EnviroGRIDS sensor data use and integration guideline

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Abstract

The document describes current state-of-the-art in sensor technologies, Wireless Sensor Network and Web Sensor. It also analyses different solutions to integrate sensor measurements into Grid-enabled Spatial Data Infrastructures (GSDI).

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Abbreviations and Acronyms

CCSS	Czech Centre for Science and Society
FHSS	Frequency Hopping Spread Spectrum technology
GENESIS	FP7 IP project in area of ICT for Environment
GEOSS	Global Earth Observation System of Systems
GMES	Global Monitoring for Environment and Security
GSDI	Grid enabled Spatial Data Infrastructure
INSPIRE	Infrastructure for Spatial Information in the European Community
NASA	National Aeronautics and Space Administration
NCAP	Network Capable Application Processor
O&M	Observations & Measurements
OGC	Open Geospatial Consortium
OSIRIS	FP7 CT project with focus on Sensor Development
RFID	Radio-frequency identification
SANY	SANY Sensor Anywhere, 6.FP project
SAS	Sensor Alert Service
SDE	ESRI extension for Oracle and MS SQL for Spatial Data
SDI	Spatial Data Infrastructure
SML	Sensor Model Language
SOAP	Simple Object Access Protocol
SOS	Sensor Observations Service
SPS	Sensor Planning Service
STIM	Smart Transducer Interface Module
SWE	Sensor Web Enablement
TLC	Telecommunication
TML	Transducer Model Language
URM	Uniform Resource Management
VLIT	Very Long range Identification Tag
WCS	Web Coverage Service
WFS	Web Feature Service
WINSOC	7th FP project, Contract number 33914
WNS	Web Notification Services
WSN	Wireless Sensor Network
XML	Extensible Markup Language

1 Executive summary

The objective of this deliverable is to analyse the state-of-the-art in sensor technologies, Wireless Sensor Network and Web Sensor. It also analyses different solutions on how to integrate sensor measurements into Grid-enabled Spatial Data Infrastructures (GSDI).

The first chapter analyses the role of the sensors in the international observation systems such as GEOSS, GMES and INSPIRE. GEOSS objective is the development and implementation of the future Earth observing systems, including satellite, airborne, and in-situ observations. GMES defines in situ observations as one of the pillars of its infrastructure (one of the two groups of Core services). In situ observation is therefore an essential part of GMES and GEOSS. However, in comparison with the remote sensing, in situ observations are not well integrated. For example in INSPIRE, in situ monitoring is not included. Although several FP6 and FP7 projects are dealing with in situ monitoring (e.g. SANY, Osiris, Winsoc, Genesis), one example of the integration of in situ monitoring with SDI is the Uniform Resource Management GeoPortal (URM), which is based on INSPIRE, GMES and GEOSS principles. The URM concept divides in situ observations into three relatively independent blocks: Sensor technologies including networks of wireless sensors, sensor measurement integration, and Sensor Web. The problem of current research in the field is that most projects target these three parts separately and until now there is a large integration gap at the low level of Sensor Web protocols.

A sensor measures a physical quantity and converts it into a signal that can be read by an observer or by an instrument. Sensors are most commonly used to make quantifiable measurements. For the sensor selection there are four criteria: what do we need to measure; in which environment is measurement being done; what is the required accuracy of the measurement; is the whole system calibrated or certified. These four aspects can influence the selection of sensors, but also their costs. Every sensor is described by the following characteristics: transfer function, sensitivity span or dynamic range, accuracy or uncertainty, hysteresis nonlinearity, noise, resolution and bandwidth.

Wireless Sensor Network is an emerging technology made up from tiny, wireless sensors - nodes. Each node is a tiny computer with a power supply, one or more sensors, and a communication system. Sensor networks are receiving a significant attention because of their numerous potential civilian and military applications. The main features that a sensor network should have are: each node should have a very low power consumption, each node should be allowed to go in stand-by mode, the estimation/measurement capabilities of the system as a whole should significantly outperform the capabilities of each sensor, a sensor network is ultimately an event-driven system, congestion around the sink nodes should be avoided by introducing some form of distributed access and processing the information should flow through the network in the simplest way. WINSOC developed very innovative concept where the whole network is achieved by introducing a suitable coupling among adjacent and low cost sensors. The sensors are enabling a global distributed detection or estimation more accurately than is achievable by each single sensor and without the need for sending all data to a fusion centre.

Several examples of Wireless Sensor technologies can be mentioned: Cirronet, which has created high-performance components for industrial wireless applications; MeshNetics, which is a leading provider of short-range wireless sensor technologies; Moteiv is a venture-funded company that provides wireless sensor networking solutions to enterprises worldwide; MaxStream is a premier manufacturer of high-performance wireless device networking solutions; IntelliSensing LLC is a young technology company that stems from a solid footing in the aerospace market; Vulcain, a leader in the gas detection industry, designs and manufactures technologically superior products in order to provide clear solutions to ensure clear air; Crossbow Technology, Inc. is the leading end-to-end solutions supplier in wireless sensor networks. As for latest novelties, VLIT-NODE technology, which is a Wireless Sensor Network based on RFID of second generation allowing communication on distance around one kilometre. This solution will open new possibilities for large scale deployment of Wireless Sensor Network.

For the integration of sensor measurements with SDI we can use the concept of Sensor Web introduced by NASA. OGC started to release the Sensor Web Enablement (SWE) as a standard for integrating a variety of sensors into one communication language and a well defined web environment. The goal of SWE is to create web-based sensor networks and to make all sensors and repositories of sensor data discoverable, accessible and, where applicable, controllable via the Internet. OGC members have developed and tested the following standards and candidate specifications: Observations & Measurements (O&M), Sensor Model Language (SensorML), Transducer Model Language (TransducerML or TML), Sensor Observations Service (SOS), Sensor Planning Service (SPS), Sensor Alert Service (SAS) and Web Notification Services (WNS).

The first existing implementations are decribed in this article. NASA has adopted the vision of sensor as advance sensor web technology for satellites. Northrop Grumman's PulseNet has been using the SWE standards in a major internal research and development project called Persistent Universal Layered Sensor Exploitation Network, which is a real-world testbed to prototype a global sensor web. SANY Sensors Anywhere recognises the OGC's SWE suite of standards as one of the key technologies that can eventually lead to development of self-organising, self-healing, ad-hoc networking of in-situ and Earth observation sensor networks. The German organization 52North provides a complete set of SWE services under GPL license. The European Space Agency and various partner organizations in Europe are collaborating on the Heterogeneous Mission Accessibility (HMA) project. HMA's high level goals include, among other things, consolidating Earth imaging and other geospatial interoperability requirements; defining interoperable protocols for cataloguing, ordering and mission planning; and addressing interoperability requirements arising from security concerns. CUAHSI has been researching, prototyping, and implementing Web services for discovering and accessing different hydrologic data sources, and developing online and desktop applications for managing and exploring hydrologic time series and other hydrologic data. This is a first attempt to define what will be supported in MapServer to be able to deploy a Sensor Observation System (SOS). SOS provides several operations divided into core mandatory operations (GetCapabilities, DescribeSensor and GetObservation) and optional transactional and enhanced operations. CCSS implemented Sensor Observation Service based on Java Architecture for XML Binding.

The development of standards on sensor technologies and the development of Sensors Web standard run in parallel, without any synergies. There is no direct integration of sensors with SDI. Winsoc project suggested a solution based on the utilisation of two levels sensors. Level 1, which is focused on terrain data collection, level 2 guarantees IP communication with the Web environment using OGC SWE standard. The sensors on the level 2 are represented by mobile units that are a type of industrial computers, which allow limited implementation of SOS standard or easy integration of measurement with databases.

One task of the enviroGRIDS project is to analyse the needs for sensor measurements, including the definition of the observed phenomena, the definition of the accuracy of measurement and the definition of the frequency of measurement. This project task will test different approaches for integrating standards of observation sensors with wireless sensors network. It will further explore the development of hardware and software solution to plug sensors into SDI. It will pursue the implementation of SWE standards and their integration with SDI and grid technologies.

2 Introduction

2.1 The enviroGRIDS project

EnviroGRIDS @ Black Sea Catchment aims at building capacities in the Black Sea region to use new international standards to gather, store, distribute, analyze, visualize and disseminate crucial information on past, present and future states of this region, in order to assess its sustainability and vulnerability.

2.2 WP2: Grid-enabled Spatial Data Infrastructure

The aim of WP2 is to create a Grid-enabled Spatial Data Infrastructure (GSDI) so that the data necessary for the assessment of GEO Societal Benefit Areas, as well as the data produced within the project can be gathered and stored in an organized form on the Grid infrastructure and distributed across the Grid in order to provide a high performance and reliable access through standardized interfaces. Using the standardized technologies of the Grid we can provide a Single Information Space for environmental data in the Black Sea Catchment.

2.3 Task 2.3: Sensor data integration

This task consists mainly of providing interfaces so that any kinds of sensors can publish their data on the SDI and Grid, as well as providing SDI and Grid tools to access sensors, and finally store the gathered data. Integration of the data generated by active sensors with the Grid environment is a prerequisite for the handling of this data and for the integration with the Grid middleware.

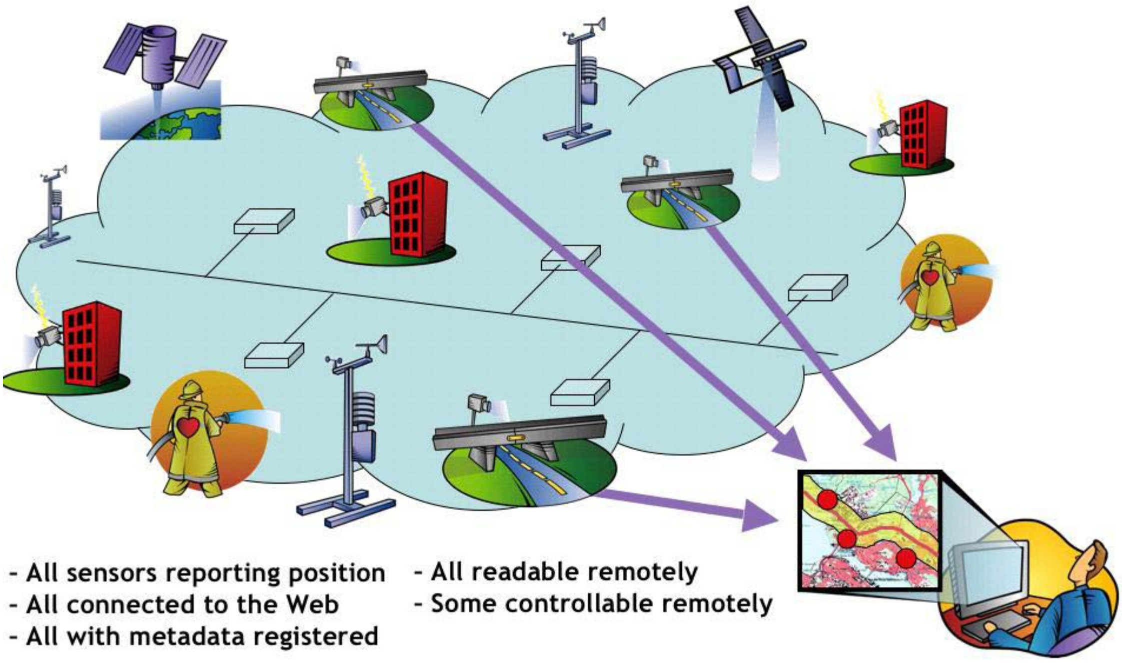

Figure 1. Sensor Web concept (OGC)

2.4 Scope and purpose of this deliverable

The objective of EnviroGRIDS sensor data use and integration guideline is to support EnviroGRIDS partners by informing them about current sensor technologies, new development in the area of the Wireless Sensor Network and integration of sensors using Web Sensor standards. The deliverable analyses the role of a sensor in monitoring by using the current GMES Earth Observation model (Fig. 2). A part of the description is also the analysis of the possibilities on how to integrate sensors with Grid Enabled SDI.

An important part of this document focuses on the description of the current solutions developed in the previous projects by Czech Centre for Science and Society (CCSS). These solutions will be extended for future utilisation in the EnviroGRIDS Black See project.

2.5 The role of Sensor measurement in SDI

The Global Earth Observation System of Systems (GEOSS) is a coordinated and integrated network of Earth observing and information systems to support informed decision making for society, including the implementation of international environmental treaty obligations. There is a contribution on a voluntary basis by Members and Participating Organizations of the intergovernmental Group on Earth Observations (GEO). One of the goals of GEOSS is to ensure the fully-coordinated development and implementation of future Earth observing systems, including satellite, airborne, **and in-situ systems**, as well as a transition of research systems into operational systems [1]. In situ observations represent therefore one of the essential components of the GEOSS system. The Global Monitoring for Environment and Security (GMES) programme defines also in situ observation as one of the two basic pillars of its infrastructure [2].

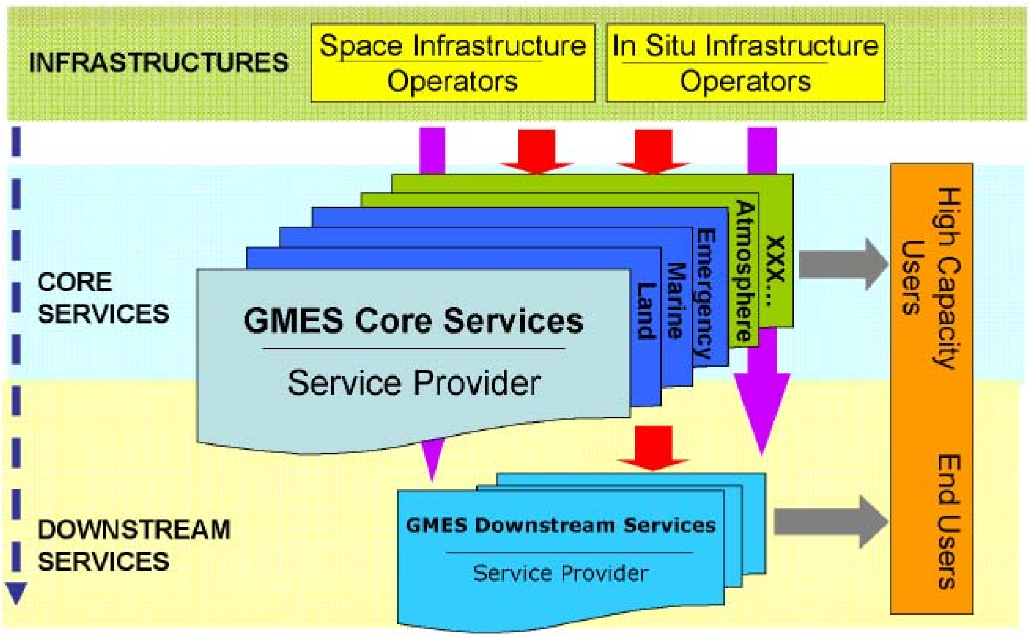

Figure 2. GMES scheme (GMES source)

From the point of view of GMES and GEOSS, in situ observations are an essential part of Earth monitoring. In comparison with remote sensing, in situ observations are still not very well integrated. In the INSPIRE directive, for instance, in situ monitoring is not yet included as a part of the proposed Spatial Data Infrastructure (SDI). Nonetheless, there are several FP6 and FP7 projects dealing with in situ monitoring (e.g. SANY, Osiris, Winsoc, Genesis), and different approaches exist already to integrate in situ observations into SDI.

2.6 The Uniform Resource Management (URM) GeoPortal

One example where all components of in situ monitoring are integrated into an SDI is the Uniform Resource Management (URM) GeoPortal. The basic components of the URM GeoPortal, which are based on INSPIRE, GMES and GEOSS principles and standards, are shown in figure 3.

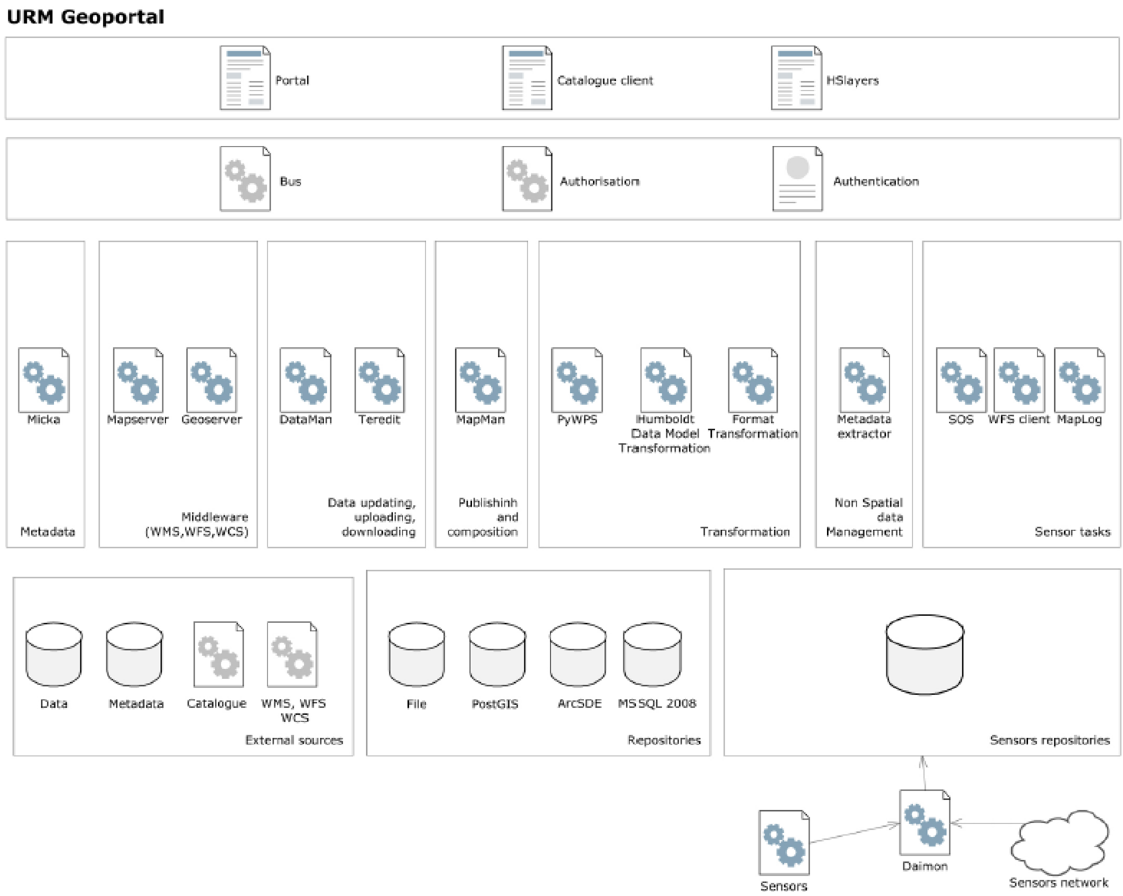

Figure 3. The URM GeoPortal components (URM definition for EnviroGrid purposes)

In the URM, the integration of in situ observations was divided into three relatively independent blocks:

- Sensors technologies, including wireless sensor networks;
- Sensor measurement integration;
- Sensor Web.

The problem of the current research is that most projects are focusing either on sensor technologies development or on Sensors Web. Until now, there was a large gap in the integration of low level protocols with Sensor Web. The Sensor Web community expects some standardisation at the level of sensors themselves, which in reality is not happening.

3 Sensors and sensor networks

3.1 Sensors

A **sensor** is a device that measures a physical quantity and converts it into a signal that can be read by an observer or by an instrument. Many kinds of sensors for surveillance and intrusion detection exist including infrared, other optical, microwave-based, or other types. They can be effectively used to support manned surveillance, e.g. video cameras. There are also video-based systems that sense changes in the image and trigger an alert. Since every sensor used for this kind of applications can be characterised by its location – space and time coordinates, the spatial extension and near-real-time availability of sensor-originated information layers in geospatial applications represent a great potential.

Sensors are most commonly used to make quantifiable measurements, as opposed to qualitative detection or presence sensing. For the sensor selection there are four criteria:

1. What do we need to measure? Sensors can measure almost everything, but every phenomena needs a different type of sensors.
2. In which environment will we measure? There are different needs for outdoor and indoor sensors, and there are also specific requirements for sensors working in extreme conditions.
3. What is the required accuracy of the measurement?
4. Is the whole system calibrated or certified?

These four aspects can influence the selection of sensors, but also their costs.

Every sensor is described by the following characteristics:

- Transfer Function - the functional relationship between physical input signal and electrical output signal
- Sensitivity - relationship between input physical signal and output electrical signal
- Span or Dynamic Range - range of input physical signals that may be converted by the sensor to electrical signals
- Accuracy or Uncertainty - largest expected error between actual and ideal output signals
- Hysteresis - width of the expected error in terms of the measured quantity
- Nonlinearity - maximum deviation from a linear transfer function over the specified dynamic range
- Noise - sensors produce some output noise in addition to the output signal
- Resolution - minimum detectable signal fluctuation
- Bandwidth - response times to an instantaneous change in physical signal

When we are talking about sensor, we usually consider both parts - sensor and transducer. A *sensor* is a device that receives a signal or stimulus and responds with an electrical signal, while a *transducer* is a converter of one type of energy into another. From a signal conditioning viewpoint it is useful to classify sensors as either active or passive. The active sensor requires an external source of excitation. The passive (or self-generating) sensor generates its own electrical output signal without requiring external voltages or currents [3].

3.2 Wireless Sensor Network

3.2.1 Principles

The current innovation in sensor technologies is mainly focused on development of Wireless Sensor Network. This is a new solution based on small nodes (sometimes called smart dust - mote). The ultimate goal is to have nodes or motes as small as pin heads. Each node is a small computer with a power supply, one or more sensors, and a communication system. Each mote contains a network independent module - Smart Transducer Interface Module (STIM). It contains the transducers, signal conditioning circuitry and a standard interface. The other part of the mote is a network specific module - Network Capable Application Processor (NCAP). It implements the interface to the desired control network and also implements the standard interface of the transducer module. Sensor networks are receiving a significant attention because of their many potential civilian and military applications. The design of sensor networks faces a number of challenges resulting from very demanding requirements on one side (such as high reliability of the decision taken by the network and robustness to node failure), and very limited resources on the other side (such as energy, bandwidth, and node complexity) [4].

Sensor Network Systems provide a novel paradigm for managing, modelling and supporting complex systems requiring massive data gathering with pervasive and persistent detection/monitoring capabilities. Therefore it is not surprising that in recent years a growing emphasis has been steered towards the employment of sensor networks in various technological fields, e.g. aerospace, environment monitoring, homeland security, smart buildings. A significant amount of resources has been allocated for national (USA, France, Germany) and international (e.g. European Commission) research programmes targeted at developing innovative methodologies and emerging technologies in different application fields of wireless sensor network. The main features of a sensor network are the following:

i) each node should have a very low power consumption, the capability of recharging its battery or scavenging energy from the environment, and very limited processing capabilities;
ii) each node should be allowed to go in stand-by mode (to save as much battery as possible) without severely degrading the connectivity of the whole network and without requiring complicated re-routing strategies;
iii) the estimation/measurement capabilities of the system as a whole should significantly outperform the capabilities of each sensor and the performance should improve as the number of sensors increases, with no mandatory requirement on the transmission of the data of each single sensor toward a centralised control/processing unit; in other words, the network must be scalable and self-organising, i.e. capable of maintaining its functionality (although modifying the performance) when the number of sensors is increased;
iv) a sensor network is ultimately an event-driven system, it is necessary to guarantee that the information about events of interest reach the appropriate control nodes, possibly through the simplest propagation mechanism, not necessarily bounded to the common OSI protocol stack layer;
v) congestion around the sink nodes should be avoided by introducing some form of distributed processing;
vi) the information should flow through the network in the simplest way, not necessarily relying on sophisticated modulation or multiplexing techniques.

In summary the fundamental requirements for the sensor network are:

- Very low complexity of elementary sensors, associated with a low power consumption and low-costs;
- High reliability of the decision/estimation/measurement of the network as a whole;
- Long network life-time for low maintenance and stand-alone operation;
- High scalability;
- Resilience to congestion problems in peak traffic conditions [5].

3.3 Winsoc approach

The WINSOC [6] project introduced a new concept of WSN which is very different from previous solutions. The network could be compared with principles of neural networks, where every node of neural network is represented by low cost sensors with limited memory and computing capacity. The network supports distributed detection or estimation. This approach is more accurate than the observation reached by each single sensor. The advantage is also that it is not necessary to send every observation into fusion centre. The whole network is hierarchical and composed of two levels. A lower level, composed of the low cost sensors. The lower level network provides observation and guarantees a consensus. A higher level guarantees communication with the fusion centre. The key point is the interaction among the low cost sensors that increases the overall reliability. It also insures a scalability and a tolerance against failure and/or stand-by of some sensors, (e.g. battery recharge and energy saving). The Winsoc solution supports distributed processing capabilities. It was tested on environmental risk management (forest fire and landslides) using heterogeneous networks with various degrees of complexity and capabilities.

3.4 Wireless Sensor Technology companies

Since 1987, the Atlanta-based Cirronet company has created high-performance components for industrial wireless applications. They started with their own frequency hopping spread spectrum (FHSS) technology, which has been continually optimized. They have also focused on emerging standards, incorporating the best of them into their product mix. Their line of products today encompasses the industry's broadest range of technologies and options, ensuring that they meet their customers' needs precisely. Cirronet was acquired in 2006 by RF Monolithics (RFM) and is now a wholly owned subsidiary of this 25 year-old leader in low-power wireless sensor networks and high performance RF components (NASDAQ: RFMI).

MeshNetics is a leading provider of short-range wireless sensor technology. They offer market-ready solutions for wireless sensing applications that are based on IEEE802.15.4 / ZigBee standards. Their goal is to help their partners establish a solid footprint in the emerging M2M market with their MeshNeticsTM product family. The MeshNeticsTM product portfolio includes wireless ad-hoc mesh-networks software, hardware designs, and customization services that enable M2M applications, based on open systems and standards. MeshNetics offers low power, high sensitivity ZigBee Modules adding wireless connectivity to a sensor device. The platform-independent ZigBee Embedded Software configurations that provide various levels of ZigBee Standard compatibility for the wireless sensor products. The ZigBee Evaluation Kit and ZigBee Development Kit contain hardware and software that you need to quickly prototype and test wireless sensor network (WSN) applications.

Moteiv is a venture-funded company that provides wireless sensor networking solutions to enterprises worldwide. They sell hardware, software and services to innovative companies. Their customers leverage wireless sensor networks to create business value and expand market leadership. Moteiv's mission is to accelerate the integration of physical world data and processes into the enterprise, by removing the existing barriers to mass wireless sensor adoption. Moteiv's founding team has several decades of collective experience leading the implementation of the world's largest wireless sensor network deployments from UC Berkeley. They have leveraged their domain and technology expertise to build innovative solutions that address the real-world problems and barriers they've encountered working with customers around the globe.

MaxStream is a premier manufacturer of high-performance wireless device networking solutions. MaxStream's patent-pending wireless designs have garnered multiple awards and thousands of design wins for the innovative technological advances. MaxStream's highly reliable data radios are deployed worldwide in an array of industrial and commercial applications, creating easy-to-implement wireless connectivity

IntelliSensing LLC is a young technology company that stems from a solid footing in the aerospace market. With a strong background in sensing instrumentation design, embedded development and information technology, they combine the trusted methods of physical measurement with advanced wireless technology to produce sensors that interface directly with control and measurement systems, using no external power or wiring. Their mission is to design, manufacture and support wireless sensor products that enable advanced applications in demanding markets. Their slogan, The Network is the Sensor, highlights their commitment to provide a system solution not only incorporating sensors, but also the infrastructure responsible for transporting the measurement data to the destination.

Vulcain, a leader in the gas detection industry, designs and manufactures technologically superior products in order to provide clear solutions to ensure clear air.

Crossbow Technology, Inc. is the leading end-to-end solutions supplier in wireless sensor networks. Crossbow provides a scalable product portfolio comprised of hardware and software development platforms, complete product designs, manufacturing and professional services that enable OEMs and system integrators to bring end-to-end wireless sensor network systems to market quickly [7].

3.5 VLIT Node Technology

VLIT NODE technology is a new solution for Wireless Sensor Network developed by Cominfo (Czech SME company) in cooperation with Czech Centre for Science and Society (CCSS). The solution is based on RFID of second generation allowing communication on distance around one kilometre. This solution will open new possibilities for large scale deployment of Wireless Sensor Network.

4 Sensor Web

4.1 What is the Sensor Web?

The concept of the sensor web was introduced by NASA. The sensor web was introduced as a link connecting together ground and space-based instruments to enable autonomous collaborative observation collections. These observations can be triggered via a variety of sources. Typically, scientific events of interest trigger observation campaigns in an ad hoc sensor constellation and supply multiple data acquisitions as rapidly as possible and in as much depth as possible in a given time period. This is accomplished through a seamless set of software and communications interactions in a system of linked sensors [9].

4.2 Sensors Web Enablement

As the communication of sensors with GIS tools is becoming necessary, the OGC is starting to release the Sensor Web Enablement (SWE) that should become a standard in integrating of variety kind of sensors into one communication language and well defined web environment. Open geospatial consortium SWE is intended to be a revolutionary approach for exploiting Web-connected sensors such as flood gauges, air pollution monitors, satellite-borne Earth imaging devices, etc. The goal of SWE is the creation of web-based sensor networks. That is, to make all sensors and repositories of sensor data discoverable, accessible and where applicable controllable via the Internet. Open geospatial consortium defines a set of specifications and services for this goal. Short descriptions of these services are shown below [10].

OGC members have developed and tested the following candidate specifications. Others are planned.

1. **Observations & Measurements (O&M)** - Standard models and XML Schema for encoding observations and measurements from a sensor, both archived and real-time.
2. **Sensor Model Language (SensorML)** - Standard models and XML Schema for describing sensors systems and processes associated with sensor observations; provides information needed for discovery of sensors, location of sensor observations, processing of low-level sensor observations, and listing of taskable properties, as well as supports on-demand processing of sensor observations.
3. **Transducer Model Language (TransducerML or TML)** - The conceptual model and XML Schema for describing transducers and supporting real-time streaming of data to and from sensor systems.
4. **Sensor Observations Service (SOS)** - Standard web service interface for requesting, filtering, and retrieving observations and sensor system information. This is the intermediary between a client and an observation repository or near real-time sensor channel.
5. **Sensor Planning Service (SPS)** - Standard web service interface for requesting user-driven acquisitions and observations. This is the intermediary between a client and a sensor collection management environment.
6. **Sensor Alert Service (SAS)** - Standard web service interface for publishing and subscribing to alerts from sensors.
7. **Web Notification Services (WNS)** - Standard web service interface for asynchronous delivery of messages or alerts from SAS and SPS web services and other elements of service workflows [11].

4.3 Existing Implementation of SWE [12]

4.3.1 NASA

The US National Aeronautics and Space Administration (NASA) has adopted the vision of sensor webs as a strategic goal and has thus funded a variety of projects to advance sensor web technology for satellites. A number of these projects have recently adopted the OGC's Sensor Web Enablement (SWE) suite of standards. The focus of many of these efforts has been the collaboration between the NASA Jet Propulsion Lab and the NASA Goddard Space Flight Center using the Earth Observing 1 (EO-1) and assorted other satellites to create pathfinder sensor web applications that have evolved from prototype to operational systems. GSFC, Vightel Corporation, and Noblis initiated a wildfire sensor web scenario using EO-1 and recently prototyped the preliminary transformation to SWE implementation using the Open Source GeoBliki framework that was developed for the OGC's OWS-4 interoperability testbed. Both JPL and GSFC are in the process of changing the remaining interfaces to OGC SWE compatibility.

4.3.2 Northrop Grumman's PULSENet

Northrop Grumman Corporation (NGC) has been using the SWE standards in a major internal research and development (IRAD) project called Persistent Universal Layered Sensor Exploitation Network (PULSENet™). This real-world testbed's objective is to prototype a global sensor web that enables users to:

- Quickly discover sensors (secure or public), task them, and access their observations in ways that meet user needs.
- Obtain sensor descriptions in a standard encoding that is understandable by a user and the user's software.
- Subscribe to and receive alerts when a sensor measures a particular phenomenon.

In its first year, PULSENet was successfully field tested under a real-life use case scenario that fused data from four unattended ground sensors, two tracking cameras, 1,800 NOAA weather stations and NASA's EO-1 satellite.

4.3.3 SANY Sensors Anywhere

SANY IP is an FP6 Integrated Project co-funded by the Information Society and Media Directorate General of the European Commission. SANY IP intends to contribute to GMES (Global Monitoring for Environment and Security, a major European space initiative) in the area of in-situ sensor integration, by developing a standard open architecture and a set of basic services for all kinds of sensors, sensor networks and other sensor-like services.

The SANY Consortium recognises the OGC's SWE suite of standards as one of the key technologies that can eventually lead to development of self-organising, self-healing, ad-hoc networking of in-situ and earth observation sensor networks.

4.3.4 52 North

The German organization 52North provides a complete set of SWE services under GPL license. This open source software is being used in a number of real world systems, including a monitoring and control system for the Wupper River watershed in Germany and a forest fire monitoring system in South Africa.

4.3.5 HMA in Europe

The European Space Agency and various partner organizations in Europe are collaborating on the Heterogeneous Mission Accessibility (HMA) project. HMA's high level goals include, among other things, consolidating earth imaging and other geospatial interoperability requirements; defining interoperable protocols for catalogueing, ordering and mission planning; and addressing interoperability requirements arising from security concerns. HMA involves a number of OGC standards, including the Sensor Planning Service, which supports the feasibility analysis requirements of Spot Image optical satellite missions.

4.3.6 Web Services for Unified Access to U.S. Hydrologic Data

CUAHSI (Consortium of Universities for the Advancement of Hydrologic Science, Inc.) is an organization founded to develop cyber infrastructure to support advanced hydrologic research and education. CUAHSI represents more than 100 U.S. universities and is supported by the U.S. National Science Foundation. CUAHSI's Hydrologic Information System (HIS) project involves several research universities and the San Diego Supercomputer Center as the technology partner. For three years, the CUAHSI HIS team has been researching, prototyping, and implementing Web services for discovering and accessing different hydrologic data sources, and developing online and desktop applications for managing and exploring hydrologic time series and other hydrologic data.

The core of the HIS design is a collection of WaterOneFlow SOAP services for uniform access to heterogeneous repositories of hydrologic observation data. SOAP is a protocol for exchanging XML-based messages over computer networks. SOAP forms the foundation layer of the Web services stack, providing a basic messaging framework where more abstract layers can be build on. The services follow a common XML messaging schema named CUAHSI WaterML, which includes components for transmitting observation values and time series, as well as observation metadata including information about sites, variables and networks.

4.3.7 Support of Sensor Observation Service in MapServer [13]

This is the first attempt to define what will be supported in MapServer to be able to deploy a Sensor Observation System (SOS). SOS provides several operations divided into core mandatory operations (GetCapabilities, DescribeSensor and GetObservation) and optional transactional and enhanced operations. The first implementation of SOS in MapServer will only address the core operations:

- GetCapabilities Request
- GetCapabilities returned document
- GetObservation Request
- Get Observation Response
- Describe Sensor

4.4 CCSS implementation

This section describes specific implementations that were recently developed by CCSS using XML and JAXB standards.

4.4.1 Sensor Observation Service

The SOS is an OGC standard that defines a web service interface for discovery and retrieval of real time or archived data. Data are produced by many sensors, including mobile, stationary, in-situ or remote sensors. Data can be observations or descriptions of the sensor (calibration information, positions, etc.). Observations are returned encoded as an O&M Observation and the information about the sensor are returned encoded in SensorML or TML.

The operations of the SOS are separated in four profiles:

- core profile – three basic operations, provided by every SOS implementation
- transactional profile – operations to register sensors and insert observations into SOS
- enhanced profile – additional optional operations
- entire profile – implements all operations

Core profile has three mandatory core operations that provide its basic functionality:

- GetCapabilities – returns a service description containing information about the service interface and the available sensor data.
- DescribeSensor – returns a description of one specific sensor, sensor system or data producing procedure. The response returns information like position of sensor, calibration, input- and outputs encoded in SensorML or in TML.
- GetObservation – provides access to sensor observations and measurement-data.

Our recent work was focused on creating an SOS implementation which contains core operations. Communication between consumer and implementation is based on xml documents. An XML schema describes the structure of an XML document. An XML Schema:

- defines elements that can appear in a document;
- defines attributes that can appear in a document;
- defines which elements are child elements;
- defines the order of child elements;

- defines the number of child elements;
- defines whether an element is empty or can include text;
- defines data types for elements and attributes;
- defines default and fixed values for elements and attributes.

For reading and parsing XML document, JAXB utilities that are core a part of JAVA are used. JAXB constitutes a framework for processing XML documents.

JAXB accesses the XML document from a Java program by presenting the XML document to the program in Java format. The first step in this process is to bind the schema for the XML document. Binding a schema means generating a set of Java classes that represents the schema. All JAXB implementations provide a tool called binding compiler to bind a schema.

The compiler is called by command:

xjc –d <dir> –p <package> –b <binding.xjb> schema.xsd

The -p option identifies a package for the generated classes, and the -d option identifies a target directory. Binding file (*.xjb) is used for customization, JAXB allows you to annotate a schema with binding declarations that override or extend the default binding behaviour. This customization is useful by compiling a complex set of schemas to prevent collisions of attribute names or method names.

Unmarshalling an XML document means creating a tree of content objects that represents the content and organization of the document. The content objects are instances of the classes produced by the binding compiler. Marshalling is the opposite of unmarshalling. It creates an XML document from a content tree.

We have successfully generated all required classes so we can handle now all SOS related XML documents. Next work is to add a convenient API to deal with specific requirements of SOS more comfortably [14], [15], [16], [17], [18].

5 A Gap between Sensor Technologies and Sensor Web

5.1 What is the gap between the Sensor Web and the Sensor Technology?

The previous chapters described the main sensors technology and Sensors Web implementations. For practical utilisation, there are still several gaps that introduce problems for integration of sensors with Spatial Data Infrastructure. The development of standards on the level of sensor technologies and development of Sensors Web standard run for instance in parallel, without any synergies. So there is no direct way to integrate sensors with SDI. It is therefore necessary to build a proprietary interface that supports the plug in of sensors into SDI. The most commonly used solution is to store sensor measurements into a database, and then to build SWE interfaces for this database.

5.2 How could we fill the gap between the Sensors Web and the Sensor Technology? - the CCSS solution

CCSS participates in the WINSOC project and suggested general scheme for integration of sensor networks with SDI.

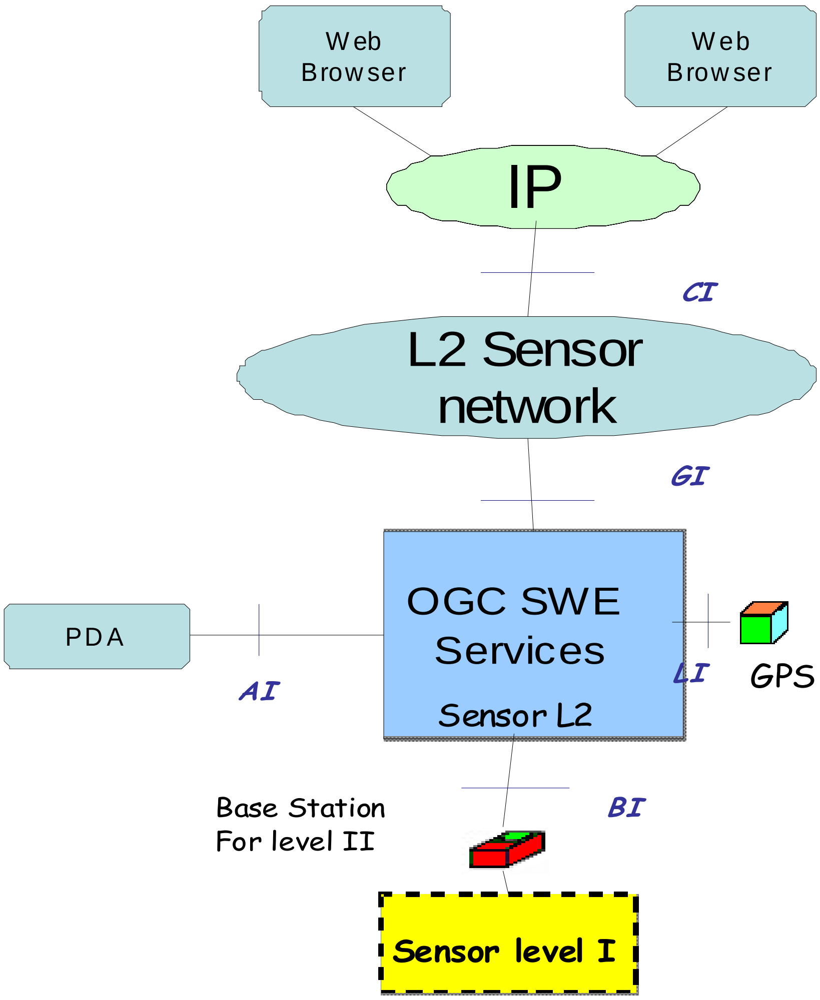

Figure 4. Basic scheme for integration of sensor network with Geospatial database management (Winsoc design for forest fire scenario).

The general scheme presented in Figure 4 represents two levels of sensors. A level 1 is focused on terrain data collection and a level 2 guarantees IP communication with Web environment using OGC SWE standard. A pilot solution proposed in WINSOC for Forest fire scenario is presented in Figure 5.

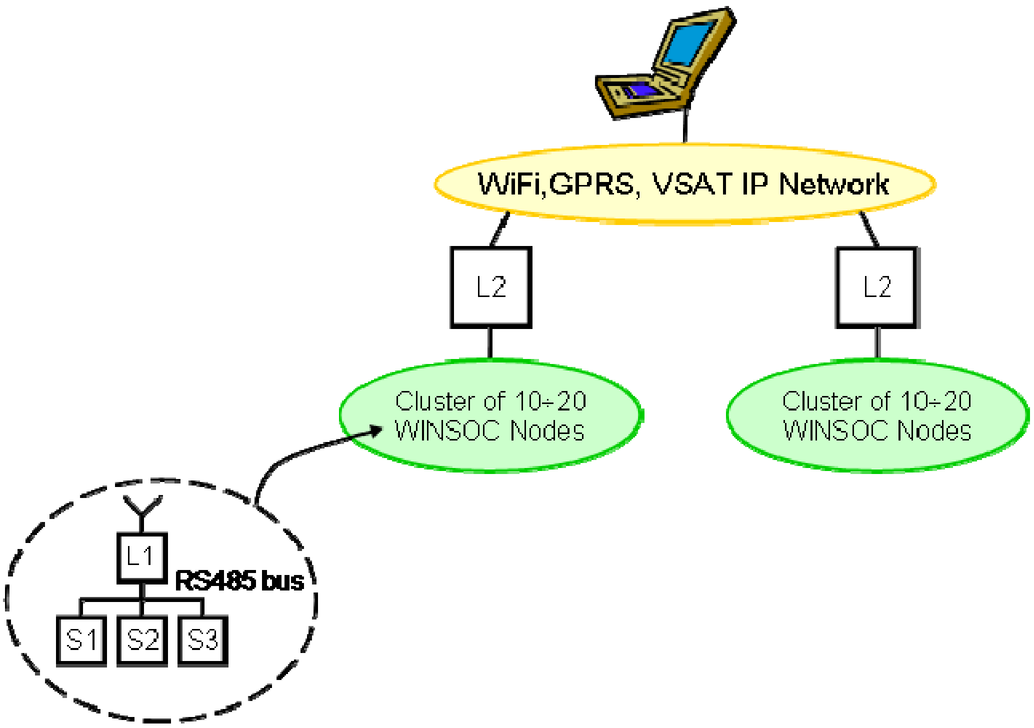

Figure 5. Basic scheme for integration of sensors network with Geospatial database management for forest fire scenario (Winsoc design for forest fire scenario).

The sensors in the level 2 are represented by mobile units developed inside CCSS with a type of industrial computers allowing limited implementation of SOS standard or easy integration of measurement with databases.

Mobile Communication Unit device is using AT91RM9200 Main board as a central unit, Wavecom Fast track modem as a GPRS communication device. Power supply for all parts is provided by underlying power board, backed-up by reachable battery. Main power source is external 230V plug, which is stabilized by switched power supply built in separate box mounted sideway to the main box.

Simple board is used as a sensor interface device that allows connection of RS485 sensors with its own communication proprietary protocol. It allows also the connection of sensors that are sending data by modulating power line, and sensors with generic digital or analogue signals.

Data from this interface card are transferred into the main processor by RS485 through our protocol and with these properties:

- Modular bus system
- Automatic configuration of all devices
- Individual addressing and identification of each module
- Address collision solving
- Immunity to interference
- Short circuit and collision
- Immunity to OOB (out of band) traffic on the same bus
- Hot-plug support

The computational part of the mobile unit is based on ARM processor. Communication is supported using GPRS protocol.

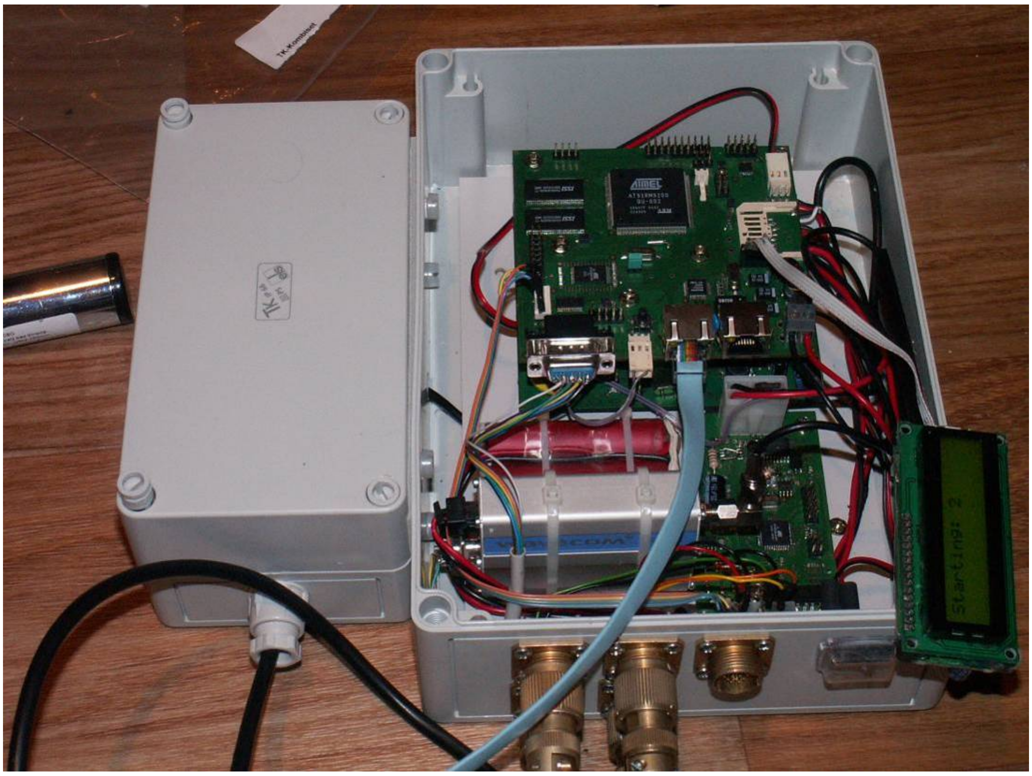

Figure 6. Mobile Communication Unit

The main role of the server is to store measured data and publish them though the proper service. The database that is used in our case is PostgreSQL with PostGIS extension. The GPRS can call a proprietary web service that stores the data into the database or OGC compliant SOS transactions can be performed. In this way the measurements are inserted into the database. The sensor position (continually measured by GPS) is also stored in the database in real time using again the proprietary web service or transactional WFS.

Once the data are in the database we have many possibilities how to present them to the clients. For instance:

- Direct connection to PostGIS by common GIS viewer - as far as PostGIS is compliant with OGC Simple Feature Specification, we can connect directly to the database by various kinds of GIS desktop applications (uDig, QGIS, Jump etc...).
- Set up WFS or WMS (by Geoserver or UMN Mapserver) and access the data by whichever web or desktop client. The measured values can be represented by feature attributes.

This solution allows publishing the position or the track of the sensor and some of the measurements. To publish the measurements in a better way, we will be able to access the data by SOS service (still in development). We have also implemented a web service that generates charts from database query.

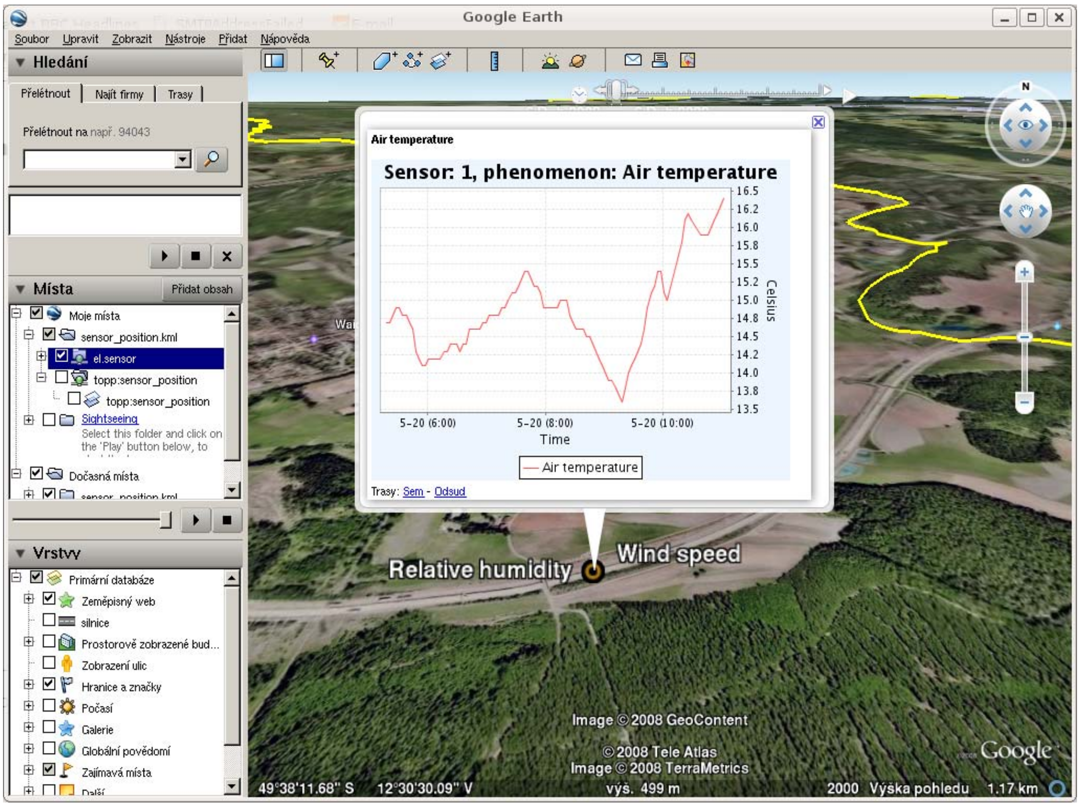

Figure 7. Client based on Google Earth

One of the offered possibilities is to access the data through Google Earth (Figure 7). Figure 8 demonstrates the generation of graphs based on Senor Observation Services.

For the purpose of Winsoc project a special client based on HSLayers library was also developed (extension of popular Open layers library developed by Help Service Remote Sensing member of CCSS) (Figure 9).

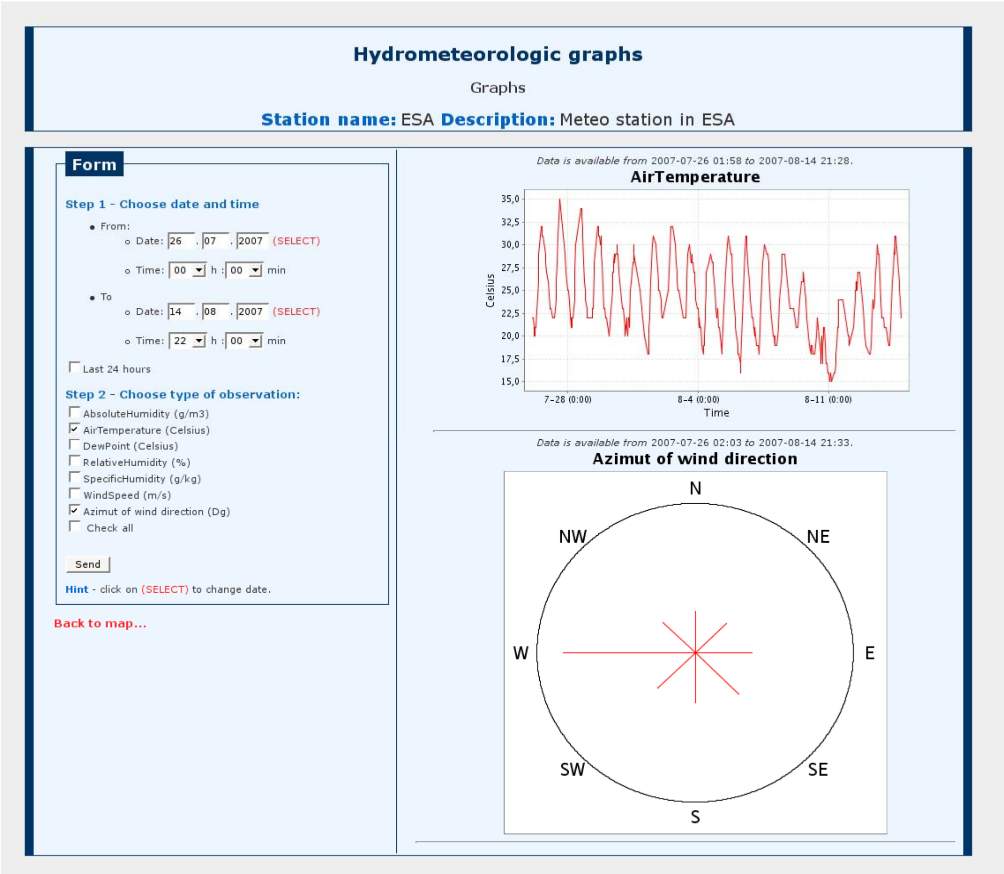

Figure 8. HTML based client

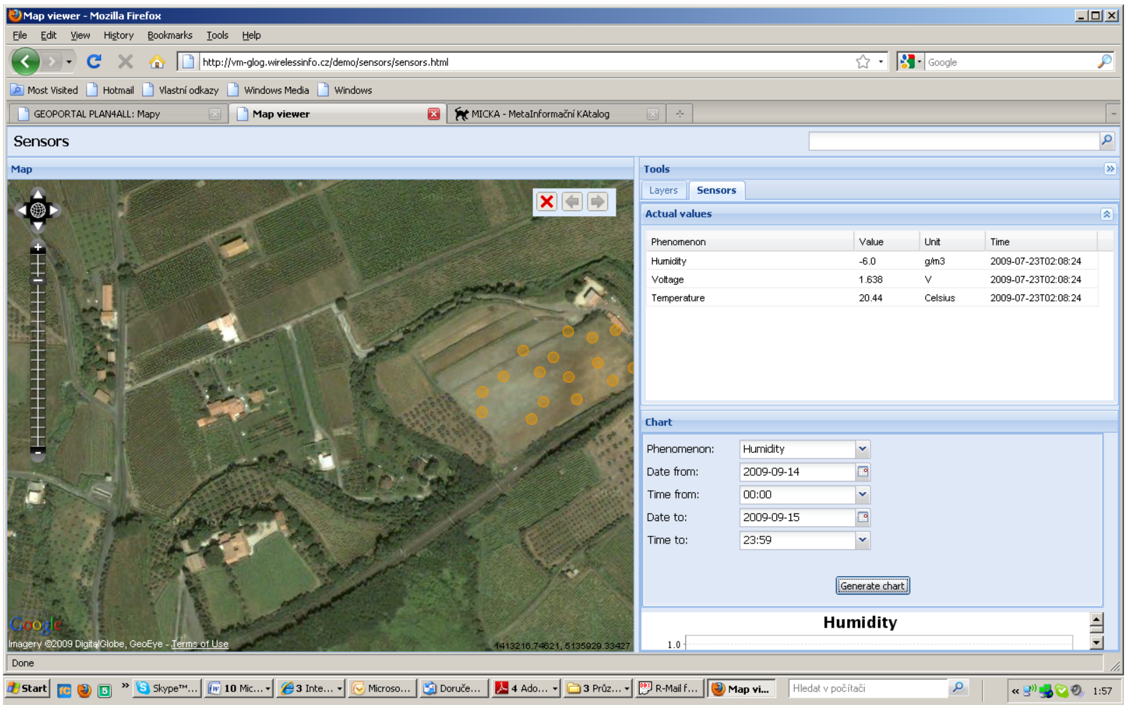

Figure 9. HSlayers client

The sensor position can be visualized by any WFS client. Observed values are available in the form of chart (PNG image) through web service (http GET) where one of the parameters is the ID of the feature representing the sensor position.

There are many possibilities to deal with sensor measurements using free and open source software. The described approach can be easily used for tasks like car monitoring and many others by using almost free technologies.

Nevertheless, the complex and interoperable solution that will be able to deal with all sensor-based tasks (e.g. alerts, sensor processing,...) is still an open issue, even though the OGC initiative put a lot of efforts into this task recently. The reason is that the support by concrete implementations of these specifications is still low. It is probably necessary that the GIS and sensor communities reach some conformity to bring sensors and measurements topic to the same level of interoperability than for example spatial data sharing with WMS, WFS and WCS standards [19].

6 Recommendations

From our review of the state-of-the-art in Sensors and Sensor Web technologies, we can derive some recommendations for the EnviroGRIDS project in the Black Sea:

- To analyse the needs for sensor measurements in pilot areas. This includes:
    - Define the phenomena to be observed
    - Define the accuracy of measurement

  - Define the frequency of measurement
- To test different approaches for observation standard sensors and Wireless Sensor Network.
- To continue the development of hardware and software solution for plugging in sensors into SDI.
- To continue the implementation of SWE standards and integration of sensor measurement with SDI and Grid technology.

From the current models and also from previous experiences of CCSS, it seems that the most promising implementation of sensor technology in the enviroGRIDS project should be focused on climate change model and catchment hydrological model (see Figure 10).

The research challenges for the climate change model could be the comparison of classical sensors measurement with Wireless Sensor Networks for the purpose of local climatic conditions modelling. The future potential large scale deployment of WSN seems to open new possibilities in climatic changes modelling. The locals models are currently missing and they are very important in many areas like risk management, agriculture, etc.

For hydrological models, sensor or sensor network could be used for river water quality data collection and also for monitoring.

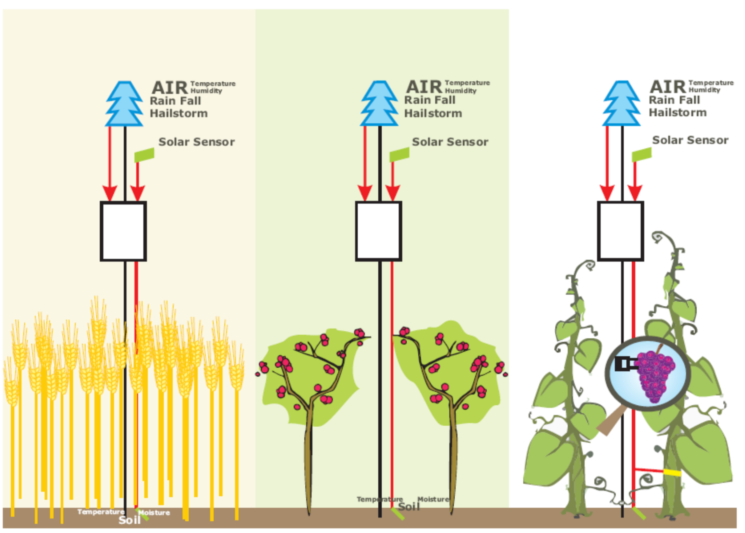

Figure 10. Examples of crop conditions monitoring [19]

The integration of this measurement technology into SDI and Grid technology could introduce new possibilities for modeling that could be reused in other regions and other disciplines. Generally, the focus should be on improving the methods for integrating sensors measurement with SDI and finally with Grid technologies. Current Grid and OGC standards do not support direct integration.

7 Conclusion

In the near future, sensors and Wireless Sensor Network will be an integrated part of both GEOSS and GMES. The fast development of sensor technologies, Wireless Sensor Network and Web Sensors allows to start the integration of sensor technologies within the enviroGRIDS infrastructure. There are still gaps in the integration of sensors measurement into Sensors Web, but previous results from CCSS research could help overcome these barriers. The report recommends to focus on two scenarios:

- Climatic changes
- Hydrological model

The main research tasks should to be:

- Exact definition of use cases
- Selection of sensor technology
- Integration of sensors measurements with Sensor Web
- Integration of sensors with Grid technologies

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