Chapter 10
LPWAN in Civil Engineering:
An Overtopping Detection System Application

Alberto Alvarellos González
https://orcid.org/0000-0002-3404-3354
Universidade da Coruña, Spain

Juan Rabuñal Dopico
Universidade da Coruña, Spain

ABSTRACT

Wave overtopping is a dangerous phenomenon that, in a port environment, takes place when waves that are higher than the port's breakwater meet it and water passes over the structure. This event can lead to property damage or physical harm to port workers. It is difficult to detect an overtopping, so this chapter proposes a solution to the overtopping detection problem by describing the design and development of a system that can detect an overtopping event in real-time and in a real environment. To achieve this goal, the proposed overtopping detection system is based on devices that use ultrasonic ranging sensors and communicate using the Sigfox low-power wide-area network, together with a backend that processes the data the devices send, issuing alerts to inform the interested parties that an overtopping took place.

INTRODUCTION

Wave overtopping is a dangerous phenomenon that takes place when waves meet a submerged reef or structure. It also happens when waves meet an emerged reef or structure lower than the approximate wave height. The latter case is the one that affects a port's breakwater and the one we want to measure.

When a wave overtopping occurs in a commercial port environment, the best-case scenario will be the disruption of activities and even this best-case scenario has a negative financial repercussion. Possessing a system that detects overtopping events would provide valuable information to port operators, allowing the minimization of the impact of overtopping: the financial impact, the property damage, or even physical harm to port workers.

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During an overtopping, two processes take place: wave transmission and the passing of water over the structure. We want to measure the passing of water over the structure. This process can occur in three different ways, either independently of each other or combined:

- **Green Water**: It is the solid step of a certain volume of water above the crown wall of the breakwater due to the rise of the wave (run-up) above the exposed surface of the said breakwater.
- **White Water:** This occurs when the wave breaks against the seaside slope. This creates so much turbulence that air is entrained into the water body, forming a bubbly or aerated and unstable current and water springs that reach the protected area of the structure either by its impulse or as a result of the wind.
- **Aerosol**: It is generated by the wind passing by the crest of the waves near the breakwater. This is not an especially meaningful event, even in the case of storms. This case is the less dangerous, its impact on the normal development of port activities is negligible.

The more important overtopping types, in terms of the damage they could cause, are green and white water. To detect these events, we need to use a distance sensor, a type of sensor that allows detecting the location of objects without physical contact by outputting some kind of signal, (e.g. laser, ultrasonic waves, or IR LED) and reading how the signal has changed on its return. The change may occur in the strength of the returned signal or the time it takes the signal to return.

Once a potential overtopping is detected, a message has to be sent to a backend (server) that can process it. A port breakwater is usually several kilometers long and lacks wired internet connections and power supplies, so we need to use a Wireless network to send the data. Since the amount of data we need to send is small (only one message per overtopping event needs to be sent, and these events happen rarely), the best approach is to use a low-power wide-area network (LPWAN), a type of wireless telecommunication wide area network that allows long-range, low bit-rate communications among things (connected objects that conform the Internet of Thing, IoT), such as sensors operated on a battery (the case of the devices presented in this chapter). Right now, there are several types of IoT networks. One of them is Sigfox and it is the one the Overtopping Detection System uses.

The main objective of this chapter is to show how to use IoT, LPWAN technologies, and ranging devices to create a full system that can detect an overtopping event in real-time in a real environment.

This chapter provides an analysis of civil engineering applications of IoT, LPWAN technologies, and ranging devices. The chapter also considers the security aspect of the system which is an important consideration due to the nature of the problem and the energy supply solution for practical deployment.

The remainder of the chapter is organized into five sections. Section 2 presents the literature review of IoT, LPWAN, and ranging devices based solutions used to solve civil engineering problems. Section 3 presents the design and development of the measuring device that detects an overtopping event. Section 4 presents the design and development of the backend part of the system that is responsible for collecting the data of the device and issuing the alerts if necessary. Section 5 presents the future research directions based on the knowledge acquired in the development of the system this chapter presents and possible improvements to the system. In Section 6, the chapter concludes with the main points of the section 5.

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