Adoption of a FIWARE based platform in intelligent transportation systems

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***Abstract* – General understanding of possible benefits achieved through implementation of industrial Internet of Things (IoT) solutions, set a clear need to develop new approaches to manage and orchestrate distributed and heterogeneous data and components within an IoT environment. Vf-OS initiative provides FIWARE enabled solutions with focus on the manufacturing domain. The challenge to be addressed here, is on how to instantiate the vf-OS concept to other relevant domain sectors, as the mobility and transportation, in order to provide a full-fledged FIWARE functionality based on Generic Enablers, by reusing and proposing new ones.**

Keywords: Industrial Internet of Things, vf-OS, FIWARE, intelligent transportation systems, OPTIMUM, smart toll charging system

I. Introduction

Emerging concepts of Industrial IoT and Industry 4.0 in regard to the developments made in other areas such as Smart Systems, Smart Sensing Systems, Cyber-Physical Systems and Cloud computing, set large opportunities as well as challenges for both research and industrial communities. All emerging areas suffer from lack of standardization, terminology base, middleware platforms bringing various stakeholders such as service providers, consumers and developers, and state of the art solutions which can be recognized by most of the parties. European Commission is undertaking efforts within Horizon 2020 framework to contribute to all mentioned aspects, and thus facilitate wide implementation of new technological achievements.

A. Motivation

Internet of Things concept is an important part of the fourth Industrial Revolution with application cases in different areas of human activities. Besides its clear importance for the manufacturing domain, transportation is another area for sufficient multi-vector contribution. Among relevant IoT solutions, several could be mentioned: autonomous driving, smart parking systems, smart tolling payments, solutions for minimizing negative impact on environment, etc. Sensors inside the cars, as well as sensors installed on the road infrastructures can provide relevant information about available parking facilities, traffic jams, and in the case of road payment systems, information about size, weight and a category of a vehicle.

This sets important requirements to hardware and software, as well as to management capabilities of the target systems. Some of those are the vast amount of data being sensed, generated and collected from sensors. Some of those requirements might be satisfied by using Smart Systems and Smart Sensing Systems which are able, when properly processed, to provide the necessary level of autonomy, managing uncertainty or even possess self-recovering capabilities. However, as those systems in some cases are very complex, based on heterogeneous technologies and different ways of representing their services/data, efficient management of such systems becomes a nontrivial task. In this case, platforms which can serve as intermediate layers and provide high-level abstraction from technical details, focusing on user's needs and bringing together various stakeholders such as service providers, consumers or developers, are needed in order to create competitive environment for further evolution is a key element.

New requirements for design of new systems as well as need to provide a collaborative platform for parties involved in data generation and exchange lead to emergence of Virtual Factory (VF) concept. To our best knowledge there is no unified definition for VF. However, VF might be described as "representation across the hierarchical levels" of a real factory [1] or in broad terms a testbed and/or simulator for information flows and corresponding business processes. VF aims at providing interoperability among distributed components. It covers following technological issues: a common data model for representing different factory nodes, shared data storage for effective data provision and retrieval and a middleware to enable access for outer users, services and applications [2], including adapter functions, if different technologies or data models are applied.

Vf-OS project launched under the Horizon 2020 framework, is intended to provide a distributed, heterogeneous collaborative environment shifting from device-centric to user-centric paradigm [3]. Besides the basic technological issues which are addressed by Operational System itself, additional modules are planned: Open Application Development Kit (vf-OAK) for software developers, Manufacturing Application Store (vf-mApp) and collaborative platform for all involved parties or involved groups, namely Software Developers, Manufacturing Users, ICT Providers and Service Providers – the Virtual Factory Platform (vf-P). However, vf-os and all corresponding components are not just limited to pure manufacturing cases and can be applied for a wide variety of scenarios including the ones in transportation.

B. *Research Question and Hypothesis*

Some recent activities undertaken to fill the gaps in the area of industrial IoT are mostly focusing on high- or low level solutions, thus covering just slightly middleware and corresponding bridging of heterogeneous components within shared collaborative environment. Solution discussed in [4] considers a modular design and distributed nature of a proposed system, being more device-centric than user-centric, without assuming heterogeneous information assets, as well as their data models. Another work [5] describes a platform attempting at integration and management information flows from different sources. However, it implies common data model for all entities being integrated in the proposed platform, it also does not benefit to needed extent to creation of common marketplace and provision of agile instruments for software/application developers. After analysing existing solutions and relevant gaps, the work proposed here aims at addressing the following research question:

> **What kind of a collaborative platform is needed to cope with orchestration of instances within heterogeneous, high distributed manufacturing and logistics environment with focus on particular needs of different users' groups?**

Hypothesis to solve above raised research question:

> **Needed result can be achieved through integration of vf-OS deliverables with Optimum solution in order to provide necessary functionality for proper utilization of FIWARE components and data flows management.**

II. VF-OS AND FIWARE

As mentioned before vf-OS project is aiming at developing Open Operating System for Virtual Factory – platform enabling collaborative Environment for the Factory of Future. Platform being developed within vf-OS project intended to meet the key requirements: modularity, wide availability through cloud deployment, representation of IoT devices capabilities as services, virtualization on different layers, interoperability provision, scalability and open standards basis. The core component of which is Virtual Factory System Kernel (vf-SK) or Enablers Framework (EF), designed to fulfil the core management activities within VF. Among functionalities being provided by vf-SK are: processing and managing access and usage of main resources or assets, application requests management, integration of heterogeneous components, management of ascending and descending information flows. Other important elements of vf-OS are: Virtual Factory Connect to ensure interoperability among factory and vf-OS applications, and Virtual Factory I/O responsible for provision of Plug-and-Play mechanisms, drivers and API's.

"Vf-OS project uses some key developments accomplished within FIWARE community, such as NGSI specifications, Generic Enablers (GE) and Specific Enablers (SE). FIWARE initiative was launched by the European Commission in order to "build an open sustainable ecosystem around public, royalty-free and implementation-driven software platform standards that will ease the development of new smart applications in multiple sectors" [6]. FIWARE platform offers a set of reusable components: GE's and SE's, those building blocks are intended to ease development of new application in different areas. GE's are offering the basic functionality of a platform in its turn SE's can extend GE's offering additional features or target specific application domains such as, for instance, multimedia. In other words, GE consists of a combination of modules implementing a certain set of functions and providing a certain set API's, defined in the specification [7]. The figure below represents some key nodes of the EF:

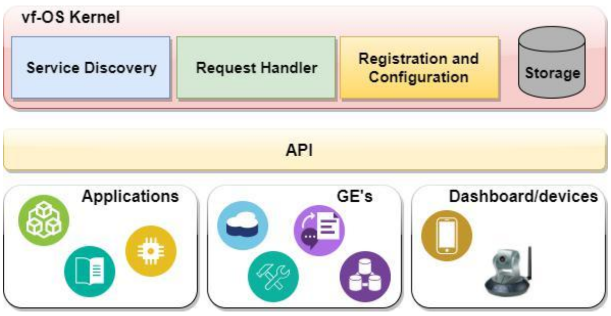

Figure 1. *General/High level representation of Enablers Framework architecture*

Two main components of the EF are enablers-registry and request-handler modules. Enablers-registry encapsulates three models: Enabler, Connection and Service. Enabler model can represent both GE as well as SE containing the name and short description of particular enabler. Connection describes some important technical details, as for instance, the type of protocol which has been used. And Service corresponds to functionality which is provided by a concrete enabler. This model allows flexible approach for enablers managing, as it allows flexible and dynamic change of certain characteristics, for instance, if user application works on specific port, new instance of enabler can be created or Connection model updated with desired value. Request-handler allows users to interrelate physical entity, for instance sensor, with enabler. It also provides mechanisms for entities management, according to NGSI specifications developed within FIWARE initiative. Thus, applications, enablers and devices are integrated into the common collaborative environment providing flexible, open API's.

III. IOT BASED TOLL CHARGING SCENARIO

The mobility and transportation sector, is dynamically changing as a result of several factors in many diverse but interconnected fields: cutting edge technological innovations such as, for example, increasing penetration of digital and space-based technologies in automated, connected and cooperative vehicles, transport infrastructure, logistics operations, safety applications. Transportation also responds tomajor socio-economic trends such as ageing population, migration and urbanisation; global targets such as those set by the COP

21 Paris Agreement on the fight against climate change and by the UN in support of Sustainable Development Goals. Moreover, increasing international competition for the European transport industry across all modes multiplied by new operations and business models based on increased connectivity between infrastructure, transport means, travellers and goods is a significant factor contributing to development of seamless door-to-door mobility. Aligned with such challenges, the OPTIMUM project (OPTIMUM consortium, 2015) aims at developing of an Intelligent Transportation Systems platform, establishing a largely scalable architecture for the management and processing of multisource big data, which enables the continuous monitoring of transportation system needs while facilitating proactive decisions and actions in a semi-automated way, introducing and promoting interoperability, adaptability and dynamicity.

One of the business cases covered by OPTIMUM project addresses a dynamic toll charging scenario being tested in Portugal, with the objective of developing a dynamic toll price model for highways, based on the real congestion levels on national roads. The infrastructure accesses traffic sensor data, both in national roads and highways, and other kinds of data sources (weather, events, floating-car, etc.), cleans and harmonizes the data against predefined standards (Datex-II), and processes it by utilising machine learning algorithms, which are being used by the toll pricing model.

Taking into account the challenges being addressed by OPTIMUM project described above, an interesting business case, could instantiate the vf-OS concept into the OPTIMUM's data processing pipeline [8], which handles the data collection and harmonization processes. In fact, the pipeline could use several of FIWARE's features, such as FIWARE data models and generic enablers to process data, as depicted in the image below:

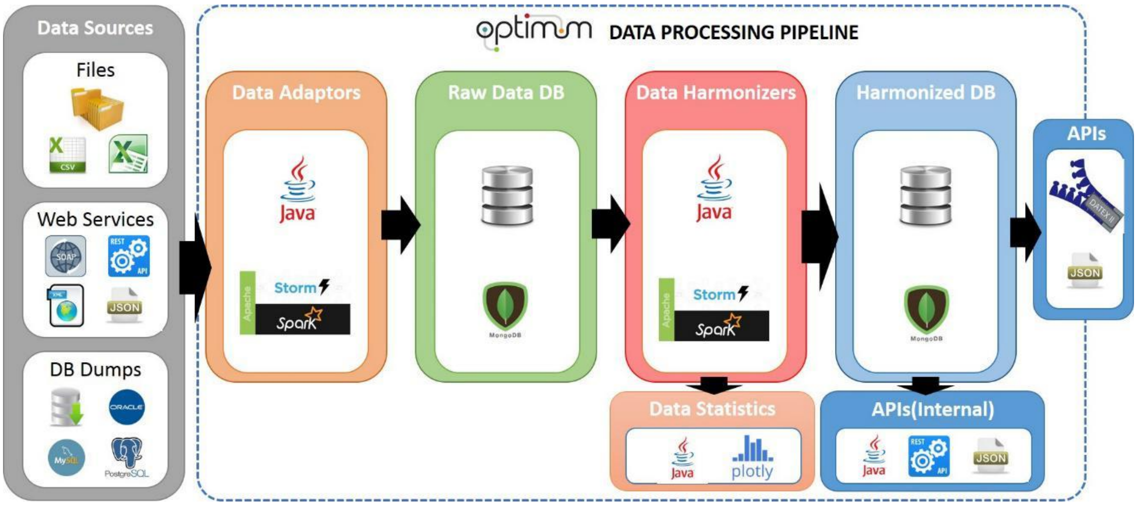

Figure 2. Representation of OPTIMUM data processing pipeline

- In order to enable direct communication with sensors, avoiding the need for third-party web services, which may not be reliable or not suitable for particular requirements, OPTIMUM could use one of several IoT middleware or publish-subscribe framework GEs already available in FIWARE GE Catalogue[1]. Two examples could be the Fast RTPS GE[2] for sharing data in distributed systems using a decoupled model based on Publishers, Subscribers and Data Topics, or the KIARA Advanced Middleware GE, which is a Java based communication middleware for modern, efficient and secure applications.
- To persist data between collection and harmonization processes, the Cygnus GE[3] could be used, as it is a connector in charge of maintaining certain sources of data in certain configured third-party storages, creating a historical view of such data sources.
- Finally, FIWARE's Transportation Harmonized Data Models[4] could be used as the base schemas for OPTIMUM's Data Processing Pipeline, meaning that all data accessed by OPTIMUM would use these Data Models as standard data schemas.

In order to support the goals set towards implementation and to ease development of the OPTIMUM platform, the integration model with vf-OS components is proposed (Fig. 3). Two components considered as the most valuable for the OPTIMUM context are the EF and Data Management Component (DMC). Both can be easily integrated as third-party or standalone services which are requested on demand. The EF allows managing connections with basic GE's, SE's created by the third parties or Enablers developed for specific transportation case [9]. As long as new Enabler registered in EF it becomes available for requesting by Data Processing Pipeline (DPP). Thus part of load related to enablers' management as well as enablers search can be transferred to EF component.

[1]https://catalogue.fiware.org/enablers/
[2]https://catalogue.fiware.org/enablers/fast-rtps
[3]https://catalogue.fiware.org/enablers/cygnus

[4]http://fiware-datamodels.readthedocs.io/ en/latest/Transportation/ doc/introduction/index.html

Second vf-OS component which might have a great impact on OPTIMUM platform is DMC being able to cover or ease data handling process. The libraries delivered by the DMC can be requested as services for data harmonization as well as analytical tasks. This primarily supports the Data Harmonization unit of DPP. Libraries provided by DMC are isolated and implementing different functionalities including some specific algorithms for classification, dimension reduction, etc [10]. In other words if a particular task, for instance: classification, need to be performed there is no need to download all libraries or the full package. This can be an advantage over requesting third-party enablers for data analytics, thus the consumer (DPP) receives even not needed functionality.

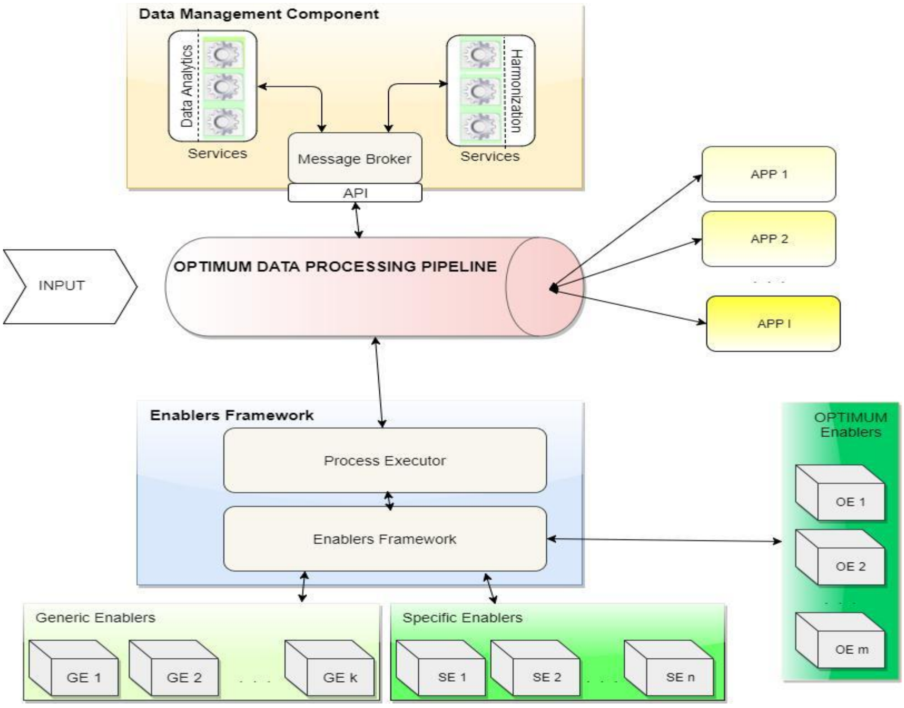

Figure 3. Integration of vf-OS components with OPTIMUM platform

IV. CONCLUSION

As described here, Transportation and Logistics, are areas which can benefit from rapidly developing technologies of Industrial Internet. This paper is focused on applying deliverables achieved in vf-OS project to a transportation business case, currently being addressed by OPTIMUM project. The Enabler Framework developed within vf-OS initiative is aimed at combining the usage of FIWARE generic, as well as specific enablers for complex industrial systems bridging enablers' providers and consumers. It assures reliable platform corresponding to key requirements, such as modularity, distributiveness, virtualization of underlying processes and serves as a middleware between enablers' provider and enablers consumer, in particular case: Intelligent Transportation System Platform. Intelligent Transportation System (ITS) is a complex solution developed within OPTIMUM project covering broad set of issues in transportation sector, such as handling multisource data with proactive response on events happened in the environment where the system operates in. A valuable support in data handling tasks is possible through integration with DMC providing various services in the area of data harmonization and analytics.

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REFERENCES

[1] S. Jain, D. Lechevalier and A. Narayanan, "Towards Smart Manufacturing with Virtual Factory and Data Analytics", Proceedings of the 2017 Winter Simulation Conference, W. K. V. Chan, A. D'Ambrogio, G. Zacharewicz, N. Mustafee, G. Wainer, and E. Page, eds., p. 3018-3029.

[2] T. Tolio, M. Saccob, W. Terkajb and M. Urgo, "Virtual Factory: an Integrated Framework for Manufacturing Systems Design and Analysis", *Procedia CIRP 7*, pp. 25-30, 2013.

[3] Virtual Factory Open Operating System. Retrieved from: http://www.vf-os.eu/wiki

[4] Y. Hao, P. Helo, A. Shamsuzzoha. "Cloud-Based Data Exchange and Messaging Platform Implementation for Virtual Factory Environment", *IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, p. 426-430, 2015.

[5] N. Shariatzadeha, T. Lundholma, L. Lindberga and G. Sivarda, "Integration of digital factory with smart factory based on Internet of Things", *Procedia CIRP* 50, pp. 512-517, 2016.

[6] J.A. López-Riquelme, N. Pavón-Pulido, H. Navarro-Hellín, F. Soto-Valles and R.Torres-Sánchez. "A software architecture based on FIWARE cloud for Precision Agriculture", *Agricultural Water Management 183*, p. 123-135, 2017.

[7] J.P. Brogan and C. Thuemmler. "Specification for Generic Enablers as Software", *11th International Conference on Information Technology: New Generations*, p. 129-136, 2014.

[8] G. Guerreiro, P. Figueiras, R. Silva, R. Costa and R. Jardim-Goncalves, "An architecture for big data processing on intelligent transportation systems. An application scenario on highway traffic flows", in IEEE 8th International Conference on Intelligent Systems, DOI10.1109/IS.2016.7737393, 2016.

[9] P. Corista, J. Giao, J. Sarraipa, R. Almeida, O.G. Perales and N. Moalla, "Enablers Framework: an approach to develop applications using FIWARE", submitted to *I-ESA18*, held in Berlin 22-23 March (2018).

[10] A.A. Nazarenko, J. Giao, J. Sarraipa, O.J. Saiz, O.G. Perales and R. Jardim-Gonçalves, "Data management component for Virtual Factories Systems", submitted to *I-ESA18*, held in Berlin 22-23 March (2018).