System Architecture of the BIVEE Platform for Innovation and Production Improvement

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Abstract. The BIVEE acronym stands for Business Innovation and Virtual Enterprise Environment. The ICT outcome of the BIVEE Project is the BIVEE System: an integrated solution enabling business innovation in virtual factories and enterprises. In line with the Future Internet vision, the BIVEE System is delivered as a set of modular applications deployed on top of a commodity, cloud-ready service platform, This service platform, named *BIVEE Platform*, provides a base layer of data, knowledge, services and capabilities. This paper briefly describes the BIVEE Platform, from both the conceptual and the technical point of view.

Keywords: BIVEE, Innovation, Virtual Enterpise, Platform, Future Internet, FInES, FI-PPP, ISU, Generic Enabler, Knowledge Base, Ontology, KPI.

1   Introduction

Quoting from the BIVEE Project's Description of Work document: "*Business Innovation is the most promising exit strategy for European manufacturing industry to recover from the current economic crisis… The   BIVEE   Project aims to develop a conceptual reference framework, a novel management method and a **service-oriented ICT platform** … to enable Business Innovation in Virtual Factories and Enterprises*" [1]. This paper briefly describes, from both the conceptual and the technical point of view, the service-oriented ICT platform proposed by BIVEE.

The BIVEE Project focuses on two areas: **value production space** and **innovation space**. Value production space is where all activities related to the core business take place, and where business models and processes are designed, deployed, monitored and adjusted over time. At the same time, to counter the natural tendency of models and processes to become obsolete in a rapidly changing scenario, continuous open innovation is promoted and fostered in its own separate – but tightly connected – space. There is a continuous information flow between these two spaces, in both directions: value production feeds innovation with new challenges, innovation feeds value production with new ideas.

Each BIVEE space is covered by a dedicated application, targeted at end users: the Mission Control Room (**MCR**) tackles value production [4], while innovation is addressed by the Virtual Innovation Factory (**VIF**) [5]. Both rely on a common, shared platform providing both with a base layer of data, knowledge, services and capabilities. The fully integrated solution – the two **BIVEE Applications** plus the **BIVEE Platform** – is collectively known as the **BIVEE System**.

The FInES Cluster Research Roadmap envisions a 2020 Internet-based universal business environment, where a common, available and affordable service infrastructure, based on the concepts of Interoperability Service Utility (ISU), will set the playing field for innovation [2].

This infrastructure is seen as a commodity: basically, it results from the aggregation of several generic, stable and well understood building blocks – implemented by commodity software – into a feature-rich, integrated, universally-available environment where the new generation of Future Internet applications can be developed and deployed.

The BIVEE System can be considered as a small-scale experimentation of the Future Internet vision. The BIVEE acronym stands for Business Innovation and Virtual Enterprise Environment, and is well-representative of the underlying architecture: the specific Business Innovation goal is targeted by BIVEE Applications, which run on top of a Virtual Enterprise Environment represented (and serviced) by the more generic BIVEE Platform. Actually, the BIVEE Platform aims at being the first prototype of a "commoditized", Future Internet-ready platform for enterprise ecosystem.

2   The BIVEE System Reference Architecture

The block diagram in Fig. 1 illustrates, from a logical perspective, the reference architecture of the BIVEE System, and the relationship existing between the BIVEE
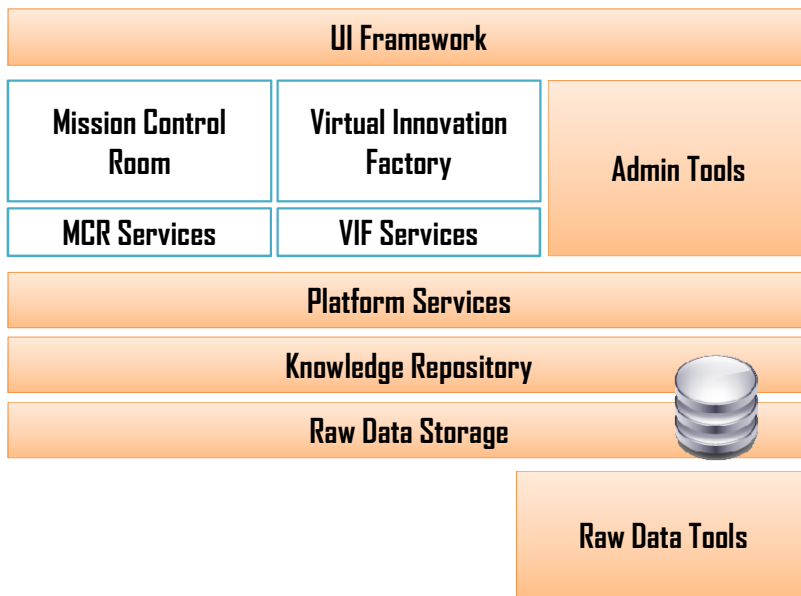

Fig. 1. BIVEE System reference architecture: the logical layers

Platform and the two BIVEE Applications. It also shows the composite structure of the Platform: three layers of foundation – Raw Data, Knowledge and Services – plus platform-specific capabilities such as a User Interface Framework and some Administrative Tools. Raw Data Tools, while an integral part of the Platform, are depicted as a separate element due to their substantially different technology.

3   The BIVEE Platform

In a handful of words, the scope of the BIVEE Platform can be defined as "enterprise ecosystem interoperability". To achieve this goal, the Platform needs to address some basic requirements [8]. From a top-level point of view, these can be categorized as **Sharing of knowledge**, **Harmonization of data**, **Unified access**, **Federated security**. Quite obviously, such a wide range of functionality cannot be successfully implemented by a monolithic architecture. The BIVEE Platform is actually a collaboration of Modules, which are designed as self-contained components.   Modules can be deployed on separate nodes of the network, to achieve a distributed BIVEE System. The following sections will describe the two main Modules, PIKR and RDH, in some detail.

3.1   Production and Innovation Knowledge Repository (PIKR)

The PIKR Module is a multi-tier application implementing a knowledge base, and enabling knowledge sharing across the ecosystem [6].   Knowledge in PIKR is materialized as a set of ontologies and of semantic annotation of knowledge resources – i.e., documents and data records which can be physically stored anywhere.

   Ontologies and semantic annotations are maintained by PIKR as RDF triples (assertions in the form: subject, predicate, object) in its Triple Store, which is PIKR's implementation of the Knowledge Repository layer as defined by the BIVEE System logical architecture (Fig. 1). On top of this, PIKR also provides semantic reasoning and query rewriting services, the latter as a semantic-enhanced access path to the KPI data (see below). All these, as well as direct access to the Triple Store, are exposed to BIVEE Applications through a Web API, corresponding to the Platform Services logical layer.

   As a practical example of PIKR's role in shaping ecosystem knowledge, we consider a specific BIVEE ontology which describes Key Performance Indicators (KPI): *KPIOnto*. KPIs are universally used to assess the performance of a process or of a whole business, with a strong focus on critical ("key") aspects like time and cost, customer satisfaction, employees happiness, environmental respect, etc. In BIVEE, KPIs are the final result of a complex data gathering and processing pipeline, where the mediation of KPIOnto is mandatory in order to collate raw data from heterogeneous sources. Raw data are defined as Process Indicator (PI) Facts – i.e., data records representing atomic measurements.

As with other PIKR ontologies (here we can mention *DocOnto* for document-like resources, and *ProcOnto* targeted at business processes, KPIOnto comes off-the-shelf as basic set of classes, and is meant to be extended by the user to suit her own ecosystem needs. Extensions are in the form of new sub-classes and class instances. E.g., KPI definitions are instances of the Indicator ontology class, while KPI properties are sub-classes of the Dimension class. Once complete, KPIOnto represents a standardized, machine-readable model of the real world from which raw data originates: using this model, it is then possible to achieve a unified view of PI Facts, regardless of their original source and structure.

3.2   Raw Data Handler (RDH)

The RDH Module addresses the need of collecting heterogeneous KPI raw data – PI Facts – from ecosystem members, and make it available and understandable to consumer applications. The most relevant feature of RDH is its integration with the PIKR, which defines the KPIOnto ontology for the semantic enhancement of raw data (see also the Production and Innovation Knowledge Repository section above).

In the RDH context, the Raw Data Storage logical layer of the reference architecture (Fig. 1) is implemented by the RDH-DS sub-module. Facts are kept in *normalized* form – i.e., in a form that is highly compatible with the logical structure modelled by KPIOnto. The main value of data normalization is that application queries, which are expressed in terms defined by KPIOnto, can be automatically translated into equivalent RDH queries, which will perform very fast. By virtue of this mechanism, facts can be collected from heterogeneous sources - typically Enterprise IT systems belonging to different organizations - and still be presented and analyzed in a homogeneous way. This ontology-driven approach to data interoperability is commonly called *semantic lifting* [7].

RDH-DS is implemented as a SQL database, with a specific data schema in which Facts are stored. This schema is auto-generated, and continuously kept in-sync, using KPIOnto as a blueprint. Basically, KPIOnto classes derived from the Dimension class are translated into domain tables following a set of rules (Fig. 2), and are populated with records corresponding to concrete instances; each Indicator instance becomes a fact table by its own, connected with the relevant domains. The resulting schema is described in the RDH-DS Catalogue, and from there entities can be easily mapped back to KPIOnto concepts.

The collection of PI Facts follows a de-centralized approach: each data contributor – typically an enterprise – designs, deploys and runs its own set of ETL batch procedures which *E*xtract data from ICT systems, *T*ransform them in normalized form, and finally *L*oad them on the BIVEE Platform. To support this strategy, the BIVEE Platform provides the Raw Data Tools layer (Fig. 1), implemented by the RDH-ETL sub-module. This is a desktop application for the assisted development of executable programs capable of feeding RDH-DS with normalized PI Facts. The loading of PI Facts is accomplished by a Platform Service (Fig. 1), which in the RDH context is implemented by the RDH-WS sub-module.
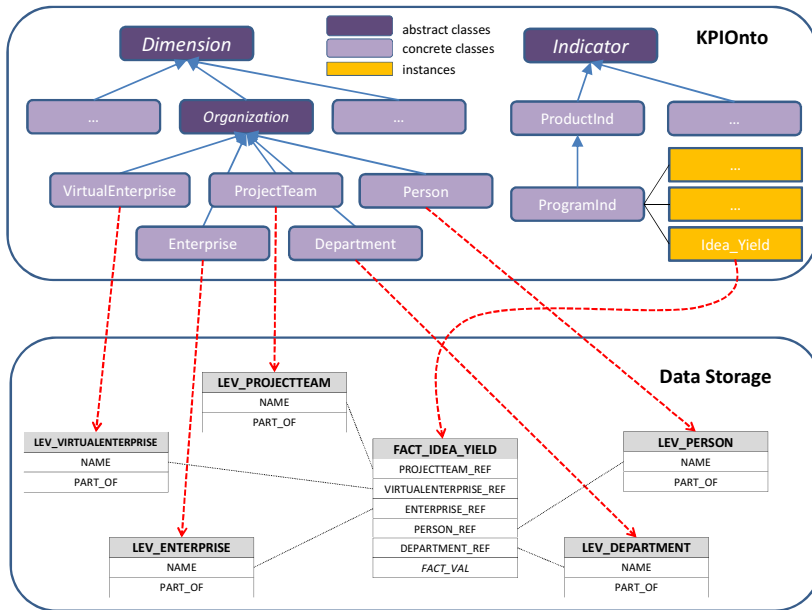
Fig. 2. Example of how KPIOnto concepts are mapped to RDBMS tables

4   Conclusions

The BIVEE System, as composed by the two BIVEE Applications – MCR and VIF – and by the BIVEE Platform, is currently under active experimentation.

At the end of the BIVEE Project (December 2014), a cloud-based instance of the complete BIVEE System will be deployed, as a proof-of-concept demonstrator of BIVEE's results. This instance will actually provide a Future Internet environment as well: the BIVEE Platform as an enabling infrastructure for enterprise ecosystems, on which to build domain-specific extensions and/or applications. The BIVEE Platform captures and implements the low-level, cross-domain requirements of such enterprise ecosystem environments, and translates them into the Raw Data, Knowledge and Services layers of its reference architecture. We believe that such architecture is well suited for Future Internet applications in the Business Innovation usage area, and we expect that it may evolve into – or at least significantly contribute to – a Future Internet commodity infrastructure.

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