CHAPTER 1
LITERATURE REVIEW AND RESEARCH OBJECTIVES

1.1 INTRODUCTION
The central idea of this research is to develop low cost intelligent remote monitoring system using mobile (cell phone) with emphasis on its utilization in rural areas. In past few years, there has been tremendous rise in number of mobile users in India. Due to widespread growth of wireless cellular networks and drastic reduction in call rates and handsets, mobile usage has percolated all sections of society from business magnates to skilled and unskilled laborers like carpenters, masons, farmers and even dabbawalas. Cell phone is gradually emerging as powerful tool for many commercial applications like train reservation booking, banking, etc. Remote monitoring of processes, machines, etc is popular due to advances in technology and reduction in hardware cost. Internet based monitoring is one of common approaches of remote monitoring. Cellular networks provide Short Messaging Service (SMS) and Multimedia Messaging Service (MMS), which have been utilized by many researchers for telemetry applications especially in medical field. Wireless sensor networks (WSN) also offer attractive opportunity for remote monitoring. However, deployment entails substantial investments in infrastructure. Major applications of WSN are in field of environment monitoring, defense, etc. The research work presented here aimed to provide cellular phone based remote controlled smart embedded system with various features to provide status of system and fault detection capabilities. It was observed that technological capabilities of cellular phones have varied widely during last decade from simple voice and messaging features to very powerful ones having high resolution camera, high speed GPRS capabilities, etc and connection interface have varied from simple RS-232c based data link, USB based link to wireless Bluetooth and Wi-Fi based links. There have been rapid advances in microcontroller technologies and powerful processors with low power consumption have been developed. Due to diverse technological developments, work was carried out on range of Nokia cell phones starting from 3310 model which works on F-Bus protocols to 2700 classic which is Series 40 5th Edition model which involved the use of Java ME platform. Major focus of the work was to develop system which can cater to the needs of local rural population where industrial firms are
reluctant to invest due to lower returns and lack of suitable infrastructural facilities. The work has achieved tremendous success in this regard as it is able to offer remote control capability using obsolete cell phone model and even cell phone having non-working display and operational cost can be minimized to negligible level through novel concept of miscalls.

The work has been divided into following subsections:

A) Literature review, analysis and building the research objectives.

B) Study of technical features of various cell phone models for control adaptation.

C) Study and selection of sensors, communication protocols and microcontroller suitable for development of prototype system.

D) Design and implementation of prototype systems based on capabilities of selected Nokia cell phone model, micro-controller, sensors and cost factors.

E) Conclusions, Limitations of work and Future scope.

1.2 LITERATURE REVIEW:

The literature related to the research topic has been reviewed for last twenty years in order to find out work carried out by various researchers.

There are many systems for remote monitoring and control designed as commercial products or experimental research platforms. The TABLE I depicts the status of the work of select researchers who specifically developed or experimented with remote monitoring systems using various techniques. It is noticed that most of the research carried out belongs to the following categories

a. GSM-SMS protocols using GSM module individually or in combination with internet Technologies.

b. Internet based Monitoring using GPRS modems, Servers, etc. with different approaches.

c. Monitoring using Wireless Sensor Networks

d. Wireless Monitoring using Bluetooth, Wi-Fi, Zigbee and RF

e. Applications have varied widely like Home Automation, Security Systems, Bio-medical applications, Agriculture, Environment, Reservoir, Bridge health monitoring, etc.
<table>
<thead>
<tr>
<th>Researchers</th>
<th>Year</th>
<th>Remote Monitoring Technique Used</th>
<th>Application / System specs</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen Peijiang, Jiang Xuehua</td>
<td>2008</td>
<td>GSM -SMS in PDU mode, Remote Mobile Station &amp; Central Monitoring station use GSM Module Siemens TC35.</td>
<td>Remote MS based on MSP430F149 MCU, Central Monitoring Station based on PC with database</td>
<td>System costly due to usage of ≥ 2 GSM modules. Facility to store and print data at CMS. Low power consumption at Remote MS.</td>
</tr>
<tr>
<td>Scanaill C.N, Ahearn B., Lyons G.M.</td>
<td>2006</td>
<td>GSM-SMS, Portable unit &amp; Remote Server use GSM module Falcom A2D-1</td>
<td>accelerometer-based portable unit using ADuC812S μC for mobility measurement of elderly person</td>
<td>Useful bio-medical application where appropriate medical expertise provided when mobility levels decrease below threshold level</td>
</tr>
<tr>
<td>Baris Yuksekkaya, A. Alper Kayalar, M. Bilgehan Tosun, M. Kaan Ozcan, Ali Ziya Alkar</td>
<td>2006</td>
<td>GSM, Internet &amp; Voice between user &amp; home server. RF ASK between home appliances. Home server provided with GSM module.</td>
<td>Home automation with ventilation, lighting, camera, temp., motion nodes using PIC 16f876. User cell phone application in JavaME</td>
<td>Versatile Home automation Control application developed with diverse comm. Technologies to provide reliability but is costly in implementation.</td>
</tr>
<tr>
<td>Peng Liu, Guojun Dai; Tingting Fu</td>
<td>2007</td>
<td>Internet using Web services based email extension for remote monitoring</td>
<td>Remote meter reading, Home automation</td>
<td>Non-real time but free email services result in reduction in operational cost.</td>
</tr>
<tr>
<td>Flammini, A.; Marioli, D.; Sisinni, E. Taroni, A</td>
<td>2007</td>
<td>GSM with centre server &amp; DECT (between acquisition sensors)</td>
<td>Acquisition system based on PIC 18F452. Transmitter module on ARM S3F441FX</td>
<td>Low power scheme developed for environmental monitoring using temp., humidity &amp; CO sensors</td>
</tr>
<tr>
<td>Alheraish, A</td>
<td>2004</td>
<td>GSM-SMS</td>
<td>89c52μc with GM47 GSM module with AT Commands usage</td>
<td>Home automation system developed for lighting control and fan speed.</td>
</tr>
<tr>
<td><strong>Chia-Shen Tsai; Bo-Fu Shen</strong></td>
<td></td>
<td>Bluetooth between appliance &amp; mobile, GPRS/WLAN between mobile &amp; Data Server (Internet/Intranet)</td>
<td>Bluetooth MBM-C2.1 for home appliances &amp; Dopod 699 PDA as mobile device controller (Java ME)</td>
<td>Limited range capability for control due to Bluetooth. However status can be known using Internet.</td>
</tr>
<tr>
<td>Saito, T.; Tomoda, I.; Takabatake, Y.</td>
<td>2000</td>
<td>Home Server Gateway for interconnection</td>
<td>remote control of appliances on home networks from</td>
<td>Costly implementation of Home server</td>
</tr>
</tbody>
</table>
### Intelligent Embedded System based Remote Monitoring using Mobile

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Description</th>
<th>System Features/Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arni, J.; Teramoto, K.</td>
<td>2009</td>
<td>http connection using cgi between browser &amp; X10 devices protocols</td>
<td>involving use of X10 protocols and IEEE 1394 AV network</td>
</tr>
<tr>
<td>Al-Khateeb, K.; Al-Khateeb, W.F.; Hameed, S.A.;</td>
<td>2009</td>
<td>web server hosts a web page using Homeseer s/w that provides access control to various unit</td>
<td>Relative cost of system is high but user friendly graphical interface is available for user</td>
</tr>
<tr>
<td>Bencini, L.; Chiti, F.; Collodi, G.; Di Palma, D.; Fantacci, R.; Manes, A.; Manes, G.;</td>
<td>2009</td>
<td>MIDRA mote with 868 MHz radio transceiver, Chipcon CC1000-node. Master node sends data to remote server through TCP-IP Protocol</td>
<td>Agricultural monitoring to sense soil moisture, humidity, temp. for irrigation and pest management at vineyards</td>
</tr>
<tr>
<td>Woodward, B.; Istepanian, R.S.H.; Richards, C.I.;</td>
<td>2001</td>
<td>ECG signal measured through processor and processed signal transmitted through patient mobile</td>
<td>Telemedicine application extended using mobile. Inconvenient due to infrared commn.</td>
</tr>
<tr>
<td>Jiehui Jiang; Zhuangzhi Yan; Jun Shi; Kandachar, P</td>
<td>2008</td>
<td>Processor board consists of DSP processor, sensors and SMS module</td>
<td>Low cost BP sensing application developed.</td>
</tr>
<tr>
<td>Wijetunge, S.P.; Wijetunge, U.S.; Peiris, G.R.V.; Aluthgedara, C.S.; Samarasinghe, A.T.L.K.;</td>
<td>2008</td>
<td>Bluetooth controller based on atmega64 µc. receives control &amp; config command from PC server. Controls commn. between various sensor modules</td>
<td>Limited range up to 100m for device control. Home automation system developed for temp., illumination, AC and current sensing and control.</td>
</tr>
<tr>
<td>Alkar, A.Z.; Buhur, U.;</td>
<td>2005</td>
<td>Secured web page based through /2 sets of simple comm. protocols</td>
<td>Powerful Low cost secure home</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Year</td>
<td>Methodology</td>
<td>Main Features</td>
</tr>
<tr>
<td>-----------</td>
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<tr>
<td>Yen-Shin Lai; Jennshing Wang; Zhong-Qing Lin; Min-Hao Wang; Su-Chen Tien;</td>
<td>2002</td>
<td>Internet monitoring between PC client and Server. RS232 Connection between server and PLC</td>
<td>Fuzzy logic based algorithm developed in PLC for inverter based control of induction motors in AC. Costly implementation due to PC Client to PC Server based control access.</td>
</tr>
<tr>
<td>Ximin Zhang; Junding Sun; Lihua Zhou;</td>
<td>2005</td>
<td>Internet between client &amp; Home PC server. RS32C serial comm. Between Home server &amp; Home appliance controller(E-controller)</td>
<td>E-controller consists of C8051F005 µc with 8 analog channels and 32 digital ports, LCD Display and 9 keys keyboard. Provision to assign dynamic IP address to Home server. Program based on Java allows multi platform capability and reduces cost compared to commercial software usage.</td>
</tr>
<tr>
<td>Al-Ali, A.R.; Al-Rousan, M.</td>
<td>2004</td>
<td>Internet (Java Beans &amp;JSR) between client &amp; Home PC Server. RS232C between Home server &amp; Home appliance controller (E-board)</td>
<td>Technical details of E-board not specified. Feedback circuit incorporated to check whether command is actually carried out or not. Java based programming permits Server based on any OS and reduces cost compared to commercial software.</td>
</tr>
<tr>
<td>Colak Ilhami; Demirbas Sevki; Sefa Ibrahim; Irmak Erdal; Kahraman, H. T.;</td>
<td>2008</td>
<td>Internet (CGI/http) between server PC &amp; client. Server has PCI based DAQ which communicates with µC system (PIC 16F877)</td>
<td>Internet, local and infra-red based remote control supported for heating ventilation AC systems (HVAC) with web camera to read present status. Sleeping mode offered to reduce power consumption. Versatile remote strategies provided with MATLAB based program for internet based remote operation.</td>
</tr>
<tr>
<td>Xu Meihua; Fei Yu; Zhao Fangjie; Zhu Qian;</td>
<td></td>
<td>GSM-SMS between user mobile &amp; Hospital PC server</td>
<td>Medical Monitoring based on GSM Module TC-35, Actel Fusion FPGA, Blood pressure, temp, measurement modules. Practical implementation not clear but theme has great significance in low cost bio-medical remote monitoring systems.</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Year</td>
<td>Method Description</td>
<td>Application Details</td>
</tr>
<tr>
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<tr>
<td>Van Der Werff, M.; Gui, X.; Xu, W.L.;</td>
<td>2005</td>
<td>GSM-SMS between user mobile &amp; Home server using AT commands</td>
<td>Home server based on AVR169 µC &amp; cellular modem. Java ME application on user mobile for sending commands and receiving status</td>
</tr>
<tr>
<td>Ren-Guey Lee; Kuei-Chien Chen; Chun-Chieh Hsiao; Chwan-Lu Tseng;</td>
<td>2007</td>
<td>GSM-SMS between patient mobile and health care assistant/expert mobiles and Hospital server. Bluetooth between physiological signal meas. systems and patient mobile</td>
<td>Priority Alert message mechanism developed based on ECG, Hemoglobin, Pulse rate etc. Java ME application on patient mobile for ECG, hemoglobin measurement.</td>
</tr>
<tr>
<td>Chen Chao; Meng Keqilao; Gao Muyu;</td>
<td>2009</td>
<td>GPRS (TCP-IP embedded) between GPRS modem and server and serial commn. Between controller and GPRS modem using AT command</td>
<td>Off-Grid Wind Turbine monitoring system developed. µC LM3S1138 (ARM7) acts as a controller and GPRS modem Q2406B works as comm. device</td>
</tr>
<tr>
<td>Vasantha D. Kumari and M. Malleswaran;</td>
<td>2010</td>
<td>Embedded Web server using VB.net technology. Embedded controller connected to PC through RS232 connection. PC connected to Internet using modem.</td>
<td>Controller based on LPC 2148 µC. Two parameters illumination intensity and audio gain are measured and controlled.</td>
</tr>
<tr>
<td>Burger, E.W.; Frieder, O.;</td>
<td>2006</td>
<td>Internet through IAD using normal Telephone or directly through SIP phone</td>
<td>Uses KPML protocols to inform key presses to the controller.</td>
</tr>
<tr>
<td>Fang Hongping; Fang Kangling;</td>
<td>2010</td>
<td>Embedded Web server using Java applets</td>
<td>Technical details relating controller not provided</td>
</tr>
<tr>
<td>Zhen Zhu; Ruchun Cui;</td>
<td>2007</td>
<td>Embedded Internet technology.</td>
<td>Alerts about theft &amp; fire based on sensing of temp., smog, image and sound. Uses µC S3C44B0 with 32-bit ARM kernel.</td>
</tr>
<tr>
<td>Authors</td>
<td>Year</td>
<td>Network/Technology Used</td>
<td>Implementation Details</td>
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<tr>
<td>Yunseop Kim; Evans, R.G.;</td>
<td>2008</td>
<td>(WSN)Bluetooth between sensing, weather, irrigation control &amp; Base station. Internet</td>
<td>Real time GPS based Irrigation system was developed with variety of sensors. Versatile system with accurate water control based on various parameters to ensure minimum losses and optimum yield. Very costly implementation.</td>
</tr>
<tr>
<td>Iversen, W.M.;</td>
<td></td>
<td>between client and Base station</td>
<td></td>
</tr>
<tr>
<td>Liu Zhong-xuan; Jiang Xiao-yu</td>
<td>2010</td>
<td>GPRS between data acquisition system (89C58 µC based) using GPRS module and Monitoring centre with AT commands</td>
<td>Monitor centre initially sends current IP address to data acquisition system through sms. Data acquisition system now communicates with monitor centre using this IP address through GPRS. The system containing temp. &amp; pressure sensors tested in Thermal Station for control of valves. No provision to send/receive information through mobile user.</td>
</tr>
<tr>
<td>Han Zhao-fu; Zong Yan-tao;</td>
<td></td>
<td>GPRS between Mobile and Centre Server. LAN/Internet between House hold appliances &amp; Home server</td>
<td>Home automation system with graphical status of equipment on mobile. LAN between appliances increase the cost of system but provide flexibility to increase number of appliances networked.</td>
</tr>
<tr>
<td>Du Meng;</td>
<td></td>
<td></td>
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<tr>
<td>Atukorala, K.; Wijekoon, D.;</td>
<td>2009</td>
<td>GPRS between Mobile and Centre Server. LAN/Internet between House hold appliances &amp; Home server</td>
<td>Study of various Home automation systems. Basically a review paper with no implementation.</td>
</tr>
<tr>
<td>Tharugasini, M.; Perera, I.;</td>
<td></td>
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<tr>
<td>Silva, C.;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delgado A., Picking R., and</td>
<td>2006</td>
<td>Internet, GSM</td>
<td>Study of various Home automation systems. Basically a review paper with no implementation.</td>
</tr>
<tr>
<td>Grout V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Khiyal M. S. H., Khan A. and</td>
<td>2009</td>
<td>GSM between user mobile &amp; Home automation control system</td>
<td>Study of various Home automation systems. Basically a review paper with no implementation.</td>
</tr>
<tr>
<td>Shehzadi E.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Tam Van Nguyen; Dong Gun</td>
<td>2007</td>
<td>Internet between home server and client/cellphone.</td>
<td>Study of various Home automation systems. Basically a review paper with no implementation.</td>
</tr>
<tr>
<td>Lee; Yong Ho Seol; Myung</td>
<td></td>
<td></td>
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<tr>
<td>Hwan Yu; Deokjai Choi;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wensheng Liu; Yu Guo;</td>
<td>2009</td>
<td>Web server (Internet) between clients(Users) and Server</td>
<td>Study of various Home automation systems. Basically a review paper with no implementation.</td>
</tr>
<tr>
<td>Ciubotaru-Petrescu, B.,</td>
<td>2006</td>
<td>Internet through Local server and GSM-SMS to report</td>
<td>Reliable Monitoring system using Internet and SMS</td>
</tr>
<tr>
<td>Chiciudean, D.;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authors</td>
<td>Year</td>
<td>Technology</td>
<td>Approach</td>
</tr>
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</tr>
<tr>
<td>Cioarga, R., &amp; Stanescu, D.;</td>
<td></td>
<td>change in monitoring state like power failure</td>
<td>audio &amp; video streams and delivers to user at specified intervals through internet. ATMEGA128 μC system along with GSM modem is used to transmit SMS for any change in state</td>
</tr>
<tr>
<td>Shaosheng Dai; Yue Zhang;</td>
<td>2006</td>
<td>Internet &amp; GSM-SMS</td>
<td>Transmission of physiological signals from patient to mobile monitoring centre (PDA) with alarm &amp; information exchange with hospital server/doctor</td>
</tr>
<tr>
<td>Bing Li; Songyuan Li; Ling Chen; Xusheng Li; Shangyong Qu;</td>
<td>2008</td>
<td>Internet (PPP) &amp; GSM-GPRS</td>
<td>Remote Image Monitoring system developed using S3C2410 (ARM 920core) &amp; UART GPRS module. ARM_linux OS APIs for video images and data comm.</td>
</tr>
<tr>
<td>Yang Musheng; Zhang Yu; Chen Rong;</td>
<td>2008</td>
<td>Internet (PPP) &amp; GSM-GPRS</td>
<td>Reservoir remote monitoring system using 89C55 μC &amp; GPRS modem. Sensing of water level, Gate level, Flow rate, Rainfall and evaporation rate</td>
</tr>
<tr>
<td>Mulyadi, I.H.; Supriyanto, E.; Safri, N.M.; Satria, M.H.;</td>
<td>2009</td>
<td>Zigbee &amp; Bluetooth</td>
<td>2 processor with Bluetooth &amp; Zigbee modules are used. Data from medical devices are passed on PC for analysis through Bluetooth</td>
</tr>
<tr>
<td>Sung-Nien Yu; Jen-Chieh Cheng;</td>
<td>2006</td>
<td>Bluetooth &amp; Wifi Technologies.</td>
<td>89C51 μC with ADC and Bluetooth sense medical parameters and pass it to Monitoring unit which passes data to Hospital server through Wifi.</td>
</tr>
</tbody>
</table>
1.2.1 The major strengths and the weaknesses drawn from the conclusions laid by various researchers are as under:

1.2.1.1 Major strengths:

1. Exhaustive research has been carried out on Internet based Monitoring scheme with various protocols and systems providing detailed description of remote process states to the authorized users.

2. Many systems have been designed and experimented by using GSM-SMS which normally involved the use of GSM modem for carrying sensing and control of devices in the system using message transfer.

3. Numerous systems have been developed using Wireless Sensor Networks which consists of several sensor nodes in proximity and having data transmission and reception capability between nodes and central base station.

1.2.1.2 Major Weaknesses:

1. Most of systems based on Internet monitoring require higher operational cost based on bandwidth / data speed requirements and hence is justified only in industrial or biomedical applications in developing countries. These systems generally do not have alert facilities against occurrence of abnormal conditions.

2. The development and deployment cost of wireless sensor networks is very high due to need of motes, sensors, radio transceivers, etc spread over large area.

3. It is difficult to upgrade existing conventional control systems with remote control capabilities.

1.3 RESEARCH OBJECTIVES:

At a glance:

- To design low cost intelligent embedded system based remote monitoring system using mobile / cell phone.
- To provide flexibility to use any cell phone model for remote monitoring.
- To incorporate alternative mechanism for communication when messaging fails.
- To implement a simple embedded system as a proof of concept.
In depth:

1. Primarily looking at the existing status of research in remote monitoring, major impetus is only for development of system applications in industrial automation, home automation, health care systems and defense.

2. With explosive growth of cellular networks in India and sharp reduction in cost of handsets and call charges with coverage of >70% of area, cell phones offer unique opportunity for remote control even in rural area.

3. The research work presented in this summary thesis is aimed to remotely monitor the system using cell phone by designing and implementing embedded system.

4. It is aimed to provide facility to use even any obsolete mobile model having simple messaging and calling function to make remote system affordable to all categories of users.

5. The major aspect of the research had been to work out strategies to keep operational cost of the system minimum to emphasize its utility to automate simple systems with remote monitoring capabilities.

6. The implementation part of the research has been carried out using range of cell phone models including one phone model having non-working display monitor and one application on remote control of motor-pump based irrigation was carried out to demonstrate the feasibility of the concept.
CHAPTER 2.
STUDY OF CELL PHONE MODELS FOR CONTROL
ADAPTATION

2.1 Cell Phone Models:
There has been tremendous development in cell phone technology and cell phones have now been transformed from simple communication tool to powerful personal assistant with multimedia, GPRS and internet- access capabilities (smart phones). All cell phones generally contain hardware or software modem for data communication through cellular networks. Cell phones also have optional data link cable for interface to PC for Flash Programming, downloading of music tones, phone book / SIM memory entries back-up etc. Most mobile phone manufacturers like Nokia, Siemens, Ericsson, and LG etc. also provide associated communication software (mostly in form of free downloads from Internet) to perform some of these tasks. For e.g., Nokia provides software “PC Suite” for accessing data for its range of mobile phone to PC. This software was used to check whether data link between mobile and PC was working correctly or not. Most common method for remote control using cell phone is to use short messaging service (SMS). In this approach, text message up to 160 characters can be transmitted or received. The various Nokia cell phone models which were studied for remote control applications are discussed.

2.1.1 Nokia Model 3310/ 3315:
In pre-Ph D research phase (year 2004-06), some simple popular Nokia models like 3310 & 3315 having simple call and messaging properties were studied. It was observed that these cell phones had software based modem and did not support AT commands. A system was developed using PC and devices were controlled through parallel printer port and 3315 mobile was connected to serial port through DAU-9P data cable using F-Bus Protocols. For device control, 8 output ports from printer interface have been used with LED for indication of ON/ OFF status. For reading status, 5 input ports were used through DIP switches. Technical paper describing this work was published in IETE journal of Education.
2.1.2 Nokia Model 3120

This cell phone model is one of early phones enabling Java ME support (MIDP 1.0) and belonged to Series 40 1\textsuperscript{st} Edition Nokia OS platform. This model also did not support AT commands and experimental work was carried out using F-BUS protocols for remote device control operation.

2.1.3 Nokia Model 6610

This cell phone model was quite popular during 2004-2008 in India. Nokia 6610 model supports most of AT commands related to messaging. Moreover, data link cable compatible with RS232 serial connection is available with this model. Therefore this model can be easily adopted as control system mobile for remote control applications. Majority of the experimentation work was carried out on this model.

2.1.4 Nokia Model 6681

This cell phone is an early smartphone based on Symbian operating system. It was launched in 2005. It has enhanced features like Java ME support, Bluetooth interface, MMC card, etc. However, data link cable is USB based, so direct connection to simple embedded system is not possible.

2.1.5 Nokia Model 3500 classic

This Java enabled phone belongs to Series 40 3\textsuperscript{rd} edition Nokia OS platform. It has many features like Bluetooth interface, SD micro card interface, etc. However, this device does not support all AT commands related to messaging. Moreover, it is not possible to directly interface this cell phone to simple embedded system due to non-availability of RS232 serial connection. Instead it has mini USB interface which provides two separate serial ports for data and command interface in PC through drivers.

2.1.6 Nokia Model 2700 classic

This cell phone is recent java enabled phone belonging to Series 40 5\textsuperscript{th} edition Nokia OS platform. It is similar to Nokia 3500 with higher resolution and enhanced features. It is Bluetooth enabled and also have local micro USB interface connectivity cable for communication using USB.

2.2 Adaptation Methods for usage of cell phone for remote control:

It is observed that earlier Nokia cell phones belonging to 3310 generation and 3120 did not support AT commands and require F-bus based protocols for message transfer.
Models 6610 and its derivatives can be easily adapted for remote control due to their AT command support for messaging and RS 232C communication support using converter. Later generation cell phones like 6681, 3500 and 2700 are provided with plenty of attractive features but their control adaption for embedded based remote control was rendered difficult due to lack of full AT commands support and absence of RS232C connectivity. Some tricks like downloading of Java application programs, Bluetooth based connections, automated control of soft keys were used to adapt these models for remote control. Nokia models were chosen for experimentation because of their highest market share. However, other company cell phone models can be also molded in similar fashion for remote control. The unique advantages associated with this approach over GSM modem module are the relatively low cost for using discarded cell phone model, efficient recycling or increasing life cycle of the product and low cost of replacement in case of problem. A casual market survey recently undertaken showed that all latest available cell phones are Java enabled with Bluetooth technology support. Therefore, adapting these phones for remote control is easily feasible and there exists scope for more powerful communication strategies like GPRS based internet monitoring, Wi-Fi interface between embedded system and cell phone, etc. Our major focus is on providing low cost solutions and so these cell phones were not considered for experimental work.
CHAPTER 3.

SELECTION OF SENSORS, COMMUNICATION PROTOCOLS AND MICROCONTROLLERS

3.1 Selection of Sensors:
Initial work was carried out to show the demonstration of remote monitoring capability using PC and output devices were simple LEDs and input devices were dip switches. The messages / commands were transferred between system control cell phone (3315/3210/6610) and user cell phone based on changes in input status or desired control of outputs. At a later stage, remote temperature monitoring application was developed using temperature sensor DS 1820. Finally, a cell phone based remote monitoring system for motor pump based irrigation in agriculture was developed and sensors and protection schemes were designed for this application.

3.1.1 Three Phase Voltage Sensing:
Three single phase transformers have been used to sense power failure, unbalanced phase voltages, single phasing, undervoltage and overvoltage conditions. The secondary voltages of these transformers are rectified and given to analog inputs of microcontroller based system. Message is sent to user cell phone through control system mobile on occurrence of any abnormal conditions.

3.1.2 Overcurrent/ Bearing Failure Sensing:
Whenever overcurrent or bearing failure of induction motor occurs, there is rise in temperature of motor enclosure. One temperature sensor DS 18S20 is mounted on the enclosure of induction motor and second temperature sensor is mounted at suitable place to measure ambient temperature. Whenever temperature difference between two sensors exceeds specified limits, fault occurrence message is sent to user cell phone. DS18S20 is based on single wire transaction protocols and data pin is interfaced to one port pin of microcontroller to obtain temperature related data.

3.1.3 Dry Running Sensing:
For detection of dry running condition of induction motor pump, water level of well are sensed at five different levels. Lowest level indicates the point at which pump should be switched off. Present level of water is read by microcontroller and during pump-on conditions micro-controllers continuously checks the level of water through its port. If
water level does not fall within specified time, micro-controller switches OFF the pump and sends message to user cell phone indicating dry running condition.

**3.1.4 Moisture Content Measurement:**
The moisture content measurement circuit determines whether sufficient water has percolated through soil in the region under test. This circuit is used in surface based irrigation scheme to switch off the motor pump when optimum quantity of water has been distributed in the specified region and send message/ alarm to indicate the completion of work to the user.

**3.1.5 Time Based Control:**
For sprinkle based irrigation scheme, time duration of on-state on pump is specified for water distribution. RTC chip DS1307 is used for logging time based events. It is based on I²C protocols. Accurate time based operations can be carried out by regularly reading registers of this IC and power failure periods can be known and taken into account for optimum water distribution.

**3.1.6 Voice Messaging & Control:**
Optional Feature of voice messaging and control is provided for the application using IC APR 9600 and DTMF decoder IC 8870. This approach is based on making voice call instead of messaging wherein control system mobile microphone receives selected voice message from speaker connected to IC APR 9600 relating present state of system. Moreover, it also allows user to send commands in form of DTMF code by pressing relevant number keys. DTMF decoder IC is connected to speaker of control system mobile to decode the received code and send it to microcontroller to carry out specified operation.

**3.2 Selection of Communication Protocols:**
Remote Monitoring involves transfer of information between control system and user. The selection of communication protocols is predominantly dependent on the technical features of the selected control system cell phone and choice of control system chosen. PC based control system results in greater flexibility as even USB based data link cables can be directly used due to availability of software drivers for conversion into serial COM ports. However, simple micro-controller based system have only RS232C Serial communication port and so additional hardware in form of converters have to be added for data link connection with cell phone.
3.2.1 F-Bus Protocols:
Nokia has developed its own proprietary F-Bus protocols which contain series of commands that allow users to make calls, send and receive SMS messages, and perform many other functions using PC. Number of researchers / engineers have probed the activity on serial bus and provided unofficial information about the list of commands through trials for Nokia mobile. In F-Bus protocol, the information has to be sent in specific frame format from source (PC / mobile phone) and response/ acknowledgement be received in specific manner from destination (Mobile phone / PC) to indicate information is correctly received. This protocol was used for control system mobile models 3310, 3315 & 3120.

3.2.2 AT Commands:
AT (attention) commands were initially developed by Hayes to carry out communication between computers and modems. These commands have been extended by mobile manufacturers to carry out specified tasks through serial communication interface with terminal equipment (TE). Extensive list of mobile AT commands are available for carrying out various activities like sending SMS, using GPRS services, sending fax, controlling speaker volume, battery status indication, etc. It was observed that Nokia 6610 model supports all the AT commands related to SMS while later mobile models 3500 classic, 2700 classic, etc. do not support incoming message indication command (CNMI).

3.2.3 Java ME application:
Due to lack of complete support of AT commands in many recent mobile models, it was decided to use Java ME application for messaging. J2ME defines elements for building complete Java runtime environments that meet the requirements for a broad range of devices. The core of the J2ME is the MIDlet; each application has its own MIDlet. Most of present cell phones are Java enabled, so programs can be developed in Java ME and this application in Javabyte code can be downloaded into cell phone (Files having .jar extension). Java ME provides APIs for supporting various activities like UI & graphics, wireless messaging, multimedia, networking etc. So it is possible to receive / send messages to other cell phones as well as communicate with PC using serial communication ports by writing Java based programs. However, the java based applications are basically designed for user based inputs and display and so certain
additional modifications are needed to automate the running of application. As signed certificates for higher authorization level are costly to implement, it was decided to control the pressing of the soft keys of user interface of cell phone through analog switches controlled by microcontroller ports. Eclipse version 3.2.2 with Java ME plug-in was used to develop program in JAVA ME. Sun Wireless Tool Kit for CLDC WTK2.2 was used for simulation and debugging of Java program and Nokia PC Suite software was used to download generated file with extension .jar into cell phone model.

3.2.4 Bluetooth Serial Port Adaptor:
Simple embedded systems with RS232 serial connection cannot be directly connected with modern cell phones having USB based cables. USB-to-RS232C converters can be used. However, Bluetooth based connection can offer greater flexibility and mobility at lower cost. Bluetooth can be considered cable replacement technology and has been developed by consortium of companies including Ericsson, IBM, Intel, Nokia, Toshiba, etc to provide royalty free, open specification for short range wireless connectivity. It is radio-frequency technology that uses 2.4 GHz Industrial-Scientific-Medical (ISM) band. For providing Bluetooth connectivity to the microcontroller system, Bluetooth Serial Port Adaptor (SPA) from Connect Blue cB-OEMSPA312 was chosen. SPA works in data and AT modes and needs to be properly configured before it can start data communication with other Bluetooth devices. SPA is configured in Bluetooth Serial Port Profile and provided with BT address of control system cell phone and then moved back to data mode. Now SPA scans for Bluetooth enabled devices in the neighborhood and checks if the discovered device address matches with its stored BT address. If match is found, it can start data communication between micro-controller system and specified cell phone.

3.3 Selection Of Microcontroller
The selection of microcontroller depends on computational speed, power consumption, memory requirements, available on-chip peripherals, cost and application’s specific requirements. There are plenty of popular families of microcontrollers.

3.3.1 89C51/89C52 Microcontroller:
89c51/89c52 is very popular 8-bit micro-controller initially manufactured by Intel and then licensed to many other microcontroller manufacturers. It has 4K of flash ROM, 256 bytes of memory, 2/3 Timers, 32 I/O ports & UART. However, non-availability of
internal ADC, I²C interface, SPI interface and inability to work at >115 kpbs baud rate at 12.00 MHz resulted in rejection of this device in our application.

3.3.2 MSP430F2013 Microcontroller:
MSP430F2013 Microcontroller is a 16 bit ultra low power mixed signal microcontroller from Texas Instruments. It has 2k Flash, 128 bytes of RAM, watchdog timer, 2 timers, USI with I²C & SPI, 4 channel 16-bit sigma-delta ADC, etc. with JTAG debugging and emulation support. Because of its powerful features, humidity and temperature measurement application was developed using this microcontroller. However, it was difficult to develop an efficient C program for application using only 2K of flash. Therefore, this microcontroller was not used further.

3.3.3 AT Mega32 Microcontroller:
AT Mega32 is part of AVR series of microcontroller manufactured by Atmel with 8-bit RISC architecture, 32 kB of in-system programmable Flash, 1k E²PROM, 2k SRAM, 32-bit multi-function General purpose I/O, 8 channel ADC,TWI, USART, SPI, JTAG interface support, etc. Atmel provides free software support in form of AVR ‘C’ compiler, AVR Studio for software debugging and simulation in assembly language and Ponyprog software is also available for flash programming. Most of the work was carried out on this microcontroller due to presence of several desirable features and flash of sufficient capacity for application development.

3.3.4 LPC2148 Microcontroller:
LPC2148 microcontroller from Philips semiconductors is based on a 16-bit/32-bit ARM7TDMI core with flash memory of 512 kB, on chip S-RAM of 40kB, Serial communications interfaces ranging from a USB 2.0 Full-speed device, multiple UARTs, SPI, SSP to I²C. Various 32-bit timers, RTC, single or dual 10-bit ADCs, 10-bit DAC, PWM channels and 45 fast GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers suitable for industrial control and medical systems. It was observed that USB interface cannot directly used for connectivity with Nokia models as drivers are available only for Windows OS and need tremendous software efforts for implementation on non-OS based embedded systems. Since the application envisaged requires less computation efforts it was decided to continue with AT Mega32 micro-controller for the work.
CHAPTER 4.
DESIGN AND IMPLEMENTATION OF PROTOTYPE SYSTEMS

Various prototype systems were developed during the course of work.

4.1 Remote Monitoring using control system mobile model 3315/3120

In pre-PhD phase, mobile based remote control was implemented using PC. The mobile models 3315 and 3120 were used which are based on F-bus Protocols. In Nokia model 3315, there are 4 gold pads under battery holder for the connection. We decided to use computer itself as part of system and interface devices through parallel port and interface 3315 mobile through serial port using DAU-9P data cable that supports both F-Bus and M-Bus protocols. Figure 1 shows the block diagram of the system. The communication between the computer and mobile is through COM1 port in which DTR pin must be active and RTS pin inactive for F-BUS protocol. For device control, 8 output ports from printer interface have been used with LED for indication of ON/ OFF status. For reading status / abnormality information, 5 input ports were used through DIP switches. In F-Bus protocol, the information has to be sent in specific frame format from source (PC / mobile phone) and response/ acknowledgement be received in specific manner from destination (Mobile phone / PC) to indicate information is correctly received. This work was published in IETE Journal of Education, Vol 46, No. 4, pp 165-170, Oct-Dec 2005.

For Nokia Model 3120, DKU-5 USB cable is provided for connectivity through 10 pin pop-up port and drivers contain USB to serial port bridge which permits communication through F-Bus protocols.
4.2 PC based Remote Monitoring using mobile through spoken commands

A novel scheme was developed for mobile based remote control using spoken commands. This scheme is specially suited for elderly persons and illiterate people who have difficulty in typing messages on mobile keypad. One mobile in this system is dedicated for receiving and executing commands from authentic users and informing status about change in input to the user through SMS. Mobile phone model 6610 is used for experimentation through AT commands protocols. The software algorithm is developed to generate text message from spoken commands of user through extraction of features like Cepstral coefficients, short time energy and zero crossing rate and multi layer feed-forward Neural Network is used for recognition of suitable words. The derived text message is then sent as SMS to the mobile connected to control system through PC. On receiving SMS, the system responds by activating appropriate port bits. The system is also designed to send SMS to specified mobile user if there is a change in the status of the input ports. PC forms a part of control system and interfaces devices through parallel port and is connected to 6610 mobile through USB port using DKU5 data cable. Figure 2 shows the block diagram of the system. The communication between the computer and mobile is through COMX port through USB to serial bridge. For sending voice commands, user mobile is interfaced with computer for analysis and generation of required text message, which is then transmitted as SMS to system mobile. The isolated spoken command phrase "<password> DEVICE <0-7> ON/OFF" is used to send control message to control system mobile. The accuracy of spoken word is 84%. The speech recognition process in this work was carried out by N. P. Jawarkar.

![Block Diagram of Scheme](Fig. 2 Block Diagram of Scheme)
This work was presented in 2\textsuperscript{nd} International conference WSCN organized by IIIT, Allahabad, 17-19 Dec 2006 and in IEEE-ICSN 2007 conference organized by MIT, Anna University, Chennai, 22-25 Feb 2007. The work was carried during registration phase of Ph D.

4.3 Micro-controller based Remote Monitoring using Mobile through Spoken Commands

A system is developed for remote monitoring and control of devices using mobile through spoken commands. The Block Diagram of the scheme is shown in Fig. 3. On the user side, microphone is used to translate the voice signal to electrical signal. The microphone is connected to MIC interface of sound section on motherboard of Pentium IV based PC. User mobile is connected through DKU-5 cable using USB port. In this approach, predetermined phrases of words are selected for various commands. The Mel cepstrum features are extracted from the spoken words for recognition. The spoken words are isolated and recognized after extraction of features. Learning Vector Quantization Neural Network is used for recognition of various words used in the command. A text message is generated if all spoken words are identified as per specified format. This message is transmitted in form of SMS to control system mobile using AT commands.

![Micro-controller based Remote Monitoring using Mobile through Spoken Commands](image)

On control side, system mobile is connected to AVR micro-controller based system through RS-232C cable. Process block consists of 8 digital output ports, 8 digital input ports and one analog input port. The configuration of number of inputs, output and analog input ports can be varied as per the needs of the applications. Presently, LEDs are used to indicate status of output digital ports, dip switches to change the status of input digital ports, and potential divider provided to vary analog input voltage. The accuracy of spoken word is 98%. The speech recognition process in this work was carried out by N. P. Jawarkar. This work was published in Journal of Networks, Vol 3, No. 2, pp 58-63, Feb 2008, Academy Publishers, Finland[Open Access Journal].

Sant Gadge Baba Amravati University, Amravati, MS, India March 2011 Page 21
4.4 Versatile Low Cost Cell Phone Based Remote Monitoring

The development of versatile cell phone based remote control application using cheap, off-the-shelf components is show in this work. Remote temperature monitoring of process is chosen as an application for demonstration. The users are provided the option of text message, spoken commands or DTMF based voice call for remote monitoring of the process. AVR microcontroller ATMega32 is chosen for implementation of the control system. DS18S20 sensor is used for measuring temperature. The system alerts user in case of occurrence of any abnormal conditions like power failure, loss of control etc.

![System Block Diagram](image)

**Fig. 4. System Block Diagram**

The Block Diagram of the scheme is shown in Fig. 4. Spoken commands are accepted through microphone. User mobile is connected to PC using USB/serial interface in case of spoken commands. The predetermined phrases of words are selected for various commands. The spoken words are isolated and recognized after extraction of features. Learning Vector Quantization (LVQ) Neural Network is used for recognition of words. A text message is generated if all spoken words are identified as per specified format. This message is transmitted in form of SMS to control system mobile using AT commands.

Process block consists of two heater-bulbs and cylinder setup in which DS 18S20 temperature sensor is mounted on cylinder whose temperature is being controlled. Heat
input to cylinder is dependent on the status of relay, which is controlled by port bit. The temperature is measured through communication between microcontroller and DS 18S20 using sequence of transactions of 1-wire protocols. Relay is activated / deactivated if temperature fails/rises above desired temperature.

For voice call implementation, voice chip APR9600 is interfaced to AVR microcontroller based system through decoder. This device offers voice recording, non-volatile storage, and playback capability up to 60 sec. In our system, this device is configured in random access mode using eight message segments. Port PC1-PC3 pins of AVR microcontroller through decoder control message trigger pins. Initially APR9600 is operated in record mode using slide switch and suitable messages are recorded through microphone. In our application, ‘Communication Failure’, ‘Command Completed’, ‘Control Failure’, ‘Power Failure’, ‘Invalid Command’ and ‘OK’ messages were recorded. APR 9600 is now operated in playback mode under control of micro-controller. The speaker connected to APR9600 is placed near microphone of control system mobile to allow audio message to be transmitted to user during voice call mode. The selected prerecorded audio message is sent to user mobile from speaker of voice chip through microphone of control system mobile using AT dialing command. Similarly arrangement is made to receive DTMF tones from user mobile voice call through microphone connected to DTMF decoder IC 8870, which is placed above the speaker of control system mobile to pick audio tones. The microcontroller responds to any incoming ring signal and verifies the incoming call number and if its access is permitted, it checks for any valid DTMF tones and carries out specified command. Whenever valid tones are detected, microcontroller reads the 4-bit value of code.

The accuracy of spoken commands recognition of the system is about 96.4%. The speech recognition process in this work was carried out by N. P. Jawarkar. This work was published in Conference Proceedings of 4th IEEE Workshop on advanced EXPerimental activities ON WIRELESS networks (EXPONWIRELESS 2009), June 15-19, 2009, Island of Kos, Greece.

4.5 Design Of Embedded System For Agricultural Water Management

Rural regions of India, especially of Maharashtra state, are plagued by erratic power supply and unscheduled power interruptions. The system developed ensures protection of motor against overloads, overheating and phase imbalances and also provides optional automated
restarting if normal conditions are reestablished to complete specified task. The system can ensure uniform distribution of water at regular intervals at nights (In Maharashtra state, rural regions have heavy load shedding schedule in the day time) and also reduce labour cost and more effective utilization of labour as it alerts the user through sms / buzzer after completion of task. This system will prove to be great boon to farmers whose pump sets are far away from their homes as they can remotely control operation using mobile and be intimated about any abnormal conditions.

![Block Diagram](image)

**Fig. 5 System Block Diagram**

The Block diagram of the scheme is shown in figure 5. The commands to the system can be set by keyboard or received in form of SMS from user mobile through serial cable connected to control system mobile (Model Nokia 6610). Based on commands received and present sensor conditions, microcontroller system sends commands to switch on / off motor through Starter through relays controlled by its ports. Mobile 6610 is connected to AVR Microcontroller board through RS232C serial interface. The serial communication parameters are 115.2 kbps, no parity and one stop bit. PA0- PA2 bits monitor the present values of supply phase voltages. PA3 and PA4 port bits indicate water level of well while PA5 to PA7 are used to sense whether water has reached the desired final destinations of the region. Lower 6 bits of Port B are connected to 2 × 16 characters LCD display in 4-bit data length mode. Upper 2 bits of Port B are used to control two relays. One relay is connected across terminals of start (Green) pushbutton of starter for automated starting of the pump from micro-controller board while second is connected in series with stop (red) pushbutton for stopping the motor pump from microcontroller. Upper 4 bits of Port C and upper 4 bits of Port D are used to interface 4 × 4 keyboard matrix. DS1307 (serial RTC) is chosen for
implementation of timing applications. It is connected through TWI interface (I²C) i.e PC0(SCL) and PC1(SDA) pins of microcontroller. Two temperature sensors (DS18S20) are used. One temperature sensor is mounted on body of Motor pump to sense motor temperature while other is used to measure ambient temperature. These sensors use single wire interface for connectivity.

PC2 bit of Microcontroller is used for single-wire interface. In order to ensure reliable processing by micro-controller irrespective of power outages, battery of 6V, 1.5A-hr is used to supply power to micro-controller board at time of occurrence of failure of ac supply. Under normal supply conditions, battery is charged at constant current of 0.15A. This work was presented in National Conference RTIT 2007 at SGGCME, Shegaon 7-8 Dec 2007.

4.6 Design of Ultra Low Cost Cell Phone Based Embedded System for Irrigation

After carrying out trial of the system developed in section 4.6, following drawbacks were noticed:

i) Some illiterate farmers found difficulty in typing keywords for sending control SMS.

ii) Operational cost increases due to bidirectional flow of SMS between system and user mobile (average 4 SMS/day/ mobile). The users belonging to lower income group may not be able to bear additional financial burden.

iii) SMS are dependent on network traffic. So sometimes, messages use to take invariably long time defeating the basic purpose of system.

Therefore, some modifications were tried in communication algorithm without changing the basic system. The operational cost of communication between user and control system cell phones was further reduced by using novel concept of miscall where in no charges are incurred by using only ring signal for information transfer. A voice call is treated as miscall when either calling party disconnects after receiving ring tones or called party does not respond to call within specified time. The system cell phone was designed to send specified number of miscall(s) within five minutes duration to user cell phone to report various conditions as shown in Table 1. Similarly, user cell phone sends commands to system cell phone by making specified number of miscalls as shown in Table 2. This novel concept of miscalls results in substantial savings without comprising the utility of system. Another advantage of miscall over SMS is
that during night time, ringing tone can easily wake-up farmer to carry out necessary arrangement like shifting pipes to new locations, etc.

Table 1. Message based on miscalls from system cell phone

<table>
<thead>
<tr>
<th>No. of Miscalls in 5 mins.</th>
<th>Message Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Task completion</td>
</tr>
<tr>
<td>02</td>
<td>Power Failure/ Single Phasing/ Dry Running</td>
</tr>
<tr>
<td>03</td>
<td>Probable Motor Fault</td>
</tr>
</tbody>
</table>

Table 2. Commands based on miscalls from user cell phone

<table>
<thead>
<tr>
<th>No. of Miscalls in 5 mins.</th>
<th>Command Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Repeat Task</td>
</tr>
<tr>
<td>02</td>
<td>Increase ON time by 1 unit</td>
</tr>
<tr>
<td>03</td>
<td>Decrease ON time by 1 unit</td>
</tr>
</tbody>
</table>

For implementing miscall based control, CLIP command was used to activate indication of received cell phone telephone number. On receipt of first unsolicited code RING along with CLIP, micro-controller checks incoming number with user cell phone. If match was found, then micro-controller waits for five minutes duration to check total number of calls and carries out specified task. Similarly, microcontroller carries out number of voice calls from control system cell phone to user cell phone within five minutes time duration using ATD command. During the voice call progress, if BUSY or ERROR result codes are received, micro-controller retries this operation and if there is no success, it tries SMS mode to inform user.

The major attraction of the scheme is its ultra low cost due to capability to use obsolete cell phone model and concept of miscalls. The system cell phone requires just lifetime incoming calls subscription and small top-up amount for miscall and emergency SMS services. It is preferable to use same network operator for control system and user cell phones to ensure greater probability of successful connection as cellular network operator accord higher priority for calls within their own network. The specified duration and number of miscalls can be increased or decreased according to users requirements and network traffic. This work has been presented in IEEE International Conference on Machine Vision and Human-Machine Interface (MVHI), pp.718-721, 24-25 April 2010, Kaifang, China and published in Journal of Instrument Society of India, Vol. 40, No.2, June 2010, pp 101-102.
It was observed that though protection was provided to switch OFF pump if water level falls below foot valve level, when foot valve is defective or occurrence of air leakage in suction pipe, motor runs at no load for quite long time before temperature rise is sufficient to switch OFF the motor. One solution is to reduce the difference in temperature setting for switch-off. However, this may result in frequent switch-offs due to continuous slight imbalances in phase voltages. So ultrasonic sensor based circuit was added for continuous water level measurement of the well. Figure 6 shows the interfacing diagram of microcontroller system for implementation.

![Microcontroller System Interfacing Diagram]

PC₃ and PD₃ port bits are used in ultrasonic sensor circuit as inputs to enable transmitter and receiver to send burst and receive echo respectively while PD₂ (capture input 1) is used to capture contents of 16-bit counter 1 of microcontroller to calculate time delay of reflected echo. Siemens Ultrasonic Transducer Echomax XPS40 is used to measure water level in well. This transducer can measure water level up to 40 meters. The ultrasonic transducer is mounted on the top of perforated pipe in which wooden float of diameter slightly less than that of pipe is placed. This float responds to water level conditions of the well and permits reflection of ultrasonic waves for measurement with very less absorption. Transmitter emits burst of 12 pulses of 22 kHz frequency at regular intervals under control of PC₃ bit of micro-controller and present 16-bit value of counter 1 is read at the beginning of each burst. Immediately after end
of burst period, receiver is enabled under control of PD \(_3\) bit and waits for reception of echo burst. Echo burst is received after filtering and signal processing on capture input of timer1 (PD \(_2\)) and software calculates the time difference between instant of transmission of burst and instant of reception of echo burst which is proportional to water level in well. After motor pump is switched ON, the water level of well is measured at regular intervals. If results of this measurement indicate the rate of decrease in water level is not sufficient, micro-controller sends error message through miscall / SMS to indicate defective foot-valve or air leakage in suction pipe or motor failure.

These features ensures that catastrophic event like burning of motor due to any fault like over-current, bearing blockage, insulation failure, dry running, etc. are avoided and preventive maintenance is carried out at substantially lower cost. This work was presented in National Symposium of Instrumentation (NSI-35) held at Vishwesvarya Technological University, Belgaum, Jan 7-9, 2011.

### 4.7 Design of micro-controller system with cell phone as remote control console using Bluetooth and Java ME

There still exists many conventional process control systems which are based on keyboard/ alarm based approach which requires physical presence of operator near the system for keying appropriate commands based on readings from various sensors. It is proposed to provide more flexibility and greater utilization of operator manpower of such system without disturbing the basic data acquisition and sensor subsystems by providing wireless local communication facility in hands of operator through his Bluetooth enabled cell phone. Bluetooth can be considered cable replacement technology and has been developed by consortium of companies including Ericsson, IBM, Intel, Nokia, Toshiba, etc to provide royalty free, open specification for short range wireless connectivity. It is radio-frequency technology that uses 2.4 GHz Industrial-Scientific-Medical (ISM) band.

![System Block Diagram](image-url)
The Block diagram of the scheme is shown in Fig. 7. For providing Bluetooth connectivity to the microcontroller system, Bluetooth Serial Port Adaptor (SPA) from Connect Blue cB-OEMSPA312 was chosen. Nokia 3500 classic model (Series 40 3rd Edition Feature Pack 2 device) is used as user mobile. 2 × 16 character LCD display, 8 LEDs, 6 DIP switches, 8 analog channels and RTC chip DS1307 are connected to micro-controller. Fig. 8 and 9 shows the images of AVR microcontroller kit and Bluetooth Serial Adaptor respectively.

Fig. 8 AVR AT Mega16 Microcontroller kit

Fig. 9 Connect Blue’s Bluetooth SPA cB-OEMSPA312i-04AVR

Bluetooth SPA cB-OEMSPA312 is connected to AVR Microcontroller board through RS232C serial interface. The serial communication parameters are 57.6 kbps, 8 data bits, no parity, one stop bit and hardware flow control mode. SPA works in data and AT modes and needs to be properly configured before it can start data communication with other Bluetooth devices. On power-on condition, SPA is initially in data mode and by sending “///” characters within 3 seconds, the device can be moved into AT mode for configuration. In AT mode, series of commands can be sent for proper...
SPA is configured in Bluetooth Serial Port Profile and provided with BT address of user cell phone and then moved back to data mode. Now SPA scans for Bluetooth enabled devices in the neighborhood and checks if the discovered device address matches with its stored BT address. If match is found, it can start data communication between micro-controller system and specified cell phone.

Fig. 10 shows the image of Bluetooth SPA with RS232 connector, signal conditioning circuit for display of status on LEDs, connector for power supply and switches for default settings (reset) and serial connection on external signal. Three LEDs Red, Green and Blue indicate the status of current operation as per Table 3.

Table 3. Signal States in different SPA modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Green LED</th>
<th>Blue LED</th>
<th>Red LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Mode</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>AT Mode</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>Data Transmission</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
</tr>
</tbody>
</table>

8-bits of Port A are configured as analog inputs ports. Lower 6 bits of Port B are connected to 2 × 16 characters LCD display in 4-bit data length mode. Upper 2 bits of Port B and upper 6 bits of Port D are connected to LEDs through transistor driver circuits to simulate the status of output ports. Upper 6 bits of Port C are used to interface 6 DIP switches to accept digital input conditions. DS1307 (serial RTC) is chosen for recording of timing information related to occurrence of events. It is connected through TWI interface (I²C) i.e. PC₀ (SCL) and PC₁ (SDA) pins of µc.

In this application, Bluetooth SPA is connected to micro-controller based system through RS-232C data link cable. Internally RxD (PD₀) and TxD (PD₁) are connected to 9-pin RS232 female connector through MAX 232 IC for TTL-RS232C signal.
translation. The crystal of 1.8432 MHz is chosen for generating baud rate of 57.6 kbps for serial communication with SPA.

Whenever there is change in the input status of DIP switches or analog inputs exceed specified limits, the micro-controllers transmits the message to the user cell phone through Bluetooth SPA and waits for response from user cell phone. On receipt of message from user cell phone, it carries out the specified activity and sends acknowledgement to user cell phone. It scans for response from user cell phone at regular intervals. If there is no response within specified duration (if cell phone is not within Bluetooth range), the microcontroller moves into powerdown mode and waits for response at periodic intervals.

Bluetooth SPA device does not need detailed programming for Bluetooth protocols as it is optimized for Bluetooth serial data communication application. However, user cell phone is general purpose device which require additional programming to support serial data communication with SPA. Most of cell phones are Java enabled, so we can develop programs in Java ME and download this application in Javabyte code into cell phone (Files having .jar extension). Java ME provides APIs for supporting various activities like messaging, Bluetooth connections, display, etc. JSR-82 is Bluetooth API which supports all functions related to device discovery and service discovery processes.

For Bluetooth based serial data communication, the basic URL starts with btspp:// along with BT address and other parameters. The device discovery process is used to determine Bluetooth devices in the vicinity. The device discovery process helps to determine Bluetooth address and the friendly name of remote Bluetooth device (in our case, Bluetooth SPA). Since single Bluetooth device can offer multiple services, search for appropriate service on the selected Bluetooth device is needed. The service search process is dependent on type of service needed. For serial data communication, the unique identifier for wireless serial services is 0x1101. The connection URL is completely determined after these two processes and now connection can be opened for communication with remote device.

The screen shots for various stages of the process are shown in fig. 11. Eclipse version 3.2.2 with Java ME plug-in was used to develop program in JAVA ME. Sun Wireless Tool Kit for CLDC WTK2.2 was used for simulation and debugging of Java program.
and Nokia PC Suite software was used to download generated file with extension .jar into cell phone model.

![Screen shots of some processes](image1)

Thus scheme has been developed for remote monitoring of embedded system from operator cell phone using Bluetooth communication. This scheme ensures greater flexibility and mobility to the operator and provides capability to control multiple systems also (up to 7 systems in Bluetooth pico-net). The system accepts command message from operator cell phone, executes the task specified and sends acknowledgement after completion of task. The system is having inbuilt security against unauthorized users as data message is only communicated to cell phone with unique Bluetooth Address. The major attraction is its ultra low cost as Bluetooth connectivity incurs no call charges and requires only initial cost of Bluetooth serial port adaptor device and minor modification in flash program to upgrade the existing systems. This work has been presented in National Symposium of Instrumentation.
4.8 Innovative Cost Effective Approach for Cell Phone based Remote Controlled Embedded System for Irrigation

This work is an extension of work described in section 4.6 with some modifications for further improvements. Recent mobile model 2700 classic was chosen for implementation with Bluetooth SPA for wireless Bluetooth connection with microcontroller system and control system cell phone. Fig. 12 shows system block diagram.

Recent generation of cell phone have USB or Bluetooth based data link. Since simple and many conventional systems do not support USB interface, Bluetooth Serial Port Adaptor (SPA) from ConnectBlue cB-OEMSPA312 is connected to AVR Microcontroller board through RS232C serial interface. The serial communication parameters are 57600 bits/s, 8 data bits, no parity, 1 stop bit, and hardware flow control. SPA works in data and AT modes and needs to be properly configured before it can start data communication with other Bluetooth devices. On power-on condition, SPA is initially in data mode and by sending “///” characters within 3 seconds, the device can be moved into AT mode for configuration. In AT mode, series of commands can be sent for proper configuration [9]. SPA is configured in Bluetooth Serial Port Profile and provided with BT address of control system cell phone and then moved back to data mode. Now SPA scans for Bluetooth enabled devices in the neighborhood and checks if the discovered device address matches with its stored BT address. If match is found, it can start data communication between micro-controller system and specified cell phone (Nokia 2700 model). This arrangement is suitable for any Bluetooth enabled mobile
adding versatility and flexibility to keep user control system mobile anywhere within 10m range.

It is observed that cellular operators allow 60 second duration for response from called party after sending ringing tone. For default tone, this duration amounts to 20 rings. However, RING response of AT command interpreter is checked periodically at end of every 5 second. Hence maximum number of commands which can be sent using single miscall is 12. This results in remarkable improvement compared to our recent work (section 4.6) involving usage of number of miscalls with substantial decrease in utilisation time of the cellular network. The system cell phone is designed to send miscall for specified duration to user cell phone to report various conditions as shown in Table 4. Similarly, user cell phone sends commands to system cell phone by making miscall for specified duration as shown in Table 5.

**Table 4. Message Based On Miscall From System Cell Phone**

<table>
<thead>
<tr>
<th>No. of rings</th>
<th>Message Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>Acknowledgement of command</td>
</tr>
<tr>
<td>04</td>
<td>Power supply failure during operation</td>
</tr>
<tr>
<td>06</td>
<td>Resumption of task after power supply restoration</td>
</tr>
<tr>
<td>07</td>
<td>Task Completion</td>
</tr>
<tr>
<td>09</td>
<td>Dry Running</td>
</tr>
<tr>
<td>11</td>
<td>Single phasing</td>
</tr>
<tr>
<td>12</td>
<td>Probable Motor Fault</td>
</tr>
</tbody>
</table>

**Table 5. Command Based On Miscall From User Cell Phone**

<table>
<thead>
<tr>
<th>No. of rings</th>
<th>Command Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>Acknowledgement of message</td>
</tr>
<tr>
<td>04</td>
<td>ON time - 1 hr</td>
</tr>
<tr>
<td>06</td>
<td>ON time - 2 hr</td>
</tr>
<tr>
<td>07</td>
<td>ON time - 3 hr</td>
</tr>
<tr>
<td>09</td>
<td>ON time - 4 hr</td>
</tr>
<tr>
<td>11</td>
<td>ON time - 5 hr</td>
</tr>
<tr>
<td>12</td>
<td>ON time - 6 hr</td>
</tr>
<tr>
<td>14</td>
<td>Region based ON time</td>
</tr>
<tr>
<td>16</td>
<td>Stop Task</td>
</tr>
<tr>
<td>17</td>
<td>Get status</td>
</tr>
<tr>
<td>19</td>
<td>Cancel previous command</td>
</tr>
</tbody>
</table>

Further instead of ultrasonic based water level measurement, alternate arrangement of 3 more level measurement points are added through available ports pins to reduce cost. PC₃, PD₂ and PD₃ port bits are used in intermediate water level detection of well. After motor pump is switched ON, the water level of well is measured at regular intervals. If results of this measurement indicate the rate of decrease in water level is not
sufficient, micro-controller sends error message through miscall / SMS to indicate defective foot-valve or air leakage in suction pipe or motor failure. There is in-built security against unauthorized use by any other cell phone within its Bluetooth range due to incorporation of unique Bluetooth address in BT-SPA configuration and checking of incoming caller identification number by microcontroller system. Its major attractions are capability to use any cell phone model, ease of use compared to typing of messages and ultra low operating cost through this novel concept of miscall. It was observed that even cell phone whose display was damaged during accidental fall can be utilized as control system mobile provided that it is able to communicate AT commands using Bluetooth SPP. The system cell phone requires just lifetime incoming calls subscription and small top-up amount for miscall and emergency SMS services.

4.9 General Purpose Remote Monitoring using recent cell phone models

Cell phones models are designed primarily for human interaction using key-pads and graphical interfaces. For remote monitoring purposes, cell phone needs to be modified to have automated response. It was observed that AT commands relating incoming SMS indications are not supported in recent models. The systems designed in earlier sections obviated the need of incoming message indication by intelligent use of voice miscall which provided unsolicited RING indication and additional parameters relating commands were obtained through number of miscalls or miscall duration. Even if Java ME based SMS application is developed using push registry, it was found that incoming message provides audio and visual alert but requires human intervention in form of pressing key to finally receive the message. Applications having trusted certificate from vendors can run directly by changing priority level but increases cost. After exploring various possibilities, it was finally decided to extract tones of audio alert at time of incoming message and use it to run the application. It was observed that standard message alert dominant tone of various models varies between 1.2 kHz to 2.0 kHz. For Nokia 6681 model, dominant tone is 1.85 kHz, where as for Nokia 3500 classic, it is 1.57 kHz. Secondly it was observed that it is possible to control cell phone operation using soft keys. The numbers of soft key vary depending on models and earlier models had less number of keys. In recent models, central key has 5 contact points, one central for selection and remaining four for moving cursor in 4 different directions. Apart from that, there are right and left soft keys for various operations and
call and end soft key for direct voice call and termination of present application. For dedicated remote control application, selected cell phone was opened and contacts of soft keys were soldered and brought out to external connector.

The Block diagram of the scheme is shown in Fig. 13. External microphone is coupled to speaker of cell phone model and audio signals are sent to input of tone decoder IC. Tone decoder IC 567 is set according to dominant messaging standard alert tone frequency of selected cell phone and output of tone decoder is connected to one input port bit of micro-controller. 3 output port bits are connected to control pins of analog controlled switches (IC 4066) through 3 to 8 decoder IC (74HCT138).

The selected Nokia cell phone model is loaded with applications relating serial communication and messaging using Java ME APIs. Whenever incoming message is received, standard messaging alert tone occurs which causes tone decoder IC to provide active output. Micro-controller detects this signal and sends signal to analog controlled switches to activate central key press. As a result, application is executed by the cell phone which causes message to be captured and transferred to micro-controller system through serial communication and micro-controller interprets the message and carries out the desired activity. Many powerful functions of cell phone like camera image capturing, sound recording, sending MMS can be carried out due to full control of soft keys by microcontroller.
CHAPTER 5.
CONCLUSIONS, LIMITATIONS & FUTURE SCOPE

5.1 Conclusions

After exhaustive study of literature and present technological advances, several prototype systems were developed for remote monitoring using cell phone. Initial systems were based on early cell phone models and later systems were implemented using recent Nokia cell phones. The features of system vary widely depending on the user requirements. The existing facilities in the available cell phone models were probed deeply to facilitate development of systems which utilize features in an optimum manner. Some systems were provided with facility of accepting spoken commands, some with prerecorded audio error messages and some were designed with ultra low cost objectives.

It is believed that just like cell phones have brought great convenience throughout all classes of people, remote monitoring systems using these cell phones can help to carry out control tasks in an easier manner and faults and abnormal conditions can be brought to the notice of users instantaneously enabling people to take corrective measures.

5.2 Limitations

Systems based on miscall concepts require some training time for user to code their commands. An incorrect code can result in wrong command being executed. However, provision has been made for confirmation of command and so there exists possibility for correction of command code if it is detected immediately. Unfortunately MIDP profile does not support voice call control commands, hence it is not possible to provide user friendly interface. Incorrect sequencing of automated softkey presses can result in unpredictable response.

5.3 Future Scope

With the reduction in cost of GPRS services, it will be possible to provide more interactive and detailed information of parameters using remote monitoring system with cell phone having internet connection. Similarly more powerful processor based systems will be able to provide move exhaustive data logging for trouble shooting.
CHAPTER 6.

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