Mobile Sensor Network Architecture for Environmental Monitoring

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Abstract- Environmental sensors are developed and used for environmental assessment such as electromagnetic field, thermal and air environments. The specified items for the thermal environmental assessment are temperature, humidity, and air flowing rate and so on, and the items for air environmental assessment include all kinds of gas sensor [1]. The main goal of this paper is to present an implementation of an environmental mobile sensor for distributed measurement system based on the web service approach. The proposed system is based on a freeware widely utilized technology, the Gnutella network, to route and share information adopting a low-cost hardware architecture. This solution offers great possibility in terms of fast and easy access to measured data, of integration of large complex Web sensor network, of realization of flexible custom applications and of service reusability. The goal is to give the possibility to every client and every developer to obtain only the needed information or to develop new measurement application starting with different information also coming from different sensors.

I. INRODUCTION

The control of electromagnetic field, temperature and environmental air pollution is imperative for improving quality of life and enhancing industrial processes. This has stimulated activity in the field of chemical solid-state sensors, pushing forward the development of new devices with steadily improved parameters [2]. Today, sensors and sensory systems for environmental assessment have reached a high technical level [3-5] but, the real problem, consists in the connection and in the interaction among the sensors.

Distributed systems based on smart web sensors represent the best solution to many different measurement problems. By adopting these sensors, a client can receive the measure of a particular physical quantity with a browser or an application, developed to receive information from the web server. Distributed systems can be basically grouped in three categories.

The first, widely adopted, approach is based on a number of smart measuring system, linked with a centralized system (figure 1), a central server keeping a list of users and resources shared. The primary advantage of centralized systems is their simplicity. Because all data is concentrated in one place, centralized systems are easily managed and have no problems of data consistency or coherence. During a search, every client sends a request to the central server that consults its lists providing results of IP addresses of users. The file downloading happens between the two interested users from outside-centralized network. So, the server does not keep up any files. Each system is an independent server and must be selectively interrogated by the clients. The client needs to know the server position on the network (IP address) before starting the operations.

The second approach, a decentralized system (figure 2), is always based on a number of smart measuring systems, but presents the advantage to make easier the interrogation by the clients. This gives more extensibility to the network in which any node can join the network and instantly making new files available to the whole network. Another important feature of decentralized network is that the failure or shutdown of any particular node does not influence the rest of the system. In the other hand, the intrinsic nature of this network gives two problems: the difficulties to manage the network because all the nodes have the same hierarchic level and the possibility to have packet loop that causes useless traffic.

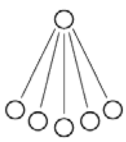
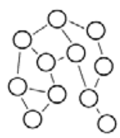


Figure 1: Centralized   Figure 2: Decentralized   Figure 3: Hybrid

The user can search all the information available on the network using dedicated (special) services. Then he can ask to transfer the needed data form one or more measuring systems. There is no need to know any information related to the server (address list) before starting the search.

A hybrid schema is also possible combining centralized and decentralized systems (figure 3). Decentralization contributes to the extensibility, fault-tolerance, and lawsuit-proofing of the system, while the partial centralization makes the system more coherent than a purely decentralized system.

From developer side, smart web sensors present always a closed approach to interact with them, so Web services are adopted in order to give a standard approach in developing a Service Oriented Architecture [6]. From network side, internet is a wide network where any user is uniquely identified with its IP address. So, to implement a distributed measurement system, it is necessary to use a common and open communication protocol to exchange information and a methodology to auto-configure any smart sensor is linked to the network.

Peer-to-peer networks allow individual computers to communicate directly with each other and to share information and resources without using specialized servers. A common characteristic of this new breed of applications is that they build, at the application level, a virtual network with its own routing mechanisms. The topology of this virtual network and the adopted routing mechanisms has a significant influence on the application properties such as performance and reliability [7].

Significant advantages can be gained using a freeware and widely adopted technology, such as that we adopted, the Gnutella. Our choice has been motivated by its large diffusion (more than 2.2 million users), even if for different kind of applications, such as file sharing. Our aim is to make possible the use of this technology to share measurement information supplied by smart sensors, instead of files, with the same straightforwardness and reduced costs.

II. Web Service Approach

Web service provides an infrastructure for the exchange of structured data in a distributed environment whatever language and platform are used. It is possible to think to Web service as distributed application, but instead of creating a class instance and invoking its methods, a Web service consumer locates a Web service and invokes the operations it provides. XML Web services are the fundamental building blocks moving to distributed computing on the Internet. Open standards and the focus on communication and collaboration among people and applications have created an environment where XML Web services are becoming the platform for application integration. All Web services communications are done through messaging mechanism of SOAP that is based on eXtensible Markup Language (XML) that is a Standard Generalized Markup Language (SGML): a language that facilitates the structuring of data in documents. In addition to XML documents, information about name and attributes of each data element are provided, therefore each client can extract, from a message, only the information needed. This, of course, gives to users a great deal of freedom [8].

A. Web Service: description and finding

Web Service Description Language (WSDL) is Web service public interface in which data type, services and operations provided by Web service are published. This means that WSDL defines everything required to write a program to work with Web service. Like SOAP, WSDL is XML-based language, so, it is platform and language independent.

The UDDI (Universal Description, Discovery and Integration) repository is a searchable directory of Web services. It is developed to give a join between WSDL documents with Web services present in its directory using SOAP messages. WSDL documents, however, do not need to be published in a repository for consumers to take advantage of them. It is possible to obtain a WSDL document through a Web page or an e-mail message.

III. The Implemented Distributed Architecture

In a wide distributed measurement network, the main disadvantages are the difficulties to access single data from a Smart Web Sensor and the necessity to use proprietary technology to obtain information and to communicate through the network.

When a client computer asks for a measurement task to network devices, it has to found some information: the IP address of the servers that can perform the measurement, the list of measurement tasks and sensors available, the server geographic position and the network routing.

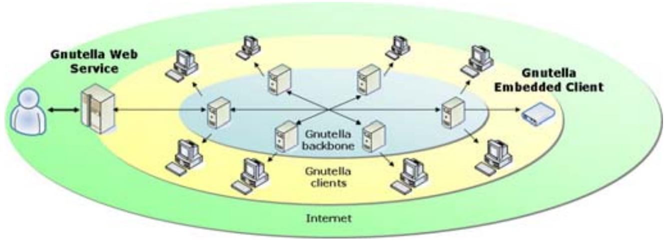

Figure 4 : Architecture of the proposed measurement network

In our proposal, we adopted the “Web Service” that gives a new degree of freedom in developing a measurement network, because based on standard communication protocol and software interface. Web Service is the fundamental building block in the move to distributed computing on the Internet. Open standards and the focus on communication and collaboration among people and applications have created an environment where Web Service is becoming the platform for application integration. All Web Service communications are done through messaging mechanism of SOAP (Simple Object Access Protocol) that is based on XML that is a Standard Generalized Markup Language (SGML): a language that facilitates the structuring of data in documents. In addition to XML documents, information about name and attributes of each data element are provided, therefore each client can extract, from a message, only the information needed. This, of course, gives to users a great deal of freedom [8].

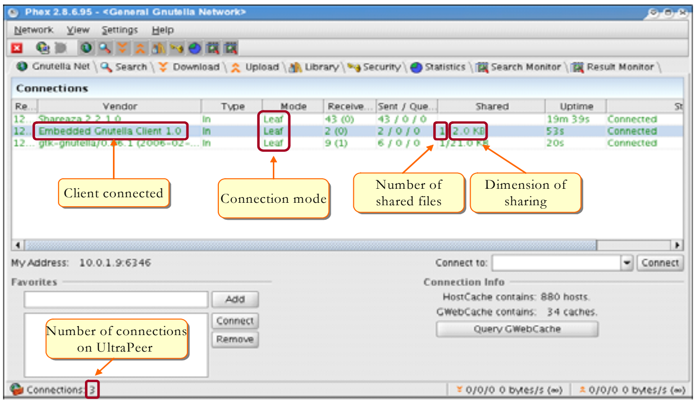

Figure 5 : GEC presents on the list of Gnutella client in common Gnutella sharing software

As previously introduced, the proposed architecture uses the Gnutella network, a network that allows linked hosts to share arbitrary resources [9]. This is a decentralized P2P system, consisting of hosts connected to one another using TCP/IP. In this network a client request for a measurement application is addressed to a computer which performs a particular Web service (Gnutella Web Service). This computer uses the Gnutella network to search all the users able to perform the specific measurement, called Gnutella Embedded Clients (GECs) as reported in Figure 4. The name client for GEC is because it is a client of the Gnutella network. As shown in Figure 5, the GEC is revealed by common Gnutella sharing software (Phex).

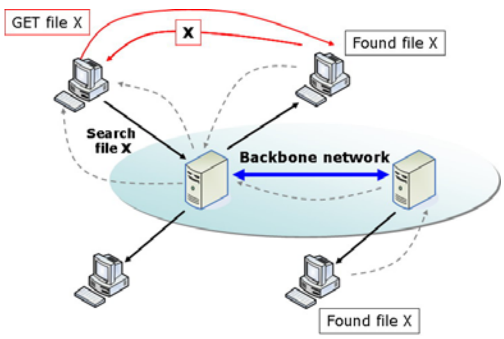

Figure 6 : The measurement server search, route and download

To execute the user search the request (query message) is repeated to all the Gnutella network computers (figure 6). When the suitable user is found, this network sends back the GEC address to the

client. At this point, the client can download the measures directly from the GEC, without overloading the Gnutella network [10].
In our proposal the measurement points are the GECs. Each GEC can perform special measurements depending on the kind of sensors embodied. When a measurement operation is asked, GEC sends the results to the Gnutella Web Service (GWS).
One of the advantages of the proposed solution is the simplification of the activities to search and locate the measurement systems (GEC). This network creates an Internet over-structure from which all clients can perform a free access without external configuration and the GECs are visible without special operations.
In order to implement this kind of system, a special Gnutella Web Service, a kind of interface between the client and the Gnutella network, has been implemented (figure 7). The need for this implementation is because the current implementations, referring exclusively on files sharing, cannot support a measurement process.

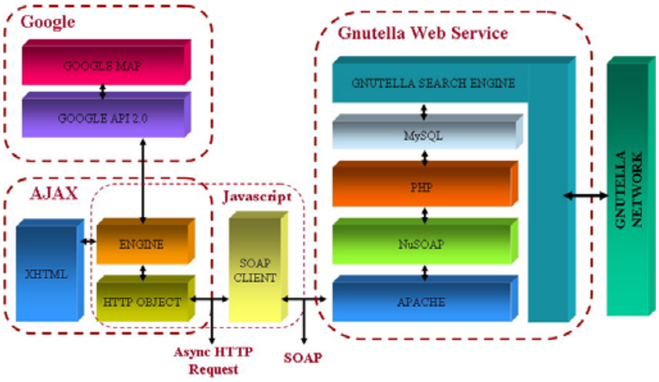

Figure 7 : Architecture of the implemented Web Service and Operator Interface

IV. Sensor Architecture

A simplified block diagram of hardware implementation of the proposed sensor is shown in figure 8. In the first section the input signal is transduced and adapted for A/D converter. The acquired samples are pre-processed (i.e. averaging the measurements) and the results are sent through serial interfaces to the networking embedded system that performs the final processing, storing and publishing of data.

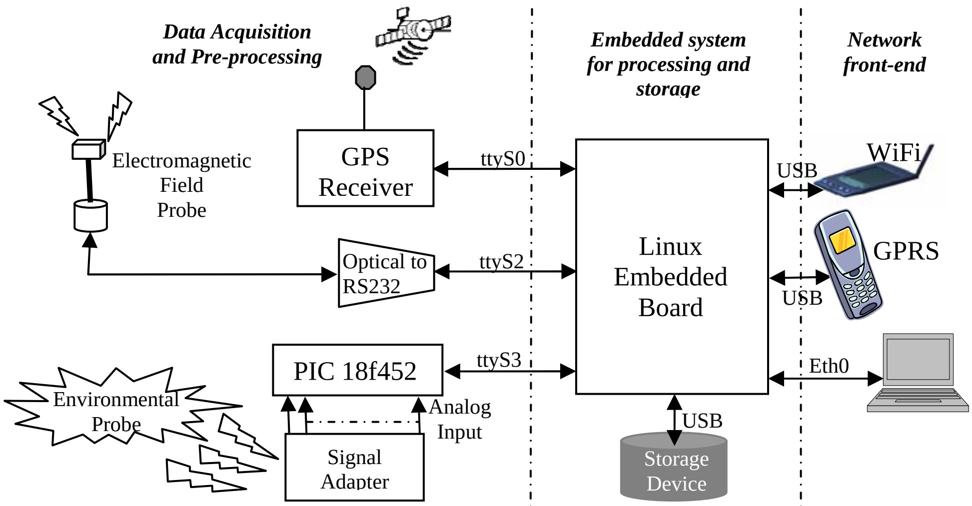

Figure 8: Sensor Architecture.

Linux embedded board has to control and communicate with three devices: the GPS device adopted to acquire date, time, position and speed of sensor; the Electric field probe PMM EP330 with optical repeater, 0.3 to 300 V/m measurement range and 0.1 to 3000 MHz frequency range. It has been necessary to add an optical-serial converter; the last device is a microcontroller PIC 18f452 with up to

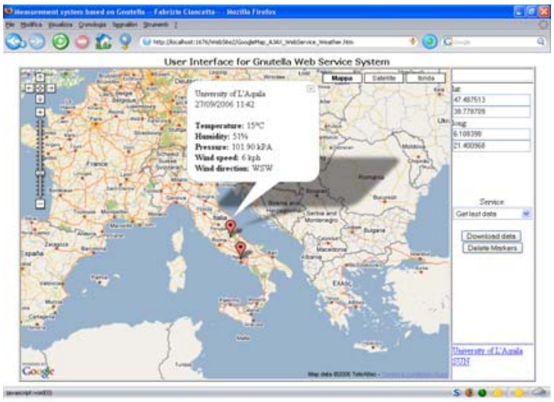

Figure 9: Screenshot of user interface.

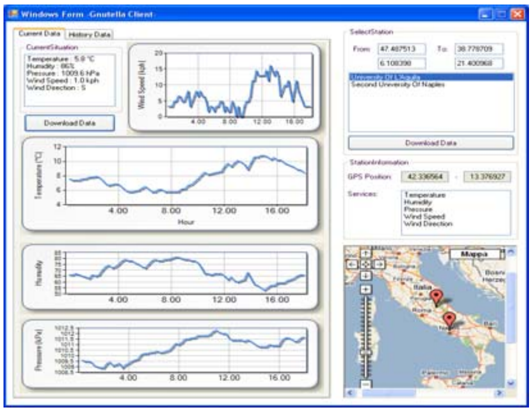

Figure 10: Windows Form Current Data Panel.

8 analog input 10-bit and 50kSps adopted in order to implement the data acquisition and pre-processing. Thanks to the PIC it is possible to connect up to 8 analog environmental probe.
Moreover Linux embedded board stores received information in a date base on USB mass storage device and publishes it, on demand, through one o more network interfaces connected to the system(i.e. GPRS/UMTS, WiFi, Ethernet). The web user interface has been developed as a XHTM page that sends request to Web Service and displays the results using Google Map (figure 9). The web user interface gives a more degree of freedom of the whole systems allowing the user to access to measurement information directly with a common browser. In particular, on the remote station we have the services temperature, humidity, pressure and wind direction and speed that are all show in the Google Map Balloon accessible directly on the map. In figure 10 we have a current view of the sensor with the data acquired and stored by the Gnutella Embedded Client and a graphical view.
For test of our system we have used the application of distributed electromagnetic field monitoring; we have installed on some cars, our mobile sensor with the PMM EP330 probe.
The cars have covered a limited area to Aversa (CE) Italy and the data collected from the sensors have been send through GPRS modem to the ceneral server date base. The web user interface is following: the user selects, through Google Map (figure 11), the interest area and sends the request to the central server; central the server selects from the date base the data that are found inside of the selected area and it returns the map with the marker (figure 12); to this point or a smaller area is selected, or the user can choose to group the data in one cell for averaging it.
In figure 13 and in figure 14 are showed respectively, the 8X8 and 16X16 grids; the marker shows the average field and the maximum field value inside any cell.

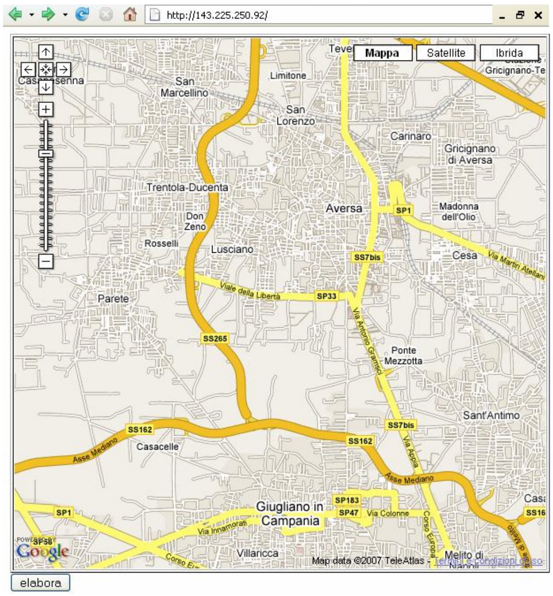

Figure 11: Interest area, selected through Google Map.

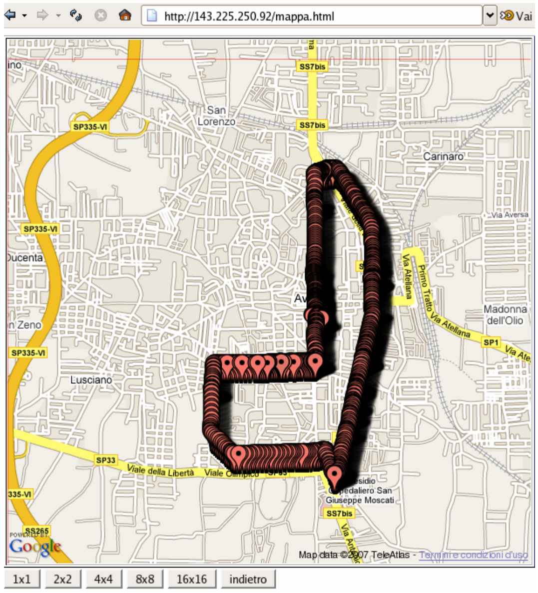

Figure 12: Selected area with the Markers.

V. Conclusions

The main goal of this paper was to present an implementation of an environmental mobile sensor for distributed measurement system based on the web service approach. The proposed system is based on a freeware widely utilized technology, the Gnutella network, to route and share information adopting a low-cost hardware architecture. Finally the web user interface and an graphical view of the experimental results have been shown. Finally it has been showed the monitoring application of electromagnetic field and its user interface.

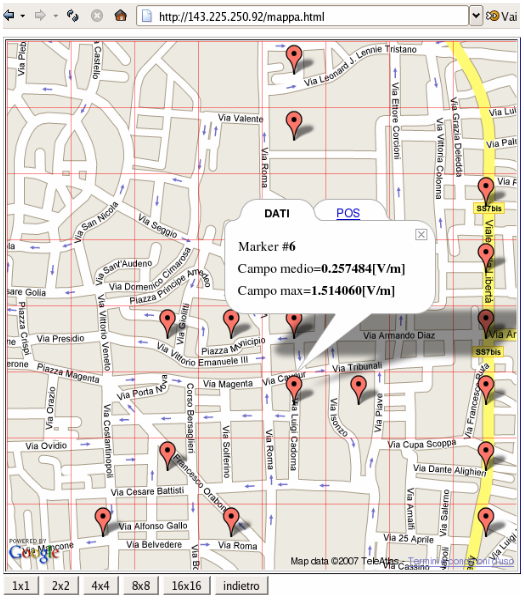

Figure 13: Grid 8X8

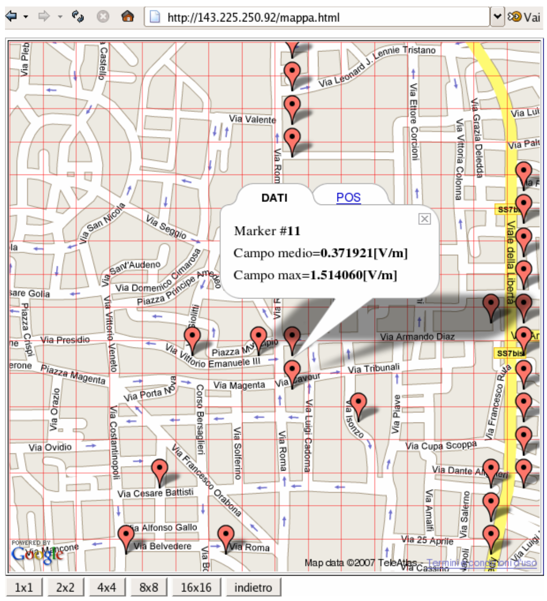

Figure 14: Grid 16X16

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