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Environmental Monitoring Supported by the Regional Network Infrastructures

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1. Introduction

The aim of this chapter is the presentation of studies and research results concerning environmental monitoring techniques promoted by Lepida SpA across a wide area, the Italian Emilia-Romagna Region.
Lepida SpA *Lepida SpA* (2011) is an in house providing company established by a Regional Law (11/2004, "Regional Development of the Information Society") of Emilia-Romagna region, which consolidates a common vision and a collaborative approach with the local Public Administrations.
Lepida SpA was created in the end of 2007 by the Emilia-Romagna Regional Government, as unique shareholder and founder. Currently has 395 Public Administrations and Public Entities as shareholders. Lepida SpA is involved in the governance of the Regional ICT Plan which defines the regional ICT strategies and policies within the regional territory, acting as innovation facilitator among its partners.
The core business of Lepida SpA is represented by the regional ICT infrastructure but its operations range between telecommunication networks, digital divide and broadband networks strategies and ICT applications and services. Among the main activities and experiences pursued by Lepida SpA we can mention: the planning, development, management and monitoring of the telecommunications networks (fixed and mobile) of the P.A., including the deployment of new broadband networks (wired and wireless) within the region; the definition and implementation of suitable solutions for the Digital Divide topics and for the Next Generation Access Networks in order to ensure high speed internet for the citizens and businesses; the realization of ICT platforms and services for the Public Adminitrations (federation of authentication, payments, ..) that enable a large number of on-line services in favor of citizens and Enterprises; the realization of on-line services for e-Governement purposes and interaction between the P.A. and the Enterprises and citizens.
The infrastructure provided by Lepida and owned by the Public Administrations partners of Lepida spA, is an heterogeneous interconnected network covering the whole regional territory (more than twentytwo thousand square kilometers of area). It includes a regional area network (Optical Fiber) called *Lepida*, wireless networks (Hyperlan) that are extensions of *Lepida* which allow to solve Digital Divide in some mountain territories, and a regional emergency digital radio network (TETRA) called *ERretre*. A map of the Optical Fiber and Hiperlan link is illustrated in Figure 1.

The availability of this powerful infrastructure offers many opportunities for the P.A. to deploy and provide useful and interesting services to the citizens. Furthermore it represents a unique great regional test bed for the development and testing of new applications and services exploiting the potential of the ICT infrastructures.

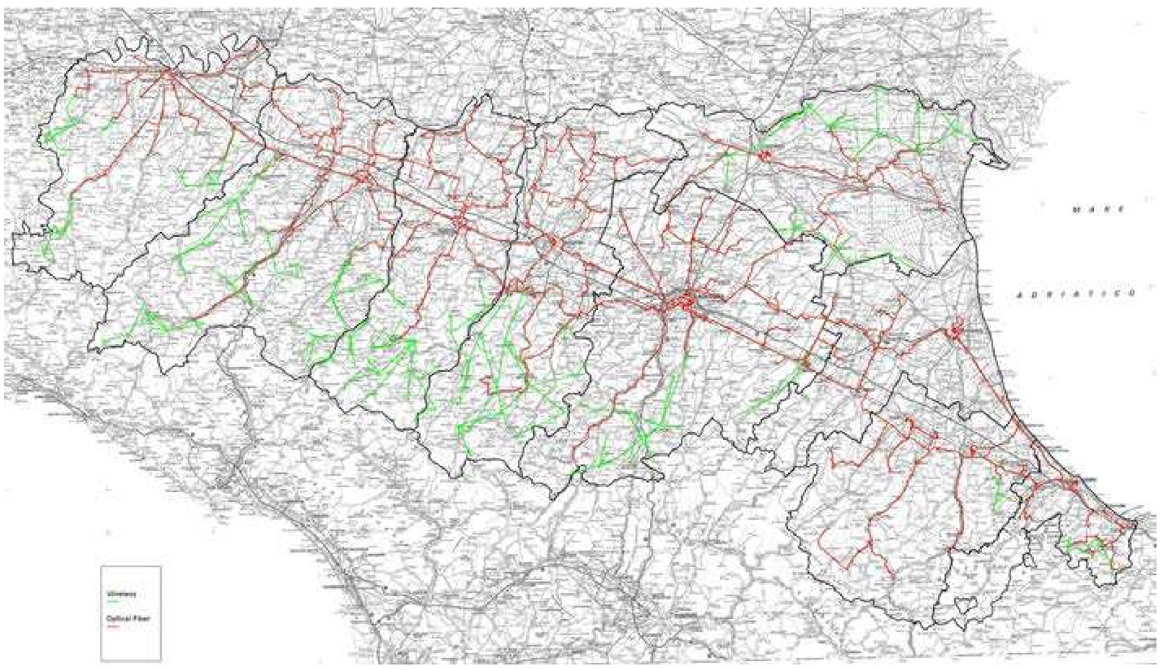

Fig. 1. Optical Fiber and Hiperlan link

In particular, this chapter will present efficient sensor network applications promoted by Lepida SpA and based on the regional hybrid access network, with the aim to realize environmental monitoring through an efficient usage of the territorial assets, by reaching therefore the important goal of public resources savings. The effort of Lepida SpA has been directed towards two primary directions: the first one is the exploitation of the Lepida SpA networks as a communication infrastructure that enables the messages exchanged by the softwares of data management that the Public Administrations already owns and uses for their environmental monitoring activities; the second one, besides the exploitation of the Lepida SpA networks like described in the first model, also proposes the usage by the Public Administrations partners of a proper software and/or hardware platform of data management, planned, tested and promoted by Lepida SpA.

In order to achieve this aim Lepida SpA has adopted a research method based on the following steps: 1) census of the sensor networks and communication networks used for environmental monitoring purpose, existent and operating across the whole regional territory 2) proposal of architectural, infrastructural and application service solutions 3) realization of experimental test-beds 4) adaptation and tuning of the solutions proposed during the second step in view of the results obtained during the third step 5) realization of a full service.

The census activity has been performed all over the Emilia-Romagna territory, by taking into consideration all the Public Organizations. This investigation has highlighted the presence of a huge amount of small sensor networks deployed all over the regional territory, consisting of spatially distributed devices for the monitoring of environmental conditions, such as temperature, sounds, pollutant, traffic, river and basin and also a lot of cameras for the video surveillance and video environmental monitoring. Typically they have been realized in the past as independent and autonomous systems, each one by using its own communication network to transport the collected data, each one by using its own sink to elaborate the data and each one belonging to a specific local Public Administration.

This scenario often brings the local Public Administrations to inefficient and expensive managements and maintenance of the data transmission, collection and elaboration. In such a scenario, the two working directions followed by Lepida SpA and mentioned above, can represent an effective way for the Public Administrations to pursue environmental monitoring activities while saving as much as possible resources and while following economies of scale. In particular Lepida SpA has defined a centralized architecture Taddia et al. (2009) based on a centre of collection, elaboration, management and diffusion of the sensor data that, by exploiting the hybrid access regional network, beside solving the inefficiencies can also provide further benefits that would be impossible to realize with independent and separate management systems. Let us mention just a few of the possible benefits enabled by the architecture promoted by Lepida SpA: data sharing among different Public Administration by saving the data property thanks to authentication and profilation solutions; correlation of data belonging to different Administrations. Lepida SpA has tested this architecture with some Public Administrations Taddia et al. (2010).

This chapter starts with a description of the adopted research method, by giving a comprehensive description of the first step of this research, the census of the resources available inside the Emilia-Romagna region. The rest of the chapter will describe more in detail how the aforementioned research method has been applied to three scenarios, by presenting three test bed actived by Lepida SpA in collaboration with three Public corporations: River Basin Consortium of the River Po affluents, Drainage Consortium of the western Romagna, River Monitoring for the Civil Protection of the Emilia Romagna Region.

The three cases all exploit different network technologies among the ones offered by the the hybrid regional infrastructure, depending on factors such as the geographical position of the monitoring systems and the amount of data exchanged during the monitoring process.

2. Research methods

The method adopted by Lepida has performed, as a first step, an exhaustive census of all the automatic sensor networks deployed in the regional territory, not already integrated with regional sensor networks (sensor networks owned and managed by a regional Entity called ARPA *ARPA* (2011), Regional Agency Prevention and Environment for the Emilia-Romagna region). The Public Administrations in fact, may acquire and use their own networks in order to meet local needs that are within their competence. In order to carry out the census, all municipalities, provinces, the River Basin Consortium of all the provinces and the civil protection have been contacted. For each network, the following items have been surveyed: type of measured data, number of sensors used, number of data loggers used, transmission media and the Administration involved. Offices for environment and mobility, farming, civil protection and provincial police, have been consulted in main cities of each province. Received responses have been inserted in a database containing the following information: the owner Administration, the service manager, the operator, type of monitoring, number of stations installed, number and type of sensor used and the transmission media. Subsequently an analysis of these responses has highlighted different trends and consolidated needs, depending on the responsible Administration and its skills and jurisdiction. Various types of networks, used by different Administrations, that have been found thanks to the census, are shown in Figure 2.

Types of Monitoring Systems	Entity					
Type of Monitoring	Municipality	Province	River Basin Consortium	Mountain Association	Regional Civil Protection	Total
Videosurveillance	14			1		15
Accesses control	8					8
Traffic Monitoring	7	1				8
Landslides Monitoring		1	6			7
River Monitoring	1	4			1	6
Metereological station	1	4				5
Traffic light infraction	4					4
Messages	3					3
Traffic light optimization	3					3
Speed control	1	1				2
Acoustic	1					1
Bycicles count	1					1
Parking control	1					1
water monitoring		1				1
Building stability	1					1
Total	46	12	6	1	1	66

Fig. 2. Types of monitoring systems related to different entities

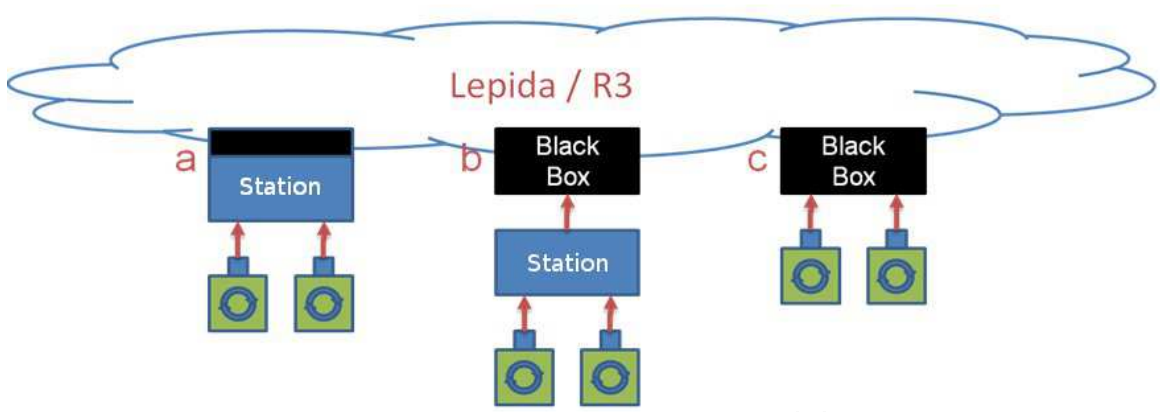

Fig. 3. Models of integration.

Afterwards, for each type of monitoring system, the type and number of sensors used have been mapped, so that their spread could be better understood. As a result was noted that the most common sensors are: the inductive coil (its low cost and its simplicity of use have made it the leader in sensor networks for traffic monitoring); the camera (used by local Public Administrations in response to a need of an improved security for citizens, furthermore the wealth of information intrinsic in its data detected, that is a stream of images, makes this sensor suitable also for other applications such as traffic monitoring or rivers flow control); the inclinometer (its purpose is related to applications for landslides monitoring).

A further analysis about possible efficient architectures that could be proposed to shareholders Administrations, pointed out that is desirable to integrate all existing networks, both for surveillance systems, which are increasingly spreading throughout the territory, and for landslides monitoring, currently managed in a summary way. The presence of a unique wide regional network on the territory, composed by Lepida and *ERretre*, makes this integration possible and it represents also the opportunity to have a uniform and guaranteed transmission of data gathered by all sensor networks. Three different models of integration with Lepida network have been proposed, as shown in Figure 3. Two of them exploit a small hardware and software module programmed by Lepida SpA and called BlackBox, which is mainly devoted to the integration between the communication infrastructure and the sensors.

(a) IP and TETRA driver: a monitoring station, provided by third-parties, on one hand interfaces to sensors and on the other hand to the most suitable telematic infrastructure, chosen between *Lepida* and *ERretre*, through suitable management drivers;

(b) Gateway: a control board interfaces to the monitoring station provided by third-parties through a proprietary protocol or through the standard protocol Modbus. The BlackBox, on the transport network side, provides the most suitable driver depending on the transmission media that will be chosen;

(c) Direct interface: the BlackBox could directly interface to sensors and at the network side performs the gateway functionalities as described in step (b).

The results obtained by the census activities have given the room of defining a suitable architecture able to face the problematic arisen, both in terms of data management system and in terms of communication technologies and infrastructures. Starting from this architectural solutions, some test-beds have been activated nad they will be described in detail on the following Sections.

3. River basin consortium

The subject involved in this testing is the River Basin Consortium of the "Po" River, an agency that deals with the emergency activities related to the water channels and seismic events of "Piacenza", "Parma", "Reggio-Emilia" and "Modena" territories.

The current sensor network that the River Basin Consortium owns and uses presents a lot of problematic aspects: these are particularly correlated to the communication networks currently used, and to the management and storage of data. The data management and storage are fully delegated to private companies that do not offer a system able to ensure the necessary levels of availability and persistence of data. Furthermore, data are distributed on different servers that differ in technology and data representation: there is not a single centralized system that could gather all available information in a standardized format.

Lepida SpA in this case has proposed to the River Basin Consortium of the "Po" River a test-bed activity based both on an interface to the communication infrastructure provided by the *ERretre* network, and on a prototype of a data management center that could satisfy all the needs requested by a full monitoring system.

3.1 BlackBox

The BlackBox prototype has been realized through a control board based on ARM Linux. As shown in the second model of Figure 2 it could be connected transparently to all proprietary tracking stations which export the Modbus interface. This is an open serial communication protocol, master-slave or master-multislave, developed to transmit

information between several PLCs (Programmable Logic Controllers) through a network connection and has become, over the years, a de facto standard communication protocol for the industry. Otherwise, in the third model schematized in Figure 2, the BlackBox provides the management of three different types of sensors: digital sensors, that could also be connected in a multiple modality through a multi-master and multi-slave communication bus; a single generic alarm button; a single serial sensor.
In order to properly handle these three types of sensors, for each one of them a dedicated parallel task has been implemented in the BlackBox: this ensures the management of any kind of warning, even asynchronous, from sensors. Furthermore, the BlackBox interfaces to the network both to transmit data and receive commands, through two different ways: either using the Ethernet connection for communication via IP or the serial connection for communication via Tetra terminal, in this case by SDS. The software is based on a task that periodically requests a measure to all the sensors connected and sends them to the data collection center, also managing the reception of any command configuration parameter, such as changing the sampling rate or actuating connected devices, for example an acoustic or light signal. A software unit receives as input the messages sent by the BlackBox, interpreting and storing them properly. The server where this unit resides, is interfaced both to the IP network and ERretre through a modem connected to a ttyUSB port. In particular, when a message is received the unit, according to the opcode message and to the sender sensor typology, properly extracts the information and stores them in a table or in another textual file available in the system and used by the entity, considering them as a single sensor in a unique instant of sampling. A single message, in fact, could also contain several measures of a unique sensor but related to subsequent sampling instants, or measures sent by different sensors but related to the same sampling instant.
The experimentation with the River Basin Consortium is based on the second model of integration and, due to the isolated location of the test-bed site which does not allow an ethernet connection to the Lepida Network, the communication is done via SDS.

3.2 Landslides monitoring

The test-bed organized by Lepida SpA was installed on the 16th of July, 2010, at the landslide by Fosso Moranda, in the Polinago municipality, province of Modena. It consists of a proprietary survey station (Datalogger) with two biaxial inclinometers at different depths, which perform accurate measures related to millimetric movements of the ground, and a piezometer, which measures the hydrostatic pressure, attached to it. The BlackBox is connected to a Tetra modem for the transmission of data, according to the configuration where the detection station acts as a slave and the BlackBox is both the master and the gateway towards the Tetra transmission network, as shown in Figure 4. The system is powered by a photovoltaic panel and is normally turned off. At a scheduled sampling rate, typically every hour, the monitoring station will "wake up" and control the power supply of the entire system: both Tetra modem and Blackbox. The BlackBox requests to the station data from sensors, then sends the response message to the data management center and commands the proprietary station, that supervises the power control, to shut down the system. The communications between the proprietary station and the BlackBox physically occur through a serial connection and logically exporting at both sides the standard interface Modbus, as previously explained. In addiction to specific parameters the system also includes the monitoring of the backup battery level, which is useful in checking the functioning of the whole automated measurement system. All processed data have a low weight, that is about

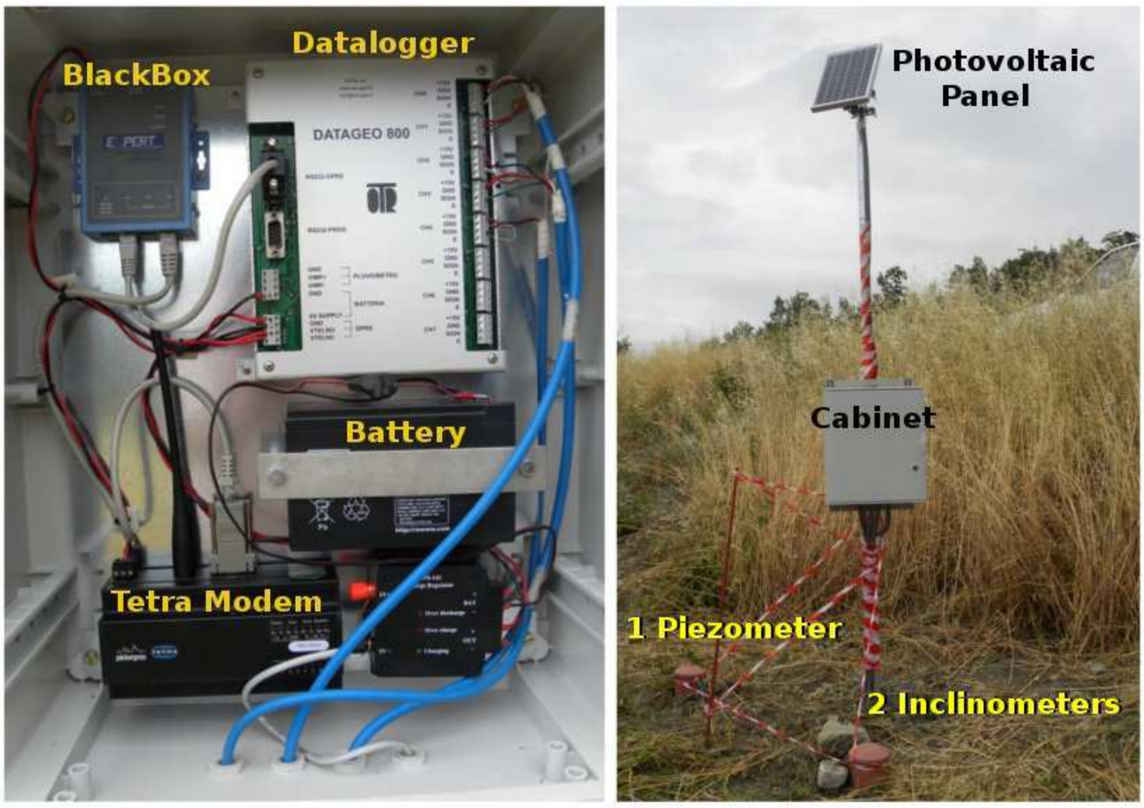

Fig. 4. Cabinet and installation site

20 bytes for each transmission. However the test-bed is highly significant because it is related to a real installation site characterized by particularly hostile conditions, located in an isolated area without any continuous electrical power available. The activation of the whole system has been made possible thanks to a survey about Tetra modems on the market and the identification of which one of them are compatible with the regional network. These could be, unlike ordinary terminals, turned on and off through a simple contact, providing less current absorption and having a lower price.
As a consequence of the good results achieved, the River Basin Consortium and Lepida Spa has arranged a second experimentation phase that should include three new installations connected to multiple sensors and an extension of the BlackBox features, such as remote log retrieval, remote change of the frequency sampling.

3.3 LabICT and Data Management Center

In a previous research phase, a prototype of a unified Data Management Center (DMC) was internally carried out at Lepida SpA R&D Laboratory, in order to receive data, normalize and validate them depending on operation thresholds according to their type and brand. A further analysis of data also allowed a cross-checking of different sensors to trigger alarms for values exceeding from defined thresholds, or for failures. An initial authentication foresaw a base profiling that determined primarily two types of users: basic and operator. for the basic one, thanks to a web interface, a real-time graph with the last samples gathered could be visualized, an historic archive including all measurement done could be consulted and these values could be sent, in a graphic format or through a pdf table, to an e-mail address. Moreover a map showed the location of the stations and the BlackBoxes installed all over the regional territory; for the operator one, in addition to the basic features, this type of user could

insert new units and sensors pertaining to his entity or his partners. Finally he could define new alarm thresholds.
Although this system was quite complete, it had been implemented with the aim to show its potential in environmental monitoring and some features were in an embryonic stage of development. As a result of an increasing interest and a great satisfaction showed by the entities, at the end of the experimental phase, starting from this previous experience the prototype is evolved into a more complex and efficient solution taking advantage of the LabICT-PA (Laboratory for Information and Communication Technology for Public Administration). The LabICT-PA, created in 2007 by the Emilia Romagna region, is part of the Regional High Technology Network and aims to accelerate innovation in public administration. Since 2011 LabICT-PA is also a member of European Network of Living Labs *ENoLL* (2011). The organizational model of LabICT-PA is based on the living labs, where the functional requirements and specifications are defined by and with the users, that is Public Administrations. Design and testing phases will be also carried out through a continuous dialogue with end users. The main partners and their roles in this living lab are: the Emilia Romagna Regional Government that determines the police through the ICT plan; Lepida SpA that, as in house providing company established by a regional law, coordinates activities and provides technical competences and effort; almost 400 public shareholders of Lepida SpA that represent end users; almost 100 business partners, called the club of stakeholders Lepida, that are the think tanks that create added value for PA and for the market; finally universities and research institutes serve as research partners for the laboratory. In this sensor networks context, LabICt-PA has created a fully working prototype, non-engineered, of data management center for sensor networks.

3.3.1 Architecture

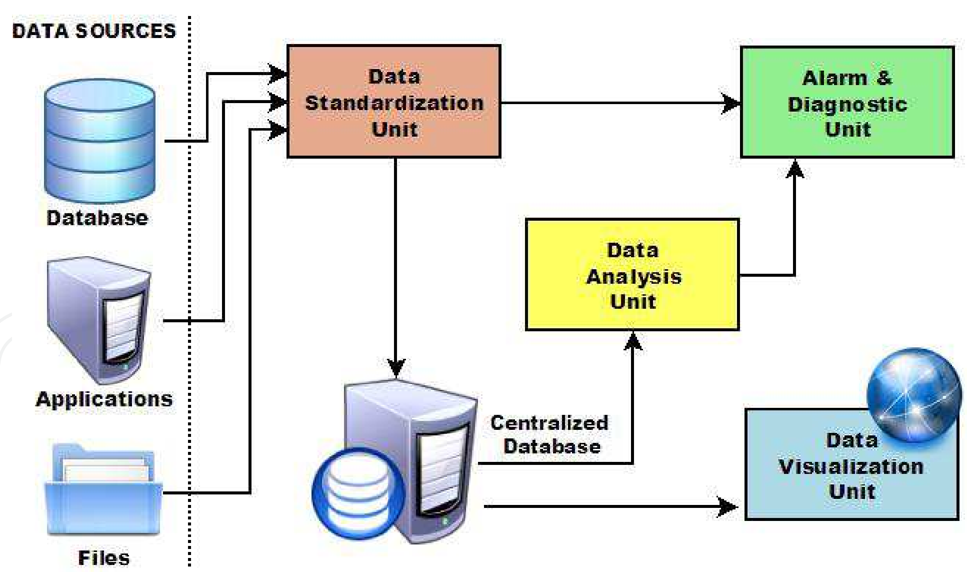

Fig. 5. Data Management Center Architecture

This project aims to integrate all sensor networks deployed in the region through the implementation of a shared platform that could uniformly handle all kinds of environmental data. Firstly, the database of the previous prototype was completely revised to improve the management of the data, intended as a single measure detected by the sensor, making it the most generalized as possible. In fact, the main architectural features are:

- Modularity: each block is independent and communicates through the exchange of XML files;
- Scalability: each module can be implemented on different physical machines;
- Configurability: main operating parameters could be defined in a database, including the definition of new types of sensors, thresholds, alarms, and so on.

All sensors have been schematized in a hierarchical way so that multiple sensors may depend, whether or not, on a BlackBox, which can be connected to another unit, too, for example proprietary stations. Each one of these elements is categorized as a sensor, this is because they are all able to send and receive signals, moreover each sensor can perform different types of measurement with different timing for the acquisition. Finally, measures may be punctual, aggregated or their avarage is calculated, depending on various time intervals. In addition to the tables dedicated to sensors management, the database also includes additional tables necessary to provide addresses, ticketing, alarms, profiling, logging. The Middleware, the Control Center and the Monitoring Center consist of opensource units (Figure 5): each one has its own characteristics, in order to satisfy all the features proposed and also maintain a huge flexibility, in fact each unit inside t he project is independent from the others. The whole managing of data within the Data Management Centre can be divided into three main phases, acquisition, processing, viewing, and this allows to describe each single functional unit. Heterogeneous data sources will be homogenized by the first standardizing unit and then the measures will be evaluated by the analysis unit that will validate them and will check all alarm thresholds. The alarm and diagnostic unit will be contacted by both units and manages and logs the events. Finally, the validated data will be displayed by the visualization unit through a web interface. Communications between two different units are done by using Web Services.

3.3.2 Data standardization unit

This module is the interconnection and standardization middleware between the data and the central unit, therefore plays the role of collector and uniforms data sent from different sources storing them in the database of the DMC. It is based on the following elements:

- Atomic modules for data retrieval: are used to retrieve the data, both automatically at a preset timeslot and on-demand, gathering data from various sources or databases. Inside each atomic unit the access procedure and the detailed commands used to retrieve data from a specific source are specified.
- Atomic units manager: is always active and coordinates the required units. It also serves as a collector for messages sent by the individual atomic modules and redirects them through the units of communication, alarming, diagnostics and data analysis.
- Communication unit: it allows the manager to communicate with other modules inside the platform, on one hand by collecting the total number of messages and errors from the manager, on the other hand receiving as input all requests sent by the DMC and directed to the manager.

Output messages produced by this unit are: the standardized data subsequently stored on a centralized database, the notification messages that new data has been inserted in the database so that the proper unit could start to analyze them, errors and log messages that are transmitted to the diagnostic unit.

3.3.3 Data analysis unit

Its purpose is to control the last data processed by the unit of standardization and to do periodic monitoring on the centralized database in order to trigger the following types of alarms:

- Failures: they occur in two cases, when the unit detects that a certain sensor does not send values in a timeslot that is longer than the sampling rate specified for that sensor, or when the measure is not performed correctly in respect to the working range of the sensor.
- Alerts: several alert situations can be assigned to a unique measure and they may depend on the overcoming of a minimum or maximum threshold, or on an excessive increase or decrease of the measure compared to the previous value stored. The amount of subsequent occurrences of the same state of alert, that must be verified before triggering the proper signaling to the unit of alarms and diagnostics, could be also specified.
- Simplex: this event is triggered as a result of the simultaneous testing of multiple alarm conditions. In a unique simplex both alerts and failures could be associated, linked together by logical operators (and, or, not) so that an event could be characterized by critical conditions based on multiple sensors in very complex relationships.

When one of these alarms occurs, it is communicated to the alarm and diagnostic unit specifying which sensor has triggered the alarm event, the type of event and which alert message has been associated to the event, so that all information needed are forwarded to the dedicated unit, due to simplify and speed up its alarm procedures.

3.3.4 Alarm and diagnostic unit

In addition to alarms generated by the analysis unit, all units part of the system architecture could send error messages in case there is a generic malfunctioning in the DMC such as database connection errors, query failed, units that are not working and so on. The diagnostic unit is implemented using a web service SOAP and handles all the incoming XML requests storing and logging them properly. If they are associated with one or more alarm procedures the unit sends the warning message to one or more users by an email, an SMS or an SDS on a Tetra terminal. Finally, the unit manages generic events that could be scheduled at certain timeslots and which may be linked to the linear chart of a sensor so that when a value exceeds from its alarm, an e-mail should be sent not only including a warning message but also with the graph related to the sensor involved as attachment, due to have a visual feedback of the current situation.

3.3.5 Data visualization unit

This unit is based on a web site consisting of several forms that allow the user to query and monitor the various data structures included into the DMC. All the forms have been integrated into a single portal and are made up of different tabs, available on the main screen of the site. A tree view in the left side of the web site represents all the system control stations and sensors connected to them, then each sensor will match one or more type of measures. This tree is generated according to the initial login: in fact an association is possible between a profile and a user, that specifies which sensors he could visualize. The icons of the tree have different colours to provide visual indications about the status of each sensor: green if the sensor works correctly, red in case of alert, yellow in case of failure and gray if is disabled. The tree view allows the selection of multiple components. A geo-referenced map of the region is also provided in the homepage and the markers shown on it indicate the stations installed

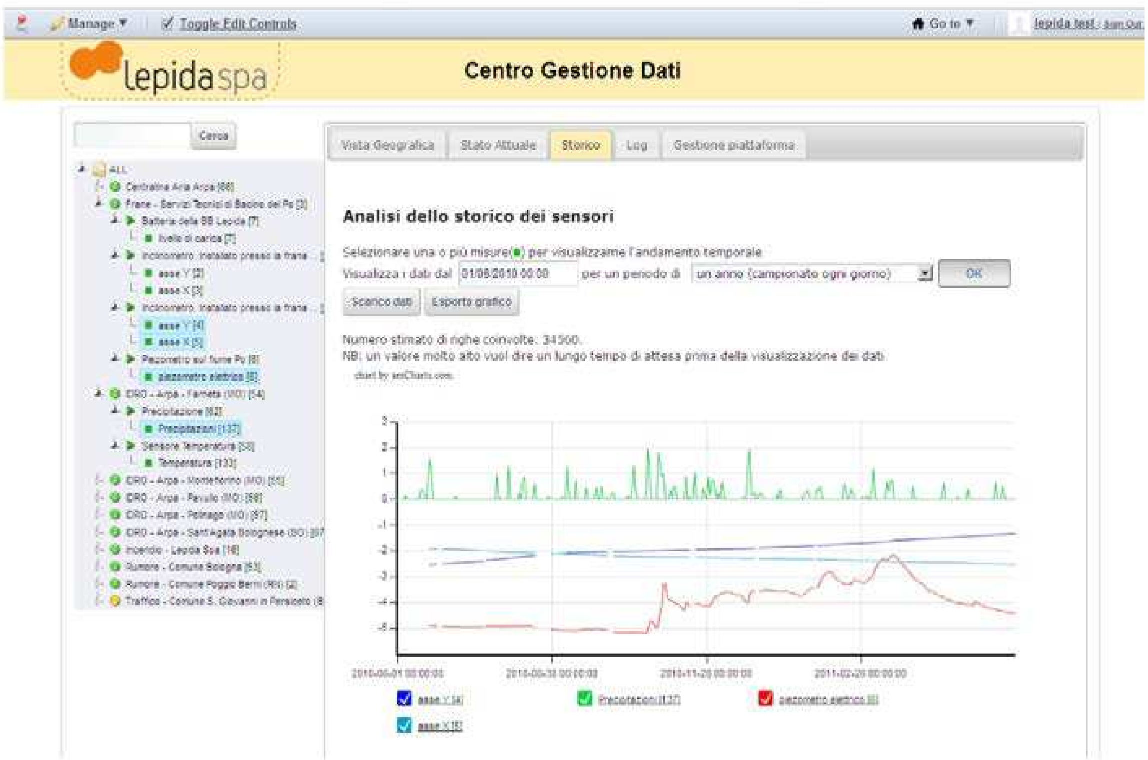

Fig. 6. Data Management Center homepage

using colors in agreement with those defined for the tree view icons. Clicking on a marker a description of the unit and a description of the sensors connected to it are shown. The additional tabs are:

- Real-time monitoring: it provides a graphical and tabular representation of the last data sent by the sensors. The measures to be displayed can be selected through the tree view. The chart adapts its time scale according to a selection done in a drop down menu and then automatically updates itself every 5 seconds. In Figure 6, for example, a multiple real-time chart related to one inclinometer, the piezometer and one ARPA pluviometer is shown.
- Analysis of historical data: in this tab, data could be analyzed with an historical depth that is greater than the one on the real time tab, selecting a start date and a period to display. It 'can be downloaded locally both in a graphic and a tabular format.
- Logs viewing: provides a list in chronological order of all the significant events detected in relation to sensors failures (started or stopped), alerts (started or stopped), invalid values, and so on.
- Platform management: supplies some statistics about the current state of the system, for example the status of the various units involved and an overview of all detected events.

4. Drainage consortium of western Romagna

A Drainage Consortium is a public corporation that coordinates both public actions and private activites concerning the drainage of its territory of scope. For example, hydraulic

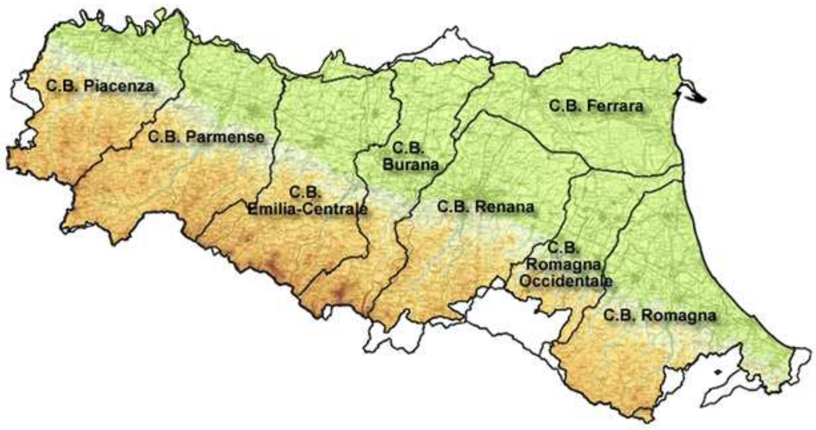

Fig. 7. Drainage Consortiums in Emilia-Romagna region

security, management of the waters intended to the irrigation, involvement into urban planning, environmental and agricultural heritage protection can be considered typical activites and actions covered by a Drainage Consortium.
In Emilia-Romagna region eight Drainage Consortiums exist, subdivided depending on their area of scope, as illustrated in Figure 7. All of them are partners of Lepida SpA, therefore Lepida SpA is legitimized to be involved for the support of their activities, by favouring economies of scale.
Currently each Consortium manages a suitable small sensor network, consisting of a set of data logger, devoted to hydrographical detection and remote control functions, thanks to the use of Programmable Logic Controllers (PLCs) and sensors connected to the data loggers. Furthermore each Consortium has got a suitable monitoring system (typically a server hosting a software system of data management) devoted to the collection of all the gathered data. Data are exchanged between data logger and server and among the data loggers (often there is the need to spread some specific control command from a data logger to other data loggers, by following as a sort of tree communication path) by using analog or GSM technologies (generally GSM is used to send alarm messages to people that need to be activated in case of danger or alarm situations while analog communication channels are used for the data collected by the sensors). Economies of scale could be found in such a scenario, by exploiting the network infrastructures owned by Lepida SpA.
For this purpose Lepida SpA will support the Consortiums, by starting from the Drainage Consortium of the Western Romagna *Lugo* (2011), which has been involved in a test-bed stage. The condition of the equipement managed by the Drainage Consortium of the Western Romagna, before the mentioned test bed stage, can be summerized as follows. It is composed by fifteen data loggers, each one including a PLC with some sensors for the hydraulic data collection and an analog communication module. Each module communicates the monitored data trough UHF channel while the alarm signals are sent through GSM network, by means of Short Message Service (SMS). The monitoring activity is mainly performed by following a polling communication protocol: a central server, devoted to the data collection and elaboration, polls each data logger every thirty minutes, by receiving the data that the sensors connected to the data logger have recorded at a one minute frequency during the last

thirty minutes; every poll requires about 300 bytes for each data logger. Besides the polling scheduled activity, the central monitoring system has also the possibility of directly poll a specific data logger at any instant, for example in case of emergency; in this case the polled data logger will send the data collected since the last polling.
The effort of Lepida SpA has been addressed to the communication technology used by the described system. In particular by offering the opportunity of exploiting the regional tetra radio infrastructure of the *ERretre* network as a data transportation driver. This represents for the Consortium an opportunity of economic and resource saving, by replacing the old analog radio with the modern digital tetra radio. Furthermore the *ERretre* network can offer other fundamental advantages: it can guarantee a full coverage inside the whole regional territory, allowing also intercommunications among the devices of different Drainage Consortiums in Emilia-Romagna region; it can offer guaranteed communications, avoiding the congestion events that instead may occur in a GSM network. Another role of Lepida will be the support in defining the technical specifics for a future furnishing of digital tetra radio to be used in a long-term solution when the test-bed stage will be definitely ended.
The test bed activated in collaboration with the Drainage Consortium of the Western Romagna exploits the *ERretre* network, with single slot packet data communication policy.

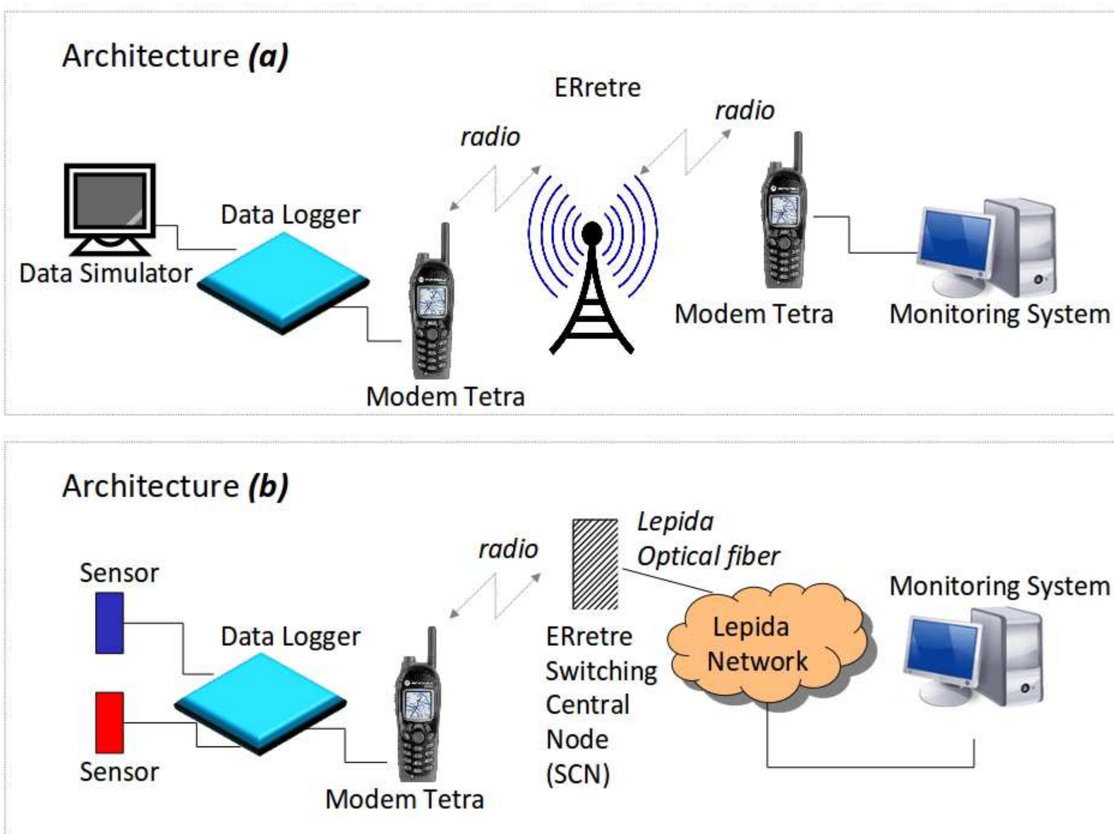

Fig. 8. System architectures tested in collaboration with the Drainage Consortium of the Western Romagna

The test bed has been conducted through two phases. The first one has been realized at Lepida Spa R&D Laboratories, by implementing two different architectures, illustrated in Figures 8, which leads to two different network performances. In architecture *(a)* both the data logger and the monitoring system are connected to two tetra radio modem: in this case any data tramission requires the activation of two radio links (the first one between the data logger and the *ERretre* base station covering the area in which the data logger is located and the second one between the monitoring system and the *ERretre* base station covering the area in which the monitoring system is located). A more efficient usage of the network resources is presented by architecture *(b)*, that exploits the existent cabled connection (optical fiber) between the *ERretre* Switching Central Node and the Lepida network infrastructure. The main advantage of this solution is represented by the reduction of the traffic routed inside the *ERretre* network, which institutional role is mainly represented by emergency communications, and the exploitation of the bandwith offered by the optical fiber link. concerning the data logger element, this has been emulated during the tests realized at the Lepida Laboratories, with a specific data simulator connected to the PLC of a real data logger. Both the two architectures have shown very good results when tested at the laboratories. These are both fundamental: one optimizing the network performances, the other enabling the implementation of sequential commands to more data loggers.

The second experimental phase has been activated with a real data logger, collecting real data from the sensors connected to it. The remote data logger was located at "Mordano" city and the central monitoring system was located at"Lugo" city, each one equipped with a tetra radio. The network architecture implemented is the *(a)* type (by referring to Figure 8 *(a)*, the only difference in terms of the real sensors that were used instead of the data simulator appliance), mainly because of two reasons: the head office of the Drainage Consortium of Western Romagna, located at "Lugo", was not yet connected to the Lepida optical fiber; the Drainage Consortium needs to activate also communications among each single data logger, by following a sort of tree path, in order to allow a data logger to send particular commands directly to other data loggers (for example a data logger being able to sequentially command a more draining installations).

Basically the communication is realized by following a polling communication protocol: the central server polls the data logger every thirty minutes, by receiving the data that the sensors connected to the data logger have recorded at a one minute frequency during the last thirty minutes; every poll requires about 300 bytes. Nevertheless the communication is bidirectional: the PLC is devoted both to the data gathering from sensor like temperature, water levels and water flow and to the reception of commands from the central server, like bulkheads closing or pumps activations; similarly the server receives the data gathered by the sensors and it can send remote commands to the PLC.

Figure 9 shows the place where the draining pump of "Mordano" is located, the control systems with PLC and data loggers and the tetra modem used for the test bed. Figure 10 shows the panel observable at "Lugo" with the monitoring system. The data management software and the data logger have been implemented and supplied by private enterprises that directly collaborate with the Drainage Consortium of Western Romagna.

This experimental phase has shown optimal results in terms of network performance and communications reliability. The test bed will be soon extended to fifteen other PLCs. The long-term installation will see the architecture *(b)* for the connection of the monitoring system and the architecture *(a)* among the single data loggers.

5. Civil protection

A further test bed has been created with the aim of realizing integrated systems for data and video communication on the Emilia-Romagna Regional territory, particularly for hydro geological and hydraulic risk, in cooperation with the Civil Protection of the Emilia-Romagna

Fig. 9. Draining pump located at “Mordano” city.

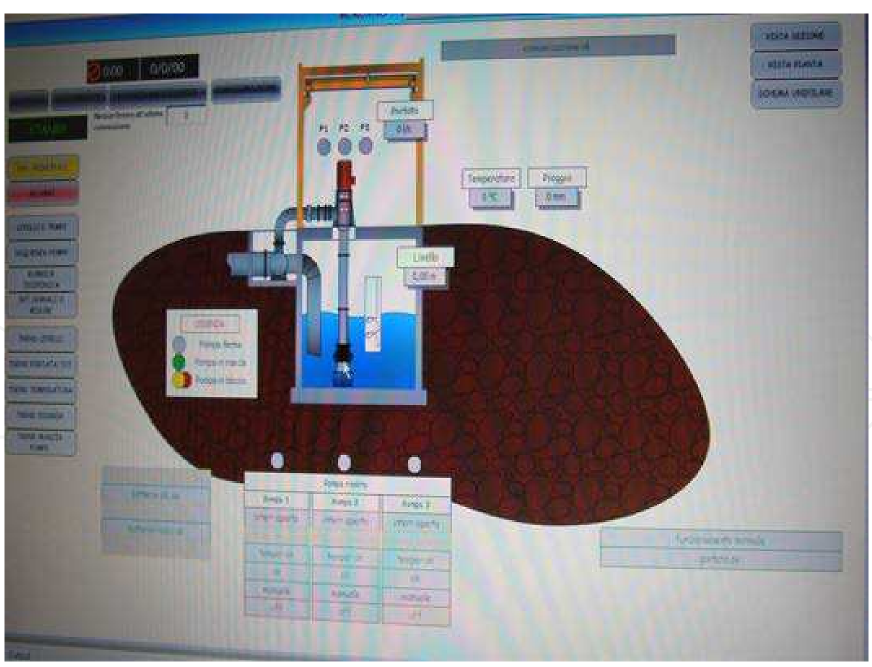

Fig. 10. Monitoring systema located at “Lugo” city.

region. Generally speaking, Civil Protection works around the whole national territory and it is divided in regional agencies, which are subdivided in smaller agencies, devoted to the

execution of pregressively more local aspects. Its main working acivities are forecasting and preventions, rescue activities, emergency trainings.
The project, promoted by the Civil Protection of the Emilia-Romagna region, aims to the realization, with the technologies at disposal nowadays, of a set of integrated systems devoted essentially to the monitoring and to the communication of data/video over the Emilia-Romagna Regional territory, to fulfill the requirements of the Civil Protection: prevention and management of hydrogeological-hydraulic risk, emergencies, disasters, trainings. More precisely, the project includes the following items:

- system for the visualization of large area and for the visual integration of images and data, both newly generated than preeexistant, trough a rear projection videowall located at the Operating Center of the Civil Protection of the Emilia-Romagna Region, in Bologna City;
- capturing systems of territorial images for the permanent monitoring of critical area such as bridges or other infrastructure located near rivers or torrents or dry detention basins;
- capturing systems of territorial images for emergency or temporary situations, devoted to the monitoring of rivers or landslides or disasters area or even training activities, by exploiting a transportable device and a motor vehicle.

The project has started with a first stage implementation that has been developed and employed as an experimental test bed, usefull to understand the limits and strength of the architecture of the whole system. More in detail, this first stage has realized the videowall and a sort of “mini network” of video monitoring, which specfications are explained as follows:

- One video camera and related data/video transmission systems (in Hiperlan technologies at 5.4GHz) devoted to the permanent video monitoring of the river “Savio” near “Cesena” city and located at the railways bridge over this river 11.
- One kit of video monitoring and recording and related data/video multistandard transmission systems (Hiperlan, TETRA, UMTS, Ethernet, etc...). This kit has been installed over a transoprtable device (a trailer truck) devoted to temporary video monitoring activities in area such as rivers, torrents, landslides or other situations of emergency or temporary training exercises.
- One kit of video monitoring and data/video transmission installaed over a motor vehicle (in this case a vehicle owned by the Group of Amateur Radio Operators Volunteers of the city of “Imola” was used) devoted to monitoring activities during training exercises or disasters or emergency situations.
- One hardware and software centralization system (server) for the centralized recording and management of the data/video collected by the remote video systems listed in the previous items; the mentioned server was located at the Data Elaboration Center of the Emilia-Romagna Region, in “Bologna” city;
- Four workstations related to the four systems listed above: two located at the Operating Center of the Civil Protection of the Emilia-Romagna Region, together with the videowall; one located at the of Operating Center of the River Basin Consortium of the city of “Forlí”; the last one located at the Operating Center of the River Basin Consortium of the city of “Cesena”.

Lepida SpA has been involved in this first stage of the project for the definition of network architectural specifics and for the configuration of the network active devices involved (switches, routers...), besides offering to the Civil Protection the usage of its network

Fig. 11. Design of camera installation at the railways bridge over the “Savio” river, near “Cesena” city.

infrastructures. A full description of the architecture realized for this first stage test-bed is illustrated in Figure 12. More precisely, Lepida SpA fiber network has been used as a backbone between the camera and the centralized server located at Operating Center of the Civil Protection of the Emilia-Romagna Region, while the connection between each single camera and the closest point of presence of Lepida network has been designed and implemented as an ad hoc wireless link, with the proper and better technology (Hiperlan, TETRA...), depending on the specific use case (temporary or permanent monitoring station).
For this reason, this stage has represented for Lepida SpA mainly a test bed in which testing the network performances serving as collector of many data/video distributed all over the regional territory. The cameras used for the test bed stage are professional Megapixel IP cameras supporting H.264 video streaming. As far as the centralized system of data recording and management is concerned, the first stage used a solution based on a commercial product (Genetec Omnicast).
The item monitored by the camera is the “Savio” river. The amount of traffic over the network is about one image of thirty kBytes every fifteen minutes. When the TETRA channel is used, each image is sent by exploiting the single slot packet data type of communication, that offers a 3kbits/sec of bandwith. The amount of traffic exchanged is compliant with the performances offered by the TETRA channel.
The first stage test bed has shown positive and promising results, leading to the definition of guideline for a second stage of this project. This second stage will involve the realization of at least thirty other video camera located at different river area already defined and spread all over the Emilia-Romagna regional territory. The main requirement of the future new installation is the full compatibility with the infrastructures, the hardware and software equipments already used during the first stage of the project.

5.1 Video management center

During the test bed realized in collaboration with the Civil Protection, the role of Lepida SpA has been mainly focused over the definition of the proper architecture of the communication

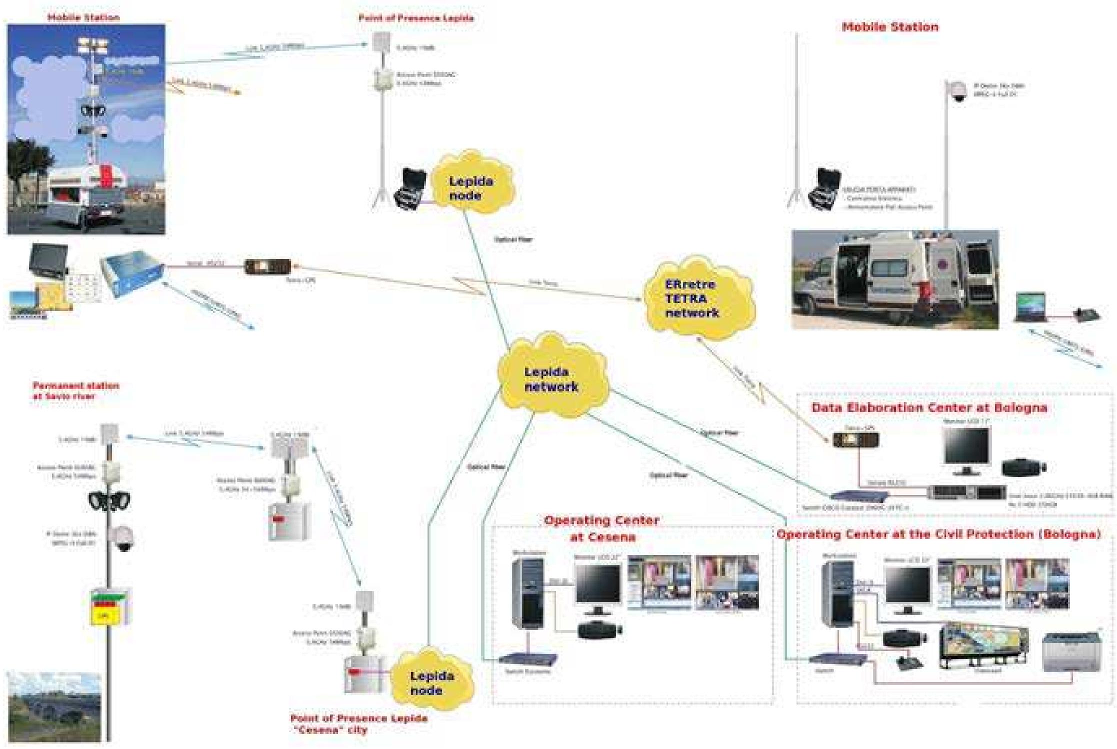

Fig. 12. Architecture of the first stage of the test bed realized in collaboration with the Civil Protection.

network to be used, in terms of the selection of the proper communication driver technology (hiperlan, TETRA, fiber...) and in terms of the proper addressing policy to be adopted among the different Entities (Regional Administrations and Regional Data Elaboration Center, Civil Protections...) involved. During the first stage test bed, differently than during the activity with the River Basin Consortium, no central data management system has been proposed and tested by Lepida SpA, since a commercial one was currently at disposal of the Civil Protection, at least for the purpose of the first stage activity.

As the census results has shown, a lot of Public Administrations in the Emilia-Romagna region are equipped with videosurveillance cameras for the purpose of public security maintenace. As the census activity has highlighted, these video show the same behavior of the environmental sensors installations (temperature, landslides, pollutions...): they often have been installed in former times by each single Administration, as separate and independent systems, resulting in a lot of camera managed by autonomous, independent and very expensive videosurveillance appliances. Furthermore, during the more recent years, expecially the smaller Public Administrations located in the Emilia-Romagna region, have expressed the necessity of providing themeselves with videocamera systems, asking support to Lepida SpA, the natural and institutional reference for the resource efficient development of their activities. More precisely these Administrations needs support concerning the definition of the technical specifics to include in public announcements devoted to the cameras, ad hoc communication infrastructures and video management systems. Such a scenario, like the scenario explored with the River Basin Consortium, points out the necessity of a central management system that could help resource saving policies in the management activities correlated to the video data. Lepida SpA, in order to readily face and solve the necessities that arise from the regional territory has designed a global architecture for an efficient management of all the video data that potentially could be generated by the cameras and videosurveillance systems installed by all the Public Administrations in Emilia-Romagna region.

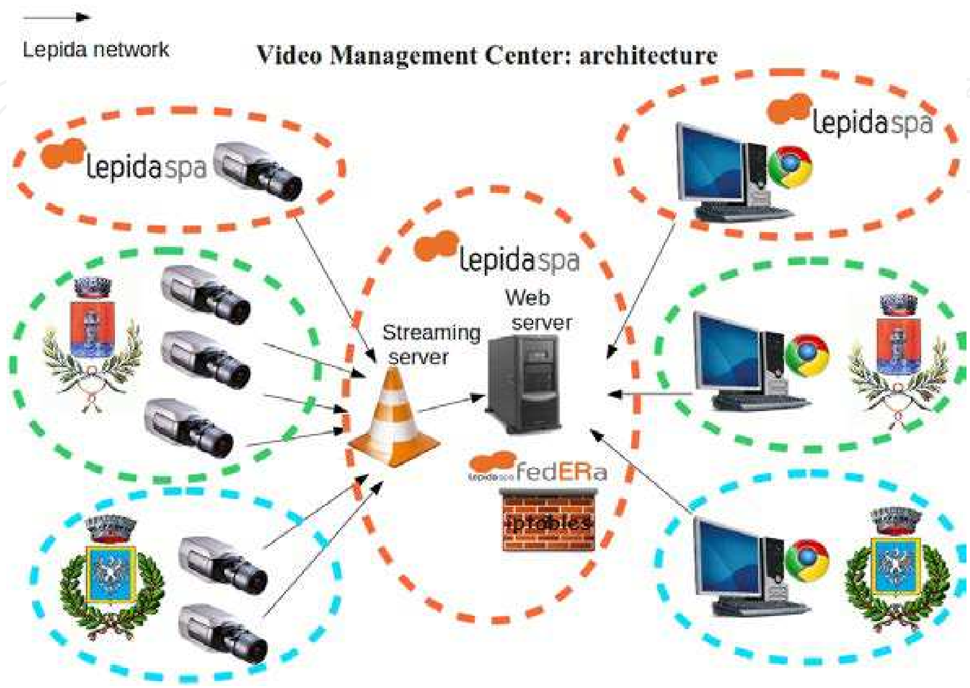

Fig. 13. Architecture for the management of camera strems produced by the Public Administrations.

The architecture proposed by Lepida SpA is illustrated in the Figure 13: Lepida SpA will provide a central server (or a proper cluster of servers) devoted to the storage of all the video streams recorded by the cameras, that will be collected by exploiting the Lepida network infrastructures; this centralized system will host also a full video management service, completely designed and implemented by Lepida SpA with the exploitation of open source technologies, that thanks to the Lepida network infrastructures, will offer to the remote Public Administrations client workstations features like: live streaming view, recorded video of at least one week old (in accordance to the italian law), downloading of recorded video.
Lepida Spa has implemented these features in a Video Management Center prototype. Figures 14 and 15 show some snapshot. More precisely this prototype is composed by a streaming server that collects all the streming video produced by the cameras and streams them to a management server. The management server functions as a web broadcaster of the data streamed by the streaming server, a choice that allows a big scalability in terms of network traffic: each client can watch a live video directly from this streaming server, avoiding the multiplication of network traffic that would be necessary if each client would refere directly to each camera stream. Management and streming server can be hosted in the same hardware server (specifically, the prototype realized follows this policy). The management server is implemented with web services technologies (php, apache, html, javascript, ajax) and it provides a web interface with tabs for the live view, for the recorded video view and for the downloading of the recorded video. In order to be compliant with all the requirements contemplated by the italian law in terms of privacy related to the management of video

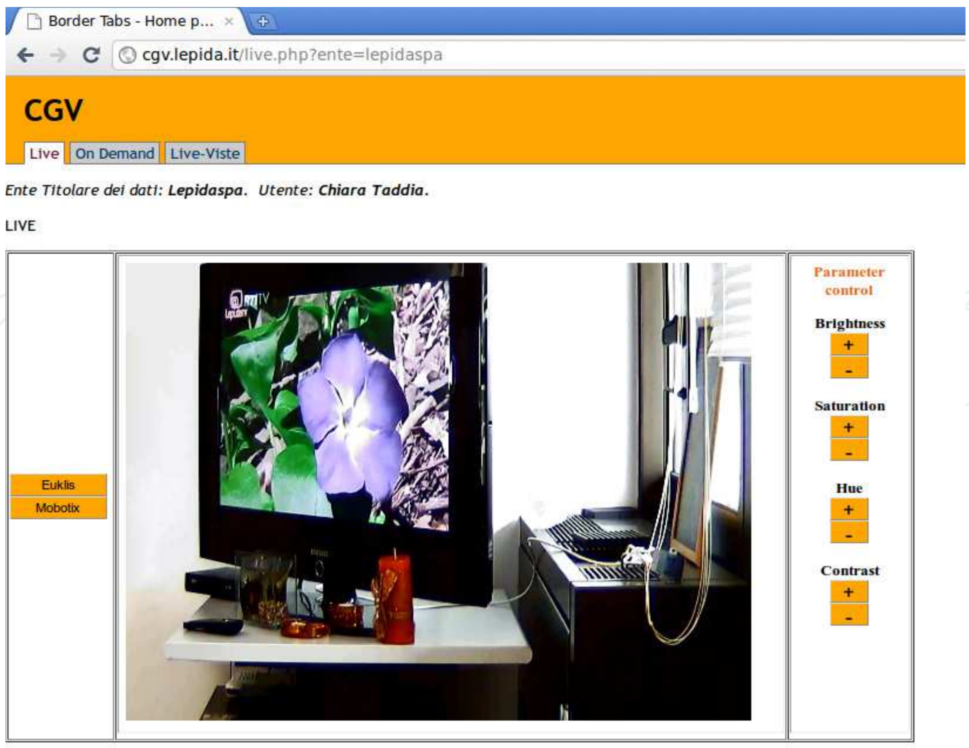

Fig. 14. Video Management Center prototype (CGV): streaming live view feature available on the web interface. The camera shown and listed are used in Lepida SpA R&D laboratories as a test-bed.

data, the prototype also implements other features such as: strong authentication of all the users that can access the web interface; profilation of the users that can access the web interface, in order to limit and specifically select the features each users is enabled to access; logs collection related to all the operations that each user makes on the web interface. The authentication is performed by exploiting the "fedERa" system. "FedERa" *fedERa* (2011) is the regional authentication system designed and promoted by Lepida SpA; it is a federated authentication system that allows the access to all the online services offered by the federated Public Administrations, with the usage of a single username-password that is valid for all the federated services. The profilation system has been implemented ad hoc for this prototype and it allows to differentiate the features that are available to each user: live view, view on demand of the recorded video, download of the recorded video. The profilation system, strictly correlated to the authentication system, allows the creation of logs to trace the activities of video data managements, as required by the italian privacy laws: the log systems collects information about the timestamp, identity of the user and specific operation made on the Video Management Centre (live view, on demand view, download). Actually the Video Management Center prototype has been tested by Lepida SpA internally. In a couple of months it is scheduled the start of a test bed usage of such a system in collaboration with a small Public Administration of the Emilia-Romagna region, for public security purpose. The architecture designed for security videosurveillance purpose and the developed prototype could nevertheless also be used in scenarios such as the one described by the project of the Civil Protection, so for environmental monitoring purposes that are based on video images.

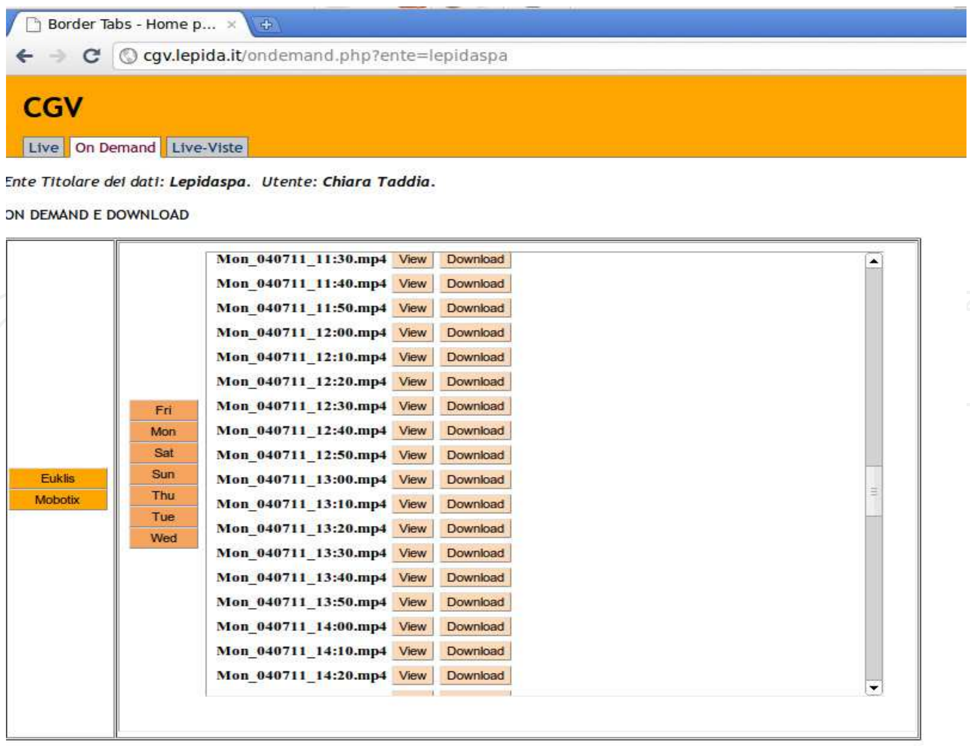

Fig. 15. Video Management Center prototype (CGV): video recorded on demand feature available on the web interface. The camera shown and listed are used in Lepida SpA R&D laboratories as a test-bed.

6. Conclusions

This publication has highlighted some interesting aspects of environmental monitoring mainly related to the Public Administrations context. Let us stress that, expecially in the Public context, an effective usage of the available resources and a development based on economies of scale are fundamental. The research method proposed and adopted by Lepida SpA has represented, as the described test-beds have shown, a valid instrument for the efficient planning, without any resource wasting, both phisical and economic, of all the environmental monitoring activities managed at a regional level. In particular the method proposed has given the opportunity of increasing the knowledge of all the infrastrucutes and system concerning the environmental monitoring field, active and used inside the whole regional territories, resulting in a more aware development of new hardware and software solutions able to face with the practical problems and necessity raised by the Public Administrations of the Emilia-Romagna region. The test-beds activated and described in this chapter will offer in the next months the chance to properly set and define all the systems variables and parameters in order to become useful models for the definition of future full services devoted to the Public Administrations.

7. Acknowledgment

This chapter was prepared in collaboration with Eng. Stefania Nanni, Laboratories ICT Manager at Lepida SpA, Eng. Anna Lisa Minghetti, Lepida network Manager at Lepida SpA, Eng. Federico Marcheselli, ERretre network Manager at Lepida SpA, Eng. Fabio Brunelli, Services Development area at Lepida SpA.

Authors would like to thank the following people and organizations, for their competence and their data: River Basin Consortium of the "Po" River, Civil Protection of Emilia-Romagna Region, Drainage Consortium of the Western Romagna, Marconi Labs, Dab, Misa, Eltel4, IEIIT-CNR Bologna, IConsulting, MEEO.

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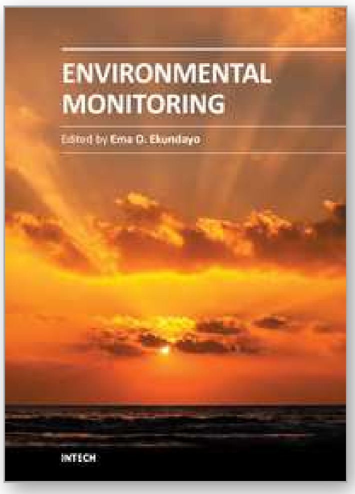

Environmental Monitoring

Edited by Dr Ema Ekundayo

ISBN 978-953-307-724-6
Hard cover, 528 pages
Publisher InTech
Published online 04, November, 2011
Published in print edition November, 2011

"Environmental Monitoring" is a book designed by InTech - Open Access Publisher in collaboration with scientists and researchers from all over the world. The book is designed to present recent research advances and developments in the field of environmental monitoring to a global audience of scientists, researchers, environmental educators, administrators, managers, technicians, students, environmental enthusiasts and the general public. The book consists of a series of sections and chapters addressing topics like the monitoring of heavy metal contaminants in varied environments, biolgical monitoring/ecotoxicological studies; and the use of wireless sensor networks/Geosensor webs in environmental monitoring.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Elisa Benetti, Chiara Taddia and Gianluca Mazzini (2011). Environmental Monitoring Supported by the Regional Network Infrastructures, Environmental Monitoring, Dr Ema Ekundayo (Ed.), ISBN: 978-953-307-724-6, InTech, Available from: http://www.intechopen.com/books/environmental-monitoring/environmental-monitoring-supported-by-the-regional-network-infrastructures

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