the weight depressed along with the passage of time.

$Decay(t)=e^{-\omega(t-t_k)}(t>t_k)$, its value scope is (0, 1) and it decreased along with passage of the kth transaction time. $\omega(\omega\geq 0)$ is a parameter to control the decay speed of weight and set its size according to specific needs.

GMoney ($name_i$,t) is the total transaction amount between the leader and partner i up to current time t:

$$GMoney(name_i,t)=\sum_{k=1}^{T(k)}Money(name_i,t_k) \quad (2)$$

$$\frac{Money(name_i,t_k)}{GMoney(name_i,t)}$$

in Eq. 1 is the proportion of the kth transaction in total businesses between the leader and partner i.

This model reflects the comprehensive quality of a partner and giving attention to various factors that may affects business transactions. It can not only prompt partners provide better services, but also facilitates MAS making intelligent decisions.

Evaluation model for new partners: The evaluation of new partners mainly depends on valuable information that gathered by intelligence departments of leader enterprise. This information mainly contains the peer review information about enterprises, enterprises' aptitude information, negative information about enterprises, etc. For the scientific and effective of this model, following parameters are introduced:

- **Number of peer assessment items:** Gathered peer review information about a enterprise
- **Aptitude information of enterprise:** It is the registry capital scale of a enterprise and it reflects the power of one company to some extent
- **Negative information:** This is the dishonor information about a enterprise in its developing process, such as violate agreements, illegal behaviors, etc.

The evaluation module for MAS evaluates new partner i at current time t as follows:

$$Reckon(name_i,t)=\sum_{m\in M(name_i)}\frac{appr(name_i,m)*weight(m)*apti(name_i)}{\sum_{m\in M(name_i)}weight(m)}*e^{-\lambda p} \quad (3)$$

M ($name_i$) is the set of members that give peer review about $name_i$.

Appr($name_i$,m) is the evaluation of estimation to $name_i$ from m, it reflects the reputation of a enterprise in its business fields and its value scope is (-1, 1).

apti($name_i$) is the aptitude value of one enterprise, it reflects the enterprise's registry information in the government, moreover, it show the power of a enterprise to some extent; its value scope is (0, 1).

$$\frac{weight(m)}{\sum_{m\in M(name_i)}weight(m)}$$

In Eq. 3 is the weight of m in all members that give their evaluations about $name_i$ and its value scope is (0, 1).

$e^{-\lambda p}$ is a decay function that reflects negative information of a enterprise, p is the number of negative information about $name_i$, the final result decreased with the growth of p, $\lambda(\lambda\geq 0)$ is a parameter to control the decay speed of weight and set its size according to specific needs.

This model takes the key factors when evaluating a new partner into account. It incorporates peer review about a partner as well as the enterprise qualification into the model; moreover, negative factors are also included. Best first agent can do well in evaluating new partners with the facilitation of this model.

Algorithm for MAS seeking copartners: When the leader enterprise of a VE demands external services, it sends out its requirements to Outsourcing Process Center and then OPC relegates the requirements to MAS. Best First Agent examines the received information at first and then it starts to seek the best partner with the leader's goal driven. MAS interact with users as well during its seeking process. The following is key strategies for intelligent VE construction and the processes are shown in the algorithm below.

```
Algorithm: Seeking partners' strategy
if (the leader sends out requirements requests = true)
Best First Agent received the requirements information;
   if (Best First Agent is busy)
      The request enters into the waiting queue;
   else Best First Agent stars to choose partners according to service
   matching programs;
   if (proper partners =0)
      {feedback seeking failure information to users;}
      if (proper partners =1)
         {Best First Agent accesses CKB;
      if (exist information about the partner in CKB) evaluate the partner
      with proposed computation model, then feed back evaluation results
      to Negotiation Agent;
         else inform users and start manual evaluation processes;
          }
if (proper partners>1)
            {Best First Agent accesses CKB;
            if (exist information about partners in CKB)
            evaluate every partner that exist information in CKB and
            feedback evaluation results to Negotiation Agent
            then abandon those partners with none information in CKB;
               else inform users and start manual evaluation processes;
               }
```

A SCENARIO

With the development of economic globalization and markets integration, the business competition is becoming fiercer day by day. Customer demands are becoming diversity and individuation, thus how to meet customers' personalization requirements under the premise of high quality and low cost, becomes the primary problem of modern enterprises. Enterprises fully exert their own core competitiveness in the markets and outsourcing some tasks that they are not capable or good at and then they integrate superior resources in the markets, achieving the All-Win goal. A mobile phone production process of communication enterprise is proposed as a scenario in this section. The life circle of a mobile phone mainly includes three stages: designing, production, sales, etc. Communication enterprise only responsible for the designing and sales stages as well as the production stage was outsourced for external cooperation. This is because that a mobile phone is composed of more than 200 components and it costs too much time and liquid capital for self production of so many parts. Figure 4 shows the workflow of developing a new mobile phone in a communication equipments company. Activities in the topside and the nethermost square stand for internal tasks that the communication enterprise can complete itself; activities in the middle square stands for external tasks that should be outsourced for cooperation. And Fig. 5 is the description of this workflow model in XML.

As is described in Fig. 5, activities of the workflow instance are divided into external activities and internal activities according value of <is-remote>. If the workflow comes to an activity that its <is-remote> value is true,

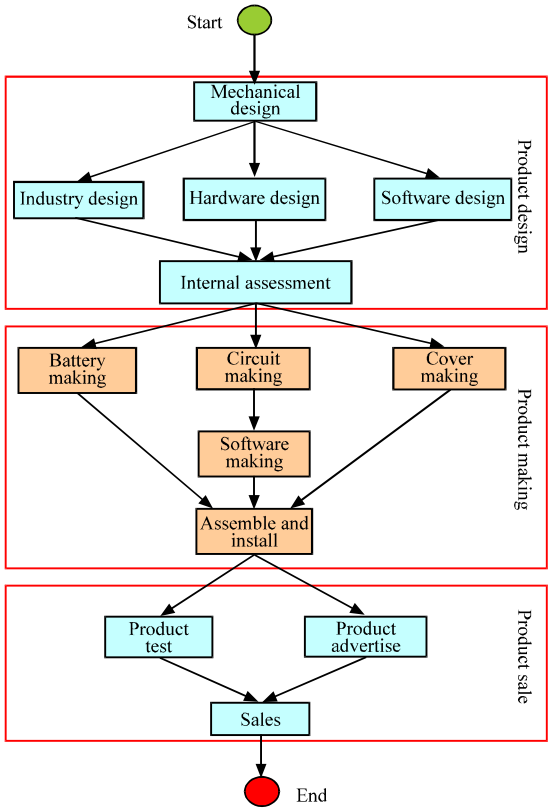

Fig. 4: Workflow model for mobile phone making

```
<?xml version="1.0" encoding="GBK"?>
<business-process-definition>
<processname>DevelopMobilePhone</processname>
<ID>20091212085</ID>
<Founder>Peter</Founder>
<Date>20091212</Date>
<Deadline>20100415</Deadline>
<process-element>
<name>Start</name>
<pre-name>null</pre-name>
<post-name>MechinicalDesign</post-name>
<is-remote>false</is-remote>
</process-element>
<process-element>
<name>MechinicalDesign</name>
<pre-name>Start</pre-name>
<post-name>IndustralDesign</post-name>
<post-name>HardwareDesign</post-name>
<post-name>softwareDesign</post-name>
<is-remote>false</is-remote>
</process-element>
            .
            .
<name>BatteryMaking</name>
<pre-name>InternalAssessment</pre-name>
<post-name>Assemble&Install</post-name>
<is-remote>true</is-remote>
</process-element>
            .
            .

<process-element>
```

Fig. 5: XML description of workflow model

Table 1: Historical information of candidates

Parameters	k	satis	Money($)	Cper	$t-t_k$
A	1	0.6	10000	0.8	2
	2	0.9	20000	0.5	4
	3	0.75	40000	0.7	6
B	1	0.8	30000	0.5	1
	2	0.55	60000	0.9	7
C	1	0.7	10000	0.6	3
	2	-0.2	20000	0.2	5
	3	0.85	40000	0.7	9

Table 2: The evaluation results of candidate enterprises by best first agent

Evaluation model	Values
Eva(A,t)	0.276
Eva(B,t)	0.319
Eva(C,t)	0.146

workflow system of communication equipments enterprise (leader of the VE) will send out requests information to its OPC. Multi-Agent system in OPC will start to seek the best partner for the outsourced task. If the task is battery production and here we assume that MAS found three candidates and the three candidates all have business transactions with the leader in the past and then MAS have to choose the best one from the three. Table 1 shows the historical information of the three candidates, MAS will make decision according to these data.

Best First Agent evaluates these candidates with Eq. 1 and set the decay function parameter $\omega = 0.5$. The evaluation results are as shown in Table 2.

MAS choose partner B as the best cooperator, because partner B get the highest value among these candidates. After the selection of best partner, Negotiation Agent started to negotiate the details with successful bidder.

We assume there are following problems to be tackled during the negotiation processes: (1) the weight of battery; (2) the electric quantity of battery; (3) the service life of battery; (4) the safety factor of battery and (5) the supply mode of products. In view of the above five problems, the Negotiation Agent negotiate with the successful bidder.

Suppose that the final result of negotiation is (α, β, γ, δ, ε) and the letters in brackets stand for negotiation results of corresponding problems. After the end of negotiation, the bid-winning enterprise B starts to organize production according to the negotiation results. Other outsourcing processes are similar with this and will no longer be described here.

CONCLUSIONS

Rapid changing business environments demand modern enterprises response promptly to market information. Enterprises fully exert their own core technology and integrate superior resources in the markets, achieving a goal by multiple enterprises' collaboration. The development of information technology provides possibility for enterprises' fast collaboration. This study proposed a framework for Virtual Enterprise dynamic formation based on dynamic workflow and MAS technologies, this framework can find partners for enterprises intelligently at workflow instance run time. Moreover, the computation models and algorithm are also put forward to help realizing the intelligent decision making process of MAS.

There are still many problems remains to be tackle in this framework, such as the negotiation strategies between MAS and partners, exception process model when encountering accidents in collaboration process, data updating strategies for CKB, etc. and these will be our future works.

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