Environmental Monitoring Based on the Wireless Sensor Networking Technology:
A Survey of Real-World Applications

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ABSTRACT

This paper investigates real-life environmental monitoring applications based on Wireless Sensor Networks (WSNs). Wireless sensor networking is an emerging technology, which through the research in the labs and the real deployments has proved to be a significant and valuable tool for scientists in their effort to explore various environmental phenomena. During the last decades, this wireless networking technology has been adopted by many scientific fields in order to accurately and effectively monitor climate phenomena such as air pollution, destruction phenomena (i.e., landslides), etc. It has also been widely used in agriculture as well as in horticulture for field monitoring. This paper provides a critical overview of the basic components existing WSN deployments use. It also categorizes these deployments, 111 in total, into five different field categories, namely agricultural monitoring, environmental monitoring, air-water pollution monitoring, monitoring of destruction phenomena, as well as monitoring of livestock, and wild animal, in order to provide a general view of the technologies used, the conditions under which the deployments were conducted, and much more. Then, five easy-to-use guides are provided discussing basic considerations for deploying WSNs in each of these fields. These guides cover various issues, such as sensor node platforms, operating systems (OSs), topologies, installation and maintenance issues, and much more. In order to showcase the usefulness of consulting the resulted guides, this work considers representative application scenarios for each of these field deployments.

Keywords: *Deployment Guidelines, Environmental Monitoring Applications, Sensor Node Hardware, Software Components, Wireless Sensor Networks*

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1. INTRODUCTION

The curiosity of humankind for the natural environment was the driving force that led him to search and learn issues related to complex environmental phenomena. Thanks to that and through detailed monitoring, nowadays we have the knowledge to predict events or prevent them from happening. At the very beginning, every physical condition and parameter was measured by some analog devices, which, at that time, were very innovative, but too costly and not very accurate. Following on, the use of digital data loggers replaced these analog devices, and despite being less expensive and more easy to use, this data logging technology was still inefficient. Recent technological advances, namely continuing miniaturization of electronics, the availability of large data storage and computational capacity, and the pervasive connectivity of the Internet, led to the development of tiny sensor devices with sensing, processing, and communicational capabilities that were able to provide with accurate local measurements of the monitored parameters. These devices, which are called wireless sensor nodes, when deployed in an area, form a Wireless Sensor Network. WSNs constitute a powerful and promising tool for monitoring events (Akyildiz, Su, Sankarasubramaniam, & Cayirci, 2002). This new approach of gathering information from the environment could provide with the much-needed feedback between the monitored field, the local climate conditions, and the human's decisions of treating the field.

The initial development of WSN was motivated by military applications such as enemy monitoring and tracking, force protection, battlefield surveillance, etc. Nowadays, WSNs are used in many other application fields such as agriculture, environmental monitoring (e.g., air-water pollution, greenhouse phenomena, monitoring of oceans, volcanoes, forests, etc.), health monitoring, home automation, and more. In this article, we consider the case of WSNs being deployed for environmental monitoring purposes. Such WSNs are also referred to as Environmental Sensor Networks (ESNs) (Martinez, Hart, & Ong, 2004), (Corke, Wark, Jurdak, Hu, Valencia, & Moore, 2010). Depending on the application, ESNs can be employed to perform habitat monitoring (Polastre, 2003), flooding-landslide-earthquake detection (Tan, Xing, Chen, Song, & Huang, 2013) monitoring of volcanic eruptions (Song, Huang, Xu, Ma, Shirazi, & Lahusen, 2009), (Huang, Song, Xu, Peterson, Shirazi, & LaHusen, 2012), micro-climate monitoring for farms and rain forests (Wark, et al., 2008), cattle monitoring and control (Kwong, et al., 2009), and much other.

While there is an endless list of scientific papers discussing WSN-based environmental monitoring applications, these works do not provide deployment guidelines or design considerations with regard to the deployed sensor network. Hence, someone willing to deploy a WSN for these applications is left alone to choose the technologies to be used. In order to fill the gap, this paper provides generic guidelines on how to deploy WSNs in five different real-life environmental monitoring applications. In achieving this objective, the paper discusses the different field deployments summarizing at the same time the software and hardware components used in each of them. *Using this information, it then proposes five easy-to-use guides for deploying WSNs in these deployment fields.* Finally and more importantly, it showcases the usefulness of consulting the resulted guides, by considering representative real-life application scenarios for each of the five different field deployments. It is expected that a number of stakeholders including researchers, scientists, *environmentalists,* agronomists, farmers, etc., will be benefited from consulting the produced guides.

To the best of our knowledge, limited work has been conducted in this largely extensive investigated research area. In (Giannopoulos, Goumopoulos, & Kameas, 2009), the authors present their experience in deploying a WSN for environmental monitoring applications, and based on the gained experience, they introduce guidelines for these types of deployments. *They do not provide similar guidelines for alternate field deployments such as for the*

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