1st International Conference on Sensing Technology
November 21-23, 2005 Palmerston North, New Zealand

Remote Monitoring and Control for Hydrogen Safety via SMS

Daniel J.S. Lim[1], Vishy Karri[2]
School of Engineering,
University of Tasmania
Hobart, Australia
jsdlim@utas.edu.au & Vishy.Karri@utas.edu.au

Abstract

The benefits of remote monitoring and control have long been realized in the industrial sector for uses in automation as well as increase of safety/security standards. This led to the emergence of the popular SCADA (Supervisory Control And Data Acquisition) systems. Currently, the common conditions of use of SCADA systems only allow for control and supervision to take place when the operator and the plant being observed are in the same general vicinity. While the actual proximity of the operator-plant relationship may vary from system to system, physical limitations constrain the maximum distance allowed for the propagation of signals.

This paper explores the feasibility of tapping into the Short Message Service component of existing mobile communications network infrastructure, particularly the GSM (Global System for Mobile communications) [1] network to act as a medium for the communication of control signals. Coupled with hydrogen sensors that are able to detect the concentration of hydrogen in the surrounding atmosphere, this would then enable the achievement of truly mobile global remote monitoring; the control of the hydrogen laboratory and other industrial processes; as well as security and safety applications.

Keywords:

GSM, SMS, Automation, Telemetry, Ubiquity, Hydrogen Safety

1 Introduction

The use of mobile phones or handsets has grown exponentially over the years [2]. As the number of mobile phone users increased, the technology and infrastructure supporting the handsets have also evolved to cope with the traffic created by the number of users. On top of that, the demands of mobile phone users have also changed, and the average mobile phone of today can do many things that would have never been dreamt of 10 years ago.

Voice telephony has always been the primary use of the mobile handset; however, some time ago, 'texting' or text messages were introduced to operate over mobile phone networks and maximize bandwidth utilization [3]. There are two dominant mobile phone networks in the world today, namely the GSM (Global System for Mobile Communications) and CDMA (Code Division Multiple Access) [4] networks. Both networks have coverage in most urban areas and offer support for the SMS (Short Message Service) that allows users to communicate with each other by sending short text messages to each other at minimal cost. The maximum length of the messages cannot exceed 160 alphanumeric Latin characters [3]. This is enough to send short alert/notification messages and/or commands to a remote system. In the world of automation and control, several methods have thus far been employed to attain remote monitoring and sometimes control of various processes. These attempts have met with varying levels of success.

The primary aim of this paper is to propose the concept of a remote monitoring and control system (RMACS) using the combination a microcontroller (PIC 16F873/877) [5] and a GSM Communications Module [6] linked by a serial communications port.

The benefits of this setup will include:

- Flexibility/modularity in control by the use of a microcontroller
- Global coverage through the use of the GSM network
- Efficient and cheap means of communication by use of SMS
- True mobility using mobile phone sets

Depicted in the figure below is an overview of a possible application scenario for which this system was initially developed. In this application, the system was set up in a dedicated hydrogen research facility to monitor the hydrogen concentration level.

System Overview

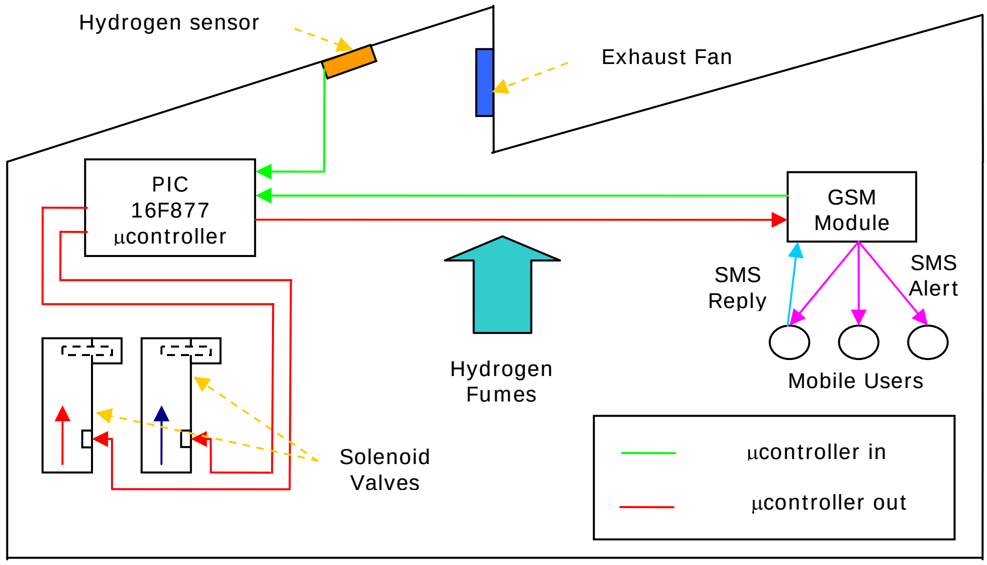


***Figure 1**: System Overview as Installed in the Hydrogen Laboratory*

The system uses the microcontroller as the brain or centre of operations. The Microcontroller may be attached to several I/O devices which will in most cases be either:

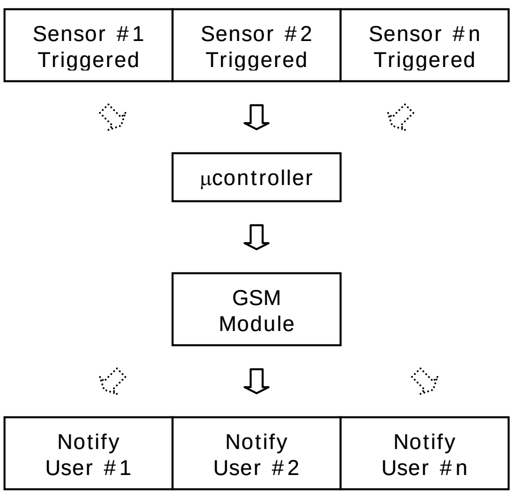


***Figure 2**: Flowchart depicting the monitoring process*

- Sensory inputs for process control or safety/security monitoring
- Actuators on the outputs to exert control over various aspects of a process

The microcontroller is then connected to a GSM module to give communication capabilities to the system. The GSM module is operated by issuing a string of commands from either the system via the microcontroller or from the user via SMS over a mobile handset [6].

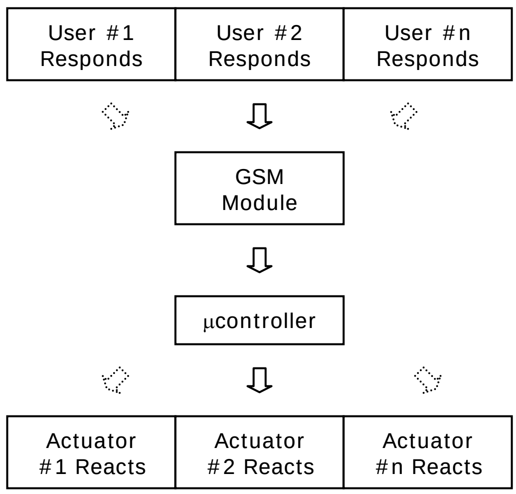


***Figure 3**: Flowchart depicting the control process*

By coupling the two devices, a cost effective, flexible and modular system is achieved. Since the devices run on relatively low power and may be battery operated, and the GSM module being a wireless communication module, not only does the system grant mobility to the user, but the system itself may be operated on a mobile platform (i.e.: a vehicle or mobile laboratory.)

2 Hydrogen Safety

This project was developed to monitor the hydrogen content in a laboratory and ensure that it was within safe operating limits. Constant monitoring of the gaseous flow of hydrogen through the pipes as well as the surrounding atmosphere is essential in the laboratory environment to ensure that the lower explosion limit (LEL) of hydrogen (4%) is not breached [7].

Several peculiar characteristics of hydrogen need to be considered for safe operation besides its wide flammability limit of 4%-75% mass in air [7]. Firstly, hydrogen is undetectable by most conventional means as it is an odourless and colourless gas [8]. It is also the least dense element known and is thus able to permeate a lot of materials or seals. Hydrogen is also known to cause embrittlement of certain materials, causing them to crack or fail. Thus material compatibility is an important consideration when dealing with hydrogen [9]. Hydrogen is a highly flammable gas and has very low minimum ignition energy of about 0.02mJ [10].

The use of a hydrogen sensor together with the RMACS makes for an effective safety solution. By tuning the sensor with both hardware and software to respond to the appropriate concentration levels of hydrogen in air, the RMACS can be programmed to take appropriate action when the level of hydrogen detected exceeds acceptable ranges.

3 Possible Areas of Application

While this system was developed mainly with hydrogen safety in mind, the actual field of application for this system is diverse. The use of a microcontroller that is easily programmable to respond to inputs from sensors and produce outputs to actuators makes the system able to control and monitor almost any process. The actual control and communication process only draws low power and can be powered by batteries such as those found in vehicles, making the system appropriate for use in vehicles as anti-theft devices. If the use of high powered actuators or sensors is required, an auxiliary power source may be utilized with suitable adaptive circuitry driven by the microcontroller via transistors or relays.

Adaptations of this system may be used in industrial control processes to monitor automated processes such as production lines, or certain parameters of a system such as the temperature of a boiler unit or the liquid level in a receptacle. Specialized sensors may even be used to pick up the presence of certain chemicals or objects such as metal in food items. The sensors will then continuously update the microcontroller with the measured parameters and the microcontroller will relay an alert message to the user(s) via the GSM module should anything go wrong.

The user then has the option of replying to the system via SMS to issue commands for certain actuators on the system to take steps to rectify the problem.

Similar approaches may be taken for security applications, whereby security type sensors such as infrared light barriers, proximity sensors, vibration sensors, breaking glass sensors and such are employed to secure an area of residence or commercial plant. The system may be run off a static power source such as a power outlet and have a backup battery to power the system should the power source be rendered inoperable.

An added benefit of the use of a wireless mobile communication network as opposed to a wired connection is that it becomes impossible for a perpetrator to physically severe the communication channel. This gives the system an additional layer of security.

Similarly the RMACS can be extended to a variety of other possible application areas so long as there is the need for the monitoring of a measurable parameter and possibly the necessity of extending some form of control that is achievable via electronic actuators. Healthcare is such a sector that may benefit from the deployment of the RMACS system in the monitoring of patients.

4 System Appraisal

The difficulty in appraising a system of this sort is that the GSM infrastructure which is used to communicate the warning messages to the user from the RMACS as well as commands back from the user back to the system is beyond our control.

The time taken for internal communication of the RMACS system is small in comparison to the time taken for SMS messages to be delivered. Communications between the sensors/actuators and microcontroller is nearly instantaneous as there is not much data to be sent each time.

The main time delay with this aspect of communication is the polling time set by the microcontroller and this is dependant on the coding as well as the timing crystal used for the microprocessor. If the application is time critical, interrupts may be used for the sensor inputs instead of the polling method. Communication between the microcontroller and the GSM module is via a RS232 link. The time it takes to send a message between the two is dependant on the length of the message but again the time is in the order of microseconds and not an issue compared to the time delay over the GSM network.

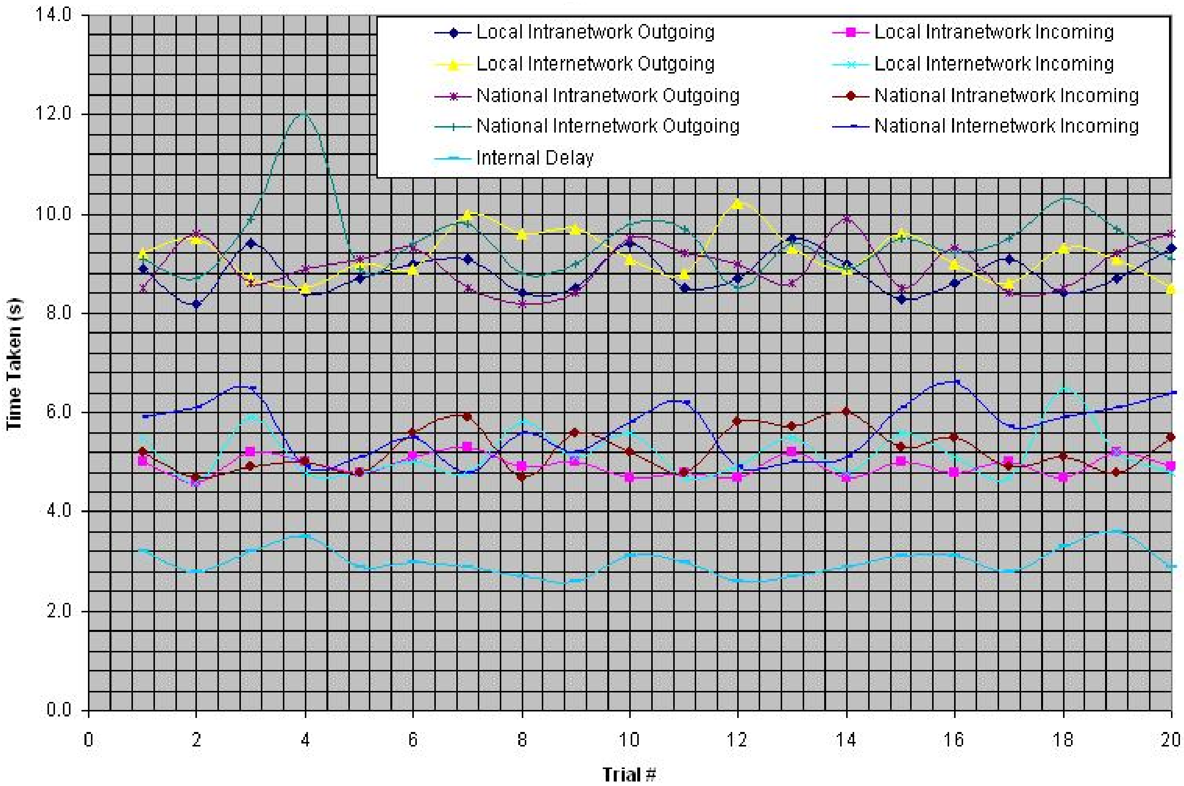
While the transfer of signals on the hardware of the system is near instantaneous, there will sometimes be delays and/or losses in the Short Message Service system especially when transmitted across long distances via different networks. Delays in the sending and receipt of a SMS depend heavily on the traffic load of the networks that are traversed in the course of delivery of the particular message [11] [12] [13].

The SMS system does however provide services such as confirmation of receipt to give assurance that a message has successfully been delivered. Further, the RMACS is programmed to transmit an acknowledgement message upon receipt of a command. Thus the reliability issue is not so much whether or not the message gets through but rather how long it takes. This becomes a concern when dealing with time critical applications where the security or safety of a plant may be compromised.

In order to establish the typical response times of the system, a series of 20 trials were conducted across various networks and localities and timed.

The results are depicted graphically in Figure 4 and Figure 5:

Figure 4: Chart Showing Time Trial Results

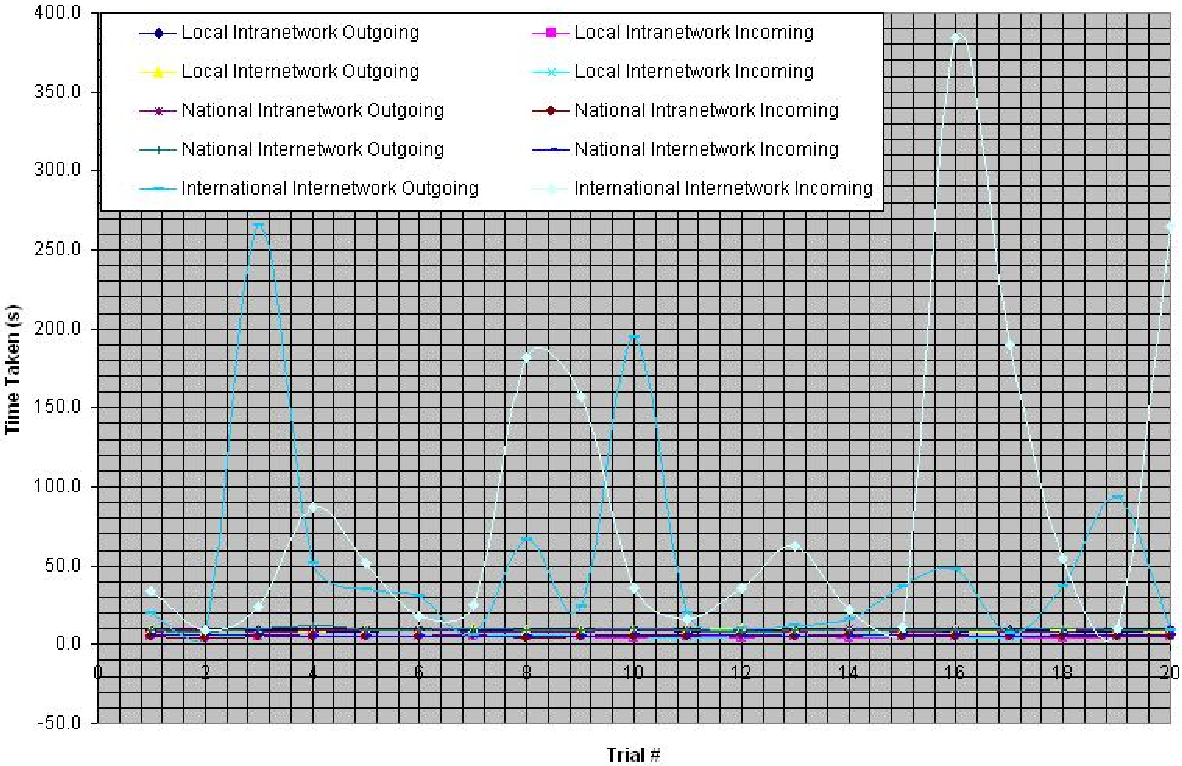


In the results, the outgoing delay refers to the time between when a sensor is triggered and the user receives a warning message on his/her mobile. Conversely the incoming delay refers to the time taken by the RMACS to respond after the user transmits a command via SMS. The internal delay is measured from the time a sensor is triggered until the RMACS responds without user intervention (i.e. without a command from an external source). Intra-network refers to messages sent to and from the same service provider while inter-network communications are messages sent between various service providers.

Using the RMACS on a local intra-network system yielded fairly good response times in terms of both mean and standard deviation at 8.8 and 0.40 seconds respectively for outgoing messages and about half of those values for the incoming response. The reason the incoming response is faster is attributed to the programming structure used whereby the sensors that generate outgoing messages are polled periodically while incoming messages are treated as an interrupt. The response time from the actual sensor it self also plays a part in the delay of the outgoing messages.

It is observed that as different networks were used and the distance between the user and system increased, both the mean and standard deviation times increased. This is to be expected as the data has to traverse across several networks and space and thus longer delays is to be expected. The reliability of the SMS server on each network also may vary thus affecting the outcome of the result. It is noted that the internal delay as well as the delay in outgoing messages due to the device remains constant regardless of the network used in communicating the message.

Figure 5: Chart Showing Time Trial Results Including International Networks



With the inclusion of international networks, the mean and standard deviation times increase drastically. The system was tested with various mobile networks in Malaysia, the United States and the United Kingdom.

It was found that the time it took for a message to be successfully transmitted depended heavily on traffic at that time of day consistent with the findings in [11][12][13]. During peak traffic times in either the host or destination location, the time it took to send a message increased significantly. Conversely, during non peak hours, some of the results achieved were as low as those of trials conducted within local networks. The longest recorded time was approximately 6 minutes. None of the messages were lost in the course of the tests. It is however, not unheard of for SMS messages to never reach the destination, hence delivery confirmation services.

5 Autonomous Operation Strategy

While one of the roles of the RMACS system is to alert users to the occurrence of an incident, the RMACS is also capable of autonomous operation. Using a set of pre-programmed instructions, the RMACS may respond to a given situation as described in its program.

In the specific case of use as a safety measure for hydrogen leak detection, the RMACS could be programmed to respond to a leak by sealing off the solenoid shut-off valves, sound a local audible and visual alarm to alert occupants of the building and fully utilize all venting capabilities in the lab. All this could be executed autonomously and the SMS alert messages sent out to the relevant people to alert them to the situation at hand. This may be described as the default reaction to a scenario that is described in the programming of the RMACS. In many cases, the user will not have to return a command to the system as the measures undertaken by the RMACS is already adequate. The user may then go on to alert to fire department and any other relevant authorities.

However, as the device is used for broader applications, the number of different possible scenarios will increase as well. Each additional sensor integrated into the system adds another dimension of possible scenarios which may or may not be accounted for in the programming. In such situations the default response may be inadequate and human discretion is required. Giving the user remote and local control over each component of the actuator bank will then become important. Local authenticated control may be provided via a terminal available in close physical proximity to the building but outside of the hazardous area and connected via physical wiring. This avails an extra method to extend control over the system increasing the safety of the system via redundancy.

6 Conclusion

The use of a microcontroller and GSM module coupled sensors and actuators provide exciting possibilities. This feature is especially useful when dealing with hydrogen safety as hydrogen, like any other highly flammable material, requires stringent safety measures. Solenoid shut off valves and circulation fans may be controlled by the user and/or microcontroller in order to shut off the supply of hydrogen and ventilate the laboratory in the event of a leak.

7 References

[1] Global System for Mobile Communications Organization. "GSM World" http://www.gsm-world.com visited on 16/06/2004

[2] Ken Wieland, "Spreading the Word" *Telecommunications Magazine International Edition October 2004, Issue Highlights.*

[3] Puneet Gupta, SMS: How, what and where, *Wireless Developer Network*

http://www.wirelessdevnet.com/channels/sms/features/sms.html visited 23/06/2004

[4] The CDMA Organization. "Home Page" http://www.cdg.org visited 23/06/2004

[5] Microchip Technology - *PIC 16F87x Data Sheet*, Microchip 2001.

[6] Telit - *Telit GM862 Software User Guide*, Dai Telecom 2003.

[7] Ghazi A.K., "Hydrogen as a SI Fuel", *International Journal of Hydrogen Energy 28 2003, pp 569-577.*

[8] United States Environmental Protection Agency. "*Clean Natural Fuels, Compressed Natural Gas*", Transportation and Air Quality.

[9] Valenti M., "Fill'er up-with hydrogen", Mechanical Engineering *2002*, pp 44-48.

[10] Swgal L., et. al., "Safety Considerations in the Design of a Gaseous Hydrogen Fuel Supply for Engine Testing", *International Journal for Hydrogen Energy 11, 1986, pp 737-743.*

[11] C. Murray, L. Cleary, "A Clearer Channel for SMS", *IEE Communications Engineer, April/May 2004 pp. 28-31*

[12] K. Allen, P. Fitzpatrick, M. Ivanovich, "Joint Traffic and Signalling Capacity Analysis in GSM", *Proc. Australian Telecommunications, Networks and Applications Conference, Melbourne, 2003.*

[13] Naor Z., "An Efficient Short Message Transmission in Cellular Networks", *IEEE INFOCOM, Hong Kong, 2004.*