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Real Time Wireless eCommerce for Agricultural and Forestry Operations

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Abstract

This paper describes an application of real time data capture and wireless transmission of meteorological data used by agricultural administrators to support operational decisions such as irrigation scheduling and pesticide application. Forestry companies need such information for managing operations during the fire season. The system architecture based on distributed wireless data communication using cell phone components is selected as the required interface and software drivers are implemented to connect different brands of meteorological data stations with a GSM cell phone and thereby insulate the variations in technology, transmission and storage schemes from the overlying database and application software layers.

1. Introduction

The fundamental objective of the paper is to describe the conceptual basis and practical implementation of the interfaces developed to incorporate a variety of automatic weather stations into a homogeneous network serving agricultural and forestry end users in South Central Chile. The need for this work arose in response to the realization that the returns from the investment in automatic weather stations that had been made over previous years could be greatly improved with a relatively small additional effort in inter-institutional coordination and technical development. This paper focuses on the technical and architectural approaches used to homogenize the data capture and communication. The data storage and administration aspects are not covered in this paper.

2. General Background

Meteorological information is an important tool for agricultural and forestry management; processing of meteorological data and sale of the derived information is a commercial activity that has bloomed in the past decade. With adequate weather information a farm administrator can significantly reduce the pesticide applications needed to maintain production quality as well as lowering operational costs (LaTorre, 1972; LaTorre et al 1987; Gleason et al., 1995). These benefits plus the advent of small and inexpensive embedded microcomputers in the late 1970's gave rise to the commercialization of automatic meteorological stations oriented toward farm administration (Jones et al, 1980). These specialized units are automated weather stations programmed with models of fungal or pest growth: models which use the weather data as input and as output give the risk of infection.

Before the advent of electronic commerce, a farm manager would install a station at a representative point in the farm then periodically go out to the station to check out the recorded data and forecast of the risk of infection. The infection forecast would assist him to decide whether or not to prepare his equipment and workers for pesticide application. Since the infection forecast is likely to be valid over a wide zone, a careful agricultural chemicals dealer would be able to adjust his inventory by estimating the demand for pesticide by the local farm managers.

The next generation of equipment included communications capabilities for downloading recorded data directly to a personal computer or using a telephone modem link (Brock, 1993) and radio telemetry systems were developed in which a set of stations were programmed to form part of a network and to cooperate in transmitting and relaying information to a central server. As a parallel development small embedded Web servers were used for environmental monitoring, usually connecting to Internet via the point-to-point protocol or Ethernet. Most recently cellular phones have been incorporated into the data communications link.

Using the electronic commerce paradigm the farm manager can have access to agrometereological data and information through web-based services, which not only are more convenient, but also far more complete. However, these services require of uniform and modern technology, which is not always possible given the infrastructure available.

The current status of installed systems in the agricultural and forestry industries includes a variety of technologies and approaches, running from manually operated stations where an observer writes down measured values on paper, to fully automated networks with Web enabled access. A major problem confronting a regional meteorological systems integrator is the variety of technologies, proprietary protocols and data formats that need to be incorporated into the data administration service. The end user of the data, for example an agronomist or meteorologist, has no interest whatsoever in data representation formats, run length encoded compression algorithms or relational data base structures. The systems integrator is responsible for hiding these esoteric concerns from the end user and delivering data in an easily understood and manageable format.

The study area stretches from the Andes Mountains down across the Central Valley of Chile and includes the Coastal Mountain Range down to the Pacific Ocean (See Figure 1)

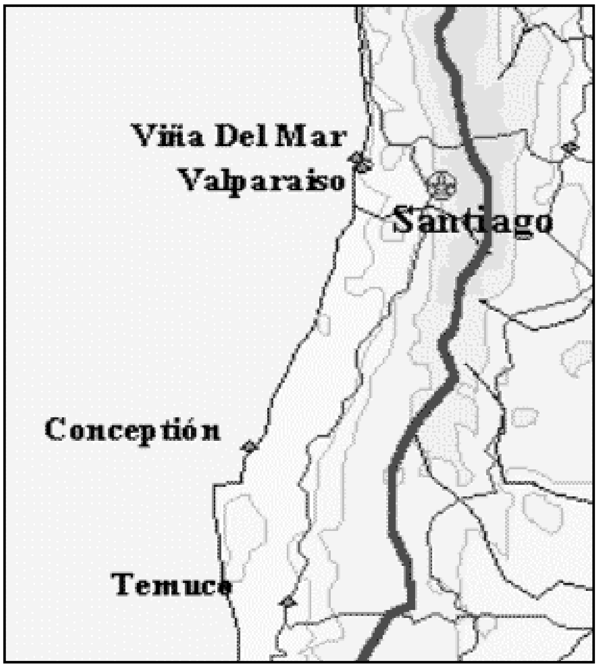

Figure 1: *Map of Central Valley of Chile*

The distance from the Andes to the Pacific in the region is about 300km. Aside from the urban and industrial centers at Concepción, Santiago and Temuco, the region has a rural economy based on forestry and agriculture. The major products are fruit (apples, raspberries, pears), grains (wheat, corn, oats), lumber, cellulose and paper.

In order to maintain operational efficiency, protect raw materials and serve the local population, forestry companies, agricultural industries and government agencies have acquired several dozen automatic weather stations over recent years. A partial listing is included in Table 1.

Table 1: *Listing of Weather Stations*

Institution	Location	Type
INIA	Sta. Rosa Cato	Delta-T
INIA	Portezuelo	Delta-T
INIA	Cañete	Delta-T
INIA	Cauquenes	Delta-T
INIA	San Pedro	Hogg
INIA	Humán	Delta-T
INIA	San José Ninhue	Campbell
INIA	Renaico	Li-Cor
CONAF	Coihueco	Didcot
U. de Concepción	Buli	Delta-T
U. de Concepción	Chillán	Delta-T

Institution	Location	Type
EULA (U de C)	Talcahuano	Campbell
EULA (U de C)	Talcahuano	Delta-T
Mill.F. Chile	Dadminco San Nicolás	Delta-T
Cementos BioBio	Casablanca	Delta-T
FRISAC	San Carlos	Delta-T
Mininco SA	Coronel	Davis
Mininco SA	Talcamávida	Davis
Minico SA	Nacimiento	Davis
Mininco SA	Mulchén	Davis
Mininco SA	Cabrero	Davis
Mininco SA	Los Álamos	Davis
Mininco SA	Tirua	Davis
Mininco SA	Lanalhue	Davis
Mininco SA	Laurel	Davis

As might be expected these stations are from different suppliers and with completely different hardware and software. Due to the lack of inter-institutional communication and coordination, there is significant overlap between meteorological coverage in some areas while no coverage is available in others. In addition many stations are incompatible. The National Agricultural Research Institute (INIA) in collaboration with the University of Talca (UTalca) and the Regional Office of the Forestry Corporation (CORMA) undertook to organize the private and public actors involved to take advantage of the investment and to improve public access to the data and information (Acuña, 2002). Administrators at the INIA expect to be able to include up to 500 stations in the network during the next few years.

3. System Requirements

Weather station locations, data communication modes, degree of processing and data storage formats are designed in order to fulfill the requirements of agricultural and forestry management users. Station location is highly influenced by the distribution of existing stations, local infrastructure and access as well as specific end user needs. This paper illustrates the more general principles used and the experience gained in the configuration of the station network, and the communications with e-commerce system, in order to assist in future implementations. The network and e-commerce applications need to respond to both agricultural and forestry users with differing information needs.

The basic forestry requirement is for forest fire prevention. When the risk of a fire is high, the logging companies must restrict operations in the woods, since fires are generally associated with human activity. Fire risk models use temperature and wind as basic meteorological parameters as well as cover and terrain descriptors. During high risk days meteorological information is required on an hourly basis, and occasionally more frequently and is not aggregated into averages or sums.

The agricultural end user requires information for irrigation scheduling, pesticide application and operations programming. The basic data needed include temperatures of soil and air, relative humidity, wind, precipitation and solar radiation and this data will be averaged or accumulated hourly, daily and monthly. Based on this basic data other parameters will be calculated and stored such as degree-days, evapotranspiration and cold-hours. Predictions of fungal growth and freeze are also calculated. The end user will need hourly access to these forecasts and at some times will want to update the forecasts every 15 minutes. In off-peak periods the need for data access is more likely to be on a daily basis. During these times, the data can be stored at the station until it is uploaded at the end of the day. The most significant user requirement is the wide geographical coverage necessary, and the location of stations in remote points. The agricultural users need stations in the cultivated area, where public infrastructure such as roads, power and telephones exist, however the forestry folk need data from the woods and mountains far off the beaten track.

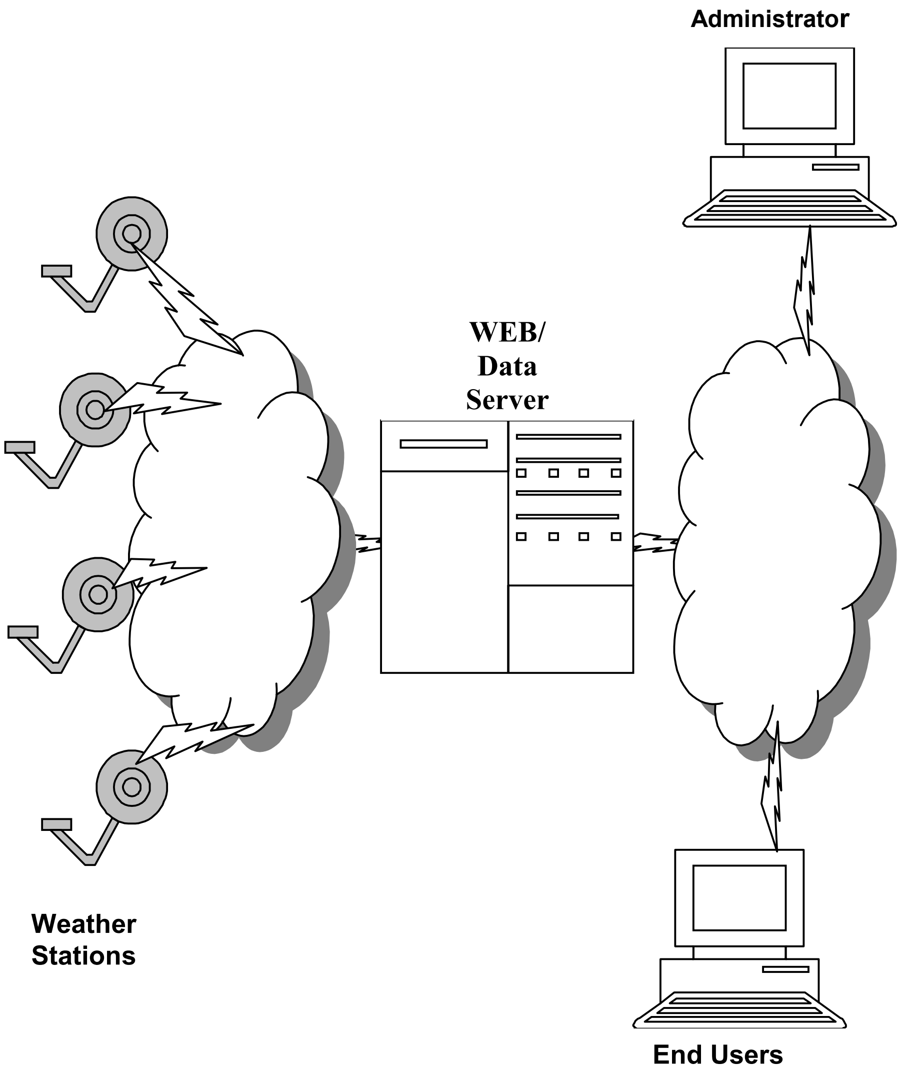

Figure 2: *Conceptual Schema Describing the System*

The volume of data to be stored is estimated by assuming that every 15 minutes each station records 100 bytes so that on a yearly basis each station will need approximately 3.5Mbytes of storage for raw data without indices. Assuming 100 stations for the network of this application, the yearly storage requirements will be over 350Mbytes.

The user requirements imply that relatively little data must be communicated, in comparison with modern multimedia systems and typical Internet connections, and that this data need be transmitted between once daily up to 96 times daily, hourly communication being a typical mode. The need for direct access to the stations is a very rare event. As a consequence the communications infrastructure does not need to reflect a permanent connection, but can be periodic reflecting the specific user requirement. Note that the frequency of communication is dependant on the time of year, the fire hazard and climatic conditions and so the access must be programmed to fit the varying needs of the end users. Figure 2 shows conceptual schema describing the system.

4. Methodology

The work performed to develop a solution for the meteorological network administrators included the following steps, not necessarily in precisely sequential order:

1. System requirements were specified with regards to types of data needed by the end users, data capture frequency, query frequency and communications reliability.
2. Technical, human resources, budgetary and time restraints were analysed as a means of guiding the feasibility of the proposed solutions. The prime technical restriction was the limitation on communications due to the highly dispersed rural locations of the data capture stations.
3. Determination of availability of system components in the reduced national marketplace.
4. Database and data access software design

5. Implementation

The fundamental concept for the implementation of the communication interface was to include a microcomputer between the automatic meteorological station and the cell phone. This can lead to the ironic situation in which the interface microcomputer might well have more computing power than the station itself. The justification for this design choice was the homogenization of the data stream and application protocols at the lowest level possible and as a consequence to reduce the project dependence on specific communications hardware.

The major problem with integrating different stations into one unified network is the proprietary interface software with which each station communicates data to the user's PC. In some cases not only the communications protocols are proprietary and unavailable to the public, in addition the data storage formats are reserved. In some cases the user cannot remotely activate data transfer; as a consequence data must be stored at the station site with the possibility of generating or receiving a data transfer request to or from the central server.

Table 2: *Wireless Protocols per OSI Layer*

Wireless Protocol	OSI Protocol Layer
Phone specific protocol for (in this case, the 6110 model family includes the 5190)	Physical layer
Radio link protocols	
GSM data link protocol provides connectivity for data transfer to the cell phone company control computers.	Data link
Virtual modem protocol. Since the purpose is to create a flexible and transparent link, a Hayes modem is emulated in software.	Application layer
AT emulation provides the AT command set emulation	
Data pump protocols. When the virtual modem is not in command mode, this protocol handles data transfer.	

As the first of a series of design and implementation decisions, the implementation team chose the Nokia 5190 GSM cell phone and connection service through the telecommunications firm EntelPCS as the basis for the communication module in the project. One reason was the widespread availability of this inexpensive phone and possibility of adapting the open source software Gnokii (http://www.gnokii.org) for accessing this model. The gnokii project is an open source implementation of the Nokia GSM mobile phone communication protocols, in parallel with the commercial Nokia Data Suite (http://www.nokia.com) product. This software package separates the wireless communications process in several layers. These layers are shown from the bottom up in Table 2.

In addition a protocol for communicating the cell phone to a connecting computer is necessary. In this case the FBUS protocol was selected as opposed to the older MBUS. In either case a voltage conversion circuit in needed to link the telephone to the computer. Another reason for selecting the Nokia 5190 was the extended geographical coverage through EntelPCS, which provides the 5190.

A second development decision was to implement Gnokii in the Motorola M-Core processor as distributed on a single board computer by New Micros Inc. (http://www.newmicros.com). The MMC2107 central processor has 128K of on-chip FLASH for program and data storage, 8K of on-chip SRAM for variable data, 2 serial ports, 10 bit A/D converter and operates between 2.7 and 3.6 volts. This processor is specifically oriented towards battery and low power applications.

The GNU C language compiler is available in source code for the M-Core. The C language code, which implements the communications protocol between the M-Core and the Nokia 5190, is available at http://ing.utalca.cl/GSM

The selection of microprocessor and cell phone model is somewhat arbitrary and not centrally important to the system development. Almost any modern microcomputer with development software would be adequate. Other cell phones models would also be adequate if communications protocols are available and if local telecommunications firms support them. When the development of this application initiated, the only cell phone capable of data transmission with the conditions of the national market (frequencies, protocols, individual mobile phone company configurations) was the Nokia 5190. During the implementation, 3 new alternatives appeared on the market, an Ericson model, and two devices that integrate cell modems with cell phones.

As illustrated in Figure 3 the server side of the communications link is implemented with a mobile phone, though the server is a fixed installation. Note that at this end of the link, the cell modem is not necessary since the coding of the protocols is performed directly in the server itself. In this application, the server is a master and the stations are slaves; the stations only respond to the server and do not generate messages independently.

The pseudo code of the server side application (see Figure 4) includes the concept of a pseudo terminal, which is an artefact of Unix that facilitates communications between programs (Johnson and Troan, 1998). A user program creates a file like device (tty driver) that another program can treat as though it were a regular communications port, though in fact it is no more than another program on the same machine. So, in the case of the server application, the code creates a pseudo terminal that communicates with a normal user application for connecting to a station. The pseudo terminal program inserts the commands necessary for controlling the wireless communications link and passes this modified data stream on to the 5190.

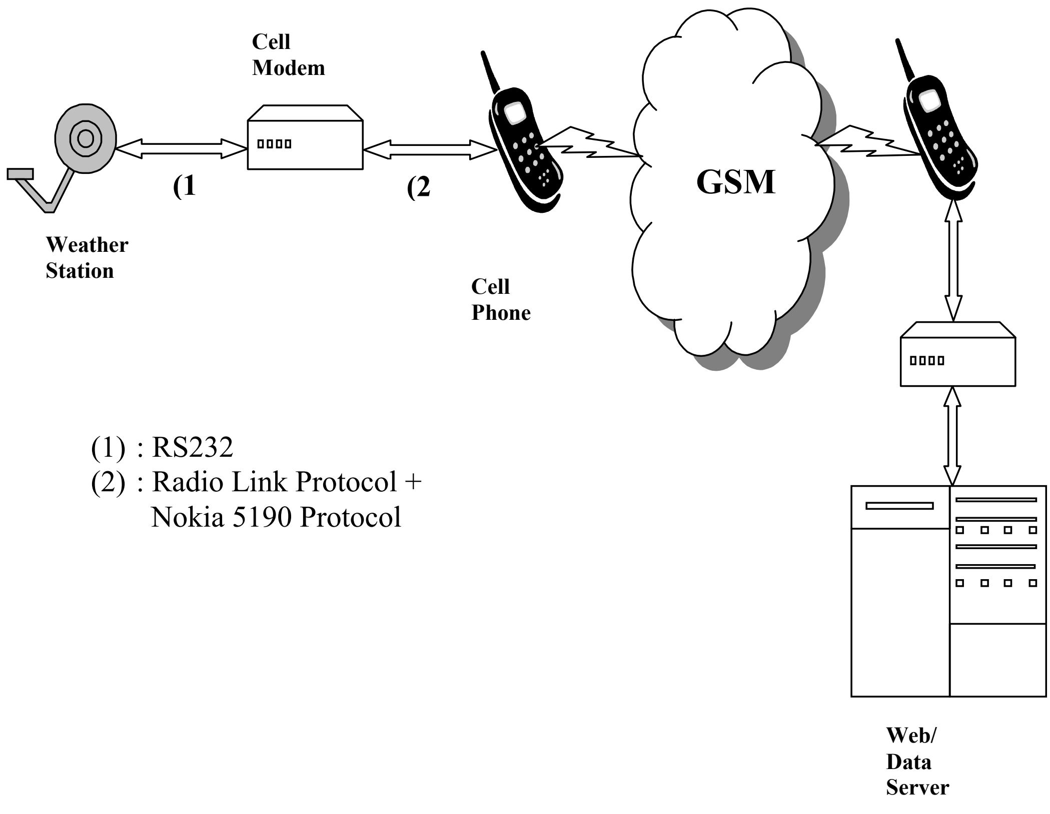

Figure 3: *Communications System Architecture*

As illustrated in Figure 3, the station end of the communications link includes a cell modem where the communications protocols are implemented. This is necessary because the station cannot be directly programmed to implement the mobile phone data protocols.

In this sense the cell modem replaces the pseudo terminal present at the server end. The pseudo code for the cell modem application is shown in Figure 5.

The pseudo code for the cell modem does not include the important tasks of entering and leaving standby mode, and putting the 5190 back into standby mode; standby mode is exited when an electrical impulse is received and entered under program control.

```
create pseudo terminal
open pseudo terminal
open physical port to the 5190
initialise protocols AT, Data Pump, RLP and FBUS
infinite loop {
        poll the pseudo terminal
        if pseudo terminal requests communication {
                generate message to 5190 for a data call
                await station response
                identify station
                request  data from stations
                while data is received {
                        deliver data to pseudo terminal
                        }
                send acknowledgment to station
                generate message to 5190 to hang up
                }
        }
```

Figure 4. *Pseudo Code for Server Side*

6. Conclusions

The principal conclusion from this work is that the technology permits data communications across the mobile phone network, however in a fashion that is significantly more complicated than the concept of "plug and play". The proprietary configurations, protocols and data formats create significant problems for end users, whose interest is solely in obtaining data from which to extract information useful for their operational decisions. The mobile phone companies implement the basic protocols partially in some cases; using different communications frequencies and the support personal are not able to respond to detailed technical questions. Equipment providers are looking to future standards and do not provide much new equipment for GSM. This difficulty also represents an opportunity to provide a more user-friendly service to end-users.

An additional conclusion is that the software developed for the cell modem can be very easily extended to include basic data capture functionality. Given that the interface microcomputer is of significant processing power, contains digital and analogue input ports and is programmed with the wireless communications protocols, the next step of adding data capture functionality is logical and useful opportunity to serve the agricultural and forestry end users.

```
open physical port to the station
open physical port to the 5190
initialise protocols AT, Data Pump, RLP and FBUS
Create separate execution threads for the station and for the 5190
Station thread:
        if (station sends data) {
                raise lock flag
                store new line of data in memory
                mark the line as only local (not transferred to server)
                if (data exceeds available space) {
                        erase oldest record
                        readjust data indices
                        }
                lower lock flag
                }
5190 thread:
        if (5190 message received) {
                await data request
                await release of station lock
                while (unsent data present) {
                        send data line
                        mark line as sent
                        go to the next line
                        }
                await acknowledgement from server
                if (acknowledged)
                        erase sent data
                }
```

Figure 5: *Pseudo Code for the Cell Modem*

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