Chapter 5

An Architecture and Reference Implementation for WSN-Based IoT Systems

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ABSTRACT

The Internet of Things and its technologies have evolved quickly in recent years. It became an umbrella term for various technologies, embedded devices, smart objects, and web services. Although it has gained maturity, there is still no clear or common definition of references for creating WSN-based IoT systems. In the awareness that creating an omniscient and ideal architecture that can suit all design requirements is not feasible, modular and scalable architecture that supports adding or subtracting components to fit a lot of requirements of various use cases should be provided as a starting point. This chapter discusses such an architecture and reference implementation. The architecture should cover multiple layers, including the cloud, the gateway, and the edges of the target system, which allows monitoring the environment, managing the data, programming the edge nodes and networking model to establish communication between horizontal and vertical embedded devices. In order to exemplify the proposed architecture and reference implementation, a smart irrigation case study is used.

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1. INTRODUCTION

The Internet of Things (IoT) is a paradigm that aims to connect physical objects, intelligent devices, vehicles, machines, buildings and/or sensors to the Internet using communication protocols, wired/wireless hardware and embedded software (Karimpour, et al., 2019). The background technology of IoT includes radio-frequency identification (RFID), near-field communication (NFC), Wireless Sensor Networks (WSN), and other wired or wireless communication. Generally, IoT is based on establishing a bridge between the digital and the physical world by sensors and actuators. According to a study (Sharma et al., 2019), over 70 billion devices will be connected to the Internet by 2025, and the world will become more digitized through smart, distributed and power-efficient nodes.

In order to increase the network coverage of an area, these IoT devices can create ad-hoc networks with their neighbor nodes, termed a Wireless Sensor Network (WSN). The WSN paradigm is well-suited for distributed data acquisition using low-power antennas and embedded devices for various applications (Arslan, et al., 2017). Generally, wireless sensor networks use routing protocols to send a packet from a source node to the sink node. If a gateway transmits this data from a sink node and sends it to a computer or log manager system, that WSN system can be considered part of an IoT ecosystem. Inside the IoT ecosystem, various platforms can be included, such as IoT nodes, WSN nodes, Long Range Wide Area Network (LoRaWAN) and Bluetooth Low Energy (BLE) devices. The common basis of these systems is embedded computing systems designed to perform tasks such as measuring environmental changes and converting them into a human-readable format or digital data. These systems can perform the tasks in an event-based or real-time manner. Additionally, the embedded systems may have an operating system to manage the system resources and have an antenna to establish wireless communication. Therefore, hardware and an accompanying protocol are required to create a network between embedded systems to wirelessly collect data in a wide area.

1.1 Motivation

IoT systems should be designed considering both environmental and user-oriented requirements. They are inherently connection-based systems, and as expected, there will be billions of these devices where scalability becomes an essential feature in the future. Moreover, these devices may not have any user interface or maybe abstracted from human intervention. Therefore, they need a log and event management system that handles changes in the environment by remotely controlling IoT devices. However, the design constraints of the system should be aligned considering the conditions of the environment. In particular, the lifetime of the IoT node is essential when these nodes are deployed in vast rural areas. It may not be possible to find a power source to provide continuous energy to these nodes. Therefore, the dependency on the power source should be reduced to increase nodes' lifetime. The necessity of creating a network without requiring a direct Internet connection has emerged.

For these reasons, IEEE 802.15.4-based WSN nodes are suitable since they are designed for low-power and long life-time dependent applications. When this low-power antenna technology is merged with energy-efficient micro-controllers (Chéour et al., 2020), it can create a mesh network without requiring a direct Internet connection and any power source. WSN nodes create their dynamic network, and new nodes can be easily added/removed. The network can organize itself if the topology changes. The WSN can be opened to the Internet. When the sink is connected to the gateway, data can reach to Internet level via a gateway. Internet level may also have IoT nodes. Suitable communication protocols