Sensor Web Technology Application for Environmental Monitoring

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***Abstract* – Pollution of the environment is a problem of the modern age. The technology developed and used over the past decades has left serious consequences on human environment and implied the need for resolving them. Preserving quality of water, air and soil are quite common issues in many countries. This paper presents one way of dealing with these challenges, based on sensor networks and the Sensor Web concept. The solution is given as GinisSense system. GinisSense is designed accordingly to Open Geospatial Consortium specifications and recommendations for the field of Sensor Web. This paper explains GinisSense architecture and presents its opportunities for environmental monitoring, preservation and protection.**

***Keywords* – sensor web, environmental protection, environmental monitoring**

1. Introduction

Environmental concern is present nowadays all over the world. Modern way of living has left some serious consequences on human environment. While the technology developed in latter half of the previous and the beginning of this century has brought many facilities to human society, the same technology now threatens to destroy basic environmental resources necessary for living. Fumes, waste water, air pollution are just some of many problems the society's dealing with today. We are now in position to use that same technology for preventing further contamination and we can also apply it to many more threats present nowadays.

Sensor technology has significantly improved over the past few years. Sensors are smaller, lighter, more reliable and portable. They are capable of monitoring and measuring certain features of observed phenomena and can be placed anywhere. Sensor networks, as networks of connected sensor nodes, can be used in various application areas.

Environmental monitoring and protection is an area where these networks are of huge importance. Data collected by sensors are sent through the network to the control centers where are than being processed and analyzed. The results can indicate if there is some critical situation in the field allowing operators to react in time and prevent or mitigate the catastrophic consequences.

Simple data gathering and sending through the network, however, are not precise enough. In order to perform more detailed and comprehensive analyzes, the process of data gathering should be based on some intelligent rules and pursued by intelligent hardware components. The Sensor Web concept precisely presents an intelligent sensor network, comprised of sensor pods which can have built-in intelligent modules enabling them to make decisions while measuring.

CG&GIS Laboratory at the Faculty of Electronic engineering in Nis is working on researches in the area of Sensor Web for several years now. As a result, we have developed GinisSense, the architecture for monitoring real-time environmental data, and for reacting when possible danger is noticed. The architecture can be applied to various environmental problems and can work with distributed, heterogeneous data sources. It is designed accordingly to Open Geospatial Consortium (OGC) specifications and recommendations and it is based on Sensor Web concept. In this paper we will explain the GinisSense architecture and show its application for monitoring river water quality and for preventing fires in forested areas.

2. Sensing the environment

Dealing with environmental monitoring issues requires constant attention and collaboration of monitoring system components. Sensor networks are perfect candidates for addressing this problem.

Sensor network is a network of connected sensor devices scattered over sensing area. Each sensor node within the network is equipped with adequate instruments for observing and measuring required features of a certain phenomenon. Each node must have a communication device, a microcontroller and an energy source, usually a battery. Sensors can communicate with each other over a communication device in order to forward data packets to the gateway. This is usually done accordingly to a multi-hop routing algorithm.

Sensing areas are usually very large and sensors must be quite distant from each other. Monitoring systems, which are responsible for gathering and processing of the collected data, don't necessarily have to be near the critical areas. Therefore, the communication between sensors and between sensor network and the main system must be performed wirelessly. This further requires additional equipment for sensors: network modules that will enable sensors to send their readings over some wireless network.

For the purposes of monitoring river water, for example, adequate sensors have to be used. The sensors will be placed in the water and will be exposed to all weather conditions. They have to be resilient enough in order to survive the worst weather and still function properly. Sensor technology nowadays has significantly improved and sensors are smaller, cheaper, energy-efficient and more reliable. Sensors can also have additional modules, such as GPS and GPRS modules that enable transmitting information about sensor's geo location and sensor data over GPRS network. In situations where data loggers are used for real time data collection, there must be a way for immediate data processing and alerting.

Sensor Web is a concept which describes a type of sensor network especially well suited for environmental monitoring. It has been defined as a system of wireless, intra-communicating, spatially distributed sensor pods that can be easily deployed to monitor and explore new environments [1].

The main characteristic of a Sensor Web is that all data collected by one sensor can be shared and used by all other sensors in the network. Sensors communicate and with each other, meaning that if one sensor fails to function, others will notice the event and increase their activity in order to collect enough data. In case of mobile sensors, they can communicate in order to position themselves at correct locations for the purposes of certain measurements. The Sensor Web is thus an intelligent sensor network of collaborating sensor nodes capable of self-maintenance to some level. Another important characteristic of a Sensor web is availability of sensors' measurements through the Web. This enables the development of Web systems for accessing and online processing of real-time sensor data.

The Open Geospatial Consortium (OGC), as a leading organization in the field of developing new standards for geo-spatial and location services, has developed a set of standards and specifications named Sensor Web Enablement (SWE) [2]. SWE represents a recommendation for implementing a Sensor web system and is comprised of four Web Services specifications: Sensor Observation Service (SOS), Sensor Planning Service (SPS), Sensor Alert Service (SAS) and Web Notification Service (WNS), and three modelling languages specifications: Sensor Markup Language (SensorML), Transducer Markup Language (TML) and Observations and Measurements (O&M). Web services are responsible for communicating with sensors, collecting their measurements and polling them when necessary. Modelling languages are used for modelling observations and measurements as well as for describing sensors.

3. GinisSense architecture

GinisSense is a Sensor Web architecture based on OGC SWE specifications [2]. GinisSense enables creation of systems for monitoring, acquisition, control, on-demand measurements and analysis of data received from heterogeneous data sources.

The GinisSense SWE architecture has the following components (as illustrated in Figure 1.): Data producers (sensors), Data access component (Web services), Knowledge based component (DMA) and Graphical user interface (Web GIS). Components of the architecture communicate using various protocols and media. The most common communication means are the Internet, satellite, mobile-phone or radio networks.

Data producers are heterogeneous data sources capable of harvesting or measuring physical phenomena. Data sources are typically sensors or sensor networks, set in critical areas, with ability to measure different phenomena and deliver data to other systems for the purposes of further data processing. GinisSense architecture supports also applications or databases as a data sources.

Data access component is in charge of collecting and processing sensed data. This primarily includes real time sensor data, spatial data necessary to display sensor position and objects of interest on the map, as well as data collected by users who contribute with gathered information regarding objects of interest. For each data type, there is a separate database used for data storing.

Data access component comprises of seven different Web services designed accordingly to OGC specifications. The following Web services: SPS, SOS, SAS and WNS are used for accessing sensor data. They are responsible for planning, acquisition, analysis, user subscription and user notification about sensor observations. Web Map Service (WMS) and Web Feature Service (WFS) are used for accessing geographic data. There is also possibility for connection to external Web services, such as community service. This is an external service for gathering and retrieving data from environmental friendly users.

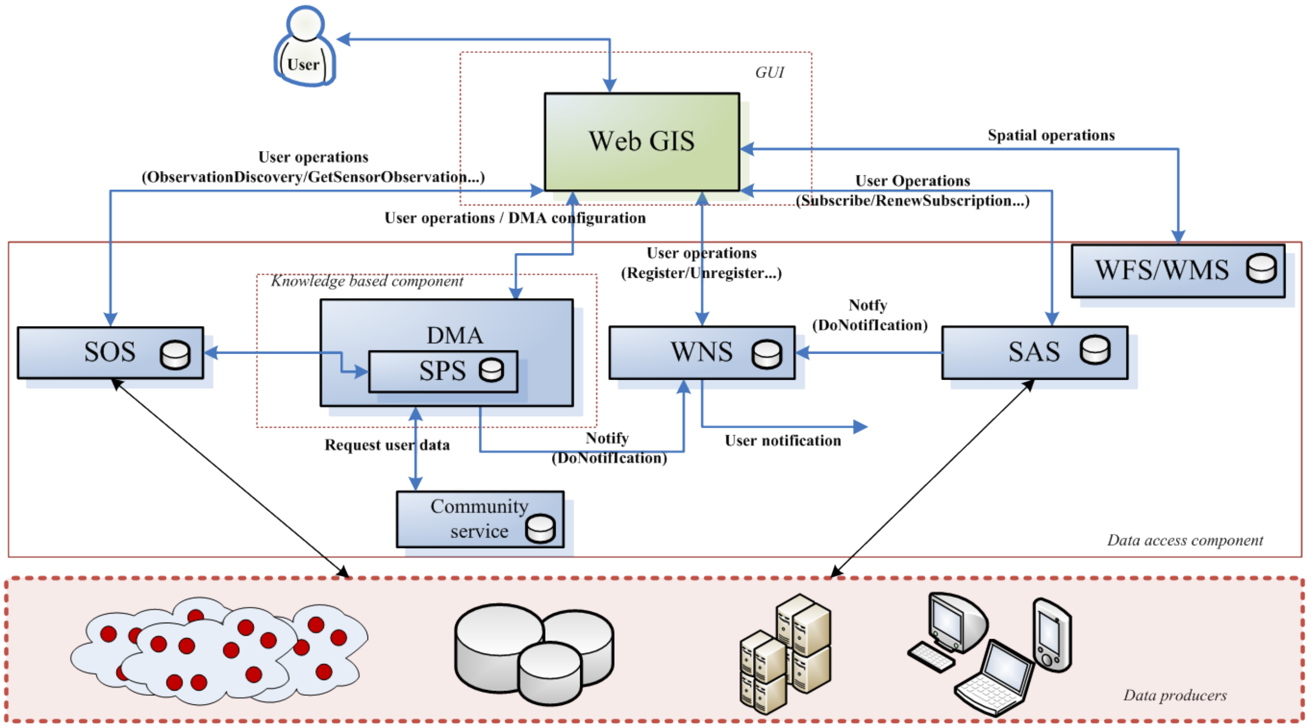

Figure 1. GinisSense architecture

Knowledge based component is a service used for comparing and analyzing data obtained from different sources, making action plans, running on demand or automated actions and proposing action plans to system operators. Decision Making Agent (DMA) is an intelligent module responsible for generating conclusions based on prepared rules and collected data. This module is used for the calculation of risks or for the prediction of events for the monitoring area.

Graphical User Interface (GUI) is a Web GIS application [3]. Spatial location, from which the sensor information is obtained, is very important in the analysis, which is why GIS is used as default. Besides the basic GIS functionality, the Web GIS application provides users with support for accessing Web services layer.

4. GinisSense architecture application

GinisSense architecture can be applied for different environmental issues. Here we will present two possibilities of GinisSense architecture application. One for monitoring river water quality [4] and the other for the prevention of forest fires [5].

River Water Quality Monitoring

River water pollution appears as a quite common problem, mostly due to human and industrial negligence. GinisSense system for water quality management has been developed with aim to help with preventing river pollution. This is done by measuring river water quality and notifying when a potential problem occurs.

GinisSense water quality monitoring system is depicted in Figure 2.a. It is composed of the following components: Sensor stations, GinisSense server and GinisSense client. Sensor stations have different types of sensors for measuring water quality. Water quality can be measured by several groups of parameters [6]: biological, hydro-morphological, physico-chemical, specific synthetic pollutants and specific non-synthetic pollutants. Each of these groups consists of many specific parameters which are further divided into subgroups. Thus, water quality can be described by more than 100 parameters. Building a monitoring system that will observe and measure all parameters would be too expensive. For most purposes, water quality can be adequately described with less than 20 characteristics.

In the GinisSense system for the water quality monitoring, we have chosen the basic set of parameters for calculation of water quality: temperature, electrical conductivity, pH, dissolved oxygen and total suspended solids [7]. Each parameter is measured by a specialized sensor, and all sensors are grouped within one sensor station. Multiple sensor stations can be placed along the river bed.

They have a collector unit, which gathers all measurements and sends them to the GinisSense server over a wireless network.

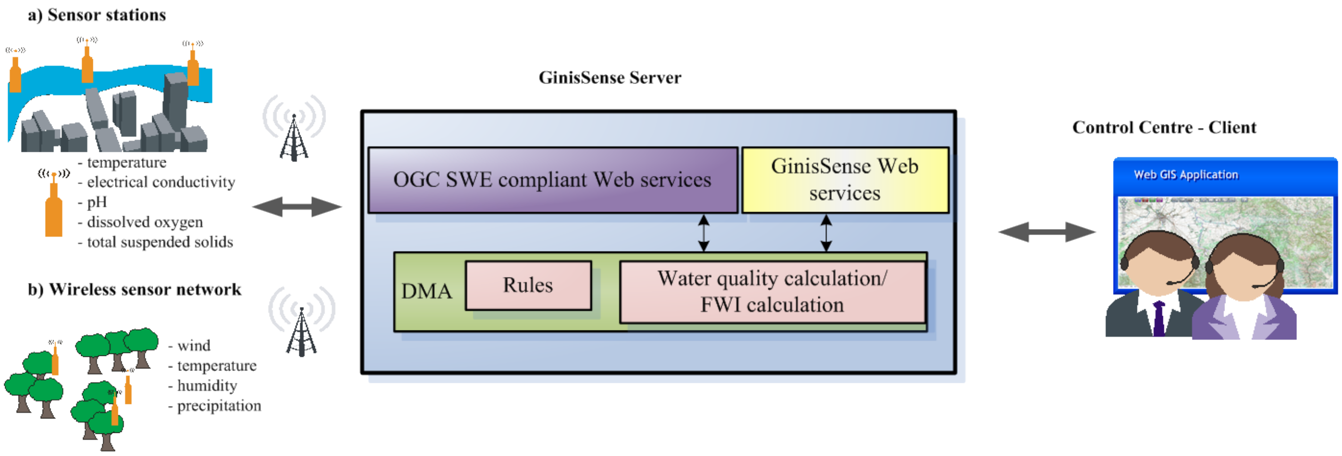

Figure 2. GinisSense monitoring system

GinisSense server component hosts Web services that are responsible for communicating with sensor stations and end users. They poll sensors and overtake their measurements, store them in databases, perform analyses over received data and generate responses to users' requests. Server component also hosts a Decision Making Agent (DMA), which is an intelligent module responsible for generating conclusions based on prepared rules and collected data.

Data consumers (whether users or applications) subscribe themselves, in order to receive observation data. During the subscription, they provide filters according to which sensor data will be queried. Filters can be sensor identification, location or measuring phenomenon value e.g., Temperature > 30°C. The SAS service performs filtering of sensor data. Whenever matches are discovered, a notification is sent to subscribers via WNS service. Besides the notification based on the subscription, GinisSense system performs a regular notification of system operators in case when the critical value of measured parameters is reached.

GinisSense client component (Figure 3) is a Web GIS application that provides user interface towards the monitored area and sensing devices. Client application highlights critical areas on the map, based on the calculated water quality and in this way allows system operators to react quickly. Operators can retrieve more measurements from sensors placed in the highlighted area along the river bed and see whether there is a current increase in the measured values, or is it the case of constant pollution.

Forest Fire Monitoring

GinisSense system for the prevention and prediction of fire in the forested areas is comprised of three major components: wireless sensor network, server component and control centre units (Figure 2.b). Wireless sensor network is a network of connected sensing devices, scattered over monitored, forested area. There are two types of sensors in the system: meteorological sensors and video cameras.

Meteorological sensors are set within sensing stations and are responsible for collecting meteorological data, such as temperature, wind, precipitation and humidity. Meteorological data values are necessary for calculating fire weather index (FWI). Video cameras are distributed over the forested area and are used for real-time monitoring and capturing events that could not be predicted based on FWI values. Sensing devices are equipped with additional modules that enable them to observe and measure features of surrounding phenomena and send measured values to the server component over the network.

The Canadian Fire Weather Index (FWI) is a numerical indicator that represents current state of a forested area and the potential of fire in that area. It is a complex component, comprised of six subcomponents, which determine the effects of fuel moisture and winds on forest fires behaviour, based on observations of weather conditions and parameters. FWI gives a potential risk of forest fire ignition in an area, expressed as an integer number in range 0-100.

GinisSense server hosts web services responsible for receiving sensor measurements, processing them and extract valuable information by combining given values and user defined criteria. System databases, beside sensed data, preserve information about access road network of forested areas, which is of great importance for calculating the fastest and shortest paths to burning area. They also store and preserve previous weather stations' measurements, as well as information regarding characteristics of terrains of forested areas.

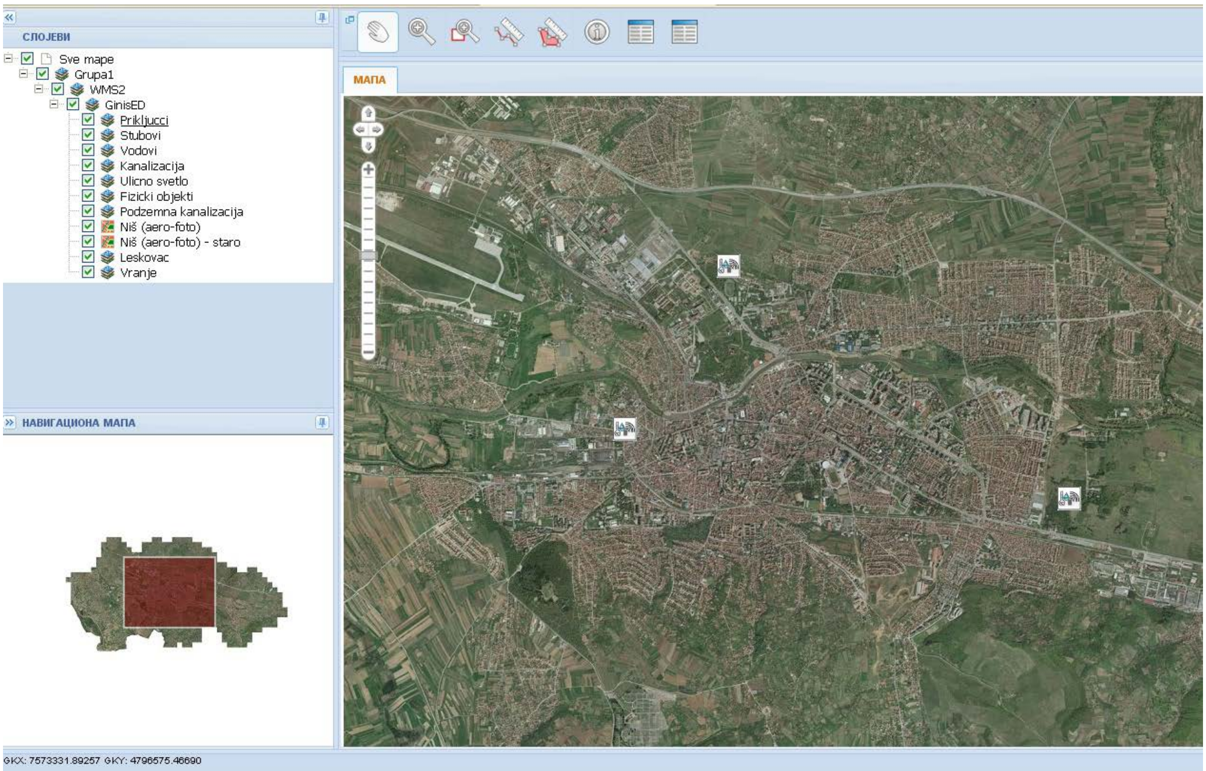

Figure 3. GinisSense client component

DMA uses collected meteorological data and terrain information in order to produce meaningful conclusions about the risk of forest fire in a certain area. Terrain data contains information about forest fuels and land topography, both extremely important for determining the forest fire risk. Combining data stored in databases with actual measurements, DMA can generate accurate conclusions regarding the forest fire risk. If FWI value increases over 20, an alarm will be triggered informing operator about the possible danger. If FWI value is over 60, an alarm will also inform fire fighter units about increased danger of forest fires.

Control Centre units are responsible for monitoring of forested areas and reacting in case of fire. Each centre is equipped with WebGIS client application, through which an entire forested area can be monitored. When a fire is detected, Control Centre operator informs fire fighters about precise location of burning area. Fire fighters road units use PDA devices to receive information about shortest and fastest path to critical area and calculations about fire spread, performed based on fire spread model. Fire fighters airborne units go directly to the locations and begin fire extinguishing operations.

Other applications of GinisSense architecture

Besides for monitoring river water quality and forest fires, GinisSense architecture can be applied in many other areas of environmental protection. Since GinisSense architecture is general it supports different types of sensing devices as heterogeneous data sources. This allows us to create different specialized systems based on this architecture. For example, if we place sensors for measuring level of carbon dioxide in the selected locations in the town, and connect them with the GinisSense server, then we can inform operators in the control centre as well as subscribed users about the most polluted town areas. In this way we can have a GinisSense system for monitoring pollution. If we connect multiple GinisSense systems into one centralized system we can then talk about a system for crisis management that will combine data from different sensing systems, create valuable conclusions and react in the case of crisis [8]. In this way we can raise awareness about preserving and protecting the environment, but also help community to lower the losses that happen very often in the critical situations.

5. Conclusion

The environmental protection is a noticeable problem and a challenge nowadays, requiring our full attention and effort. The technology today provides possibility of developing efficient monitoring systems that can be installed anywhere and used for all types of environmental issues. GinisSense, as a Sensor Web based architecture, enables creation of various monitoring systems. In this paper we have shown only two of many possible applications of GinisSense architecture for environmental monitoring. Still this is not the only domain of application. Being built on the OGC Sensor Web recomendations, GinisSense architecture has a certain generality and is applicable in various domains.

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