A Human Sensor Web for Water Availability Monitoring

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Abstract. In recent years the Sensor Web Enablement (SWE) standards of the Open Geospatial Consortium (OGC) have been successfully applied in several practical applications. Typical domains range from environmental monitoring over homeland security to disaster management. At the same time, mobile communication technology has spread widely so that large parts of the world's population are able to communicate electronically. In several developing countries the mobile communication infrastructure has even reached a better availability than the supply with water and electricity. The combination of these two aspects - the SWE architecture and the common availability of mobile communication networks - opens up the perspective to create even more powerful monitoring systems. This work shows how human observations can be integrated with the Sensor Web technology and presents a system design which makes use of the Human Sensor Web idea to build a monitoring system for improving the water supply in Zanzibar.

1 Introduction

Water is an important good and rare in large parts of the world. Information about quality and quantity of water in the surroundings of human settlements is very important. This is particularly relevant for certain African regions, such as Zanzibar, where water supply is limited and water for the daily needs has to be carried over long distances (e.g., from remotely located wells). In such regions, it is desirable to know beforehand if a well is dry (or even polluted) to prevent unnecessary walks [1].

Therefore, the aim of this work is the creation of an information system for dry regions to share knowledge about the state of the wells in an area. The infrastructure in Africa is not as well developed as in countries of the western hemisphere. However, mobile phones are already quite common [2]. Hence, our approach of a information system for water availability utilizes mobile phones of the local population to collect observations about the water supply. Mobile phones provide various new ways to gather such information [3]. In our scenario, humans can be considered as sensors to provide volunteered geographic information [4].

2 An Architecture for a Water Supply Monitoring System Based on Human Sensors

The Water Supply Monitoring System (WSMS) (see figure 1) presented in this paper distinguishes two kinds of users. First, reporters who submit observations about the water supply and quality. Second, subscribers who are interested in receiving alerts regarding the local water supply. The submission of data as well as the alert notification relies on the Short Message Service (SMS) technology. The users of the system are untrained citizens which report if a water point is dry, out-of-order, or the provided water is not drinkable. The system is open to the public so that everybody can subscribe (reporters are implicitly subscribed). The water points (e.g., wells, water kiosks, or shallow wells) within the covered region are equipped with signs providing citizens the necessary information for submitting observations: the ID of the water point, a phone number where to send the observation, and the allowed vocabulary to encode the observation.

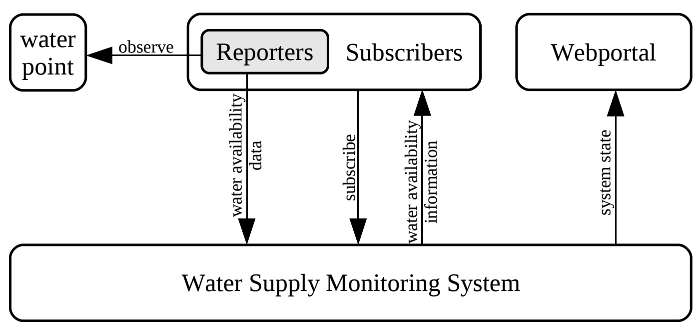

Fig. 1. water supply monitoring system

The system architecture (see figure 2) is based on specifications of OGC's[4] Sensor Web Enablement (SWE) initiative. Observations submitted by a reporter are forwarded to a Sensor Event Service[5] (SES) [5] which offers Complex Event Processing (CEP) [6] functionality. Within this architecture the SES acts as an information broker. It filters observation events submitted by reporters before forwarding appropriate notifications (e.g., a dry well) to the subscribers. For encoding the filter expressions OGC's Event Pattern Markup Language (EML) [7] is used by the SES.

All incoming observations are processed by the SES using a trust model based on Bishr [8]. Depending on the reputation of the user submitting an observation the system holds the message back or forwards it. The reputation of each user is adjusted after each sent message. Thereby, the model is based on the principle of

[4] http://www.opengeospatial.org/

[5] The SES is currently an OGC discussion paper and a successor of the Sensor Alert Service (SAS).

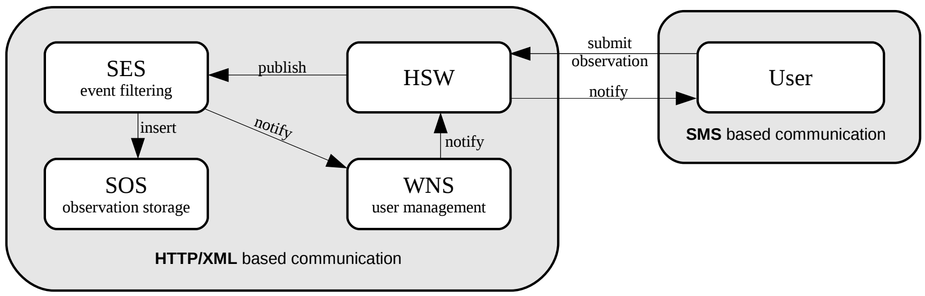

Fig. 2. human sensor web application architecture – simplified

fast decrease and slow increase with the notion that trust is built slow and lost fast. Also, for each message a certainty value is calculated depending on the age of the information. To be able to use this reputation model by the SES we integrated it with EML. If an alert is computed by the SES a Web Notification Service (WNS) [9] is triggered to broadcast notifications to interested users. Therefore, the WNS also handles the management of users subscribed for the different water points.

The data generated by the human sensors is not only filtered and used for alert notification but also archived in a web-accessible repository. To allow interoperable access to the gathered data the repository is encapsulated by a Sensor Observation Service (SOS) [10] instance which offers operations to store and query sensor observations and metadata. As part of the overall system, a web portal can be used by the public to access the SOS and to view the observed data.

Since the communication of the SWE services is based on HTTP communication, a bridge to the SMS protocol is needed. This is realized by the Human Sensor Web (HSW) component. The HSW component is able to receive user observations, forward incoming observations via HTTP to the SES, and to broadcast SMS messages to subscribed users in case a notification is triggered by the WNS.

3 Conclusions and Further Work

This work presents an architecture for a water availability and quality monitoring system based on human observations which has been successfully deployed in a test area in Zanzibar. It is based on open standards developed by OGC's SWE initiative. Observations are submitted to the system via mobile phones. Those messages are received and filtered by a Sensor Event Service instance. If an alert such as a defective water point is identified, a Web Notification Service instance is called to broadcast notifications to registered users. Additionally, a web portal enables users to display collected data which is offered through a Sensor Observation Service.

Because of the open and modularized architecture the system can flexibly be transferred to further application domains and scenarios. Basically, each system relying on data observed by the public can be realized using the approach described within this paper. This includes for example the monitoring of all other kinds of infrastructure like power grids or water mains. But also completely different domains like traffic monitoring, disaster management, or crime reporting can benefit from the presented technology.

The implementations of the different components used and developed within this project are published as free software through the SWE community of the Open Source initiative 52° North[6].

Acknowledgment

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