ARMONIO – “Plug and Play” ARchitecture for a MONItoring System of the Portuguese Ocean

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Abstract

This paper describes an implementation of a distributed architecture for environmental monitoring systems used for hydrographic and meteorological applications. The architecture is based in the producer-consumer model and uses wireless communications and commercial telecommunications to simplify the set-up, operation and maintenance procedures. The Bluetooth standard was found adequate to be used at the so-called local monitoring systems (LMSs) which are the units that gather information in the field. The architecture of these LMSs is presented in the paper. An overview of the connection of the LMSs to the final users is also discussed.

1. Introduction

Environmental monitoring systems used in some specific applications can often become cumbersome in what concerns assembly, installation exploitation and maintenance. This is particularly true when dealing with systems that must cover a large geographic area, requiring often sub-systems located in remote regions, in places with difficult access and in sites with complex installation. The case of monitoring the ocean margins is one of the examples and is, in fact, the application that led to the research carried on in the ARMONIO project[1].

Some of the authors have felt the problem of managing the complexity of environmental monitoring systems in a previous project [1] in which sea water quality monitoring was done. The interconnection of units, some of them under water, the installation in places subject to tide levels changing more than 4 meters, were just some of the problems encountered.

Another project [2], in which one of the authors was involved, would benefit from an improvement in the architecture. This project has brought also to the ARMONIO project experience in the development of systems for control and monitoring of environmental variables. This system, called SIMOQUA and used by the Aveiro Water Company (called SMA) to monitor the production of water for domestic use, integrates applications developed for data analysis, for extracting data and information reduction. These are built on the top of a SCADA system, supported by a common database. The developed SCADA model allows the integration, in the same platform, of the quality control and of the remote management of the devices.

Commercial products such as the ones that can be found in [9], [10], [11] keep the traditional architectures, using interconnection solutions such as telephone, cellular telephone, radio links, satellite telephone to build SCADA systems that don’t show a common integrated architecture.

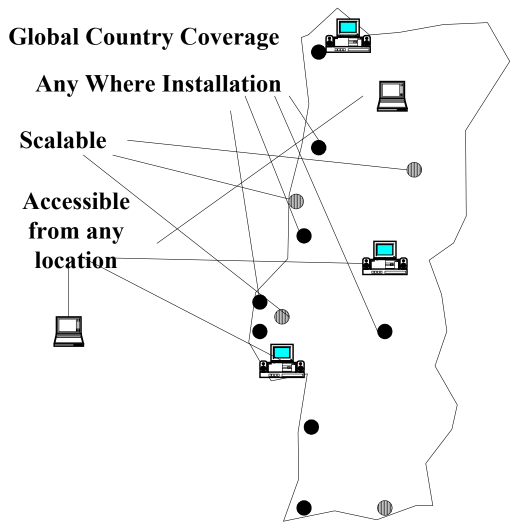

Figure 1-Geographical Area Coverage

In the ARMONIO project, there must be a set of local monitoring subsystems (LMSs, the round shapes in figure 1) collecting several parameters of interest for hydrographical, meteorological and, in the future, military applications. Examples of such parameters are water and air temperatures, pH, tide level, conductivity, turbidity, humidity, wind speed, seismic data.

The local units are to be installed all over the country, most of them in the ocean margins. The number of local units is scalable as well as the number of physical parameters measured in each local unit. Measurement data should be accessible from anywhere. Security issues are not under consideration.

In this paper the global system operation model, the architecture thought to implement the model and some

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solutions already achieved are discussed. At this point of the on-going work, the emphasis is on the architecture of the LMSs and on the solutions to implement the Bluetooth based wireless versions of those units.

2. System operation model

The solution envisaged in the ARMONIO project to help in achieving a more user friendly monitoring system is based on the producer-consumer model. It is considered that this model has characteristics well adapted to the “Plug and Play” concept.

Following the producer-consumer model, a measurement device is obviously a producer of data. Any entity interested in the data, e.g., a meteorological observatory, a research laboratory, an individual, can be a consumer.

When a measurement device is added to the global system it must start producing its data and make it available to the interested consumers. To follow the “plug and play” paradigm, then this addition should just require turning the device on.

If the concept of measurement device is associated with just one physical parameter then the configuration requirements are minimal. An adequate acquisition period and parameter ID can be previously defined. On-line changes of the acquisition period within specified ranges can be accepted with adequate procedures.

Most of the referred environment parameters face slow variations. Thus, bandwidth requirements tend to be modest. This means that the data production can be done at the rate required by the consumer that needs more resolution or by the adequate acquisition period for the parameter. Consumers that do not require the highest resolution can just discard part of the samples.

Additionally, the use of the producer-consumer model brings some intrinsic advantages that can be recalled. This is the case, for example, of the information coherence between different consumers which can be important for higher-level functions of the system. Also, the easy detection of faulty devices (the periodic production acts as a heartbeat signal) is also an interesting function for a large scale system.

3. Overall system architecture

The system architecture is closely tied to the producer-consumer model. At a higher level, the LMSs, local monitoring subsystems, produce, in regular time intervals, information about their inner measures. This information is gathered by the different units that are the final users (consumers) of the measured data.

At this level there can be two different types of final users: system users (SUs) and private users (PUs). SUs consume directly the measurement data. Private users must get the measurement data from a system user. The number of SUs is much smaller than the number of PUs. SUs require data with reduced latency and are meteorological institutes, research and military units.

Data flow between LMSs and SUs is done through telecommunication networks, currently GSM. The LMSs have a list of SUs and send autonomously data to each SU in the list. The normal situation is that every SU receives data from every LMS. However, in some specific cases, SUs may just require data from a specific LMS or from a subset of LMSs. In this case a subscribing process is envisaged to enable SUs to register in specific LMSs. Thus it can be considered that the system uses here a publisher-subscriber model.

In order to enable PUs to access data, one (or several) SU must have a connection to the Internet. A Web server can then access the SU raw database. Measurement data is then available to interested PUs, independently of their location.

One important requirement at this level is the “Plug and Play” operation of the LMSs. This requirement is solved by using geographically referenced information associated to each LMS. Once plugged, a new LMS added to the system starts transmitting its measurement data stamping in it its geographical coordinates. The measurement data coming from each LMS is then identified without risk of duplicates. The resolution of the coordinates can be adapted to the application, depending on the required proximity of different LMSs.

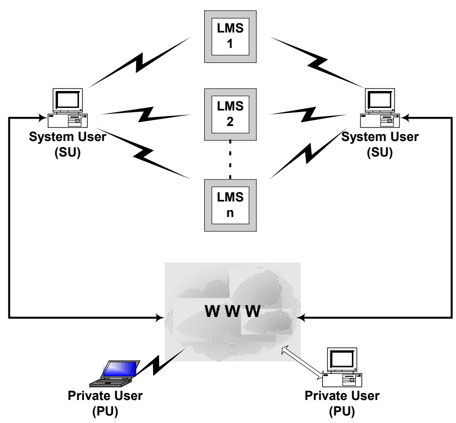

Figure 2-Overall ARMONIO Architecture

4. The local monitoring subsystems (LMSs)

Each LMS aggregates a set of measurement devices and intelligent sensor subsystems which number depends on the application needs. All LMSs include also at least a gateway to the telecommunication network and a GPS to stamp geographical information and time information. The possibility to have an easy connection to a debugging system based on a portable computer is also required. The LMS is thus a distributed system relying in a communication backbone (LMS-CB) to provide the interconnection between these different elements and subsystems.

Measurement devices are used for certain parameters, e.g. solved oxygen in water, when it is not easy, for complexity or economical reasons, to integrate a sensor. Typically these devices have one or more external interfaces (RS232, RS485, NMEA, etc.) that can be used to connect them to the LMS-CB. Almost always these devices show operation modes very well adapted to the producer operation, i.e., autonomous periodic data acquisition and data transmission. It is then quite easy to include a small microprocessor based interface between the device external interface and the LMS-CB.

Specifically developed intelligent sensor subsystems integrate a microprocessor based circuit similar to the one used with measurement devices and the conditioning circuits to connect a sensor. Temperature (water or air), water column, humidity are examples of parameters for which intelligent sensor subsystems were developed, and include a built-in interface to the LMS-CB.

Gateway nodes are also microprocessor based systems with a built-in interface to the LMS-CB. They include an interface to the telecommunications network, currently GSM. The option for GSM comes from the fact that the geographical coverage is satisfactory and the exploitation is cheap, mainly, if messages are used (SMS – Small Message System). This becomes possible due to the reduced length of data required. Also, a GSM modem is easy to embed in the gateway. It should be noticed that more than one gateway must be provided in order to achieve some fault tolerance.

In what concerns GPS, it is possible to use an embedded module in the gateway node or a dedicated node with interface to the LMS-CB. This module must send periodically the time and geographical information.

The LMS must also include a debugging system (DS). This system will not be present all the time. So, the LMS operation must be able to support the plugging and unplugging of the DS. In what concerns the internal operation this is not a problem due to the use of the producer-consumer model and of the technological solutions to implement it. In what concerns the verification of the correct operation of the LMS at the overall system level, which could be a problem, the solution relies on the subscription process. The DS registers in the LMS gateway and in consequence it must receive all data produced by the LMS. The envisaged DSs are laptop computers with the adequate interfaces and specific software.

When looking within the LMS, it is possible to map the producer-consumer model in the operational architecture described previously. It is obvious that the measurement devices, the intelligent sensor subsystems and the GPS module are producers and that the gateway modules and debugging system are consumers. It should be noticed that the active gateway module must also produce a special heartbeat signal used to detect its own failure.

5. Implementing the LMSs

The LMSs under development can be wired or wireless. In the first case the CAN (Controller Area Network) [3] fieldbus is used. The wired version will not be further discussed in this paper. For the wireless version, Bluetooth [4] is used. The sensor modules of the LMS are based in small processors (MICROCHIP PICs or 8051 processors) having the referred communication interfaces embedded. The gateway modules are similar, currently using a 8051-based processor.

The information flow within the LMS is performed according to figure 3.

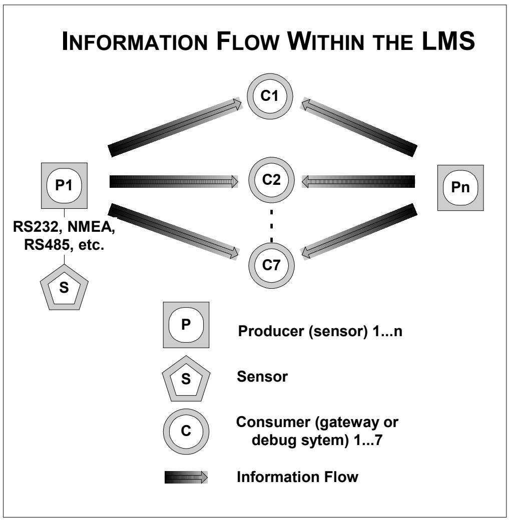

Figure 3-Information Flow

The main concept is that each producer has its own individual network. The producer and all the active consumers in the area form this network. The producer node sends information to the consumer nodes in its network using broadcasted frames. Each consumer node can belong to several local networks and, according to its function (gateway or debugging system), it must route the information to the outside network or collect the received information for debugging purposes.

In the target applications of this system, sensors don't need to receive information from other sensors. As every consumer can participate in all the producer/sensor mastered piconet networks, a scatternet is not required.

Another important advantage of the architecture comes from the efficient use of Bluetooth low power modes [4]. The sensor is normally in sleep state and it is only using Bluetooth in a small time interval. This operation mode increases the longevity of the supply batteries [5] and, at the same time, the autonomy of the nodes which are more difficult to install, i.e., the sensors. Also, it decreases the probability of collisions between node transmissions.

The Bluetooth implementation follows the primitives for group oriented communication channels specified in the L2CAP layer. Each producer node is configured only as a master and each consumer node is configured only as a slave. The configuration process guaranties that no producer will ever be a slave in a piconet. This is done by disabling the *Inquiry* and *Page Scan* parameters of the Bluetooth module. Then, the local Bluetooth module will never reply to those packets.

In this configuration it is assumed that several piconets will be placed in the same limited space, though, several slaves will be common to those piconets (see figure 4). Because only producers will be masters, the slaves are not allowed to produce information within the piconet. The number of piconets in the LMS is equal to the number of information producers which results in several side-by-side independent piconets. There will be no scatternet formation. If there are ***n*** producers present, there will be ***n*** piconets in the area.

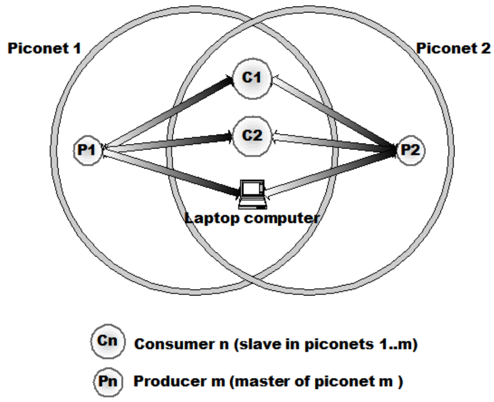

Figure 4-Bluetooth Implementation

The maximum number of local consumers in a LMS is seven; this is the maximum number of active slaves in a Bluetooth piconet. This figure is more than adequate for the application.

The group orientation channel is implemented with the use of the L2CAP primitives [4] for group communication. These are *Group Create*, *Group Add Member*, *Group Remove Member*, *Get Group Membership*, *Group Close*, and allow the interface of the application layer to the L2CAP channel.

The responsibility of creating and managing the group is issued to the information producer. This way, when it returns from the sleep state, it scans the neighborhood for active consumers and creates a group channel for them. Then, it transmits the produced information and closes the group, returning to the sleep state until new local sensor data is acquired. The consumers remain in active state waiting always to be added to a group of some producer in the area.

Prototypes of the 8051 based modules of the LMSs are already available. They are based in a Cygnal C8051F041 processor with an Airlogic ABM-200, class 1 Bluetooth module. The gateway uses a Falcom GPS JP3 module. Some air quality PIC based modules are also available, adapted from the ones developed for a related work [8]. A final prototype of the LMS is practically finished.

6. Conclusions and work in progress

In this paper a producer-consumer based architecture for environmental monitoring systems was presented. This architecture uses Bluetooth based wireless modules that are organized as Local Monitoring Systems (LMSs). LMSs use geographically referenced information from GPS to identify the measures they produce and GSM to convey data to consumer systems. The architecture seems promising since it facilitates the set-up, operation and maintenance of the target applications.

A prototype of the LMS is almost finished. A demonstrator of the full system will be available in July. Besides the assessment of the system performance, future work in the scope of the ARMONIO project includes analyzing the use of Plug and Play smart sensors that follow the IEEE P1451.4 standard in the Plug and Play architecture proposed and studying the problem of identification of mobile LMSs.

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