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An Autonomous and Adaptable Wireless Device for Flood Monitoring

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Abstract

Wireless devices can be used to monitor and record a broad range of phenomena. Their advantages include ease of installation and maintenance and considerable reduction in wiring costs. The addition of battery power and radio communication to such wireless devices can result in a completely autonomous system.

The operating environment of monitoring systems is often hostile, due to temperature fluctuations, humidity, electromagnetic noise, and other interfering phenomena. The system should be able to adapt to changing conditions to maintain dependability in its operations.

This paper presents the case study of adapting a flood detection device to the environmental threat of submersion.

1. Introduction

The flexibility and low cost achieved by wireless devices has led to their near-ubiquity in recent years. In particular, wireless sensor networks have been successfully used in applications ranging from shooter localization [1] to habitat monitoring [2]. The size, unobtrusiveness, and expendability of wireless sensor nodes make them ideal candidates for detection and monitoring systems.

In our approach, a one or more sensor nodes are distributed in areas of interest. Each node is equipped with sensors that measure relevant environmental and structural parameters. These sensors collect data that is transmitted to a base station for processing. The base station processes the data received from the network, and announces the detection of an event of interest if a sufficient number of nodes provide consistent supporting data.

The number of nodes and base stations and the particular sensors deployed will vary from one application to another, but the vast majority of applications share a number of basic requirements, in particular independence from power and transmission wires. The use of battery and radio communication eliminates the need for manual intervention, but also introduces new challenges for the device, especially when installed in a hostile environment. Implementation of appropriate power saving techniques for the hardware and software can extend the battery life to several years, but exposure to the elements and other environmental factors can necessitate site visits and reduce the autonomy of the device.

To remain survivable despite uncertain environmental conditions, adaptability should be incorporated into the design. Depending on the installation environment, a monitoring system should be able to adapt to unpredictable operating conditions, including changes in temperature, humidity, or electromagnetic noise, or severe conditions arising from floods, human tampering, wildlife, or accidents. Examples of adapting to temperature or electromagnetic noise, respectively, may include the activation of fans to cool the device or temporary suspension of radio transmission. Adapting to all hostile circumstances may be impossible, but graceful degradation requires that at the very least, an alarm be activated.

2. Case Study

The case study presented in this paper is a wireless flood monitoring device for bridges or dams. It is primarily designed to trigger an alarm in case of flood, but can be adapted to survive and continue normal operation even in case of severe overflow.

Depending on the size of the structure being monitored, the wireless sensor network is composed of one or more instances of the flood monitoring device. Each instance of the device is enclosed in a waterproof box, and can function when completely submerged. The main challenge that arises from submersion is continuing radio communication,

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which can be severely affected by the water overlay. For either long range communication (e.g., mobile GSM network) or short range communication (e.g., ZigBee or custom protocol), the water may become an obstacle that completely detaches the device from the external world. The safety-critical nature of this application necessitates high dependability, despite the hostile environment.

The system installation requires the box to be close to the water level. The basic architecture has been designed to recognize when the water level reaches a prespecified threshold. As illustrated in Figure 1, the device is fixed on the structure (e.g., a dam), with the magnetic floater encased in an empty pipe. Two magnetic reeds regularly check for the presence of the floater. In the default position, which appears on the left side of Figure 1, the floater is located in front of the lower reed. If the water level exceeds the threshold, the floater will rise to face the upper magnetic reed, as seen on the right side of Figure 1, and the flood alarm and related actuators are activated. If neither reed detects the floater, an alarm is activated to notify authorities of the problem.

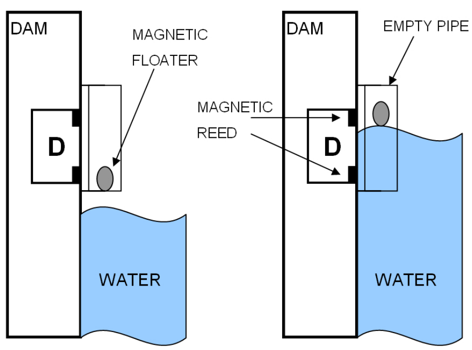

Figure 1. Original flood detection device.

In its simplest form, this application is a binary detection system that sends an alarm in the event of a flood. The device is installed in a fixed position on the monitored structure, and is not able to adapt in the event of a flash flood. To save energy, the device is maintained in sleep mode under regular (non-flood) conditions. When an alarm is required, the device needs at least 30 seconds to wake up, enroll in the long-range communication network, and send a message.

To increase the survivability of the system, the device needs to adapt to rising water levels during a flood. System functionality needs to be maintained under these conditions, and radio communication is critical. This necessitates keeping the box above the water level at all times, which in turn implies major modifications to the physical installation of the system.

In the simple architecture described above, the box was stationary and the floater in motion. In the modified architecture, the box will move, essentially serving as the floater, and the magnets will remain stationary. To guarantee radio communication during a flood, the box has to remain above the water level. This can be achieved by placing the device on a large floater, as depicted in Figure 2. The floater slides along a vertical shaft installed on the wall of the dam, but always remains above the water.

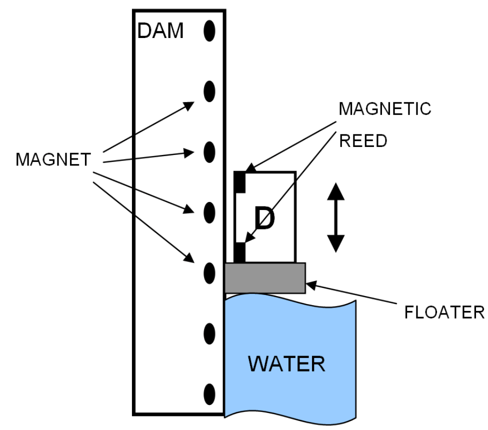

Figure 2. Modified flood monitoring device.

In this new configuration, the magnets are placed inside the vertical shaft, so as the box moves, the two reeds open and close allowing the controller to recognize the direction of the movement (upward or downward). This modification also allows for measurement of the water level, which can be carried out by placing a series of equally spaced magnets inside the shaft, and implementing a state machine to record the current position and update each time the box moves.

In addition to simple binary detection of a flood event, the modified device can be programmed to trigger an alarm when a certain water threshold is reached or send periodical information about the water level. Moreover, the device is now able to adapt to the surrounding conditions; even in the event of flash flood. The water can temporarily cover the box but, due to the large size of the floater, it will quickly raise above the water level and be able to communicate as usual.

References

[1] M. Maroti, G. Simon, A. Ledeczi, and J. Sztipanovits. Shooter localization in urban terrain. *IEEE Computer*, 37(8):60–61, Aug. 2004.

[2] R. Szewczyk, E. Osterweil, J. Polastre, M. Hamilton, A. Mainwaring, and D. Estrin. Habitat monitoring with sensor networks. In *Communications of the ACM*, volume 47, pages 34–40, June 2004.