Towards an Enterprise Operating System – Requirements for Standardisation

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Abstract

This paper tentatively presents a proposal to develop an Enterprise Operating System (EOS), with the focus on the requirements for potential standardisation. The proposed EOS will behave in the same way as an Operating System of the computer, but under enterprise context and system wide. At first some basic concepts and definitions will be given. Then an overview of relevant works relating to EOS is presented. A set of preliminary requirements on a possible EOS is outlined. Potential for standardisation is discussed and followed by conclusions.

1. Introduction

This paper aims at tentatively presenting a set of preliminary requirements to develop an Enterprise Operating System (EOS) for enterprise operations monitoring and control. In analogy to the Operating System (OS) of a computer, the proposed EOS will fulfill the same mission as an interface between enterprise resources performing various business/manufacturing operations and enterprise managers defining what and how those operations will be performed.

With the massive use of digital equipment (both for manufacturing and information processing) and sensors at shop floor level, it will be possible for enterprise operations to be be more and more monitored and controlled through computers. This means that the enterprise will be operated based on models and controlled by models that are elaborated by enterprise business managers at high level of abstraction [Wei15]. Today, most existing enterprise models are not executable. They are built for the purpose of understanding, analysis and design. In the context of moving to next generation of enterprises, one grand challenge in the future is to develop executable enterprise models. These executable enterprise models should be derived from the conceptual ones built in collaboration with business users and should cover various aspects of enterprise operations such as processes, decisions, collaborations, interoperations and organisations [Wei15].

To make the future next generation Enterprise a reality, enterprise models and their execution must rely on an enterprise-wide digital infrastructure capable of implementing and executing models. When an Enterprise Operating System (EOS) becomes a part of the enterprise in the same way as the operating system of a computer, the EOS will be an integral and vital part of the enterprise. This EOS will interpret content of enterprise models according to the command from business managers, trigger various enterprise operations with dynamically allocated enterprise resources and monitor the status of those enterprise resources (Humans, Machines, Computers) through various

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sensing devices and front-ends for their optimal use [Wei15].

This paper is structured as follows: section 2 introduces basic concepts and definitions on enterprise operating system and enterprise monitoring and control. Section 3 gives a survey on existing works related to enterprise operating system. In section 4 a potential enterprise operating system is discussed in detail focusing on the requirements. Section 5 discusses some standardization potentials of the proposed EOS. Section 6 concludes the paper.

2. Basic concepts and definitions

In this session we introduce some basic concepts and definitions that can help better understand the concepts and requirements of Enterprise Operating System presented in the paper.

A. Enterprise

An enterprise is a unit of business organization, a systematic purposeful activity grouping individuals, structured and organized around technical and financial means with the goal of satisfying needs on a market. In the economic world, we distinguish manufacturing enterprise and service enterprise. Enterprises can be classified according to various criteria ranging for example from small and medium enterprises (SMEs) to big and multinational enterprises; from single enterprises to networked enterprises etc.

B. Enterprise Architecture

Enterprise architecture (EA) is a conceptual blueprint for conducting enterprise analysis, design, planning, and implementation from the business and technology perspectives. According to the standard ISO/IEC/IEEE 42010, the purpose of EA is to achieve greater coherency between the various concerns of an enterprise (HR, IT, Operations, etc.) including the linking between strategy formulation and execution [ISO11].

C. Enterprise resource

An enterprise resource is an entity of enterprise that performs an operation (management, decision, manufacturing, information processing…). According to EN/ISO 19440, there are basically three types of resource: Computer type (including all information processing hardware and software); Machine type (including all tangible material processing and handing devices); and Human type (including manufacturing operators, managers and deciders…).

D. Enterprise operation

The term enterprise operation used in this paper designates those operations (or activities) that an enterprise wishes to monitor and control through the Enterprise Operating system. Those operations are performed by enterprise resources. There are three basic types of operation as well (material handing, information processing, human operations).

E. Operating system

An operating system (OS) is software that manages computer hardware and software resources and provides common services for computer programs; it acts as an intermediary between programs and the computer hardware [Sta05] [Dho09].

F. Enterprise Operating System

The enterprise OS, like the computer OS, provides the services that business functions and operations run on, much like an application like MS Word or Excel runs on Windows or Mac OS X. The enterprise operating system is part of a much larger platform for applications and data that extends across the LAN, WAN and Internet [Ost10].

G. Enterprise operation monitoring and control

Enterprise operation monitoring consists in supervising the availability of enterprise resource and matching required capability to the capability of existing available resources. Enterprise operation control is the deliberate act of synchronizing business strategy with operational execution in real-time to combine control, intelligence and process management in order to enable business optimization that is inclusive of business and production operations. It is realised through the control of starting (triggering) and ending (finishing) of enterprise processes.

3. Survey of related works

The idea and preliminary concept of an Enterprise Operating System first appeared at the end of the 80's in the form of an Integrating Infrastructure (IIS) within the CIMOSA architecture [ESP93]. However the IIS mainly focused on enterprise integration issues rather than monitoring and control and it was not implemented.

In the 90's, this concept was further studied by CEN TC310/WG1 with the aim to develop a standard to support system-wide business process monitoring and control [Sho97]. CEN TC310/WG1 has elaborated the ENV 13550 [CEN99] to express the capabilities of environments for developing, executing and integrating enterprise models on an open IT-based platform. The services needed to provide these IT services are referred to as EMEIS (Enterprise Model Execution and Integration Services) as shown in Fig. 1.

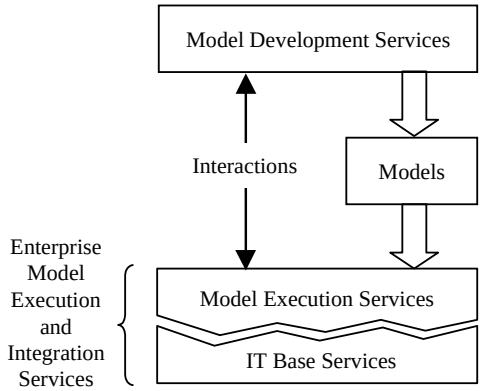

Figure 1: EMEIS [CEN99]

Unfortunately, the EMEIS concept is based on CIMOSA IIS and mainly focused on enterprise process model execution. It remains at the concept stage and has not been utilized in industry. However the EMEIS can be considered as a basis with necessary adaptation and be extended to an EOS so that it serves as an interface between business managers and all of enterprise resources (not just IT resources).

In the late 90's, The WfMC developed standards in the field of Workflow management for enterprises [Wor99]. In particular, it defined an architectural representation of a workflow management system, identifying the most important system interfaces, mostly adopted in the Workflow management field (Figure 2). This representation places a workflow engine at the centre of the architecture that orchestrates different applications. It contains the process definition tool (to describe a model of the process), the administration tool (to control and monitor the process execution), the Workflow client application (to involve human–machine interface in the process), the invoked applications (to interface with specific application computation not tackled by the model) and the facilities to link with other Workflow environments. Nevertheless the general idea provided by this framework has not been fully explored the organization since the WfMC has been more focused afterward in the process description itself, providing the XPDL format that can be considered as one ancestor of BPMN.

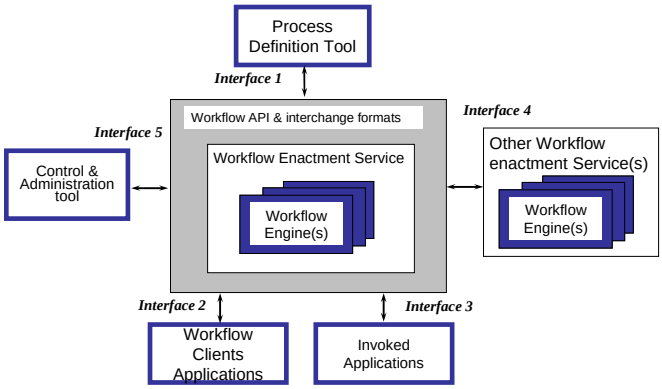

Figure 2: Workflow reference model: components and interfaces [Wor99]

Some other relevant early enterprise IT infrastructures and platforms have been also proposed (Chen, 2015): We can mention OSF/DCE, OMG Corba [OMG12] or later on ESBs (Enterprise Service Bus) [Chap05] [Man07]. Although supporting integration and interoperability of enterprise applications, they do not provide the ability of enterprise model execution. The same applies to the promising Enterprise Application Integration (EAI) platforms of the late 90's that are now abandoned [Lin00].

Major IT providers, such as IBM, Microsoft and Oracle, providing powerful application servers have also envisioned such a 'super enterprise server' that collectively serve the needs of an enterprise rather than a single user, department or specialised application. However, no satisfactory implementation in industry has been reported so far that would cover the complete need of an EOS [Wei15].

Driven from manufacturing point of view, and with a limited scope and extent, ERP (Enterprise Resource Planning) packages associated with MES (Manufacturing Execution System) also move a step towards this direction but mainly focus on manufacturing related activities using ERP software [Wei15]. More recently, some new proposals have been presented to build an Operating System for the enterprise. For example, a framework for Enterprise Operating Systems based on the Zachman framework has been proposed by Ostadzadehet al. [Ost10]. On the other hand, industrial practitioners also consider the model execution approach as key to enterprise agility and improving business performance. For example, the Direct Model Execution approach has been proposed by E2E1. With the help of E2E-bridge under OMG MDA, instead of transforming an enterprise model to code with unnecessary complexity, efforts and cost, direct enterprise business model execution has been proposed as well [E2E08].

4. Towards an Enterprise Operating System

This section presents an extract of some preliminary requirements for a potential standard on Enterprise Operating System. This is not exhaustive but basic set of required capabilities that such an EOS should provide. Figure 3 shows the envisioned EOS serving as an interface between business managers commanding the enterprise and enterprise resources that perform enterprise operations. The required capabilities are independent of technologies to be used for implementation and expressed at a higher level of abstraction. Part of the requirements are based on and inspired from ENV 15350 EMEIS [CEN99]. It also extends the WfMC reference model by considering all category of resource while WfMC was focused on software and human interfaces.

[1] E2E is part of the Scheer Group innovation network, headquartered on the University Campus in Saarbrücken, Germany.

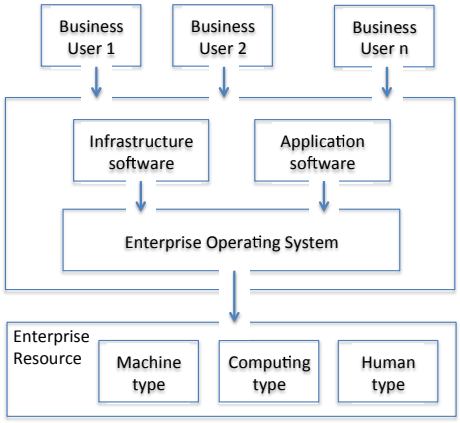

Figure 3: Enterprise Operating System (Adapted from OS of computer)

4.1. Enterprise Resource Management

From the point of view of EOS, Enterprise Resource Management (ERM) aims at dynamically monitoring the status of enterprise resources system-wide (available, occupied, out-of-order…) by providing an integrated view of core competence, location and availability, often in real-time, using common databases maintained by a database management system [ANS13]. This information is essential to allow EOS to dynamically locate and allocate available enterprise resource(s) to tasks (operations). More precisely the following functionalities are required:
- Checking the availability of resources and reporting their availability to Enterprise Process Management service;
- Searching available resources on the request of Enterprise Process Management
- Matching the required capabilities to the capabilities of existing available resources
- Selecting an appropriate resource as defined by its capabilities
- Allocating or making reservation of resources to operations upon requests from Enterprise Process Management
- Ensuring that the right resources are affected to the right operations in the right place at the right time.
- De-allocating resources at the end of operations

The enterprise resources must be modelled and described beforehand. The status of the resources can be either obtained automatically using sensors and other suitable devices or reported to EOS by human at the beginning/end of an operation.

4.2. Enterprise Process Management

Enterprise Process Management (EPM) helps orchestrating and organizing activities and improving corporate performance by managing and optimising the enterprise business processes [Pan12]. It aims at dynamically controlling the execution of enterprise processes by sending ‘start’ command triggering the starting of processes and recording ending status of processes (done, not done, fail…). This functionality is essential for an enterprise to control its business and manufacturing processes through EOS. Some detailed functionalities for Enterprise Process Management are listed as follows (not restricted to this list) [CEN99]:
- Interoperating (Plug-and-play) with available commercial and other compatible process models through Interoperability Management
- Executing process model (process model run-time execution); sending ‘start’ and ‘end’ signals to resource concerned
- Interpreting logical conditions and other conditions/constraints (process junction) during process execution
- Sending required capability for executing a process to Resource Management in order to find an available qualified resource

- Receiving and interpreting resource status from Resource Management and sending request to Resource Management to allocate resource to process
- Receiving and interpreting resource status from Resource Management and sending request to Resource Management to release allocated resource

Enterprise Process Management must be able to execute/run a process model either from commercial process modelling tools, either a process model built by enterprise business managers themselves.

4.3. Enterprise Information Management

The Enterprise Information Management (EIM) aims at managing, protecting and supporting information and data exchange of all kinds (documents, video, multimedia files, drawings…) between all enterprise resources connected to the Enterprise Operating System in a company. The goal is to provide and preserve information as a business asset that remains secure, easily accessible, meaningful, accurate and timely [Rud09]. The main functionalities of EIM are listed below:- Requesting Interoperability Management to provide needed services to establish interoperability between non-interoperable data sources.
- Ensuring and maintaining system-wide consistency and integrity of enterprise data exchanged through EOS
- Providing transparent access to data sources whatever the type of data storage means (heterogeneity) and wherever it is located
- Ensuring information and data confidentiality and security to protect from non-authorized access
- Providing an appropriate data storage facility needed for running EOS (example, Enterprise Resource status, capabilities….).

4.4. Interoperability Management

Interoperability is crucial to run divers existing commercial software products on Enterprise Operating System (plug-&-play) by providing facilities for allowing events to interact in an EOS in order to exchange defined messages and data. It is also considered a precondition for a successful development and implementation of EOS before it is accepted as a standard in industry. The EOS should interoperable with two different types of software environments:
- Business applications used by business managers at level of enterprise management and control, such as ERP, CRM, etc. In particular enterprise modelling tools must be able to interoperate with EOS so that the enterprise model elaborated by the tools can be executed via EOS.
- Software provided for device controllers and sensors at shop floor level to monitor and execute manufacturing operations, in particular controllers for various commercial NC machines, robots, AGVs… as well as bar code readers and mobile communication devices for human operators to receive and send back information to EOS.

4.5. Presentation Management

Presentation Management is concerned with the interface between internal and external worlds of EOS. It has the responsibility to organise and coordinate the communication and information flow between Enterprise Resources and internal entities of EOS. More precisely, it interacts with the three types of enterprise resources (adapted from [CEN99]):
- Human Dialogue service, requiring information to be presented and commands received through an appropriate human computer interface (display management service).
- Machine Dialogue service, i.e. services for manufacturing technology resources requiring commands to be transmitted and results returned via an interface to the physical world
- Application (software) Dialogue service, requiring service activation through an Application Programming Interface of some kind.

5. Potentials for standardization

The development of an Enterprise Operating System is certainly a high challenging and difficult initiative. However this is also a key step to move to next generation enterprise as envisioned in Sensing Enterprise, Industry 4.0… The

main concern is to create a general consciousness and consensus both in manufacturing and IT industries to accept EOS as a standard in order to develop and commercialise compatible enterprise software applications. To achieve this objective, it is necessary to proceed in steps in a progressive way:
- Involve industry and appropriate standardisation working groups to collect and consolidate requirements on EOS
- Define standard specifications of EOS based on the requirements and build demonstration industry use cases
- Create user interest groups and associations to disseminate EOS and provide technical support and consultancy to end users.

To start, the CEN 13350 [CEN99] initially drafted to support Enterprise Model Execution and Integration can be used as a basis with necessary extensions and adaptations towards a sound Enterprise Operating System.

6. Conclusions

This paper tentatively presented a proposal to develop an Enterprise Operating System to support the implementation of Sensing Enterprise and Industry 4.0 initiatives considered as the next generation enterprise. The proposed EOS and the set of preliminary requirements are mainly based on and inspired from ENV 15350 that at origin proposed for enterprise integration purpose. Thus the proposed EOS is generalised and extended from an Integrating Infrastructure for enterprise model execution to a true Enterprise Operating System acting as an interface between enterprise resources and enterprise business managers. Evidently the use of an EOS in an enterprise doesn't mean that all enterprise resources must be connected to and controlled by the EOS. It depends on the strategy and specificity of each enterprise. Consequently, an enterprise will have the choice to decide the set of resources and processes that are monitored and controlled by EOS and those that will run outside EOS. The proposal presented in the paper is just an outline and must be further refined and detailed.

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