Resilience in IoT Infrastructure for Smart Cities

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Abstract. Nowadays companies and governments are using Information and Communication Technologies (ICTs) as tools to deploy their services and make them accessible to citizens; in order to expand urban resources efficiency with a low environmental impact and contributing with the development of the economy. This trending is known as the Smart City paradigm [1]. The smart city paradigm has taken advantage of two recent technologies, Internet of Things (IoT) and cloud computing.

There are two basic ideas behind the IoT, the first one is that any object could be identified and recognized unequivocally and the second one is the use of the Internet infrastructure to enable communication between objects. According to Tan and Wang [2], IoT could be defined as a global network infrastructure integrated by a huge number of devices connected that rely on sensors, actuators, communication, and information processing technologies. Taking in consideration the smart city paradigm, the main benefit of the IoT is the possibility to read, recognize, address and control these objects or things anytime and anywhere. With these features it is possible to collect a massive amount of data that could be processed and analyzed by applications in order to provide smart services.

In the context of IoT the interaction between objects has challenging characteristics (e.g. energy awareness, heavy density) that require new ways to enable a reliable and secure communication system. Many routing protocols have been proposed to achieve the specific communication requirements in this context, and one of the most promising of these routing protocols is the IPv6 Routing Protocol for Low-Power and Lossy Networks (RPL) [3]. RPL is a routing protocol specifically designed for Low-Power and Lossy Networks (LLC) following the guidelines of the 6LoWPAN IETF Working Group. This routing protocol is based on a distance-vector algorithm and follows a proactive approach, with the capacity of managing flat and hierarchical topologies. Furthermore, RPL has high scalability thanks to its ability of auto-configuration, self-healing, and supporting multiple edge routers. Because of these characteristics RPL has gained a lot of popularity and is awakening interest in both the scientific and industrial community.

Besides of the importance of the communication infrastructure in IoT, in a smart city environment it is often required to run services in real time

and frequently it is necessary to process huge amounts of data. Given that the components in the IoT have strong constraints on data processing, many times it is not possible to achieve these requirements only using these objects, thus it is necessary to use an alternative. The cloud computing paradigm permits to tackle these barriers, enabling heavy calculations that run inside powerful data centers.

The cloud not only offers power to process data, but also makes it possible to use virtualization technologies to enhance how the object heterogeneity could be managed. A new approach for computing resources defined as "Sensing and Actuation as a Service" (SAaaS) is proposed by Distefano and Merlino [4] in the context of IoT and Smart Cities. Using this approach it is possible to think in the cloud as an environment capable to implement a bridge between IoT and Internet using Internet of Services to establish an efficient communication and collaboration among actors.

In the context of smart cities the ICTs have the important role to provide the infrastructure to deploy the devices and services, thus it is vital to keep this infrastructure alive. With the purpose to improve the robustness and reliability of the services in smart cities, it is needed a resilient IoT framework capable to react and self-configure after unpredictable events. This important requirement, include resilience in IoT infrastructure, is one of the open issues in the IoT field that needs to be tackled.

The SusCity project is an example of the efforts that governments, institutions and universities are doing to understand how to deploy services in a clever way for a smart city to enhance the quality of live of the citizens. Specifically this project aims to advance at science of urban systems modeling and data representation supported by urban "Big Data" collection and processing, with the objective of enabling and demonstrating new services that arise as economic opportunities in this new urban environment. Given the importance of increasing the availability of the services in a smart city to maintain and enhance the quality of life of the citizens, one of the objectives of SusCity is to research and develop new mechanisms to enable the communication between smart objects in IoT infrastructures, taking in consideration the scalability, security and resilience problems, in the context of smart cities. In this research we present a survey of efforts made to guarantee the reliability and flexibility of services using an IoT communication infrastructure. Additionally we identify the requirements and metrics that need to be taken in consideration to improve the resilience of the networks in this environment.

Concerning the requirements and metrics identified, we propose a network architecture, in the framework of the SusCity project, with high levels of resilience using the RPL routing protocol and the cloud computing paradigm to achieve a multilayer recovery mechanism based in a global view of the network. In this architecture the lower layer objects (smart objects) interact with each other using the RPL routing protocol and the virtual Gateways (vGs), that reside in the edge of the network (fog of the cloud), enabling the access to the Internet. The idea is to collect the metrics required in the IoT environment to enhance the levels of resilience and aggregate them with the data in the vGs. After this first level of aggregation, it is possible to obtain knowledge about the local environment of the network, however to go further in the improvement of the resilience, data and metrics of different vGs can be aggregated in an upper level (in the cloud) to obtain a global view of the IoT infrastructure in order to build a multi-layer mechanism against faults.

In the extended version of the paper besides to provide a critical review of the related work in resilience of IoT infrastructure, our intention is to describe in detail the proposed architecture, as well as to discuss how the data and metric aggregation could be achieved. The aim of this network architecture is to offer a resilient end-to-end environment for the services that could be deployed in a smart city. The validation of these mechanisms will be done in the context of the SusCity project.

Keywords: resilience, IoT, RPL, cloud, SusCity

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