Geocoding Sensor Data – Applying OGC's Sensor Web Enablement Specifications

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Introduction

The Open Geospatial Consortium (OGC) addresses the requirement of integrating sensor information into spatial information infrastructures by developing service interfaces, protocols and data types in the Sensor Web Enablement (SWE) specification series. Using web-based services as tools for interdisciplinary data exchange, as well as for the extensive usage of heterogeneous data resources is an important step towards addressing today's larger scale environmental problems (Bacharach, 2008). By making measurements and results discoverable and accessible over the internet, data producers can reduce data redundancy and existing data sets can be used to their full capacity.

Even though SWE services are designed to be a foundation for »plug&play« access to sensors and sensor networks, questions about how to apply standards for information providers still have to be answered. Compared to the »state of the art« of specialised mass-market ready sensor and communication technology, SWE standards appear bloated, impractical and hard to implement. The project SLEWS (**S**ensor-based **L**andslide **E**arly **W**arning **S**ystem) uses existing commercial sensor products, implementing SWE technologies on top as a middleware layer to provide the data in an open and interoperable manner as a proof-of-concept. Results of the project's work outline approaches to improve the process of providing sensor data in a SWE-enabled format using today's commonly used internet technologies.

Sensor-based Landslide Early Warning System

The collaborative research project SLEWS aims for the systematic development of a prototype alarm and early warning system for mass movements. Project partners are the Department of Engineering Hydrogeology at RWTH Aachen, the Federal Institute for Geosciences and Natural Resources (Hannover), the Chair of Geodesy and Geoinformatics at Rostock University and ScatterWeb GmbH (Berlin). Early warning and alarm systems are an effective tool to reduce risks from landslides (Fernandez-Steeger et al., 2008). The main goals of SLEWS are the utilisation of ad hoc wireless sensor networks and spatial data infrastructure technologies according to OGC guidelines to produce a low-cost, interoperable and performant early warning system. Methods of data access, communication and visualisation are to be implemented using SWE specifications, concurrently offering information resources via open standards to external applications while importing interoperable resources in return (Bill et al., 2008).

System Architecture

Wireless Sensor Network

Wireless sensor networks (WSN) provide an inexpensive and easy to implement monitoring system for landslide events. Sensor nodes are fitted with sensors such as tilt meters and pressure, acceleration and displacement detectors specifically chosen to monitor engineering-geological parameters of landslide events. Due to improved manufacturing processes and progress in the area of micro sensor systems, small but precise low-cost sensors can be integrated in such systems.

The WSN used in SLEWS is constructed by the project partner ScatterWeb. As a modern and autonomous ad hoc wireless sensor network it is characterised by self-organisation and self-healing capacity. Data packages from each node are sent via radio waves directly or via other nodes (multi-hop) to a collection point (gateway). Energy efficiency is achieved by reducing transmission power to only communicate with adjacent nodes. The bi-directional structure of the system enables data transfer from each node via the gateway interfaces to the main computer unit (PC, laptop, server) and also allows the transmission of commands such as data requests and software-updates to individual nodes or to a group of nodes (Arnhardt et al., 2007).

Measurement data is retrieved from the WSN via a specialised gateway node. To read out the data the gateway node has to be connected to a computer unit (gateway server, see Figure 1) via wired or wireless connection. An application running on the gateway server can access the data stream arriving at the gateway node, consisting of text output representing data packages received from sensor nodes.

SWE Services

Sensor Observation Service

A Sensor Observation Service (SOS) offers a web-based interface to retrieve measurement data and sensor information via HTTP-based spatial and temporal queries (OGC, 2008). Response formats of the SOS are the XML-based data encoding schemes SensorML and Observation & Measurement (O&M):

SensorML is used to describe and formalise the parameters of a sensor or data producer. The way sensors are described in SensorML is strictly process-based and can be used to capture sensor metadata, operation sequences as well as software patterns of data-related operations. Every procedure a SOS offers data from has to be described by a particular SensorML document, which will be returned in response to a *DescribeSensor* query. SensorML is thus used to enable interoperability of sensors by allowing a client to discover new sensors and to prepare for the interpretation of measurements in a hardware-independent manner.

O&M is used for the exchange of actual measurements and observations. O&M output documents can be requested using the *GetObservation* operation with options to filter all available observations by time, location, observed phenomenon or sensor. O&M is comparable with the well-established OGC format for vector data, Geography Markup Language (GML). Elements of GML are already used in O&M and the OGC SWE working group is currently attempting to fully harmonise both standards.

To understand the functionality of a SOS it is helpful to outline the SWE spatial view on the conventional sensor/measurement concept. Consistent to well-established OGC models, a sensor, as one of many possible data producers called *procedure*, is well-defined by a location called *feature of interest*. At a location an *observation* is recorded which represents a certain *phenomenon* at a certain time.

Sensor Planning & Sensor Alert Service

Bi-directional communication with the WSN to remotely control functions such as energy management or measurement cycle rate is possible by sending instructions via the gateway node. The process of communicating these instructions to the WSN can be encapsulated using a Sensor Planning Service. A SPS offers the execution of a set of instructions via standardised web-based interface. Users of the SOS can thus remotely adapt the process of

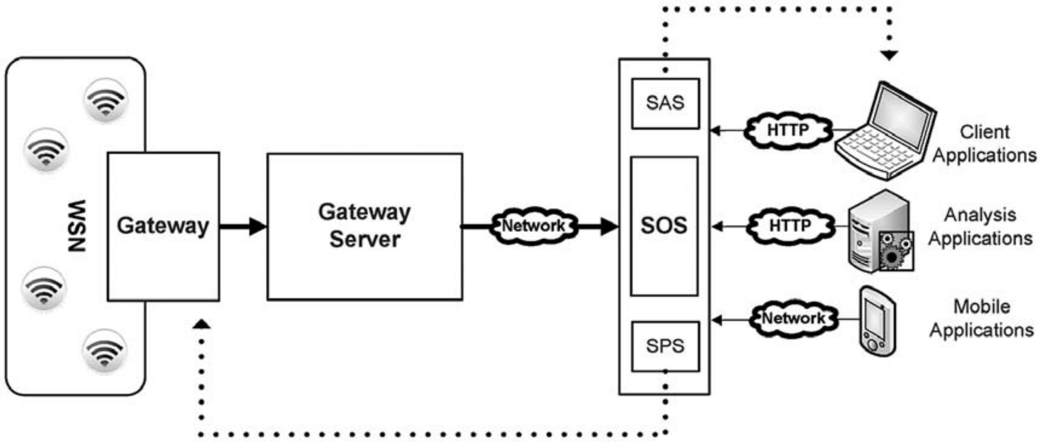

Figure 1: Current SLEWS information infrastructure (SAS = Sensor Alert Service, SOS = Sensor Observation Service, SPS = Sensor Planning Service)

data gathering without the requirement of knowing details of the WSN's operations.

Another aspect of bi-directional communication with the WSN is the need for event-based notification to users without having to continuously »poll« the SOS for new information. A Sensor Alert Service (SAS) allows the subscription of clients to messages coming from a sensor system matching certain criteria. Users are then able to receive messages about threshold exceedance or sensor malfunction asynchronously, being notified to request more detailed information from the SOS or to heighten the WSN's measuring sensibility via SPS.

Methods

Geocoding WSN Data
To be processable by the SOS and SAS, measurement data coming from the gateway node have to be transformed to fit the appropriate SWE data model. This process is also called formalising or geocoding sensor data. A manufacturer-specific application running on the gateway server is used to access the data stream arriving at the gateway node, consisting of text output representing data packages received from the WSN. A typical measurement string has the form

S4 20 2008-08-13#16:14:12 2696

where *S4* is the network identification number (node number 4), *20* is the sensor identification number for the specific node, followed by sampling date, time and the actual sampling value (*2696*, sensor specific hexadecimal form). While date, time and value can be adopted almost unchanged, network and sensor identification numbers have to be resolved using previous knowledge. Knowing the identification numbers, information such as sensor location (*feature of interest*), sensor properties (*procedure*) and observed phenomena (*phenomenon*) can be determined.

Another application running on the gateway server parses the incoming data strings, dividing them into tokens using look-up tables (shown simplified in Table 1) to determine adequate SWE parameters. Most parameter values must be expressed in a certain XML-based form, e.g. values for *procedure* and *phenomenon* are used in Uniform Resource Name (URN) notation. URNs, as specialised cases of Uniform Resource Identifiers (URI – W3C, 2006), serve in XML-based O&M or SensorML documents to unambiguously identify information resources and phenomenon definitions by semantic descriptions.

Making WSN Data Accessible
Within the SLEWS project, the determined »SWE-enabled« data set can be inserted in the

Table 1: Simplified look-up table for SWE-based parameters

SWE parameter	Node-ID: (S4)	Sensor-ID: (20)
procedure	urn:ogc:object:feature: Sensor:SLEWS:slewsMote_0.1.1	
offering		Atmospheric_Temperature
phenomenon		urn:ogc:def:phenomenon: OGC:1.0.30:temperature
feature of interest	locationID: id001 descr.: Aachen sampling point 1 coord.: 50.776208,6.080085	

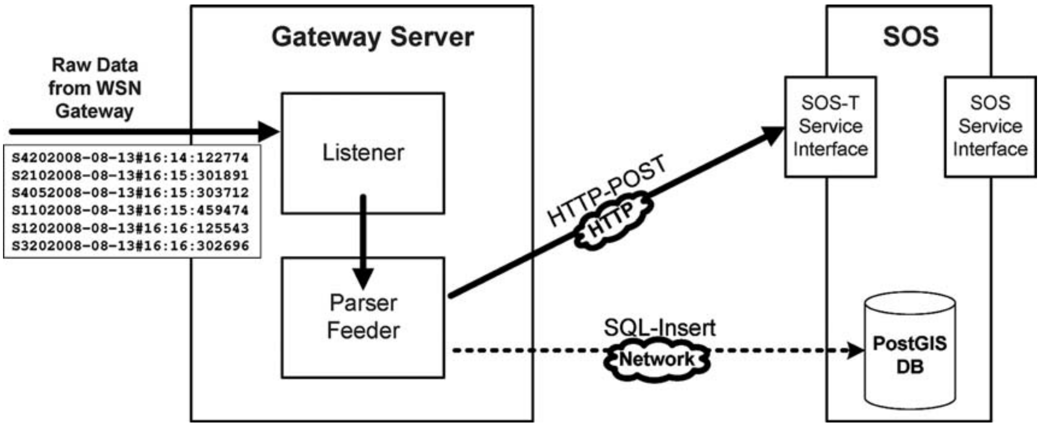

Figure 2: Importing data from the WSN into the Sensor Observation Service

SOS database by a feeder application running on the gateway server (see Figure 2). Even though this way of data transmission shows very good performance, it is not further discussed because of its lack of interoperability. In order to be able to insert data directly the database has to be remotely accessible and a considerable amount of detailed knowledge (access parameters, access permission, database structure) is required. Another way to transmit data is using the SOS interface itself. For this, the transactional SOS operations (*RegisterSensor*, *InsertObservation)* require data sets to be O&M- (and SensorML-) formatted. Any data provider using proper HTTP-requests is able to register with the SOS and supply it with data sets without previous knowledge. As a result the parser/feeder applications running on the gateway server were modified to support transactional SOS operations. The transmission performance is currently under evaluation.

Discussion

Even though the use of web-based interfaces to supply SWE services with data benefits interoperability, extending and reformatting sensor-specific data to fit a SWE-based layout still requires a high amount of training and the implementation of highly specialised software applications. Within the SLEWS project significant customisation has proven to be necessary, however building an Early Warning System on top of SWE services makes very specific demands. In order to advance the widespread usage of SWE standards in the sensor community, more intuitive methods to interface sensor data and SWE services should be devel-

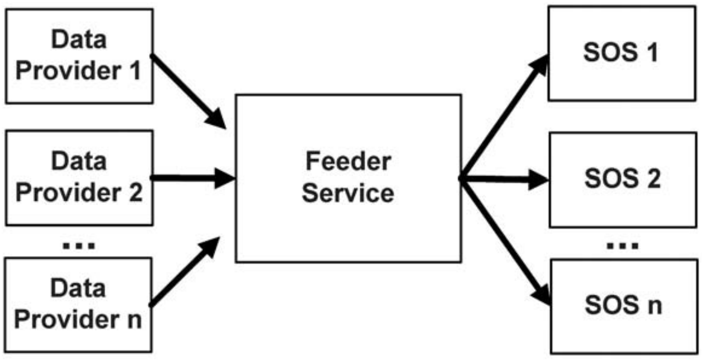

Figure 3: Using a feeder service a single entry point to supply different Sensor Observations Services with data

oped. »Casual« users and data providers should not directly be confronted with the production of feeder software, XML code or SWE semantics, thus the technical encapsulation of services with easy-to-use web-based applications functioning as mediating middleware seems to be a feasible approach. Here we present a potential model for future developments. Another more specialised sensor-system layer based formalisation model is described in (Walter et al., 2009) and will not further be discussed.

SWE Feeder Service

Using dedicated feeder web services (e.g. see 52° North, 2008) to transfer data from provider applications or sensor systems to SWE services is an important step towards »plug&play«-capability. Single feeder services can serve as an entry point for the data import in several transactional or non-transactional SOS (Figure 3). To publish their services, each SOS provider can register with the feeder service to provide the necessary information such as database access or the web address of the transactional interface. Potential data providers can supply a SOS with data without the requirement to know technical details. In addition, feeder services can hierarchically or thematically organise different SOS and present them to the user. However, at this point the data transmitted from the feeder service to the SOS must already be fully SWE compatible and O&M formatted so the process of geocoding raw sensor data has to take at place an earlier stage.

SWE Connector Client

Even when using middleware between SWE services and data provider, and considering the large number of different sensor systems, implementing solutions to convert a proprietary sensor format into a SWE-based format is still unavoidable and requires detailed knowledge. In order to overcome this problem, we propose that a dedicated »SWE connector« application should be developed. The application is proposed to act as a client to the previously described feeder web service, supporting the data provider in the process of geocoding the sensor data and transmitting it to a SOS via the feeder service. The SWE connector client, designed to be a user-friendly frontend to the feeder web service, should be implemented as a browser-based application. The use of JavaScript/AJAX technology would offer the user a vey intuitive interface rich in features previously available only in desktop applications.

The client has to support the option to upload raw data from different sources supplying generic tools for database-, file- or stream-based access. As a basic but widespread example, the CSV format (comma separated values) is very often used by sensor (network) operators as a file-based exchange format. The SWE connector application could easily implement functionality to upload and parse CSV or other file types. In a next step the user would have to provide a number of SWE parameters to expand the data model of the provided raw sensor data. A combination of user-friendly

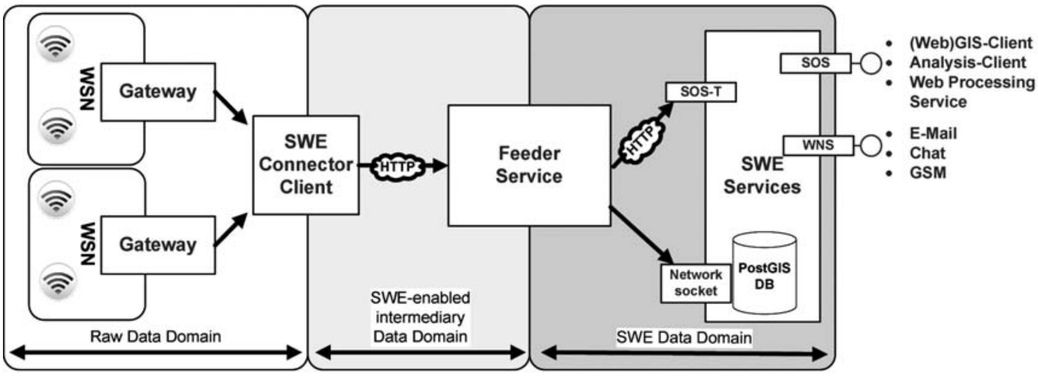

Figure 4: Layout of a middleware layer based SWE standardisation process (SOS-T: transactional SOS; WNS: Web Notification Services)

browser selection menus on top of SWE parameter dictionaries (e.g. for. phenomenon, sensor and location definition) would provide a sufficient tool to create complete SWE-based data sets. However, for transmitting the data from the SWE connector client to the feeder service, taking the overhead of uncompressed XML data traffic into account, the exchange format should not necessarily be O&M-based but in an intermediary lightweight format. Using JSON (JavaScript Object Notation) as a structured but compact data exchange format is a feasible approach. SWE parameters in the form of placeholder identification codes could be transmitted together with the sensor data as a data block which could easily be parsed and remodelled by the feeder service (Figure 4).

Conclusions and Future Work

The vision of the SWE-initiative is to create standards as a foundation for »plug&play" web-based sensor networks (Botts, 2007). The services and models produced provide effective tools to realise the concept envisioned by the OGC of uncoupling sensor information from the way they are collected and to make this information available over the web using standardised formats and interfaces. However connecting sensors to SWE services remains a difficult task requiring detailed knowledge of both the sensor system and of the SWE standards, and off-the-shelf WSN as used in the SLEWS project do not support SWE standards. As the experience in the project, shown in detail in the previous sections, this leaves an interoperability and usability gap which must be bridged by anyone wishing to provide data via SWE services.

First steps towards closing the gap are being taken with the utilisation of transactional SOS and multifunctional web service-based feeder services, mapping sensor data to the data model of the service backend. Further efforts in this process must be made focussing on the earlier stages of the data delivery chain. The result should be an easier way of providing sensor data from a large number of different sensor-native formats to a SWE-enabled format. Therefore we suggest a lightweight »SWE connector« web service application working as a frontend for feeder web services, providing a generic toolbox which can be adapted to import different raw data and exchange formats and transform them to a SWE-based data model. Taking system performance and limited communication resources into account, data transfer between services should not necessarily use O&M but rather a structured lightweight intermediary format such as JSON. Customised import plug-ins could be designed for a wide range of different data formats.

Current work within the SLEWS project is concentrating on the evaluation of different specialised as well as generic approaches. Different architectures and application implementations will focus on interfacing WSN and SWE services effectively. In the context of a time-aware alarm and monitoring system the principle usefulness of SWE technologies have to be determined. Furthermore, implementation of landslide event-based data analysis and decision management processes will be tested using a system architecture based on the coupling of SWE services with further OGC web service-based visualisation and notification technologies.

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