Ultra-Wide Band Sensor Based Ground Monitoring

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ABSTRACT: One of the most important aspects of early warning systems and risk reduction techniques is early detection of events such as landslides or subsidence is ground displacement monitoring. Landslide is considered as one of the most dangerous natural disaster which occurs mainly in hilly areas. There are already many types of instrumentation, but those capable of delivering real-time alerts on multiple time series are usually based on expensive hardware, illustrating the need to develop a low-cost, easy-to-install device suitable for emergency surveillance. Consequently, a wireless network based on ultra-wideband radiofrequency impulse technology was realized. This network's uniqueness is its ability to determine the distance between nodes using the same signals that are used for transmission without the need for an actual measuring sensor. The system was tested in Central Italy by tracking a mudflow, and revealed its suitability as an early warning device. Further work on potential low-cost hardware integration and eventual industrialization will boost this promising technology further.

KEYWORDS: Wireless sensor network, Slope stability, Subsidence, Early warning, Monitoring.

INTRODUCTION

Landslides play an important role in the development and shaping of aerial/subaerial environments, posing a major cause of loss of life, injury, property damage, socio-economic disruption and environmental degradation, especially when they are combined with other natural hazards (such as earthquakes, volcanic eruptions, meteorological events and wildfires). Because of these repeated variations, accurate social impact figures are difficult to achieve on a global scale only due to landfill slides and economic losses are definitely underestimated.

This general situation also helps to reduce the fear that individuals and authorities have about risk of landslide. While consideration of the socio-cultural and socio-economic conditions in relation to their physical protection is still very confusing in most of the disaster-prone areas, the installation of effective landslide detection, monitoring and early warning systems is increasingly considered crucial by local authorities in reducing the risk of landslide disasters [1]. EO from space has found many applications in the natural sciences, but technical developments have also spread to study of landfill slides only in recent decades.

Nowadays rapid developments allow EO techniques more effective for the identification, mapping, tracking and hazard assessment of landslides. Applications come from almost any form of sensor available today. Rapid advances in this area are fostered by the very high spatial resolution obtained by optical systems (currently in the order of tens of centimeters) and by the launch of SAR sensors, developed specifically for interferometric applications with revisiting times of a few days, such as TerraSAR X and COSMO-SkyMed. Detection and mapping of landslides benefit from both optical to research slow moving landslides.

The ability to perform numerous point displacement measurements over the landslide body allows one to detect and map the actively deforming slopes, characterize and monitor landslide mechanisms and, by analyzing time series of deformation, identify velocity changes in landslide evolution, as well as model large slope instability. In the field of slope instability identification, mapping and tracking, advanced terrestrial remote sensing technologies such as GB-InSAR, TLS, IRT and optical photogrammetry (DP) are now used for short / long-term landslide management.

LITERATURE REVIEW

This article presents a tutorial view to introduce the basic principles of seismic acquisition systems that are required to establish requirements for the wireless geophone network. All specifications for a scalable network system where ultra-wide band radio transmissions play a key role as the only viable technology are strict sampling synchronization restriction over vast geographic areas, high precision sensor localization and high data rate [1]. LoRa is a modern wireless ISM band system for Low Power, Unlicensed, Long Range operations. LoRaWAN is a Wide Area Network protocol incorporating the wireless LoRa into a networked infrastructure. These technologies' indoor and outdoor efficiency, the physical layer of wireless and multi-gateway large area network, was assessed across Glasgow City's central business district (CBD) (Scotland). The results indicated that this technology could serve as a reliable connection for remote sensing applications with low cost [2]. This paper uses natural rubber as the substrate to implement a thin, low-profile, planar, and versatile ultra-wide band (UWB) antenna. Using natural rubber as the substratum for UWB antenna is the primary solution. The UWB antenna is designed for WBAN applications, the latest innovation within wireless sensor networks. The antenna works from 3.1-10.6GHz, a candidate for service on WBAN. The antenna's lightweight nature makes it comfortable for use as a body- worn WBAN antenna. This paper is a case study on whether rubber can be used as a UWB antenna substratum and compares the results using FR4 substratum [3]. The wireless network was realized using ultra-wideband radiofrequency impulse technology. This network's uniqueness is its ability to determine the distance between nodes using the same signals that are used for transmission without the need for an actual measuring sensor. The system was tested in Central Italy by tracking a mudflow, and revealed its suitability as an early warning device.

More work on the integration of future low-cost hardware and eventual industrialization will give this promising technology more development. This paper introduces a new protocol based on a dual-band physical layer technology, Medium Access Control (MAC). MATLAB- and OPNET-based co-simulation models were developed to evaluate the performance of the proposed MAC protocol. For a practical situation, we evaluated the performance of the MAC protocol where both implantable and wearable sensor nodes are involved in the data transmission. Priority-based packet transmission techniques have been used for serving various sensors according to their QoS specifications in the MAC protocol. Significant network parameters such as packet loss ratio, packet latency, percentage throughput, and power usage are analysed [4]. Temporary coupled-mode theory and numerical simulations explore lamellar gratings. An engineered grating with shallow grooves under normal incidence can achieve complete absorption, and the full width is only 0.4 nm at half maximum (FWHM). The structure displays high absorption for certain wavelengths even within an ultra-narrow angle, which means it can be used as a highly directional thermal emitter according to Kirchhoff's law. Alternatively, the resonant wavelength is sensitive to the dielectric ambient refractive index. The main objective of this research is to implement sensor technologies which affect the modern world. There are many innovations on them, and many different views.

Recent developments are pushing the entire world to work on different combinations of various technologies. This helps us to simultaneously look at the world in wide spectrum through a camera. Depth camera is suitable for scanning one's face or body using an IR sensor. New technologies allow us to use and reconnect the best features of these. Ultra-broad band sensor is a system which is identical to ultrasound but does not see any obstacles in traditional radio communication technologies [5]. This paper presents a detailed study of a magnetic sensor device benefiting from a new technique to substantially increase the magnetoelastic coupling of acoustic surface waves (SAWs). The system uses shear horizontal acoustic surface waves driven by a fused sheet of silica with a thin amorphous FeCoSiB magnetostrictive film on top.

Depending on the magnetic field current, the amplitude of these so-called Love waves reflects the magnetoelastically induced shifts of the shear modulus. The SAW sensor is worked at approximately 150 MHz in a delay line configuration and converts the magnetic field into a time lag and a related phase shift [6]. This paper provides a novel framework for approaching discrete IoT applications. LoRa is a newly developed LPWAN system with a wider band based on the spread spectrum technique. LoRa uses the entire channel bandwidth to relay a signal that makes it channel noise tolerant, long-term relative frequency, doppler effects, and fading effect. This paper focuses on the new IoT-dedicated transmission technologies. LoRa features are based on three main parameters: Code Rate (CR), Spreading Factor (SF) and Bandwidth (BW). This paper offers an in-depth study of the impact these three parameters have on data rate and air time [7]. This paper uses inertial sensors, monocular vision, and ultra large band (UWB) sensors to present a method for global pose estimation. It is shown that the complementary characteristics of these sensors can be exploited to provide improved global pose estimates, without needing any visible infrastructure such as fiducial markers to be added. Alternatively, natural landmarks are jointly calculated using a simultaneous localization and mapping process with the platform pose, assisted by a small number of easy-to-hide UWB beacons with known locations. The approach is tested with high-precision ground-truth data from a controlled indoor experiment [8].

METHODOLOGY

Wireless Sensor Network (WSN) technology is capable of recording, storing, and transmitting data rapidly in real time. Wireless sensors establish a network after deployment in the area, by interconnecting with each other. This sensor network has the advantage of being highly scalable and simple to install: sensors can be distributed and tailored to the environment, as needed. This satisfies a significant need for real-time monitoring, especially under hazardous or remote conditions. WSN does have its own drawbacks, however. The sensors have size limitations which means that both hardware and software can't be very complex. In addition, they can't usually hold huge quantities of battery power.

In the literature, the WSNs primarily leverage radiofrequency signals to provide connectivity to the sensor nodes so as not to quantify the node size. By comparison, the Wi-GIM method proposed in this paper attempts to use a particular WSN in a landslide scenario to estimate its deformational area. This is accomplished by using impulsive radiofrequency technology, such as ultra-wideband (UWB), to calculate the gap between nodes of a WSN, thus forming a "line" across the surface of the soil to track landslide movements. A single node is basically a multi-component electronic board and an intelligence which controls them. The board is designed to house the microcontroller, all other elements being external I/Os. Then, each node can be fitted with various components / modules. Depending on how certain components / modules are integrated, it is possible to introduce distinct types of nodes with different functions. The basic components used on Wi-GIM for master and slave nodes are:

1. Master node: this device contains the following modules: SD memory card, ARM Cortex M3 microcontroller, Battery, Communication and Range UWB module, GPS, GSM / GPRS/3 G communication module;

2. Slave node: The computer contains the following modules: ARM Cortex M3 microcontroller, battery, communication and range UWB module.

A cluster is formed by a single master node and a number of slave nodes (typically from 1 to 15). Larger clusters are possible but the number of communications will increase (since each node interacts with each other visible node) thereby reducing the battery life.

The contact module (GSM / GPRS/3 G) is used to send a regular update on the cluster / network status remotely (on a web page), with all the distances measured / collected by the controller, and other useful details such as battery level, potential non-responding nodes, temperature, etc. The UWB hardware is the DWM1000 module of the Decawave Sensor. It incorporates in one module antenna, both radiofrequency circuits, power control, and clock circuits. It can be used to locate properties to a precision of 10 cm in two-way or ToF location systems and supports data rates of up to 6.8 Mbps. The antenna used in the module is the dielectric chip antenna Abracon ACA-107-T (range of frequencies 3200–7200 MHz), part number ACS5200HFAUWB. For the data sheet and full information please see Abracon (2017) and Mouser (2017).

The estimated distance measurement error is more than 150 m by 10 cm. In ideal conditions this is a nominal value: line-of-sight (LOS) and one-shot calculation. This performance can be enhanced with the application of digital processing techniques over multiple measurements, which can reduce the error to 2–3 cm. This is covered under Section 2.4. Experimentally tested the operating range of the sensor nodes. Nodes in LOS condition can properly communicate and perform the range procedure up to 150 m, although the Decawave data sheet records 290 m. NLOS condition can decrease range accuracy, as well as communication quality between nodes. Depending on the nature of the obstacle (stone, tree, bush, etc.) the precision in NLOS condition was calculated to be in the range of 20–50 cm.

SYSTEM ARCHITECTURE

The machine architecture (Fig. 2) is master-slave: a master node co-ordinates the slave behavior under their influence. It's particularly an ad hoc network using a modified topology of stars. The master controls the slave sensors by deciding which slave should be activated; the slave then calculates the distance between himself and all the surrounding nodes (slaves and masters alike), which occupy the channel.

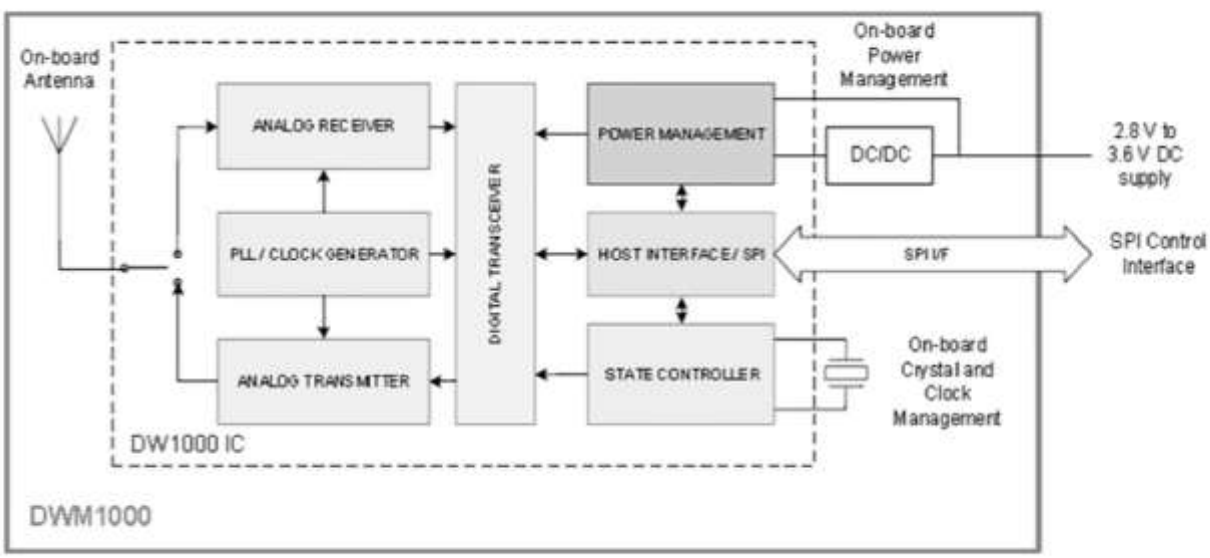

FIGURE 1: Block diagram of Decawave UWB module.

When the slave has finished measuring distance, it sends the results to the master and then releases the link. The master can now give the control signal for activation to another slave. And so on, until all slaves are turned on. The master could not look directly at all the slaves. It has the information, however, coming from the initial network scanning, of which the nodes and slave can reach are. This helps the master to draw a diagram of the relations between the nodes in the network. Consequently, a slave not seen explicitly by the master may still be triggered by another slave, which will transmit the master's commands to the final destination node. The concept of ad hoc refers to the possibility of relaying the master commands to all the network nodes, and also to the possibility of setting any node as a master.

Growing node has a microcontroller, a module UWB, a battery and a power supply (Fig.2). The power supply is a 12 V, 7.2 Ah lead acid battery but it can be built into the UWB module in the future with a lithium rechargeable battery. The master node also has a GPS module and a memory card. The GPS is not important for positioning but a time guide. Before starting the ranging measurements the master node spreads the GPS time reference among the slaves. The master node orders each slave to calculate the distance to the surrounding nodes which is visible to that node during the ranging process. The master has the slaves' IDs in memory, as well as how many hops are required to reach each particular node. The distances calculated by a node are sent to the master, which stores the information in its memory card, and the time stamp. After gathering all the distances, the master sends the report file via 3 G link to the cloud server. The master also gathers information from the slaves about battery level and puts it in the report log.

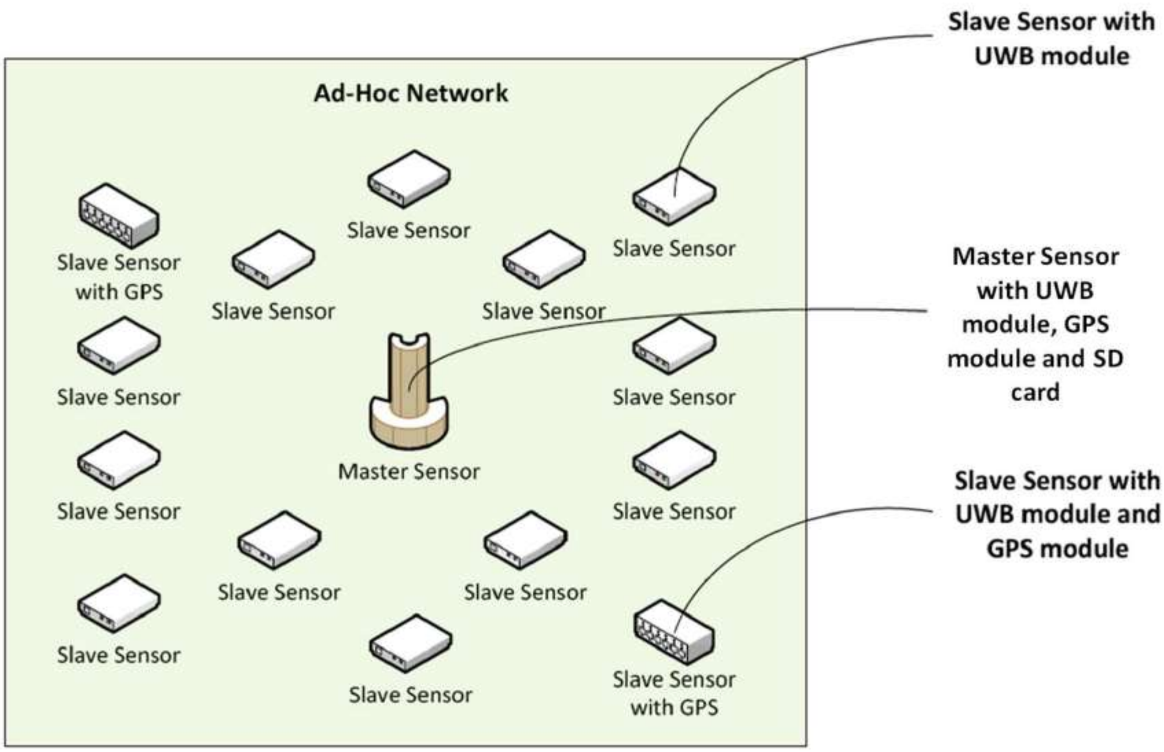

FIGURE 2: Wi-GIM system architecture i.e. for master and slave.

Because battery consumption is a critical point for the WSN, the nodes should have a sleep mode enabled. The master node is configured to calculate the distances regularly during the day, e.g. over 24 h every 10 min. The master sends the sleep order and the wake-up time to the slaves after a full scan of the nodes has ended. All the nodes deactivate and reactivate all of their power-consuming modules at the programmed time. A single whole cycle of measurements (from activation to back in sleep mode) lasts around 90 s. Due to its slow temporal evolution, the measurement frequency for an earth flow (like the one mentioned in Section 4) may be 2–4 acquisition per day to save batteries. For a longer usage of the WSN on a landslide, one may change the battery of each node without moving the node.

When the master triggers a node it sends an impulsive UWB signal to any close node with which it can communicate. It is received by the neighbor node, and it is sent out. Thus, the active node will estimate the distance between nodes by measuring the ToF bidirectional. If the ToF has been determined the distance is obtained by multiplying the ToF times the light speed. The master sensor makes the calculation. Post-processing takes place after the data is obtained by the server, using explicitly generated Matlab functions used for data filtering, automatically comparing displacement velocities with defined thresholds and sending automated alerts, as well as plotting displacement diagrams of all possible node combinations, useful for advanced node analysis by the operator. Master sensor periodically sends the data collected (distance between its network nodes, temperature, battery levels, etc.) using the GSM/GPRS/3 G moduleThe basic processing is: (1) detection and elimination of outliers; (2) correction of temperature-dependent errors; (3) averaging over several measures (e.g. one day); 4) continuous correction of offset. The continuous offset is an consequence of the receiver having many echos.

CONCLUSION

A new prototypical ground instability monitoring tool known as Wi-GIM was developed. It consists of a WSN composed of nodes that, by measuring the ToF of a UWB impulse, can calculate their mutual inter-distance. Therefore, no sensors are included in the network, since the transmission signals are often used for ranging. There is a general lack of low-cost instrumentation in the field of ground stability, encompassing both landslides and subsidence, to track displacement over a large area. The key reason for this is the difficulty in delivering good results, particularly in terms of accuracy, acquisition frequency and robustness. While Wi-GIM is still a prototype device and, as such, is vulnerable to changes, it shows potential as a tool for monitoring speeds classified as slow which are typical of earth flows, mudflows, mining subsidence, earth slides, and after failure rockslides.

The program was first applied in a field study, and then to track the displacement of an real landslide, the mudflow of Roncovetro in Central Italy. Data from the experiments showed that the measurements were affected by temperature, in addition to outliers and multi-path effect that were filtered with normal data processing. After studying the temperature correlation a simple correction was sufficient to improve the accuracy and increasing the temperature effect. Wi-GIM has been evaluated for tracking very slow to rapid landslides, subsidence and stress cracks as an early warning device. These applications are possible thanks to the fast deployment of the nodes, network adaptability and pace of acquisition. Automatic alerts are issued when the battery level is low and adjustable speed thresholds are exceeded.

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