The Future Architecture for Internet of Things- A Review

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***Abstract*—The Internet is probably the most successful computing innovations that forms the bedrock to most computing applications and services nowadays. Build on top of the Internet are several technologies bridging both geographical differences and time barriers. Cloud computing and the Internet of Things (IoT) are among such technologies delivering computing resources and services that would normally be difficult if not impossible to acquire, by a start-up organization, yet serve as a middle layer for developers to build domain-specific applications. FIWARE platform, an initiative of the European Commission evolves to aid developers minimize development time of domain-specific applications while exploiting state-of-the-art computing resources and artifacts. This paper presents a review of innovations in the Internet and Internet of Things paradigms, and exploits the potentials of FIWARE ecosystem for IoT architecture.**

Keywords— Cloud computing, Internet of Things, FIWARE, Generic Enablers

I. Introduction

With the advances in Internet technology, wireless sensor networks, wearable & mobile computing gadgets and the adoption of Cloud computing technologies, present day Internet is faced with immense challenges that beyond any doubt call for its transformation and redesign [1] for Future Internet to succeed in the delivery of contents, services and scalability to meet the demand of technology consumers.

Whereas the Internet facilitates internetworking of computers around the globe eliminating geographical and time barriers, Cloud computing builds on top to provide pool of sophisticated computing resources to consumers. The integration of the aforementioned development today creates numerous opportunities such as the Internet of Things (IoT), facilitating internet connectivity for embedded devices and sensors. The present day Internet is heavily characterised by human-to-human communications means, the IoT is envisioned to move towards the realisation of machine-to-machine communications [2] connecting heterogeneous devices, leading to immense pressure for development of Future Internet standards. Cloud computing and Internet of Things are the leading research perspectives in the Future Internet landscape [3].

The European Commission thus established the Future Internet (FI-WARE) funded project, aimed to realise the Future Internet mission. This paper begins with a review of technological innovations that form the bedrock of IoT applications (Section II and III), presents a discussion on the FIWARE ecosystem and FIWARE components or Generic Enablers (GEs) to support IoT architecture (Section IV) and Section V concludes this paper.

II. Cloud Computing

The notion behind cloud computing is the provision of computing services and infrastructure to subscribing consumers as a service, against been supplied as a resources, [4] thereby promoting five distinctive features:

- *On-demand self-service:* entails the provision of self-managed computing resources to consumers.
- *Broad network access:* so applications are accessed through heterogeneous platforms (PCs, mobile devices, PDAs etc).
- *Resource pooling:* location independent pooling of computing resources to serve multiple cloud consumers in a multi-tenant fashion.
- *Rapid elasticity* of these resources and services provided to *quickly scale-out* and released to *quickly scale-in,* and
- *Metered services:* automatic control and optimisation of resource usage.

Cloud computing has long been envisioned to be the next generation of computing paradigm towards the provision of basic level computing services [5]. Cloud computing delivers encapsulated task as *"service"* to consumers in three different models: *Software as a Service, Platform as a Service* and *Infrastructure as a Service*, and open-up opportunities to application developers overcoming barriers to resource limitations. FIWARE platform results from the reap benefits of cloud computing innovations.

III. Wireless Sensor Networks

Wireless Sensor Networks (WSN) specifically describes the representation of spatially dispersed sensors deployed to observe and record environmental conditions such as temperature, air quality, object tracking/monitoring [6] and send recorded measurement over the network to a central back-end. This is essential as it facilitates analysing recorded data set, visualisation as well as promote effective decision-making process and response to sudden environmental changes: air pollution for instance.

Wireless Sensor Networks technology has been acknowledged in recent studies as promising development towards achieving reliable and cost-effective remote monitoring [7] making it a good choice nowadays in the industry for such operations as industrial process monitoring and control, and machine health monitoring [8]. Sensor *nodes* in WSN are interconnected to one and often many other sensors, equipped with a *microcontroller* circuit to connect with other sensors, a *radio transceiver* with internal or sometimes external antenna, and a *power source*, such as a battery or an ambient power (e.g. solar powered).

WSN deployment has been embraced in diverse areas of application domain. Research [9] suggests that future objects would have embedded sensors in them such that they become smart objects. Thus, effective utilisation of the Future Internet and the realisation of envisioned IoT ecosystem requires the deployment of large-scale Wireless Sensor Networks infrastructure as its bedrock [10], Several domain areas of human endeavour applications already touched by the IoT revolutions: both personally at home and the Enterprise, Table 1 shows some areas of IoT applications.

TABLE I. IOT APPLICATIONS BY DOMAIN AREA

Domain Area	Features	Examples
Agriculture	-Monitoring farm productivity -Animal tracking -Farm registration	Testbed [30]
Environment (Smart City)	-Pollution control -Traffic management -Waste disposal -Tourism	StreetLamp [28] SmartPort [13]
Energy	-Load balancing & energy management -Operational decision-making	Smart Grid [7] FINSENY [24] SGAM [25]
Health	-Medical equipment monitoring -Remote health service delivery. -Care giver assistance	RPM [26] iTaaS [29] Doukas & Maglogia [27]
Industry	-Industrial process monitoring -Equipment maintenance	Industry 4.0 [30]

IV. FIWARE ENABLERS FOR IOT DEVELOPMENT

Building an IoT architecture is largely a complicated process, partly due to the heterogeneity [17] of connected devices in terms of communication protocols supported and the constrained nature of device processing capability (e.g. limited memory and battery). Thus, development of a framework that abstracts device-specific peculiarities while on the other hand reducing application development time therefore becomes necessary. Fortunuátely, FIWARE ecosystem offers these framework in a way that IoT developers, service providers, enterprises and other organisations can develop products that satisfy their requirements. This section describes an architecture comprising different FIWARE generic enablers for IoT development.

A. The Orion Context Broker

The Orion Context Broker is the core component of the FIWARE, the publish/subscribe reference implementation from the Data/Context Management GEs category, charged with the responsibility to gather context data [21] about entities and their attributes within the FIWARE components or services subscribed to it. An implementation of the NGSI9 and NGSI10 (*Next Generation Service Interface)* publish/subscribe REST API, Orion provides NGSI9 (*context availability*) and NGSI10 (*information exchange*) interfaces for clients [15] to perform such operations as:

- *Context provider registration* - (sensors for instance, to report temperature measures).
- *Context information updates* - (read and send temperature value).
- *Observe /notify* - inform Orion when changes occur.

Thus, Orion CB stores information about context (entities) registered and can provide updated information about the entity queried. Orion usually stores entity information as a MongoDB collection, a NoSQL document-oriented database system.

B. The IDAS Generic Enabler

Device management in the FIWARE ecosystem is handled by the IDAS GE from IoT Service Enablement Chapter. An IoT Agent Gateway enabler for inter-networking and protocol conversion functionalities between devices and the IoT Backend GEs. Context information exchange within FIWARE platform is done using NGSI interface only, connecting objects or things therefore requires resolving the difference in FIWARE-device communication model. IDAS thus, provides support for several device-specific protocols to simplify device management and integration. Currently, IDAS provides the following agents for IoT devices [22]:

- *Ultralight 2.0 (UL2.0)* - a text-based messaging protocol IoT agent for low bandwidth devices with limited memory.
- *Lightweight M2M* - FIWARE standard IoT agent bridging communication between devices running OMA Lightweight M2M protocol and FIWARE components (NGSI).
- *JSON* - bridges HTTP/MQTT messaging for communication with devices using simple JSON protocol.
- *LoRaWAN* - facilitates information exchange and command with devices using LoRaWAN protocol.

C. The Cygnus Generic Enabler

The Orion CB maintains current state context information only. For persisting historical data however, FIWARE provides the Cygnus GE. Cygnus in turn implements connectors supporting context data from Orion intended for persisting historical data third-party in storage engines such as PostgreSQL ,STH Comet, MySQL databases and HDFS back-end. The Cygnus simply connects FIWARE Orion with thirty-party persistence storage engine.

D. The Cosmos Generic Enabler

FIWARE provides Cosmos (the Big Data GE) deployed to facilitates means for Big Data processing and analysis (batch and stream data). Whereas stream data is processed in near real-time, batch data is stored and processed at a later time.

E. Short Term Historic (STH) Comet Generic Enabler

This a FIWARE component intended for storage and retrieval of time series aggregated historic data about entities and their attributes within the Orion CB.

As FIWARE runs within Docker container [23], an operating system-level lightweight virtualization technology alternative to hypervisor-based, these components are usually containerised to run and managed via Docker commands. Figure 1 shows a simplified architecture of a FIWARE-based IoT system.

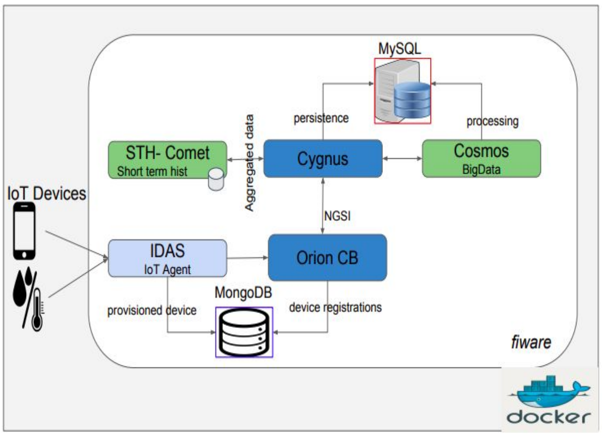

Fig. 1. Simplified FIWARE-powered IoT Architecture with MySQL persistence.

V. CONCLUSION

The overall goal of this paper is to review the trends in Internet and Internet-based technologies, and discusses the potential of using the FIWARE ecosystem for the development of Internet of Things (IoT) applications. FIWARE ecosystem is a broad and complex platform with an immense collection of tools and services that require time and effort to understand, this paper serves to provide a guideline about most commonly used enablers and the purposes they serve. With the current trend in the Internet of Things market and widespread of connected devices, FIWARE platform has proven to be the next generation of IoT applications development. The paper also describes the bedrock technologies that give birth to the FIWARE platform and discusses major generic enablers used in IoT ecosystem.

REFERENCES

[1] Tsai Chun-Wei, Lai Chin-Feng, and Athanasios V. Vasilakos. “Future Internet of Things: open issues and challenges”. Wireless Networks. November 2014, 20(8), pp. 2201–2217.

[2] Khan R, Khan SU, Zaheer R, Khan S. Future Internet: “The Internet of Things Architecture, Possible Applications and Key Challenges”. 2012 10th International Conference on Frontiers of Information Technology, 2012. doi:10.1109/fit.2012.53.

[3] Sotiriadis S, Stravoskoufos K, Petrakis EGM. Future Internet Systems Design and Implementation: Cloud and IoT Services Based on IoT-A and FIWARE. Designing, Developing, and Facilitating Smart Cities, 2016, p. 193–207.

[4] Marston S, Li Z, Bandyopadhyay S, Ghalsasi A. Cloud Computing - The Business Perspective. 2011 44th Hawaii International Conference on System Sciences, 2011. doi:10.1109/hicss.2011.102.

[5] Buyya R, Yeo CS, Venugopal S, Broberg J, Brandic I. Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. Future Gener Comput Syst 2009;25:599–616.

[6] Han G, Jiang J, Zhang C, Duong TQ, Guizani M, Karagiannidis GK. A Survey on Mobile Anchor Node Assisted Localization in Wireless Sensor Networks. IEEE Communications Surveys & Tutorials 2016;18:2220–43.

[7] Fadel E, Gungor VC, Nassef L, Akkari N, Abbas Malik MG, Almasri S, et al. A survey on wireless sensor networks for smart grid. Comput Commun 2015;71:22–33.

[8] Mini S, Udgata SK, Sabat SL. Sensor Deployment and Scheduling for Target Coverage Problem in Wireless Sensor Networks. IEEE Sens J 2014;14:636–44.

[9] Rawat P, Singh KD, Chaouchi H, Bonnin JM. Wireless sensor networks: A survey on recent developments and potential synergies. Journal of Supercomputing 2013;68:1–48.

[10] Gubbi J, Buyya R, Marusic S, Palaniswami M. Internet of Things (IoT): A vision, architectural elements, and future directions. Future Gener Comput Syst 2013;29:1645–60.

[11] About Us - FIWARE. FIWARE n.d. https://www.fiware.org/about-us/ (accessed November 10, 2018).

[12] Fernández P, Santana J, Ortega S, Trujillo A, Suárez J, Domínguez C, et al. SmartPort: A Platform for Sensor Data Monitoring in a Seaport Based on FIWARE. Sensors 2016;16:417.

[13] FIWARE Architecture - FIWARE Forge Wiki https://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php/FIWARE_Architecture (accessed December 6, 2018).

[14] Rosangela de Fatima Pereira Marquesone, Tereza Cristina M. B Carvalho, Lucas Batista Guimaraes, and Eduardo Mario Dias. A FIWARE-Based Component for Data Analysis in Smart Mobility Context. 2017 IEEE First Summer School on Smart Cities (S3C), 2017. doi:10.1109/s3c.2017.8501373.

[15] Salhofer P. Evaluating the FIWARE Platform. Proceedings of the 51st Hawaii International Conference on System Sciences, 2018. doi:10.24251/hicss.2018.726.

[16] Alvarez F. FIWARE overview: examples of usage of big data, and the benefits for smart cities. 5th EU-Japan Symposium on ICT Research and Innovation, 2014.

[17] Zanella A, Bui N, Castellani A, Vangelista L, Zorzi M. Internet of Things for Smart Cities. IEEE Internet of Things Journal 2014;1:22–32.

[18] Zahariadis T, Papadimitriou D, Tschofenig H, Haller S, Daras P, Stamoulis GD, et al. Towards a Future Internet Architecture. Lecture Notes in Computer Science, 2011, p. 7–18.

[19] Santos IL, Alves MP, Flavia C, Li W, Y ZA, Khan SU. A System Architecture for Cloud of Sensors. IEEE 16th Int. Conf. on Dependable, Autonomic & Secure Comp., 4th Int. Conf. on Big Data Intelligence & Comp, 2018, p. 666–72.

[20] Hernández-Muñoz JM, Vercher JB, Muñoz L, Galache JA, Presser M, Hernández Gómez LA, et al. Smart Cities at the Forefront of the Future Internet. Lecture Notes in Computer Science, 2011, p. 447–62.

[21] Bellabas A, Ramparany F, Arndt M. Fiware Infrastructure for Smart Home Applications. Communications in Computer and Information Science, 2013, p. 308–12.

[22] Fiware. Fiware/tutorials.IoT-Agent. GitHub n.d. https://github.com/Fiware/tutorials.IoT-Agent (accessed December 16, 2018).

[23] Morabito R. A performance evaluation of container technologies on Internet of Things devices. 2016 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), 2016. doi:10.1109/infcomw.2016.7562228.

[24] FINSENY | Future Internet for Smart Energy http://www.fi-ppp-finseny.eu/ (accessed December 17, 2018).

[25] Smart Grid Architecture Model (SGAM). Smart Grid Reference Architecture, November 2012. https://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf

[26] Fazio M, Celesti A, Marquez FG, Glikson A, Villari M. Exploiting the FIWARE cloud platform to develop a remote patient monitoring system. 2015 IEEE Symposium on Computers and Communication (ISCC), 2015. doi:10.1109/iscc.2015.7405526.

[27] Doukas C, Maglogiannis I. Bringing IoT and Cloud Computing towards Pervasive Healthcare. 2012 Sixth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, 2012. doi:10.1109/imis.2012.26.

[28] Ramparany F, Marquez FG, Soriano J, Elsaleh T. Handling smart environment devices, data and services at the semantic level with the FI-WARE core platform. 2014 IEEE International Conference on Big Data (Big Data), 2014. doi:10.1109/bigdata.2014.7004417.

[29] Martínez R, Pastor JÁ, Álvarez B, Iborra A. A Testbed to Evaluate the FIWARE-Based IoT Platform in the Domain of Precision Agriculture. Sensors 2016;16. doi:10.3390/s16111979.

[30] Lu,Yang. "Industry 4.0: A survey on technologies, applications and open research issues". Journal of Industrial Information Integration. 2017; 6: 1-10.