



# **COSIBAS**

Cognitive Services for IoT-based Scenarios

## ***D1.4- COSIBAS Report about liaison with FIWARE***

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## 1 INTRODUCTION

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This document describes the open source FIWARE platform supported by the European Community and the TIC industry to facilitate the development of new smart applications in multiple sectors. It starts by explaining what FIWARE is, and then describes the characteristics that make it an ideal platform to achieve the main objective of COSIBAS; "*Integrating Artificial Intelligence and Machine Learning into an IoT platform*", and then, analyses the main Artificial Intelligence platforms currently on the market, in order to compare them with the possibilities and advantages offered by FIWARE.

Once the FIWARE platform has been described, as well as a thorough comparison of the main Artificial Intelligence Cloud platforms, a detailed explanation about how to integrate with COSIBAS, and why FIWARE has been selected as the platform to achieve the COSIBAS objective is presented.

The document ends by providing some conclusions from the analyses carried out, in which the pros and cons of FIWARE are detailed based on the information provided in this document, and from these, why FIWARE is the ideal platform for the objectives of COSIBAS.

## 2 FIWARE

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FIWARE is an open-source initiative, promoted by the TIC industry and the European Community, which defines a universal set of standards for managing contextual information, as well as harmonised data models in order to facilitate the development and deployment of intelligent solutions and services for different domains quickly, easily, and cheaply. In fact, FIWARE motto is "*An open-source platform for a smart digital future*".

FIWARE aims to facilitate the creation and cost-effective delivery of Internet applications and services in various areas, including smart cities, sustainable transport, logistics, renewable energy, and environmental sustainability.

FIWARE is sponsored and supported by the European Union's *Future Internet Public-Private Partnership (FI-PPP) project*. The platform and its entire ideology are very promising and are already producing considerable results. Major companies and organizations such as the European Engineering Consortium, Telefonica, and Orange S.A. announced in March 2015 a project to standardize their technologies with FIWARE.

In detail, FIWARE is a platform that starts from a market of portable and interoperable solutions. It is made up of open-source components that can be assembled among themselves, and with other components of third-party platforms, thanks to a simple and powerful standard API called *FIWARE NGSI* that provides the basis for interoperability and portability of intelligent solutions. The central component of FIWARE is the *FIWARE Context Broker* that allows the system to collect and to manage context information, and inform external actors allowing them to act, modify, and enrich the current context.

FIWARE provides process automation throughout the value chain, easy plug & play integration with other solutions and services and allows connection to IoT with the context information management and Big Data services in the cloud.

A schematic representation of the overall FIWARE platform is illustrated in the next figure:

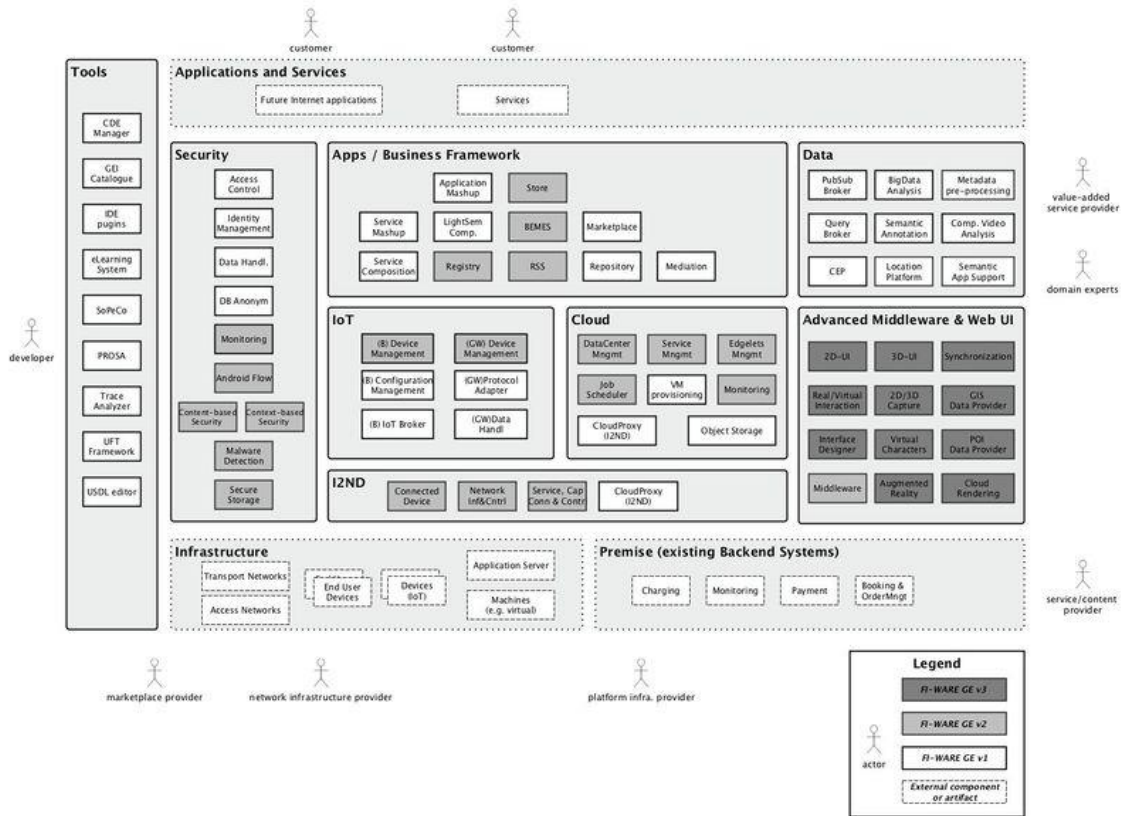


FIGURE 1. SCHEMATIC REPRESENTATION OF THE FIWARE PLATFORM

FIWARE is promoted by the *FIWARE Foundation*, that validates FIWARE technologies and supports the *FIWARE community* by providing shared resources. The *FIWARE Community* is an open and independent community made up of both technology contributors and those who help on building and maintaining FIWAER ecosystem, as well as those who display relevant resources in the activities of *FIWARE Lab*, *FIWARE Accelerator*, *FIWARE Mundus* or *FIWARE iHubs*. These four frameworks are detailed next, and depicted in the following figure:



FIGURE 2. FIWARE COMMUNITY

- **FIWARE Lab** is a non-commercial environment implemented in a geographically distributed network of federated nodes, aimed at innovation and experimentation based on FIWARE technologies.
- **FIWARE Accelerator** is a programme focused in particular on SMEs and start-ups, whose mission is to promote promising new FIWARE ideas, products, or services through funding, mentoring, training, and networking.

- **FIWARE Mundus** is a program designed to promote FIWARE activities and ecosystem configuration worldwide.
- **FIWARE iHubs** offer services to companies, such as technology support, training, research, and testing with FIWARE technology, certifications and detailed product analysis, as well as individual training for start-ups and SMEs. It also offers market information and programming of events and outreach activities.

Around the FIWARE platform, ecosystems have been created through which, on the one hand, entrepreneurs can materialize their ideas by building applications and services in the cloud quickly and easily and, on the other hand, application developers, technology providers and solution demanders can innovate.

This platform is not just an idea, but also consists of hardware and software and provides a basis for application development. The difference between this platform and others is that there is a community for developing application components that can be used for free. These components are divided into two categories: Generic enablers and domain-specific enablers:

- **Generic Enablers:** They offer several functions for conventional use, through well-defined APIs, allowing the intelligent development of applications in multiple sectors. There are several types of *Generic Enablers*, such as IIoT, web user interface, security, application architecture. Each of the above examples has a well-defined API in which services are created and made available by making calls to this API. An example would be the use of the IIoT Enabler to ask if there is wood for a specific cut in the warehouse.
- **Domain-specific enablers:** They are responsible for helping those who plan to develop applications in the energy, media, manufacturing, health and welfare, and agriculture sectors. These are well-defined enablers who have a great deal of development in a specific domain. They can be used in conjunction with *Generic Enablers*, to make the development of applications and solutions more agile and intelligent.

## 2.1 Features

In this section the characteristics that make FIWARE an ideal platform for COSIBAS are detailed, taking into account that not only the integration of AI/ML in an IoT platform is sought, but also that this integration allows and facilitates new developments based on standards aimed at combining IoT with AI.

### EXTENSIBILITY

The extensibility of a FIWARE solution is determined by the modular nature of this type of solution, as well as by the use of standards that facilitate interoperability with other platforms or third-party solutions.

FIWARE is a platform composed of generic open-source components, also called *Generic Enablers*, which can be assembled with each other and with other third-party components thanks to a simple, powerful and standard API called FIWARE NGSI.

FIWARE uses *Kubernetes*<sup>1</sup> for the orchestration of the services provided by the components. The components that make up *Kubernetes* have been designed to be loosely coupled yet expandable to support a wide variety of workflows.

<sup>1</sup> Kubernetes. Open source system for the automation of deployment, scaling and handling of containerized applications.

Every FIWARE based solution requires the central component *Context Broker*, which is in charge of managing the context information, around which new components can be integrated offering diverse functionalities, thus allowing to redesign a solution as it evolves according to the emerging business needs.

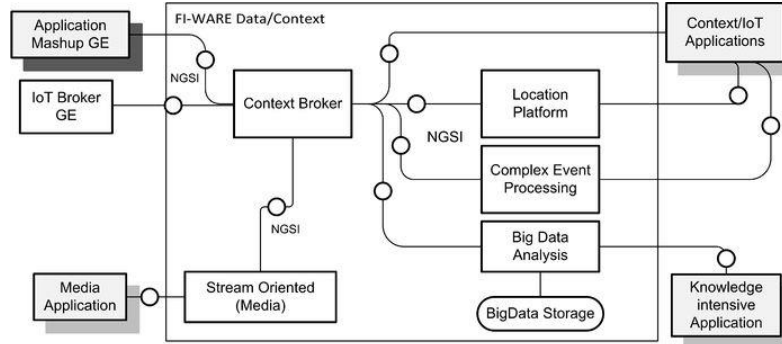


FIGURE 3. DATA/CONTEXT NGSI BASED GES INTEGRATION

The main requirement for a component to be integrated with a FIWARE based solution is that it must comply with the *FIWARE NGSI* standard interface. Thanks to this interface, not only the components offered by the platform can be integrated, but also components developed by third parties, as long as they are compliant with the *FIWARE NGSI* interface.

By using this standard and providing a public FIWARE generic enabler specification and reference implementation, **it makes easier for developers to extend a FIWARE-based solution**, and allows new FIWARE vendors to emerge on the market, removing potential lock-ins.

FLEXIBILITY

The FIWARE platform is made up of several components or generic enablers that offer different functionalities. However, to develop intelligent applications **aiming at supporting flexible deployments**, it is necessary to have information about the context, i.e., what is happening at any given time. To do so, the **FIWARE Context Broker** is the component in charge of managing context information in a massive way. Around this component, FIWARE provides a wide range of complementary components that offer additional functionalities. Depending on the business needs of the FIWARE solution, these components may or may not be part of.

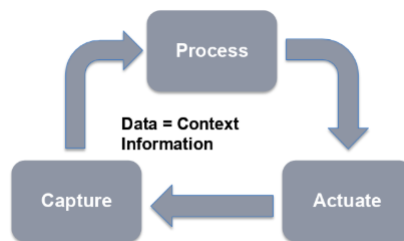


FIGURE 4. SMART SOLUTION

**Another feature that FIWARE offers related to flexibility is the ability to develop a solution in a cloud hosted or on-premises environment.** *DockerHub*<sup>2</sup> offers a library of containers that provide different components for developing a commercial FIWARE solution.

<sup>2</sup> DockerHub is the world's largest image container library and community (<https://hub.docker.com/>)



In particular, within the container catalogue offered by *DockerHub*, it can be found the **Orion Context Broker**<sup>3</sup> container that contains the *Context Broker* component required by every FIWARE solution. On the other hand, for **non-commercial solutions**, **FIWARE Lab** offers a cloud development environment, made up of a geographically distributed network of federated nodes, aimed at experimentation and innovation.

## FUNCTIONALITY

FIWARE is a framework of open-source platform components that provide a range of functionalities through standardized data management and exchange services and interfaces, as well as standardized data models, as presented in Figure 5.

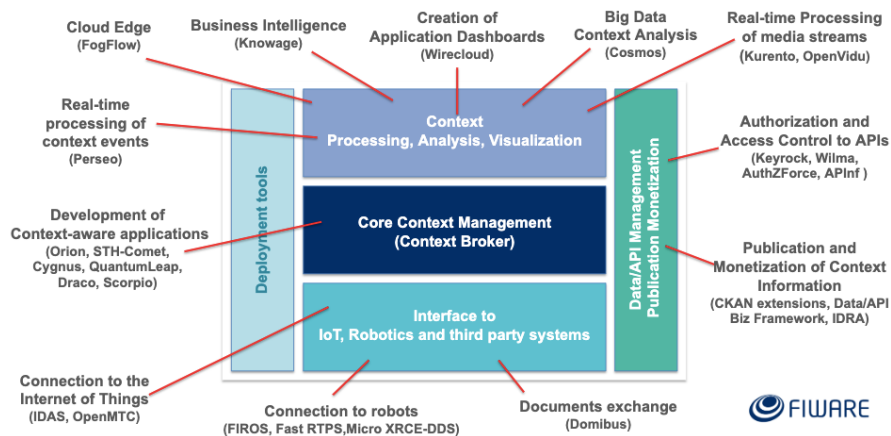


FIGURE 5. FRAME FIWARE COMPONENTS

Among the different components that make up this framework, the *Context Broker* component stands out as the minimum component required by every FIWARE compliant solution. Through this component, customers can perform various operations such as:

- Consult the context information
- Update the context information
- Receive notifications when there are changes in context information
- Register context vendor applications

Context information consists of entities and their attributes such as a vehicle and its speed.

In addition to this component, a wide range of non-required, and therefore complementary, components for a FIWARE solution are provided through this framework (see Figure 5), which deal with:

- **Interface with IoT, robotics and third-party systems:** Define interfaces to capture updates on context information and translate them into required actions.
- **Data Context / Management, Publishing and Monetization API:** Provide intelligent decision support to end-users, and implement the intelligent behaviour expected by applications.
- **Processing, analysis and display of context information:** Provide support for usage control, as well as the means to publish and monetize some of the managed context data.

<sup>3</sup> Orion Context Broker is a Publish/Subscribe Context Broker GE implementation, which provides an NGSI interface for managing context information and its availability (<https://hub.docker.com/r/fiware/orion>)

- **Security, identity, roles, and permissions:** Provide the necessary functionalities for authentication, authorization, and management of roles and users

INTEROPERABILITY

FIWARE provides a set of APIs for data access and interaction with services and allows information to be shared according to homogeneous data models between cities, ensuring interoperability between them. This guarantee is due to compliance with global standards, such as oneM2M<sup>4</sup>. According to these standards, FIWARE provides a middleware or service layer of IoT that provides security functionalities, device and service management, data management and connectivity. The FIWARE context information model provides a data interoperability framework so that applications and services can easily consume information and/or trigger actions in various systems, including IoT systems such as oneM2M.

FIWARE follows the federated platform architecture model, in which different platforms exchange data with each other as well as management capabilities allowing interoperability. This architectural pattern highlights a controlled exchange of information between autonomous components by communicating through messages attached to common models using defined interfaces.

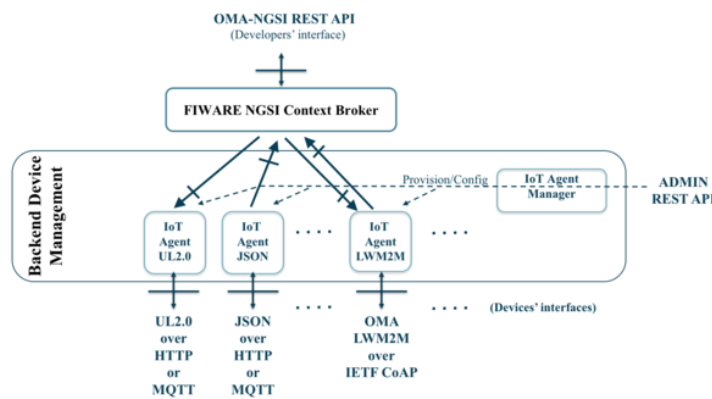


FIGURE 6. SOUTHBOUT IOT PROTOCOLS

For interfaces linked to the federated architectural pattern, FIWARE makes use of the API RESTful FIWARE NGSI<sup>5</sup>, a version of the OMA NGSI interface. NGSI is a protocol developed by OMA<sup>6</sup> (Open Mobile Alliance) to manage context information. This API offers a standard information model that allows to eliminate adaptation costs for the interoperability of heterogeneous systems, as well as the capacity to port the applications developed through different platforms "Developed by FIWARE". In addition, this API also solves in a simple way the complexity of treating the information collected by the sensors, and translating them into a common language, even though they communicate using different protocols and IoT languages. Moreover, within the OASC<sup>7</sup> (Open & Agile Smart Cities) initiative, this API has been adopted as the first open-license standard API aimed at providing the basic artifact for the portability and interoperability of smart city solutions.

<sup>4</sup> oneM2M <http://www.onem2m.org/>  
<sup>5</sup> FIWARE NGSI <http://fiware.github.io/specifications/ngsiv2/stable/>  
<sup>6</sup> OMA (Open Mobile Alliance): <https://www.omaspecworks.org/>  
<sup>7</sup> OASC <https://oascities.org/>

STANDARDIZATION

Following recommendations from a variety of independent standardisation bodies, **FIWARE proposes a standard** that describes how to collect, manage, publish, and report changes in context information **called FIWARE NSGI**. It is a simple but very powerful open standard, selected by the *European Commission* as a core element of the *CEF<sup>8</sup> (Connecting Europe Facility)* for the implementation of new smart applications and public administration, on the basis of which all interactions between the applications or platform components and the *Context Broker* component take place.

As described in the interoperability feature above, the *FIWARE NSGI API* is a version of the *OMA NSGI* interface and has been adopted as the first open-licensed standard API to provide the basic device for the portability and interoperability of Smart City solutions, within the *OASC* initiative.

Furthermore, the current *FIWARE NSGI* specifications are aligned with the published *ETSI<sup>9</sup> NSGI-LD Connectivity Information Management API* specifications. This API allows users to provide, consume, and subscribe to context information in multiple scenarios involving multiple stakeholders, as identified in Figure 7.

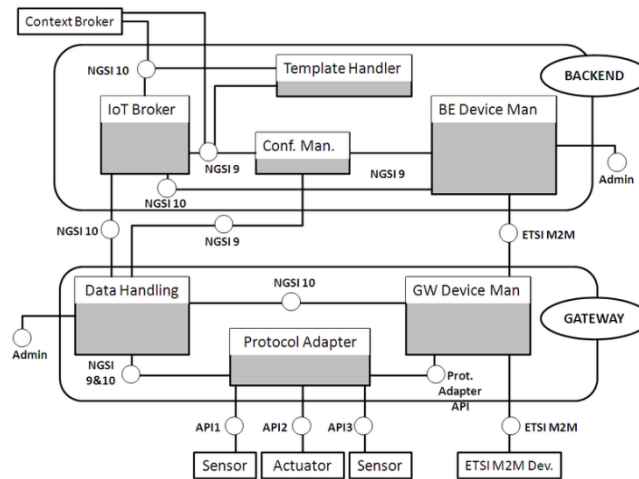


FIGURE 7. ARCHITECTURE OF THE IOT SERVICE ENABLEMENT

The *FIWARE NSGI API* defines a data model for context information, based on a simple information model using the notion of a context entity, a context data interface for the exchange of information through meaningful queries, subscriptions and update operations, and a context interface available for the exchange of information related to the availability of context information. An example of the NSGI data model elements (Entity, attributes, and metadata) are depicted in the next figure.

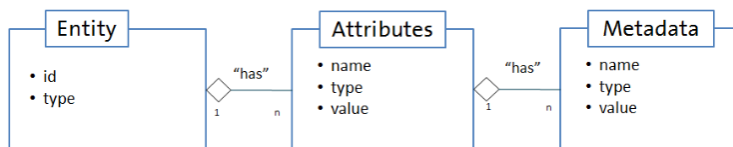


FIGURE 8. NSGI DATA MODEL ELEMENTS

<sup>8</sup> CEF (Connecting Europe Facility): <https://ec.europa.eu/inea/en/connecting-europe-facility>

<sup>9</sup> ETSI European Telecommunications Standards Institute: <https://www.etsi.org/>

Following the standards, in this case the *oneM2M* standard, FIWARE incorporates an intermediate layer of IoT services that provides different functionalities related to safety, device, service and data management and connectivity.

Regarding security, FIWARE has a generic component that provides authorization services that comply with the *XACML* standard, through an API that allows managing access control policies based on attributes and role-based access control and obtain authorization decisions for these policies.

### USABILITY

The *FIWARE Community* provides to developers with countless resources, including a comprehensive collection of step-by-step tutorials. These tutorials consist of a series of exercises that demonstrate the correct use of the various FIWARE components and the flow of context data in an intelligent solution by managing context directly or through dummy devices. In addition, developers have access to the published code of FIWARE components through GitHub (see an example of resource in FIWARE’s GitHub in Figure 9). In addition, they have the *FIWARE Tour Guide* where the steps to develop a first FIWARE application are recommended, as well as the possibility to download the *FIWARE Tour application* with which they can practice. Additional training can also be obtained through the *FIWARE Academy*, through video tutorials, slides, and other materials, and through recorded FIWARE and *FIWARE for Smart Cities Webinars*, as well as other multi-functional courses that describe how to combine various generic enablers to create a smart system, and additional *System Operations* courses that explain how to implement FIWARE and use the *FIWARE Lab*.

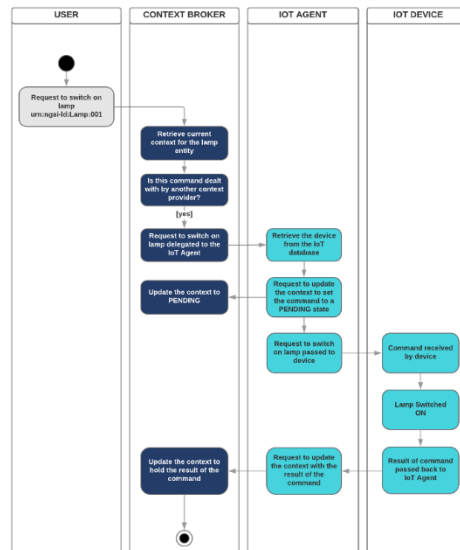


FIGURE 9. EXAMPLE OF RESOURCE IN GITHUB OF FIWARE

*FIWARE Lab* is a working instance of FIWARE that provides a more stable and temporary basic virtual infrastructure in a geographically distributed network of federated nodes available only for experimentation. Through *FIWARE Lab*, the developer can configure the infrastructure to run applications implemented as global or private services, which make use of the APIs provided by the generic FIWARE enablers, allowing the exploitation of open data published by cities and other organizations.

From a security point of view, to access *FIWARE Lab* services a user account is required, whose duration in time is determined by the type of account, trial or Community. While the first type only allows access for a short period of time and provides limited access to resources, the second offers long-term access and use of resources, renewable after a period of time.

FIWARE offers components to manage access control to services. These components cover a number of aspects related to user access to networks, services, and applications, such as user authentication and authorization, single sign-on (SSO) for service domains and identity federation for applications, etc.

### COST & ROYALTIES

**FIWARE is a royalty-free open framework** for future development. With respect to its cloud approach, FIWARE uses *OpenStack* (see Figure 10), a free and opensource software distributed under the terms of the Apache license, as the basis for the Infrastructure as a Service (IaaS) platform, through which FIWARE provides the developer with everything s/he needs to implement an application without having to provide an underlying infrastructure. Almost all FIWARE nodes are hosted worldwide using *OpenStack*.



FIGURE 10. FIWARE CLOUD

Moreover, because FIWARE components are container-based, it uses *Docker* for the orchestration of the services provided by its components, which is also an open-source system primarily aimed at handling container applications. In addition, the specifications and interfaces of the generic FIWARE enablers are public and royalty-free and are aligned with the published *ETSI NGSI-LD* specifications.

According to a Machine research analysis, the use of non-standardized solutions increases the cost of implementation<sup>10</sup>. As mentioned in previous sections, FIWARE proposes the *FIWARE NGSI* standard based on the *OMA NGSI* standard adopted by the *OASC* initiative. On the other hand, FIWARE also makes use of the *oneM2M* standard incorporating an intermediate IoT service layer.

## 2.2 Exploitation

FIWARE is a framework of selected open-source platform components that can be assembled together with other third-party platform components to accelerate the development of Intelligent Solutions. This framework makes use of standards and information models that enable portability and interoperability between applications, as well

<sup>10</sup> <https://machinaresearch.com/news/smart-cities-could-waste-usd341-billion-by-2025-on-non-standardized-iot-deployments/>

as reliable data exchange between systems and organizations, key factors in driving Industry 4.0.

In this digital transformation, FIWARE is working together with *iShare* and *FundingBox*<sup>11</sup> on reference architectures and information models, which allow making use of context information, both manufacturing and non-manufacturing related, in order to help companies to improve their efficiency and considerably accelerate their production processes with minimal effort. These architectures allow data providers to maintain control over the use of their data (data sovereignty).

FIWARE uses the *FIWARE NGSI API* as well as *Orion Context Broker* to develop innovative services in different domains that can be exploited by external providers, in order to unlock the potential of contextual data from IoT and other systems.

FIWARE NGSI's RESTful API allows developers to merge IoT data with other data sources, simplifying IoT management. There are also IoT devices, known as FIWARE-Ready IoT Devices, that are capable of sending and responding using FIWARE NGSI, either natively or indirectly through the use of IoT Agents, responsible for translating the IoT native message and transport protocol supported by the device.

Orion Context Broker is the main component of FIWARE. This component is responsible for managing the context information, a fundamental requirement for any intelligent solution, and is the only component required for a solution to be considered as a FIWARE solution. In addition to this enabler, FIWARE provides other software enablers, known as FIWARE-ready, which provide advanced functions, thereby extending the capabilities of the platform and enabling the development of more sophisticated applications. The vast majority of these components are available as container images through GitHub.

FIWARE is offered as a service in both private and public clouds by FIWARE platform service providers. These providers offer an enhanced cloud environment based on OpenStack, in addition to an extensive set of open standard APIs.

From an economic point of view, the possibility of having FIWARE in a private environment without the need to contract the services of external providers is one of the factors from which COSIBAS has benefited. On the other hand, having royalty-free components developed from standards such as Orion Context Broker and the FIWARE NGSI API has allowed COSIBAS to develop an architecture from which low-cost intelligent solutions capable of managing the context information provided by IoT devices can be developed.

From a business point of view, the services provided by the FIWARE Foundation to be described in this section will allow COSIBAS to scale and promote itself internationally.

For the dissemination of commercial offerings, **FIWARE has a Marketplace** through which it gives visibility to a wide variety of solutions and platforms *Powered by FIWARE®*. Through this Marketplace, FIWARE also offers consulting, integration, and technical support services. On the other hand, infrastructure operators from different countries are incorporating FIWARE services to their commercial portfolio and making them available to customers.

FIWARE also offers online training and coaching services through the FIWARE Academy, and many of its partners, such as FICODES<sup>12</sup>, also offer customized training services.

<sup>11</sup> <https://www.fiware.org/news/fiware-ishare-and-fundingbox-launch-the-i4trust-initiative-that-will-mobilise-5-8-million-euros-to-boost-data-sharing-and-facilitate-sme-innovation-capability-through-the-creation-of-data-spaces/>

<sup>12</sup> FICODES: <https://www.ficodes.com/en/>

Improving competitiveness in the digital economy requires internal resources that enable access to disruptive technologies, tools, and solutions. To solve this need for resources, FIWARE provides the **iHubs** network, a one-stop shop focused on building communities in order for companies to thrive locally and globally. Through iHubs, FIWARE provides:

- A meeting point for the ecosystem that acts as a physical access point, called iHub Center.
- A place to learn FIWARE technology, both from a commercial and technical point of view, called iHub School.
- An iHub Lab to test and certify FIWARE solutions and services.
- A service for the diffusion and promotion of FIWARE solutions, called iHub Business Mentor.

Regarding the **FIWARE Community**, being part of it brings a series of benefits, both from a strategic and business point of view (scalability), as well as from a marketing point of view (international promotion). These benefits depend on the category of membership, as well as the role to be played within the community. More information about these benefits can be found at the URL: <https://www.fiware.org/wp-content/uploads/2019/12/Membership-Benefits-Foundation.pdf>.

Finally, through the **FIWARE Accelerator** program, companies, especially SMEs and start-ups, can bring innovative and commercial smart solutions "Powered by FIWARE" to international markets. This program promotes the adoption of FIWARE technologies among solution integrators and application developers.

## 2.3 Relevant FIWARE-based solutions

### SMARTPORT

The rise of IoT in the maritime sector has brought the need to monitor in real time the large amount of information provided by sensors, in order to improve their efficiency. The efficiency of a seaport has a direct impact on the economic development of the country, enabling trade, transport of goods and people, as well as environmental protection. For the processing and storage of this large volume of information, it is necessary to have secure and scalable architectures that allow the collection, storage, visualization and management of information in order to facilitate rapid decision making.

FIWARE is one of the platforms used by some ports for the development of intelligent applications capable of handling large volumes of information in real time. As an example of a FIWARE solution oriented to the port sector, it can be taken a look at SmartPort<sup>13</sup>, a Web platform developed by the Maritime Port of Las Palmas de Gran Canaria in conjunction with the University of Las Palmas de Gran Canaria (ULPGC) for monitoring data from the sensors of a maritime port. This platform provides a back-end architecture that allows the processing and storage of the information provided by the sensors of the Port in a secure way. It also provides high-level functionalities on the data provided by the sensors for decision making. Users have a Web interface (front-end) through which they can manage and visualize the recorded information as well as its history.

Like this solution, new FIWARE solutions are planned for the near future. In order to facilitate decision-making in environmental management, the FIWARE Zone IoT 2020 challenge presented the basis for participating in the challenge consisting of presenting innovative

<sup>13</sup> SmartPort. <https://www.mdpi.com/1424-8220/16/3/417>

technological solutions that allow obtaining real-time data on the environmental footprint of port activity. This challenge was developed by the Ministry of Transformation Economy, Industry, Knowledge of Spain, in collaboration with universities of the Junta de Andalucía, as well as with Telefónica in order to address the problems in environmental management of the Port Authority of the Bay of Algeciras.

Like other ports, the Port Authority of the Bay of Algeciras (APBA) faces problems arising from the environmental impact of burning fuels as a result of increased port activity. Therefore, achieving a greener and more sustainable port logistics chain is one of the main objectives of the ports in their future development.

As a result of this challenge, the winning solution was presented by the start-up Hop Ubiquitous SL (HOPU)<sup>14</sup>. This company plans to develop a solution consisting in the development of a platform based on AI to standardize, integrate and analyze in real time the data coming from platforms such as SAMPA or SafePort, and from APBA's air quality measurement stations in order to facilitate decision making and future forecasts.

## SMART GRID

Modern grid applications need to accommodate the interaction of a variety of actors. What was once a direct value chain is now transforming itself into complex ecosystems. Consumers are becoming prosumers and supply and demand are optimized in real time and at a very granular level. The need for flexibility has grown notably with the innovations of renewable energy resources, batteries, power electronics, electric mobility, and rapid digitalization.

The main goal of a smart grid implementation is the creation of an automatic process. It is critical to define for every possible data exchange both, the semantics of the information as well as the communication protocol.

A number of data standards are available, and many data exchanges are already formalized. New standards, emerging from the recent work of ETSI with the FIWARE Context Broker, are an important piece of the puzzle. The increasing significance of data at customer/prosumer level requires platforms which are able to aggregate large amounts of data and avoid data silos. Data platforms need to be based on open standards in order to support open competition.

At the same time, there are many business model innovations – rapid integration of distributed energy resources, decentralized markets, and Peer-2-Peer energy exchanges – that are driving differentiation and commodification across the energy sector, leading to the electrification of everything.

As the FIWARE community highlights<sup>15</sup>, the FIWARE Orion Context Broker is the core component of FIWARE that gathers, manages and provides access to the information coming from different sources that describe what is going on in an Energy Ecosystem. Therefore, it allows to assemble together with other third-party platform components to accelerate the development of Smart Solutions.

The IDEASFORUM Community<sup>16</sup> was born out of the smart energy mission support committee of the FIWARE Foundation, and its work in cooperation with Linux Foundation for

<sup>14</sup> HOPU: <https://hopu.eu/es/>

<sup>15</sup> Smart Energy – FIWARE Foundation <https://www.fiware.org/community/smart-energy/>

<sup>16</sup> Competence Center Smart Energy (IDEASFORUM) <https://ideasforum.org/competence-center-smart-energy/?lang=en>



Energy, DG Energy and DG CNECT of the European Commission and the CEF Digital Program Team. The members of the Competence Centre are all actively participating to the open-source community, which is focused on supporting the development of software to accompany the energy transition and assure that the digitalisation of the energy infrastructure has the right tool, with initiatives such as SARGON (Smart eneRGy dOmain oNtology), derived from SAREF.

## 3 AI PLATFORM

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In order to automate and provide better solutions for decision making, the integration of ML capabilities is becoming essential. Consequently, the platforms and frameworks that provide this type of service have been evolving, providing more sophisticated ML services.

**MLaaS** (*Machine Learning as a Service*) is the most complete type of solution provided by automated and semi-automated cloud-based platforms that covers most infrastructure problems, such as data pre-processing, training, and model evaluation, with additional predictions. These types of platforms provide predefined modules and tools for automating the design, testing and implementation of self-learning services, as well as a hardware infrastructure, making them the ideal environment for companies that do not have enough resources or experience.

### 3.1 Main Competing AI Platforms

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Currently, the main leading *Artificial Intelligence platforms* in *MLaaS* that allow a fast implementation and training of models are

- IBM Watson
- Google AI
- Microsoft Azure
- Amazon AWS AI
- Oracle AI

Next, we will describe the most outstanding characteristics of each one of them, to finish with a summary of the most significant aspects.

#### IBM WATSON

*Watson* is a computer system developed by IBM for the search of answers capable of answering questions formulated in natural language. IBM defines it as "*An application of advanced technologies designed for natural language processing, information retrieval, knowledge representation, automatic reasoning, and automatic learning in the open field of answer-seeking, built on IBM's DeepQA technology for hypothesis generation, mass test retrieval, analysis, and scoring*". The DeepQA high-level architecture is illustrated in Figure

11

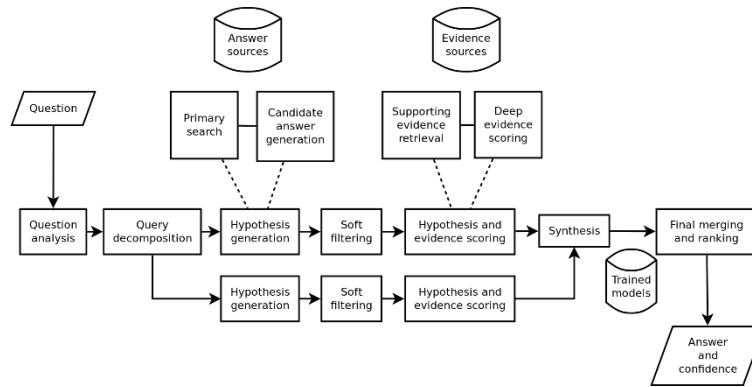


FIGURE 11. HIGH LEVEL ARCHITECTURE USED BY DEEPQA

IBM offers this technology through a flexible environment (local, in the cloud, or hybrid) called *Watson Studio*<sup>17</sup>. IBM describes this environment as "an enterprise platform for creating and training artificial intelligence and machine learning models, as well as preparing and analyzing data". This platform provides tools to facilitate work with data in order to create offline and online models at scale:

- Automation of data preparation
- Text analysis to extract knowledge from unstructured data, creating predictive models
- Creation of predictive models using visual modelling tools, without open-source and self-service functionalities
- Access to raw files, spreadsheets, and major relational databases
- Graphical display and export of data

However, some of the functionalities, such as the natural language modelling wizard, are available depending on the version to be used.

*IBM Watson* provides a number of methods (logistic regression, decision tree classifier and regressor, random forests, gradient-enhanced trees, naive berries, linear and isotonic regression) to cover three main types of tasks: binary classification, multiclass classification, and regression. It also provides advanced notebook capabilities such as *Jupyter* for manually programming models using frameworks such as *TensorFlow*, *Scikit-learn*, *Pytorch* and others.

This platform provides a free trial version within the *Lite plan* whose duration is only limited based on monthly limits that are updated each month. Besides this version, the platform provides two additional paid versions within the standard and business plans. Both versions provide the same functionality, differing, in addition to the price, in the number of unit capacity hours per month, the number of users and viewers, among other aspects.

The different IBM Watson versions available are presented next.

### Watson Studio Cloud

- Payment by consumption
- Quick start up
- Integrated environment for calculations
- Cloud publishing and collaboration
- Servers for interactivity and data visualization

<sup>17</sup> Watson Studio. <https://www.ibm.com/es-es/cloud/watson-studio/faq>

### Watson Studio Desktop

- Aimed at users who want to create and run data models without coding on their desktop
- Provides access to IBM SPSS Modeler Premium at no additional charge
- Provides various data science tools
- Unlimited modelling, no surplus
- Support for up to 2 weeks of offline use through open-source integration
- Access to a variety of remote databases
- Offers a free 30-day trial

### Watson Studio Local

- Intended for business data and scientific teams
- Scalable cluster deployed in a private infrastructure
- Perpetual and temporary licences
- Ability to deploy in the private or public cloud, including AWS and Azure
- Lightweight directory access protocol for user authentication
- Collaboration with projects inhabited by Git
- Servers for interactivity and visualization of data and for data encoder scientists
- Offers add-ons for visual productivity and prescriptive analytics
- Price provided by the company after contact

One of the restrictions imposed by this tool is the size of the files to be uploaded. This tool does not allow data files larger than 5 GB to be uploaded into a project. For this purpose, IBM provides an alternative consisting in using the *IBM Cloud Object Storage API* that allows loading data in multiple parts.

Finally, IBM provides a *Stack Overflow* forum as support for this tool.

## GOOGLE AI

The Google Artificial Intelligence Platform (Google AI) is an end-to-end *MLaaS* platform for data scientists, developers, and AI engineers. The Google AI Platform has services to address the life cycle of ML models and provides building blocks for developing and deploying sophisticated ML models.

The Google AI Platform provides a code based data science development environment compatible with *Kubeflow*<sup>18</sup>, for compiling and running machine learning applications in a Kubernetes environment. This platform allows to store data using *Cloud Storage* or *BigQuery*, tag data, using classification, object detection and entity extraction functions to images, videos, audios, and text; to import this tagged data into *AutoML*, and to manage ML models. The platform provides the tools to train self-learning models, as well as custom containers to run training tasks with other self-learning frameworks.

The full cycle development and learning framework of Google AI is presented in the figure below.

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<sup>18</sup> Kubeflow is an open source platform from Google that allows you to create transferable self-learning processing flows

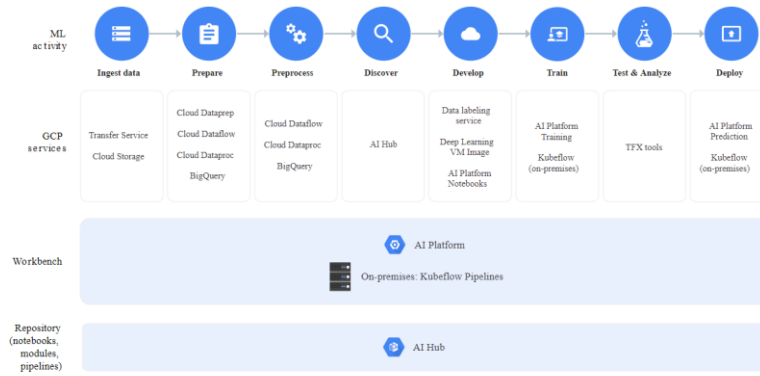


FIGURE 12. FULL CYCLE DEVELOPMENT AND LEARNING

Through *AI Platform Prediction*, you can request model predictions and obtain target values. This platform also provides a hypothesis tool to assess model performance and provides *Deep Learning Virtual Machine Images* that allows to launch instances of virtual machines pre-configured with AI frameworks in the Google Cloud. This platform also integrates a set of hardware accelerators called *Cloud TPU* that enables streamlining and scaling of self-learning workloads to run self-learning models with AI services on the Google Cloud.

Google AI also supports ML for *Kubernetes*. In detail, this kit provides services for creating and managing interactive *Jupyter laptops* (a custom *TensorFlow* training job operator for training ML models). This kit supports a *TensorFlow* service container for exporting trained *TensorFlow* models to *Kubernetes* and includes a comprehensive solution called *Kubeflow Pipelines* for the implementation and management of end-to-end ML workflows. It can be integrated into multiple frameworks and has an open community of software developers, data scientists and organizations.

*TensorFlow* is an open-source ML library from Google, it lacks a visual interface, and its learning curve is quite steep and, it is mainly aimed at deep neuronal networking tasks. Among the AI elements offered by TensorFlow, it provides the following:

- Artificial vision for image analysis (*Vision IA*) that allows to detect objects and faces, read printed and handwritten text, and obtain metadata through user interface and API.
- Video analysis (*Video IA*) for object location and action recognition in stored and streaming videos through a graphical interface and by using an API.
- Text analysis through a graphical interface (*AutoML Natural Language*) and API for content classification and syntactic, opinion and entity analysis.
- The translation of texts into different languages by means of an API, the conversion of audio into text (*Cloud Speech-to-Text API*), and the conversion of text into speech (*Cloud Text-to-Speech API*)
- The creation of conversation interfaces (*chat bots*) in various languages (*Dialogflow*).
- The creation and automatic deployment of automatic learning models from structured data (*AutoML Tables*) (see Figure 13).
- Collect real-time information from time-series type datasets (*Cloud Inference API*)
- The creation and execution of automatic learning models using standard SQL language (*BigQuery ML*).

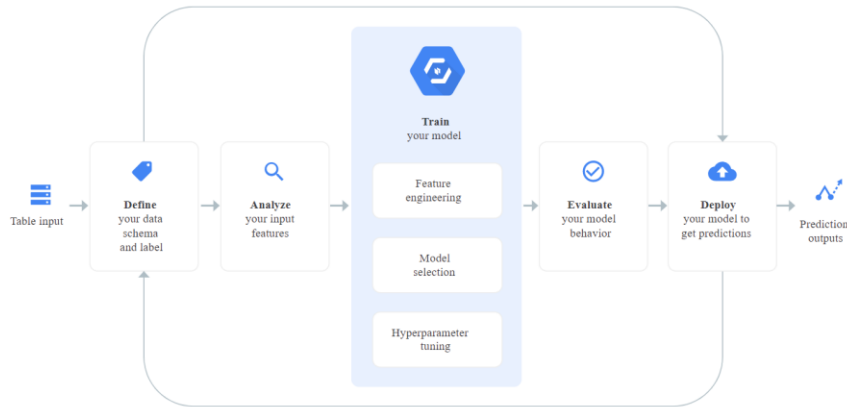


FIGURE 13. OPERATION OF AUTOML TABLES

Some of the tools mentioned allow scalability. On the other hand, the general use of this platform and its products is paid, and its price varies depending on various factors such as versions, usage, etc. Nevertheless, it should also be acknowledged that many of the products offered through this platform have free use but limited to factors such as requests made in a period, volume of data, etc.

### MICROSOFT AZURE AI

Microsoft Azure AI offers a set of Python-based ML services for businesses that can be used in the cloud and at the edge. It includes a set of pre-trained AI services, which can be accessed through an API to build applications with cognitive features. Some of these services are language and speech processing, computer vision, cognitive search, and decision management. It also offers a set of development tools for the creation of personalized models of automatic learning.

Azure's services can be divided into two categories:

- Azure ML Studio
- Azure Cognitive Services

### Azure Machine Learning Studio<sup>19</sup>

This is an automatic learning service that allows the creation, delivery, and implementation of automatic learning models anywhere, either in the intelligent cloud or in perimeter intelligence, in a quick and easy way through a visual interface without code, as well as the administration of these models through integrated tools such as *Azure DevOps* (see Figure 14).

<sup>19</sup> Azure Machine Learning. <https://azure.microsoft.com/es-es/services/machine-learning/>

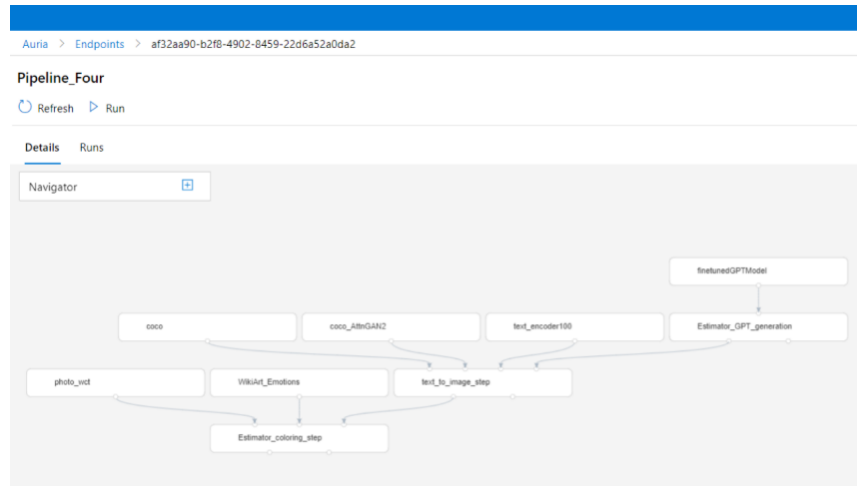


FIGURE 14. AZURE DEVOPS FOR MACHINE LEARNING

This service also provides a self-learning user interface aimed at training self-learning models in a quick and easy way, as well as notebooks offering *Code First* self-learning. In addition, it offers hardware-accelerated models in order to reduce cost through very low latency. Moreover, this service also provides model interpretation functionalities in a more transparent way. Through this service, Microsoft joins the open source *MLFlow* platform project designed for end-to-end self-learning model lifecycle management. This project includes data exploration, pre-processing, selection of around 100 methods and validation of results. Methods address classification, anomaly detection, regression, recommendation, and text analysis.

*Azure ML Studio* also provides an integrated data service, such as meteorological, socioeconomic, security, satellite image and other data, called *Azure Open Datasets* in order to improve the accuracy of the automatic learning models.

### Azure Cognitive Services<sup>20</sup>

These services provide developers with the possibility of inserting AI into their applications, either in the cloud or locally via docker containers, in order to provide their users with functionalities aimed at:

- Improve decision making by detecting potentially offensive or unwanted content (*Content Moderator*), predicting potential problems (*Anomaly Detector*) and customizing experiences in the use of applications based on reinforcement learning (*Personalizer*).
- Extracting meaning from unstructured text to help readers understand text through visual and audio prompts (*Immersive Reader*), incorporating natural language recognition into applications, bots and IoT (*Language Understanding*) devices, creating a question-and-answer conversation layer from data (*QnA Maker*), detecting opinions, key phrases and named entities, and detecting and translating text into over 60 languages.
- Integrate speech processing into applications and services by enabling the conversion of speech to text and vice versa and identify speakers.
- Identify and analyse image content (*Computer Vision*), video (*Video Indexer*) and digital pen input, customize image recognition (*Custom Vision*), detect and identify people and emoticons in images (*Face*), extract par-value text from forms (*Form Recognizer*), recognize digital ink and handwriting input (*Ink Recognizer*).

<sup>20</sup> Azure Cognitive Services. <https://azure.microsoft.com/es-es/services/cognitive-services/>

A very important part of *Azure ML* is *Cortana Intelligence Gallery*, a collection of ML solutions provided by the community to be reused by data scientists.

Unlike *Azure ML Studio*, *Azure Cognitive services* do not have integrated methods and require custom model engineering, hence these services are more targeted to more experienced data scientists.

The cost of using the services provided by *Azure AI* varies according to the resources used and the editions of the different products. According to Microsoft, its cost is comparable to AWS or the equivalent of a Microsoft company contract.

### AMAZON AWS AI

The *Amazon AWS* is a collection of cloud computing utilities that together form a cloud computing platform, offered on the Internet by Amazon. It provides a set of abstract technical infrastructure and building blocks and tools for distributed computing. In addition, it also provides an integrated development environment for building, training and deploying custom self-learning models. Examples of some services are voice and text processing, computer vision and cognitive search, among others.

Amazon offers pre-trained AI services for various fields, tools to design, train and deploy scaled machine learning models, or custom models compatible with the most popular open source languages.

*Amazon ML* services are available at two levels:

- **Amazon ML.** Predictive Analysis.
- **SageMaker.** Tool for Data Scientists.

### Machine Learning Services

These services allow you to create, train and deploy ML (*Machine Learning*) quickly. *Amazon ML* incorporates algorithms optimized for large data sets and computations in distributed systems.

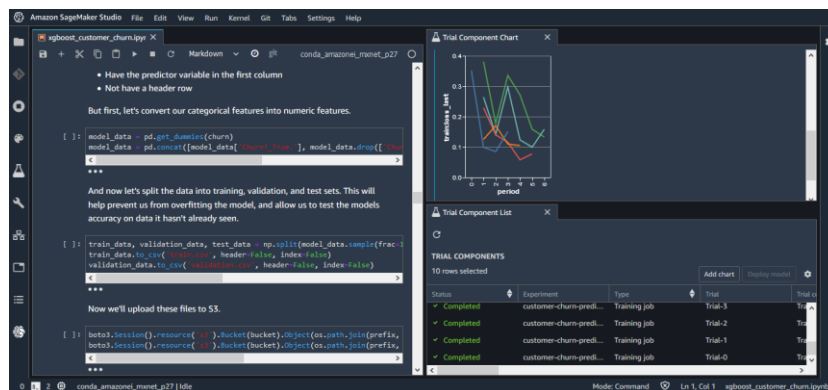


FIGURE 15. AMAZON SAGEMAKER STUDIO

- **Amazon SageMaker**

This service allows developers and data scientists to create, train and implement machine learning models. This service provides an integrated development environment called *Amazon SageMaker Studio* for self-learning through which you can upload data, create and share notebooks, train and fit HL models, debug and compare results, and deploy and monitor HL models. It also provides a utility called

Amazon SageMaker Autopilot through which you can automatically create, train and fit models.

Data scientists can use SageMaker's built-in methods or add their own and run models through this tool. This tool can be integrated with TensorFlow, keras, Gluon, caffe2, Torch, MXNet and other ML libraries.

### AI Services (Artificial intelligence)

Amazon Web Services' Artificial Intelligence services provide ready-made and pre-trained intelligence for use in applications and workflows.

- **Amazon Personalize**

This service uses automatic learning algorithms to create recommendations that respond to specific needs. You only pay for what you use.



FIGURE 16. AMAZON PERSONALIZE FUNCTION

- **Amazon Forecast**

This service uses machine learning to create forecasts by combining time series data with additional variables. You only pay for what you use.

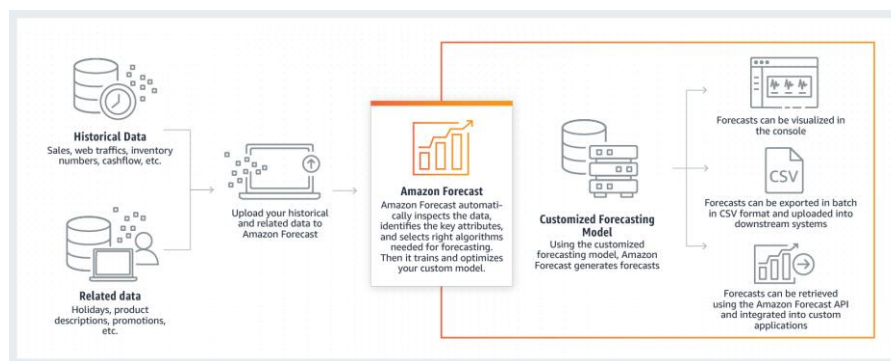


FIGURE 17. AMAZON FORECAST FUNCTION

- **Amazon Rekognition**

This service allows to identify objects, people, text, scenes and activities in images and videos, facial analysis and searches of facial type to detect, analyse and compare faces.



- **Amazon Comprehend**

This is a service for finding information and relationships in texts. This service identifies the language of the text, extracts phrases, names of places, people, brands or key events. It allows to know the degree of positivity of the text, to analyse the text through grammatical categories and to organize by topic a collection of text files.

Related to this service, Amazon provides a service called *Amazon Comprehend Medical* specifically for extracting complex medical information from unstructured text, such as medical conditions, medications, doses, concentrations and frequencies from different sources.

- **Amazon Textract**

This service allows you to extract text and data from scanned documents, identifying the content of fields in forms and information stored in tables.

- **Amazon Polly**

This is a service that allows text to speech (TTS) conversion that resembles a human voice and can be adapted to several languages.

- **Amazon Lex**

This service allows the creation of conversation interfaces with voice and text. Through *Amazon Alexa* developers can quickly and easily create natural language chatbots.

- **Amazon Translate**

It is a neural automatic translation service that offers language translation. This service allows localizing content, such as websites and applications, for international users, and translating large volumes of text.

- **Amazon Transcribe**

This service allows you to convert audio into text. Related to this service, Amazon offers *Amazon Transcribe Medical* that allows you to add text functionality to medical audios for clinical documentation applications.

- **Amazon Kendra**

*Kendra* is a service that allows end users of websites and applications to perform natural language searches.

- **Amazon Fraud Detector**

This Amazon service allows you to identify potentially fraudulent online activities, such as online payment fraud and the creation of fake accounts.

- **Amazon Codeguru**

This is a code review service aimed at improving application performance. It allows finding and correcting problems in the code, and at the moment it is only compatible with applications in Java.

## ML Frames

Amazon offers popular frameworks such as *TensorFlow*, *Pytorch*, *MXNet Apache*, etc... To experiment and customize the self-learning algorithms. In addition to these frameworks,

Amazon offers the AMI (*Amazon Machine Images*) that already come pre-configured with the latest versions of the most popular frameworks and deep learning tools.

**Infrastructure**

*Amazon Elastic Compute Cloud (EC2)* offers 275 types of optimized instances for any self-learning use case, from training models to running inferences on already trained models. These instances are categorized in:

- For general use. Aimed at business critical applications, databases up to medium size, web applications, etc...
- Optimised for computers. Focused on high performance computing, batch processing, video, etc..
- Optimized for memory. Designed for high performance databases, distributed memory caches with web scale, big data analysis, etc...
- Accelerated information. Intended for automatic learning, graphics applications, video games, etc..
- Optimized for storage. Ideal for NoSQL databases, distributed file systems, etc.

*EC2* offers an on-demand, reliable and scalable infrastructure. It is a web service created to simplify the use of web-scale cloud computing, providing complete control over computing resources.

With *EC2* the user can quickly configure the capacity. *EC2* offers high availability for application execution thanks to the availability region and zone model adopted in Amazon *EC2*.

With regard to security, it uses a blocking security model that prohibits administrative access, and supports 89 security standards and compliance certifications.

**Security and Analysis**

Within the security section, Amazon offers, apart from services aimed at security, services for data storage and analysis.

- **Amazon Simple Storage Service (Amazon S3)**

Scalable, available and secure data storage service. This service offers administration features for the organization of data and configuration of data access control.

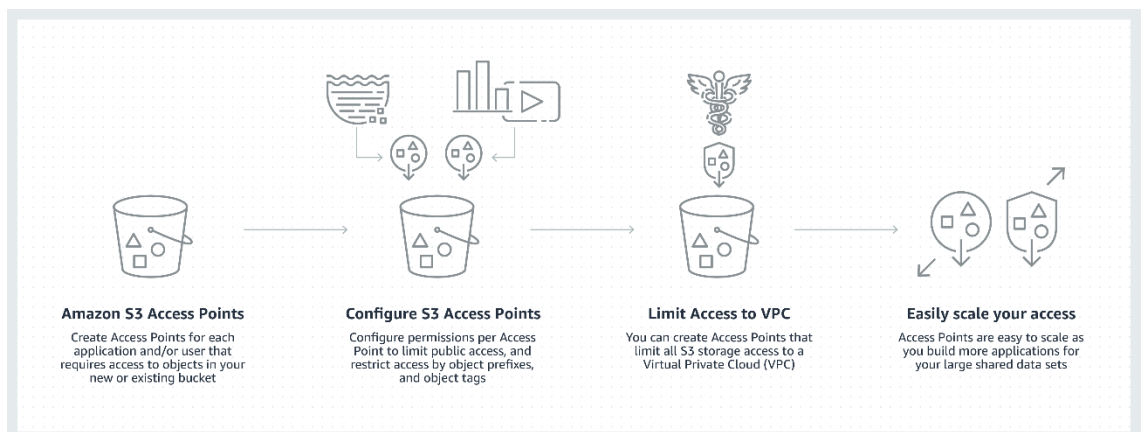


FIGURE 18.

- **AWS Analytics**

Within this section, Amazon provides a wide variety of services grouped by category and focused on different use cases.

- **Analysis.**

Within this category, Amazon provides services for interactive analysis (*Amazon Athena*), big data processing (*Amazon EMR*), data processing (*Amazon Redshift*), real-time analysis (*Amazon Kinesis*), operational analysis (*Amazon Elasticsearch Service*), and dashboards and displays (*Amazon QuickSight*).

- **Data migration**

This category includes services for real-time data migration (*Amazon Kinesis data Analytics*, *Amazon Kinesis data Firehose*, *Amazon Kinesis data Streams*, *Amazon Kinesis Video Streams*).

- **Data Lake**

This category includes services for object storage (*Amazon S3 and AWS Lake Formation*), backup and archiving (*Amazon S3 Glacier and AWS Backup*), data catalog (*AWS Glue and AWS Lake Formation*), and third-party data (*AWS data Exchange*).

- **Predictive Analytics and Machine Learning**

This category includes framework and interface focused services (*AWS Deep Learning AMI*) and platform services (*Amazon SageMaker*).

The predictive capabilities of *Amazon ML* are limited to three options: binary classification, multi-class classification, and regression. *Amazon ML* does not support any unsupervised learning methods.

On the one hand, the user must select a target variable to be labelled in a training set, and on the other hand, the user is not required to know any ML method, as it is Amazon that automatically chooses it based on the data provided.

- **AWS Security**

Amazon provides the infrastructure and services to protect its customers' information, identities, applications and devices.

Using AWS, a global infrastructure can be created that includes data encryption, relocation and management capabilities. With AWS services, customers can control where data is stored, who can access it, and what resources their organization is consuming. These services also allow for the automation of security tasks. In addition, these services can be extended by using services from other providers selected by Amazon, as well as inheriting the most comprehensive security and compliance controls.

The AWS security, identity and compliance services are grouped into categories, each of which in turn groups a set of use cases.

- **Identity & Access Management.**

This category groups together services for secure service and resource access management (*AWS identity & Access Management*), single sign-on (SSO) in the cloud (*AWS Single Sign-on*), application identity management (*Amazon*

*Cognito*), Microsoft active directory management (*AWS Directory Service*), AWS resource access manager (*AWS*), AWS governance and account management (*AWS Organizations*).

- **Detection**

This category includes services for threat detection (*Amazon GuardDuty*), application security analysis (*Amazon Inspector*), registration and evaluation of AWS resource settings (*AWS Config*), monitoring of user activity and API usage (*AWS CloudTrail*), security management for IoT-compatible devices (*AWS IoT Device Defender*). In addition to these services, Amazon also offers a unified security and compliance center (*AWS Security Hub*).

- **Infrastructure protection**

This category offers services aimed at protecting against *DdoS* attacks (*AWS Shield*), filtering of malicious web traffic (*AWS Web Application Firewall*), as well as central firewall rule management (*AWS Firewall Manager*).

- **Data protection**

In this category are services for the discovery and protection of confidential data at scale (*Amazon Macie*), management and storage in the cloud (*AWS Key Management Service*), storage of keys in hardware for regulatory compliance purposes (*AWS CloudHSM*), provisioning and management and implementation of public and private SSL/TLS certificates (*AWS Secrets Manager*).

- **Responses to indications**

This category contains services for investigating possible security problems (*Amazon Detective*) and disaster recovery (*CloudEndure Disaster Recovery*).

- **Conformity**

Within this category is a single service that offers a free portal for on-demand access to AWS compliance reports (*AWS Artifact*).

### Learning tools

*Amazon AWS* provides a set of tools for developers for the different types of artificial intelligence learning; machine learning, reinforcement learning and deep learning.

#### AWS DeepComposer

*AWS DeepComposer* is a tool designed to instruct developers in machine learning. It provides a keyboard from which you can create a melody that is transformed into an original song thanks to artificial intelligence.

This learning tool includes tutorials, sample code, and training data as a starting point for creating models of generative artificial intelligence without writing any lines of code.

"*The Generative Artificial Intelligence technique compares two different neural networks to produce new and original digital creations based on sample inputs*".

#### AWS DeepRacer

It is a fully autonomous 1/18 scale car, designed to start using learning by reinforcement, consisting of learning complex behaviours without the need to use tagged training data and making short term decisions.

Developers can design models in *Amazon SageMaker*, and then train and test them on the track using a 3D racing simulator provided by this tool.

### **AWS DeepLens**

This tool consists of a video camera with in-depth learning support for developers. This camera is integrated with *Amazon SageMaker* and other *AWS services*. The developer can choose a deep learning model from the *AWS DeepLens* model library or opt for their own models trained with *Amazon SageMaker*.

This device allows the creation of projects for object detection, bird classification, activity recognition such as guitar playing, face detection, etc.

### **ORACLE AI**

*Oracle AI* is a cloud platform for businesses, data scientists, and developers. It offers pre-trained AI models and development tools, covering the different stages of the AI development life cycle, from data management to application development and data science.

Oracle offers intelligent applications adaptive to machine learning and real-time artificial intelligence through data, decision science. These applications have been designed for the business user, are cloud-based and have a scalable structure.

Oracle's cloud data platform for machine learning provides data scientists and application developers with a suite of fully integrated services ranging from data origin to data science and open source application development based on artificial intelligence. This platform consists of the following products:

- Oracle Cloud Infrastructure Data Science
- Oracle Machine learning
- Oracle Business analytics
- Oracle Big data
- Oracle Digital Assistant
- Oracle Cloud Services for Application Development

The suite of services provided by Oracle Cloud Infrastructure Data Science provides functionality for:

- Manage new machine learning models
- Automate data management based on automatic learning (*Oracle Machine Learning*)
- Discover, search, organize, enrich, and track data assets in the Oracle Cloud (*Oracle Cloud Infrastructure Data Catalogue*)
- Run Spark machine learning in memory (*Oracle Big data service*)
- Communicate with Oracle databases to work with data from other stores and minimize data movement (*Oracle Cloud Sql*)
- Running Apache Spark applications without deploying or managing the infrastructure (*Oracle Cloud Infrastructure Data Flow*)
- Use virtual machines with preconfigured environments that include self-learning notebooks that provide a collaborative interface

### **Oracle Machine Learning**

It allows the processing of data where it resides, by moving the algorithms to the data, thus reducing data movement and improving scalability, while preserving security and reducing implementation times of automatic learning models. These models are nothing more than

native SQL functions that can be implemented through scripting and R. In addition, within this tool, Oracle also offers parallel implementations of the self-learning algorithms and integration with open source R in the database.

### **Oracle Business Analytics**

It is a comprehensive solution based on Artificial Intelligence that allows the modelling of business scenarios, programming and massive business reporting, as well as receiving real-time alerts and managing the environment by voice.

### **Oracle Big Data**

It is an Oracle platform that allows you to connect to over 2000 *Software as a Service (SaaS)* applications and other *Oracle tools*, manage predictive analytic models and dashboards using Machine Learning.

### **Oracle Digital Assistant**

It is a platform for the creation of assistants with artificial intelligence, which connect to back-end applications, for the processing and understanding of natural language by automating responses through conversation interfaces.

### **Oracle Cloud Services for Application Development**

It offers a range of services for developers to create modern native applications in the cloud using the languages, databases and tools of their choice.

## SUMMARY

The following tables show a different comparison of ML services and modelling platforms for the analysed platforms, based on the analysis made in <https://sitiobigdata.com/>.

### Platforms for custom modeling

	IBM Watson ML Studio	Google ML Engine	Azure ML Services	Amazon SageMaker	Oracle AI
Incorporates algorithms	✓	✗	✗	✓	✓
Supported frameworks	TensorFlow SparkMLlib Scikit-learn XGBoost PyTorch IBM SPSS PMML	TensorFlow Scikit-learn XGBoost Keras	TensorFlow Scikit-learn Microsoft Cognitive Toolkit Spark ML	TensorFlow MXNet Keras Gluon Pytorch Caffe2 Chainer Torch	Keras Caffe Scikit-learn TensorFlow Numpy

### Automated and semi-automated ML services

	IBM Watson ML Model Builder	Google Prediction API	Microsoft Azure ML Studio	Amazon ML	Oracle ML
Classification	✓	Deprecated	✓	✓	✓
Regression	✓		✓	✓	✓
Clustering	✗		✓	✓	✓
Abnormal detection	✗		✓	✗	✓
Recommendation	✗		✓	✗	✗
Ranking	✗		✓	✗	✗

### Speech and text processing API's

	IBM	Google	Microsoft	Amazon	Oracle
Voice Recognition (Speech to Text)	✓	✓	✓	✓	✓
Text to speech conversion	✓	✓	✓	✓	✓
Extraction of entities	✓	✓	✓	✓	✓
Key Phrase Extraction	✓	✓	✓	✓	✓
Language recognition	+60 languages	+120 languages	120 languages	+100 languages	31 languages
Topic extraction	✓	✓	✓	✓	✓
Spell checker	✗	✗	✓	✗	✓
Autocomplete	✗	✗	✓	✗	✓
Voice verification	✗	✗	✓	✓	✓
Intention analysis	✓	✓	✓	✓	✗
Metadata extraction	✗	✓	✗	✗	✓
Relationship Analysis	✗	✓	✓	✗	✗
Analysis of feelings	✓	✓	✓	✓	✓
Customized analysis	✗	✓	✗	✗	✗
Syntax analysis	✓	✓	✓	✗	✗
Label parts of the speech	✓	✗	✓	✗	✓
Filter out inappropriate content	✓	✗	✓	✗	✗
Handling of low quality audio	✓	✓	✓	✓	✗
Translation	21 languages	+100 languages	+60 languages	6 languages	+100 languages

	IBM	Google	Microsoft	Amazon	Oracle
Chatbot Toolkit	✓	✓	✓	✓	✓

### Image Analysis API's

	IBM	Google	Microsoft	Amazon	Oracle
Object detection	✓	✓	✓	✓	✗
Scene detection		✓	✓	✓	✗
Face detection	✓	✓	✓	✓	✓
Facial Recognition		✗	✓	✓	✓
Facial analysis	✓	✓	✓	✓	✗
Detection of inappropriate content	✓	✓	✓	✓	✗
Celebrity recognition	✗	✓	✓	✓	✗
Text recognition	✓	✓	✓	✓	✗
Written text recognition	✗	✓	✓	✗	✗
Searching for similar images on the web	✗	✓	✗	✗	✗
Logo detection	✗	✓	✗	✗	✗
Reference point detection	✗	✓	✓	✗	✗
Food recognition	✓	✗	✗	✗	✗
Detection of dominant colours	✗	✓	✓	✗	✗

### Video Analysis API's

	Google	Microsoft	Amazon	Oracle
Object detection	✓	✓	✓	✗
Scene detection	✓	✓	✓	✗
Activity detection	✗	✗	✓	✗
Facial Recognition	✗	✓	✓	✓
Facial and sentimental analysis	✗	✓	✓	✗
Detection of inappropriate content	✓	✓	✓	✗
Celebrity recognition	✗	✓	✓	✗
Text recognition	✗	✓	✓	✗
Video tracking of people	✗	✓	✓	✗
Audio transcription	✓	✓	✗	✗
Speech Indexing	✗	✓	✗	✗
Keyframe extraction	✗	✓	✗	✗
Video translation	✗	9 languages	✗	✗
Keyword extraction	✗	✓	✗	✗
Brand recognition	✗	✓	✗	✗
Annotation	✗	✓	✗	✗
Detection of dominant colours	✗	✗	✗	✗
Real-time analysis	✗	✗	✓	✓

## 3.2 Comparative with FIWARE

The platforms analysed in the previous point are cloud-based, automated and semi-automated platforms. On the one hand, they provide the hardware infrastructure necessary for data processing, model training and evaluation, prediction, etc, and their results can be



combined with local infrastructures through RestAPI. On the other hand, they provide design automation tools and predefined modules, testing and implementation of automatic learning services, which makes them ideal environments for companies that do not have sufficient resources or the necessary experience. However, all of this provided functionality has its pros and cons, particularly with regard to interoperability, extensibility, and cost.

### **Interoperability**

Interoperability is a very important aspect in the digital world and especially so in some contexts, such as smart cities. Today we all have a multitude of data sources related to our health, our finances, etc... The benefit of the latest developments in AI and automatic learning would be greater if all these data could be used as a whole. In order to improve interoperability and shared optimization, **ONNX** (*Open Neutral Network Exchange*), an open-source AI ecosystem, was created. The ONNX format was created as a community-driven open-source standard for deep learning and traditional self-learning models. "*ONNX defines a common set of operators, the basic components of the machine learning and deep learning models, and a common file format to enable AI developers to use models with a variety of frameworks, tools, runtimes, and compilers*<sup>21</sup>". ONNX is compatible with Amazon AWS and Microsoft Azure among others. However, although some of the AI platforms analysed have improved their interoperability thanks to ONNX, they are still proprietary solutions developed exclusively for AI/ML. They are not IoT platforms that integrate automatic learning and artificial intelligence.

COSIBAS aims to integrate AI/ML into the FIWARE platform, making it a pioneer in the market by combining IoT and AI. This objective is possible thanks to the high degree of openness, interoperability, modularity, and standardisation of the FIWARE platform compared to the AI platforms previously analysed.

### **Modularity**

From the point of view of modularity, the AI platforms previously analysed are characterised by offering services, some accessible through APIs and Graphic Interfaces, which make use of open-source ML libraries, but are strongly coupled to a platform whose infrastructure is in the cloud. The customer can select which already trained AI and Automatic Learning services he wants to contract, but these are still opaque tools explicitly developed to work within a proprietary platform. From an architectural point of view, the vast majority of ICT implementations are customised and not entirely scalable. These aspects together with the lack of a common language/taxonomy, as well as the lack of convergence around architectural design principles is affecting the market growth in different sectors. On the other hand, the fact that an architecture is not open is a critical aspect for some contexts that require interoperability and open-source solutions.

FIWARE's modularity is determined by its generic and specific components, also known as enablers. The building blocks of FIWARE are 100% open source. FIWARE uses OpenStack, a free and open-source software distributed under the terms of the Apache license, as the basis for the IaaS platform. Developers have access to FIWARE component code through GitHub, where it is published. This makes it easy to incorporate them into the design of solutions, thus reducing potential vendor lock-in. In addition, this availability allows developers to use their own local or cloud infrastructure for publishing their FIWARE solution, so that the FIWARE provider is not subject to an infrastructure that may incur additional costs.

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<sup>21</sup> Fuente: <https://onnx.ai/>

### Cost

Another aspect to bear in mind with regards to the AI platforms analysed is their cost. The FIWARE components are royalty-free, which translates into a reduction in the cost of using and burdening the hosting environment and the costs of commercial extensions. Although some of the services provided by the platforms described are free, they are usually limited to the use, volume, and version of the product. The cost of these services includes both usage and hosting. However, unlike these platforms, the cost of FIWARE is much lower due to its open-source approach, which makes it easily accessible at no cost.

But not everything will be advantages in FIWARE. Like any platform, FIWARE has its strengths and weaknesses. Unlike the platforms discussed above that have focused on providing great functionalities through multiple services accessible via graphical interface or APIs, the FIWARE platform has been up to date more focused on providing basic capabilities for IoT, than on providing tools and capabilities around data and AI. Therefore, FIWARE lacks visualization features, geospatial analysis, and ease of use. Nevertheless, this should not be a problem as over time these shortcomings can be developed and incorporated into the platform thanks to its aforementioned extensibility features.

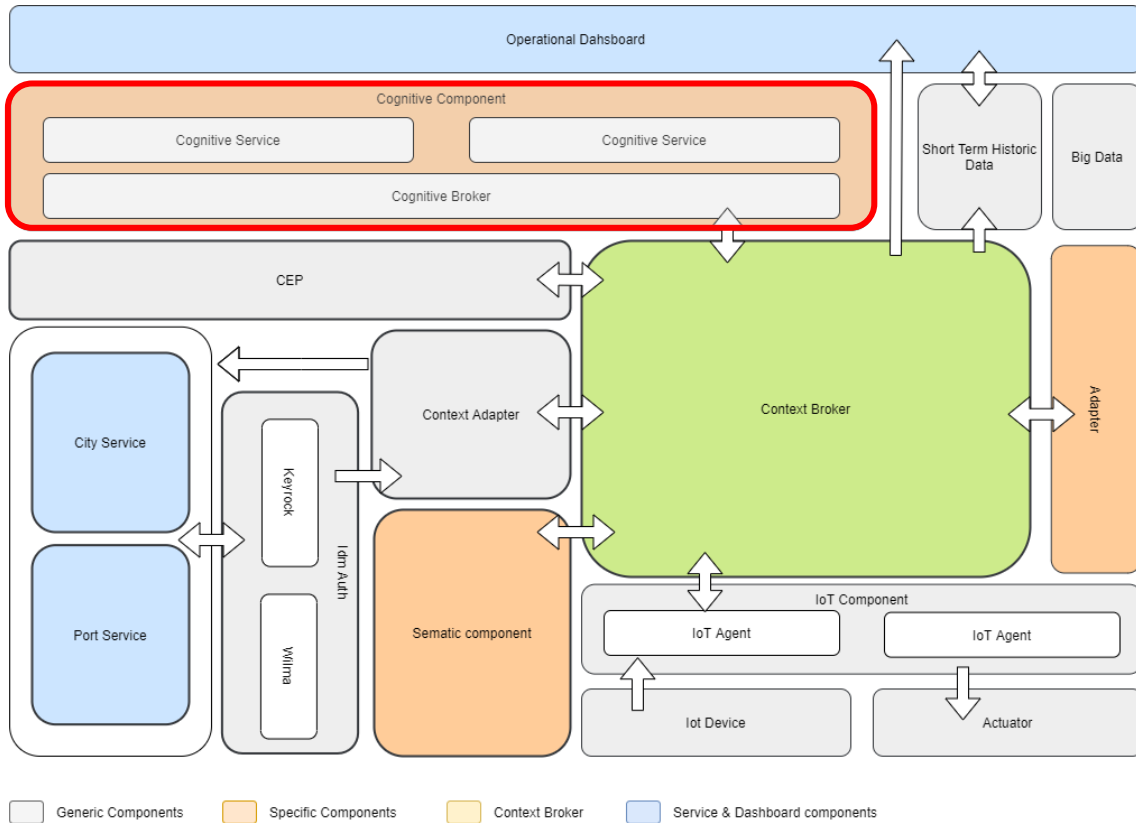
## 4 LIAISON WITH FIWARE

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FIWARE is an open platform that promotes the participation of users and developers whose ultimate goal is to become a standard platform with reusable solutions. It emerges as an open-source initiative promoted by the *TIC Industry* and the *European Community* in order to facilitate the development and deployment of intelligent solutions and services by defining a universal set of standards for managing contextual information, as well as harmonized data models for different domains in a rapid manner. These characteristics of the FIWARE platform, together with the fact that it is an IoT platform, have made it one of the ideal platforms for achieving the main objective of COSIBAS: “*To incorporate cognitive capabilities via AI into IoT*”.

COSIBAS benefits from FIWARE features to extend its architecture, by incorporating a new generic Cognitive Component, oriented to AI/ML. This new component integrates with the *Context Broker* component, the core component of FIWARE platform, using the standard FIWARE NGSI API that provides the basis for interoperability and portability of intelligent solutions. The integration of this new AI/ML component will provide added value to the FIWARE IoT platform, making it as one a reference open-source Intelligent IoT platforms.

Figure 19 illustrates how the new cognitive component is integrated into the FIWARE architecture.



**FIGURE 19. COGNITIVE COMPONENT INTEGRATION INTO FIWARE FRAMEWORK**

The FIWARE NGSI interface allows applications to inquire about the context (synchronous mechanism) and to subscribe to their changes that are received through notifications (asynchronous mechanism). This functionality allows the *Cognitive Component* to be notified by the *Context Broker* component of changes made in the context. Similarly, this functionality also allows the *Cognitive Component* to notify the *Context Broker* of changes made to the context information, and this, in turn, to other components, such as the *CEP*. Therefore, this *Cognitive Component* can act as a publisher/consumer of the context information.

The *Cognitive Component* being developed follows the architectural specifications contemplated in FIWARE specifications. It consists of a *Broker* responsible for managing the communications between the different *Cognitive Services* with the rest of the components of the platform. *Cognitive Services* have been developed as open-source microservices with specific cognitive purposes, so that they can cover any field and make use of the main AI libraries existing in the market, such as *TensorFlow*, *Scikit-learn*, *Keras*, etc. with no other restriction beyond the imposed by the ad-hoc development itself.

The *Cognitive Component* provides, through the *Cognitive Broker*, all the generic functionality common to all cognitive services, such as those related to security and communications. The latter are sub-components of the former, and provides the functionality required for each case through one or more cognitive agents that, in turn, can make use of one or more cognitive algorithms. Internal communications within the component follow the guidelines and standards assumed by FIWARE. This modularity together with standardization and open-source will allow developers to add new cognitive services to the platform according to their needs. Figure 20 presents the general *Cognitive Component* developed in COSIBAS and their communication flow compliant with FIWARE specifications. For more details, please refer to deliverables D2.1 and D3.1 of the project.

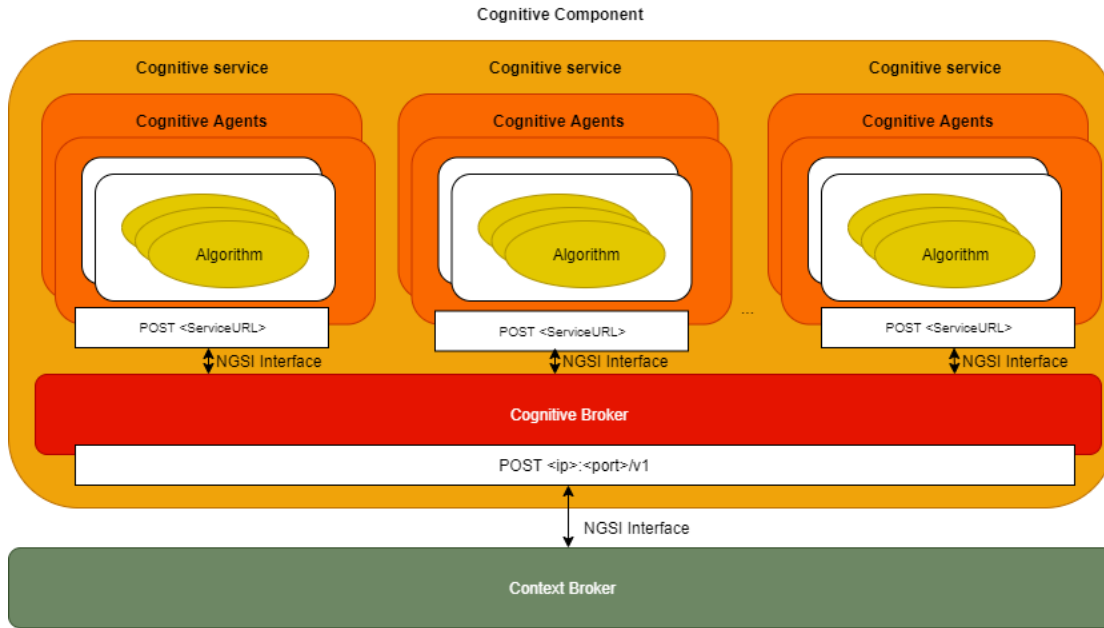


FIGURE 20. COGNITIVE COMPONENT FUNCTIONAL ARCHITECTURE AND LIAISON WITH FIWARE SPECIFICATIONS

In terms of functionality there are no limitations, over time, providers can enrich their FIWARE solutions as they develop new AI/ML services. Regarding the interface of these, there are no limitations either as these cognitive services will be able to provide both a graphical interface to facilitate the user's tasks when training the algorithms and an RestAPI to achieve the same goal.

## 5 WHY FIWARE?

### 5.1 From a technical point of view

To answer the question of why FIWARE is necessary to know the different types of platforms that exist in the market. All of them can be classified into three main types, taking into account the reason for their creation and the main characteristics:

- **Traditional IoT platforms:** They are those systems that were born explicitly to solve the problem of creating solutions adapted to the IoT paradigm. They support a wide range of lightweight protocols for device integration, tools for rule creation, data storage, data exposure for application creation, etc.
- **Extended Cloud Services Platforms:** Cloud providers were originally born with the aim of offering mainly IaaS. However, they later began to develop different modules aimed at offering facilities for developing applications. Along these lines, this type of platform has incorporated a wide variety of IoT modules that allow the integration of data from devices, subsequently offering as an additional feature their entire product offer for data processing, analysis, application creation, etc. Many of these modules are valid for the IoT, although they are also valid for many other uses.
- **Technology suppliers:** This group includes traditional software providers which, unlike cloud providers, have gone from simply offering their *software-as-a-service* (SaaS)

platforms, to incorporating different modules that facilitate the transition to a model closer to the IoT paradigm.

Since technology providers' platforms do not have basic IoT features, nor a variety of additional cloud services, they will be discarded in this analysis. The following figure illustrates the two types of IoT platforms under consideration in this analysis:



FIGURE 21. TYPE OF IOT PLATFORM ACCORDING TO ITS ORIGIN

Within the remaining two types of platforms, they can be classified as either open-source platforms, or proprietary solutions.

The main open-source platforms are:

- FIWARE - <https://www.fiware.org/>
- OpenMTC <https://www.openmtc.org/>
- SiteWhere - <https://sitewhere.io/es/-->
- Webinos - <http://webinos.org/>

The main patented solutions are:

- Amazon AWS IoT - <https://aws.amazon.com/es/iot/>
- IBMS Watson IoT - <https://www.ibm.com/internet-of-things>
- Microsoft Azure IoT Hub - <https://azure.microsoft.com/es-es/overview/iot/>
- Oracle AI <https://www.oracle.com/es/artificial-intelligence/>
- Samsung SmartThings - <https://www.smarthings.com/>

The following table below presents how each of the platform components is associated with the components identified in the reference platform.

Platform	FIWARE	OpenMTC	SiteWhere	Webinos	AWS IoT	IBM Watson IoT Platform	MS Azure IoT Hub	Samsung SmartThings
Sensor / Actuator	.*	Sensors & Actuators	.*	.*	.*	.*	-	Sensors & Actuators & Devices & Users & Things
Device	Device / NGSI Device	.*	Data from Devices + Commands to Devices	PZP: Policy + Session + Discovery + Context Manager	Things	.*	Device	Sensors & Actuators & Devices & Users & Things + Clients (-Devices)
Gateway	IoT Edge	Front-End: Core Features + Connectivity + Back-End: Connectivity	.*	PZP: Sync + Messaging Manager + PZH: Sync Manager	.*	Connect	Cloud Protocol Gateway + Field Gateway	Hub and Client Connectivity + Device Type Handlers
IoT Integration Middleware	IoT Back-End + Data Context Broker	Back-End: Connectivity + Core Features + Application Enablement	SiteWhere Tenant Engine	PZH: User Authentication + Policy Repository + Policy Enforcement + Web APIs	Message Broker + Thing Shadows + Thing Registry + Rules Engine + Security & Identity	Analytics + Risk Management + Connect + Information Management + Bluemix Open Standards Based Services + Flexible Deployment	IoT Hub + Event Processing and Insight + Device Business Logic, Connectivity Monitoring + Application Device Provisioning and Management	Application Management System + Subscription Processing
Application	.*	Applications + Other M2M Platform	Integration- + REST-components	Third Party Applications	Amazon Services + IoT Applications	IoT Industry Solutions + Third Party Apps	Application Device Provisioning and Management	Event Stream + Web UI + Core APIs + External System + Physical Graph

\* Not represented in the figure of the architecture, but described within the documentation.

FIGURE 22. SUMMARY TABLE OF IOT ARCHITECTURE<sup>22</sup>

Taking a look at the table above, several reasons founded the motivation of choosing FIWARE as the ground IoT platform of COSIBAS:

1. **FIWARE provides process automation across the value chain**, easy plug & play integration with other solutions and services and allows connection to IoT with *Contextual Information Management* and *Big Data* services in the cloud. It consists of generic components, also called generic open-source enablers that can be assembled with each other and with other third-party components thanks to the *FIWARE NGSI API*, a simple, powerful and standard API. This modular feature, the use of standards and the fact that the specifications of the generic components will be made public makes it easier for developers to extend FIWARE and for new projects to emerge.
2. **Another reason for choosing FIWARE is its broad consensus and support at both the public and private levels.** FIWARE is an open platform promoted by the *European TIC Industry* and the *European Community*, used by more than 15 European cities, among others. This platform allows the sharing of homogeneous data information between cities, which guarantees the interoperability between them. FIWARE follows the model of federated platform architecture, in which different platforms exchange data with each other, as well as management capabilities allowing interoperability.
3. **The open architecture approach of FIWARE has been also considered critical for some contexts**, particularly in intelligent cities, energy management, and logistics, as it addresses the need for interoperability and open-source solutions.

<sup>22</sup> Guth et al., "A Detailed Analysis of IoT Platform Architectures: Concepts, Similarities, and Differences", Jan. 2018

Beyond analysing the technical characteristics reflected in the table and summarized above, since from the beginning commercial solutions have been discarded because of their cost issues, as they do not fit the open solution principle of the project, FIWARE is chosen, which being said before, it is an open platform that promotes the participation of users and developers, as the ultimate goal is to become a standard platform with reusable solutions. Until this maximum objective is reached, there is another objective that is linked to it, which is: “FIWARE aims to facilitate the creation and cost-effective delivery of future Internet applications and services in a variety of areas, including smart cities, sustainable transport, logistics, renewable energy and environmental sustainability”. In fact, FIWARE motto is: “An open-source platform for a smart digital future”.

## 5.2 From a business point of view

FIWARE offers through *FIWARE Marketplace* different alternatives to globally disseminate a FIWARE solution. In *FIWARE Marketplace*, it can be found a wide range of FIWARE-ready solutions and technologies such as IoT devices and enablers, as well as FIWARE platform service providers and FIWARE-related consulting, training, integration, and support services.

The COSIBAS architecture provides the necessary tools for the development of intelligent solutions that make use of AI and ML. This architecture has been developed according to the standards and requirements that a solution must meet in order to be considered a FIWARE solution. Within this architecture, it can be found a new generic enabler developed, namely Cognitive Component, aiming at incorporating Artificial Intelligence to the FIWARE platform. The cognitive enabler is a software component that allows extending the basic capabilities of the platform with cognitive features. This new component allows building intelligent applications by acting as a middleware between the platform and the cognitive services responsible for the cognitive analysis of context information in real time. Therefore, its exploitation can be performed in several ways:

- One of the possible exploitations of COSIBAS consists in publishing the new cognitive enabler in FIWARE Marketplace. This alternative requires the enabler to provide one or more connectors to one or more other FIWARE enablers.
- Another possibility to exploit COSIBAS through FIWARE Marketplace is to provide this service as an instance of the FIWARE platform on-premises at the service provider, or in the cloud for customers. In this case the platform will be labelled "*Powered by FIWARE - Platform*".
- The last possibility through the FIWARE Marketplace is to exploit COSIBAS as an intelligent solution. For this, the solution must be based on FIWARE standards that allow to manage context information on a large-scale, as well as to collect it from different sources. In this case, the solution must be considered as "*Powered by FIWARE*", a requirement that COSIBAS fulfils by making use of the enabler required by any solution that can be considered as "*Powered by FIWARE*", i.e., the Orion Context Broker.

For all these alternatives presented through *FIWARE Marketplace*, prior to their publication and according to FIWARE policy, it is necessary to comply with a series of requirements:

1. The applicant (in this case the COSIBAS exploitation management board) must be registered in the *FIWARE Marketplace*.
2. One or more domains for the product should be defined (i.e., smart cities, sustainable transport, logistics, renewable energy, and/or environmental sustainability).

3. It must provide one or more manuals describing how to connect the developed technology with one or more FIWARE enablers.

Finally, beyond becoming an agnostic “Powered by FIWARE” platform, COSIBAS can also focus on the two specific scenarios of the project:

#### SMART PORT

In the Smart port domain, COSIBAS can be exploited as an advanced cognitive service within the port-oriented products, thanks to the development and validation of the Estimated Time of Arrival (ETA) intelligent algorithm. This service provides an added value to these products by allowing its customers to obtain more accurate and reliable information regarding the ETA of a vessel in port. In this case, COSIBAS would be operated as an instance of the FIWARE platform outside the *FIWARE marketplace*.

#### SMART GRID

When COSIBAS acts as a smart grid solution by providing multiple services (prediction and negotiation algorithms as well as visualization system) to potential customers, COSIBAS should be also exploited as an instance of the FIWARE platform outside the FIWARE marketplace. In addition to this, each cognitive service particularly developed for the smart grid domain could be exploited in a separate way like Smart Energy Management Solutions “Powered By FIWARE”, which could address FIWARE-based Smart City Platforms.

## 6 CONCLUSIONS

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FIWARE is a commitment of the *TIC industry* and the *European Community* for the development of intelligent solutions in multiple sectors, based on standards and royalty-free open-source paradigms that provides process automation throughout the value chain and easy integration with other applications and services. The components that make up this platform can be combined with each other to offer solutions that allow connection to IoT with contextual information management services and *Big Data* in the cloud, thanks to a *Restfull FIWARE NGSI API* developed from the *OMA* standard for context management, data exchange and the definition of harmonised data models. This last aspect is very important, proof of which is that the FIWARE API has been adopted as the first open-licensed standard API, aimed at providing the basic artifact for portability and interoperability in intelligent cities.

The AI and ML platforms analysed in this document provide a cloud infrastructure through which they offer a variety of services for AI/ML with algorithms already trained for certain functionalities within a proprietary solution. Thus, this limits both their extensibility and their interoperability with other platforms to external providers. On the other hand, the use of the infrastructure provided by these platforms implies a cost for the user that varies according to the use, volume and versions of the different products/services offered. In contrast, FIWARE provides a set of generic and specific open-source components that can be downloaded from GitHub to be installed within a local infrastructure, or in the cloud, thus, reducing the costs derived from hosting.

At the moment, the FIWARE platform does not provide any kind of AI and automatic learning services, but thanks to COSIBAS this platform will be ready for developers to add functionality aimed at providing cognitive capabilities without losing the main characteristics of modularity, flexibility, extensibility, interoperability, standardization and royalty-free open source, making this IoT platform one of the main platforms in the market.