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*Dynamic instrumentation for the management  
of EJB-based applications*

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THÈME 1



*Rapport  
de recherche*



## **Dynamic instrumentation for the management of EJB-based applications**

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Thème 1 — Réseaux et systèmes  
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**Abstract:** With the growing number of distributed component-based applications for enterprises, an efficient management should be applied over these applications to evaluate their performance, to provide them with a good quality of service(QoS), and to maintain them during their life cycle. In this report we focus on Enterprise JavaBeans distributed applications. We define a unified and automatic instrumentation mechanism to allow managing EJB-based applications. The mechanism is based on an instrumentation interface extracted automatically from the home and remote interfaces of EJB beans. The interface is then used by the management system of the application server hosting the EJB applications in order to generate Managed EJBs corresponding to each initial EJB bean of the application. The generated Managed EJBs form the basic elements of a management system over EJB-based applications. They are manipulated by a management application through an agent that allows the access of a number of managed objects including EJBs. We propose implementing the unified instrumentation for EJB-based applications automatically by integrating an instrumentation service into application servers hosting these applications. The instrumentation service generates a unified instrumentation interface for all EJBs living or willing to live in the application server and then it generates the corresponding Managed EJBs according to the requirements of the management system used by the application server.

**Key-words:** EJB, instrumentation, distributed application management, management systems

*(Résumé : tsvp)*

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## **Instrumentation Dynamique pour l'administration d'applications à base d'EJB**

**Résumé :** Avec l'augmentation du nombre d'applications à base de composants distribués dans les entreprises, une gestion efficace devrait être proposée sur ces applications afin d'évaluer leurs performances, de leur fournir un bon niveau de qualité de service (Qos) et de pouvoir les maintenir pendant leurs cycle de vie. Dans ce rapport, nous nous focalisons sur les applications à base d'EJB. Nous définissons un mécanisme unifié et automatique d'instrumentation afin de permettre l'administration d'applications à base d'EJB. Le mécanisme est fondé sur une interface d'instrumentation extraite automatiquement des interfaces Home et Remote des EJB. L'interface est alors utilisée par le système d'administration du serveur d'applications hébergeant les EJB afin de générer des "EJB Gérés (Managed EJB)" correspondant à chaque "EJB initial" de l'application. Les "EJB Gérés (Managed EJB)" ainsi générés constituent les éléments de base d'un système de gestion des applications à base d'EJB. Ils sont manipulés par une application de gestion indépendante par l'intermédiaire d'un agent qui permet l'accès à un certain nombre d'objets administrés comme par exemple les EJB. Nous proposons d'implanter le système d'instrumentation des applications à base d'EJB automatiquement en intégrant un service d'instrumentation dans les serveurs d'applications. Le service d'instrumentation génère une interface d'instrumentation unifiée pour tous les EJB s'exécutant ou voulant s'exécuter sur le serveur d'applications puis il génère l'"EJB Géré" de manière conforme aux prérequis du service d'administration utilisé par le serveur d'applications.

## 1 Introduction

Object-Oriented technologies have had a large impact on industrial information system development process. Object-Oriented features such as encapsulation, composition, and abstraction lead to more flexible and extensible software products. OO programming however has failed to isolate specific standard functionalities in order to be reused in different domains. Component technologies have been introduced to provide isolation and encapsulation to such functionalities and to offer them as services. While the object approach emphasizes design and development, the component approach emphasizes description and deployment [9]. The deployment term is a new convention in applications implementation which implies the maintenance of the application's components during their life cycle.

Component technologies has, then, expanded to provide distributed systems with distributed component models. Three main distributed models were presented in the industrial world : COM/D-COM from Microsoft [6], CORBA Component Model (CCM) from the OMG [8], and EJB from Sun Microsystems [23]. There are also some research groups developing component systems in the academic world [26], [4]. All of these models follow the three-tier architecture : presentation tier which is the application's entry point for end users, middle tier where middleware services reside, and the backend tier where data is maintained persistent.

Application servers are middlewares that help isolating the business logic of an enterprise application from the platform-related code. They offer standard services such as security, transaction and persistence for enterprise applications allowing the developers to concentrate on the business logic of an application.

With the growing need for enterprise distributed applications satisfying high performance, scalability and availability features, the demand for effective management, observation, and control solutions has been raised. The management of distributed applications needs additional requirements exceeding what is necessary for stand-alone applications because of the heterogeneity of the operating systems, the heterogeneity of the distributed component models, and the distribution of the manageable code.

Despite of the business application development simplicity brought by the above mentioned distributed component models, the developer still need to implement its own management code to manage its application since no management frameworks were implemented for each of these models. Although few research works handled the distributed application management [16], [35], [29], they didn't address the issue of automating the management of the distributed applications although such applications would follow one of the distributed components models.

Among the different existing distributed component models, we focus in this report on automating the management of EJB-based applications through instrumentation. The term "instrumentation" was initially used with instruments and devices. The instrumentation meant the control of hardware devices and instruments by assigning them a soft interface to configure and manage them. The term was basically used by industries, then it was introduced in the research papers in the context of enabling management of different kinds of resources including devices, network services and applications. We can now present our definition of EJB Instrumentation in order to avoid any possible confusion with other possible definitions of "instrumentation". Considering an EJB application as

an instrument, we want to define a way to manage this instrument dynamically. Enabling a dynamic control over EJB applications is what we call EJB Instrumentation. In this report we provide a unified and automatic instrumentation mechanism to free the developer from the management duties he/she has to add for the EJB applications in order to enable them for management.

The report is structured as follows. Section 2 presents our motivation. Section 3 provides an overview of instrumentation and application management, we first present the management principles, then the architecture of management system, and finally we present an overview of distributed application management. In section 4 we introduce the EJB instrumentation architecture. In section 5 we present some related work. We finally conclude by summarizing our work and presenting few perspectives in section 6.

## 2 Motivation

Java was the first programming language that presents the notion of WORA (Write Once, Run Anywhere). The success of Java came from this notion that relieved the developers from rewriting the same code for different operating platforms. Since then, all other information technologies were directed to be used in a standard way with different underlying technologies. Likewise, the Java 2 Enterprise Edition (J2EE) [14] introduced the EJB technology which is a standard way to implement distributed Java applications that are runnable on different application servers. To continue this chain of standardization we need a standard way to manage EJB applications.

Meanwhile most of the J2EE-compliant vendors include ad-hoc management solutions in their products. Some application servers like iPlanet [11], AppServer [32], WebSphere [38] handle manageability by adding SNMP (Simple Network Management Protocol) agents [5]. Other application servers like JBoss [15], BEA Weblogic [37] and IONA iPortal [12] handle manageability by adding JMX (Java Management eXtensions) agents [22]. In both cases, manageability is limited to the basic services offered by the application server itself like naming, transaction, and security. None of the presented management solutions handled the management of the hosted application functional code. That is why we try in our research works to define a unified way to instrument EJB applications.

We also aim to perform the EJB instrumentation automatically, which frees the application developer from the heavy management duties. Being both unified and automatic, EJB instrumentation presents several benefits :

- **Standardization** : A unified EJB instrumentation allows heterogeneous management systems to access the same instrumented EJB application.
- **Management user interface** : performing automatic instrumentation over EJB applications facilitate building management user interface automatically while instrumenting the EJB application without the need to code it manually by the developer.
- **Dynamic management** : EJB instrumentation allow dynamic management over EJBs. This functionality provides the management system with flexible management over applications while they are running.
- **Fault tolerance** : Enabling dynamic management over EJB-based applications provides them with the ability to repair failures when occurring since the management application will be

able to : access the application dynamically, stop the infected component, and reinitialize it with its last operational state.

- **Load balancing** : EJB instrumentation enables the management system to collect management information describing the activity of each component of the EJB-based applications. When the system is over loaded with so many client sessions connected to the same station, the management system can migrate one or more application(s) to a more free station according to some load balancing algorithm and redirect clients transparently to that station [2].

## 3 Management and Instrumentation

### 3.1 Management and Instrumentation

- *Management* is the mechanism of observing and controlling system elements. Elements might be devices, services, or software applications. Each element in the system needs to be instrumented in order to enable an overall supervisory and control activities to the whole system.
- *Instrumentation* is the process of providing a descriptive interface defining the management information and the operating modes of the element in order to enable it for management. Each element of the system is instrumented according to its type and to the required management functions.
- *Management systems*, that are responsible to ensure the overall management of the underlying system, use the management information of all the elements in the system in order to provide major management functions like life cycle, configuration, performance, security, and fault management.
- *Alarm notifications* are sent by the instrumented elements to the management system when a pre-defined event is occurred. Events which are critical for management functions are specified according to a set of measures that defines the performance and operating indicators of the system's elements.

According to the type of event received by the management system, it performs pre-set operations in order to provide the underlying system with the required Quality of Service at a reasonable cost.

### 3.2 Management systems

While some success has been realized in the areas of system and network management, only few efforts have been paid on the management of distributed applications. Despite of the huge existence of different management standards and technologies, they were directed to manage networks and their devices. There are mainly two well known management protocols : The Simple Network Management Protocol (SNMP) [5] which is an IP-oriented protocol, and the Common Management Information Protocol (CMIP) which is based on the Open System Interconnection (OSI) [13]. Both SNMP and CMIP define management standards, management services and management protocols. This makes them viewed as management frameworks rather than management protocols.

Other management frameworks are also available but are not yet widely adopted and still under improvement, these include : the CIM/WBEM (Common Information Model/ Web-Based Enter-

prise Management) [7] which is a set of management and Internet standard technologies developed to unify the management of enterprise computing environments. Sun has also defined its own Java specification for the management of Java applications and called it JMX (Java Management eXtensions) [22]. While SNMP and CMIP are network management oriented, CIM/WBEM and JMX are application management oriented and can be dedicated to distributed object computing in order to manage distributed applications.

Despite of the wide variety of management standards [33], [19], most management system frameworks follow the Manager/Agent architecture pattern showed in figure 1. The architecture has three component levels :

- - **Managed object** : is an abstraction for a device, a service or an application. It exposes the appropriate data in the form of an interface for use by a management system. The data contains both attributes to be monitored and operations that can be performed to control the underlying resource.
- - **Agent** : is the responsible of the direct interaction with the managed resource. It is the only component capable of performing management operations exposed by the managed resource. The agent provides some other management services to be used by management applications like the scheduling service and the event notification service.
- - **Manager** : is the application responsible of managing one or more resources on a network. It communicates with the agent to collect management information and to perform management tasks on the Managed resources associated with the agent.

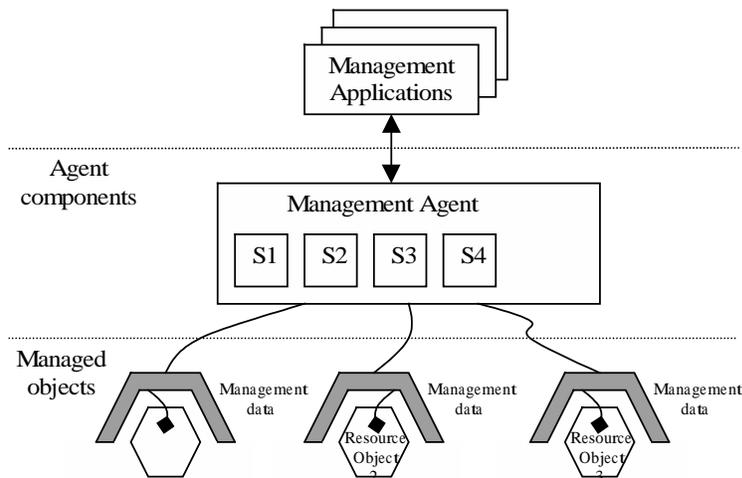


FIG. 1 – Manage/Agent architecture model

In our research work we apply this architecture to manage distributed applications. We focus mainly on the management of J2EE applications and more precisely on the instrumentation of EJB

applications. Our work consists mainly on automating the transformation of an EJB bean into a managed object. We then work at the first level of the above described architecture.

### 3.3 Distributed Applications Management

With the growing number of complex distributed applications having a large number of components, the need for effective management over the whole system is increasingly important. Unlike stand-alone applications, distributed applications are mission critical since they are expected to serve many client sessions all at the same time and are expected to be continuously available for clients. This would require applying management over all the components, their behavior, their functionality, and their life cycle in order to manage their creation, suspension and reactivation. High manageability of distributed applications is then very essential for enterprise applications to provide their clients with a high quality of service.

Most of the work on quality of service has concentrated on the network and communications infrastructure. Recently, QoS has also become increasingly important in distributed applications due to the increasing use of internet which facilitates the access to the distributed applications. Many efforts were paid on performance, monitoring, and tests of distributed system [17]; some of them were applied on CORBA distributed applications [31] and others were applied on EJB applications [25], [28]. Although no standard parameters for the QoS of EJB applications are defined yet, the QoS should be taken into consideration when developing EJB applications which would essentially implies effective management over EJB applications.

Until now, management tends to be developed specifically for one application since different applications have different specialties, different structures, and different goals. Nevertheless, with the arrival of the component standards (CCM, COM+, EJB), distributed applications following the same model could be managed in a standard way using one of the existing management frameworks [5], [13], [7], [3] since none of these component models defines its own management framework yet.

## 4 EJB Instrumentation Architecture

In this section we define an architecture to instrument EJB applications dynamically and automatically in a unified way. The architecture doesn't depend on a specific application server or on a specific management framework so that it can be applied for different application servers with different management systems.

An EJB application contains a number of EJB beans packaged together in a Jar file with an XML descriptor that contains all information about the EJB beans characteristics and their usage of the services provided by the application server. The main services provided to EJB applications by their hosting application servers are : Transaction, Security, Persistence, Messaging, and Naming. Some application server vendors provide additional services such as an administration service to monitor the activities of the application server. Although this administration service provides a kind of management over the EJB's containers, they don't handle the instrumentation of the EJB functional code that represents the business behavior of an application.

Our instrumentation architecture is based on integrating a new instrumentation service beside the existing ones to provide all EJB beans in an EJB-based application with an instrumentation interface that can be used later by different management systems in order to build the corresponding managed EJBs.

The instrumentation interface is a description of how an EJB can be managed. Some research works [30] proposed an object management interface description that extends the interface description language known from CORBA and DME (Distributed Management Environment) compliant systems [27]. In our instrumentation architecture we followed the same interface description with XML as a description language.

In the rest of this section we first present our view of a managed EJB, then we describe the parts of the EJB instrumentation interface, and finally we introduce the architecture of the instrumentation service.

## 4.1 Managed EJB

Each component of a distributed application should be a managed component in order to enable the whole application for management. Thus to manage an EJB-based application, each of its EJB beans should be transformed into a managed component that we call managed EJB. The main problem that rises in application instrumentation is defining the parts of the code that need to be instrumented in the application. This process often requires human intervention in order to choose the critical parts of an object to be instrumented. While some methods would be necessary to automate the placement of instrumentation code in a large number of applications, EJB applications are already structured in a way that the different parts of the code are well defined. This allows the selection of instrumentation parts automatically and in a unified way for all EJBs. Home and Remote interfaces of an EJB bean defines the important methods of an EJB to be managed.

The home interface defines the bean's life cycle methods : creating new beans, removing beans, and finding beans. These methods can then be used to manage the life cycle behavior of the EJB bean. The remote interface defines the bean's business methods : the methods that the bean presents to the outside world to do its work. These methods can be used to manage the business behavior of the EJB bean. Thus, both life cycle methods and business methods should be presented in the instrumentation interface since they play an essential role in the management of EJBs. Figure 2 shows the abstract architecture of the Managed EJB.

## 4.2 EJB Instrumentation interface

One of the most time consuming challenges in information technology has been to represent data in a standard way so that it can be manipulated by and exchanged between heterogeneous information systems [1]. Presenting the data in a neutral specification language such as XML can greatly reduce this complexity and create data that can be read by different types of applications. Thus, to create the instrumentation interface we chose to use the XML language that has proven its strength and flexibility to define standards in different domains [9]. Each management system can then access this interface, parse it, and create its appropriate managed object describing the underlying EJB. Any

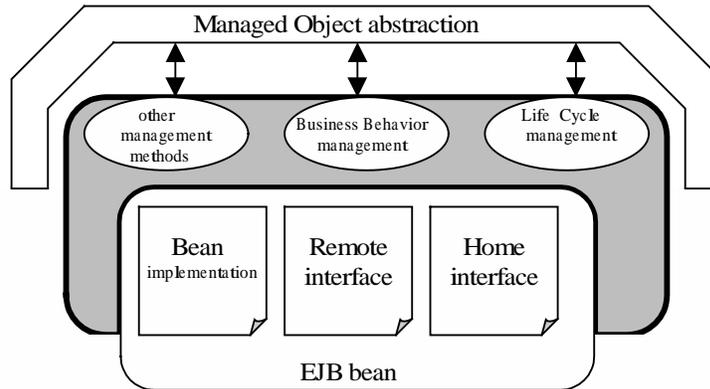


FIG. 2 – Abstract architecture of a managed EJB

XML document can be transformed automatically to another document form conforming to the management system using the XSLT [36] which uses an XML parser to transform the XML document into any other document form according to a style sheet transformation document.

The EJB instrumentation interface is then written in XML, and is based on a previous proposed object instrumentation interface that consists of three elements : attributes, operations, and states [30]. We followed this interface description after including few modifications to adapt it to EJB beans. Dealing with Java beans, object's attributes are not accessed directly since they have their corresponding getter and setter methods. Thus we gathered both attributes and operations under one management category, the business behavior management category. The object states represent the life cycle management category. Beside these two management categories we added a third one that is appropriate to EJB-based applications, the EJB QoS management category.

- Life cycle Behavior management :  
The first task of EJB Instrumentation is to manage and monitor the life cycle for each EJB instance. This management category allows dynamic instantiation, deletion and locating of EJB objects and can be used to perform some statistics on instances in their different states which allows performance testing of the EJB application, the application server, and the configuration specified by the EJB application developer. Life cycle behavior management methods are extracted from the home interface of the EJB bean.
- Business Behavior management :  
The second task of EJB instrumentation is to manage the business behavior of an EJB bean by managing all of its business methods. Managing these methods would allow us to test the time needed to have a response from the method, the number of times a method is called, and other management information depending on the requirements of the manager application. Business behavior management methods are extracted from the remote interface of the EJB bean.
- QoS methods :

The QoS methods allow a global management over the EJB application. They allow testing the pre-set parameters to ensure a specific quality of service. In contrast to both business and life cycle behavior methods that depend on the implementation of the EJB, QoS methods are independent on the implementation of the EJB beans ; that is, they are applicable to all EJB beans. The goal of these methods is to gather information about the performance properties of the application in order to perform the appropriate actions to provide a better quality. These methods may include : getting the number of instances for each EJB bean of the EJB application, getting the most active EJB beans, allowing EJB migration, and others.

This instrumentation interface is generated automatically from the EJB code thanks to the direct relation between the main parts of an EJB bean and the above mentioned three management categories. The generation is done automatically by the EJB instrumentation service.

### 4.3 EJB instrumentation service :

To allow EJB instrumentation for all EJB applications deployed in an application server we need to integrate a new instrumentation service beside the standard services offered by all application servers. The main task of the EJB instrumentation service is to create automatically the instrumentation interface for each EJB bean of a new deployed EJB-application in order to implement its corresponding managed EJB. The managed EJB represents the managed object level of a management framework. For example, in the JMX management framework the abstraction of a managed resource is called Managed Bean or MBean, thus with JMX the managed EJB needs to be implemented as an MBean.

The managed object is generated automatically from the extracted XML instrumentation descriptor. There will be as many managed EJBs as there are EJB beans in the application. Figure 3 shows the architecture of the proposed EJB instrumentation.

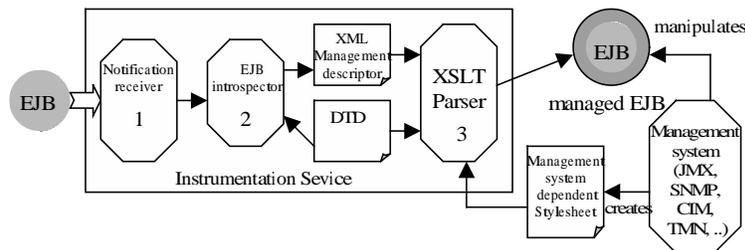


FIG. 3 – EJB instrumentation architecture

The EJB receiver (1) is responsible of receiving new deployed EJB applications. For each EJB bean of the application the notification receiver retrieves both the home and remote interfaces and sends them to the EJB introspector (2) which generates the corresponding XML instrumentation descriptor that conforms to the EJB instrumentation DTD.

The XSLT parser (3) is the last part of the instrumentation service. It allows different management systems to access the XML management interface and produce their own managed objects accordingly. The transformation from XML to the corresponding managed object is done automatically applying the transformation stylesheet that describes how the XML management descriptor should be transformed to produce a managed object dependently on the management system implementation.

The produced managed EJB can be seen as a wrapper of the managed parts of the EJB. It receives the method invocations for the managed methods and redirect them to the underlying EJB.

#### 4.4 Example : HelloWorld managed EJB

We implemented the service on the JBoss application server that uses JMX as its management framework. JMX provides an HTML adaptor which presents the agent and its MBeans as HTML pages viewable in any web browser. Methods presented in the MBean interface can then be accessed and viewed through the HTML adaptor. It also provides additional protocol APIs for interacting with existing management environments. These APIs are still under development as JSRs [21], [20] within the Java Community Process.

The instrumentation service generates an MBean for each EJB bean of the application that will be registered in the MBeanServer of the JMX management framework. Once registered to the MBeanServer, each MBean exposes its management interface for other MBeans in the same MBeanServer and for manager applications willing to perform management operations over the EJB application. Having an HTML adaptor, the JMX MBeanServer generates automatically an HTML view for each MBean. Providing this utility we can access and perform operations on managed EJBs directly from an HTML browser without the need to create a specific client application.

To show the steps that an EJB bean passes through in our management framework we present HelloWorld EJB example. We deploy the HelloWorld EJB on the application server where we have integrated the EJB instrumentation service. Listings 1, 2, 3 shows the three main classes of the EJB bean.

Listing 1 – HelloWorldBean implementation

```
public class HelloWorldBean implements SessionBean {  
    String message;  
    public void ejbCreate(String message){  
        this.message=message;  
    }  
    public String getHelloMessage() {  
        return this.message;  
    }  
    public void ejbPostCreate(){}  
    public void ejbRemove(){}  
    public void ejbActivate(){}  
    public void ejbPassivate(){}  
    public void setSessionContext(SessionContext sc){}
```

```
}
}
```

Listing 2 – HelloWorld Home interface

```
public interface HelloWorldHome extends EJBHome{
    HelloWorld create(String message) throws RemoteException , CreateException;
}
```

Listing 3 – HelloWorld Remote interface

```
public interface HelloWorld extends EJBObject{
    public String getHelloMessage() throws RemoteException;
}
```

After the introspector phase of the instrumentation service the XML instrumentation descriptor showed in listing 4 will be generated.

Listing 4 – HelloWorld XML instrumentation descriptor

```
<?xml version="1.0" ?>
<!DOCTYPE MBean SYSTEM "MBean.dtd">
<MBean name="HelloWorld">
<BusinessMethods>
<method name="displayMessage"
        id="0"
        abstract="false"
        static="false"
        synchronized="false"
        volatile="false"
        transient="false">
    <type>String </type>
    <throws />
</method>
</BusinessMethods>
<LifecycleMethods>
...
</LifecycleMethods>
<QoSMethods>
...
</QoSMethods>
</MBean>
```

The XSLT parser will take the above XML instrumentation descriptor and produce, corresponding to a Style sheet, the appropriate MBean representing this EJB.

Listing 5 shows the two main classes of the managed EJB.

Listing 5 – InstrumentedHelloWorld MBean class

```

public class InstrumentedHelloWorld implements InstrumentedHelloWorldMBean{
    Vector beanInstances=new Vector();
    //Life Cycle Methods
    public String create(String msg){
        Context ctx=new InitialContext();
        Object ref = ctx.lookup("HelloWorldBean");
        HelloWorldHome home = (HelloWorldHome)
        PortableRemoteObject.narrow(ref , HelloWorldHome.class);
        HelloWorld instance=
            beanInstances.addElement(home.create(msg));
        newInstCreated(instance);
        return "Instance"+hell;
    }
    //business methods
    public String getHelloMessage(){
        HelloWorld requiredInst=getInstance();
        getHelloMessageInvoked(requiredInst);
        return requiredInst.getHelloMessage();
    }
    //QoS methods
    public void newInstCreated(){...}
    public void getHelloMessageInvoked(){...}
    public int getActiveInstanceNumber(){...}
}

```

Listing 6 – InstrumentedHelloWorld MBean interface

```

public interface InstrumentedHelloWorldMBean{
    public String create(String msg);
    public String getHelloMessage();
    public int getActiveInsanceNumber();
}

```

## 5 Related work

Similar studies were presented in the past by a research group at the university of western Ontario in Canada /citekatchabaw97, [10], [34]. They were directed to manage distributed applications through instrumentaion, but they considered that management should be added to applications while they are being developed which would make it heavier to the developer to implement the application. These studies were directed to object approaches while our work is directed to component approaches.

Another research group in Spain is currently working on an European project [18] devoted to the management of EJB-based applications. Some of their experiences in the management of EJB-based

applications where presented in Germay /citeasensio01. In fact, they instrument EJBs by wrapping them manually into Model MBeans of the JMX management framework.

Finally, Sun is now developing the Java 2 Enterprise Edition Management Specification [24] that seems to be implemented based on JMX framework. The specification defines a common framework for the delivery of Java enterprise management and monitoring services. In addition, it handles the mapping to both SNMP and CIM/WBEM. The specification is not complete and until now it doesn't seem to handle automatic instrumentation although it defines MEJB which is itself built as an EJB component. We are still waiting this Management framework to combine our instrumentation solution with it since we believe they do complement each other.

## 6 Conclusion and perspectives

The work we describe here is part of an ongoing research works on EJB management and services integration in application servers. In this report we propose instrumenting deployed EJB applications by integrating a new instrumentation service to the application server. The instrumentation service generates a managed EJB for each EJB bean of the application. The managed EJB enables management application to perform management operations on the underlying EJB bean dynamically while it is running.

Although we implemented the managed EJB as MBeans of the JMX management framework, the instrumentation service can be used with other management frameworks since it provides a management descriptor that can be used to produce managed EJBs conforming the description of the desired management system. The management descriptor can be written in a neutral language as XML or even with any other definition language.

Instrumenting EJBs allows managing EJB-based applications without changing the application's code, and without considering management at development time. This would free the developer from additional work which is considered as standard functionality for all EJB-based applications since they all follow the same logic of development.

EJB instrumentation is the first step toward managing EJB-based applications. Manager applications for EJB-based applications that will use the managed EJBs should also be studied in order to perform global management over one or more EJB-based applications.

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