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Shared Management of Dynamic Business Process Extensions

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Abstract

As the global marketplace becomes more and more competitive, business organizations often need to team up and operate as a virtual enterprise to utilize the best of their resources for achieving their common business goals. As the business environment of an enterprise is highly dynamic, it is necessary to develop a workflow management technology that is capable of handling dynamic workflows across enterprise boundaries. This paper proposes a Workflow Extension Model (WEM) and a dynamic workflow management system for modeling and controlling the execution of multi-organizational business processes. WEM enables the specification of dynamic properties associated with a business process model. It extends the underlying processes by adding connectors, conditions of application, extension process definition, and rules as its modeling constructs. Using WEM as the underlying model, an IBM workflow engine is extended by an extension service to trigger extensions during the execution of a workflow process to enforce business rules and policies and to adapt the process model at run-time.

Introduction

Nowadays organizations compel workflow management in order to ease creation and execution of workflow so as to streamline business processes. Organizations often require developing custom activities. For instance a multinational company must adapt its processes to comply with local laws and regulations, or a delivery service must change its way to ship materials depending on the weight, size, manipulation care, etc. Adaptation and flexibility are keys for business success.

Regrettably, most of existing workflow management solutions only handles static business processes. Specific cases are then expressed as branch in a unique and global workflow process. This approach raises many problems in terms of management and maintenance of large and complex error proneworkflow processes, as well as extensibility and adaptation issues. Companies would benefits a lot from the delegation of governance. Global business processes should be defined at the company scale while specific adaptations should be handled at a local scale. This approach would avoid maintaining locally modified copies of the global process, which may lead to coherency losses between the multiple copies and the base process.

We propose a method to extend existing processes, which we call as "base processes", without changing them. It allows adding multiple extensions conditionally to a base process. Those multiple extensions can be defined concurrently by different administrators.

Problem statement

Changes may range from ad-hoc modifications of the process for a single customer to a complete restructuring for the workflow process to improve efficiency. Today's workflow management systems are ill suited to dealing with change. They typically support a more or less idealized version of the preferred process. However, the real run-time process is often much more variable than the process specified at design -time. The only way to handle changes is to go behind the system's back. If users are forced to bypass the workflow management system quite frequently, the system is more a liability than an asset. Therefore, we take up the challenge to find techniques to add flexibility without loosing the support provided by today's systems.

Typically, there are two types of changes: (1) ad-hoc changes and (2) evolutionary changes. Ad-hoc changes are handled on a case-by-case basis. In order to provide customer specific solutions or to handle rare events, the process is adapted for a single case or a limited group of cases. Evolutionary change is often the result of reengineering efforts. The process is changed to improve responsiveness to the customer or to improve the efficiency (do more with less). The trend is towards an increasingly dynamic situation where both ad-hoc and evolutionary changes are needed to improve customer service and reduce costs as outlined in [Paul C. J. 2007].

Related work

Workflow management is now widely accepted as the better technology to support business processes. Nowadays many commercial solutions for workflow systems are available. However one may regret that a large majority of those workflow systems is restricted to centralized and internal use within an organization. They do not offer mechanisms to deal with runtime adaptation nor with shared administration of process definitions. The Workflow Process Definition Language, WPDL for short [WfMC, 1995] [WfMC, 1999], has become the reference standard for workflow. WPDL has been originally developed by the Workflow Management Coalition (WfMC) in the first half of nineties. It offers textual grammar for the specification of process definitions and comes with a meta-model providing a set of modeling constructs for defining business processes. Typically a business process is represented by a set of inter-related activities connected by different kinds of connection lines. The activities represent tasks performed by human or computer that are related to a context (workflow data, environment, and operators). The connection lines that link those activities control the flow within a workflow process. Unfortunately, WPDL has been designed to model business processes only in the scope of a unique organization whose need are uniform for all its parts. WPDL fails to provide a system allowing the creation of inter-organization or inter-division business processes. Along with evolution of IT industries and complex business interactions the need for the possibility to dynamically adapt processes to particular cases raised.

Several projects attempted to address this issue by introducing some dynamic capabilities to workflows. Some solutions appeared:

- The *evolutionary changes* have a structural nature. From a certain moment in time, the process changes for all new cases to arrive at the system. Those changes may result from the definition of a new business strategy, the modification of a law, etc. It mainly consists in the modification of running process. Such modification of process is a global and does not allow specific adaptation.
- The *inheritance of workflows* defines a base process containing the necessary tasks of a process and allowing additional tasks. Concretely the base process identifies the sequences can be extended. One can regret that it becomes impossible to extend a piece of the process that has not been originally intended to be extended.
- The *dynamic inter-organizational workflow management* provides complex extensions by modifying the base process itself at runtime depending on rules pre-defined by the user. Unfortunately this approach does not permit a shared and concurrent administration of extensions. Moreover the extensions may be in conflict with each others.

Later several attempts were made to solve this issue. The approach chosen by some projects was to define events and rules used to define and enact the control flow in a business process model. The most representative example among this solution is the EvE project [Geppert and Tombros, 1998]. The EvE project introduced a distributed Event-Condition-Action (ECA) rule-based enactment architecture. The use of events and rules to handle exceptions and failures during workflow execution falls into another category. In this category, events are produced outside a workflow execution, by either system environment or customers. Corresponding rules will be triggered when these events occur. An example is the WIDE project [Ceri et al., 1997]. The WIDE project uses a distributed architecture for workflow management based on a database management system. It is enhanced with rule evaluation capabilities in order to allow the definition of ECA rules to support exception handling and implement asynchronous behaviors during workflow execution.

More recently the project AgentWork [Müller, 2002] is based again on the concepts of event and rules, but slightly different. AgentWork deals with dynamic adaptation appearing when the workflow instance encounters unexpected failures. The main difference between the approach of AgentWork and the ECA rules presented abovecomes from the fact that the rules and events are directly part of the workflow model. In order to allow adaptation at runtime one describes at edition time the adaptation to perform. This description describes the given moments at which adaptations start and the synchronous or asynchronous nature of the events. During execution of workflow the system emits the events as described and activates the rules to trigger adaptation. A second major difference with ECA model is that the approach promoted by AgentWork is not restricted within a single organization as it even ts can be defined and managed in a distributed environment [Lee, 2000]. [Meng and al. 2006] names the AgentWork's approach ETR for Event-Trigger-Rule.

Several projects attempted to solve the dynamic adaptation problem using the Object-Oriented paradigm: [Zur Muehlen M. and Becker J., 1999], [Basten T. 1997], [Basten T. 2002], [Manolescu D. A., 2001a], [Manolescu D. A., 2001b], and [Sadiq, W. et al. 2006]. This approach thanks to dynamic bindings could provide some mechanisms to call a task instead of a similar one (an ancestor or interface task). The benefit of this approach was more to produce enterprise-oriented implementations of workflow engines for object-oriented languages than the actual flexibility it may have allow to adapt processes. The strong architecture defined by inheritance limited the ability to freely and limitlessly modify a process.

Lately a trend was to consider that adynamic workflow management system should to be able to dynamically modify a workflow definition in order to adapt to dynamic business conditions and exceptional situations. [Reichert and Dadam 1998] presents a formal foundation for supporting dynamic structural changes of running workflow instances. The work reported by Muller and Rahm (1999) describes a rule-based approach for the detection of semantic exceptions and for dynamic workflow modifications, with a focus on medical workflow scenarios. The work in the TAM project [Zhou et al., 1998] presents a dynamic restructuring of distributed transactional activities. These works mainly focus on the structural changes of process models. Finally, DynaFlow [Meng and al. 2006] supports both structural (e.g. drop an activity or bypass some activities) and semantic (e.g. replace an activity or modify a transitional condition) chan ges to an inter-organizational business process model. The 'Code Generation' approach, which is used to develop the workflow engine in DynaFlow makes it easy to support these changes. The adaptability a workflow instance is enhanced with when these changes to the process model are performed dynamically by the business rules that are triggered by synchronous events posted by the running business process.

Despite some projects try to address the problem of correctness or validity of a composed process [van der Aalst, W.M.P. , 1999], [van der Aalst, W.M.P. , 2003] [Kin, et al., 2004] none of the solutions presented above provide an integrated mechanism to seamlessly define, extend, adapt, and change a business process in a decentralized manner that hierarchically assigns specific modifications to specific environments and data.

Extension

Proposal

Usually, most of workflows systems are data-centered, i.e., every piece of work is related and executed for a specific data object. Examples of data object are an asset of a company, a person profile, a tax declaration, an order, or a request for information.

The Workflow Management Coalition (WfMC) uses the term "process instance" to denote the dynamic version of process definitions attached to an object and which need to be handled by the workflow management system (i.e. workflow engine). A task, also referred to as "activity" by the WfMC, is an atomic piece of work. Tasks are not specific for a single instance but are of course related to the object. In principle, a task can be executed for any process instance.

Description of this solution

Our technology provides a mechanism to share the administration of process extensions. It allows multiple administrators (process extensions' editors) to deal with isolated and/or intersected (and included) extensions. We define that two extensions are *isolated* if they can not happen at the

same time at the same point during the execution of a process (i.e. they can not enter in conflict). When editing one extension its isolated peers should not be displayed to the administrators. On the other hand, *intersected* and *included* extensions may happen at the same time at the same point during the execution of a process (i.e. they can enter in conflict). It is necessary to identify the extension s in intersection and let the administrator solve possible problems (by ordering extension for instance).
We propose a technique to identify isolated and intersected extensions. The goal is to simplify the edition of process extensions. When editing an extension on a process the administrator will be shown the entire set of extensions associated to the process (the entire contents of the *Exten sions Table*). It may result in a very complex and large picture of the process. Our invention will s elects the minimum set of extensions to display regarding to a specific extension in order to ease the administrator 's work. As extensions are only executed in accordance with their *Condition of Application* this takes an important role in our selection.

This mechanism takes place in 4 steps.

In the first step the administrator builds the variables trees with values used in the *CoA*s of the existing extensions. For each variable we build a tree following the rules: a child node is a value included in it parent node and branches are disjoint values.

The second step consists in the definition of the *CoA* of a new extension. An administrator creates a new extension and starts by defining its *CoA*

The third step is about the selection of displayed extension. Based on the *Conditions of Application* of the existing extensions ($CoAs_{ext}$) and of the new extension (CoA_{new}) the isolated extension are hidden thus showing only extensions whose *CoA* may intersect with the new extension. The rules to decide if an extension is shown or hidden use the variables trees as follow:

? If CoA_{ext} and CoA_{new} belong to different trees, or
 If CoA_{new} is ancestor of CoA_{ext} (CoA_{ext} and CoA_{new} belong to a same tree),
 it is an **intersection** $\rightarrow$ show the existing extension

? If CoA_{ext} is ancestor of CoA_{new} (CoA_{ext} and CoA_{new} belong to a same tree),
 it is an **inclusion** $\rightarrow$ show the existing extension

? If CoA_{ext} and CoA_{new} belong to different branches of a same tree,
 it is an **exclusion** (**isolation**) $\rightarrow$ hide the existing extension

Finally during the fourth step the administrator fully defines of the new extension. The administrator finishes defining the new extension (*entry-*

point, branching connectors, process, order, and exit-point). The administrator uses the *order index* to solve possible ambiguity in execution order among extensions whose entry point is similar. *The order index* is a real number comprise between 0 (excluded) and 1 (excluded). The administrator is also free to narrow the *CoA* of the new extension; in that case the step 3 will be re-executed in order to possibly hide other extensions that enter in isolation to the narrowed *CoA*.

The *Extensions Table*, even if distributively managed, is a centralized set of information. This provides several benefits such as global validation or audit of the extensions. A super-administrator may perform automatic checks on the *Extensions Table* to verify that no locally defined extension is illegal regarding the base process and to verify the compliance with standards or rules that may follow the company.

Workflow engine, design & implementation

As presented in [Bergmann S., 2008] Workflow engines are generally implemented as state-machines, i.e. a model of behavior composed of a finite number of states, transitions between those states, and actions. In most of existing implementations we identify the main components of workflows engine as a *Process Table* that stores entire set of process definitions, a *Process Definition* Table that describes processes (transitions & tasks), a *Task Definition* Table that associates actual operations to process tasks, and a *Process Instance Table* that provides a view of running processes.

A workflow engine periodically selects a process from the Process Instance Table then looks up in the Process Definition Table to discover the next task to perform. Tasks are operated by human (enter data, approve action, etc.) or automated by computer (call to a web service, query on database, etc.). Then this procedure is repeated until the process instance reaches a end point in the process definition or rises some sorts of unhandled errors.

Entry point	***Condition of Ap.***	***Branching***	***Process***	***Order***	***Exit point***
Task 1	**`OS_Type=Windows`**	**unconditional**	**$E_{(1)}$**	**0.5**	Task 1
Task 2	**`user.domain=Japan`**	**parallel**	**$E_{(2)}$**	**0.5**	End
Task 2	**`user.domain=USA`**	**parallel**	**$E_{(3)}$**	**0.5**	End

Table 1 – The Extensions Table of the process shown in Figure 1

As shown in the example of Table 1, the Extension Table is basically composed of the following data fields:

(1) the *entry-point* from where in the base process the extension process must be started,
(2) the *Condition of Application* (*CoA*) that triggers the evaluation of the extension process. At edit time the *CoA* is used to detect which other extension must be shown or hidden to the administrator.
(3) the *type of connectors* to the base process that defines the branching semantic of the extension (conditional, unconditional, parallel, etc.)
(4) the *extension process itself* describing the particular adaptation to some concern,
(5) the *order index* used to order several extensions that may happen at the same point,
(6) the *exit-point* where in the base process must be resumed after the extension process termination,

We also extend the Process Instances Table with a new field, the *Exit-points Stack*, keeping references to the exit-points when executing an extension process.

We also extend the Process Instances Table with a new field, the *Exit-points Stack*, keeping references to the exit-points when executing an extension process. The scope of our contribu tion to enact a w orkflow extension model is shown by the purple box in Figure 2.

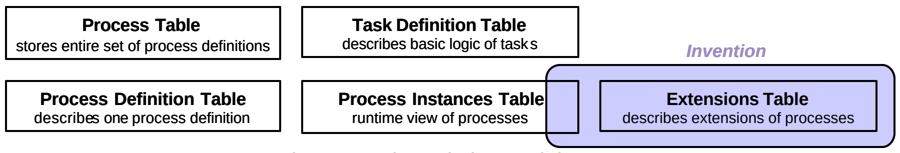

Process Table
stores entire set of process definitions
Task Definition Table
describes basic logic of tasks
Invention
Process Definition Table
describes one process definition
Process Instances Table
runtime view of processes
Extensions Table
describes extensions of processes

Figure 1 - The existing and the new

As shown in see Figure 2 the way a workflow engine operates becomes slightly different: after selecting a process in the Process Instances Table, the workflow engine picks up an extension process and identifies the next task to perform. If extension processes are found to be applied at this point (*entry-point*) they are sorted regarding their *order index* and the first extension whose *Condition of Application* is satisfied is executed in place of the regular task. The *exit-point* is registered in the Process Instance Table. This table handles the exit-points in a stack object in order to permit recursive extension. When the execution of the extension process ends, the base process is resumed at the exit point popped up from the stack. Bold tasks and labeled transitions are parts of our contribution.

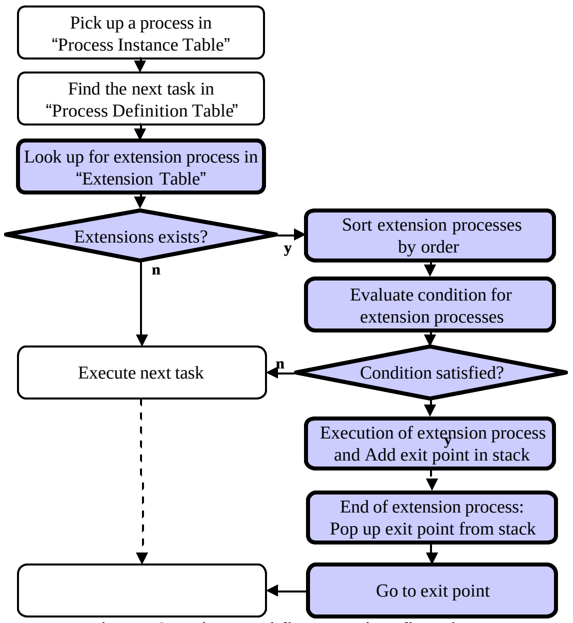

Pick up a process in "Process Instance Table"
Find the next task in "Process Definition Table"
Look up for extension process in "Extension Table"
Extensions exists?
y
n
Sort extension processes by order
Evaluate condition for extension processes
Execute next task
n
Condition satisfied?
y
Execution of extension process and Add exit point in stack
End of extension process: Pop up exit point from stack
Go to exit point

Figure 2 - The workflow engine flowchart

In the use case briefly introduced below (described in Table 1), the condition to evaluate the extension processes is based on some environment value such as `user.domain` and `OS_Type`. Figure 3 presents the base process associated with its extensions defined in the *Extensions Table* of Table 1.

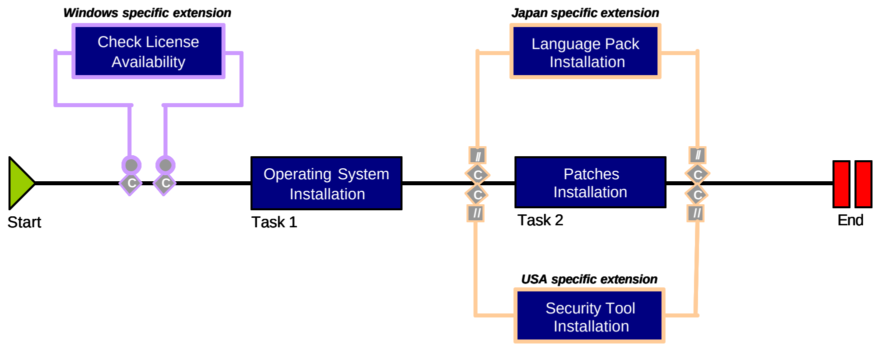

Windows specific extension
Check License Availability
Japan specific extension
Language Pack Installation
Operating System Installation
Patches Installation
Start
Task 1
Task 2
End
USA specific extension
Security Tool Installation

Figure 3 – An OS installation process with various specific extensions

The first extension ($E_{(1)}$) is unconditionally performed by all users whose domain is Japan. The two other extensions ($E_{(2)}$ and $E_{(3)}$) consists in the parallel execution of a new task along with the execution of a base process task.

Let's consider to add new extensions on the process in Figure 1. We will go through the 4 steps mechanism.

First administrators define the *Condition of Application* of the new extensions they intend to create. Let's consider three administrators who independently want to add one new extension to the base process of Figure 3. Each of them defines a *CoA* as described in Figure 4. The first administrator, on the left, wants to define an extension related to users whose domain is Tokyo. The second administrator, in the center, is introducing an extension for users in America installing a Linux operating system. Finally the third administrator 's will is to create an extension that will concern all users world-wide.

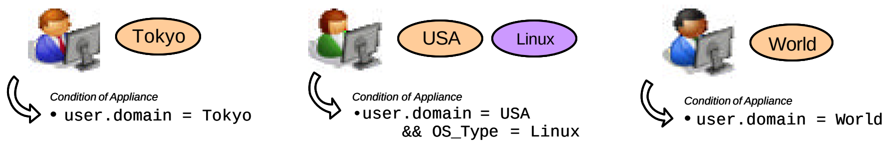


Figure 4 – Administrators define CoAs

Secondly, variables trees with values used in the *CoA* s of the existing extensions are built. Figure 5 shows possible variables trees for the process of Figure 1. The left tree organizes the different values associated with the `user.domain` variable within the extensions attached on the base process. It is obvious that the domains "Tokyo" and "Kyoto" are included in the domain "Japan". Similarly "Austin" is included in "USA", "Japan" and "USA" are included in "World", and "World" is placed under the general root case "ANY". To build the trees we rely on the data definition. We assume that variable type are defined along with some *comparable* interface or *comparator* object able to deal at least with *included* and *excluded* primitives.

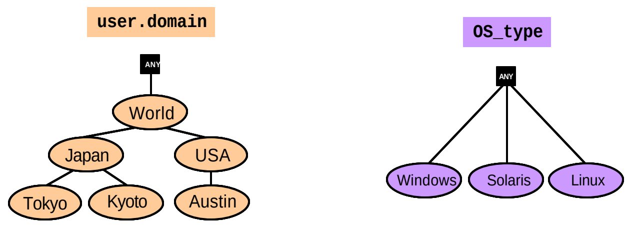


Figure 5 – Variables trees

The third step triggers the selection mechanism to identify which extensions must be shown or hidden to the three administrators. The rules to select the extension to show and hide are evaluated between the *CoA* of a new extension and the *CoA*s of existing extensions.

Finally as presented in Figure 6 each administrator will have a different view of the base process and the existing extension.

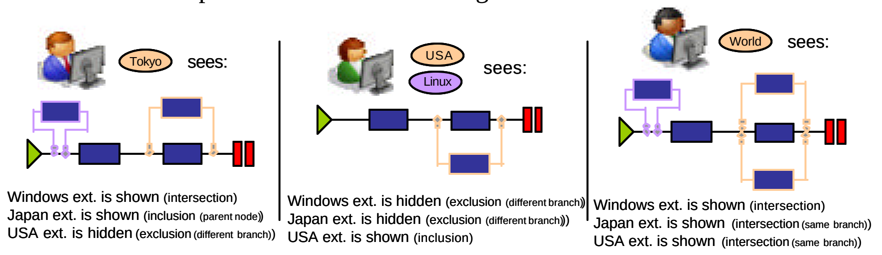
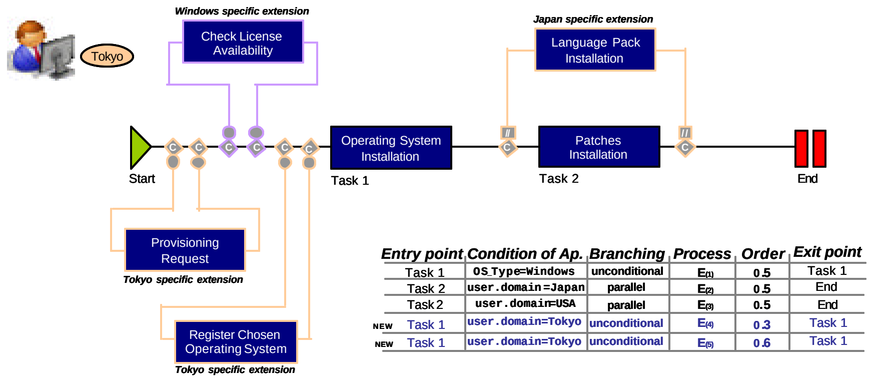

Tokyo
sees:
Windows ext. is shown (intersection)
Japan ext. is shown (inclusion (parent node))
USA ext. is hidden (exclusion (different branch))
USA
Linux
sees:
Windows ext. is hidden (exclusion (different branch))
Japan ext. is hidden (exclusion (different branch))
USA ext. is shown (inclusion)
World
sees:
Windows ext. is shown (intersection)
Japan ext. is shown (intersection (same branch))
USA ext. is shown (intersection (same branch))

Figure 6 – Administrators' view of the base process and its existing extension regarding to the CoA they provide for a new extension.

In the fourth and last step administrators fully define the new extensions. Let's continue this scenario with the case of the most left administrator who defines a Tokyo specific extension. This administrator wants to provide two new extensions before the Task1 (OS installation) for "provisioning the request" and "register the OS". An ambiguity about the order to perform those two extensions and the existing one "Check license" appears. The administrators must properly set the *order indexes* to order those extensions. Figure 7 presents the final view of the process after the administrator complete to define the two new extensions.


Tokyo
Windows specific extension
Check License Availability
Japan specific extension
Language Pack Installation
Start
Operating System Installation
Task 1
Patches Installation
Task 2
End
Provisioning Request
Tokyo specific extension
Register Chosen Operating System
Tokyo specific extension

	Entry point	Condition of Ap.	Branching	Process	Order	Exit point
	Task 1	`OS_Type=Windows`	unconditional	$E_{(1)}$	0.5	Task 1
	Task 2	`user.domain=Japan`	parallel	$E_{(2)}$	0.5	End
	Task 2	`user.domain=USA`	parallel	$E_{(3)}$	0.5	End
NEW	Task 1	`user.domain=Tokyo`	unconditional	$E_{(4)}$	0.3	Task 1
NEW	Task 1	`user.domain=Tokyo`	unconditional	$E_{(5)}$	0.6	Task 1

Figure 7 – The process view of the administrator after addition of two extensions and the Extensions Table.

Conclusion

The major benefit of our approach is an increased manageability of the business processes. Related works hardly deal with the administration of dynamic processes and only focus on the extension execution rather than considering the entire life cycle of processes and process extensions.

In order to give an evidence of the eased management introduced by our workflow extension model we will consider the case of an international organization whose offices are spread in various countries. The head office of this organization wants all its foreign offices to observe the rules and process it defines. On the other hand those offices will ask for adaptations of the processes to comply with their local laws, customs, or business rules. In a workflow model that does not permit the creation of extensions the general administrator (or administrative group) receives unceasing requests for integrating local adaptations to the general processes. It commonly results in several problems: 1) the administrator may have a limited knowledge or understanding of all local constrains and so produce errors in the adaptation he provides; 2) in case of sudden peak of requests the central administrator role represents a bottleneck that delays the creation of adapted processes; 3) the central process resulting from all adaptations is very complex and error-prone; 4) moreover any new modification of an existing adaptation that regards only one local office has to be propagated to all local offices even if they are not concerned by this adaptation.

To make it more concrete let's use an example to track how many modifications and updates are necessary with and without our workflow extension model. Let's consider a company composed of 10 divisions (head office, foreign offices, financial department, IT department, etc.). The head office produces business mainlines under the form of base processes that all other divisions would follow. Each of those divisions is free to add its own extensions on top of the base processes. Once the set of processes and extensions has been created, we are interested in observing their life cycles.

Without a workflow extension model, the processes are common to all the company's divisions and completely integrate the entire set of adaptations. Adaptations usually take the form of conditional branching in the processes. The current result is that any modification required by a division, even for its exclusive purposes, is shared with the entire company in a process definition becoming more and more complex has the company size is growing. Moreover confidentiality may be an issue: for instance the IT division may not be aware of internal procedures of the financial division. In this configuration if a division, let's say the IT division, introduces numerous extensions and modifies them often the entire set of users, from all divisions, will have to suffer from the numerous migrations to the ever new versions of the globalized processes.

With the workflow extension model we described, the impact of modifications and updates are limited to the division that has produced them. Let's imagine the distribution of employees is equal within all the division. In the scenario presented above only 10% of the employees (the IT division out of 10) suffer from the migration of the processes to its new version. 90% of process migrations are avoided. Moreover only the persons who are concerned by a specific adaptation are concerned by the updates of this adaptation. It is easier for an IT guy to understand what is changing in the process he uses that it is for another guy who never uses this particular adaptation in a globalized process. The last but not least advantage in moving adaptations out of a unique globalized process is to stabilize the base process. Frequent updates regarding adaptation and previously required on top of a globalized process are now performed on the extensions. It increases the life time of each version of the base processes, thus introducing a greater global stability in the set of business practices within the entire company.

In terms of software performances the addition of our extension model had no sensible impact on the load of the application. CPU usage does not vary as our implementation relays on existing mechanism and consists mainly in the re-routing of the flow rather than the introduction of additional mechanisms. The memory usage remains constant because no dynamic value is stored in memory; the architecture model keeps all information in database. The data storage that maintains process definitions increases in a near insensible way. Only the definitions of extension are added. The definitions of nodes and objects that consume much lager of space are not changed. Finally the logic itself only introduces a lookup to find existence of extensions and if several extensions exists in the same point a sort. Those operations are negligible in the whole process: they represent less than 0.1% of the operations required for the flow to move from one task to another.

To conclude, by opposition to existing solution our approach is much more dynamic and adaptable as extensions can be plugged or removed without modification or copies of base process. The governance of final workflows is share between different entities thus dividing the complexity of base workflow. The edition of new extensions is eased by hiding existing extensions in isolation. Finally the *Extension Table* centralizes the information about all extensions thus allowing simplified inspections and audits.

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