Business Intelligent Agents for Enterprise Application Integration: the link between Business Process Management and Web Services

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Abstract

The first IT-applications were supporting the more functional domains in an organisation and were islands in the organisation. Afterwards came other domains and the need of integration of all these functional applications became a critical issue for the management of the organisation. With the hype around Business Process Reengineering and the raise of Internet, more specifically e-Business, the priority was given to the efficient and effective working of the business processes in an integrated way, because the processes need more speed and throughput to act and react in the faster world economy.
Enterprise Application Integration was the response for the interconnection of the islands of information systems of the different functional domains in a company or network of companies throughout the Internet. In this context web services became the way to go for most of those companies.
Web services are self contained and self described modular applications, which can be published, discovered and employed on the Internet (Web). The BPM-people understood immediately the potential of using web services in the application supporting the business processes.
However, programmers need to make the link between a web service and the application that supports a step in a business process. By adding intelligence a Web Service could select, evaluate, choose and invoke other Web Services. Just like intelligent agents can act and react on their environment. In this case it is the business context. We call them BIA: Business Intelligent Agents. A program (or another IA) or a human (through a web application) can activate the BIA. In the first situation, the BIA can work autonomously; in the other situation, it will assist a human in the selection and handling of the web services.
Regarding the workflow systems, a BIA can perform in the four models (Ad hoc, Production, Administrative, Collaborative). The ad hoc system will mostly be used to assist a human in the finding of solutions for his/her problem. The other three systems may be applicable for humans and automated process. With the BIA, workflow servers can be transformed in or replaced by more flexible BPM-servers. BIA has to interface with BPM-tools for receiving the basic workflow or business processes.
In a first phase, a hybrid system has to be constructed because web services are not enough available and semantics are not standardised. In a second phase, when the conditions will be met, BIA will generate their own workflow.
If all transactions will move towards web services based system, then a more transparent, but more safe networks and storage will be a necessity. A client looks for services and makes his choice to perform transactions. Messages, information, any electronic object will be transported and stored in Electronic Object containers (EOC), during and after the business transaction. The logistic of EOC is of no concern for the client; all attention will be given to the business transactions.

Key-words:

Enterprise application integration, business process management, intelligent agents, Web Services

1. Introduction and overview

The purpose of this paper is to prove that there is a business case (i.e. an economical need) for integration of Business Process Management (BPM), Web Services (WSs) and Intelligent agents (IA). This integration is necessary to face the problems inherent to Enterprise Application Integration (EAI).
This will result in the need for a global electronic logistic infrastructure, which will safely transport and store Electronic Object (EOC) with contents of any kind, as long as it can be transformed electronically.
Early IT-applications were supporting the more functional domains of an organisation and were islands in the organisation (with a lot of functional know-how and data). Afterwards came other domains and the need of integration of all these functional applications became a critical issue for the management of the organisation.
The integration was first done at the data level. In this context the Enterprise Resource Planning (ERP) vendors made an attempt not only to let interact the functional domains and to improve them, but also to integrate the data and procedures of the different (best practices) business processes.
From the point of view of the organisation, the optimisations of the functional domains were sub-optimisations of its business processes. With the hype around Business Process Reengineering and the raise of Internet, more specifically e-Business, the priority was given to the efficient and effective working of the business processes. The processes demand more speed and throughput to act and react in the faster world economy.
Data-integration was no longer the solution; Enterprise Application Integration was the response for the interconnection of the islands in a company or network of companies throughout the Internet. In this context WSs became the way to go for most of those companies.
WSs are self contained and self described modular applications, which can be published, discovered and employed on the Internet. The BPM-people understood immediately the potential of using WSs in the application supporting the business processes. Some initiatives have been started to let business process interact with WSs, like Business Process Execution Language for Web Services (BPEL4WS).
In the remainder of this paper, the following topics will be discussed in some more detail:

- The impact of WSs in B2B and B2C environments and Business Process Management issues
- The role of the semantic web and how intelligent agents can act as intermediates between WSs and their clients
- The notion of Business Intelligent agents (BIAs) will be introduced and their role in workflow systems will be discussed
- Finally, the concept of Electronic Object Containers (EOSs) will be discussed.

2. Business Process Management and Web Services

From a business perspective, WSs can be viewed as the latest, dynamic stage in the e-business evolution, but also as a simple low cost enterprise application vehicle supporting the cross platform sharing of functions and data [18].

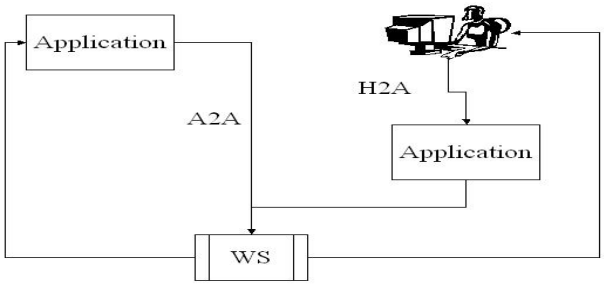

Figure 1: WSs used in A2A and H2A

WSs can be used for Business-to-Business (B2B) applications or for Business-to-Consumer (B2C) applications. However, the B2C is typically a Human-to-Application (H2A) situation, where a human always must connect to an application with a Graphical User Interface (GUI). That application can use WSs, and like for B2B, we can talk about an Application-to-Application (A2A) situation.

By using a universal communication medium (Internet, Extranet) and integration system, a company can attract additional partners (customers, suppliers, government, etc.) and improve its organisational effectiveness and efficiency [1]. As a matter of fact, WSs make it possible to exchange data and to participate in business processes (BP) between companies as well as different business units within the same company.
Some applications require transactional behaviour and context propagation. A transaction is a set of operations on the physical and abstract application level. A transaction must have the so-called ACID property: Atomicity, Consistency, Isolation and Durability. In a WSs environment, this cannot be guaranteed due to unreliable communication, uncertain duration and lack of central management [12]. An initiative to implement a transaction protocol is Business Transaction Protocol (BTP) of OASIS [11].
In a similar context, IBM has two specifications: WS-Coordination and WS-Transaction [16], which motivate descriptive transaction management. Compensation logic is typically harder to implement and to maintain than the actual services, certainly if the dependencies become more complex [16].
However, human beings do not act like applications do as prescribed by two-phase commit protocols. They act, react and anticipate actions in a larger context than an application context. Intelligent agents may act like humans, but before discussing agent technology to solve the problem mentioned above, we must first discuss the business processes structure.
A WS can be the interface between an application and automated business process (BP) (workflows). This means that BPs can exchange information and collaborate without the intervention of a human being. These are so-called executable BPs or executable workflows. Business Process Execution Language for Web Services (BPEL4WS) [16] is the main effort in this domain.
The vision behind high-level description languages, such as BPEL4WS, is the paradigm shift from distributed computing to distributed business process execution. BPEL4WS is a XML-based standard, which enables to specify processes as an aggregation of WSs. The service flows define the order of activities, where a flow is a directed graph representing activities as nodes and interactions as links connecting the nodes. The activity implementations are described via WSDL port types (Web Services Description Language).
With BPEL4WS, generic (abstract) processes can be defined that contain empty activities. The work on the BP definition can therefore be separated from its implementation (in analogy with the Object Oriented paradigm). So if we look at a definition of a BP as a set of logically connected activities to attain a certain objective, WSs can represent these activities. This implies that an electronic BP (eBP) can be a set of logically connected WSs to realize a certain business objective. This eBP can be internal to one organisation or can span several organisations.
A Business Process Management Server (BPMS) can manage those eBP. A consequence of BPMS is that BP managers can organise their BPs without the help of programmers. The programmers must only focus on the WSs and the underlying code, a consequence of the paradigm shift from distributed computing to distributed BP execution.

3. Business Intelligent Agent

There will be a lot of eBP available on the Internet. As a consequence, the number of WS will exponentially grow. Similar to Web pages, it will become more and more difficult to discover the right WS. Some intelligence will be needed to help the applications or the people to find the WS, which are required.
The solution for the problem with the Web pages is the Semantic Web. It is the representation of data on the World Wide Web. It is based on the Resource Description Framework (RDF), which integrates a variety of applications using XML for syntax and URIs for naming [17]. The idea behind the semantic Web is to make the Web as intelligent as possible.
In Figure 2, the intelligent agent (IA) is the intermediary between the WS and its clients (a human or an application). This implies that the IA has to be able to evaluate the WS. The next logical step is that WS receives the same capabilities of searching, evaluating, selecting and invoking other WSs. WSs advertise their own capabilities, search for other services on the web and invoke them without prior design. These WSs can reason about their capabilities to combine services and negotiate. Using agent technologies, WSs can become autonomous, reactive, proactive and social. In that way, a WS can interact with other services in a learning process. It can rate others services by remembering their capability, service quality and performance and thus build up skills to choose the best ones to form its won service with the highest quality in the current circumstances [12] (Figure 3)

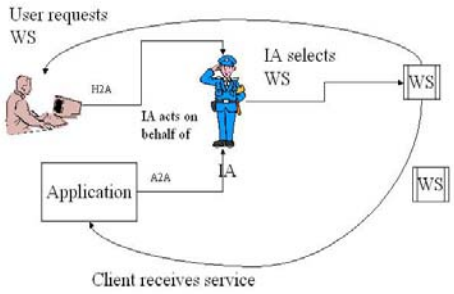

Figure 2: BIA and WS

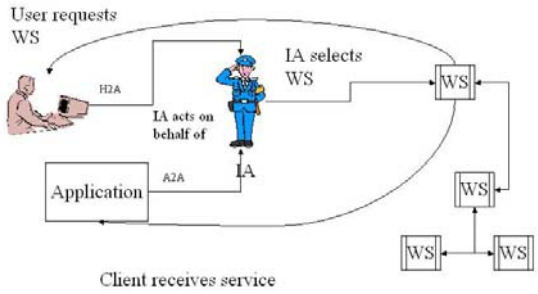

Figure 3: BIA and Intelligent WS

Therefore WSs should be enriched with a semantic dialogue interface, so they can promote themselves what they are capable of doing (delivering services). To be a flexible and dynamic system, autonomously acting software must be considered. Daconta et al. [2] see the solution for the advanced WS application involving comparison, composition or orchestration of WS in the use of semantic Web technologies for such interactions to be automated. A merge of WS with Semantic Web can indeed be a solution [13].
Before going into more details on the use of IA in a business context, we would like to define what an IA is. Knapik et al. quote Atkinson [7]: "Intelligent Agents are software entities that carry out some set of operations on behalf of a user or another program with some degree of independence or autonomy, and in so doing, employ some knowledge or representation of the user's goals or desires." Another quote of them is about a generic operation definition (of Majewski). An IA should have:

- Autonomy: Agents operate without the direct interaction of humans or others, and have some kind of control of their internal state.
- Social ability: Agents interact with other agents (and possibly humans) via some kind of agent communication language.
- Reactivity: Agents perceive their environment and respond in a timely fashion to changes that occur in it.
- Proactivity: Agents do not simply act in response to their environment; they are able to exhibit goal-directed behaviour by taking the initiative (For ethical reasons, some authors as Murch et al. [9] do not accept that IA are self-motivating).

Related to eBP, intelligent agents act and react to their environment, which in our case is the business context. We call them BIA: Business Intelligent Agents. A program (or another IA) or a human (through a web application) can activate the BIA. In the first situation, the BIA can work autonomously; in the other situation, it will assist a human in the selection and handling of the WSs.
BIA can be used to perform a business process or a part of a process. Who says business process, says also business transactions. The BIA should not only be able to build up transactions, but also resolve the problems of stopping an ongoing, not fully terminated transaction.
Mamar et al. [19] propose a system of interleaving WSs, meaning that the composition and execution of WSs may be done in parallel. As a consequence, this allows handling the execution of context of the WS (dynamic information). They use IA software to implement this capability, and by doing this, WSs can delegate their work to each other.
Research has also been done to dynamically bind WSs, so that WSs provide clients with runtime information that is pertinent to its execution and business logic. When faced with multiple service providers who can provide the same functional service, the client can dynamically select the current best service provider for its required service, according to the client's constraints and information gathered about the service providers at runtime [10].
Of course, if WS have the same intelligence as BIA, WS can invoke other WS or even IA. In this situation we have a cascade of WS or IA. However, it would be more preferable that the eBP itself -through its IA- would determine which WSs is the best suited to fulfil its need, regarding some criteria as objective coverage, reliability, availability and price. Cascading of WS with the control of the eBP or at least the logging by the eBP must be considered to evaluate the quality of service (QoS) of the different WS. Research has to be done to find a system of evaluation of QoS (e.g. estimated response time, reliability, expected output), combined with the financial evaluation.

Besides working with WSs, the BIA must work with non-web services programs. This implies that the BIA must be capable of generating another type of agent, which interfaces with those systems. In the other way, the BIA is also a service for other programs, so it can publish its services just as WSs. In that case the BIA has to generate another agent that will be responsible for the publishing and handling of WSs requests.

Workflow systems

Regarding the workflow systems, a BIA can perform in the four models:

- Ad hoc: undefined procedure and routing
- Production: well defined procedure, high transaction rates
- Administrative: well defined procedure, low transaction rates and distributed across multiple locations
- Collaborative: well defined procedure, flexible routing

The ad hoc system will mostly be used to assist a human in the finding of solutions for his/her problem. The other three systems may be applicable for humans and automated processes. With the BIA, workflow servers can be transformed in or replaced by more flexible BPM-servers. BIA has to interface with BPM-tools for receiving the basic workflow or business processes.

In a first phase, a hybrid system has to be constructed because WSs are not sufficiently available and semantics are not standardised. In a second phase, when the conditions will be met, BIA will generate their own workflow.

4. Electronic Object Container (EOC)

One of the results of the interpretation of the work "Business Process Reengineering" of Hammer and Champy [5] was the Holonic Enterprise [8]. Companies work together in a virtual organisation called the Holonic Enterprise. It is a networked organisation where (ideally) every company does outsource its non-core business to the other nodes (called holons). The huge obstacle at that time was the heterogeneity of applications and computer systems. Easy integration of the processes through ICT was quite impossible.

Fortunately, the hype of Internet moved people and companies to more open systems. If all transactions will move towards WSs based system, then a more transparent, but more safe networks and storage will be a necessity. A client looks for services and makes his choice to perform transactions. Messages, information, any electronic object will be transported and stored in Electronic Object containers (EOC), during and after the business transaction. As such the logistic of EOC should not be a concern for the client; ICT will become a commodity and all attention will be given to the business transactions.

A part of a possible solution for the implementation of an EOC-infrastructure is GRID-computing [18]. GRID [14] is a resource sharing technology without a central control instance, spanning multiple institutions across the network. GRID-technology covers any type of computing resource (storage, CPU, etc.) as well as applications supporting BP and their individual activities. It promotes flexible configuration of BP running on a GRID-infrastructure and therefore enables short response times and on-demand adaptations to business requirements. A GRID refers to an infrastructure providing the applications of BP the transparent use of ICT-services, like storage, data repositories, wherever they are provided. Like the Holonic Enterprise, a GRID creates a Virtual Organisation (VO) and implements a sort of Meta-Operating System (Meta-OS) providing applications with functions and services that shields the underlying system resources and their specific implementation technology.

The GRID technologies include security solutions that support management of credentials and policies when computations span multiple institutions; resource management protocols and services that support secure remote access to computing and data resources and the co-allocation of multiple resources; information query protocols and services that provide configuration and status information about resources, organizations, and services; and data management services that locate and transport datasets between storage systems and applications [3].

As already mentioned, WSs advertise their own capabilities, search for other services on the web, using Internet protocols and invoke them without prior design. Grid Computing act similarly: description and advertisement of services, response to service requests, invocation of services and of course accounting of used resources. [15]. As a matter of fact, the WSs framework is used in the Open GRID Services Architecture (OGSA) [4] mostly for two reasons. First, the need to support the dynamic discovery and composition of services in heterogeneous environments (WSDL); second, the widespread adoption of WSs.. Also in this domain, agent technology can be used, an example is KAoS [6].

5. Conclusion/Further Research

Already efforts have been done in the research on one hand on linking BPM with WSs and on the other hand linking intelligent agents with WSs. In our work in the applied economic science, we are constructing an economical-technical BIA-framework in which EAI will be performed for the use in the Internet, by combining BPM, WSs and Intelligent Agents, and therefore linking business closer to the ICT-services.

A result of this will be the necessity of a global electronic logistic infrastructure (as a commodity), which will safely transport and store Electronic Object containers (EOCs) with contents of any kind, as long as it can be electronically transformed.

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