LEVERAGING THE MICROSERVICE ARCHITECTURE FOR NEXT-GENERATION IOT APPLICATIONS

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***Abstract**: This paper aims to present two modern technologies that contribute to the development of the Internet-of-Things (IoT), namely the microservice architecture for application development, and their execution in the Fog/Edge computing layer, closer to the data sources, which leads to better performance. For this purpose, a four-level model is proposed and the functions of each are specified. It also introduces some platforms for building and deploying microservices launched on the Information Technology (IT) market by major companies.*

Keywords: Internet-of-Things, Microservices, Fog/Edge computing, IT management.

JEL Classification Codes: C88, M15.

1. INTRODUCTION

This paper aims to present the concept of microservices and to analyse the features that recommend it for use in developing Internet-of-Things (IoT) applications.

In a nutshell, microservices are the way of decomposing complex applications into tasks running as independent processes, and this approach can help IoT in dealing with a large pool of connected devices.

The paper is structured in five sections, as follows: Section 2 (Literature Review) starts from the definition and characteristics of the concept and presents an overview of the microservice-based architecture for IoT, Section 3 (Methodology) presents several methods and technologies for developing such an application. Section 4 (IoT platforms based on microservices) contains a comparative analysis between a monolithic application and a microservice-based application. Also, some known IoT platforms based on the microservices approach will be presented. The 5th and final section (Conclusions) provides concluding remarks about this concept and its applications and some directions regarding our future work in this domain.

2. LITERATURE REVIEW

The concept of ***microservices*** refers to a software architecture and represents the method for "designing software applications as suites of independently deployable services" (Lewis & Fowler, 2014).

The same authors explain the *microservice architecture* by comparing it with the monolithic style of building an application, which means that changing a module involves rebuilding and re-implementing the whole system (Lewis & Fowler, 2014).

On the other hand, microservices are independently created and managed objects that can be included in various applications and can be accessed through *the application programming interfaces* (APIs), having a high level of freedom, each one implements a set of narrowly, related functions. APIs are methods of communication between software components, implemented by function calls in web-based systems, database systems and operating systems.

Due to its scalability, the microservices architecture is considered a software solution suitable for developing the Internet of Things (IoT) platforms.

Garrett emphasises the importance of cloud-hosted microservices, attached to devices (sensors and controllers), API-accessible, easily collaborating and loosely connected (Garrett, 2015).

To decrease the load on the Cloud layer, an intermediate level (often called Fog/Edge computing) is recommended, one that distributes microservices, filters information transmitted by the sensors and offers a limited storage capacity. At the Fog Edge level, software developers can build microservices using the programming languages they are familiar with (C ++, Java, Python, etc.), as well as data management systems appropriate for the solution, similar to those used in Cloud computing.

3. METHODOLOGY

3.1 The microservice features

Microservices have emerged as a better alternative for the monolithic, complex and rigid applications. A monolithic application has weak scalability and an upgrade at the procedure level requires an entire system update.

A microservice architecture decomposes the application into smaller, modular, together-working components, much easier to build and upgrade than the application as a whole.
Also, this architecture offers more scalability, very useful for the huge number of deployments related to IoT devices.

The question arises: where should the microservices be placed and where will the instances of the services required by the devices be run?

There are several models present on the IT market today, such as Serverless Deployment, Service Instance per Container, Service Instance per Virtual Machine, but we will take into consideration the most popular model, meaning Multiple Service Instances per Host (Richardson, 2016). This approach allows multiple service instances sharing the same server and operating system, which has the advantage of rapidness (Figure 1).

Each microservice is an API-accessible process, and has its own database. An IoT device that uses a microservice also has a time stamp to track its temporary evolution or its synchronization with other devices (Schöne, 2017). Each service request will determine the creation of a new instance, which must have appropriate resources (CPU, memory, and I/O).

According to Patel (Patel, 2017) and Athreyas (Athreyas, 2017), microservices have several features that recommend them for using of the development of Internet-of-Things platforms:

1. Microservices are software components developed with modern, flexible Project Management (PM) methodologies (such as Agile and DevOps). Especially the DevOps methodology enables designing, changing and checking the services, followed by a fast and continuous delivery of them.

2. Microservices provide scalability to applications - an application is composed of multiple independent microservices, working in tight collaboration; at a certain moment, a service can run on a single machine or can be run as multiple instances on different machines.

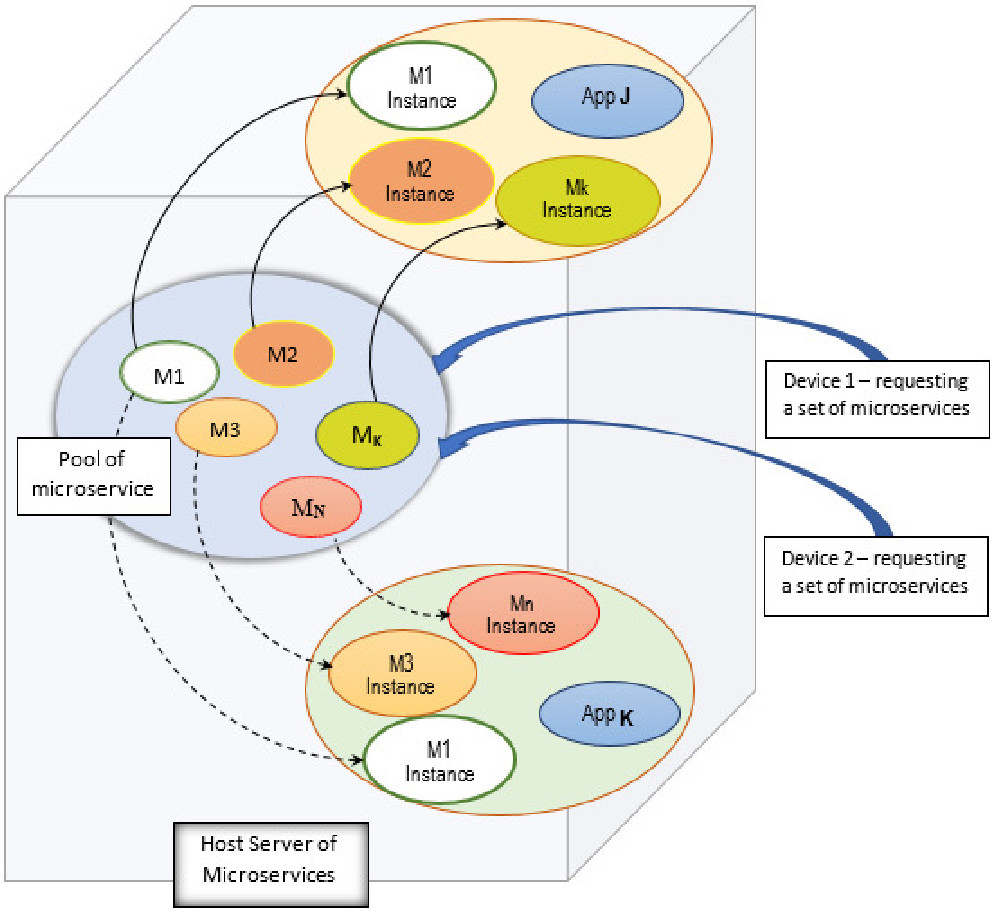

Figure 1. Microservice-based architecture

(Source: designed by the authors considering the Multiple Service Instances per Host model)

3. Microservice-based architecture has the advantage of being able to realize microservices in different technologies.

4. Microservices allow the construction of evolving models, useful in the case of unanticipated types of devices accessed by the application. This offers flexibility and proficient monitoring of the application during its life.

3.2 Building the microservices in Fog/Edge computing

Fog computing is a term created by Cisco, referring to a technology that “extends the Cloud to be closer to the things that produce and act on IoT data” (Cisco Systems, 2015).

The method of decentralizing operations from the Cloud to the Fog/Edge layer has the advantage that many applications and services are distributed on nodes placed closer to IoT devices instead of running them in cloud-based clusters, leading to faster response speeds and, consequently, improving performance.

This intermediate level is made up of nodes that have network connectivity, their own storage and service deploying capacity, required by the devices connected via API gateways.

At the Fog/Edge computing level is recommended to include the microservices, each of them having a well-defined job to accomplish (Zhang, 2016).

In the next section, we will propose a four-layer model that demonstrates the point of view of the authors regarding the role of microservices in a Fog computing architecture.

4. A FOUR-LAYER MODEL FOR DEPLOYING IOT MICROSERVICES IN FOG COMPUTING

The model proposed in this paper is organized on four levels and starts from the idea launched by Cisco Systems to introduce the intermediate layer of Fog/Edge computing. We consider an important advantage of this architecture the addition of microservices in Fog/ Edge nodes and their accessibility by any of the IoT devices.

Figure 2 shows the four-layered architecture: Physical layer, Network (Communication), Fog/Edge computing and Application:

1. at the Physical layer we may find sensors, control electronics and data captors, devices that collect data from the environment and detect other siblings,
2. the Network (Communication) layer is the one that intermediates data transfer and facilitates communication between nodes, using various communication technologies,
3. Fog/Edge computing layer has the role of storing, computing and analyzing data coming from the Network layer.

In this regard, Cisco specifies some examples of data pre-processing to minimize the impact of a large data volume and avoid overloading of the Application level with network traffic (Cisco Systems, 2016):

- Filtering data according to certain criteria
- Data formatting for processing
- Expand/decode cryptic data with additional context
- Estimate data according to a certain threshold or predefined alert level.

Fog/Edge layer supports Cloud computing but does not replace it, considering that applications and services in business environment require special data organization for Big Data, and also its processing by using best-in-class tools and technologies (Abdelshkour, 2015).

Having a unified interface that groups of devices can access led to the development of small software modules (microservices) that live at the Edge of the Cloud, in the so-called Fog, in a very close proximity of the IoT elements. These independent applications are domain specific and have their own databases, and even are able to communicate between them.

Accessing microservices is done through dedicated APIs, provided over the HTTP protocol in order to get a quick answer, and already compatible with JavaScript modules.

The end-users don't have direct access to microservices, they call an entry point through an API gateway instead, which forwards the call to the appropriate microservice and assembles them into an aggregated response. This gateway is able to offer other advanced functionalities, like user authentication, encrypted SSL connections and load balancing (Athreyas, 2017).

4. Cloud Application layer provides requested services and operations, such as the storage service to backup received data into a database, or the analysis service to evaluate the received data for predicting the future state of physical devices or data services (data mining, data analytics).

Several examples of applications included in this layer are: smart grid, smart transportation, smart cities, etc. (Wu et al., 2010). Stored data must be used intelligently for smart applications. In order to achieve automated decision making are recommended artificial intelligence techniques, such as: neural networks, genetic algorithms, intelligent agents.

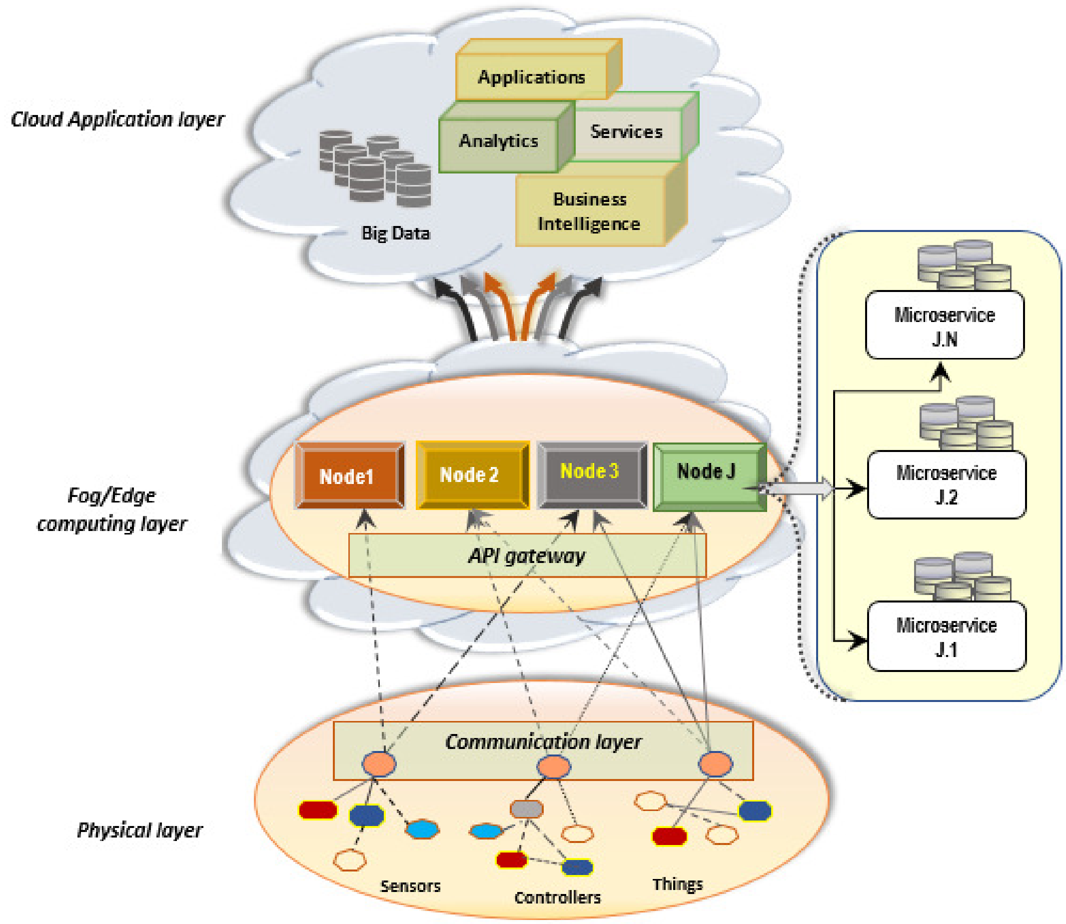

Figure 2. The four-layered model using Fog/Edge computing level
(Source: designed by the authors considering the Cisco IoT Reference Model)

A number of IoT platforms have been launched on the IT market, playing the role of bridge between the sensors and the data networks: Amazon Web Services, Microsoft Azure, ThingWorx IoT Platform, IBM's Watson, Cisco IoT Cloud Connect, Oracle Integrated Cloud (Meola, 2016).

Within the Amazon Microservices architecture, a powerful monitoring system is proposed to keep track of application performance metrics and to always have resource evidence. This monitoring system works through a monitoring agent placed on each service instance and tracks all the evolution, events, specific instance data, being able to process log data, until the session closes. This information is stored in a unified database, on which one can do all sorts of analysis, in order to create alerts or predict future trends (Jung et al., 2016).

As we mentioned in a previous paper (Banica et al., 2017) an IoT model in production, distribution and retailing is the most appropriate example of applying a model Fog/Edge-based architecture and Cloud-based. For the retail sector, a real-time process that provides the supply chain with accurate data is based on Fog/Edge computing.

This way, all involved entities are kept up to date with information from the sales activity, and the powerful Cloud infrastructure can use advanced data processing techniques to infer important feedback about the success of a product release.

Microsoft launched the Azure IoT Edge platform in 2017, running on Windows and Linux, which allows "to connect to and interoperate with Cisco Fog deployments", meaning that the applications can be built and hosted in Azure IoT, and can be used at an extended scale through the Cisco fog platform, thus optimizing Cloud processing costs (George, 2017).

5. CONCLUSIONS

In the near future, the Internet-of-Things will be as important as the Internet is for the digital society, because all end-user devices, mobile or fixed, will have to be connected/disconnected and remotely monitored. The four-layered model, presented as a case study in this paper, is a veritable approach to IoT solutions because it gives developers the freedom to choose a language or framework, to update applications independently, and also gives to business and ordinary users fast access to microservices.

The simple functions that "things" access and execute (authentication, data transmission/ reception, communication with other devices) will be accomplished with the help of microservices, which are scalable, relatively independent and can collaborate in complex applications.

Microservices will be placed in the decentralized Cloud, at Fog/Edge level, and their calling and execution will be done through friendly interfaces, accessible through API gateways.

Although real progress has been made in IoT technologies and experimental platforms have been developed for various industries, only companies and end-users will decide to adopt or not this solution, in terms of increased benefits.

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