E-Tendering: Modeling of a multi-agents system integrating the concepts of ontology and big data

Amadou Diabagate*, Computer Department, University AbdelMalek Essaadi, 416 Tangier, Morocco.
Abdellah Azmani, Computer Department, University AbdelMalek Essaadi, 416 Tangier, Morocco.
Mohamed El HARZLI, Electrical Engineering Department, University AbdelMalek Essaadi, 416, Morocco.

Abstract

This work deals with the modeling of a computer system dedicated to e-procurement specifically e-tendering. For the establishment of this system, semantic web ontologies, multi-agent systems and big data were used. To have a modular system, pledge of reliability, of speed and potential scalability, multi-agents systems have been used. The agents of the system communicate and collaborate throughout the tendering process to perform tasks such as the generation of tender documents, bids evaluation, contract signature and monitoring of the realization of the contract. The knowledge engineering through the semantic web ontologies was used in order to have a complete semantic description of the shared information and foster good communication between the different agents of the system. Finally, to store and take advantage of structured and unstructured data generated by the different sources of data relating to the governance of public procurement, Big Data technologies were integrated.

The objective of this work is to establish an efficient computer system capable of solving all or part of the problems relating to the award of public contracts.

Keywords: e-procurement, e-tendering, software engineering, big data, multi-agents system, semantic web, ontology, artificial intelligence;

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*ADDRESS FOR CORRESPONDENCE: **Amadou Diabagaté**, Computer Department, University AbdelMalek Essaadi, 416 Tangier, Morocco. *E-mail address:* **ahmadou.diabagate@gmail.com**

1. Introduction

Procurement is a major economic challenge for governments and businesses [1-2]. Public procurement has a significant economic weight [3] estimated at 20% of global GDP [2]. Procurement is granted through different modes including tendering [4] which can be defined as a process that allows emitting a request for works, services and goods to businesses and then choosing the provider after analysis of proposals according to predetermined criteria without negotiation [5]. Due its characteristics, tendering has become the natural mode for awarding public procurement [6].

However, many problems exist in the tendering process[7]. The most important of them remains corruption [2, 3, 7, 8]. Outside of corruption, the difficulty for small and medium enterprises in accessing procurement, the inefficiency of the evaluation's methods of tenders, the shortcomings in procurement code, the lack of certain procurement skills among actors… may favor the mismanagement of procurement [7].

With the advent of information and communication technology (ICT), the dematerialization of public procurement procedures has become, thanks to its many positive results, an indisputable solution of the problems in tendering [9, 10].

In this dynamic, this work focuses on a modeling of a computer system that uses advanced computer approaches namely multi-agents systems, ontologies of semantic web and big data for the implementation of an IT solution dedicated to the dematerialization of tendering process. Ontologies of semantic web have been used for structuring and sharing of information within the system via a common language. The multi-agent paradigm was established in the heart of the system to take advantage of the many benefits of a multi-agent system due to its modularity. In addition, on the one hand, big data technologies are used to store small and large data, structured and unstructured data and on the other hand the methods of data science are used for the analysis and the processing of data.

The remainder of this paper is structured as follows. Section 2 provides a general overview of the system. Section 3 focuses on the use of semantic web ontologies. Section 4 describes the use of multi-agents approach. The integration of big data concept is described in section 5. The section 6 provides a description of the technical architecture of the system. The paper ends with concluding remarks and avenues for future research in section 7.

2. System's general overview

2.1. The objectives of the system

In the context of the dematerialization of public procurement, this work consists in the modeling of a computer system with a view to achieving the following objectives:

- Modernization of tendering process
- Effectiveness of tendering process
- Bring more transparency in the tendering process
- Improve the quality of deliveries (goods, services, works)
- Promote economic prosperity of countries in curbing corruption in public procurement
- Promote the economic prosperity of businesses especially small and medium enterprises (SMEs)

2.2. Architecture of the system

The figure 1 presents the architecture of the system. It illustrates the following points:

- several modules;
- set of actors and users;
- data from internal and external sources;
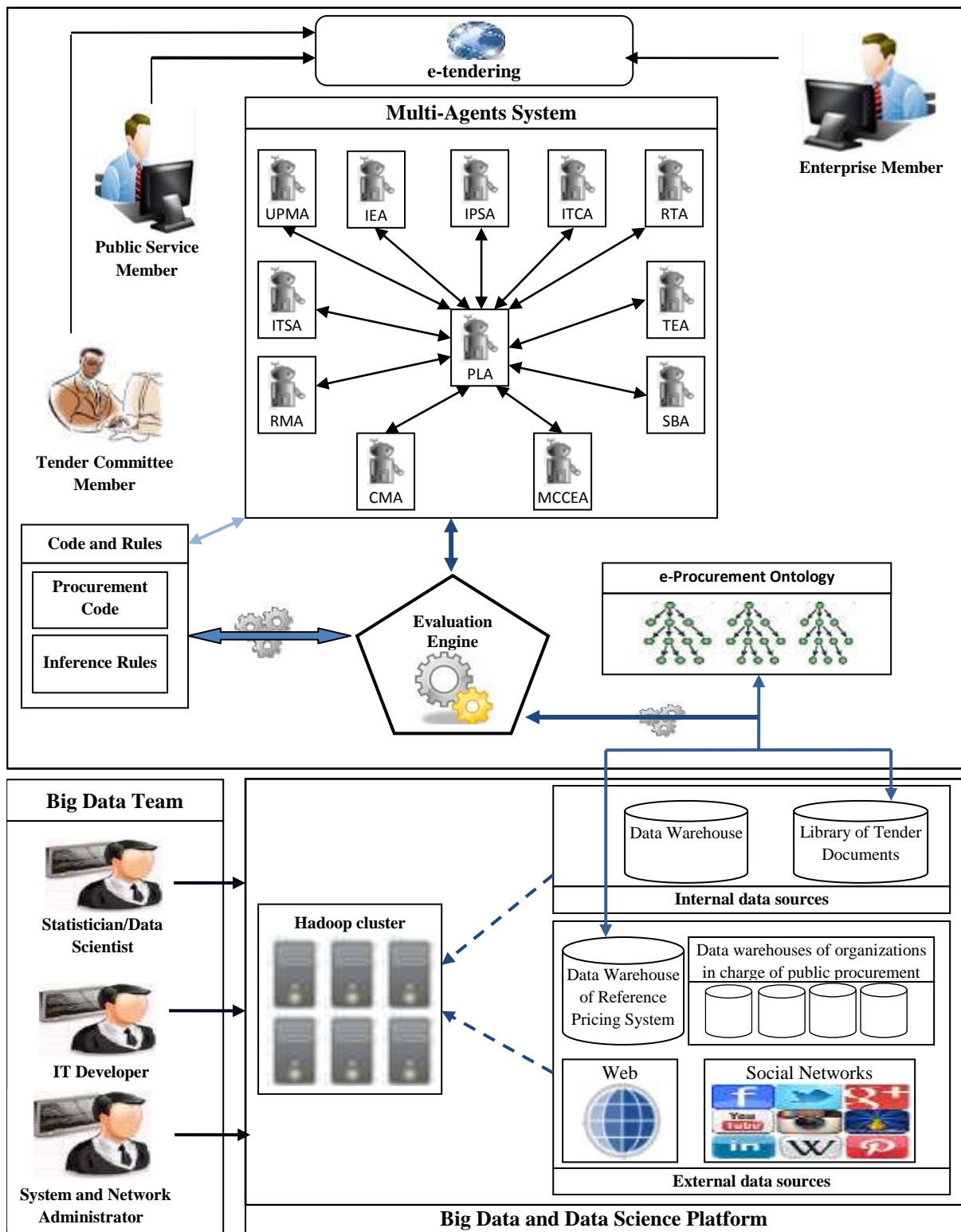
- data analysis platform.

Figure 1. Architecture of the system

From this architecture we highlight the following principles and concepts: the use of multi-agents to take benefit of a modular system, the use of semantic web ontologies to describe the resources and facilitate communication between agents and between users and system, the use of big data and big data science to store and analyze the data, the integration of methodologies from Artificial

Intelligence(AI) based on mathematical theories such as fuzzy logic, neural network, FAHP,... to render certain intelligent agents.

3. Approach based on the use of semantic web ontologies

3.1. The concepts of semantic web and ontology

Tim Berner Lee introduced the semantic web in 1998 with a view to structure information available on the web [11]. He defines the semantic web as an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in co-operation [12]. Ontologies are one of semantic web technologies. There are many definitions of ontology some of which offer more information than others. The most common definitions are that of Tom Gruber which describes the ontology as "an explicit specification of a shared conceptualization" [13] and that given by Studer et al. which defines an ontology as "a formal, explicit specification of a shared conceptualization" [14]. The main languages used for the description and the representation of ontologies are RDF, RDFS and OWL [15-16]. The manipulation of ontologies requires a specific language. To meet this need, the World Wide Web Consortium (W3C) proposed the language SPARQL (Simple Protocol and RDF Query Language) which allows running queries on RDF files, RDF Schema and OWL files.

3.2. The ontology built for the system

To build our ontology, we relied in part on the existing ontology PPROC[1] (Public Procurement Ontology) to which we have made modifications to better adapt it to our system. The modifications have consisted of adding new classes and properties to existing ontology. The ontology PPROC, very rich, focuses on e-procurement and its development was funded by the Spanish Ministry of Industry, Trade and Tourism with the participation of experts in the field of public procurement [17]. The ontology PPROC was developed using several existing reference ontologies:

- Organization Ontology (ORG)[2]
- Simple Knowledge Organization System (SKOS)[3]
- Good Relations Ontology (GR)[4]
- Public Contract Ontology (PCO)[5]
- Friend Of A Friend Ontology (FOAF)[6]

This Figure 2 represents a general view of our ontology with some classes and properties. In red color, the figure 2 displays some classes and properties which have been added to PPROC ontology in order to obtain a new ontology better adapted to our system.

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[1] http://contsem.unizar.es/def/sector-publico/pproc.html

[2] http://www.w3.org/ns/org#

[3] http://www.w3.org/2004/02/skos/core#

[4] http://purl.org/goodrelations/v1#

[5] http://purl.org/procurement/public-contracts#

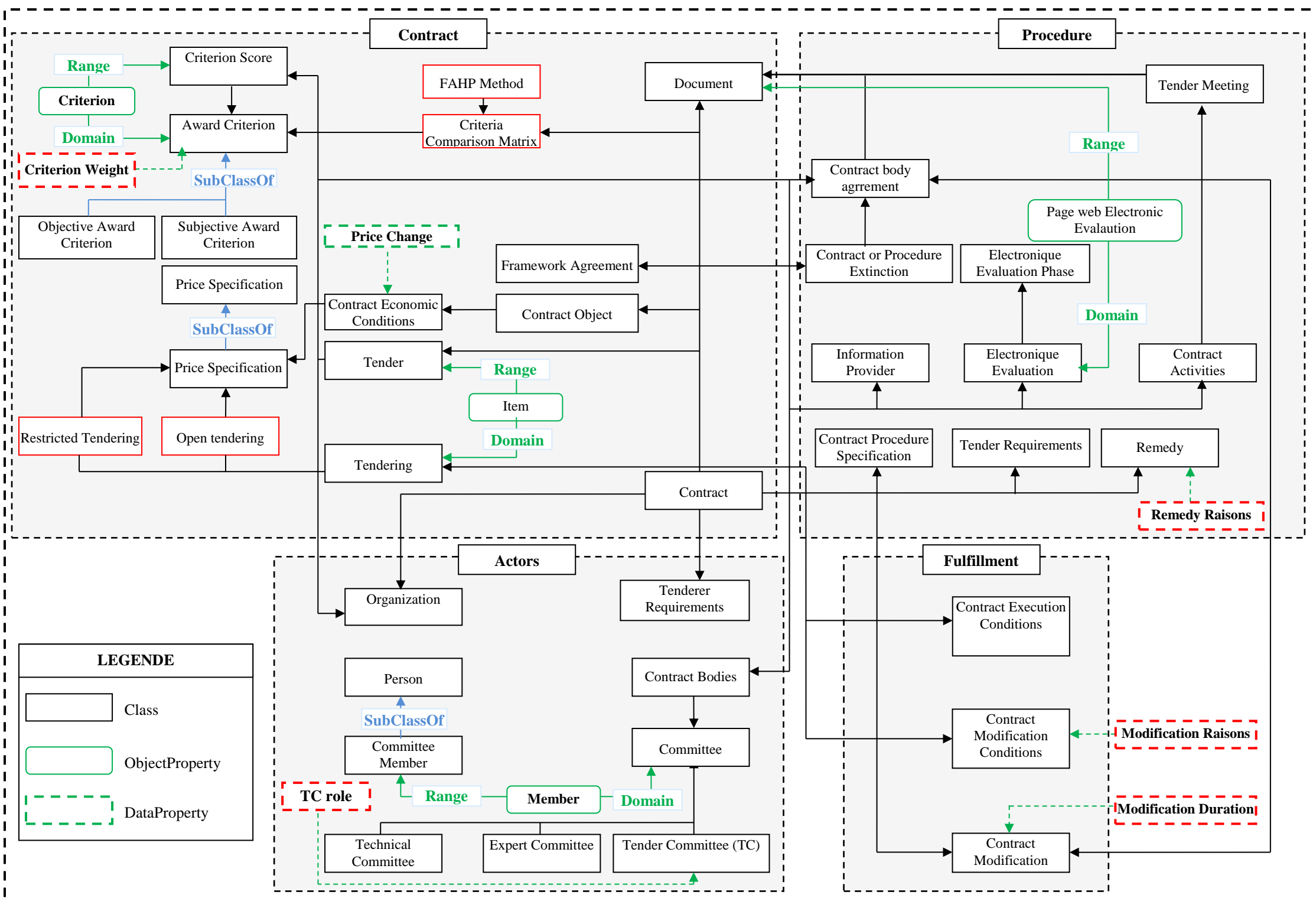[6] http://xmlns.com/foaf/0.1/

Figure 2: Overview of the e-procurement ontology built for the system

4. Multi-agents system approach

4.1. Concepts of agent and multi-agents system

The concept of agent is used in many areas and an agent is generally defined as an autonomous entity able to perform actions. According Wooldridge: "an agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives" [18]. A multi-agent system (MAS) is a distributed system composed of a set of agents. The multi-agents systems are designed and implemented as a set of agents inter-acting, more often, according to modes of cooperation, competition or coexistence [19]. The communication between agents is one of the most important aspects of multi-agent system [20]. This communication is performed by using some special communication languages such as KQML and FIPA-ACL [21]. Presently, the most language used is the FIPA-ACL which incorporates many aspect of KQML [20].

4.2. The agents of the system

In the design of our system, we have opted for a modular system based on the use of software agents from where the use of multi-agent system. There is a very close link between multi-agent systems and ontologies of the semantic web consisting in the use of ontologies in the operation of a multi-agent system [22]. There are numerous advantages in the use of a multi-agents system such as: high reliability due to redundancy, high speed due to sharing and parallelism during the execution of tasks by agents, fluency of maintenance, modeling and programming,…The part "Multi-Agents System" of the general architecture of the system (see Figure1) presents the different agents whose roles are described below:

- **Interface Public Service Agent (IPSA):** This agent manages the interactions between public administrations and the system.

- **Interface Enterprise Agent (IEA):** It is in the charge of the interactions between enterprises and the system.

- **Interface Tender Committee Agent (ITCA):** The interactions between the members of tender committee and the system are handled by agent ITCA.

- **Planner Agent (PLA):** This agent ensures the proper functioning of the system by planning the different tasks and assigning them to different agents.

- **Reception Tenders Agent (RTA):** It is responsible for the receipt of tenders submitted by enterprises**.**

- **Selection Bidders Agent (SBA):** it captures and saves queries on the report of the tender committee about the selection of bidders and draws up the list of these.

- **Tenders Evaluation Agents (TEA):** it manages the step of the analysis and the evaluation of tenders.

- **Contractualization Management Agent (CMA):** the agent CMA is requested for the signature of contract concerning the awarding of contracts.

- **Monitoring and Control of Contract Execution Agent (MCCEA):** this agent is involved in the monitoring and control of the execution of the contract by identifying and capturing all the queries sent by the public administration and the enterprise during this phase.

- **IT Security Agent (ITSA):** IT security is a major issue in the operation of the proposed system. The mission of IT Security Agent is to ensure all aspects of security.

- **Users Profiles Management Agent (UPMA):** the role of the agent UPMA involves initializing, storing and processing of user profiles.

- **Resources Management Agent (RMA):** the role of this agent is to manage the library of tender documents and data warehouse of price reference system.

5. Big data approach

5.1. Presentation of the concept of Big Data

In recent years, the size of the generated data has grown exponentially in many societies, organizations and social networks. The total size data produced in 2010 is estimated at more than one zettabyte (1021 bytes) when it should increase 50 times over the next decade [23]. This new phenomenon called Big Data refers to large data sets and complex composed of structured, semi-structured and unstructured data growing very quickly. In 2013, Stonebraker has introduced the Big Data concept according the 3V model (Volume, Velocity, Variety) [24]. Today, there are several definitions of big data with models having more than 3V. However, the general trend is that we are in a big data context when we have at least the 3V presented in the definition of Stonebraker.

5.2. The component Big Data of the system

The component Big Data plays a very important role in the system. Large and heterogeneous data are generated in the context of public procurement across multiple data sources. Storage and especially the analysis and the processing of these data are major challenges for the different actors. The part "Platform Big Data and Data Science" of the general architecture of the system (see Figure1) presents the different with more details the component big data. The main data sources are:

- **Databases of treasury:** the treasury, responsible for paying the company that has carried out the contract, has a large amount of information (data) on contracts concluded**.**

- **The Web and social networks:** the deluge of data generated by the web and social networks is a fundamental data source for Big Data [25-26]. The approach is to involve citizens in the governance of public contracts by collecting all information from citizens on public procurement through the web and social networks. It is an e-participation approach that aims to involve citizens in the management of public procurement taking into account their views before, during and after the realization of contracts.

- **Data warehouse of price reference system:** The estimation of the amounts of contracts constitutes a very important economic issue [27]. Indeed, many contracts are overestimated and that leads to a squandering of state resources. To remedy this situation, countries like South Korea have price estimation systems [28]. The latter constitutes an important data source for big data and big data science. Indeed, on the one hand, it contains a large amount of data due to information on the numerous stored objects, and on the other hand, these data evolve with great velocity due to the number of objects to add and the permanent changes of objects' prices.

- **Data warehouse of the system:** The proposed system contains a data warehouse that stores information entered by users and those generated by the system during its operation. Also, the system contains a wide library containing a large number of tender documents which is regularly updated.

6. Technical Architecture

The Figure 3 presents the technical architecture of the system by displaying the software used to build and implement the components of the system and the interaction between them. The software Protégé is used to edit the ontology. JENA API, SPARQL are used to edit and query the OWL file of the ontology.

JADE allows to implement the agents and JESS, a rule engine environment and scripts written entirely in JAVA by Ernest Friedman-Hill au Sandia National Laboratories, is used to facilitate agents' decisional process.

For big data approach, Sqoop and Flume allow importing data, HDFS and Hbase are dedicated to the storage of data, Pig and Hive are used to perform the queries on the data. R, Python and Mahout allow applying data science methods (natural language processing, social media analytics, sentiment analysis, data analysis, data visualization, machine learning, web scraping,…) to extract knowledge from data.
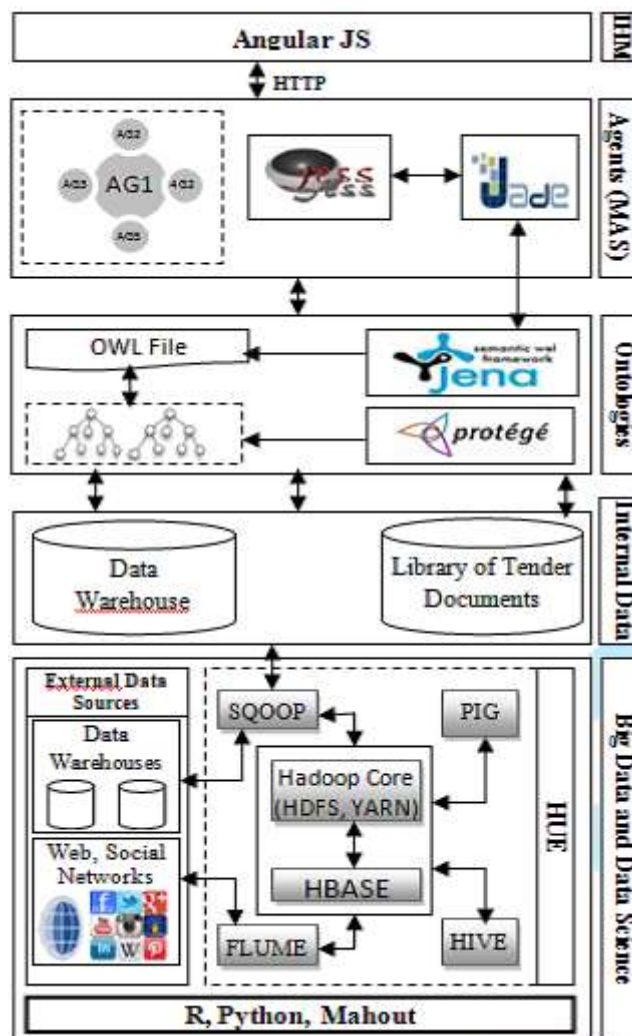

Figure 3: Technical Architecture of the system

7. Conclusion

The issue of the use of computer system for the good governance in public procurement arouses great interest among governments, businesses, international financial institutions,... Thus, many countries have included the dematerialization of public procurement as a major focus of their e-government programs.

In this dynamic, this paper proposes a multi-agents system integrating the concepts of big data and semantic web ontologies to resolve all or part of the problems of public procurement notably that of corruption. This IT solution was modeled so as to give it all the aptitudes to:

- ensure a smart dematerialisation of public procurement,
- ensure an intelligent evaluation of tenders,
- support the deployment and the use of a decision support platform based on the use of big data technologies and data science methods (data analysis, machine learning, natural language processing, sentiment analysis, social media analytics, data visualization, ...) for the processing and the analysis of data.
- minimize risks especially those related to computer security

As future works, we plan to use artificial intelligence methods to improve the performance of the system by making agents more intelligent. We also plan to use data science methods in order to extract knowledge from data stored during the implementation of big data approach. We envisage the evolving of this work by making a prototype of the proposed system with a view to materializing the different aspects of the modeling.

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