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SAPPARCHI: an Osmotic Platform to Execute Scalable Applications on Smart City Environments

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***Abstract*—In the Smart Cities context, a plethora of Middleware Platforms had been proposed to support applications execution and data processing. Despite all the progress already made, the vast majority of solutions have not met the requirements of Applications' Runtime, Development, and Deployment when related to Scalability. Some studies point out that just 1 of 97 (1%) reported platforms reach this all this set of requirements at same time. This small number of platforms may be explained by some reasons: i) Big Data: The huge amount of processed and stored data with various data sources and data types, ii) Multi-domains: many domains involved (Economy, Traffic, Health, Security, Agronomy, etc.), iii) Multiple processing methods like Data Flow, Batch Processing, Services, and Microservices, and 4) High Distributed Degree: The use of multiple IoT and BigData tools combined with execution at various computational levels (Edge, Fog, Cloud) leads applications to present a high level of distribution. Aware of those great challenges, we propose Sapparchi, an integrated architectural model for Smart Cities applications that defines multi-processing levels (Edge, Fog, and Cloud). Also, it presents the Sapparchi middleware platform for developing, deploying, and running applications in the smart city environment with an osmotic multi-processing approach that scales applications from Cloud to Edge. Finally, an experimental evaluation exposes the main advantages of adopting Sapparchi.**

***Index Terms*—osmotic computing, serverless, microservice, scalability**

I. Introduction

The *"Smart Cities"* are cities that use Cloud Computing, BigData, and Internet of Things as computational skeletons to support solutions built to aimed at the social welfare of their citizens [1], [2]. The applications and solutions produced in the Smart Cities range from simple monitoring of vehicular traffic [3] to Systems for monitoring air quality [4], such as people prone to heart attacks [5]. It also includes complex systems for monitoring and predicting disasters [6] or assisting police patrols [7]. All this varied set of technologies, domains (security, health, education, transport, housing, etc.), and stakeholders (governments, industries, citizens, etc.) results in an almost infinite universe of choices and opportunities, bringing great challenges for developers of Smart Cities applications.

Middlewares and software platforms have been proposed to fulfill those needs in the context of Smart City's environment. For instance, some surveys [1], [8], [9] have reported 97 different middlewares or software platforms to accomplish those needs. In contrast to the high number of evaluated solution, only 20 (20.61%) out of 97 have defined an Application Deployment/Runtime model (functional requirements). Besides that, when an Application Deployment/Runtime model focuses on scalability (non-functional), just 01 of those 20 (5%) is selected.

The main reasons for such small number of available solution is directly related to many aspects of smart city applications [1]:

- **Multi-domains**: Applications in the context of smart cities seek to support the most varied domains such as Economy, Traffic, Health, Security, Agronomy, etc. In addition to having several stakeholders related to the application contexts, which leads to a high degree of diversity in the solutions, it makes very difficult to delimit generalized models for scalable execution;
- **Processing**: Processing methods are also multiple, ranging from simple to complex event processing, data stream processing, batch processing [8], to the use of machine learning techniques.
- **BigData**: The high volume, speed, variability, and volatility of the manipulated data make it even more difficult to run applications, especially in terms of scalability, since the scale-up and scale-down processes must guarantee the consistency and veracity of the data.
- **High Distributed Applications**: The use of multiple IoT and BigData tools combined with execution at various computational levels (Edge, Fog, Cloud) leads applications to unveil a high degree of distribution. Sometimes, such application execution makes use of infrastructures of several providers integrating private data-centers and private clouds with public multi-clouds environments. Thus, applications tend to use SOA-based architectural models [10], [11] in combination with platform and middleware services. Therefore, resulting in a complex task of monitoring, managing, and scaling the applications.

All these complexity results in the lack of architectural models for running smart city applications. Consequently, the Computer Service Providers (Cloud Providers, Telephone Operators, Internet Providers) and Application Developers face a great challenge. For example, Service Providers are concerned with: How to measure, charge, deploy, and better execute to use the Computing Infrastructure efficiently. While

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