A Model for Integration of Internet of Things Systems in a Smart City

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Abstract - Nowadays, the Internet of Things (IoT) has received a great deal of attention from researchers as it becomes an important technology that promises the life of a smart human being, allowing communication between objects, machines, and all things together with humans. The Internet of Things is a system consisting of real-world objects and sensors attached to or combined with these things, connected to the Internet through a wired and wireless network structure. Things made available on the Internet of Things will share information about the state of things and the surrounding environment with people, software systems, and other machines. With the technology of the Internet of Things, the world will become smarter in all respects, as the Internet of Things provides the means for smart cities, smart healthcare, smart homes, and buildings, in addition to many important applications such as smart power, grid, transport, management and monitoring of waste. In this paper, a model for the integration of IoT systems is presented, including its main components.

I. INTRODUCTION

The challenges posed by the rapid development of technologies are closely related to information technology. As a new technology, the Internet of Things (IoT) is attracting a lot of attention and expectations to make a major contribution in many areas. The concept of IoT was conceived by Kevin Ashton, a member of the radio frequency identification (RFID) development community (RFID) in 1999 [1], and recently became more relevant to the practical world mostly due to the growth of mobile devices, embedded and ubiquitous communication, cloud computing and data analytics. The world of IoT is populated by billions of facilities that can sense, communicate and share information, all interconnected via public or private Internet Protocol networks. These interconnected objects have data regularly collected, analyzed, and used to initiate action, providing tremendous intelligence for planning, managing, and decision-making. The common definition states that the IoT is a network of physical objects. The Internet is not just a network of computers, but it has evolved into a network of devices of all kinds and sizes: vehicles, smartphones, home appliances, toys, cameras, medical instruments and industrial systems, animals, people, buildings, all interconnected to communicate and share information based on certain protocols to achieve smart reorganizations, positioning, tracing, security and control, and even personal real-time Internet monitoring, Internet upgrades, process control, and administration. With the rapid development of the IoT, large manufacturers are committed to exploring the combination of multiple sensors, in the sense of obtaining more environmental data with a single device. The deployment of wireless sensor networks in Smart City infrastructures has led to very large amounts of data being generated every day in a variety of domains, with applications including environmental monitoring, health insurance, and transportation monitoring. To take advantage of increased data volumes, new methods and techniques for efficient data management and analysis need to be used to generate information that can help manage resource usage both intelligently and dynamically.

In this paper, we propose a model for the integration of IoT systems in a Smart City. The model is presented as a multi-level architecture. The UML data flow diagram of the IoT systems integration model is also presented, depicting the integration and communication between the individual entities.

The rest of the paper is structured as follows. Section II focuses on some of the most popular data integration tools. Section III discusses the proposed model for integration of the IoT systems in a Smart City as a multi-level architecture. The last section highlights the conclusions.

II. INTERNET OF THINGS, SMART CITY, AND INTEGRATION TOOLS

As a new technology, the Internet of Things (IoT) is attracting a great deal of attention and expectation to make a major contribution in many areas. The Internet of Things refers to the unique identification of values and their virtual display in the Internet structure. The term Internet of Things was first used by Kevin Ashton in 1999 and has become synonymous with linking things online. RFID4 [2], sensors, actuators, and cell phones are often seen as prerequisites for the advent of the Internet of Things. The last few years have seen an explosive growth of information and communication technologies to improve the design of hardware and software. The use of ICT in cities in different forms for different urban activities has led to increased efficiency of city operations and these cities are marked by the use of many terms such as "cyber Ville", "digital city", "electronic city", "flexi city", "information city", "telicity", "wired city" and "smart city". An intelligent city is the biggest abstraction in the labels used because it encompasses other labels used for cities [3]. Data integration is the process of combining data from different sources into a single, unified view. The most popular integration tools are: SQL Server Integration Services (SSIS) is a platform that is part of the SQL

Server Management Studio, developed by Microsoft. The platform is used for data integration and workflow applications, for building high-performance data integration solutions. SSIS includes graphical building tools for debugging, tasks for performing workflow functions, such as FTP operations, executing SQL statements, sending emails, source and destination of download and write data, their transformations, calculations, etc. [4]. A widely used data integration software product, Oracle Data Integrator [5] provides a new declarative design approach to defining data transformation and integration processes, resulting in faster and simpler development and maintenance. Based on the unique ELT architecture, Oracle Data Integrator not only guarantees the highest possible level of performance for performing data transformation and validation processes but is also the most efficient solution available today. Oracle Data Integrator provides a unified infrastructure for streamlining data and application integration projects. Data integration is at the heart of the entire Talend Data Fabric platform. Convenient self-service tools make it easy to enter data from almost any source, and the built-in functionality ensures that your data is usable from day one. From fast data downloads to cloud data warehousing to the most sophisticated multi-cloud projects, Talend Data Fabric can meet your needs [6, 7].

III. A MODEL FOR INTEGRATION OF IOT SYSTEMS IN A SMART CITY

In this section, the proposed model for integration of the IoT systems in a Smart City is presented as a multi-level intelligent city architecture. It contains five levels, as follows (Fig. 1):

Level 0: Read data from the integration database. This level reads the IoT systems configuration data stored in the integration database, which is important for the next level.

Level 1: Communication and connection parameters required. The communication medium plays an important role in achieving the concept of connecting IoT systems in an intelligent city. The main goal is to establish a connection with sensors from different IoT systems.

Level 2: Download data. At this level, the data/information collected by the sensors is stored for further processing. The collected formats are further processed using semantic web technologies to convert them into a common format.

Level 3: Data preparation / formatting. The information collected is summarized before transmission, using semantic web technologies analysis and fusion. The main goal at this level is to convert the collected heterogeneous information into a common format. RDF11 is the most common way to exchange information over the Internet and facilitates heterogeneous data sharing and integration across different domains of the Smart City.

Level 4: Data storage. At this level, data is stored that is processed and ready to be shared via sensors throughout the architecture of the intelligent city.

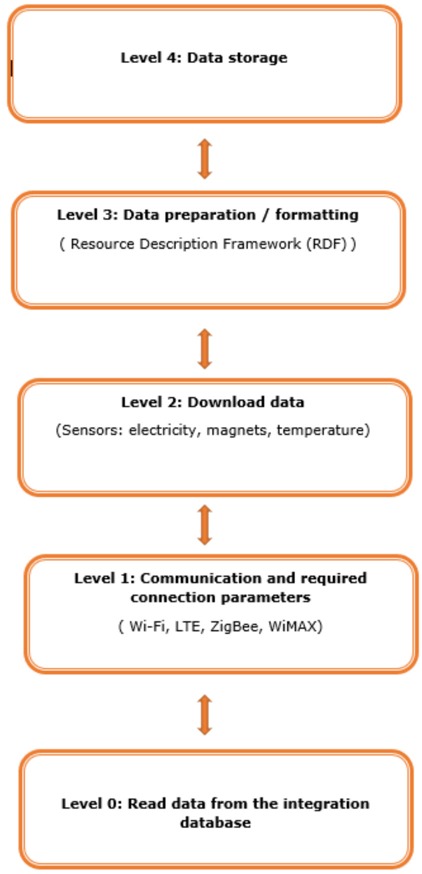

Figure 1. The five levels of the multi-level architecture

The holistic view of the proposed city architecture is depicted in Fig. 2. The approach focuses on city management as a subsystem system. Each autonomous subsystem is connected to the proposed multi-level architecture, which is fully integrated and interconnected with each subsystem. Each system shares its data with the proposed multi-level architecture that can provide cross-domain services to citizens. The proposed multi-level architecture acts as an integration point for information coming from the subsystems. The proposed multi-level architecture can use the information and data available to them to make better decisions in real-time.

The UML data flow diagram of the IoT Systems Integration Model, presented in Fig. 3, shows integration and communication between the individual IoT entities. The model consists of several entities that are interconnected and in sync. The entities, i.e. the separate parts of the model, can be physically located at different locations, but at the same time, they function as if they are a single system or a single whole.

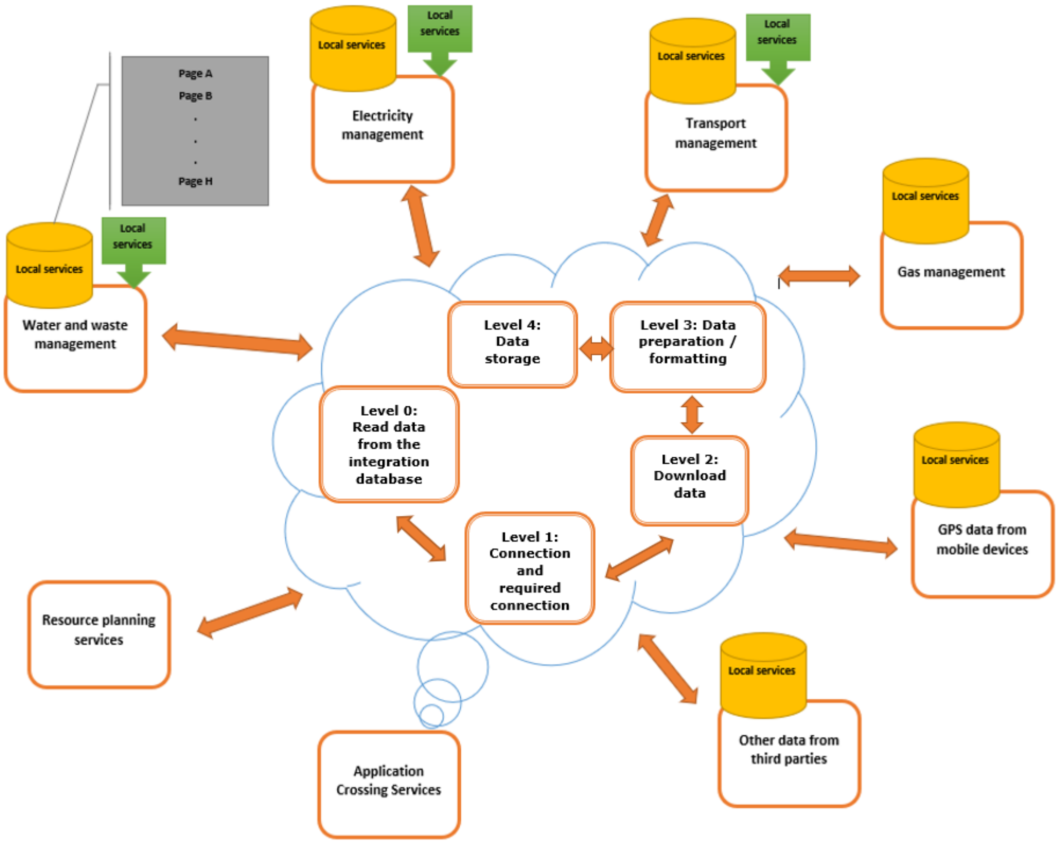

Figure 2. A holistic view of the proposed Smart City architecture

The UML diagram consists of the following entities:

- Data Warehouse
- Integration System
- Integration Database
- IoT System N ((Node N), (Sensor N), (Database for system N)).

The integration system is defined as the process of bringing entities together into a single system and ensuring that entities function together as a system. Integration system integrates IoT systems that are part of Smart City. Initially, the integration system addresses the integration database from which it reads parameters and information about IoT systems and their nodes to which they need to connect and download data, as shown in the diagram. The integration system can receive information from the nodes of IoT systems in two ways:

- Option 1 (Data pulling): The integration system sends a request to Node N for data.
- Option 2 (Push system): Node N sends data whenever there is something new.

An integration database is a database that contains data for IoT systems used in Smart City and in which data should be integrated and stored in a common data warehouse. IoT systems are configured in the database nodes i.e. the sensor nodes that make up those systems and the information for connecting and accessing sensor node data.

The UML diagram presented in Fig. 3 shows an example of System N, which is just one IoT system of all the systems that can be part of Smart City. System N consists of Node N, Sensor N, and Database for System N. Node N sends data requests from Sensor N. Sensor N returns data, while Node N writes the data to its database.

A data warehouse is a database management system designed to enable and support business intelligence and analytics. Data warehouses are intended primarily for research and analysis, and they often contain large amounts of historical data. The data in the data warehouse is usually obtained from a wide variety of sources, such as application logs and transaction-based applications. The data warehouse centralizes and consolidates large amounts of data from multiple sources. Its analytical capabilities enable organizations to extract valuable business insights from their data to improve decision-making. Over time, it builds a historical record that can be invaluable to data scientists and business analysts. Because of these possibilities, the data warehouse can be considered the "only source of truth" of the organization. In the diagram, the data warehouse writes data from System N. When the data is going to be written, the data warehouse returns a response stating that the data is written. The integration system will try to write the data until the data warehouse returns a relevant response.

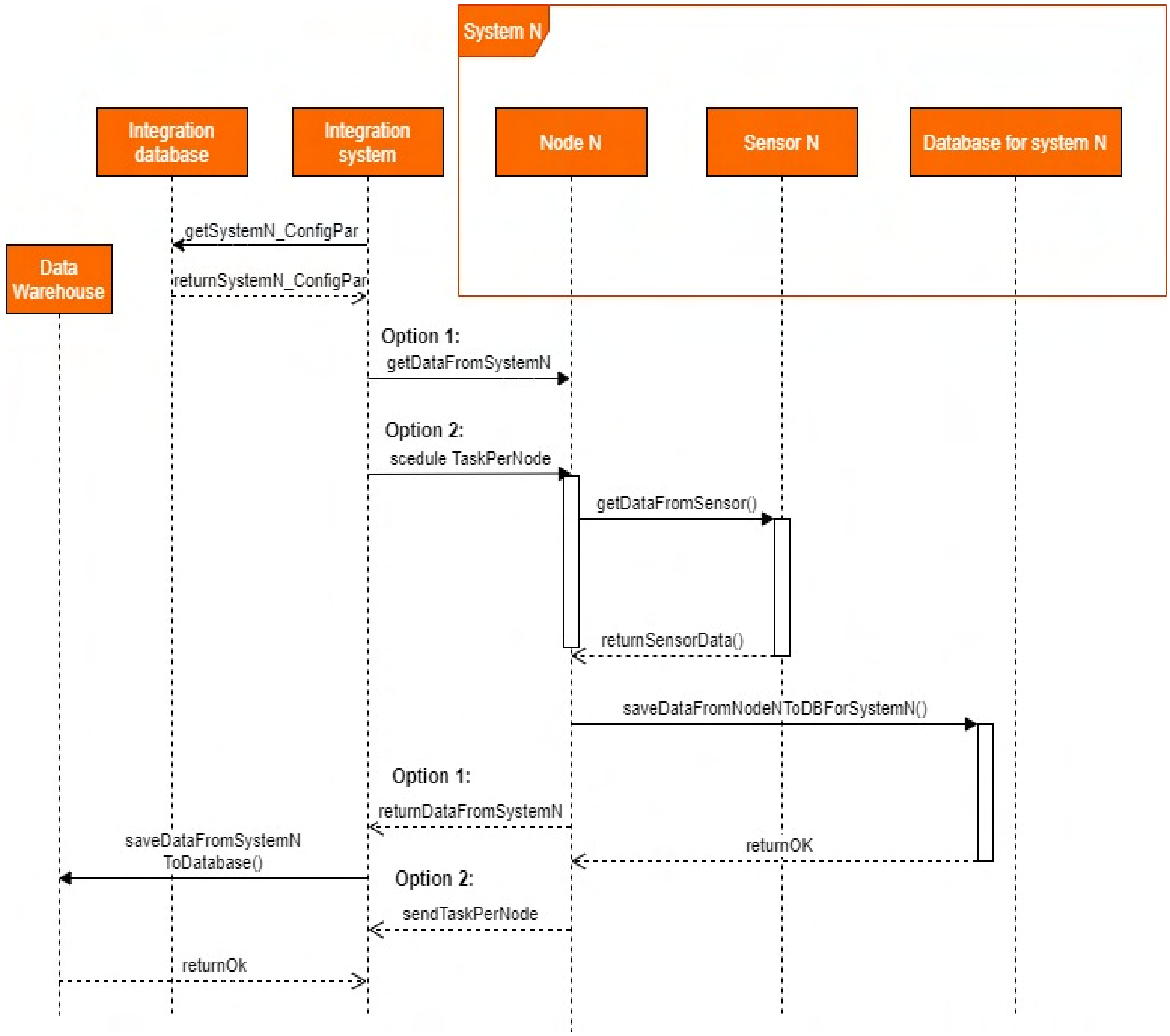

Figure 3. UML diagram of the IoT Systems Integration Model

IV. CONCLUSION

In this paper, we propose a model for the integration of IoT systems in a Smart City. The model is shown as a multi-level architecture. The UML data flow diagram of the IoT systems integration model is presented, which shows integration and communication between the individual IoT entities. The model consists of several entities that are interconnected and in sync. The entities, i.e. the separate parts of the model, can be physically located at different locations, but, at the same time, they function as if they are a single system or a single whole.

Our future work is going to be directed towards the detailed design of the integration database and the implementation of the integration system based on the hereby presented model.

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