BD4OPEM H2020 project. The 4+1 View Model of Software Architecture for enabling AI-based services in distribution grids

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Abstract

The increase of complexity and the digitalization of distribution grids rises the need for sharing energy-related data and making use of new data analysis and artificial intelligence techniques in the energy sector. To answer these needs, The BD4OPEM H2020 project aims to share energy-related data and to offer data analytics and artificial intelligence services to leverage their availability in an Open Innovation Marketplace. Multiple solutions are provided by specialized companies, addressing the needs of different energy-related stakeholders. The objective of this paper is to present the software architecture of the Open Innovation Marketplace being developed under the BD4OPEM project, based on the 4+1 View Model methodology of software architecture definition. According to this methodology, the Logical View of the BD4OPEM Platform architecture is structured into four piled up layers and one cross-cut layer addressing the architecture security and privacy needs.

1. Introduction

The management of distribution networks increasingly needs a quicker and more efficient response due to the uncertainty introduced by distributed and intermittent renewable generation sources. Simultaneously, energy systems are moving from the analogue world to the current digital interconnected real-time IoT world. Nowadays, huge amounts of energy-related data are available, mostly from smart meters latest deployments [1]. However, most of these data are underused [2]. The appropriate processing of this data can boost innovative tools and services.

Energy-related companies can be reticent to share their data as it can create security risks or compromise competitive advantages. However, great opportunities can arise if operational data from distribution grids are exchanged fairly and transparently. Several initiatives around the world are supporting energy data sharing among stakeholders and researchers, such as Green Button [3] and OpenEI [4] in the USA or ENTSO-E Transparency Platform [5] in the European Union. In addition, new business models and additional benefits can be created by offering data to external stakeholders.

Under this context, the BD4OPEM H2020 project aims not only to share data but also to provide energy-related data analytics services in an Open Innovation Marketplace, where solutions provided by specialized companies address the needs of system operators, energy suppliers and aggregators, microgrid operators, prosumers and e-Mobility service providers. The objective is to extract more value from the available data providing new big data and artificial intelligence (AI) solutions to develop services like grid topology identification, grid observability, predictive maintenance, fraud detection, buildings energy management, blockchain transactions and flexibility aggregation for demand-response. All these services will be available commercially from the Open Innovation Marketplace.

This paper presents the software architecture of the AI-based services and data sharing Marketplace being developed under the BD4OPEM project. It is structured as follows: section 2 presents the methodology followed to describe the architecture, section 3 shows the BD4OPEM architecture obtained and section 4 includes the paper conclusions.

2. Methodology

The BD4OPEM architecture is designed considering interoperability (both regarding ICT/big data techniques and

Energy asset interactions), reusability and versatility as core principles. The architecture design is based on the analysis of business and system use cases reflecting ideas, requirements and constraints of the five pilot sites where the BD4OPEM Platform will be tested and demonstrated. More than 35 use cases were collected using standard IEC methodology [6], covering all aspects of the discussed architecture. The result is a reliable baseline for the project that offers an easy way to gather requirements and define the overall software architecture.

In this context, BD4OPEM considers the "4+1" View Model of Software Architecture [7] the best choice for the architectural definition. This is a software-orientated approach (as most of the BD4OPEM assets) and it addresses all different cross-cutting requirements of the project stakeholders (final-users, programmers, integrators and systems engineers). This architecture model is based on 5 concurrent views (Figure 1):

- The *logical or structural view* is the one closest to the end-user's approach, presenting the functionalities that the system should include in a high-level static approach.
- The *implementation or development view* shows the programmer's perspective, dealing with the dependencies between modules (inputs and outputs), besides the technical and logic requirements.
- The *process or behavioural view* depicts the workflow and communication between the modules of the architecture, following a dynamic perspective.
- The *deployment or physical view* introduces the physical components and connections of the systems from the perspective of a system engineer.
- The "+1" view, *scenario or use case view* relates all other views, exposing the main functionality, including requirements and scenarios.

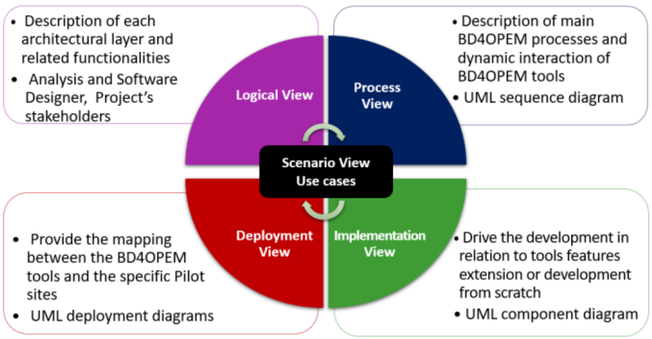

Figure 1. The "4+1" architectural view model.

3. The BD4OPEM architecture Logical View

Based on the 4+1 View Model of Software Architecture, the BD4OPEM platform architecture is presented as one leading-edge architecture. Not only because it offers an Open Innovative Marketplace, capable of providing valuable services for all the energy players chain, but also, it provides beyond the state of the art technologies of cloud-computing with big data and AI.

This section presents the Logical View of the BD4OPEM Platform architecture, which is structured into five layers, as presented in Figure 2. Four of them are piled up, with one holistic and cross-cutting:

- Starting bottom-up, the Physical Layer provides the energy-related data, mainly from the physical devices of the five pilots, besides the communication protocols for their access and control.
- The Data Layer performs the data interoperability between the BD4OPEM layers; since it ingests the data from the Physical Layer and carries out the requests/sends of data by the rest of the layers.
- The Analytics Layer represents the core of the BD4OPEM architecture. Its six submodules provide leading edge energy solutions, based on AI technologies, that will be offered through the Marketplace Layer.
- The Marketplace Layer is a virtual energy applications store where energy services and energy-related data are exchanged by stakeholders.
- Finally, the Security, Privacy and Blockchain Layer ensures and guarantees the confidentiality, integrity and availability of all the platform modules. These three principles are achieved by providing a reliable authentication model and through a strong monitoring tool.

Following subsections present in detail, the layers of the BD4OPEM platform architecture.

3.1. Physical Layer

The Physical Layer aims to collect data from physical devices. This data is to be processed by the upper layers of the BD4OPEM Platform. It considers all different field devices present on the five BD4OPEM pilot sites, such as Supervisory Control And Data Acquisition (SCADA), Smart Meters (SM), Geographic Information System (GIS), Distributed Energy Resources (DER), Electric Vehicles (EV) charging infrastructure or Photovoltaic (PV) facility, as well as Open Data Sources like Weather APIs or National Calendar data. Moreover, these on-field devices support well-known standard communication protocols (FTP, TCP, HTTP, etc).

3.2. Data Layer

The Data Layer purpose is twofold: collecting data (acting as a middleware between the Physical Layer and the BD4OPEM Platform), storing data and providing unified access to data for all other top layers. It is also responsible for the harmonization, monitoring and maintenance.

The data volume to be gathered, its heterogeneity and disparate source format, as well as the different communication protocols considered, pose a great challenge

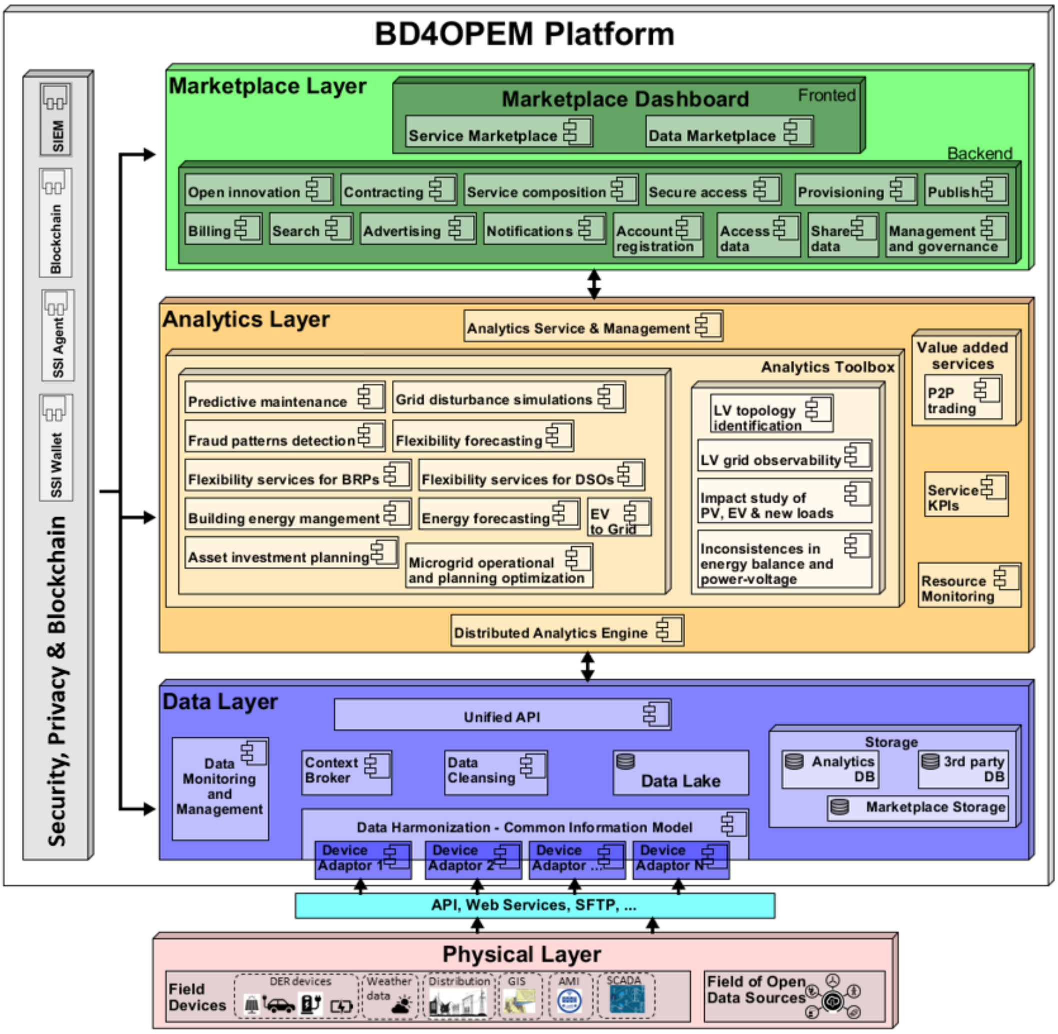

Figure 2. The BD4OPEM platform architecture.

in terms of interoperability. In an attempt to address this issue, the adopted solution implements Device Adaptors. These adaptors extract the data from devices, using standard communication protocols; and simultaneously, harmonize the data accordingly to the BD4OPEM data model, which ensures seamless interoperability with all other modules, layers and components. This data model is designed based on a combination of well-known standards (SAREF [8], NGSI-LD [9], ETSI CIM [10], IEC [11]) combining the ICT and energy domains.

The data persistence of the BD4OPEM Platform is achieved through two different modules, depending on the data characteristics. On one side, the Storage module processes operational and temporary data, such as permissions, data templates and technical information. On the other side, the Data Lake hosts the data coming from the Physical Layer, offering a distributed storage solution with high scalability and availability. Since the acquisition process may ingest inconsistent values, a cleansing process is also performed, ensuring quality and reliability. In addition, the management and monitoring processes guarantee the clear organization and supervision of the data lake, as well as its governance.

Finally, all data requests and their delivery to the upper layers are performed using a unified Application Programming Interface (API) that ensures data interoperability in the BD4OPEM Platform.

3.3. Analytics Layer

The Analytics Layer is the core of the BD4OPEM Platform. It aims at extracting the inherent value of the data with appropriates insights. It provides cutting-edge tools and solutions that are offered as services to different energy stakeholders through the Open Innovation Marketplace.

The most innovative tools are included in the Analytics Toolbox. This module is conceived as a modular big data ecosystem based on statistics, cloud computing and simulation. It employs AI techniques such as supervised learning, deep learning, reinforcement learning, data mining, pattern recognition and optimization. In addition to these analytic tools, this layer counts on value added services (VAS), in particular the peer-to-peer (P2P) Trading. In summary, it comprises novel energy tools addressing six categories of the energy domain with the prime purpose to enhance the current operation of the grid, as presented in Table 1.

The usage of these big data analysis techniques entails an intrinsic difficulty given the requirements for computing power, complexity and robustness. Therefore, the following functionalities have been defined to improve training performance and efficiency, and allow to detect early errors:

- The Distributed Analytics Engine is able to split the workload over multiple nodes in a cluster of servers
- The Resource Monitoring is in charge of monitoring the analytic tools performance and scalability
- The Services' KPIs tool is responsible for the coordination and management of services indicators calculations and of the evaluation of their performance

Table 1. Tools provided through the Analytics Toolbox

Category	Tool
Operation and maintenance	LV topology identification LV grid observability Predictive maintenance Measurement errors detection Grid disturbance simulations Impact study of PV, EV and new loads
Fraud detection	Inconsistences in energy balance and power-voltage Fraud patterns detection
Flexibility and demand response	Flexibility forecasting Flexibility services for BRPs Flexibility services for DSOs EV to Grid
Smart houses, buildings and industries	Building energy management Energy forecasting
Trading	P2P trading
Planning	Asset investment planning Microgrid operational and planning optimization

The connection between this layer and the Marketplace Layer is set up by means of the Analytic Service and Management module. This module manages operational aspects (e.g. trigger for launching) of Analytics Layer tools.

3.4. Marketplace Layer

The Marketplace Layer is defined at the top of the BD4OPEM Platform architecture. It is conceived as an energy services store, where energy stakeholders can discover different energy services able to solve their needs and help them in their business decision-making.

This Open Innovation Marketplace is built on two main objectives. The first objective is to connect different stakeholders of the energy value chain, such as Distribution System Operators (DSOs), research institutions, public administrations and SMEs or ICT experts through a dynamic market, enabling them to offer/exchange data and/or advanced energy services. The second aims at developing a digital platform, based on big data technologies and ICT principles, that provides flexibility, scalability, standardization and large-scale replicability.

To stimulate innovation and keep the platform updated from its users needs, stakeholders will be able to submit Open Innovation call on the platform to express a need and look for a specialized company to fulfil it, this ending in the creation of additional services on the Marketplace.

The Open Innovation Marketplace comprises, on one hand, the "client-side" (Frontend), where service-stakeholders' interactions are established; and, on the other hand, the server-side (Backend), which manages the results of the analytic services and enables operations such as contracting or billing. In this context, the client-side offers a set of services divided into:

- Business-energy services (Service Marketplace), including the tools mentioned in Table 1;
- Data services (Data Marketplace), dealing with the capabilities of accessing and sharing data under confidentiality, integrity and GDPR regulations.

The functionalities offered by the server-side are:

- Search: Querying of data and services offered in the marketplace;
- Contracting: Creation of a 'bond' among a provider (of data or service) and a user;
- Provisioning: Management of the instantiation of a contracted service;
- Billing: Payment/invoice management related to the purchase of services and/or data;
- Publish: Mechanism for exposing and promoting a service to the marketplace;
- Advertising: Creation of custom advertisement for offered data/services;
- Open innovation: Management of request for new services (open calls) as well as the submission of proposals;
- Share data: Mechanism for exposing and promoting sharing of data in the marketplace;
- Access data: interface for viewing, querying and downloading data;
- Service composition: enables the "chaining" of existing marketplace services, enabling service aggregations;
- Notifications: Personalised communication to the end-user of the marketplace;
- Management and governance: Handling of operational aspects;

- Secure Access: User registration and access management.

3.5. Security, Privacy and Blockchain Layer

This cross-cutting layer covers the security and privacy needs of the BD4OPEM Platform. It provides the security controls to maintain the Confidentiality, Integrity and Availability of the personal and strategic information processed and exchanged over the architecture.

Secure access to the marketplace is facilitated using a Self-Sovereign Identity (SSI) Agent that performs Decentralised Identifier (DID) Authentication, issuing and verifying Account Verifiable Credentials (VC). End Users accessing the Open Innovation Marketplace will present W3C Verifiable Credentials using SSI Wallets for persons and SSI Agent for companies/organisations which are external to and independent of the Marketplace. Service contracts will be presented as Verifiable Credentials as well.

To support the security process, Blockchain is used to root the trust in the Decentralised Identifier. Blockchain is also used for the execution of the P2P Trading Smart Contract.

Finally, to audit in real-time the security events occurring in the platform a *Security Information and Event Management* (SIEM) solution is adopted, where security events across all systems are sent to be analysed and to raise any possible security alert.

4. Conclusion

In the midst of the energy transition and with the incorporation of distributed generation, DSOs are going to be subjected to significant challenges. It is necessary to establish new tools to make distribution networks' management more efficient and secure. The use of artificial intelligence techniques in the energy sector can help to provide this requirement and boost this energy transition.

The Open Innovation Marketplace proposed by the BD4OPEM H2020 project aims to make the usage of these AI-based techniques easier. This marketplace will enable large-scale multi-party data exchanges and real-time processing of energy-related data, resulting in an energy-related data and services marketplace.

This paper presents the BD4OPEM platform Logical View architecture from the 4+1 Architectural View Model framework. This software design methodology enables addressing different stakeholders' concerns and establishing the baseline for supporting future development tasks, as it is a reusable and versatile model. According to the selected methodology, the Logical View represents the static approach of what the system should do and the functions and services it offers. As a result, the BD4OPEM one is structured into four piled up layers and one additional cross-cut layer.

The Physical Layer is in charge of providing energy-related data from the physical devices to the Data Layer, which ingests them and carries out the requests of data by the rest of the layers. The Analytics Layer provides leading edge energy solutions, based on AI technologies, that will be offered through the Marketplace Layer. The latter is a virtual store that offers energy services and data to the energy stakeholders. Finally, the cross-cutting Security, Privacy and Blockchain Layer ensures and guarantees confidentiality, integrity and availability to all the platform modules.

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