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Landsliding early warning prototype using MongoDB and Web of Things technologies

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Abstract

Nowadays Wireless Sensors Networks (WSN) are intensively used for environment monitoring. As a bridge to the physical world, WSN can gather handy data even in hazard sites. Access to hazard data is particularly crucial when anticipating risks of disasters. When integrated into the Web of Things and a Big Data database, the WSN offers a promising way to sketch an online picture of the monitored site. The paper describes a prototype of a landsliding risk early warning system hosted by a Web of Things technology and MongoDB as a Big Data database. The developed prototype collects and displays runtime telemetry observations on precipitation, soil movement and soil moisture forwarded by sensors. Sensors nodes are implemented in a Tunisian landsliding high risk zone. Embedded daemon scripts trigger specific warning alerts when some bounded values are reached.

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Keywords: wireless sensor networks; Web of Things; Big Data; early warning systems; landsliding;

1. Introduction

Landsliding can provoke disasters with dramatic impacts on people and economy. This continuous threatening dictates the use of serious monitoring measures in order to mitigate the possible effects of the ground movement such as rock falls, "slump", earthflows or slope failure. A combination of human, mechanical, optical, radar and computer systems are actually used to predict landsliding with some level of success[1 2]. The paper describes a prototype of a landsliding risk early warning system hosted by the Web of Things. The prototype uses technologies related to Wireless Sensors Networks (WSN), Web of Things and a Big Data. It uses WSN as a bridge to monitor a Tunisian zone known by its frequent landsliding events. The first section presents a light state of the art related to the WSN and

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the Web of Things and the Big Data technologies. The second section describes the architecture of the landsliding early warning system. The third section exposes the configuration and the deployment steps of the proof of the concept prototype. Results are discussed in the fourth section.

2. Technologies in use

2.1. WSN

WSNs are largely used in environmental monitoring. They capture handy data about natural phenomena and help mitigate their disastrous effects[3 4 5 6 7]. WSN are spatially distributed devices formed by four major components: 1) a processing unit based that manages inputs and outputs, 2) a radio frequency transceivers based on a standardized wireless transmission protocols used as a communication interface, 3) sensors for gathering observations and 4) a power supply units[8]. WSN nodes (motes or waspmotes) are based on a plug 'n play modular architecture. Sockets are available to plug application needed sensors.

The node can be employed according to the requirement of their applications as sense only or sense and react. Their main function is to collect observations and forward them to the closest neighbor node and so on until the data reaches a node called a sink. This later one can be a node or a router gateway connected wirelessly to a distant server through an existing communication infrastructure.

Each node processing unit hosts 1) an operating system used to manage network resources such as Contiki, Mantis or TinyOS and 2) The Sensor Network Query Processing Systems (SNQP) or SensorDB; a middleware used to initiate Continuous Queries and collect data streams generated by sensors. Reader is forwarded to[9] for an exhaustive review. Data streams are displayed or/and stored in-network or in external storage such a RAID disks or a Data Streams Management Systems (DSMS)[10].

Our application waspmotes are based on TinyOS. It presents several advantages over other mote that we can found on the market. First, it is composed of two main modular boards: a processing unit board and a sensor integration board or shield that facilitates the data merge of heterogeneous sensors.

Moreover the processing board have a compact design and includes all features is needed for mounting wireless sensor networks: wireless communications modules, RTC clock to allow scheduling interruptions, micro SD to store data from sensors, 3-axis accelerometer (very useful for detecting 3-D movement) and of course, a battery and solar socket with charge regulator for power autonomy.

Also, our sink node Meshlium is a Linux data base router offers compatibility with different radio interfaces such as Wifi, 2.4Ghz, 3G/GPRS and ZigBee. It permits WSN connection to internet through 3G/GPRS protocols inside a 12 Km communication radius and to internally store data streams in a 16 Go hard drive.

2.2. Web of Things

As stated in www.webofthings.org, Web of Things (WoT) is "a community of developers, researchers, and designers exploring the future of the physical Web. We want to leverage Web standards to interconnect all types of embedded devices (sensors, mobile phones, etc) to make them easier to use and integrate in classic Web applications. WoT aims to build a future Web of devices that is truly open, flexible, and scalable, and we believe Web standards are the best way to do it."

This statement means that WoT is an application layer of the Internet of Things (IoT). This refers to re-use and adaptation of web services (URI, HTTP, RSS etc.) in connecting, integrating and accessing functionalities of devices embedded into things through RESTful API, Atom standards or Comet programming mechanisms. Household appliances and WSN nodes are the kind of smart objects that are candidates to be part of the WoT. Some sites offer software tools to integrates WSN nodes to the web, display their collected observation and even filter them in order to identify specific events.

We intend to benefit from the WoT services to publish our WSN collected data streams as it have been used in many other works[11] to do remote monitoring data collected from WSN. Visually and with embedded daemons scripts, it will be possible to detect soil dangerous kinetics and address appropriate early warnings to whom it may concern.

2.3. Big Data

Big Data refers to data sets that become so large that they become difficult to work with conventional tools database management or information management espacially in wide WSN[12 13].

The concept of Big Data covers a combination of technology, use of innovations and social developments that led companies to rethink their strategic priorities and their operational model. The first fundamental dimension of Big data is the technological component. In fact, Big Data is based on a set of technological innovations that profoundly transforms how businesses and individuals generate, transmit, store and use data: massification of data exchange (video, text, sound, image) revolution in storage (cloud computing) and structured data (NoSQL), advances in analytical techniques, advances in data visualization tools ...

3. Architecture of the Landsliding Early Warning System (LEWS)

The basic architecture of our application is shown by fig.1.

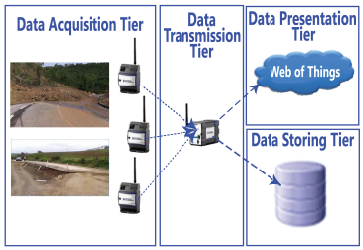

Fig. 1. Architecture LEWS

3.1. Data Acquisition Tier

The in-the-field data acquisition infrastructure is composed by the WSNs nodes, their associated OS/SNQP/transmissions softwares that power and control observation sampling and log sensors data streams. The observation sampling rate is controlled through the sensor wake up time via the RTC. This feature has a direct impact on the data rate when forwarding the packets to the sink/router.

3.2. Data Transmission Tier

It refer to the principal role of the sink/router who collect data from the nodes who had captured them from the environment where they are installed. The sink node is responsible for capturing, storing and transmitting collected data streams. In this architecture, the sink node collect data from the other nodes and transmit them to the Data Storing Tier and the Data Presentation Tier.

3.3. Data Storing Tier

Usually, WSN use an in-network storage memory used to produced data streams. Even if most of the data streams are volatile, some parts can be stored in-network. But the use of an in-network storage is limited in resources and can consume so much energy, to free scarce storage memory resources, the locally stored data is uploaded into an external database for archiving and analysis.

We had chosen to use a NoSQL database document-oriented type with a dynamic schemas. We have chosen a Big Data database because we intend to store many informations who were received from the nodes, a document-oriented type specifically a JSON-like documents because nodes can send their datas as a JSON file, and also the JSON files are easy to manipulate with few memory and processing resources to reduce the energy consume in nodes and in the sink too, a dynamic schemas because we can have many nodes that doesn't contain the same sensors and this give us

more flexibility into the integration of any necessary sensors and nodes in our system. This permit an efficient middle and long term handling by benefiting from the trusted DBMS technology advantages. Accordingly, we intend to use MongoDB as a data manager.

3.4. Data presentation Tier

As like the Data Storing Tier, we have chosen to store our data into a WoT to have more ease to see and explore the data received from nodes and we had implemented daemon scripts filter captured data streams and analyze them in order to detect specific behavior (exceeded observation value threshold) which preludes a landsliding. Alerts messages are generated and disseminated to whom it may concern. More specifically, visualization and dissemination of data streams follow the path from field implemented nodes to the client via the WoT.

4. Configuration and field deployment

4.1. Planning step

We start by describing the characteristics of the pursued WSN deployment region. In that order, we made the following assumptions: The Tunisian landsliding case inherits the overall Mediterranean soils properties. Consequently, the landsliding events are mainly related to clay soil and water infiltration due to unprecedented rainfall[14 15]. Metline is the chosen zone for the deployment of our system. It is known by its eroded landscape made of sedimentary sloppy hills covered by clay soil on limestone, its sensitivity to huge precipitation and its frequent landsliding.

Consequently, on each node, we'll plug a precipitation sensor, a humidity sensor and an accelerometer sensor. The later will monitor soil kinetics. The sensor categories choice are supported by demonstrated strong correlation between precipitation and soil kinetics[14].

4.2. Implementation step

We'll deploy a static network with a tree topology. The collected datas will be stored in the external display which is the WoT and the NoSQL database. For our WSN, we have used five waspmote nodes and a Meshlium sink and three commercially available sensors: a soil moisture, pluviometer and the internal three axes accelerometer.

Usually, a landslide phenomena can be observed under a five level scale:

1) Normal soil state; 2) Wet soil; 3) Rise of Wet rate; 4) Critical wet rate; 5) Lanslide warning.

5. Implementation steps

The first stage of the implementation was conducted into our laboratory. We have coded a C program to be flushed into the node EEPROM to collect datas from sensors and transfer them to the Meshlium sink. For the Meshlium sink, we have developed two programs: a C++ program that collect datas from nodes and forward these brute datas to a Python program that transform the data collected to a standard form and send them to the MongoDB database using a RESTful Web service written in PHP for the server side composed of a Web server and the MongoDB Server. The python program also send the data to the WoT server.

The PHP program can store the data in the MongoDB Server and can show the full contain of the MongoDB Server.

The data stored at the MongoBD server will have the following JSON format:

{ 'id':'5763e19507a38f700800004b',
'mac':'0013a2004070e9af',
'date':'17-06-2016 13:40:05',
'temperature':'27', 'luminosity':'0', 'pressure':'108', 'watermark':'51', 'battery':'28', 'x_acc':'-125', 'y_acc':'92', 'z_acc':'999' }

The lines od the previous code are explained as follow: the first name (id) refer to the id given by the MongoDB for every new line inserted. the second name (mac) refer to the MAC adresse of every node. the third name (date) refer to the second that the MongoDB have received the information and had store it in his Server. the other names refers to the data collected by the node and every information has it's own name and value.

This step is important before conducting tests in order to insure that sensors will work as expected.

Once the overall WSN configuration was set up for both the waspmotes and the sink, we deployed the network in Metline region. We repeated the same laboratory tests after choosing the best nodes locations in the landscape.

In parallel, we benefited from the WoT (data.sparkfun.com) as a development, publishing and sharing data platform. We designed a page which displays data streams histograms and monitor their incoming values by daemon scripts. The daemon scripts constitute the foundation of the early warning procedure.

1. a pluviometer daemon: it triggers an alert if the quantity of rainfall water exceeds 70 mm.
2. three accelerometer daemons: one for each of the three monitored position by this built-in sensor i.e. x,y,z. It triggers an alert if there is change of node location on the x,y plan or on the z plan.
3. soil moisture daemon: it triggers an alert if the value collected by the sensor reachs the 4th ($70mm < w < 500mm$) or the 5th ($> 500mm$) level of the scales of the landsliding phenomena previously presented.

Triggered alerts are email messages containing the node id with a text concerning the value collected by the sensor.

We have used MongoDB to store all the observations sent by the nodes simultaneously to a storing in the Web of Things. This will insure an easy way to query and access data.

For this purpose, we have developped a RESTful Web service to store data send from Meshlium sink and to consult these data from the Web with no need to a direct access to the MongoDB server.

The last step is to test our WoT page and our MongoDB server to check if our nodes are objects full integrated into the Web. In fact, the waspmotes are able to collect the valuable data as programmed and to forward it to the Meshlium sink.As configured, this later connects to our WoT web page and our MongoDB server and displays the collected data streams as exhibited in the following section.

6. Results

The fig.3. illustrate the data streams gathered by the accelerometer sensor.

Fig. 2. Accelerometer X, Y, Z values

As expected, it does not show any significant change to the initial x,y and z values of the node because no soil kinetics are observed.

The soil moisture sensor (fig.4.) behave alike because no rainfall is recorded during our proof of concept prototype testing. This will keep the soil moisture observations values constant.

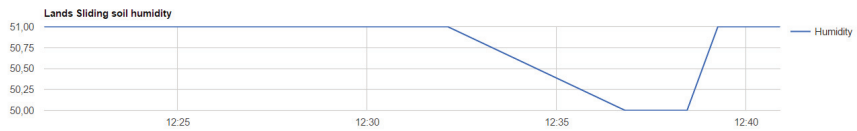

Fig. 3. Soil moisture sensor values

An alert message is emitted if one of the three values of the movement go past original values.

7. Discussion

Our proof-of-concept demonstrates the feasibility of a landsliding early warning system using WSN. The WoT as an enabling technology helped in facilitating the publishing of the collected observation on the Web and the use of email services to dispatch messages. It is also possible to send short messages *sms* from inside the WoT if an *SMS* account is available.

Nevertheless, two weaknesses are obvious. The first refers to the early warning. The emission of alerts is based on a simplistic scenario mainly related to the soil humidity. In real life, scenarios are more complex and need the combination of different indicator into a calibrated model. Consequently, our daemon triggers must be enhanced by an expert point of view that will points out the most efficient model for predicting landslides.

The second concerns the volatile nature of the collected data. For instance, the system handle the generated data streams and archive them in an NoSQL Database namely MongoDB who can handle the possibility that every node had his own sensors. This will permit the creation and storage of valuable time series big data. If analyzed, archived time series can reveal important patterns and help refine the actual predictive landsliding models[16].

8. Conclusion

In this paper, we presented a proof of concept prototype for landslide early warning system. We hosted it into the WoT and a big data. It behaves as expected. But we're aware about the simplistic scenario behind the alerts triggering. We intend to involve a geologist expert in landslides with the mission to enhance our daemon triggers by a more credible predictive model. Data streams generated by the nodes sensors are stored in MongoDB, a NoSQL database. Our objective is to archive time series that will helpful in calibrating landslides predictive model. This will be the first step in implementing a big data approach known to be appropriate to store huge volume of data.

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