Wireless Solutions for Telemetry in Civil Equipment and Infrastructure Monitoring

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Abstract: Digital systems are becoming more and more present in civil environments from private homes to industrial plants. This is why autonomous digital monitoring and control equipments have encountered an increasingly demand in industrial and domestic fields of activity. Application scenarios requiring reliable and convenient solutions for remote interaction with digital systems are becoming extremely diverse and complex. Nowadays telecommunication technologies offer a wide range of possible solutions for remote data communication, with different advantages and drawbacks regarding costs, bandwidth and coverage availability. In this paper we are presenting a theoretical and practical approach for system design in case of specific application. We have examined several technologies, emphasizing the efficiency of using such technologies in different situations based on application characteristics. Our attention is focused on a particular approach, a short message service based control system and its applicability in civil telemetry applications. We conclude by presenting some experimental and theoretical evaluations on energy consumptions, cost and efficiency in case of applications requiring small amounts of data exchanging.

Keywords: Digital monitoring, remote interaction, remote control, SMS, surveillance

1 Introduction

In many industrial and domestic application scenarios, remote controlling and monitoring of different kind of equipments, facilities and production processes is mandatory or at least required for best performance and maximum reliability. Remote controlling and signaling is most useful in case of multiple processes that are located in different places and has to be monitored and controlled from a single central control center. As mentioned before this technique can also be used for domestic applications like remote monitoring of home facilities, car security systems, environmental monitoring etc. We use the term signaling in the context of event driven operations where remote systems have to signal other systems or human operators about special events that appeared in the controlled process.

The most important part of the design of a remote controlled system is the communication module which provides the means for sending command messages and receiving status information from the remote located system. There are many solutions for communications available on the market, ranging from terrestrial wired connections to satellites based wireless communications. Each one of these has its advantages and disadvantages. The discussion about the communication solutions goes around costs, bit rates, power consumption of the transceiver equipment and communication channel availability. In order to choose from all the communication solutions available, two aspects of the applications characteristics has to be taken into account. One is the amount of power supply available for the remote systems and the bit rates necessary for to communicate command and data messages between equipments.

This paper intends to present an analysis of remote control solutions for embedded systems providing a method for evaluation and design of remote controlled embedded systems, based on application specific requirements for power consumption, bit rates and communication channel availability. In the same time all these aspects of remote controlling will be correlated with the design and implementation of a functional system based on Short Message Service provided by the mobile communication operators and used in specific industrial applications.

The next section of this paper will present other approaches, practical and theoretical on remote monitoring and control applications based on embedded platforms. Advantages and disadvantages of these platforms will be presented, discussing the characteristics of each platform with respect to several application scenarios when remote communication is required.

2 Related Work

There are many systems for remote monitoring and control designed as commercial products or experimental research platforms. One of the most important characteristics that differentiate remote monitoring solutions is the distance between the data acquisition unit that collects information from the environment and the monitoring unit that receives the data from the data acquisition unit via the communication link.

In [1] a system for remote image acquisition from inaccessible industrial environments is presented. In this case the communication is made via radio based wireless links on short distances, using 2.4 GHz wireless transceivers and RS-232 wireless modems. This solution can be used only for application scenarios where the control unit and data acquisition unit are placed within the communication range of the transceivers.

Wireless sensor network as presented in [2] is another solution for remote monitoring and control. This kind of instrumentation use a multi-hop wireless communication solution in which each node has the ability of sensing and measuring as well as of routing the messages received from the other nodes in the network. Using this communication solution the distance between the data acquisition unit and control unit can be covered by the communication links formed by several wireless sensor nodes.

This solution is not adequate for applications where the number of measuring points is small and these points are grouped together on a small area and the control unit is placed many miles away.

In case of applications where the control unit is placed at a great distance from the sensing unit, the communication has to be based on some terrestrial or satellite communication infrastructure. We can give as an example the Ethernute platform provided by Egnite Software GmbH [5], which has the ability to connect via its Ethernet controller to the Internet and communicate with any other system with an Internet connection all over the world.

This solution is most useful when a wired Internet connection is available and is most suited for complex monitoring applications where high bandwidth is required.

A wireless alternative to Ethernut solution is GPRS modem based platforms. A data acquisition system can connect via GPRS modem to the Internet and transmit data to the control system which can be placed anywhere but having an Internet connection available. This solution allows a certain amount of mobility to the acquisition and control module.

There is also a hybrid solution, as presented in [3], based on wireless communication between the data acquisition module and a local control unit and a terrestrial communication link between the local control unit and the central monitoring and communication unit.

The two solutions presented above may not be efficient in case the data to be communicated is small. We can consider as a scenario a system that only triggers some remote alarms in case a specific event occurs. In this case a short message service (SMS) based system is extremely efficient as it will be presented in the followings.

An example of a SMS based monitoring tool is the one described in [4] for cluster environments. Other approaches on inter-system communication and interaction based on different communication technologies available are presented in [6] and [7]. The monitoring systems can be used in both physically static and dynamic environments such as building monitoring or moving objects or animals.

3 Short Message Service Based Control System

In the following we will describe our implementation of a SMS based system designed for several industrial and domestic applications, mostly for control of monitoring systems. The SMS based monitoring system can be viewed as a macro scale sensor node. It is composed of three main modules. First is the sensing module, which in this case is represented by the digital input lines, analog inputs that are connected to the ADC, serial interfaces for communication with the monitored system (e.g. network server which communicates its internal status to the monitoring system via serial interface) or Ethernet controller in case the system is directly connected to the network, to monitor link availability or implements more complex monitoring applications requiring a high speed communication solution. The second module is the processing unit which, in this case is a microcontroller, interfacing the sensing unit to detect events in the process that is monitored by the system. The last module, but not the least one is the communication module which allows the processing unit to send notification messages to the system administrator in case alarms have been triggered or events have occurred in the monitored process. For the communication module a GPRS modem or a commercial cell phone interfaced with the system, via serial RS-232 interface can be used. The first solution is more reliable but more expensive, the second one is cheaper but less reliable.

Figure 1 presents the simple (reduced) configuration of the SMS based monitoring system which contains a processing unit based on ATmega128 microcontroller, a cell phone connected via RS-232 interface and several digital input and output lines for monitoring and control.

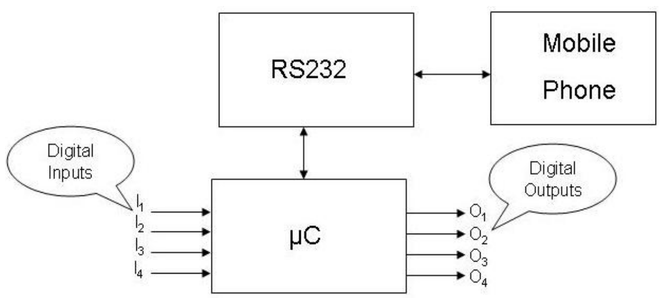

Figure 1
Minimal configuration of the SMS based control system

The system in this configuration monitors the input digital lines and sends a SMS message to the configured phone number. This message will contain the line identifier and the system time when the line has been activated. For more reliability the system will wait for a response message which can be only an acknowledge message, in which case the system will continue to monitor the lines, or a command message in which case the system will activate a specified output line. For a better understanding of the system we will explain its functioning by referring to an application scenario. We can assume that the input digital lines are connected to intelligent sensors which will activate the corresponding line, in case a specific event occurs, for example an unexpected rise in temperature of the heating system. The monitoring system will send the message to the system administrator specifying that the sensor on line n, corresponding to the heating system has detected an unnatural rise in temperature. The system administrator will answer with a command message that will lead to the activation of an output digital line which will activate the cooling system to regularize the temperature.

The configuration presented above is simple and reliable but involves a certain amount of intelligence from the monitored process. A more complex configuration of this system is presented in the Figure 2.

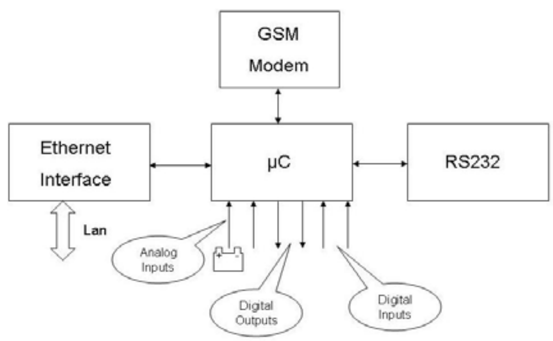

Figure 2
Extended configuration for the SMS based control system

In this case the system has more sensing capabilities like analog inputs which will allow the system to monitor directly the process and decide if a special event has occurred. This solution is more efficient but it involves a certain amount of complexity. Thus, an embedded operating system is most required, especially because implementation of the application components will require concurrent operations involving multithreading capabilities. Evaluations of the system in this configuration were made using Nut/OS, which is a real time operating system, developed with the Ethernut development board.

4 Case Study

In the following paragraph we will present a real application developed by our team, which takes advantage of the Short Message Service based control system described in the previous chapter. The main purpose of this application was activity remote monitoring in a company office or factory. The system is composed by a local control unit called “server” which interfaces several video surveillance cameras including several microphones for audio surveillance. This local control unit or server captures video and audio streams from the video cameras and microphones and operates on these streams according to the configuration of the local control software module. This module can store the video and audio streams on local hard-disks, index video and audio captures by time and place (by place means by the camera and the microphone that captured the stream), retrieve images and sound based on user specified time intervals and deliver them to the user via internet, or deliver (streaming) live images and sounds from a predefined camera.

The system is connected to the building power supply and can be connected to the internet via several communication solutions based on their availability. In case of power grid failure the system is provided with a secondary power supply based on rechargeable batteries which can keep the system functional for several hours.

The system is designed to serve as a security system, to capture images and sound in case of intrusion or to supervise on-line or off-line the activity in commercial and production environments. The main weaknesses of this system from the point of view of security and reliability are the power supply and the internet connection. Each one of these can fail or can be cut by intruders or unauthorized personnel. The main power grid failure can be overcome by the internal power source but only for a relatively short period of time. On the other hand internet connection failure leaves the entire system without any communication possibility, meaning that the system can not be accessed from outside by the user who wants to supervise the activity that takes place inside the building.

To improve the reliability of this system, an autonomous diagnosis system has been added to the main monitoring server. The additional diagnosis system has to have an independent, reliable and autonomous communication link in order to report the status of the main system. To choose the communication solution for this system we have to take into discussion the characteristics and the quality of service required by the additional diagnosis system. First the communication channel has to be highly available and independent of the possible intruders or personnel, the amount of data transferred through this communication link is quite low compared to the throughput of the main communication link for images and sound. The solution that we have considered to be the most efficient is the one based on short message service (SMS), solution presented earlier in this paper. The SMS based system has the ability to monitor the main communication link and the power supply of the surveillance system and to send messages to a preconfigured telephone number to report the status of the system. The system will detect any change in the functioning state of the main system, like communication link failure, power grid failure or internal power source depletion and will report these events by sending a short message (SMS).

After resetting the system, configuration mode can be set, when several parameters can be specified, the most important being the GSM number of the receiver cell phone which will get the SMS messages sent by the system. After the configuration, which can be made on site, remotely, via the main surveillance system or off site by the manufacturer or the system administrator; the system enters the active mode, in which case it monitors different parameters of the main system like power source availability, communication link etc. This system has also a watchdog function by resetting the main server, in case the last one is inactive for a specified period of time. For this watchdog function the diagnose system will communicate with the server via RS-232 serial interface. The diagnose system will listen on the serial interface for some information from the server on its internal state. In case the server does not send this information for a long period of time the diagnose system will consider the server frozen and will activate the reset line. These watchdog function can be further developed by implementing a diagnose software module that will run as a service on the main server and will provide the diagnose system with information on the internal state of the processes running on the server allowing a more detailed and complex decision making.

5 Energy Consumption Analysis

In this section we will make a brief analysis of the energy consumption of three wireless communication solutions. The first is based on GPRS modems (GM862-GPRS), the second is a multi-hop wireless communication link with XBee modules from MaxStream and the third one is one hop communication solution based on XStream transceiver from MaxStream. The evaluation will be made based on measurements and datasheets [8] [9][10] of the wireless modules based on the average energy spent per hop (send and receive one byte).

$$W = (NH * V * Iav * 8)/DataRate$$

NH represents the number of hops, V represents the supply voltage, Iav is the average communication current (Iav = (It + Ir)/2 where It is the transmit current and Ir is the receive current) and DataRate is the communication speed.

For this analysis we will consider the situation when the communication should occur in outdoor environment between two wireless enabled systems located 10 km away of each other. According to the capabilities of each communication module presented above, the communication can be made using three solutions. One based on 7 hopes wireless link with XBee modules, 1 hope wireless link with XStream module or via GPRS module.

In Figure 5 the result of the calculations are represented. Based on the energy spent to communicate one byte of data the most cost effective solution in case

GSM networks are available is the one based on GPRS module. The fact that this calculation was made based on the communication energy required by each module has to be pointed out. For example in case of the multi hop wireless link the energy spent by the intermediate nodes to process the messages was not taken into account. In order to make a final evaluation for choosing one solution from the three proposed has to deal with other aspects of the total cost of communication, like the cost of the intermediate nodes for the multi-hop solution, the cost of data transfer through the GSM networks in case of the GPRS (SMS) based solution etc.

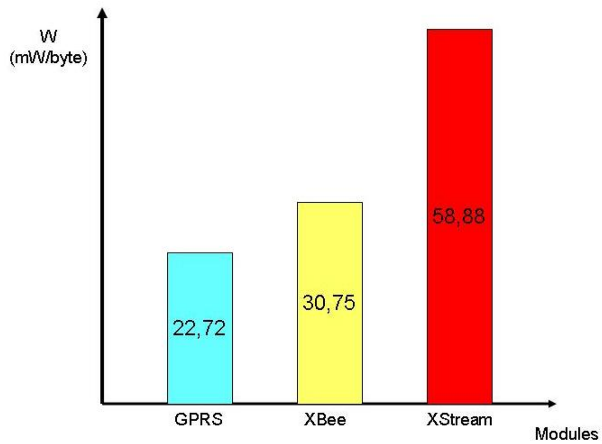

Figure 5

Energy consumption of the three different communication solutions

In Figure 6 we present the energy required by each communication solution presented above for different transmission distances.

Both solutions, XBee based and XStream based, are organized as a multi-hop network requiring several independent nodes to for the link between the sender and the receiver. As presented in the chart in Figure 6 the multi hope solution based on XBee modules is more efficient related to power consumption then the XStream based solution. Although the communication range of XBee module is shorter then the case of XStream module the power consumption per byte is smaller because of the higher data rate (250kbps – XBee, 20 kbps - XStream). In case a GSM network is available in the area where the sender and receiver are located the GPRS based solution appears to be the most cost effective with respect to power consumption.

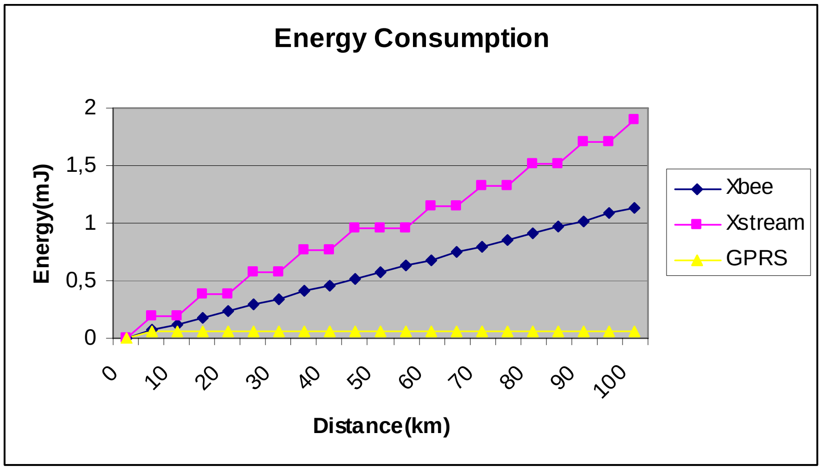

Figure 6
Energy consumption of the three different communication solutions related to the distance between the transmitter and receiver

Conclusions

Reliable system monitoring and control modules are most important, as automated systems have gained more and more control over our environment. As we have presented in the first part of this paper there are several approaches for system monitoring modules, depending on the communication solution on which they rely. The most important aspects related to communication that has to be carefully addressed by the system designer are link availability, reliability and cost. The SMS based solution presented in this paper is highly available and reliable especially in urban areas where the GSM networks are most prevalent and reliable and is also cost effective in case of reduced amount of transferred information. The drawback of this communication solution is its availability in remote areas, but in this case the platform can be adapted to use long range wireless transceivers or multi-hope wireless communication solution like in the case of wireless sensor networks where the data are transferred in an infrastructure-less communication manner. This research activity will continue by implementing the other two solutions, one based on long range wireless communication transceivers and other based on short range multi-hop wireless network. This set of implementations of a diagnosis system based on wireless data communication is meant to be a practical evaluation of the performance of wireless communication solutions, like the ones used in wireless sensor networks, and evaluation of different kind of transceivers and communication protocols, like the ZigBee ultra low power protocol for wireless communication which is the subject of the next implementation.

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