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Sensor network scenarios, services, and requirements

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Abstract: *This document defines the WINSOC project deliverable D.2.1 and deals with the description of sensor networks scenarios, services, and requirements. The purpose of the document is to provide designers of WINSOC system with a general understanding of users' needs and behaviours, propose the description of sensor services and their wider integration with relevant web services, and specify the requirements on sensor system network and radio links.*

Key words: *sensor networks, scenarios, requirements.*

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1 INTRODUCTION

This document defines the WINSOC project deliverable D.2.1 and deals with the description of sensor networks scenarios, services, and requirements. The purpose of the document is to provide designers of WINSOC system with a general understanding of users' needs and behaviours, propose the description of sensor services and their wider integration with relevant web services, and specify the requirements on sensor system network and radio links. It has been decided to investigate user requirements by means of interaction scenarios written by the WINSOC partners. Scenario-based design (Rosson & Carroll, 2002) is a methodology that has been developed in the last years and is constantly gaining attention for its power of actively engaging developers and designers in a common task. The document started from the work carried out by a number of related projects that define the operational requirements for sensor emergency networks. While these projects provide very detailed operational scenarios, it turned out, that the requirements they provide are on a level that is too high to serve as technical requirements for WINSOC project. These requirements were further refined following the chosen scenarios and respecting the specific needs defined in WINSOC project work plan..

Document has the following sections:

- Chapter 2 presents an overview of the sources that have been used for this work. There are a number of useful sources from EU projects where, in close collaboration with users of emergency systems and sensor networks, requirements have been intimately studied and defined. Other relevant overseas projects have been investigated dealing with wider emergency and information interoperability issues.
- Chapter 3 presents the different user scenarios falling within the framework of WINSOC objectives as agreed in the project proposal. The first set of scenarios was created in collaboration with Public Safety institutions and Forest Management Institute (FMI) user representatives in the Czech Republic and Governmental agencies, the research community, and the population in the landslide prone area India. During the initial phase of the project two main scenarios are taken into the account – “Forest fire detection and fire risk estimation” and “Landslides detection and prediction” Scenarios are described by a set of comparable characteristics - their type of emergency situation, operational environment (indoor, urban, rural), coverage area, user groups involved in the emergency situation, and the type of situation they are dealing with. Special attention is further paid to the description of WINSOC components for scenarios. Each scenario can be further divided to contexts according to their affiliation with emergency management cycle. There are analysed possibilities of deployment of sensor networks in the context of different scenarios. The basic architecture of sensor networks and their implementation into all system for crisis management was designed on the level of basic components.
- Chapter 4 - the first step in obtaining the technical requirements from the user based scenarios is the identification of services to be supported and actively propagated by

the WINSOC system. Chapter 4 identifies these services following the scenario split given in Chapter 3 and describes the examples of services to be implemented. This chapter also includes analysis of and proposal for standard integration procedures with global spatial data infrastructures (GSDI) as defined by Open Geospatial Consortium (OGC). A brief introduction about localization issues in sensor networks is given in the end of this chapter.

- Chapter 5 presents the requirements on sensor networks. At first examples of related user scenarios are given describing the real events and summarising the common issues and lessons learned from these events. Both European and overseas examples are given. Requirements for sensor networks (topology, reaction time, reliability, and fault tolerance) and requirements for the radio links and coverage are presented in consequent articles of this chapter.
- Chapter 6 sums up the conclusions of the previous chapters with regard to issues that should be addressed by other workpackages. Required services and system characteristics are presented in a simple tabular form subdivided according to the scenarios and contexts.

2 SOURCES OF INFORMATION

Open source material (mainly from the internet) was searched and analysed for scenarios and experiences which was deemed relevant to WINSOC. In a number of cases emergency operation reports (especially from overseas) and background knowledge from the project team members were used to compile specific requirements. In parallel, a synthesis of the services specification and requirements from other projects such as ARMONIA, FIRELAB, EU-WIDENS, and SANY (see below) was also undertaken, building on previous work and avoiding the re-inventing of the wheel. Projects studied are enumerated in the following sections.

2.1 FP6 Projects directly related to sensors in the frame of ICT for environment

SANY (Sensors Anywhere, www.sany-ip.eu). The project is concerned with general architecture sensor web. It is an integrated project focused on interoperability of in-situ sensors and sensor networks. The SANY consortium claims that SANY architecture will provide a quick and cost-efficient way to reuse of data and services from currently incompatible sensor- and data- sources.

OSIRIS (Open Architecture for Smart and Interoperable Networks in Risk Management based on in-situ Sensors, www.ist-osiris.org). The project deals with integration in-situ, UAV, HAP, mobile sensors. OSIRIS is aimed at enhancing the overall efficiency of the in-situ data processing chain by connecting the in-situ sensors via an intelligent and versatile network infrastructure that will enable the end-users to access multi-domain sensors information. OSIRIS addresses the smart deployment, use and reconfiguration of network of sensors in the monitoring as well as in the crisis phase.

DYVINE (Dynamic Visual Network, www.dyvine.eu). The project deals with forest fires. DYVINE's aim is twofold. It focuses on the integration of thousands of video sensors, fixed or mobile, in situ or airborne, and the development of exploitation applications for area monitoring to support the risk management cycle. Secondly, it concentrates on the associated resilient communication solutions to support the system.

2.2 FP6 Emergency management and ICT relevant projects

ORCHESTRA (Open Architecture and Spatial Data Infrastructure for Risk Management, www.eu-orchestra.org). The project is concerned with information space. ORCHESTRA is aimed at designing and implementing an open service oriented software architecture that will improve the interoperability among actors involved in Multi-Risk Management.

WIN (Wide Information Network, www.win.eu.org). The project is concerned with information services. WIN's aim consists of designing an info-structure architecture based on state-of-the-art information technologies, protocols, standards aiming at interconnecting systems and processes in order to deliver complete and accurate data to role based portals, providing risk management players with up-to-date information tailored to their roles.

OASIS (Open Advanced System for Disaster and Emergency Management, www.oasis-fp6.org). It deals with operations C3. OASIS is aimed at defining and developing an information technology framework based upon an open and flexible architecture and using standards (existing or proposed by OASIS) that will be the basis of a European Disaster and Emergency Management system.

OSIRIS (Open Architecture for Smart and Interoperable Networks in Risk Management Based on In-situ Sensors). The main objectives of the OSIRIS project is to enhance the overall efficiency of the in-situ data processing chain by connecting the in-situ sensors via an intelligent and versatile network infrastructure that will enable the end-users to access multi-domain sensor information.

2.3 FP6 projects on wireless communication infrastructures development

WISECOM (Wireless Infrastructure over Satellite for Emergency Communications, www.wisecom-fp6.eu). The goal is to study, develop, and validate by life trials rapidly deployable lightweight communications infrastructures for emergency conditions. Both natural and industrial hazards are taken into account. The system will integrate several terrestrial mobile radio networks – comprising GSM, UMTS, WIFI and optionally WIMAX and TETRA – over satellite systems.

WIDENS (Wireless Deployable Network System, www.widens.org). WIDENS was aimed at designing, prototyping and validating a high data-rate, rapidly deployable and scalable wireless ad-hoc communication system for future public safety, emergency and disaster applications. WIDENS studied, developed and demonstrated a prototype broadband ad-hoc mobile radio for public safety use. The system features rapid deployment, quality of service support and security.

A prototype composed of several Linux nodes equipped with a custom PCMCIA board was demonstrated in 2006.

2.4 FP6 projects on emergency management and forest fire risk

ARMONIA (Applied multi Risk Mapping of Natural Hazards for Impact Assessment, www.armoniaproject.net) The overall aim of the research project ARMONIA is to provide the European Commission with a new harmonised methodology for producing integrated risk maps to achieve more effective spatial planning procedures in areas prone to natural disasters in Europe. One of the prominent areas of risk mapping deals with forest fire vulnerability assessment.

EU-FIRELAB (Euro-Mediterranean Wildland Fire Laboratory, a wall-less Laboratory for Wildland Fire Sciences and Technologies in the Euro-Mediterranean Region, www.eufirelab.org). The main goal of the project is the enhancement of the wildland fire sciences and technologies, and the rapid and systematic transfer towards end-users and stakeholders, incite to create this “laboratory” for effectively creating a European Research Area in the wildland/forest fire domains. EUFIRELAB is enabling large exchange of knowledge, know-how, data, results and analysis for improving the level of the wildland fire sciences and technologies in the Euro-Mediterranean area.

2.5 Other relevant projects and initiatives

FireBug system (firebug.sourceforge.net). The FireBug project describes the design of a system for wildfire monitoring incorporating wireless sensors, and report results from field testing during prescribed test burns near San Francisco, California. The system is composed of environmental sensors collecting temperature, relative humidity and barometric pressure with an on-board GPS unit attached to a wireless, networked mote. The motes communicate with a base station, which communicates the collected data to software running on a database server. The data can be accessed using a browser-based web application or any other application capable of communicating with the database server. The project serves as a proof of the concept for interoperability between sensor networks and geoinformation infrastructure.

3 CHARACTERISTICS OF USER SCENARIOS

3.1 Introduction

The methods for specifying user and organizational requirements that we plan to use are scenario building in combination with literature study. Scenario building aims to predict future situations. A scenario can be defined as a description of a possible set of events that might reasonably take place. As defined by Carroll (1997, pg. 384) scenarios are “a narrative description of what people do and experience as they try to make use of computer systems and applications. [...] user interaction scenarios are a particularly pertinent medium for representing, analysing and planning how a computer system might impact its users’ activities and experiences.” Through their strong narrative, focus scenarios help in simplifying the communication among many people involved in the design of an information system. Each person can equally contribute to the discussion, envisage problems and design solutions despite differences in knowledge and experience. Moreover, scenarios can be written at different levels of detail to accommodate the different stages of design. Thus, the first scenarios written early in the development cycle may be more vague and open, subject to modifications as the system design progresses. When choices are made, e.g. which functionalities or which interface layout the system will have, scenarios can be enlarged to include a storyboard of the user’s interaction with the final system.

One of the main purposes of developing scenarios is to stimulate thinking about possible occurrences, assumptions relating to these occurrences, possible opportunities and risks, and courses of action. Therefore a scenario is well suited to the design of new product concept. We also propose to use the results of relevant standard analysis and literature review for finalizing the scenarios.

In order to obtain a common understanding of the background for the requirements, this chapter presents user scenarios. The following characteristics should be considered when describing the technical specification in order to obtain well structured and comparable description of user scenarios:

- Scenario name
- General characteristics – general description of emergency situation, its importance and description of crises situation
- Description – verbal description of a specific scenario including expected use of sensors
- Type of situation – possible emergency management situations where WINSOC systems can be deployed includes:
 - *Day by day operations* – this type of operations expects the use of sensor data transmission required for single or multiple user communications either with control room or with backbone private or public network or retrieving the surveillance information from wireless sensors during day by day operations.

- *Emergency situations* of a various scale that includes – teams operating in one or several areas, sensor installation in such areas, operations carried out at the national and optionally also international level demanding interoperability with other systems.
- *Post Crisis Assistance* – special case in the emergency cycle which includes damage assessment (not included in WINSOC scenario) and monitoring of crises area. This specific type has been added because in the case of forest fires scenario there can come along repetitive fires. This type of operations expects the use of sensor data transmission required for single or multiple user communications either with control room or with terrain workers or retrieving the surveillance information from wireless sensors
- Operational environment – description of expected environmental conditions during the scenario and its spatial determination
 - *Indoor*: Areas of up to hundreds of meters characterised by harsh signal propagation environments. Good communication infrastructure.
 - *Urban*: Areas from hundreds of meters (district or region) to up 10 kilometres (city) with signal propagation degraded by existing obstacles caused by high building and population density. Good communication infrastructure
 - *Rural*: Areas more than 10 kilometres wide characterised by a critical signal propagation., both low population and building density are expected. The level of communication infrastructure could be low or missing
- Number of users – approximate amount and possible density of sensors operating in the scenario, a brief description of user groups and their involvement
- Use of sensors – description and proposal of sensors to be deployed in specific scenario
- Coverage area - description of the scenario sensor network including preferred architecture (hierarchy, structure) and area coverage (single spot, wide area).

3.2 Scenario 1 – Forest fire detection and fire risk estimation

3.2.1 Characteristics of scenarios

In order to provide valuable input in classifying and discussing the characteristics of user scenarios we describe application scenarios using the criteria specified in chapter 3.1.

3.2.1.1 Scenario name

Forest fire

3.2.1.2 General characteristics

Forest fire can be defined as a fire which breaks out and spreads on forest and other wooded land or which breaks out on other land and spreads to forest and other wooded land. The definition of ‘forest fire’ excludes: prescribed or controlled burning, usually with the aim of reducing or eliminating the quantity of accumulated fuel on the ground. Forest fires are caused by human activities or by natural phenomena such as lightning or volcanoes. Those caused by humans can be characterized as either intentional or accidental. Some intentional fires are the result of arson — those that are set to create havoc and cause damage. Most intentional forest fires, however, are related to forest or shrub removal to transform land for silvicultural or agricultural purposes. These forest fires are not viewed simply as a technical problem but also as a complex socioeconomic issue. The term fire in this document further refers to any forest fire in the natural environment.

3.2.1.3 Description

Managing forest fires effectively depends on information (that can vary according to the user of the information), the characteristics of the geographic region, and the current and evolving phase of the specific fire. Suppression planning and prioritisation of areas for surveillance requires assessment of the forest fire potential (risk and hazard mapping) in the fire-prone areas. During the crisis phase, it is necessary to know the exact position of the fire (detection), how it is developing and spreading (behaviour), how it has progressed over time (monitoring), and how it is likely to develop into the future (behaviour prediction). After suppression it may be necessary to examine the type and extent of damage and to plan for recovery actions (assessment, mapping, and rehabilitation). It is clear that the specific fire protection activity that has to be supported must also be identified, since this one may strongly influence the approach to the fire risk assessment procedure. In fact the context and the related fire protection tasks for which the

information on fire risk is needed can be quite different. All fire risk studies address a specific requirement. The reason why the information on fire risk is needed, and consequently who and for what purpose will have to use the information, are all relevant issues.

Different phases of the combustion process can be identified. In the simplest approach they are pre-ignition, ignition, combustion and extinction. These phases are continuously occurring during a forest fire, for which the flame front is moving in space always finding new unburned fuel.

There are three main typology types of fires according to ARMONIA project (ARMONIA 2006) classification: *ground fires*, *surface fires*, *crown fire*. From the experiences of Forest Management Institute (FMI), we propose to add a fourth type of forest fire, which request special solution and it is *under surface fire* (radical burning).

Ground fire is a fire that consumes the organic material beneath the surface litter, such as a peat fire. It normally burns without flame (smouldering combustion), being the combustion occurring in scarce oxygen, just underneath a thick organic layer on the ground. Ground fire requests specific attention in the monitoring process. This fire can appear on different places and it requires specific attention in the phase of forest detection and prediction, but also in phase of post fire assessment, when fire can start again in different places.

A surface fire is a fire that burns loose debris on the surface, which includes dead branches, leaves, and low vegetation. Therefore surface fires spread by flaming combustion through fuels at or near the surface (grass, shrubs, dead and down limbs, forest needles and leaf litter, or debris from harvesting or land clearing).



Figure 1 - Surface fire example

A crown fire is a fire that advances from top to top of trees or shrubs, more or less independent of a surface fire. Crown fires are sometimes classed as running or dependent to distinguish the degree of independence from the surface fire. The rationale behind is that the different domains of fire management have specific problems to address from which the components of fire risk may result with different emphasis, and also the proper temporal and spatial scales have to be selected accordingly.



Figure 2 - Crown fire example

It is proposed to consider the following fire management contexts:

- Fire preparedness and prediction
- Fire detection and response
- Post-fire assessment

The information requirements are typically different in each phase. The most significant differences relate to the temporal and spatial resolution and accuracy of the required information.

Context I: Fire preparedness and prediction

The most important task during the preparedness phase of forest fire management is to assess the values at risk. Conducting risk assessment studies to identify areas with the greatest potential for protecting human lives, property, and natural resources can help authorities impose greater surveillance and possible restrictions on fire use in these areas. Risk assessment considers several variables such as land use and land cover, forest fire history, demography, infrastructure, and urban interface.

Current fire detection systems can be classified as either **predictive** or **supervised**. Predictive systems are based on the knowledge of the environment and of its history. They are based on a database system that gives information that is used by models to predict fires in the interested area (or fire parameters as: probability of fire event, fuel consumption, fire intensity, fire description, fire area, growth area, . . .). Predictive systems in combination with geographic information systems (GIS) modelling are usually used during the Context I. Supervised systems are described in detail in Context II.

Use of sensors: sensor networks will be developed to support measurement of parameters allowing the prediction of forest fire danger. This entails the measurement of the following physical parameters:

- Fuel moisture content,
- Weather variables as temperature, wind, precipitation
- Relative humidity,
- Presence of CO_x

These data have to be measured in testing areas that will be selected as areas with high potential forest fire risk identified by the above mentioned GIS methodology. Sensor network will communicate with other systems via OGC SWE specification (see Chapter 6 for details).

The next scheme describes basic architecture, for forest Fire preparedness and prediction.. There are described only basic components of all architecture and possibility of deployment of sensor networks. The detail definition of all architecture is expected in WP6

The basic principle of this architecture is that there exist clusters of sensors, for measuring of physical parameters, which communicate every time only inside of one cluster, and all sensors in one cluster communicate with one sensor on level 2. The role of sensor on level 2, is to collect information from sensors on level one and propagate this information to forest protection staff (through public network or directly). The sensors position is fixed, so there is enough to measure position only one time.

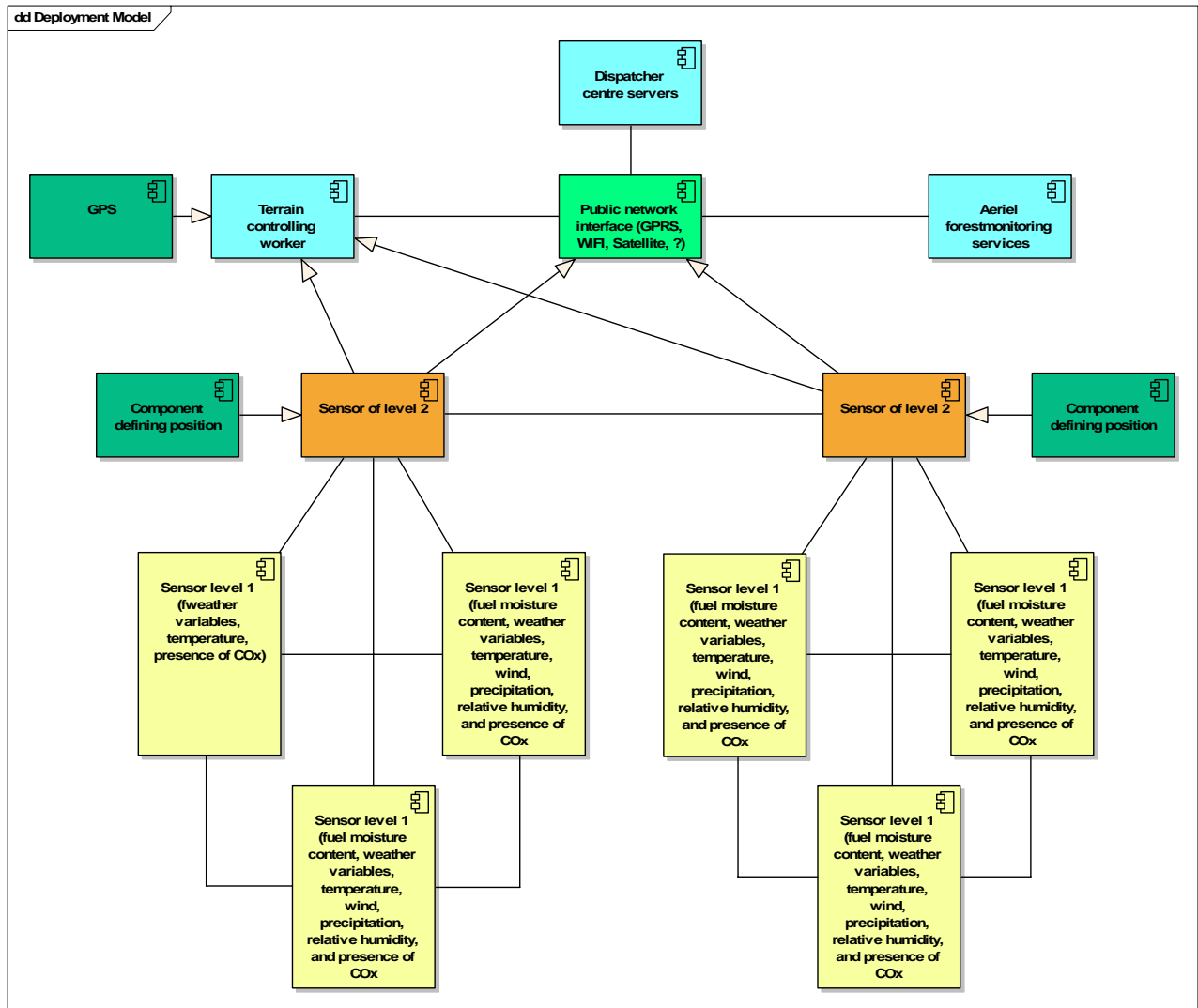


Figure 3. Context I: Fire preparedness and prediction scheme

(detail description of the scheme is in chapter 3.2.4)

The basic component of architecture on this level are:

- Protection services staff and equipment, which provide monitoring of the area
- Public communication network
- Tools for definition of position, which could be used for terrain staff or for sensors nodes on level 2 (because this network will be static, this could be done one time)

-
- Sensors on level 1, guarantee measurement of physical parameters. These sensors are organised into clusters, and every sensor communicates only with one sensor on level 2 and with all sensors in cluster.
 - Sensors on level 2, which guarantee collection of information from sensors on level 1 in single clusters, communication between clusters and communication with external environment

The detail description of single components is in next chapter describing detail scenarios.

Two temporal scales are commonly identified in fire risk estimation: short-term and long-term. In WINSOC, the focus will be only on short term risks.

Short-term fire risk estimations refer to the most dynamic factors of fire ignition or fire behaviour, mainly those based on the estimation of vegetation moisture content (either dead or live fuels) and the effect of meteorological variables on fire behaviour. Therefore short term risk estimation requires daily or also hourly information on fuel moisture content, weather variables as temperature, relative humidity, wind, and precipitation.

This kind of estimation allows organising the activity of fire pre-suppression, detection and suppression and update decisions according to changes in the fire risk level. Therefore this temporal scale has a main practical use in the update of the level of alert and in the organisation of the fire fighters actions directly on the flaming front.

Based on meteorological input data and physical, semi-physical or empirical model calculations, the Fire Danger Rating Systems provide 'indirect values' — numerical indices — at different temporal scales (e.g., daily, weekly, monthly) denoting the physical conditions that may lead to fire ignition and support fire propagation.

The results can be expressed as fire danger levels, ranging from 'low' to 'very high', and are commonly used in operational forest fire management. Today, fire danger levels are often turned into broad scale maps (with the help of GIS) showing the areas with the different fire danger levels, and are distributed via the World Wide Web.

Context II: Forest fire detection and response

To avoid or effectively reduce the damage caused by the forest fire it is necessary to reveal the places where the fire starts. Following three conditions are of critical importance:

- An alarm is to be raised when the dimensions of the fire are still small – FIRE DETECTION (the infrastructure is the same like in Context I)
- The fire is to be localised as accurately as possible to minimise spreading - FIRE LOCALISATION (the infrastructure is the same like in Context I)

In geographic areas requiring rapid response, it is necessary to develop an operational sensor forest fire detection and monitoring system with an ultimate detection time of 5 minutes, repeat time of 15 minutes, spatial resolution of 250 meters, a maximum 5 percent false alarm rate, with real time data transmission to local ground stations or an information distribution system.

- Intervention to put out the fire has to occur as quickly as possible – EFFECTIVE FIRE FIGHTING

The next part of description is focused on Effective Fire Fighting. **Supervised monitoring and detecting systems** incorporates the real time detection of fires relying on networks of sensors. The types of sensors differ by the methodology of monitoring and types of supervision: human, video, satellite, infrared, chemical, etc.. The immediate sighting of the fires and the rapid communication to intervention centres are the base for efficient fire extinguishing strategy.

Substantial part of signalling originated from the public and even today the majority of sightings are done with human intervention. Other technological systems are based on ground sensors like video, IR or on satellite. Active forest fires can be satellite-detected by either sensing their thermal or mid-infrared signature during the day or night, or by detecting the light emitted from the forest fires at night. The sensors must also have frequent over flights with data available in near real time. The spectral, spatial, and temporal resolutions of current satellite platforms do not adequately meet the need for real-time detection of forest fires.

Nowadays, there exist spatial datasets covering the whole Czech territory available online as open web map services, which allow providing effective mapping background for localisation and monitoring of forest fires. The system supports different types of geographic data - vector maps, aerial photos or satellite imagery. The system is built to support management of crisis events, but is mainly active in pre-ignition phase of forest fires. The basic technology, which is used in the period of forest dangers, is aerial monitoring, based on airplane equipments. However, this technology is expensive and can recognise forest fire events only after they have started. Certain kind of prevention could use infrared or thermal cameras, but again this kind of monitoring is very expensive.

The use of wireless sensor networks could contribute to overcome some of the above mentioned drawbacks. Assume that a network of low-cost wireless sensors has been deployed in the fire-prone areas identified during the Context I phase. Sensors could be also installed in fire fighting vehicles or even can be carried out by personnel involved in surveillance and extinguishing activities. Then, mobile sensor issues are relevant in the scenario.

The application of wireless sensor networks to fire detection has been proposed by different authors. In fact sensor nodes capable of detecting high temperature or heat exist. It could be also possible to use other sensors (i.e. carbon monoxide) to detect physical phenomena related to the presence of a forest fire. The new and promising technology seems to be Smart dust sensors, which could be distributed from aircrafts during forest fire events

The proposed system to be used in Context II is composed of ad hoc networks with large scale amount of smart dust sensors monitoring forest fire front contour and with under surface (ground) sensors measuring changes of under surface temperature.. The ad hoc networks communicate with a base station sensors, which supplies the collected data to software running on a database server. The data can be accessed using a browser-based web application or any other application capable of communicating with the database server

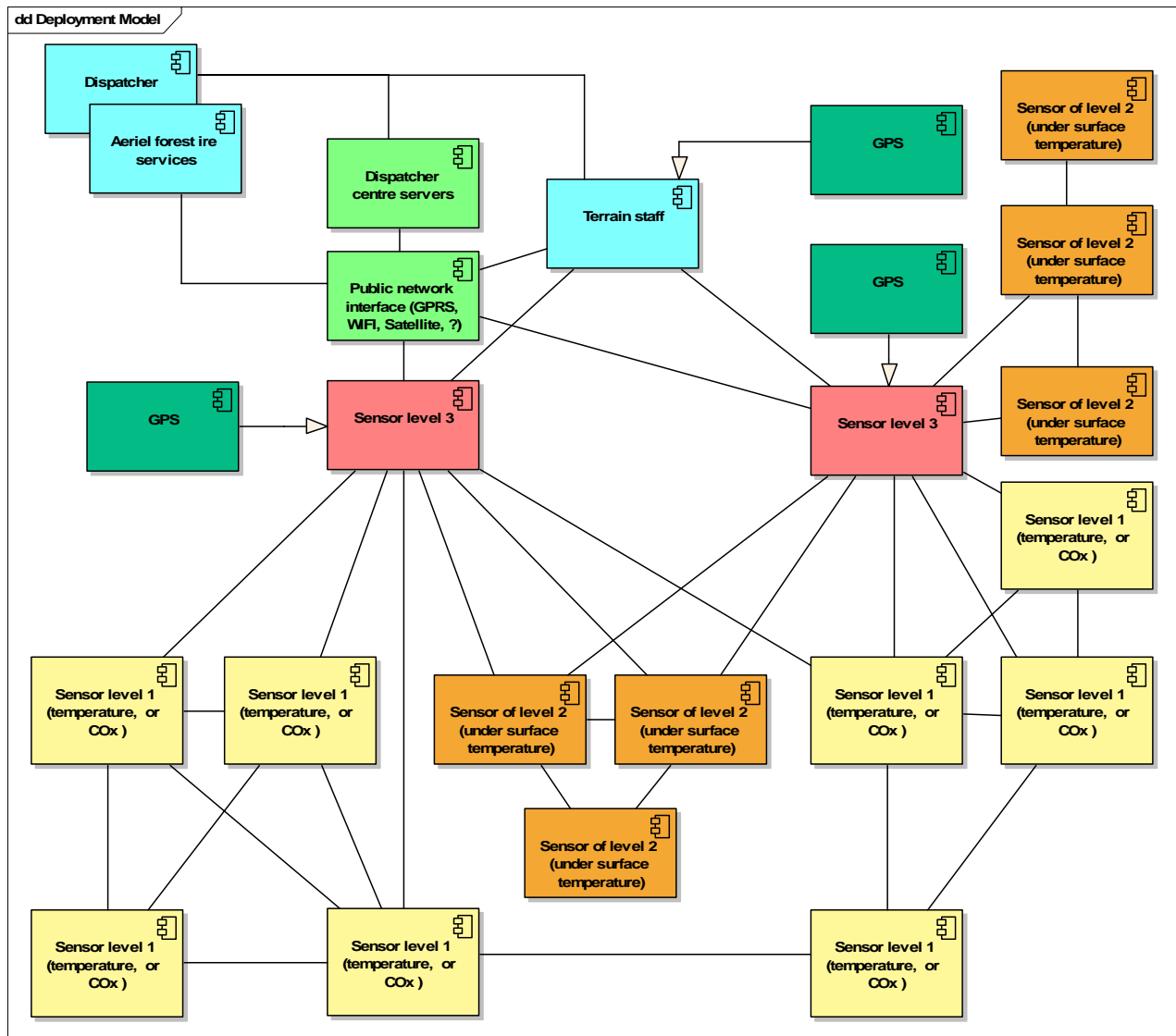


Figure 4 - Context II: Forest fires detection and respon

(detail description of the scheme is in chapter 3.2.4)

- Protection services staff and equipment, which fights against fire
- Public communication network and network of fire protection services
- Tools for definition of position, which could be used for terrain staff or for sensors nodes on level 3. the networks could change their topology, so there is necessary permanent presence of GPS

- Ad Hoc Network of Smart dust Sensors on level 1, measuring temperature. This network has ah hoc topology, which is continuously changed, when part of sensors is destroyed. The sensors calculate their position from position of base station sensor networks
- Sensors on level 2, which guarantee measure under ground temperature. This network has ah hoc topology, which is continuously changed, when part of sensors is destroyed. The sensors calculate their position from position of base station sensor networks
- Sensors on level 3, which guarantee collection of information from sensors on levels 1 and 2, communication between networks on level 3 and communication with external environment

-

On the other hand, it should be noted that the scenario involves different kinds of cooperating objects of different size and characteristics. Thus, for example, personnel device assistants (PDAs) can be used to have updated information from the environment and to guide the operational extinguishing personnel. Portable field computers and laptops on board vehicles are useful for surveillance and fire fighting. Satellite positioning systems, can also be used integrated with PDAs, portable computers and laptops to know in real time the absolute position of people and vehicles.

Context III: Post-fire assessment

The most important post-crisis activity in forest fire management is the assessment of the burned area and protection of watersheds and critical resources. Although remote sensing has already proven its usefulness in this activity, very few authorities use space-borne data operationally for assessment of forest fire damage. With space-borne remote sensing, the forest fire damage or the extent of burned area is determined by the single-date or multi-temporal analysis of the images. In this scenario, we will focus on under surface (ground) temperature monitoring, to prevent new start of forest fire.

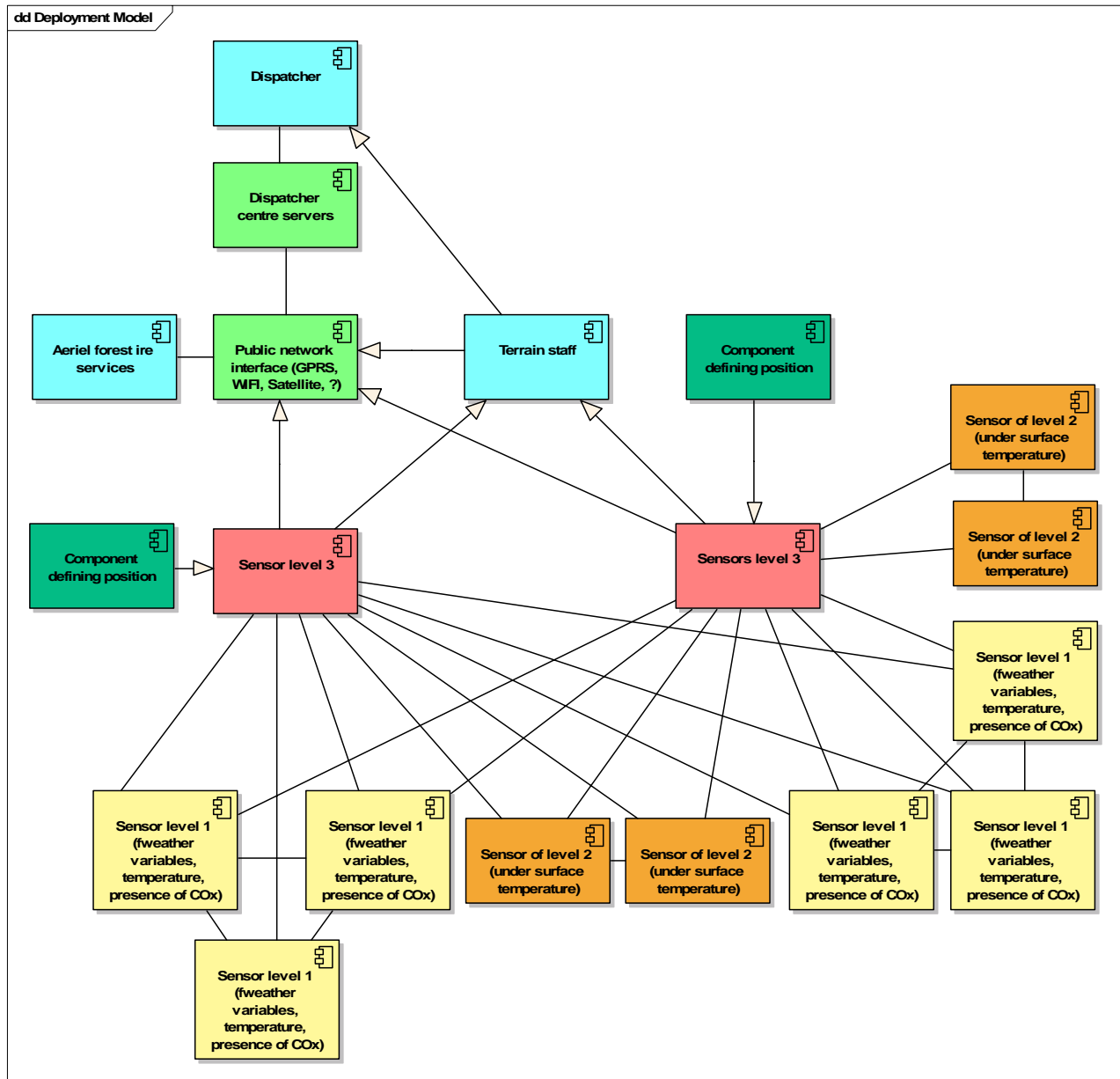


Figure 5 - Context III: Post-fire assessment

(detail description of the scheme is in chapter 3.2.4)

- Protection services staff and equipment, which fights against fire
- Public communication network and network of fire protection services
- Tools for definition of position, which could be used for terrain staff or for sensors nodes on level 3.

-
- Sensors on level 1, guarantee measurement of physical parameters. This network has ah hoc topology, which could be changed. The sensors calculate their position from position of base station sensor networks
 - Sensors on level 2, which guarantee measure under ground temperature. This network has ah hoc topology, which could be changed, when part of sensors is destroyed. The sensors calculate their position from position of base station sensor networks
 - Sensors on level 3, which guarantee collection of information from sensors on levels 1 and 2, communication between networks on level 3 and communication with external environment

3.2.2 Type of situation

The situations are described on the base of terms defined in chapter 1. These are common characteristics, used in selected scenarios description methodology.¹

Context I: Fire preparedness and prediction

The Fire preparedness and prediction is type of Day by day operations – this type of operations expects the use of sensor data transmission required for single or multiple user communications either with control room or with backbone private or public network or retrieving the surveillance information from wireless sensors during day by day operations. The period of activity depend on weather conditions in Middle of Europe it will be usually from June till September, in Mediterranean from April till November, but the network has wake up in any time, if the temperature changes is more then 5 degrees during ten minutes – exact numbers has to be evaluated in later stages)

Context II: Forest fires detection and response

On the dependence of the scale of event, the forest fires detection and response could be or emergency situation, when teams operating in one or several areas and sensors are installation in such areas, operations carried out at the national and optionally also international level demanding interoperability with other systems.. The period of activity is during emergency events, it is expected, that big part of infrastructure will be destroyed, the remaining sensors of level two and three will be removed) or large-scale disaster. The period of activity is during emergency events, it is expected, that big part of infrastructure will be destroyed, the remaining sensors of level two and three will be removed)

Context III: Post-fire assessment

¹ Scenario-based design (Rosson & Carroll, 2002) methodology

Post-fire assessment is typical example of Post Crisis Assistance.- this type of operations expects the use of sensor data transmission required for single or multiple user communications either with control room or with terrain workers or retrieving the surveillance information from wireless sensors

The assistance is provided for few days after emergency situation, tens (has to be estimated later). Part of infrastructure could be destroyed; the rest will be removed after the period }

3.2.3 Operational environment

All three contexts are typical rural context. In this rural context it is necessary taken into account, that connection to public network could be limited and it is important to guarantee accessibility of information not only inside of wireless sensor network, but also with the rest of the world. So it is necessary to design an infrastructure that enables communication with rest of the world (through dispatcher centre) will go through more channels. Information from any node has to be eventually transmitted through other nodes and for emergency situation and large scale disasters is necessary to build temporal communication infrastructure, which will not depend of accessibility of existing infrastructures.

3.2.4 User groups

In all three contexts, there will take part following users (service providers) of system

- Forest Fire Protection Services
 - Dispatcher
 - Terrain workers
 - Aerial forest protection services²
 - Aerial forest fire monitoring service³
- Forest Management Institute
- Regional Government
- Local Governments
- CCSS (Lesprojekt sluzby and Help Forest as CCSS members)

Context I: Fire preparedness and prediction

- Forest Fire Protection Services

² It will not be solved inside of WINSOC, but in synergy with other relevant projects GeoKrima and c@r

³ It will not be solved inside of WINSOC, but in synergy with other relevant projects GeoKrima and c@r

-
- Dispatcher
 - Terrain workers
 - Aerial forest fire monitoring service⁴
 - Forest Management Institute
 - Regional Government
 - Local Governments
 - CCSS (Lesprojekt sluzby and Help Forest as CCSS members)

Context II: Forest fires detection and response

- Forest Fire Protection Services
 - Dispatcher
 - Terrain workers
 - Aerial forest protection services⁵
 - Aerial forest fire monitoring service⁶
- Forest Management Institute
- Regional Government
- Local Governments
- CCSS (Lesprojekt sluzby and Help Forest as CCSS members)

Context III: Post-fire assessment

- Forest Fire Protection Services
 - Dispatcher
 - Terrain workers
 - Aerial forest fire monitoring service⁷
- CCSS (Lesprojekt sluzby and Help Forest as CCSS members)

⁴ It will not be solved inside of WINSOC, but in synergy with other relevant projects GeoKrima and c@r

⁵ It will not be solved inside of WINSOC, but in synergy with other relevant projects GeoKrima and c@r

⁶ It will not be solved inside of WINSOC, but in synergy with other relevant projects GeoKrima and c@r

⁷ It will not be solved inside of WINSOC, but in synergy with other relevant projects GeoKrima and c@r

3.2.4.1 Service provider goals.

There will be in the scenario necessary to established interaction between different types of organisation, which will realised test of the scenario. The next paragraph define role of single actors in the scenarios. The roles are focused to integrate the sensors network to infrastructure for forest fire protection (WP6) and provide practical validation of system (WP7)

Context I: Fire preparedness and prediction

Forest Management Institute

- To identify forest fire prone areas

CCSS

- Established infrastructure

Forest fire dispatcher centre or regional government or local government

- Predict dangerous situation

Context II: Forest fires detection and response

Forest Management Institute

- Information support

CCSS

- Infrastructure support

Forest fire service dispatcher

- Manage action leading to elimination of forest fire and manage cooperation of different constituent (professional, fire protection services, voluntary fire protection services, aerial fire protection services)

Regional government or local government

- Protection of citizens live and possessions

Terrain workers of forest protection services

- Eliminate forest fire

Aerial forest protection services⁸

- Eliminate forest fire

Context III: Post-fire assessment

CCSS

⁸ It will not be solved inside of WINSOC, but in synergy with other relevant projects GeoKrima and c@r

- Infrastructure support

Forest fire service dispatcher

- Monitor the danger of restarting of the forest fire

Terrain workers of forest protection services

- Monitor of dangerous of restarting of forest fire

3.2.4.2 Number of users

Context I: Fire preparedness and prediction

Forest fire dispatcher centre or regional government or local government – limited number of persons

Context II: Forest fires detection and response

Forest fire service dispatcher – limited number of persons

Regional government or local government – limited number of persons in dependence on scale of forest fire

Terrain workers of forest protection services – large number of terrain workers in dependence on the scale of forest fire

Aerial forest protection services – limited number of aircrafts

Aerial forest fire monitoring service – one aircraft

Context III: Post-fire assessment

Forest fire service dispatcher - limited number of person

Terrain workers of forest protection services - limited number of person

Aerial forest fire monitoring service - one aircraft

3.2.5 Coverage area

Context I: Fire preparedness and prediction

There could be covered large area till 50 km² allocated on the base of previous geographical analysis of forest typology. It is expected, that in average, there will be maximum 4 sensors clusters per km².

Context II: Forest fires detection and response

There could be covered relatively smaller area usually till 5 ha, only in the case of large disasters; there will be covered area of more km².

Context III: Post-fire assessment

There could be covered relatively smaller area usually till 5 ha, only in the case of large disasters; there will be covered area of more km².

3.2.6 Components of WINSOC architecture,

There are described the components of WINSOC architecture according Figure 1, 2 and 3. The text explains the role and functionality of single components.

Context I: Fire preparedness and prediction

Dispatcher server is the main place, where all data from all networks, but also other data accessible trough Web services. It guarantees also communication with other actors and dispatcher server also guarantee functionality, which is necessary for identification of forest fire event. The main functions are next:

- GIS analysis tool and methodology for evaluation of fire endangered areas
- Collection and storing of data from sensors
- Sharing data with other data sources

Communication module guarantee communication between wireless sensor network and Web environment: The potential communication technologies could be (GPRS, WIFI, WIMAX, VSAT). Communication is running on the base of OGC SWE specification

Aerial monitoring platform provide aerial monitoring of the areas, which could be potentially affected by forest fires. The goal of sensor technologies is limited this expensive monitoring⁹

The basic infrastructure for collection of data is formed by human distributed network of sensors level 1 monitoring fuel moisture content, weather variables, temperature, wind, precipitation, relative humidity, and presence of CO_x. Every sensor measure only one parameter¹⁰

- Sensors are “alert ready” and able to communicate with other sensors of level 1 and with one sensor of level 2
- Every sensor has to be able to communicate with all others sensors of level 1 in one cluster - Distance of two sensors of level 1 in one cluster is maximum ten meters
- Every sensors of level 1 has to communicate with one sensor of level 2 in its cluster. The communication is one directional
- Sensors on level 1 don't need to know their geographic position

This basic level of sensor network communicate trough human distributed network of sensors level 2, which don't measure environmental parameters, but, which guarantee transfer of

⁹ It will not be solved inside of WINSOC, but in synergy with other relevant projects GeoKrima and c@

¹⁰ Exact communication parameters are described in chapter 5

communication in wireless network¹¹ The distance of two communicated sensors of level 2 is till one kilometre

- Sensors of level 2 know their own position (or its position is stored on the dispatcher server). It is enough to measure exact position one time, the position is not changed
- Sensors of level 2 are “alert ready” and able to communicate with dispatcher server or terrain worker by sensor web notification services. The communication is one directional
- Sensors of level 2 are able to collected information from all servers of level 1 in cluster and transfer relevant information on dispatcher server
- Sensors of level 2 need to communicate with other sensors of level 2 (not with all). The distance of two communicating servers is expected till one kilometre
- Sensors of level 2 need to have capability to transmit information from other sensors of level 2 to dispatcher server or terrain workers There is not guarantee, that all sensors of level 2 will have permanent access to public network

The terrain controls could be realised also by terrain worker providing regular control of the are. He need eventually communicate with dispatcher centre or with sensors. If he will use communication with sensors level, he will communicate trough sensors on second level ¹²

- Equipped by PDA with GPS and communication interface (GPRS, WIFI)
- Terrain work has to communicate with Web environment and with Sensor level 2

Context II: Forest fires detection and response

Dispatcher is person sitting in the office, who manages all actions trough dispatcher server or eventually trough voice channel. The main tasks provided by dispatcher are

- Manage all action
- He uses information from dispatcher server from sensors
- He communicates with terrain worker or trough public network interface or trough network of sensors level 3 or trough voice channel

Dispatcher server is the main place, where all data from all networks, but also other data accessible trough Web services. It guarantees also communication with other actors and dispatcher server also guarantee functionality, which is necessary for identification of forest fire event. The main functions are next:

- GIS analysis tool and methodology for evaluation of fire endangered areas
- Collection and storing of data from sensors

¹¹ Exact communication parameters are described in chapter 5

¹² Exact communication parameters are described in chapter 5

- Sharing data with other data sources

Communication module guarantee communication between wireless sensor network and Web environment: The potential communication technologies could be (GPRS, WIFI, WIMAX, VSAT). Communication is running on the base of OGC SWE specification.

Aerial monitoring platform provide aerial monitoring of the areas, which is affected by forest fires. It could also distribute sensor network.¹³

Terrain workers in this content are humans, cars or aerial forest fire protection services. In the emergency situations, they have next requirements on sensor network.

- They need to communicate with sensor network of level 3
- They need to communicate with dispatcher using either a voice channel or a Web environment or information could be transmitted trough sensors of level 3
- They need to communicate to each others or using voice channel or through communication data network, or information could be eventually transited through sensor network of level 3

An airplane traverses a fire region and deploys massive numbers of small sensors (sensors of level 1). There is minimum one sensor per 100 m². This sensors provide monitoring temperature or COx. There are next requirements on sensors.

- The sensors of level 1 randomly scatter spatially as they land
- The sensors level 1 self-organize into an ad hoc network such that information can be transmitted in a multi-hop route to a sensors level 3 - The sensors could be destroyed during the fire. This possibility has to be monitored
- Sensors of level 1 are continuously monitoring the situation and are able to communicate with other sensors of level 1 and directly or through other sensor on level 1 with a minimum of one sensor of level 3
- Every sensor has to be able to communicate with more other sensors of level 1 - Distance of two sensors of level 1 is approximately 10 meters
- Every sensor of level 1 has to communicate directly or indirectly with minimum one sensor of level 3.. The communication is uni-directional
- Sensors on level 1 need to know their geographic position (calculated from network parameters)
- The sensors monitor and report forest fire front contour

Second part of system is network of sensors level 2, which is distributed human, measuring under surface (ground) temperature. The sensors measure temperature in three different depths. They will be in three lines around fire front. The distance between two sensors will be ten meters The

¹³ It will not be solved inside of WINSOC, but in synergy with other relevant projects GeoKrima and c@r

sensors of level 2 self-organize into an ad hoc network such that information can be transmitted in a multi-hop route to a sensor of level 3 - The sensors could be destroyed during the fire. This possibility has to be monitored by network There are basic requirements on sensors

- Sensors of level 2 continuously monitoring the situation and are able to communicate with other sensors of level 2 and directly or through other sensor on level 2 with a minimum of one sensor of level 3
- Every sensor has to be able to communicate with more other sensors of level 2 - Distance of two sensors of level 2 is approximately 10 meters
- Every sensor of level 2 has to communicate directly or indirectly with a minimum of one sensor of level 3. The communication is uni-directional
- Sensors on level 2 need to know their geographic position (calculated from network parameters)
- The sensors of level 2 monitor and report under ground forest fire

Both networks communicate with human distributed network of sensors of level 3, which don't measure environmental parameters, but, which guarantee transfer of communication in the wireless network¹⁴ The distance of two communicating sensors of level 3 is till 500 meters. There are next requirements on this network

- Sensors of level 3 know their own position, they are equipped by GPS. Their position could be changed during forest fire
- Sensors of level 3 are "alert ready" and able to communicate with dispatcher server or terrain worker by sensor web notification services. The communication is bi-directional
- Sensors of level 3 are able to collected information from all sensors of level 1 and 2 and transfer relevant information on dispatcher server and to terrain workers
- Sensors of level 3 need to communicate with other sensors of level 3 (not with all). The distance of two communicating sensors is expected till one kilometre
- Sensors of level 3 need to have capability to transmit information from other sensors of level 3 to dispatcher server or terrain workers There is no guarantee that all sensors of level 3 will have permanent access to public network

Context III: Post-fire assessment

Dispatcher is person sitting in the office, who manages all actions trough dispatcher server or eventually trough voice channel. The main tasks provided by dispatcher are

- Manages all action

¹⁴ Exact communication parameters are described in chapter 5

-
- He uses information from dispatcher server from sensors
 - He communicates with terrain worker either through public network interface or through network of sensors level 3 or through voice channel

Dispatcher server is the main place, where all data from all networks, but also other data accessible through Web services. It guarantees also communication with other actors and dispatcher server also guarantee functionality, which is necessary for identification of forest fire event. The main functions are next:

- GIS analysis tool and methodology for evaluation of fire endangered areas
- Collection and storing of data from sensors
- Sharing data with other data sources

Communication module guarantee communication between wireless sensor network and Web environment: The potential communication technologies could be (GPRS, WIFI, WIMAX, VSAT). Communication is running on the base of OGC SWE specification.

Aerial monitoring platform provide aerial monitoring of the areas, which is affected by forest fires. It could also distribute sensor network.¹⁵

Terrain workers in this content are humans, cars or aerial forest fire protection services. In the emergency situations, they have next requirements on sensor network.

- They need to communicate with sensor network of level 3
- They need to communicate with dispatcher using or voice channel or Web environment or information could be transmitted through sensors of level 3
- They need to communicate to each others or using voice channel or through communication data network, or information could be eventually transited through sensor network of level 3

The basic part of the system is human distributed network of sensors level 1 monitoring fuel moisture content, weather variables, temperature, wind, precipitation, relative humidity, and presence of CO_x. Every sensor measures only one parameter¹⁶. (Approximately one sensor per one hectare)

- The sensors level 1 self-organize into an ad hoc network such that information can be transmitted in a multi-hop route to a sensors level 3 - The sensors could be destroyed during restart of the fire. This possibility has to be monitored
- Sensors level 1 are continuously monitoring the situation and are able to communicate with other sensors of level 1 and directly or through other sensor on level 1 with minimum one sensor of level 3

¹⁵ It will not be solved inside of WINSOC, but in synergy with other relevant projects GeoKrima and c@r

¹⁶ Exact communication parameters are described in chapter 5

-
- Every sensor has to be able to communicate with other sensors of level 1 - Distance of two sensors of level 1 is approximately 100 meters
 - Every sensors of level 1 has to communicate directly or indirectly with minimum one sensor of level 3.. The communication is uni-directional
 - Sensors on level 1 need to know their geographic position (calculated from network parameters)
 - The sensors monitor and report forest fire restart

The second part of solution is human distributed network of sensors measuring under surface temperature (approximately one sensor per 100 m²)

- The sensors of level 2 self-organize into an ad hoc network such that information can be transmitted in a multi-hop route to a sensors level 3 - The sensors could be destroyed during the fire. This possibility has to be monitored
- Sensors of level 2 are continuously monitoring the situation and are able to communicate with other sensors of level 2 and directly or through other sensor on level 2 with minimum one sensor of level 3
- Every sensor has to be able to communicate with other sensors of level 2 - Distance of two sensors of level 2 is approximately 10 meters
- Every sensor of level 2 has to communicate directly or indirectly with minimum one sensor of level 3.. The communication is uni-directional
- Sensors on level 2 need to know their geographic position (calculated from network parameters)
- The sensors of level 2 monitor and report under ground forest fire

Both networks communicate with human distributed network of sensors of level 3, which don't measure environmental parameters, but, which guarantee transfer of communication in wireless network¹⁷. The distance of two communicating sensors of level 3 is till 500 meters

- Sensors of level 3 know their own position, they are equipped by GPS, their position could be changed during forest fire
- Sensors of level 3 are “alert ready” and able to communicate with dispatcher server or terrain worker by sensor web notification services. The communication is bi-directional
- Sensors of level 3 are able to collected information from all sensors of level 1 and 2 and transfer relevant information on dispatcher server and to terrain workers
- Sensors of level 3 need to communicate with other sensors of level 3 (not with all). The distance of two communicating servers is expected till one kilometre

¹⁷ Exact communication parameters are described in chapter 5

- Sensors of level 3 need to have capability to transmit information from other sensors of level 3 to dispatcher server or terrain workers There is no guarantee, that all sensors of level 3 will have permanent access to public network

3.2.6.1 Usage environment,

Context I: Fire preparedness and prediction

In this case, there are two levels of sensor. Sensors of level 1 organised into clusters. This sensor networks will be developed to support measurement of parameters allowing the prediction of forest fire danger. This entails the measurement of the following physical parameters:

- Fuel moisture content,
- Weather variables as temperature, wind, precipitation
- Relative humidity,
- Presence of CO_x

These data have to be measured in testing areas that will be selected as areas with high potential forest fire risk identified..

All sensors in one cluster communicate with one sensor on level 2. The role of sensor on level 2, is to collect information from sensors on level one and propagate this information to forest protection staff (through public network or directly). The sensors position is fixed, so there is enough to measure position only one time. For the distributed network of sensors is expected next environment:

- Sensors are supposed to work under following condition - temperature during monitoring period could vary from 0 C till 120 C, in sleeping period (winter) the temperature could decrease till – 40. Humidity could change between 0% and 100% (sensors are intended for forest fire vulnerability measurements and information transmission). Sensor network could be eventually removed during winter period.
- The functionality for all levels of sensors, without assistance of human need to be at least half a year
- Between sensors of level 2 (multihop) communication on longer distances minimum 1500 m). It is important to use non licensed spectrum
- There is no guarantee, that all sensors on level 2 will have connection to public network. To guarantee of the connection for all network, there is requirement that every sensor has to be able to transmit information from other sensors.
- Communication between sensors on level 1 or between sensor level 1 and sensor level 2 till 30 meters (single hop)

-
- Sensors of level 1 mainly measure gradient of changes for single parameters and control maximal or minimal value of parameters. The information is sent, when gradient is higher than certain limit or when the measured value reach the minimal or maximal values¹⁸
 - After recognition of rapid changes of measured parameters gradient, information has to be transited maximum till 5 minutes to dispatcher centre and network has to wake up. From this time continuous monitoring runs. After such situation network continue in measurement of the parameters and their immediately transmission to dispatcher centre. The measurement is finished on the base of confirmation from dispatcher or terrain worker
 - All sensors of level 2 will know their own position, the position could be measured only one time, because network is fixed. There is not need to have GPS on node, only when node is placed, position is measured
 - For sensors of level 1 is not necessary to know their position
 - In this case it is not expected, that sensors will be usually destroyed during the fire, it could happen randomly
 - Direct communication with terrain workers on demand, possibly trough IP protocol
 - Communication over IP with dispatcher necessary
 - Local computing in network probably not necessary

Context II: Forest fires detection and response

The proposed system to be used in Context II is composed of ad hoc networks with large scale amount of smart dust sensors monitoring forest fire front contour (level 1) and with under surface (ground) sensors measuring changes of under surface temperature(level 2). The ad hoc networks communicate with base station sensors (level; 3), which supplies the collected data to software running on a database server.

So there are two levels of sensors monitoring forest fire. In first case an airplane traverses a fire area and deploys massive numbers of small sensors (Smartdust) Sensors level 1. There are next condition on sensors, due to environment:

- Tolerance of sensors on clash
- Extreme condition on the borderline of forest fire. On the base of published information from project FireBug it could be recognised, that sensors within the burn zone recorded the passage of the flame front before being scorched, with temperature increasing, and barometric pressure and humidity decreasing as the flame front advanced. Temperature gradients up to 5 C per second were recorded. The data also show that the temperature slightly decreases and the relative humidity slightly increases from ambient values

¹⁸ Due the fact, that these values are not currently known from literature, this range has to be designed in D2.2 and then checked and evaluated in practical experiment in WP6 and WP7.

immediately preceding the flame front, indicating that locally significant weather conditions develop even during relatively cool, slow moving grass. The maximum temperature recorded was 95 C, the minimum relative humidity 9%, and barometric pressure dropped by as much as 25 mbar.

- Communication on short distances till 30 metres between level one sensors or between sensor of level 1 and sensor of level 3
- The functionality is expected till one week
- Ad hoc establishing of topology
- Part of the sensors will be destroyed, this fact has to be monitored
- Not all sensors of level 2 will reach directly sensors of level 3, so information has to be transmitted
- Topology of network will be changed during the process
- Sensors will not be equipped by GPS
- Sensors will calculate their positions from known positions of level 3 sensors and from network
- Fast response necessary till 1 second
- Fault tolerance important
- Communication with dispatcher through level 3 node using IP protocol
- Communication with rescue team through IP through level 3 sensors
- Local computing necessary – detection of forest fire border line

The second part of architecture is a human distributed network of sensors measuring under surface temperature. There are next requirements on this network:

- Extreme condition on the borderline of forest fire (see below)
- Communication on short distances till 30 meters
- The functionality is expected till one week
- Ad hoc establishing of topology
- Topology will be given by border of line
- Part of the sensors could be destroyed, this fact has to be monitored
- Part of the sensors could be positioned on other place
- Topology of network will be changed during the process
- Sensors will not be equipped by GPS,

-
- Sensors will calculate their positions from known positions of second level sensors and from network
 - Fast response necessary till one second
 - Fault tolerance important
 - Communication with dispatcher through second level node using IP protocol
 - Communication with rescue team through IP through second level node
 - Local computing necessary – detection of places with under surface fire

The communication between both systems of sensors, dispatcher centre and forest fire protection team is organised through the human distributed sensors of level 3. There are next requirements or conditions for sensors level 3

- The sensors could be mobile, they could change their position
- Relatively standard conditions, which means that temperature during monitoring period could change from 0 C till 120 C, in sleeping period (winter) the temperature could decrease till – 40. Humidity could change between 0% and 100% (sensors are intended for forest fires vulnerability measurements and information transmission). Sensor network could be eventually removed during winter period.
- The functionality without assistance of human need to be minimal one week
- Between sensors of level 3 communication on longer distances reached by multihop (minimum 1500 m). It is important to use non licensed spectrum
- Communication with public network or with terrain workers for sensors of level 3 is not guaranteed connection to public network. To guarantee of the connection for all network, there is requirement that every sensor has to be able to transmit information from other sensors.

Context III: Post-fire assessment

The most important post-crisis activity in forest fire management is the assessment of the burned area and protection of watersheds and critical resources. In Context III: Post-fire assessment we will focus on under surface (ground) temperature monitoring, to prevent new start of forest fire. Protection services staff and equipment, which fights against fire. The system is composed from next sensor components

The human distributed sensors of level 1, which guarantee measurement of physical parameters. This network has ad hoc topology, which could be changed. The sensors calculate their position from position of base station sensor networks

- Extreme condition on the borderline of forest fire. See below
- Communication on middle distances till 150 metres between level one sensors or between sensor of level 1 and sensors of level 3

- The functionality is expected till one week
- Ad hoc establishing of topology
- Part of the sensors will be destroyed, this fact has to be monitored
- Not all sensors of level 2 will reach directly sensors of level 3, so information has to be transmitted
- Topology of network will be changed during the process
- Sensors will be not equipped by GPS
- Sensors will calculate their positions from known positions of level 3 sensors and from network
- Fast response necessary till 1 second
- Fault tolerance important
- Communication with dispatcher trough level 3 node using IP protocol
- Communication with rescue team trough IP through level 3 sensors
- Local computing necessary – detection of forest fire border line

The second par of system is the human distributed network of sensors on level 2, which guarantee measure under ground temperature. This network has ah hoc topology, which could be changed, when part of sensors is destroyed. The sensors calculate their position from position of base station sensor networks

- Extreme condition on the borderline of forest fire (see below)
- Communication on short distances till 30 meters
- The functionality is expected till one week
- Ad hoc establishing of topology
- Topology will be given by border of line
- Part of the sensors could be destroyed, this possibility has to be monitored
- Part of the sensors could be positioned on other place
- Topology of network will be changed during the process
- Sensors will not be equipped by GPS,
- Sensors will calculate its positioning form known position of second level of sensors and from network
- Fast response necessary till one second
- Fault tolerance important

- Communication with dispatcher through second level node using IP protocol
- Communication with rescue team through IP through second level node
- Local computing necessary – detection of places with under surface fire

Communication with external world is running through human distributed network of sensors on level 3, which guarantee collection of information from sensors on levels 1 and 2, communication between networks on level 3 and communication with external environment

- The sensors could be mobile, they could change their position
- Relatively standard conditions, which means that temperature during monitoring period could change from 0 C till 120 C, in sleeping period (winter) the temperature could decrease till – 40. Humidity could change between 0% and 100% (sensors are intended for forest fires vulnerability measurements and information transmission). Sensor network could be eventually removed during winter period.
- The functionality without assistance of human need to be minimal one week
- Between sensors of level 3 multihop communication on longer distances (minimum 1500 m). It is important to use non licensed spectrum
- Communication with public network or with terrain workers for sensors of level 3 is not guaranteed for every sensor, so sensors of level 3 have connection to public network. To guarantee of the connection for all network, there is requirement that every sensor has to be able to transmit information from other sensors.

3.2.6.2 Required data and services

This section described data and services, which are necessary for effective providing of forest fire protection services. The session expected, that all architecture will be built on base of OGC we services, where all data and services are accessible through standardised interfaces and are shared by all team.

Context I: Fire preparedness and prediction

Data from sensors are accessible through OGC's SWE standardized interfaces, which support their effective sharing. In this scenario is not expected, that data are transferred all time, but only in some alert cases. This alert cases for sensor level 1 are in the cases, when

- fuel moisture content in %, critical level is 10%,
- temperature in C, critical level of change is 5° C during one minute
- wind ms scale from 0 m/s till 50m/s no critical limit and no critical change
- relative humidity in %, critical level is 10%,

- Presence of COx. Critical level is 35 ppm¹⁹
- Need to be able to calibrate sensors according local conditions before deployment

In this scenario no direct data are measured by sensor level 2, they can only derivate information from sensors on level 1.

For Earth observation data we expected accessibility of services giving access to EO thematically classified data for forest fire vulnerability

Forestry related data services are important for assessment of forest fire vulnerability. We expected, that this assessment will be done on base of

- Forest typology maps
- Forest functionality maps
- Flammability of forest types
- Forest fire vulnerability maps

For managing of events there will be officially collected forest fire data and information includes:

- Climatology and meteorology (precipitation, temperature, air pressure, evapotranspiration, wind speed, and wind direction)
- Terrain configuration (vegetation type, slope inclination and orientation, soil type and humidity)
- Transportation network (roads, forest trails)
- Fire vulnerability maps for regions and particular forest types
- Classified satellite images
- Water sources and networks

Localisation services will included next functions

- Localisation of forest fire prone areas
- Localisation of sensors
- Localisation of potential water sources
- Localisation of transport network

Context II: Forest fires detection and response

¹⁹ All these values are only initial estimation; this value has to be practically clarified during second six month of the project and during practical experiments. There are no relevant source in literature, which will give clear estimation of this values

Context I: Fire preparedness and prediction

Data from sensors are accessible through OGC's SWE standardized interfaces, which support their effective sharing. Data from sensors on level 1 are collected continuously during all event. There are collected next information from sensors level 1 monitoring environmental variable

- They calculate at the beginning its position on the base of position of sensors level 3 and network information
- They measure absolute temperature in scale from – 40 till 120, output is contour lines of equal temperature
- They measure gradient of changes. The result is alarm in the case, if there is for five second change higher then 3 C per second
- They monitor changes in topology of network; output information is information about destroyed sensors in network. Output information is about position of destroyed sensors²⁰
- Need to be able to calibrate sensors according local conditions before deployment

For the sensor on level 2 measuring under surface temperature are expected next services

- They calculate at the beginning their positions on the base of positions of sensors level 3 and network information
- They measure absolute temperature in scale from – 40 till 120, output is contour lines of equal temperature
- They measure gradient of changes. The result is alarm in the case, if there is for five second change higher then 3 C per second
- They monitor changes in topology of network; output information is information about destroyed sensors in network. Output information is about position of destroyed sensors²¹
- Need to be able to calibrate sensors according local conditions before deployment

No direct data are measured by sensors of level 2, they can only derivate information from sensors on level 1 and level 2

Earth observation data accessible through WMS services are expected

- Aircraft data from termovision or digital infrared vide or video
- Satellite data (only in cases of large area fires)

Forestry related data services include

²⁰ This are initial value, this value has to be more accurately estimated on the base of practical tests

²¹ This are initial value, this value has to be more accurately estimated on the base of practical tests

- Web services related to forest typology
- Forest paths
- Transport network
- Climatology and meteorology (precipitation, temperature, air pressure, evapotranspiration, wind speed, and wind direction)
- Terrain configuration (vegetation type, slope inclination and orientation, soil type and humidity)
- Fire vulnerability maps for regions and particular forest types
- Classified satellite images
- Water sources and networks

Localisation services included

- Localisation of persons
- Localisation of forest fire technology

Context III: Post-fire assessment

Data from sensors are accessible through OGC's SWE standardized interfaces, which support their effective sharing. Data from sensors on level 1 are collected continuously during all post fire monitoring. The sensors level 1 realise next services

- They calculate at the beginning their positions on the base of the positions of sensors level 3 and network information
- They measure absolute temperature in scale from – 40 till 120, output is contour lines of equal temperature
- They measure gradient of changes. The result is alarm in the case, if there is for five second change higher than 3 C per second
- They monitor changes in topology of network; output information is information about destroyed sensors in network. Output information is about position of destroyed sensors²²
- Need to be able to calibrate sensors according to local conditions before deployment

The sensor on level 2, which monitored under surface temperature provide next services

- They calculate at the beginning their positions on the basis of positions of sensors of level 3 and network information

²² This are initial value, this value has to be more accurately estimated on the base of practical tests

- They measure absolute temperature in scale from – 40 till 120, output is contour lines of equal temperature
- They measure gradient of changes. The result is alarm in the case, if there is for five second change higher then 3 C per second
- They monitor changes in topology of network; output information is information about destroyed sensors in network. Output information is about position of destroyed sensors²³
- Need to be able to calibrate sensors according local conditions before deployment

No direct data are measured by sensor level 2, they can only derivate information from sensors of level 1 and level 2, Earth observation data are accessible trough WMS and include

- Aircraft data from termovision or digital infrared vide or video
- Satellite data (only in cases of large area fires)

Forestry related data services include

- Web services related to forest typology
- Localisation of forest fire technology
- Climatology and meteorology (precipitation, temperature, air pressure, evapotranspiration, wind speed, and wind direction)
- Terrain configuration (vegetation type, slope inclination and orientation, soil type and humidity)
- Transportation network (roads, forest trails)
- Fire vulnerability maps for regions and particular forest types
- Classified satellite images
- Water sources and networks

²³ This are initial value, this value has to be more accurately estimated on the base of practical tests

3.3 Scenario 2 – Landslides Detection and Prediction

3.3.1 Characteristics of Scenarios

The scenario under discussion is the landslide. Landslides happen due to the down-slope movement of soil, rock and organic materials under the influence of gravity. These movements are short-lived and suddenly occurring phenomena, which causes extraordinary landscape changes and destruction of life and property.

Three distinct physical events occur during the process:

- Initial slope failure,
- Subsequent landslide material transport,
- Final deposition of the slide materials.

In India, landslides mainly happen due to heavy rainfall. Earthquakes can also cause landslides, however in India this is primarily confined to the Himalayan belt. High rainfall intensity accelerates the sliding and slumping in the existing hazard zones. The annual loss due to landslides in India is equivalent to \$400 million.

The factors aggravating incidence of landslides are:

- Environmental degradation due to pressure of population,
- Decline in forest cover,
- Changes in agricultural practices and land use,
- Infrastructure developments in hilly regions,
- High annual rainfall.

The Risk Zones in India are:

- Western Himalayas
 - Uttar Pradesh, Himachal Pradesh and Jammu & Kashmir
- Eastern & N.E Himalayas
 - West Bengal, Sikkim and Arunachal Pradesh
- Naga-Arakkon Mountain Belt

- Nagaland, Manipur, Mizoram and Tripura
- Western Ghats including Nilgiris
 - Maharashtra, Goa, Karnataka, Kerala & Tamil Nadu
- Plateau margins in the Peninsular India and Meghalaya in NE India

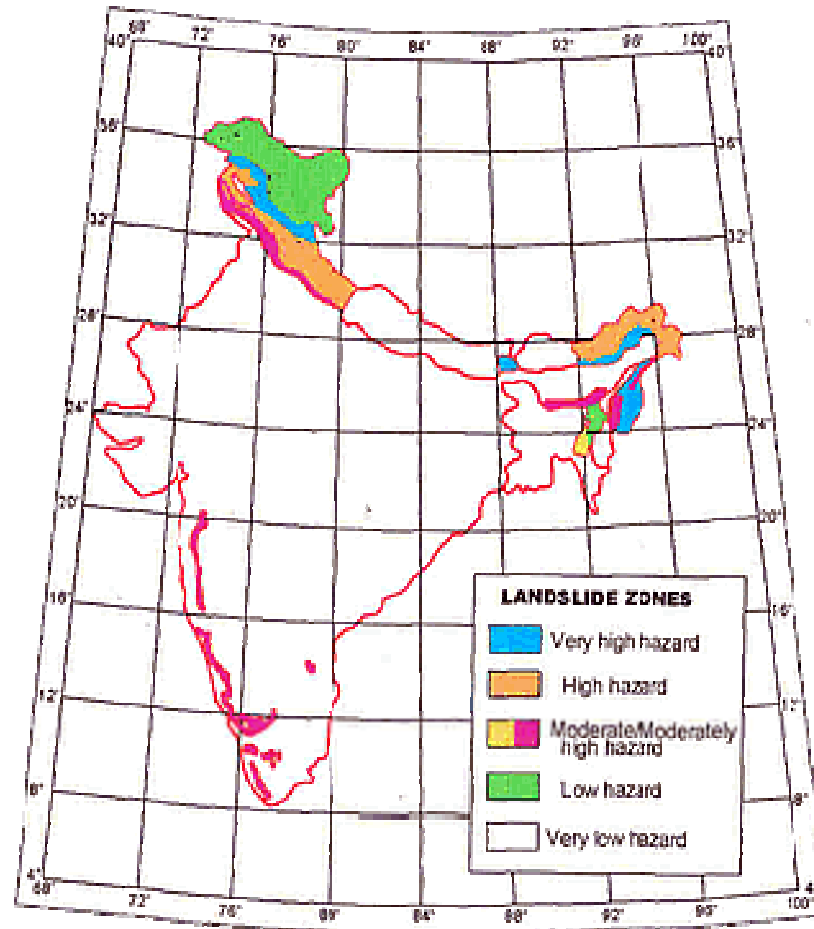


Figure 6 - Landslide Zones in India

The Western Ghats in Kerala, India, comes second in the rate of incidence of landslides. More than 40% of the land area of Kerala falls within the highland areas of Western Ghats. The slopes in this region are normally steep, with high rainfall (greater than 300cms/year), and very high density of population.

The main types of Landslides in Kerala are:

- Rock falls which are generally confined to steep slopes,

- Rock slips which occur where artificial cuts are made in rock slopes,
- Debris flows which are the most prevalent and recurring type.

Debris flows are characterized by:

- Highly water saturated overburden with a varied assemblage of debris material,
- Swift and sudden down slope movement,
- The volume of material transported ranges from a few cubic meters in smaller slides to several thousands of cubic meters in massive slides.

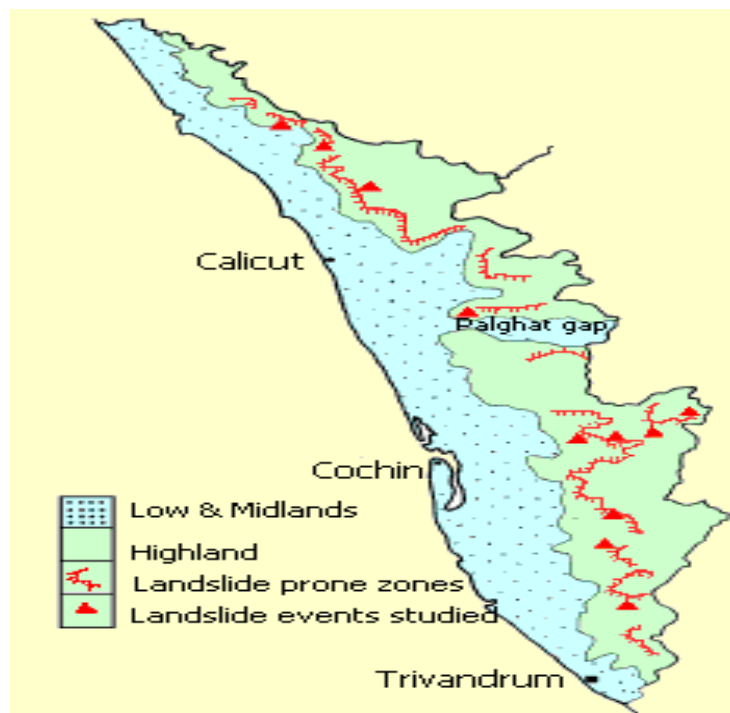


Figure 7 - Landslide Zones in Kerala State, India

3.3.1.1 Scenario name

The name of the scenario is landslide prediction.

3.3.1.2 General characteristics

Landslide is a general term used to describe the down-slope movement of soil, rock and organic materials under the influence of gravity. It also describes the landform that results.

Some slopes are susceptible to landslides whereas others are more stable. Many factors contribute to the instability of slopes, but the main controlling factors are the nature of the soil and underlying bedrock, the configuration of the slope, the geometry of the slope, and ground-water conditions.

Three distinct physical events occur during a landslide: the initial slope failure, the subsequent transport, and the final deposition of the slide materials. Landslides can be triggered by gradual processes such as weathering, or by external mechanisms including:

- Undercutting of a slope by stream erosion, wave action, glaciers, or human activity such as road building,
- Intense or prolonged rainfall, rapid snowmelt, or sharp fluctuations in ground-water levels,
- Shocks or vibrations caused by earthquakes or construction activity,
- Loading on upper slopes, or
- A combination of these and other factors.

Once a landslide is triggered, material is transported by various mechanisms including sliding, flowing and falling. Landslides often occur along planes of weakness that may be parallel to the hill slope. In bedrock, planes of weakness are usually beds, joints or fractures. Soils such as silt and clay are weaker than rock and commonly have complexes or multiple planes of weakness.

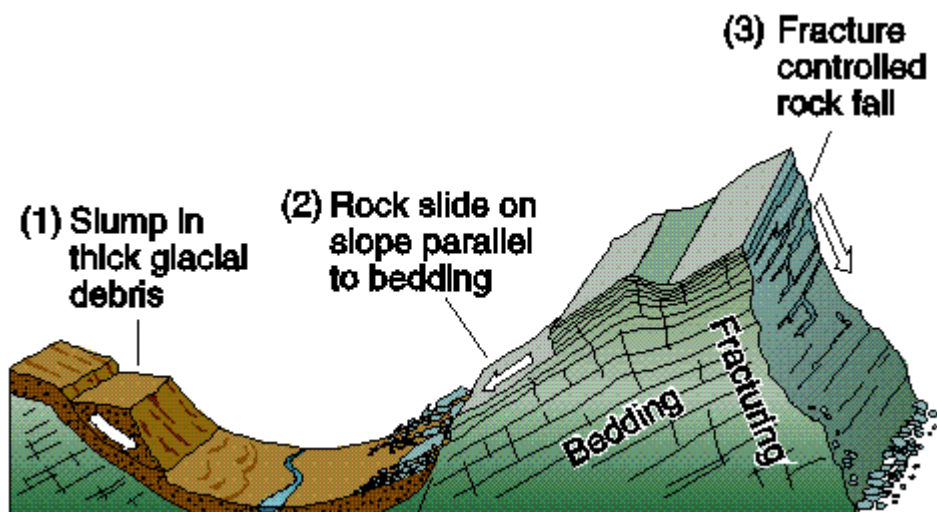


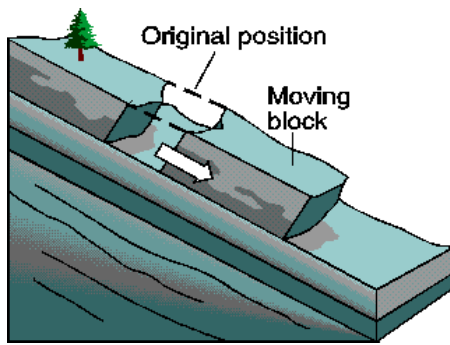
Figure 8 - Glacially Oversteepened Slope

In Figure 3 above, are the types of weakness planes and their associated landslides: (1) slope failure in glacial sediment resulting in slumps; (2) parallel bedding in rock causing slides; and (3) fracturing of rock promoting falls.

The types of landslides vary with respect to the:

- Rate of movement:
 - This ranges from a very slow creep (millimetres/year) to extremely rapid (metres/second).
- Type of material:
 - Landslides are composed of bedrock, unconsolidated sediment and/or organic debris.
- Nature of movement:
 - The moving debris can slide, slump, flow or fall.

The common landslide types are:



Slide: movement parallel to planes of weakness and occasionally parallel to slope.

Figure 9 - Sliding Landslide

Creep: gradual movement of slope materials

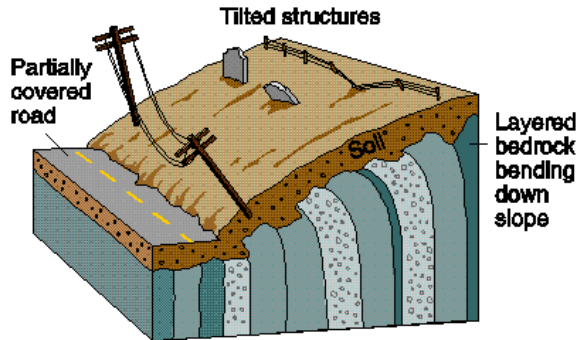


Figure 10 - Creeping Landslide

Slump: complex movement of materials on a slope; includes rotational slump.

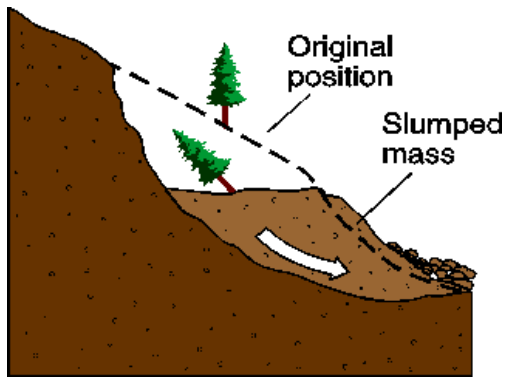


Figure 11 - Sliding Landslide

Topple: the end-over-end motion of rock down a slope.

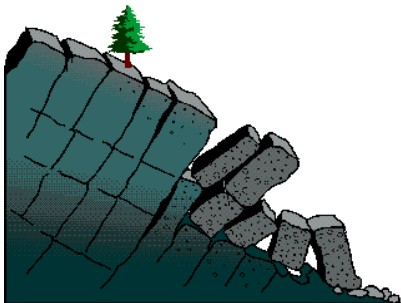


Figure 12 - Toppling Landslide

Fall: material free falls.

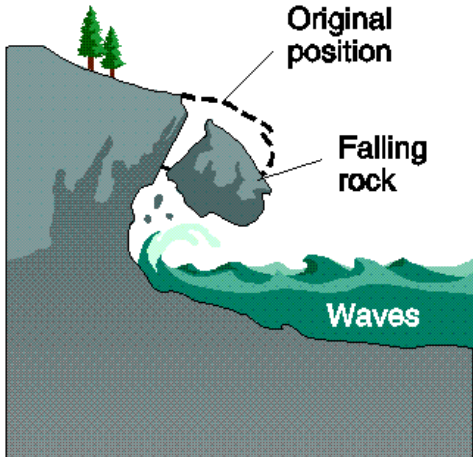


Figure 13 - Toppling Landslide

Flow: viscous to fluid-like motion of debris.

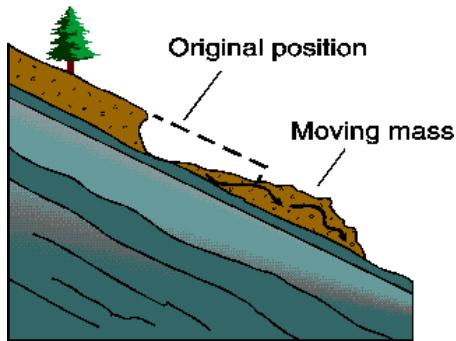


Figure 14 - Flowing Landslide

Torrent: a sporadic and sudden channelized discharge of water and debris.

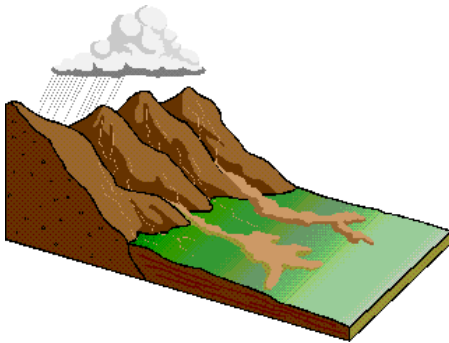


Figure 15 - Torrent Landslide

3.3.1.3 Description

Landslides constitute a major natural hazard in India that accounts for considerable loss of life and damage to communication routes, human settlements, agricultural fields and forest lands. The Indian subcontinent, with diverse physiographic, seismotectonic and climatological conditions is subjected to varying degree of landslide hazards; the Himalayas including Northeastern mountains ranges being the worst affected, followed by a section of Western Ghats and the Vindhya.

3.3.2 Type of Situation

In the emergency management cycle of the landslide scenario, WSN plays an important role in providing an efficient communication channel between the data acquisition base station and the analysis station, from where the landslide warning will be issued to the public.

We know that landslides basically involve movement.

In the *pre-event monitoring* of landslides, primarily the magnitude, rate and distribution of this event are required to be monitored.

The Landslide Instrumentation setup targets to:

- Measure pore water pressure, especially in layered areas where excessive hydrostatic pressures may exist between the layers. Pore pressure measurement, using a *Vibrating wire* piezometer, at or near the sliding surfaces can support an effective stress analysis.
- Measuring the movement and depth of the slip plane using *Inclinometers* or measuring the tensile and compressive strains on the sensor column using *strain gages*, attached to the sensor column.
- Measuring vibrations caused by mass movements and microfractures using *geophones*.

In the *event detection*, the threshold values around the occurrences of landslides are required. These thresholds will be decided by the field geologist after studying the soil properties of the selected field and initial instrument data at the Idukki district of Kerala, India. When the threshold values are exceeded due to precursors of a potential landslide, a warning signal would be sent to the analysis station and hazard mitigation operations would be put in place.

Post event monitoring is not under the scope of our project. Our main role is to issue a warning signal of and impending landslide from the analysis station to the Disaster Risk Management authority of Kerala government. Although some instruments may become non-operational after a landslide, we will continue monitoring with the existing instruments and will make efforts to return the damaged instruments to an online status.

Kerala has been identified as one of the 'multi-hazard prone' States of India and is situated in the moderate earthquake risk zone, i.e. Zone III. Experts have predicted that the State is prone to earthquakes of up to a magnitude of 6.5 on the Richter scale. Therefore plans for rescue operations are already in place and can become operational quite easily. Also, Kerala is served by a fairly extensive transport and communication network. The state has more roads relative to its area than any other states in India and is the only Indian state where all villages are connected to roads. Telephone exchanges are located every 6 kms. It is anticipated that the Kerala government will undertake the crisis management, using the above infrastructure. Amrita's role will be of an advisory capacity.

3.3.3 Operational Environment

In the Idukki District of Kerala, where the landslide test deployment will be situated, the temperature varies between 21°C to 27°C with minimum seasonal variation. The district receives

heavy rains during both the South-West monsoon from June to August and during the North-East monsoon from October to November. The former is more predominant with June experiencing the maximum rainfall. The annual rainfall in the district varies from 250 to 425 centimetres. Humidity during the rainy season can be up to 100%.

The instrumentation setup will be designed to withstand the above temperature and humidity operating conditions as well as shock and vibration. Ingress protection from vandalism, etc will also be provided.

3.3.3.1 List of Applicable WINSOC Usage Areas

The main areas that are under consideration for landslide instrumentation are the Idukki, Wayanad and Kottayam areas of Kerala; Ootyghat near Coimbatore, TamilNadu; and Konkan, India. The main landslide triggering mechanisms in these areas is intense rainfall. The main types of landslides in Kerala are rock falls (generally confined to steep slopes), rock slips (that occur where artificial cuts are made in rock slopes) and debris flows (the most prevalent and recurring type). Therefore, the technology we are developing should be useful for similar scenarios in the European Union countries, as well as other parts of the world.

3.3.3.2 Service Providers

The principal investigators developing and applying the technology are AMRITA and ANTRIX. Secondary involvement comes from other government and non-government organisations in India and abroad conducting similar types of research and development. Examples of such organizations are CESS (Centre for Earth Science Studies) in Kerala, the Wadia Institute of Himalayan Geology in Dehradun, the Kerala Government Soil Survey Department, and the Bhabha Atomic Research Centre (BARC). Once the technology is developed and deployed, other organizations such as hazard management agencies, and transport and telecommunication agencies both of in India and abroad in the European Union and other countries will be benefited.

3.3.3.3 Service Provider Goals

The goals of the service providers are social welfare by providing early warning system for landslides, research and development of new technology (wireless sensor networks), and to educate the academic community about the advantages of wireless sensor networks.

3.3.3.4 End-User Goals

To receive early warnings messages of landslides that may occur, and to reduce the hazard level.

3.3.4 User Groups

Several user groups cooperate during an emergency. They are:

- Governmental agencies,
- The research community, and
- The population in the landslide prone area.

4 SERVICES REQUIREMENT

As a background for the requirements, we propose a concise description of the services that are needed in the emergency situation from the perspective of this project. There are four basic kinds of services, which have to be analysed:

- Sensor services
- Networked services
- Services integrated sensor services with SDI
- Localisation services

This chapter gives basic information about the required services; the detailed requirements are described in chapter 5.

4.1 Use of sensors

For the single sensor node, we expected, that it will have four components has four components: a sensory transducer(s), a radio transceiver, a power unit and a processing unit, to guarantee its work in sensor network. Certain nodes in the network may possess only the latter three components: these are relay nodes meant to process and pass information from other sensors to the monitors. We assume that heterogeneity of transducers can exist in the sensor network, and that most sensors have limited computational power and storage space.

”Smart Dust” is an emerging technology made up from tiny, wireless sensors or “motes.” Eventually, these devices are smart enough to talk with other sensors yet small enough to fit on the head of a pin. Each mote is a tiny computer with a power supply, one or more sensors, and a communication system.

Dust mote battery life ranges from a few hours to 10 years, depending on the size and capabilities of the device

A forest service could use smart dust to monitor for fires in a forest (Eng 2004). In this scenario, forest service personnel would drop the dust from an airplane and then count on the sensors to self-organize into a network. In the event of a fire, a mote that notices unusual temperatures in its zone would alert neighbouring motes that would in turn notify other motes in the network. In this way the network of motes would notify a central monitoring station of the fire and the location of the mote that noticed it. Equipped with prompt notice of the fire and its approximate location, fire fighters could race to the scene and fight the fire while it is small. By linking similar networks of motes to a central fire reporting system, the system can be extended to monitor an enormous region in a national forest.

For other purposes, different kind of sensors could be used, but smart dust seems to be solution also for other level of sensors.

4.2 Required sensor network.

Large-scale sensor networks impose energy and communication constraints, thus it is difficult to collect data from each individual sensor node and process it at the sink. The expected solution will be based on the well-known representation of data – contour maps, which trade off accuracy with the amount of samples. There will be need to build:

- distributed spatial and temporal data suppression,
- contour reconstruction at the sink via interpolation and smoothing, and an efficient mechanism to convey routing information over multiple hops.

It is not possible to make general assumptions on the node density of the network, except that events are sensed by more than one sensor. By reducing the number of transmissions required to convey relevant information to the sink, the proposed contour mapping scheme saves energy and improves network lifetime. In a sharp contrast to related work in this area, the scheme does not require all nodes to explicitly share information.

It will be considered a network of fixed sensor nodes that are deployed in a 2 or 3 dimensional space. A set of monitoring nodes, defined as sinks, are responsible for collecting data reports from sensor nodes.

It is assumed that knowledge of sensor node locations will be calculated from position of sensors with GPS and from network. The location information need not be precise. It could be computed even after deployment.

4.2.1 Coverage area and sensor network hierarchy

Context I: Fire preparedness and prediction

- The network will have multiple hierarchy
- There could be covered large area till 50 km² allocated on the base of previous geographical analysis of forest typology. It is expected, that in average, there will be maximum 4 sensors clusters per km².
- The area will be covered by network clusters with one sensor of level 2 and more sensors of level 1 in one cluster. Every sensor of level 1 will communicate with more sensors of level 1 and with exactly one sensor of level 2. Every sensor of level 2 will communicate with more sensors of level 2. There is no guarantee, that all sensors of level 2 will have access to public network, so network of sensors of level two has to guarantee transmission of information among sensors of level 2 to guarantee communication with external world.

Context II: Forest fires detection and response

- The network will have multiple hierarchy
- There could be covered relatively smaller area usually till 5 ha, only in the case of large disasters; there will be covered area of more km². It is expected, that there will be in

average 1 sensor of level 1 and 2 per 100m². But they will not cover the whole area, but only the area surrounding the forest fire. The density of sensors of level 2 will be maximally 1 sensor per one hectare

- The area will be covered by two independent ad hoc networks of sensors (level 1 and 2), which both communicate with one sensor network on level 3. Every sensor of level 1 (2) communicates with more sensors of level 1 (2). Sensor of level 1 (2) communicates with 0 till n sensors of level 3. If there is not direct communication of sensors of level 1 (2) with any sensor of level 3, the information has to be transferred through other sensors of level 1 (2). There is no guarantee, that all sensors of level 3 will have access to public network, so the network of sensors of level two has to guarantee transmission of information among sensors of level 2 to guarantee communication with external world.

Context III: Post-fire assessment

- The network will have multiple hierarchy
- There could be covered relatively smaller area usually till 5 ha, only in the case of large disasters; there will be covered area of more km². It is expected, that there will be in average 1 sensor of level 1 per 1 hectare and level 2 per 100m². They will cover the whole area destroyed by forest fire and also area surrounding forest fire damaged area. The density of sensors of level 2 will be maximally 1 sensor per one hectare
- The area will be covered by two independent ad hoc networks of sensors (level 1 and 2), which both communicate with one sensor network on level 3. Every sensor of level 1 (2) communicates with more sensors of level 1 (2). Sensors of level 1 (2) communicate with 0 till n sensors of level 3. If there is no direct communication of sensors of level 1 (2) with any sensor of level 3, the information has to be transferred through other sensors of level 1 (2). There is no guarantee, that all sensors of level 3 will have access to public network, so network of sensors of level two has to guarantee transmission of information among sensors of level 2 to guarantee communication with external world.

Context IV: LandSlides

The figure below shows the sensor network architecture. The proposed wireless sensor network is planned for deployment in the landslide prone area Adimaly in the Idukki district, Kerala, with a coverage radius of one-half km square.

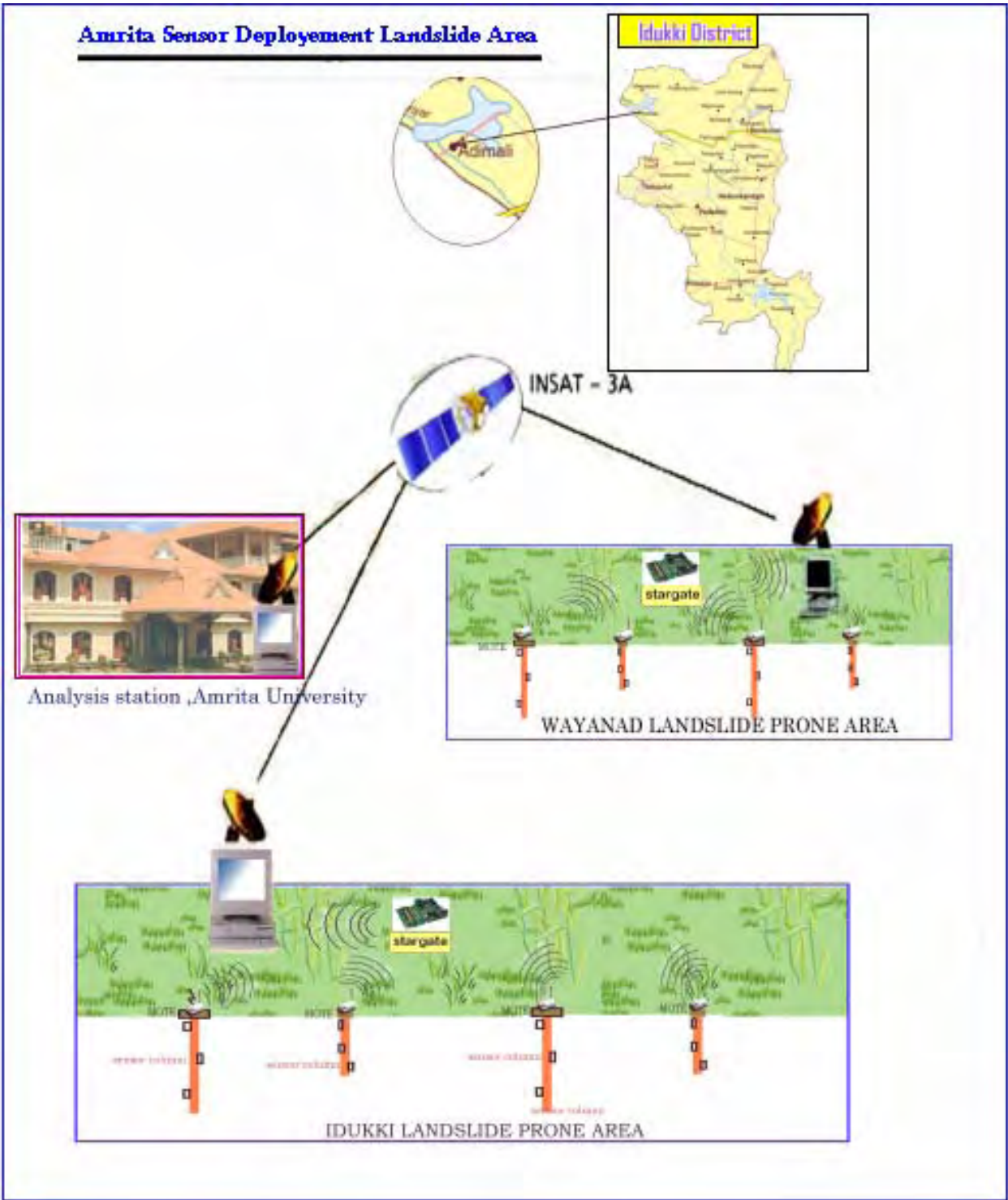


Figure 16 - Amrita Sensor Deployment Landslide Area

In the approximately 1/2 km square coverage area, the network will employ a maximum of 9 sensor columns placed inside vertical holes drilled in the ground and arranged approximately on a matrix grid pattern. Borehole depth will be decided based on the soil conditions obtained from a detailed soil survey. Each sensor column is made up of one or more geophones, 2 or 3 pore pressure transducers (vibrating wire piezometer type), and inclinometers (uniaxial and biaxial) or strain gages. We are planning to include a maximum of 8 sensors in each sensor column. The sensor column length may vary depending on the soil depth selected. The sensors are placed in a distributed fashion with a separation of 2 to 3m. For example, a sensor column can have 2 or 3 pore pressure transducers placed quarter distance above the bottom and quarter distance below the top, 3 or 4 inclinometers and 1 geophone at the bottom. The sensor tube (made of flexible fibre), having a diameter exactly the same size as the sensors, is used for the sensor column. The sensing part (sensors) of the column is under the ground and the computing component (processor + radio module) stays above the ground.

A wireless sensor network is a collection of wireless sensors that form a certain network topology. A sensor node consists of a sensing device, a sensor signal conditioning unit, and a communication module (radio interface). Each sensor node delivers the collected data to one (or more) neighbouring nodes using a multi-hop communication method. A local clustering node will then aggregate the information from a group of nearby sensor nodes. The clustering nodes will make local decisions and then pass this processed information on to a gateway between the Village Resource Centre (VRC) computer and the sensor network. At this gateway, the data will be sent over Wi-Fi or RF radio to a receiver connected to the VRC computer. This computer will aggregate and process the transmitted data, and then uplink the landslide warning data to the satellite using the existing VRC hardware. A satellite downlink located at Amrita University will then transmit the data to a main processing computer.

4.3 Sensor networks integration with GSDI

OGC's Sensor Web Enablement (SWE) activity, which is being executed through the OGC Web Services (OWS) initiatives and under the Interoperability Program, is establishing the interfaces and protocols that will enable a "Sensor Web" through which applications and services will be able to access sensors of all types over the Web. These initiatives have defined; prototyped and tested several foundational components needed for a Sensor Web (see Figure 1).

Sensor Web initiative has been conceived in 1997 at NASA's Jet Propulsion Laboratory. The main idea was to develop sensor chips that are able to monitor and control environment via internet in real-time. During the time sensors became cheaper and widely used in other subject fields – as sensor networks.

A sensor network is here defined as a computer accessible network of many, spatially distributed devices using sensors to monitor conditions at different locations, such as temperature, sound, vibration, pressure, motion or pollutants. A Sensor Web refers to web accessible sensor networks and archived sensor data that can be discovered and accessed using standard protocols and application program interfaces (APIs).

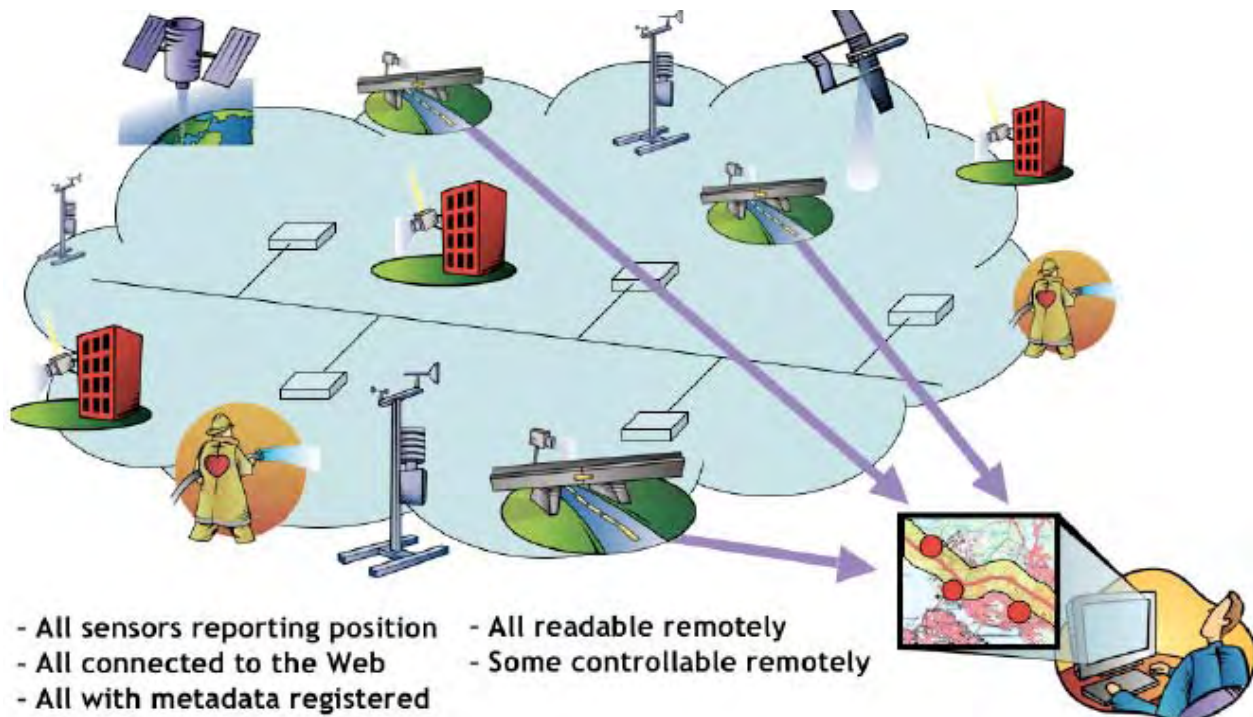


Figure 17 - Sensor Web concept

In an Open Geospatial Consortium, Inc. (OGC) initiative called Sensor Web Enablement (SWE), members of the OGC are building a unique and revolutionary framework of open standards for exploiting Web-connected sensors and sensor systems of all types: flood gauges, air pollution monitors, stress gauges on bridges, mobile heart monitors, Webcams, satellite-borne earth imaging devices and countless other sensors and sensor systems.

SWE presents many opportunities for adding a real-time sensor dimension to the Internet and the Web. This has extraordinary significance for science, environmental monitoring, transportation management, public safety, facility security, disaster management, utilities' Supervisory Control and Data Acquisition (SCADA) operations, industrial controls, facilities management and many other domains of activity. Following chapters describe both existing and under development standards defined and proposed by SWE initiative.

4.3.1 SWE Standards Framework

The initial focus of OGC's SWE has been to investigate standardized interfaces for live sensors operating in near-real-time, rather than the conventional static data stores. It addresses information gathering from distributed, heterogeneous, dynamic information sensors and sources of different structure, based on web services. It is the goal to develop common access, planning, and management interfaces and a descriptive mark up language (SensorML) for managing sensor information and metadata in common consistent manners, independent of any application. The individual parts were initially designed to fulfil the following needs in 2003 (Simonis et al., 2003):

- Describe sensors in a standardized way
- Standardize the access to observed data
- Standardize the process of what is commonly known as sensor planning, but in fact is consisting of the different stages planning, scheduling, tasking, collection, and processing
- Building a framework and encoding for measurements and observations

SWE standards framework, as presented here, is based on appropriate standards of Open Geospatial Consortium from its Web sites (<http://www.opengeospatial.org>). Figure 2 (below) shows SWE architecture of standards framework in environmental situation. We present a brief characteristic of each both – SWE standards and draft below.

4.3.1.1 Observations & Measurements (O&M)

The OGC work on Observations and Measurements (O&M) is targeted at providing a standard model for representing and exchanging observation results. O&M provides standard constructs for accessing and exchanging observations, alleviating the need to support a wide range of sensor-specific and community-specific data formats. Particularly with advancements made during the OWS3 project, the O&M *Observation* provides a standard that combines the flexibility and extensibility provided by XML with an efficient means to package large amounts of data as ASCII or binary blocks.

The *Observations and Measurements (O&M) Discussion Paper*, OGC Document 05-087r3, provides an abstract models and XML encodings for sensor observations and measurements. O&M describe a framework and encoding for measurements and observations. This model is required specifically by the candidate Sensor Observation Service Implementation Specification as well as for related components of an OGC Sensor Web Enablement capability and for general support for OGC standards compliant systems dealing in technical measurements in science and engineering.

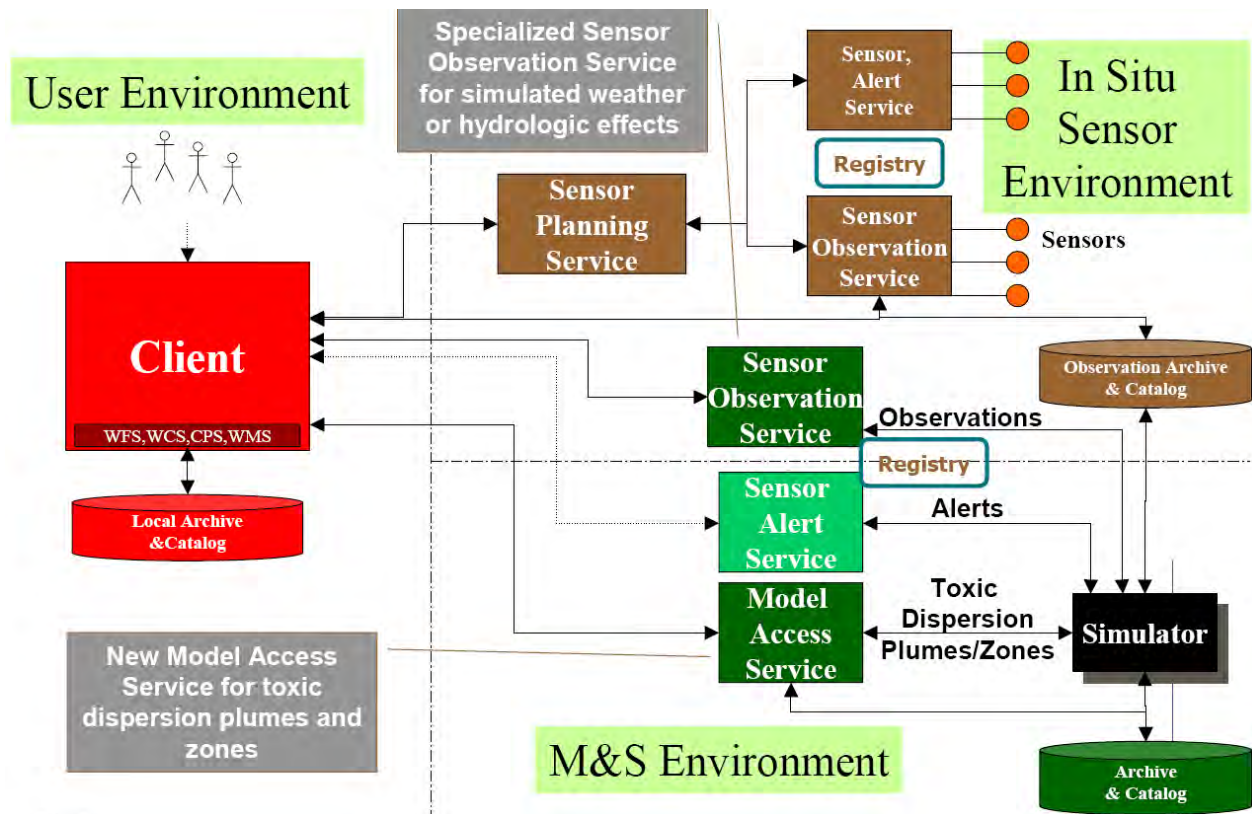


Figure 18 - SWE architecture in environmental simulation

As defined within the O&M specification, an *Observation* is an event with a *result* that has a value describing some phenomenon. The observation is modelled as a Feature within the context of the ISO/OGC Feature Model. An observation feature binds the result to the feature of interest, upon which it was made. An observation uses a procedure to determine the value, which may involve a sensor or observer, analytical procedure, simulation or other numerical processes. O&M has an accompanying OGC Recommendation Paper titled "*Units of Measure Use and Definition*" (OGC Project Document OGC 02-007r4). The basic information needed to understand a measured value is the value and the unit of measure. The document identifies eight

different ways, and various options of these ways, to tie the value and the unit of measure. The goal is to develop a preferred way to structure this information in XML.

4.3.1.2 Sensor Model Language (SensorML)

SensorML (see OGC's *Sensor Model Language (SensorML) Candidate Implementation Specification*, OGC Document 05-086r2) provides an information model and encodings that enable discovery and tasking of Web-resident sensors, and exploitation of sensor observations.

The measurement of phenomena that results in an observation consists of a series of processes, beginning with the processes of sampling and detecting and followed perhaps by processes of data manipulation. The division between measurement and “post-processing” has become blurred with the introduction of more complex and intelligent sensors, as well as the application of more on-board processing of observations. The typical Global Positioning System (GPS) sensor is a prime example of a device that consists of basic detectors complemented by a series of complex processes that result in the observations of position, heading, and velocity.

SensorML defines models and XML Schema for describing any process, including measurement by a sensor system, as well as post-measurement processing.

Within SensorML, everything including detectors, actuators, filters, and operators are defined as process models. A *ProcessModel* defines the *inputs*, *outputs*, *parameters*, and *method* for that process, as well as a collection of metadata useful for discovery and human assistance. The inputs, outputs, and parameters are all defined using SWE Common data types. Process metadata includes identifiers, classifiers, constraints (time, legal, and security), capabilities, characteristics, contacts, and references, in addition to inputs, outputs, parameters, and system location.

SensorML provides a functional model of the sensor system, rather than a detailed description of its hardware. SensorML treats sensor systems and a system's components (e.g. sensors, actuators, platforms, etc.) as processes. Thus, each component can be included as a part of one or more process chains that can either describe the lineage of the observations or provide a process for geolocating and processing the observations to higher level information. In SensorML, all processes, including sensors and sensor systems, have input, output, parameters, and methods that can be utilized by applications for exploiting observations from any sensor system. In addition, SensorML provides additional metadata that are useful for enabling discovery, for identifying system constraints (e.g. security or legal use constraints), for providing contacts and references, and for describing taskable properties, interfaces, and physical properties.

4.3.1.3 TransducerML (TML)

Transducer Markup Language (TML) is a method and message format for describing information about transducers and transducer systems and capturing, exchanging, and archiving live, historical and future data received and produced by them. A transducer is a superset of sensors and actuators. TML provides a mechanism to efficiently and effectively capture, transport

and archive transducer data, in a common form, regardless of the original source. Having a common data language for transducers enables a TML process and control system to exchange command (control data) and status (sensor data) information with a transducer system incorporating TML technology. TML utilizes XML for the capture and exchange of data.

Transducer Markup Language (TML) defines:

- a set of models describing the hardware response characteristics of a transducer
- an efficient method for transporting sensor data and preparing it for fusion through spatial and temporal associations

Sensor data is often an artefact of the sensor's internal processing rather than a true record of phenomena state. The effects of this processing on sensed phenomena are hardware-based and can be characterized as functions.

TML response models are formalized XML descriptions of these known hardware behaviours. The models can be used to reverse distorting effects and return artefact values to the phenomena realm. TML provides models for a transducer's latency and integration times, noise figure, spatial and temporal geometries, frequency response, steady-state response and impulse response.

Traditional XML wraps each data element in a semantically meaningful tag. The rich semantic capability of XML is in general better suited to data exchange rather than live delivery where variable bandwidth is a factor. TML addresses the live scenario by using a terse XML envelope designed for efficient transport of live sensor data in groupings known as TML clusters. It also provides a mechanism for temporal correlation to other transducer data

TML was introduced into the OGC standards process in 2004 and is now part of the SWE family of candidate standards. It complements and has been harmonized with SensorML and O&M. TML provides an encoding and a conceptual model for streaming real-time "clusters" of time-tagged and sensor-referenced observations from a sensor system. SensorML describes the system models that allow a client to interpret, geolocate, and process the streaming observations.

The candidate OGC Transducer Markup Language Implementation Specification is documented in OGC document 06-019r3.

4.3.1.4 Sensor Observation Service (SOS) Implementation Specification

The goal of SOS is to provide access to observations from sensors and sensor systems in a standard way that is consistent for all sensor systems including remote, in-situ, fixed and mobile sensors. The OGC Sensor Observation Service specification defines an API for managing deployed sensors and retrieving sensor data and specifically "observation" data. Whether from in-

situ sensors (e.g., water monitoring) or dynamic sensors (e.g., satellite imaging), measurements

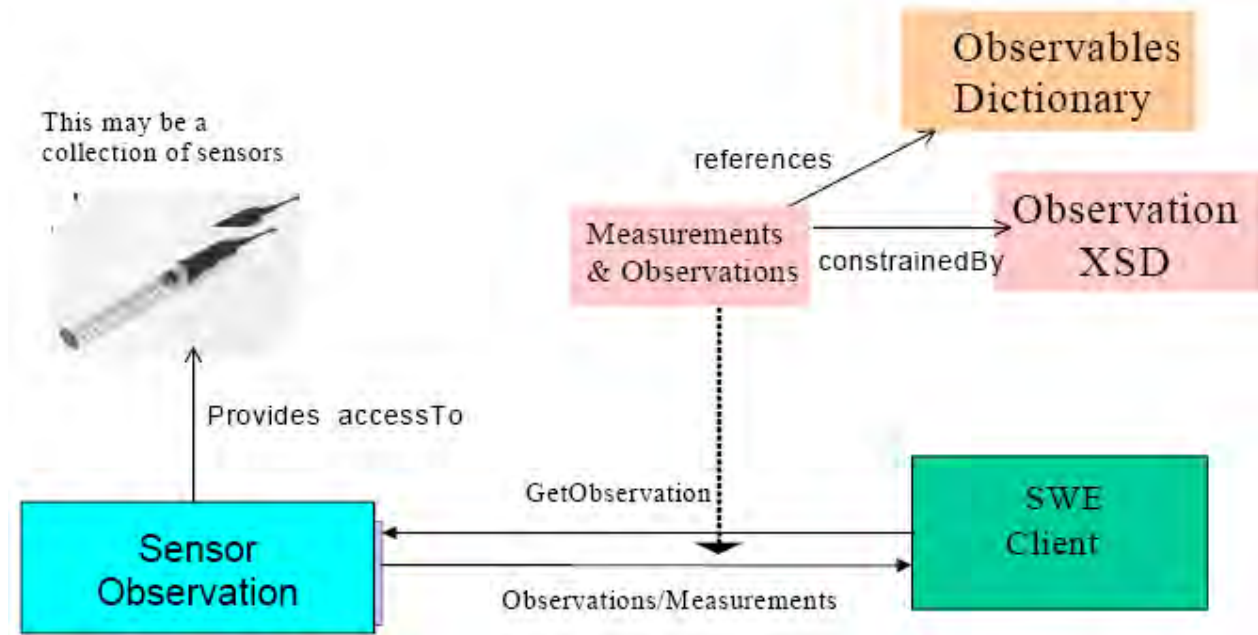


Figure 19 - Sensor Observation Service Concept

made from sensor systems contribute most of the geospatial data by volume used in geospatial systems today. Therefore, the candidate SOS Implementation Specification defines the interfaces and operations that enable the implementation of interoperable sensor observation services and clients. The Sensor Observation Service is documented in draft OGC Sensor Observation Service (SOS) Implementation Specification, OGC Document 06-009r1.

Figure 3 above shows a SWE client making use of the SOS to automatically obtain observations and measurements from a collection of sensors. The SOS might also control the sensors for the client. The client depends on registries that provide metadata for the different types of sensors and the kinds of data that they are capable of providing.

4.3.1.5 Sensor Planning Service (SPS) Implementation Specification

The candidate Sensor Planning Service (SPS) Implementation Specification was designed and developed to enable an interoperable service by which a client can determine collection feasibility for a desired set of collection requests for one or more sensors/platforms, or a client may submit collection requests directly to these sensors/platforms. Specifically, the document specifies interfaces for requesting information describing the capabilities of a SPS for determining the feasibility of an intended sensor planning request, for submitting such a request, for inquiring about the status of such a request, for updating or cancelling such a request, and for requesting information about further OGC Web services that provide access to the data collected by the requested task.

The candidate *OGC Sensor Planning Service (SPS) Implementation Specification*, OGC Document 05-089r3 defines interfaces for a service to assist in collection feasibility plans and to process collection requests for a sensor or sensor constellation.

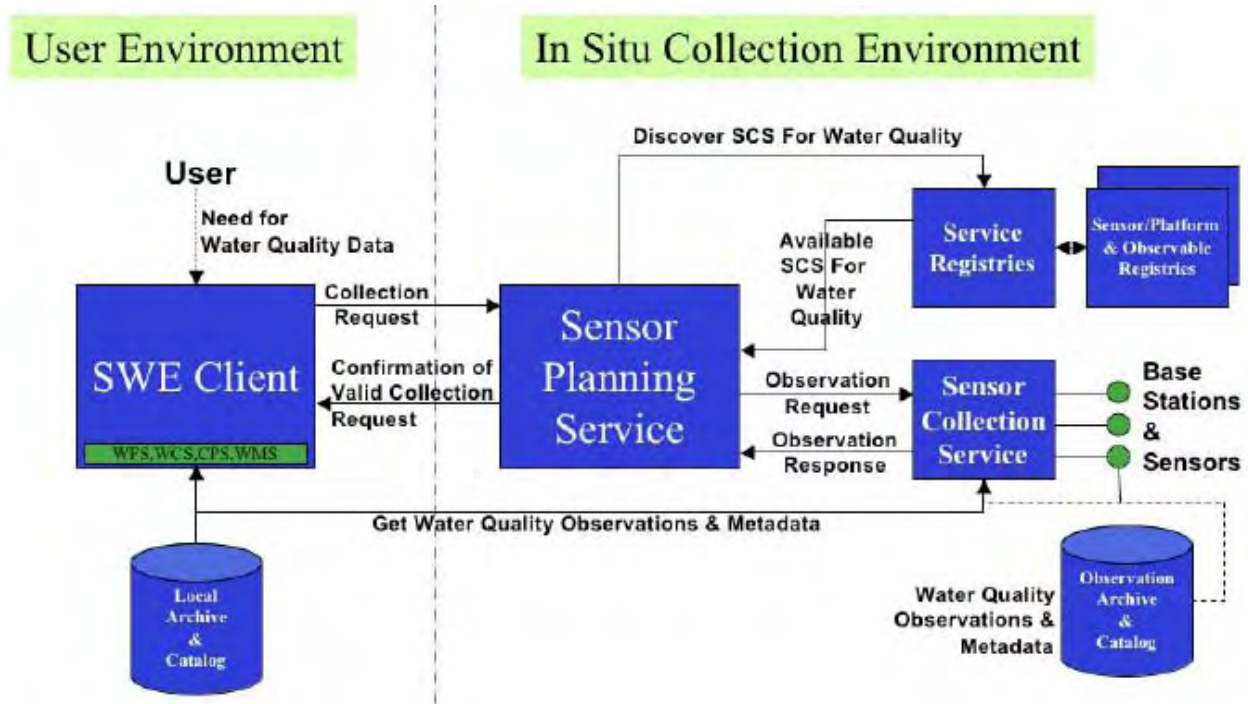


Figure 20 - Typical in situ Sensor Planning Service

The developers and likely users of the SPS specification will be enterprises that need to automate complex information flows in large enterprises that depend on live and stored data from sensors and imaging devices. In such environments, specific information requirements give rise to frequent and varied collection requests. Quickly getting an observation from a sensor at the right time and place may be critical, and getting data that was collected at a specific place at a specific time in the past may be critical. The SPS specification specifies open interfaces for requesting information describing the capabilities of a SPS, for determining the feasibility of an intended sensor planning request, for submitting such a request, for inquiring about the status of such a request, and for updating or cancelling such a request.

An example of an environmental support system is diagrammed above in Figure 4. This system uses SPS to assist scientists and regulators in formulating collection requests targeted at water quality monitoring devices and data archives. Among other things, it allows an investigator to delineate geographic regions and time frames, and to choose quality parameters to be excluded or included.

4.3.1.6 Draft OGC Sensor Alert Service (SAS) Implementation Specification

The draft OGC document 06-028 specifies interfaces for requesting information describing the capabilities of a Sensor Alert Service, for determining the nature of offered alerts, the protocols used, and the options to subscribe to specific alert types. The document defines an alert as a special kind of notification indicating that an event has occurred at an object of interest, which results in a condition of heightened watchfulness or preparation for action. Alerts messages always contain a time and location value.

The draft SAS Implementation Specification describes an interface that allows nodes to advertise and publish observational data or its describing metadata respectively. It is important to emphasize that the SAS itself acts like a registry rather than an event notification system. Sensors or other data producers do advertise their offers to a messaging server. The messaging server itself forwards this advertisement to the SAS. If a consumer wants to subscribe to an alert, it sends a subscription-request to the SAS. We want to point out that this operation is rather a lookup than a real subscription. This is based on the fact that the SAS will not send any alerts. All actual messaging is performed by a messaging server. The response sent by the SAS will contain the communication endpoint. It is up to the consumer to open a connection to this communication endpoint. The SAS response contains all information necessary to set up a subscription.

Therefore, a SAS implementation relies on other alerting protocols and standards. For instance, users could register with a SAS enabled alert registry to receive OASIS Common Alert Protocol (CAP) alerts for specific types of observations, such as weather events or earthquakes.

4.3.1.7 Draft OGC Web Notification Service (WNS) Interface Specification

WNS specified an open interface for a service by which a client may conduct asynchronous dialogues (message interchanges) with one or more other services. As services become more complex, basic request-response mechanisms need to contend with delays/failures. For example, mid-term or long-term (trans-) actions demand functions to support asynchronous communications between a user and the corresponding service, or between two services, respectively. A WNS is required to fulfil these needs within the SWE framework.

The Web Notification Service Model includes two different kinds of notifications. First, the “one-way-communication” provides the user with information without expecting a response. Second, the “two-way-communication” provides the user with information and expects some kind of asynchronous response. This differentiation implies the differences between simple and sophisticated WNS. A simple WNS provides the capability to notify a user and/or service that a specific event occurred. In addition, the latter is able to receive a response from the user.

4.3.1.8 Other Areas of Sensor Web Standards Harmonization

4.3.1.8.1 IEEE 1451 Transducer interfaces

Developing an open standards framework for interoperable sensor networks requires finding a universal way of connecting two basic interface types – transducer interfaces and application interfaces. Specifications for transducer interfaces typically mirror hardware specifications, while specifications for service interfaces mirror application requirements. The sensor interfaces and application services may need to interoperate and may need to be bridged at any of many locations in the deployment hierarchy.

At the transducer interface level, a "smart" transducer includes enough descriptive information so that control software can automatically determine the transducer's operating parameters, decode the (electronic) data sheet, and issue commands to read or actuate the transducer.

To avoid the requirement to make unique smart transducers for each network on the market, transducer manufacturers have supported the development of a universally accepted transducer interface standard, the IEEE 1451 standard.

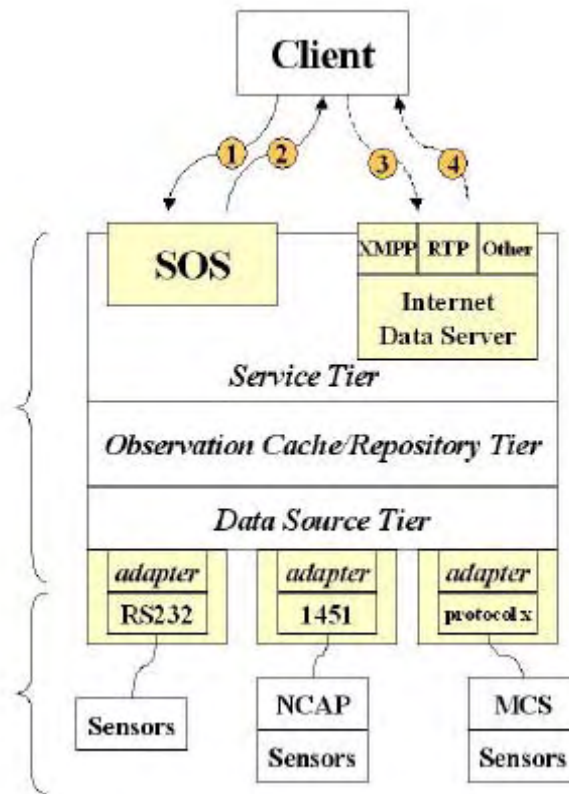


Figure 21 - Where 1451 Fits in the SWE Interoperability Stack

The object-based scheme used in 1451.1 makes sensors accessible to clients over a network through a Network Capable Application Processor, and this is the point of interface to services defined in the OGC Sensor Web Enablement specifications.

An industry-wide, open IEEE 1451 smart transducer interface standards provide common interfaces between sensors/actuators and instruments, microprocessors or networks (Sveda, M., Trchalik, R., 2006). That family consists of standards for analog, digital and wireless interfaces that include namely (i) a smart transducer information model, IEEE 1451.1, called Network Capable Application Processor (NCAP), targeting software-based, network independent, transducer application environments, (ii) and a standard digital interface and communication protocol, IEEE 1451.2, for accessing the transducer via a microprocessor modelled by the NCAP. The next two standards, IEEE 1451.3 and 1451.4, extend the possible single-attached configurations to distributed multidrop buses, and to mixed-mode, i.e. analogue + digital communication enabling also analogue transducers. The last two discussed proposals, IEEE 1451.5 and 1451.0 describe wireless communication protocols and drive harmonization of individual standards of the 1451 family.

4.4 Localization

An attractive feature of a sensor network is that it can provide information about the world that is highly localized in space and/or time. For sensor net applications for forest fire protection knowing the exact location where information was collected is critical. In fact, for almost all sensor net applications, the value of the information collected can be enhanced if the location of the sensors where readings were made is also available.

In forest fire protection application most sensor nodes remain static. Thus one way to know the node positions is to have the network installer measure these locations during network deployment. This may not always be feasible, however, especially in ad hoc deployment scenarios (such as dropping sensors from an aircraft), or in situations where the nodes may need to be moved for a variety of reasons (or move themselves, when that capability can be incorporated).

It is necessary to have techniques for *self-localization*—that is, methods that allow the nodes in a network to determine their geographic positions on their own as much as possible, during the network initialisation process. We also describe *location service* algorithms—methods that allow other nodes to obtain the location of a desired node, after the initial phase in which each node discovers its own location. Such location services are important for geographic routing, location-aware query processing, and many other tasks in a sensor network.

Since the availability of GPS systems in 1993, it has been possible to build autonomous nodes that can localize themselves within a few meters' accuracy by listening to signals emitted by a number of satellites and assisting terrestrial transmitters. But even today GPS receivers can be expensive and difficult to incorporate into every sensor node for a number of practical reasons, including cost, power consumption, large form factors, and the like. Furthermore, GPS systems do not work indoors, or under dense foliage, or in other expectable conditions. Thus in a sensor network context, it is usually reasonable to assume that some nodes are equipped with GPS receivers, but most are not. The nodes that know their position are called *landmarks*. Other nodes localize themselves by reference to a certain number of landmarks, using various ranging or

direction-of arrival technologies that allow them to determine the distance or direction of landmarks.

5 REQUIREMENTS

This chapter presents the requirements for a sensor network and the networking nodes.

5.1 Examples of related user scenarios

The European Union is supporting the efforts implemented by Member States to fight forest fires in all their stages. One of the most recent tools in this sense is represented by the Council and European Parliament Regulation (EC) N. 2152/2003 of 17 November 2003 on the monitoring of forests and of environmental interactions in the Community (Forest Focus). Forest Focus has been implemented through national programmes submitted by the EU Member States for the years 2003-2004 and 2005-2006. Forest Focus regulation focused mainly on forest monitoring and the related collection of data.

Following paragraphs document some examples of the most severe forest fire taken from Forest Focus 2005 report.

Portugal - The most affected regions were in the centre inland of the country, where fires burned mostly maritime pine areas and eucalyptus plantations. The largest burnt area occurred in the district of Coimbra (14 % of 2005 total), in the central part of country, where a total of 48 224 ha were burnt. The districts of Viseu and Vila Real were also very affected. The lowest burnt area took place in the south districts of the country, with Setúbal and Évora registering the lowest values. Faro, which was a very affected district in previous years, naturally had a high decrease on the burnt area, with 1 666 ha. The higher number of fires took place in the districts of Porto and Braga, in the Northwest Region of Portugal. This region is characterised by a large density of population who lives near forest land, associate with a small dimension of the forest property.

France - Twenty four fires exceeded more than 100 ha, including 4 with more than 1 000 ha. These figures are higher than the decennial averages which are established respectively to 17 and 3. These important fires developed in 10 of the 15 Mediterranean departments: Alpes-de-Haute-Provence (2, of which fire GREOUX-les-BAINS burned 2 100 ha), Alpes-Maritimes (1), l'Ardeche (3), l'Aude (2), les Bouches-du-Rhône (4), Haute-Corse (2 which burned 2 250 ha in CALENZANA and 1 270 ha in PIEVE), Gard (1), Herault (1), Pyrénées-Orientales (2, of which the fire of TARERACH which burned 2 150 ha), Var (6). Several of these fires (in particular in Alpes-de-Haute-Provence, Alpes-Maritimes, Bouches-du-Rhône, Var, where buildings were severely damaged or destroyed) again revealed the difficulties caused by the constructions whose owners do not generally respect the legal obligations of undergrowth clearance.

Czech Republic - In 2005, number of fires reached 619 with the total burned area 227 ha.

One of the most extensive fires in the past 30 years happened in the National Park Ceske Svycarsko in July 2005. More than 20 hectares of forest were affected. Final extinguishing continued for the next three days, because the soil was hot up to the depth of 1 meter.. The

situation was improved by the rain on the third day, which had humidified the area and helped to stop spreading of fire.

The fire started on Saturday at around 5:30 p.m. A total of 28 professional and volunteer fire-brigades with more than 30 vehicles came to the place, including help from the neighboring Germany, two police helicopters and an airplane of the Aircraft Firebrigade. On Sunday, these three airborne machines have performed a total of 380 fire-fighting drops releasing more than 325 000 liters of extinguishing agents to the area. During Saturday and Sunday, more than 10 millions of liters of extinguishing agents were used for fire extinguishing near Jetrichovice. More than 200 firemen were in operation. The intervention was significantly complicated by terrain. The area is located in rocks that are inaccessible for vehicles. Therefore, hundreds of meters of hose lines had to be laid.



Figure 22 - Fire protection in National Park Creech Saxon Swiss CZ

For the evaluation of technologies in WP7 for forest fire scenarios, we are planning three testing scenarios, where will be assets the feasibility of single case. It is not possible to realise this scenarios in full operational environment, but the crisis situation will be simulated in limited area. There will be necessary to prepare cooperation of all actors. This part describe part of processes, in stage of planning work in WP7, it will be transferred into detail UML description of processes.

Context I: Fire preparedness and prediction

The scenarios will be divided into single task, which will be realised by single actors.

Selection of area for pilot test will be realised by FMI on the base of data sets from Forest Developing Regional plans. The methodology will be designed on the base of previous experience and also on the base of ARMONIA recommendations

FMI will implement map services to support sharing of maps for pilot area using Web services

In the cooperation of all actors, there will be build WEB GIS solution for area, guarantee sharing of all services in testing area

Using the Web GIS system, there will be provided by FMI selection of areas for monitoring, where the criteria will be, that maximum distance between two neighbouring areas will be 1 km

CCSS will select sensors for every plot testing plot. On one plot could be more sensors measuring the same parameter

In the cooperation between FMI and CCSS, there will be established local sensors networks on every plot, which will tested measurement of single parameters, this plots will be connected using mobile unit. On this there will cooperate CCSS, Lesprojekt, Help Forest. Trough mobile unit will be established connection of sensors with central GIS.

After establishing of infrastructure, there will be simulate of fire situation on single plot I cooperation of FMI and Forest protection services and will be realised measurement of parameters. The exact methodology for this assessment will be designed in initial stage of WP7

Context II: Forest fires detection and response

The second case is more difficult for real practical assessment of scenario. Some parameter, like fault tolerance of single sensors could be measured in laboratory conditions (temperature, till which sensors are able to work, tolerance on fall, etc)

For terrain testing we expected next scenario.

Smart dust sensors will be randomly distributed in one plot, where will be simulated forest fire (it is expected, that there will already be established communication infrastructure).

After this, there will be realised distribution of sensors (3) with GPS

First step of testing will be localisation of every sensors in plot on the base of network information and transfer of position of single sensors to GIS.

At first stage, there will be realised test of tolerance of network on change of topology, if some sensors will be manually removed.

In second stage there will be in limited scale realised simulation of fire and realised both, monitoring of situation in plot using PDA and also monitoring of situation on dispatcher centre

Context III: Post-fire assessment

The third scenario, will be focused on testing of underground sensors. As in previous case underground sensors will be distributed in one plot, where testing will be realised. It is expected, that there already will be established communication infrastructure

First step of testing will be localisation of every sensors in plot on the base of network information and transfer of position of single sensors to GIS. At first stage, there will be realised test of tolerance of network on change of topology, if some sensors will be manually removed.

In second stage there will be in limited scale realised simulation of fire and realised both, monitoring of situation in plot using PDA and also monitoring of situation on dispatcher centre

Context IV : Landslides

Some landslide scenarios from Europe are shown below:

- The 5-6 May 1998 Mudflows in Campania, Italy

A large number mudflows were occurred in the area of pizzo d'Alvano in the southern Appennines (Campania, Italy) . The intense and long-lasting rainfalls at the start of the may triggered about 150 mudflows in 10 hours. This affected area of approximately 75 km² and their speed reached 50km/h at the exit of the Sarno ridge gullies. Maximum discharges were about several hundred m³/s and the total volume of the mudflows reached several thousand cubic meters. The event caused severe damages, therefore the intervention of the National Department of Civil Protection was required.



Figure 20: Map of Campania, Italy

Figure 23 - Map of Campania, Italy

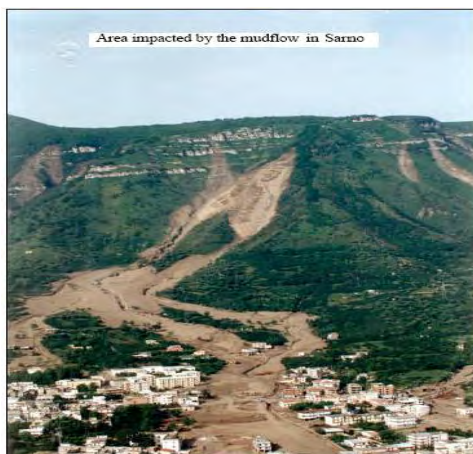


Figure 24 - Area impacted by the mudflow in Samo

- The Stoze landslide and the predelica Torrent debris flow of November 2000 in Slovenia.

It was the worst natural disaster in Slovenia. Western Slovenian hills and mountains were exposed to rainfall amounts of 250 to 500 mm in October and 600 to 1400 mm in November, which was above the average. Heavy precipitation resulted in floods on many streams, rivers and torrents.



Figure 25 - The Stoze slide of 17 November 2000

- The landslide in the “Dvarcionys” plant site , Vilius, Lithuania on 11 August, 2000

Lithuania is at the altitude of 292m above sea level. Here the landslide affected an area of 80000 m3 of soil.



Figure 26 - The landslide in Villus, Lithuania

- Landslides in Bulgaria

About 960 areas are catalogued within the territory of the country, 350 of which are situated in built-up areas and health resorts, and they are spread on a territory of 20,000 ha. The most serious landslides in Bulgaria are located on the northern part of the country’s sea coast.

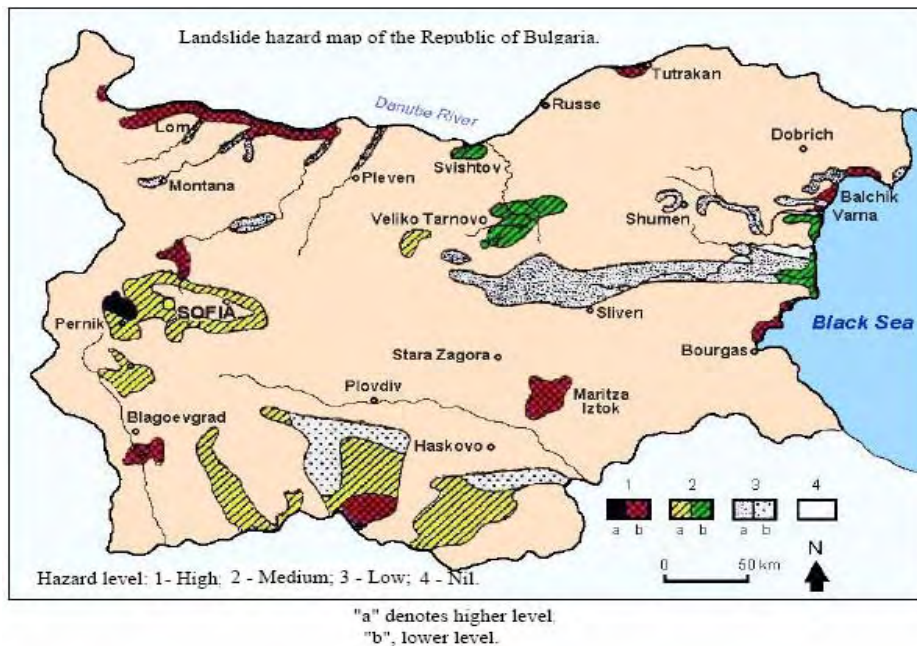


Figure 27 - The landslide hazard map of Republic of Bulgaria

Observations from the Scenarios

- *The common issues in the 5-6 May 1998 Mudflows in Campania:*

The lack of Hazard zoning map of the area subject to all environmental disastrous event and lack of adequate urban planning allowed wild urbanisation. Weather forecasts were insufficient to identify the rainstorms in the area. Rainfall data records together with the data of past mudflow events would have helped to define the rainfall thresholds to provide the warning.

- *The common issues in Stoze landslide and the predelica Torrent debris flow of November 2000 in Slovenia :*

Flooding causes the debris flow on steep slopes/torrent beds. An early warning was failed, since it was difficult to assess the debris flow hazard zones, due to state of knowledge and the lack of available data.

- *The common issues in the “Dvarcionys” plant site, Vilius, Lithuania on 11 August, 2000*

If the geological and geotechnical conditions had been ascertained and a good geological survey had been done at a proper time, the disaster could have been prevented. There was an artificial slope at the site where the storehouse and the underground communications were built, and the soil conditions were not natural.

- *The common issues in the Landslides in Bulgaria.*

The causes that lead to the disaster are intensive urbanisation, illegal building constructions without any drainage system, construction of water supply system with no sewage water system and leaks and damages in the existing old water mains.

5.2 System requirements

5.2.1 Requirements for the sensor network

The operating modes and the subsequent system specifications are tightly connected with the intended application. Nevertheless, the definitions of the physical constraints and features have to be assessed when the system has a limited amount of resources. Energy limitations, memory, processing power and capabilities, radio coverage (among other factors) may pose severe design limitations to the whole system, independent of the specific application. In the following, we will illustrate the main requirements on the sensor network focused by WP2.

5.2.1.1 Topology

Context I: Fire preparedness and prediction

For the topology of network and for communication infrastructure are expected next conditions,:

- The network will have multiple layer fixed topology, with know position of all sensors on level 2.
- Position of sensors on level 1 is not relevant in these cases. Topology of network has cluster structure, every cluster is managed by one sensor of level 2 with more sensors of level 1.
- All sensors of level 1 could communicate with other sensors of level 1 in the some cluster and with one sensor of level 2 in this cluster.
- Sensors on level 2 communicate with neighbouring sensors of level 2. Some from sensors on level 2 could communicate with public network.
- The sensors of level 2, which don't have access to public network, communicate with public network through other sensors of level 2

Context II: Forest fires detection and response

For the second scenario, we expected that topology of network; will follow next conditions and that there will be guaranteed next communication conditions

- The network will have multiple layer ad hoc topology, where position of sensors on level 3 is defined by GPS (this sensors could be mobile) and position of sensors on level 1 and 2 is calculated from position of sensors on level 3 and from networks.
- Position of sensors on level 1 (2) is fixed.
- Every sensor of level 1 (2) communicates with more sensors on the some level.

- some from sensors of level 1 (2) don't communicate directly with any sensors on level 3, some could communicate with more sensors on level 3. This could change in dependency of changes of position of sensors on level 3. But there need to be guarantee, that information from any sensor on level 1 (2) has to be transmitted through other sensors on level 3.
- The topology could change, because some sensors on level 1 (2) could be destroyed. Some from sensors on level 3 could communicate with public network.
- The sensors of level 3, which don't have access to public network communicate with public network through other sensors of level 3

Context III: Post-fire assessment

For the second scenario, we expected that topology of network; will follow next conditions and that there will be guaranteed next communication conditions:

- The network will have multiple layer ad hoc topology, where position of sensors on level 3 is defined by GPS (this sensors could be mobile) and position of sensors on level 1 and 2 is calculated from position of sensors on level 3 and from networks.
- Position of sensors on level 1 (2) is fixed.
- Every sensor of level 1 (2) communicates with more sensors on the some level. Some from sensors of level 1 (2) don't communicate directly with any sensors on level 3, some could communicate with more sensors on level 3. This could change in dependency of changes of position of sensors on level 3. But there need to be guarantee, that information from any sensor on level 1 (2) has to be transmitted through other sensors on level 3.
- The topology of the network could change, because some sensors on level 1 (2) could be destroyed.
- Some from sensors on level 3 could communicate with public network.
- The sensors of level 3, which don't have access to public network, communicate with public network through other sensors of level 3

Context IV: LandSlides

This application requires two layers (or two parts) of sensors. The lower layer consists of a sensor column, and the upper layer or part consists of wireless sensor nodes.

The working principle and the model of different sensors that are proposed to use in the designed sensor column are given below.

Ground Water Pore Pressure Measurement - The groundwater pore pressure must be measured, as this measurement provides critical information about how much water is in the ground. As the amount of water in the ground is directly related to the soil cohesion strength, this parameter is one of the most important for slope stability and landslide prediction. Pore pressure values in landslide prone soil are typically in the range 10kg/cm^2 (10 Kpa). For landslide monitoring, we need to measure ground water pressures of up to 10kg/cm^2 . Because this parameter changes relatively slowly over time, we only need to sample this value every 60 minutes. If the values start to change more rapidly with time, the sampling rate will be dynamically increased as appropriate. A minimum resolution of 0.010 kg/cm^2 needs to be measured.

Geophone - A geophone used for earthquake detection needs to detect frequencies of 1-10 Hz. However, a landslide has much different characteristics from an earthquake. In this case, frequencies of up to 250 Hz need to be measured. Since we are also monitoring for earthquake induced landslides, geophones with a frequency response of up to 250 Hz will be used. The resolution should be within 0.1 Hz. These measurements need to be collected when they occur, therefore, the geophone response will be used as a trigger to collect other measurements. This is possible, as a geophone does not require an external power source.

Strain Gauge – A strain gauge can theoretically be used to measure the movement of a bore well pipe. As part of the pipe moves due to surrounding earth movement, it will stress the strain gauges attached to the pipe. Deflections in the pipe of 0.5 mm per meter need to be detected. For a strain gauge that is 50 mm long, this corresponds to a resolution of 0.025 mm.

Inclinometer – Inclinometers measure the ground's movement. Because the ground can creep very slowly over a long period of time, extremely high accuracy is required. Ground velocities in the range of millimetres per hour need to be detected. This requires sampling every 15 minutes with a minimum resolution of 25 micrometers. The inclinometer can theoretically measure maximum movements up to its length. Thus, a 500 mm length inclinometer can measure 500 mm of movement. In reality, it will be less than this.

Temperature – Temperature is an important factor for geological incidents. The physical properties of soil and water change with temperature. The temperature in the Idukki District of Kerala, India, where the first landslide test deployment will be, varies between 21 and 27 degrees Celsius. Resolution of 1/10th degree Celsius measured every 15 minutes is sufficient.

Rainfall – Rainfall of up to 5000 mm per year can fall in the Idukki District. Because most of the rain falls in monsoon torrents, mm readings of rainfall every 15 minutes should be adequate. In addition, it is not only rainfall by itself that increases ground water levels, but also the existing saturation of the soil, i.e., the amount of water that is already in the soil. Therefore rainfall measurements are used as supplementary information and not primary information.

Wireless Sensor Nodes – Wireless sensor nodes with the capability to interface up to 8 single ended analog data channels should be used. A signal conditioning board will be necessary to amplify the sensor signals for input into the wireless sensor nodes. In addition, signal excitation of up to 5 Volts DC and different PWM frequencies are necessary. The sensor nodes should have a range of approximately 100 meters and should have the ability to use multi-hop ad hoc routing strategies for maximum coverage area with a minimum of clustering nodes. Clustering nodes will be used to locally aggregate information and deliver consensus measurements to the main processing computer (located at the VRC). The wireless sensor nodes should be easily programmable and reconfigurable, with the ability to transmit their ID. 250 kbps data transmission speed is acceptable for use with this project.

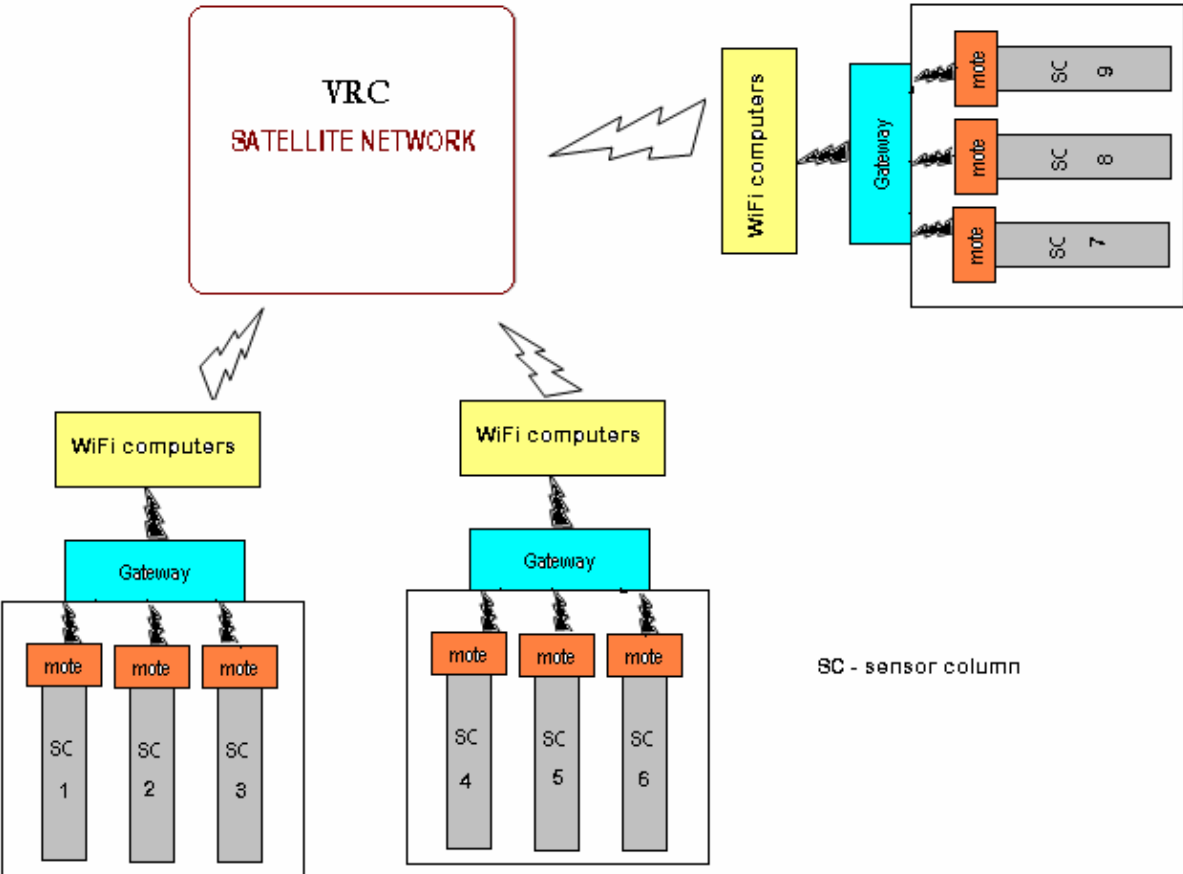


Figure 28 - Wireless sensor network scheme

5.2.1.2 Reaction time.

Context I: Fire preparedness and prediction

The first reaction, when the alert situation is recognised has to be till 5 minutes (information come on server), other information has to come in minutes.

Context II: Forest fires detection and response

The reaction on the significant changes has to come in 1 s.

Context III: Post-fire assessment

The reaction on the significant changes has to come in 1 s.

Context IV: LansSlides

The reaction on the significant changes has to come in 1 s.

5.2.1.3 Minimisation of the environmental impact.

Context I: Fire preparedness and prediction

It is expected, that all sensors level 1, 2 could be removed after working period, so there are not environmental influences

Context II: Forest fires detection and response

The part of sensors of level 1 and 2 will be burnt. So there is necessary estimate, if burning of sensors will have reasonable environmental impacts. In most cases could be expected, that temperature will be high.

The remaining sensors of level 1 will stay in environment, so there is necessary take into account environmental impacts.

The remaining sensors of level 2 could be removed after fire.

All sensors of level 3 will be removed after forest fire

Context III: Post-fire assessment

The part of sensors of level 1 and 2 will be burnt. So there is necessary estimate, if burning of sensors will have reasonable environmental impacts. In most cases could be expected, that temperature will be high.

The remaining sensors of level 1 (2) could be removed after fire.

All sensors of level 3 will be removed after forest fire

5.2.1.4 Reliability Resolutions /Assessments

As a starting point, the event detection capabilities can be quantified through the probability of the correct detection probability, for a fixed probability of false alarm (like in radar systems) vs. the signal/noise ratio on each sensor, and parameterised both on the sensors density and the radiated power. The assessment of precision can be evaluated, for instance, through the design of a suitable statistics, like media and variance, and will be benchmarked against those belonging to each sensor, before and after the matching case the requirement is supply by the specified application.

5.2.1.5 Fault tolerance

In all cases

- No alarm in the case of crisis event 0%
- False alarm 5 % maximum

5.2.2 Requirements for the radio links

5.2.2.1 Coverage

Context I: Fire preparedness and prediction

Sensors on level 1 will communicate till 30 m with band capacity till 10kb per second

Sensors on level 2 will communicate

On level of sensor level 2 till 1500 m, the minimal band capacity is 125 kb per second, recommended capacity higher then 1 Mb per second

Context II: Forest fires detection and response

Sensors on level 1 and 2 will communicate till 30 m with band capacity minimum 125 kb per second

Sensors on level 3 will communicate

On level of sensor network till 1500 m, the minimal band capacity is 125 kb per seconde, recommended capacity higher then 1 Mb per seconde, voice channel could be usefull

Context III: Post-fire assessment

Sensors on level 1 will communicate till 150 m with band capacity till 10kb per second

Sensors on level 2 will communicate till 30 m with band capacity till 10kb per second

On level of sensor level 3 till 1500 m, the minimal band capacity is 125 kb per second, recommended capacity higher than 1 Mb per second

Project bounds.

The requirements must be satisfied with the following inevitable project bounds:

(a) *Available band.* The band expected for the radio interface does not have to interfere with mobile or other pre-existent networks. We propose to use the international or national free bands employed for low emission system [e.g. the ISM bands (315 MHz, 433 MHz, 870 MHz, 2.4 GHz), or other bands already utilized by wireless connection systems, for example using an ultra-wideband radio interface.

The choice between these bands will be carried out during the project.

(b) *Radiated power.* The power radiated by each sensor must guarantee the connectivity of the network: in classical paradigm this implies that, given two network nodes, a link between them must exist, even if composed by several jumps through intermediate nodes. In the paradigm pursued by WINSOC, the connectivity requirement is in a sense more relaxed, as no multi-hop information flow of the information is required and partial disconnections are possible without necessarily sacrificing the overall network performance.

In summary, the total network coverage on a given geographic area must be under control, depending on the nodes spatial density. The situation is different in the case of mechanical solicitations monitoring; in this case the sensors are deployed nearby the critical points of the structure and their position can be known in advance. A particular case is a network where the sensors are positioned on mobile vehicles. In this case (as in the general case of topology-varying network) the power must be adapted as a function of the topology.

6 CONCLUSION

As illustrated in chapter 2 there exists only few real sensor applications readily available today, if academic test-beds do not count. Most projects are at testbed stages yet, mainly, verifying node prototypes or identifying real requirements of the applications. Today, currently deployed applications share some common characteristics; raw sensor data transmission over wireless connection, mostly data processing at collection points, simple routing schemes, best-effort data transport delivery. However these characteristics do not reflect the real requirements of most application domains.

Starting from the WINSOC project proposal we have justified the scenario usage and iterative approach. Two basic scenarios – “Forest fire detection and fire risk estimation” and “Landslides detection and prediction” were characterised giving special focus on the sensor network potential usage. These reference scenarios will be further discussed and developed as the key tools for the derivation of technical requirements for the WINSOC proposed system.

On the base of interviews with users, where we collected user requirements and on the base of comparison on this requirements with literature, this report collected requirements on data and services requested for single scenarios. Table summarizes the scenario dependent requirements and required services as well as challenging research issues for each context.

The report defines theoretical conditions, in which the sensors of network will operate and also defined scenarios for practical testing of this sensor networks. This theoretical conditions are defined for design and development of components in WP3, WP4, WP% and also for integration into operational system in WP6

This scenario has to be elaborate more detail in WP7 with focus on practical assesmnet of technologies, where all parameters, but also fault tolerance will be provided in simulated situation, which will model practical situation.

The conclusions of all parameters are in following table, which has to summarise request on parameters of sensor networks

Contest Fire

	Typology	Communication between sensors on level 1	Communication between sensors on level 2	Communication between sensors on level 3	Bandwidth on level 1	Bandwidth on level 2	Bandwidth on level 3	Communication from lower level to upper	Transmission of information in upper level	Fixed sensors of upper level	Knowledge about prostitution of sensors in upper level	Environmental impact of sensors on level 1	Environmental impact of sensors on level 2	Environmental impact of sensors on level 3
Context I: Fire preparedness and prediction	Fixed	30 m	1500 m		10 kb	125 kb Minimum 1 Mb recommended		All sensors in cluster to the sensors	Yes	Yes	One time	No	No	
Context II: Forest fires detection and response	Ad hoc	30 m	30m	1500 m	125 kb	125 kb	1Mb minimum	From 0 to N	Yes	Yes	Sensor with GPS	Yes	No	No
Context III: Post-fire assessment	Ad hoc	150 m	30 m	1500 m	10 kb	10 kb	125 kb Minimum 1 Mb recommended	From 0 to N	Yes	Yes	Sensor with GPS	No	No	No

Contest Landslides

	Topology	Sensor Sampling Bandwidth	Communication between sensors on level 1	Communication between sensors on level 2	Communication between sensors on level 3	Bandwidth on level 1	Bandwidth on level 2	Bandwidth on level 3	Communication from lower lever to upper	Transmission of information in upper level	Fixed sensors of upper level	Knowledge about position of sensors in upper level	Environmental impact of sensors on level 1	Environmental impact of sensors on level 2	Environmental impact of sensors on level 3
Context I: Pre-event Monitoring	Fixed	100 Hz per channel	350 m	750m	1500 m	10 kbps	10 kbps	40 kbps	All sensors to cluster head, aggregate values from clusterhead to layer 3	Yes	Yes	One time	Yes - drilling bore holes	No	No
Context II: Landslide detection and response	Ad hoc	100 Hz per channel	350 m	750m	1500 m	10 kbps	10 kbps	40 kbps	All sensors to cluster head, aggregate values from clusterhead to layer 3	Yes	Yes	Sensor with GPS	Yes - drilling bore holes	No	No

Level 1: Between wireless sensor nodes on top of each sensor column to the cluster head.

Level 2: Between cluster head nodes

Level 3: Cluster head nodes to Stargate

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8 LIST OF ACRONYMS

ACRONYM	MEANING
API	Application program interface
CI	Critical Infrastructure
DARPA	Defence Advanced Research Projects Agency
EC	European Commission
FMI	Forest Management Institute
GEO	Geostationary
GIS	Geographic Information Systems
GMES	Global Monitoring for Environment and Security
GPS	Global Positioning System
GPRS	General Packet Radio Service
GSDI	Global Spatial Data Infrastructure
HW	Hardware
ICT	Information and Communications Technology
IEEE	Institute of Electrical & Electronics Engineers
IP	Internet Protocol
IPR	Intellectual Property Right
IST	Information Society Technologies
ITU	International Telecommunication Union
NGO	Non-Governmental Organization
O&M	Observations and Measurements
OGC	Open Geospatial Consortium
OWS	OGC Web Services
PC	Personal Computer
PDA	Personal device assistant
QoS	Quality of Service
R&D	Research and Development
RTD	Research and Technological Development
SAS	Sensor Alert Service
SCADA	Supervisory Control and Data Acquisition
SensorML	Sensor Markup Language
SME	Small and Medium Enterprise
SOS	Sensor Observation Services
SPS	Sensor Planning Service
SW	Software
SWE	Sensor Web Enablement
TLC	Telecommunication
TML	Transducer Markup Language
TOS	Type of Service
UAV	Unmanned Autonomous Vehicle
UWB	Ultra Wide Band
VRC	Village Resource Centre
WAN	Wide Area Network
WAP	Wireless Access Protocol

WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WNS	Web Notification Service
WP	Work-Package
XML	Extensible mark-up language
ZigBee	Specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4 standard for wireless personal area networks