Integration of APRS Network with SDI

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Abstract. From the point of view of large information systems designers the most important thing is a certain abstraction enabling integration of heterogeneous solutions. Abstraction is associated with the standardization of protocols and interfaces of appropriate services. Behind this façade any device or sensor system may be hidden, even humans recording their measurements. This study presents selected topics and details related to two families of standards developed by OGC: OpenLS and SWE. It also discusses the technical details of a solution built to intercept radio messages broadcast in the APRS network with telemetric information and weather conditions as payload. The basic assumptions and objectives of a prototype system that integrates elements of the APRS network and SWE are given.

Keywords: SWE, OpenLS, APRS, SDI, web services

1. Introduction

Modern measuring devices are no longer seen as tools for qualitative and quantitative measurements only. They have become parts of highly specialized solutions, used for data acquisition and post-processing, offering hardware and software interfaces for communication. In the construction of these solutions the latest technologies from various fields are employed, including optics, precision mechanics, satellite and information technologies. Thanks to the Internet and mobile technologies, several architectural and communication barriers caused by the wiring and placement of the sensors have been broken. Only recently the LBS (*Location-Based Services*) entered the field of IT. These are information services, available from mobile devices via mobile networks, giving possibility of utilization of a mobile

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device location (Virrantaus et al., 2001), or are deployed at sites that use the position of mobile devices for their offers (OGC, 2008). LBS can be placed at the intersection of three areas: ICT (*information and communication technology*), Internet and geoinformatics. Underlying standards allow, among others, to solve some issues related to the implementation of some business processes, including authorization, authentication, reporting and billing.

Accessing sensors through web services, their control and data acquisition attracted attention of the OGC (*Open Geospatial Consortium*). The open standards developed in the scope of the OGC SWE (*Sensor Web Enablement*) framework paved the way to the integration of different sensory systems in a platform-independent and service-oriented architecture. They are recognized as common tools used in the SDI (*Spatial Data Infrastructure*) implementation, where geospatial information plays a key role.

In addition to LBS and SWE, an excellent source of information about the current state of the environment is the amateur radio network (Dabrowski K, 1994). In the 70-ies of the last century, the amprnet (*Amateur Packet Radio Network*) was created, for which IPv4 subnet 44.0.0.0/8 was reserved. The APRS (*Automatic Packet Reporting System*) is a branch of this network. Its primary use is to provide telemetry information about objects on the network (including location), or to distribute information from various sensors (eg. weather stations). Thus, the network is particularly useful in emergency situations (Lehman JJ, 2003). Based on the APRS the APRS IS (*APRS Internet System*) was created. It is a Internet-based network, connecting APRS radio networks around the world. It allows to store broadcast data for later processing and retransmission. Currently, the APRS IS consists of several *Tier* servers, which can communicate with individual customers, and *Tier2* servers, on ports of which arbitrary data filtering can be done. A special role in the APRS network is played by the IGates (*Internet Gates*) – the gateways enabling transmission of data received on the air locally to the servers managing the data and allowing their distribution to other stations.

In this paper the principles and selected details of two families of the OpenLS and SWE OGC standards are described. Their potentials are reviewed and the assumptions are stated of an implementation of a prototype system for environmental-related data acquisition from various sources. The technical details connected with the interception of radio messages from the APRS network and passing them on are discussed. Finally, the integration of the APRS network (with weather stations linked in) with the SDI trough the SWE service implementation is proposed and elements of a prototype are presented.

2. Technology

2.1. SWE

The core of the SWE version 1.0 specification includes: the O&M (*Observations & Measurements Schema*), the SensorML (*Sensor Model Language*), the TML or TransducerML (*Transducer Markup Language*), the SOS (*Sensor Observations Service*), the SPS (*Sensor Planning Service*), the SAS (*Sensor Alert Service*), and the WNS (*Web Notification Services*). The SWE specifications are updated and harmonized with other OGC standards for geospatial processing. The last upgrade to version 2.0 caused a withdrawal of the TML specification and publishing of some new documents: the SWE Common Data Model Encoding Standard, and the SWE Service Model Implementation Standard.

The SWE standards provide rules that enable an implementation of network services independently from the supported platforms and the managed sensors systems. In particular, the SOS specification (OGC, 2012) defines a protocol and an interface of a service that allow exchanging data between users and sensor systems running in a synchronous or asynchronous mode, loosely or tightly coupled with the server. Using this protocol it is possible to publish and request sensor readings using the HTTP protocol. The specification (OGC, 2006) defines four profiles of an SOS service: core, transactional, and entire. All operations defined in the basic profile are mandatory. Each SOS service must support them. Operations defined in the other profiles are optional.

2.2. LBS

Communication in the LBS is bi-directional: the user provides information about his/her location and interests (i.e. context), and the service responds with information tailored to the needs (the result). To enable easy implementation and integration of different location-based services, the OGC developed the OpenLS (*Open Location Services*) specification (OGC, 2008). This specification is closely related to other commonly used standards and provides the definitions of five basic services (*OpenLS Core Services*) along with the descriptions of their interfaces, and the ADT (*Abstract Data Type*) and information models used (*OpenLS Information Model*). The basic services include:

- *Directory Service*,
- *Gateway Service*,
- *Location Utility Service* (*Geocoder*/*Reverse Geocoder*),

- *Presentation Service* - for geographical information rendering on layered maps according to the ADT used,
- *Route Service* – for defining/retrieving route information that meets defined criteria (an enriched version of this service is the *Navigation Service*, supporting additional navigation parameters required for route rendering, cost evaluation etc.).

All these services are usually offered by the GeoMobility Server – an application that interacts with clients in an automatic manner. In the common scheme a client sends a query via a wireless network (Figure 1). The query is captured by the Service Platform and, after running some obligatory steps (authentication, payment, etc.), it is passed to the GeoMobility Server as a proper OpenLS request. The server determines the location of the client device via a gateway, using the GMLC/MPC (and a network of broadcasting stations). Optionally, the client's device itself provides information about its location using the built-in GPS. When the location data reach the GeoMobility Server they are processed and the expected response is prepared. This response is transferred through the Service Platform and the wireless network back to the customer.

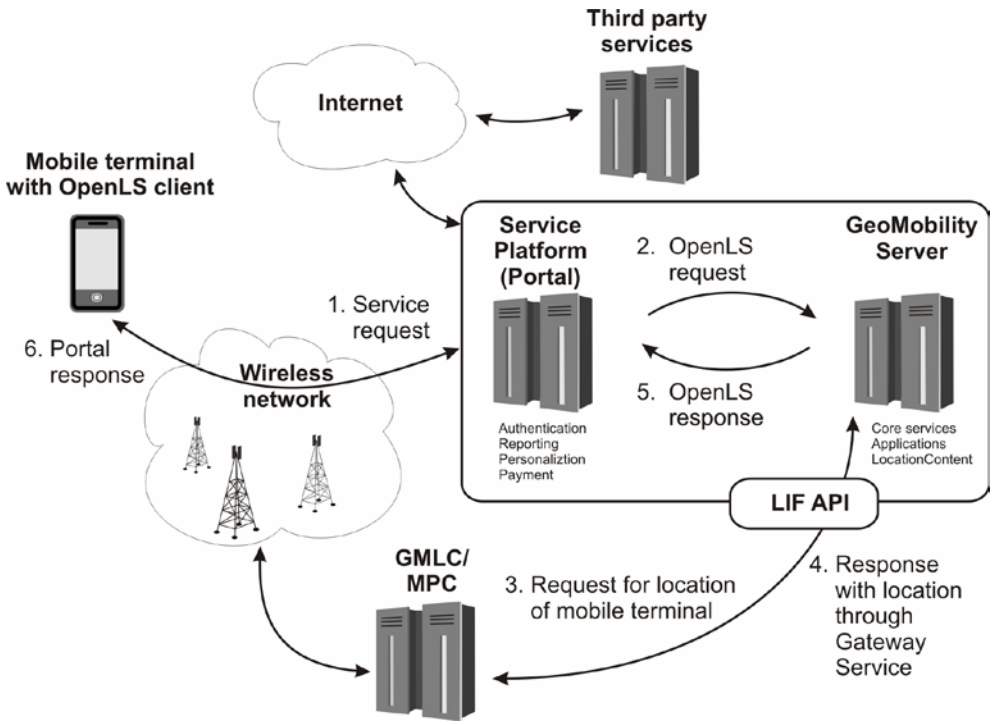

Figure 1. Common scheme of handling of client requests by the GeoMobility Server (OGC, 2008).

2.3. APRS

The APRS is based on the idea of a Packet Radio Network. However, in APRS the *one-to-one* communication scheme was abandoned in favor of *one-to-many* in order to improve the propagation of messages to multiple stations simultaneously. This also significantly simplified the issues related to the topology of the network and addressing. The broadcast messages – including both location and telemetry data (Bragg, 2011), and metadata with additional description – are available to all network users. Thanks to that, each user can keep track of the current tactical situation in the network. This is especially useful in emergency situations. The APRS has gained great popularity and now covers the whole of Europe and North America, and parts of Asia. Network coverage is limited mainly due to the use of the VHF band. The normal communication range is tens of kilometers. Using digital repeater sites located at higher elevations this can be extended up to around 200 km. The APRS can also use the shortwave band, for which the communication range may vary from of a few hundred to a few thousand kilometers. Unfortunately, because of the interference, transmission speed is limited up to 300 baud. Therefore, the use of the APRS in the shortwave band is limited only to the position reporting.

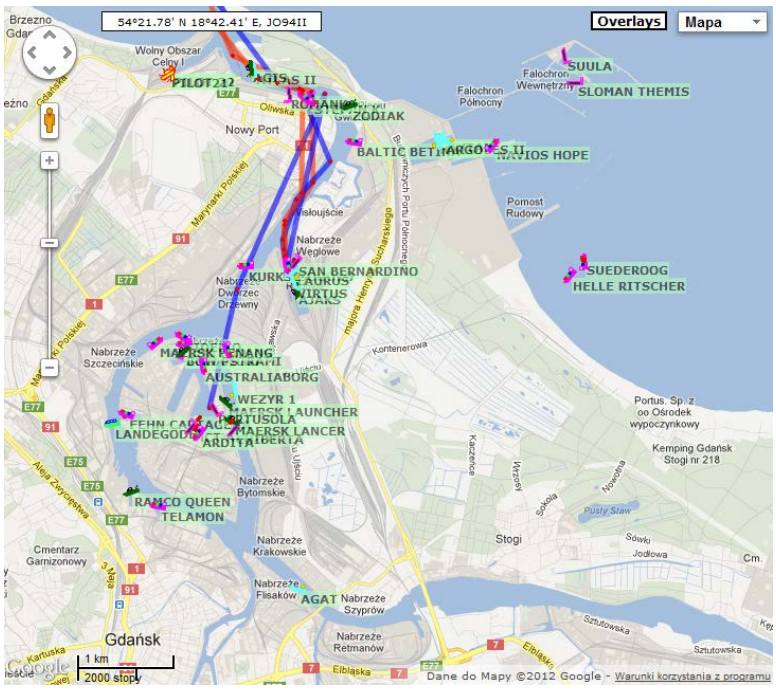

Figure 2. APRS activity for the area of the Gulf of Gdansk and Gdansk city (active map grabbed from aprs.fi service).

In the recent years the possibility of using the satellite technology gained popularity (S Ford, 2006). Amateur radio stations have now the ability to use the amateur satellite communications in the scope of the projects carried out by universities and space agencies. Launching the ISS (*International Space Station*) opened up possibilities of communication via an APRS digital repeater installed on its board. ISS has been assigned the unique identifier of RS0ISS-4 and the frequency 145.825MHz.

The data exchanged in the APRS might be exposed to the Internet through IGates. Thanks to them it is possible to observe the current traffic on computer screens. For example, to see the traffic on the server poland.aprs2.net:14579 one can open a web page under the following link: http://www.aprs.pl/live.htm. There also exist a few websites with search capabilities for individual stations, such as aprs.fi or jFindU. They offer other functions, like creation of charts, tables, maps, packet collections etc. Figure 2 shows an example of web service output that renders a map with various sensor readings broadcast in the APRS network.

3. System proposal

3.1. Assumptions

Looking at different solutions, a combination of LBS, SWE and APRS based applications appears particularly interesting. This alliance opens broad range of possibilities of data with spatial references integration (reflecting the characteristics of a phenomenon, acquired from the distributed sensor systems or created with the participation of users) and services integration (tailored to the user needs, offered by commercial companies, social organizations and other service providers). In order to check the range of features rising from the LBS (more precisely: OpenLS), SWE (specifically SOS) and APRS integration, a construction of a prototype system has been planned with the following assumptions:

- the system will use the SOS service as an interface for data retrieving;
- the system will be fed with data from weather stations broadcast in the APRS network (the data will be captured by the radio receiver and inserted into a database attached to the SOS with the use of dedicated software designed for that purpose);
- the system will allow data insertion through transactions with mobile devices equipped with sensors (by sending measurements by dedicated software) or assisted by users (who manually enter their observations with the aid of dedicated software);

- the system will offer an OpenLS compliant service;
- the prototype operation will involve the use of weather information for specific purpose (eg. planning trips) and the use of mapping components.

3.2. Available tools

Thanks to the SOS standard openness several implementations of servers and clients compliant were developed and published. An example is the open-source OX-Framework (OWS Access Framework) designed by 52°North (52North, 2012). It includes a ready-made implementation of the SOS. Distributed stable binaries are version 3.2.0, but developer version is already at 3.5.0. Version 3.5.0 is compatible with the SOS 1.0.0 specification, and has:

- all compulsory operations of the basic profile: *GetCapabilities*, *GetObservation* (O&M encoding), *DescribeSensor* (SensorML encoding),
- the following transactional operations: *RegisterSensor*, *InsertObservation* and
- additional operations: *GetFeatureOfInterest* - to obtain a GML encoded representation of features/objects, *GetResult* - to pool periodically sensors data.

This version also supports selected operations from the SOS 2.0 specification: all compulsory core profile operations: *GetCapabilities*, *GetObservation* (O&M 2.0 encoding), *DescribeSensor* (SensorML encoding) and optional *GetFeatureOfInterest*. Service performance can be tested using a generic client, available at: http://v-swe.uni-muenster.de:8080/WeatherSOS (accessed on 09.16.2012).

The architecture of this solution is shown in Figure 3. There are three distinguishable layers in it: network, business logic and data layer. The servlet in the network layer is responsible for handling the HTTP based communication. It transfers received requests to the business logic layer. The central part of the business logic layer is the RequestOperator. Each request delivered to the RequestOperator is validated and, if successful, is forwarded to the OperationListener. Each operation is handled by an appropriate listener. All listeners share the same common interface. The configuration of the system is done through files. The procedure for service setup consists of three steps: i) implementation of the OperationListener, ii) implementation of the DAO (*Data access object*) for access to the data layer, iii) registration of the listeners configuration file. The SOS 52°North by default uses a Post-

GIS database for data storage. In this database several tables have to be created (18 tables in total) assisted with relevant data types.

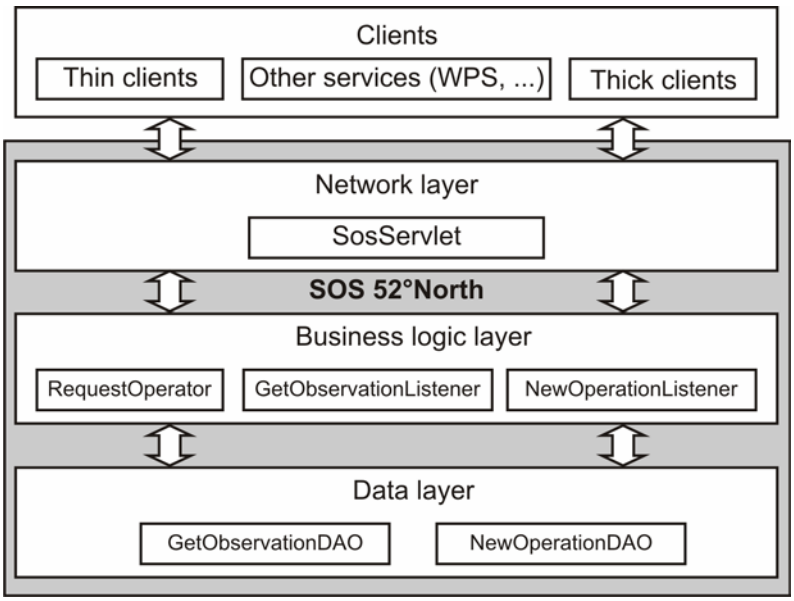

Figure 3. Architecture of SOS 52°North (Künster et al., 2012)

3.3. Solution proposed

To gain the most from the APRS network, an autonomous, universal telemetry stations were planned to be build. This decision was motivated by the experiences from the flood in May 2010 in Poland, during which the need to monitor areas at risk of flooding and already flooded emerged. The hams (licensed operators of amateur radio stations) associated in the *Lower Silesia Amateur Emergency Network* actively collaborated, among others, with the Lower Silesian Center for Crisis Management. They monitored the status of rivers, verified information about floods given in the media, or provided additional communication channels in cases where the most common communication channels failed. It was observed that the use of automated telemetry stations, such as water level monitoring devices, reporting difference in levels before and after the bridge, would greatly facilitate the tasks posed in front of radio amateurs. This is especially important at night and in low-urbanized areas with no roads or foot paths. Thus for the construction of device mentioned the following assumptions were made:

- Modularity - the individual components of the system should be structured in a way allowing their use in various projects, communication between modules should be based on generally accepted standards;
- Availability - the system should be built from readily available components, including microcontrollers that do not require complex programming systems;
- Openness – the solution should be vendor free, thus no specific manufacturers or models of equipment were suggested, the development of software parts should follow the idea of open-source.

In addition, the device of the system should assure capturing weather data from the APRS IS network and making them available on the Web via the SOS. The idea was to create a software bridging between the APRS network and the SOS service, which would allow to share information on current meteorological conditions based on readings of APRS weather stations.

As already mentioned, IGate stations transmit APRS frames from the radio network into Internet. These frames are propagated between the APRS IS servers and can be captured by client software that supports the APRS IS specific protocol. The transmission of frames from the network to the APRS IS radio network is also possible. However, for practical reasons (high traffic generated in the radio network) this case is used very uncommon. Figure 4 shows the scheme of the APRS network communication.

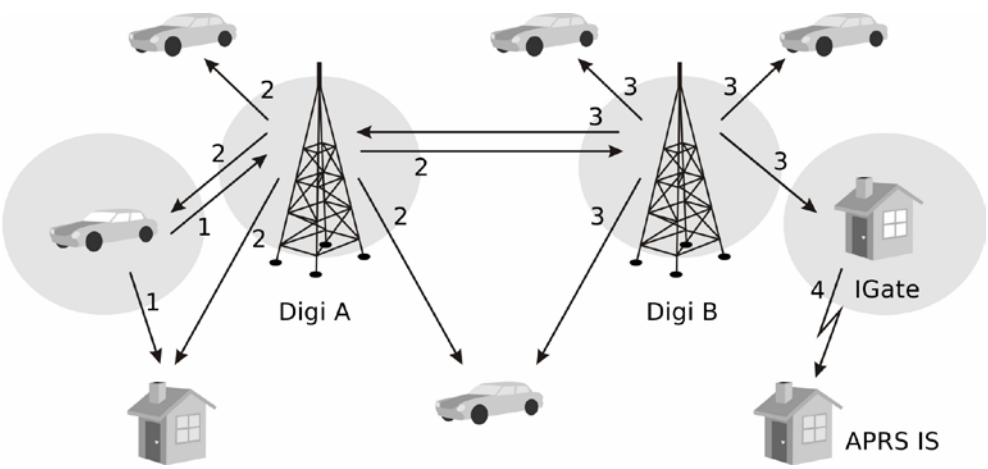

Figure 4. The scheme of APRS communication.

4. Prototype Serving Data from Weather Station

4.1. TNC

To make use of the APRS network some devices are needed. One is a TNC (Terminal Node Controller). This device is attached to the transceiver, usually combining a modem and a tracker (that uses GPS for current position acquisition and reporting). Sometimes is attached to the digital repeaters or telemetry stations (including weather stations). The KISS-modem (KISS-TNC) is a specific type of a TNC device. It acts as a modem (with modulation/demodulation of audio signals), controls data integrity (validates frame format and calculates checksums), and then outputs correct frames through the serial port. The name KISS-modem refers to Keep *It Simple Stupid*, and at the same time is a protocol definition that is used in the transmission of APRS frames via a serial link.

At the current stage prototypes of two components have been built – a modem and an APRS protocol analyzer. Both devices are based on ATmega microcontroller family. The software for the microcontrollers is written in the language C and compiled with the avr-gcc compiler .

4.2. KISS-modem

Due to the unavailability of specialized integrated circuits used in the design of modems and TNC devices working in the APRS network, it was necessary to develop an alternative solution. The common approachis to use a DSP (digital signal processor) and a microcontroller. Thus the KISS-TNC modem was build based on the ATmega328 microcontroller according to the proposal of Robert Marshall KI4MCW. This microcontroller serves many applications, including the Arduino runtime environment (see https://sites.google.com/site/ki4mcw/Home/arduino-tnc). The demodulation of an audio signal was carried out using the microcontroller's A/D converter. The modulation was done by applying a simple, four-bits D/A converter. For digital communication the serial port of the microcontroller was used.

The modem created is a stand-alone unit that can be connected to a PC via communication interface (a serial TTL port adjusted to the requirements of RS-232C standard or USB converter). It was built with the use of existing software allowing fast implementation of the functionality of an APRS network node (digital repeater, telemetry station, tracker). The prototype was assembled on an expansion board attached to the base Arduino board.

4.3. APRS protocol analyzer

The weather stations of the APRS network send information using the AX.25 protocol (WA Beech et al., 1998). The description of the data encod-

ing can be found at http://www.aprs.pl/wxparam.htm. This encoding involve frames with fixed positions defined for data values. The parameters in the weather data frame are integers, whereby substituting missing numbers with zeros is acceptable (for example, the pressure is stored in five digits and represents tenths of a millibar (hPa/10).

To verify the content of the APRS protocol frames while testing the KISS modem functions, an analyzer was designed. It was assumed that an ATmega 1280 or 2560 microcontroller will be used for the purpose (resources offered by these devices assure an execution of the tests planned). In addition, an Arduino Mega development kit (available with the ATmega 1280 microcontroller) has been utilized.

4.4. Integration with SOS

In the scope of the research described a client of APRS IS services was implemented. It receives an unfiltered stream of APRS frames and extracts these frames, that include weather data. The frames are decoded, and then the parameters provided by a weather station are extracted, such as: the name (call sign and SSID), the last reported position, a timestamp of the last frame (if the frame rate does not include the time it gives a local time frame reception), meteorological parameters (temperature, humidity, wind speed and direction, rainfall information). In case of data mismatch (when an identified station instead of weather data transmits other data, e.g. station metadata or additional comments) this information is also collected. Data already collected can be removed from a screen and saved in a chosen file on an ongoing basis. In the next development step this program will be integrated with the described implementation of SOS services.

5. Summary

This paper describes the standards and solutions used in wireless communication (in a mobile network and amateur radio network). It discuss to idea of integration of SWE, LBS and APRS through Web service implementation. The experiments and prototype implementation was done for a system offering sensor reading and localization data (from the APRS network or mobile devices) through a SOS interface. In a running example, weather station measurements were served and processed. The results received proved that assumptions highlighted are implementable and the devices designed can be used in many practical use cases.

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