CHAPTER 5
DESIGN AND IMPLEMENTATION OF PROTOTYPE SYSTEMS

Various prototype systems were developed during the course of work after undertaking study of different sensors, cell phone models and microcontrollers.

5.1 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 5.1 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 (Refer section 4.2.1). This work was published in IETE Journal of Education, Vol 46, No. 4, pp 165-170, Oct-Dec 2005.

Fig. 5.1 Block Diagram of scheme

For Nokia Model 3120, DKU-5 USB cable is provided for connectivity through 14 pin pop-up port and drivers contain USB to serial port bridge which permits communication through F-Bus protocols. It is observed that F-Bus protocols consists of tedious, lengthy and almost continuous
communication between device and terminal and therefore should be used only if AT commands interface is not available in cell phone.

5.2 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 cell phone 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 5.2 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.

![Block Diagram of Scheme](image)

The isolated spoken command phrase "<password> DEVICE <0-7> ON/OFF" is used to send control message to control system mobile. From this phrase, it is observed that total 12 isolated
words need to be identified. The distinct features of speech signals such as short-time energy, short time zero crossing rate, LPC coefficients, and Cepstral coefficients are used to carry out speech recognition in this application (Rabiner and Juang, 2005). Initially all possible words in the selected phrase are spoken and stored as speech templates and features are extracted. These features form the input to feed-forward neural network for training based on back propagation algorithm. After successful completion of training, the system is tested for recognition of spoken word. The block diagram of the feature extraction and processing for speech recognition is shown in Fig. 5.3. Fig. 5.4 shows various features (Short time Energy, ZCR and Cepstral coefficient $c_2$) for given spoken command phrase “alpha Device 4 ON”. The accuracy of spoken word is 84%. The speech recognition process in this work was carried out by N. P. Jawarkar.

![Fig. 5.3 Block Diagram of Speech Recognition System](image1)

![Fig. 5.4(a) Plot of speech amplitude vs. samples for spoken phrase](image2)

![Fig. 5.4(b) Plot of short time energy vs. no. of frames for spoken phrase](image3)
The different aspects of this work were 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.

5.3 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. 5.5.

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. 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 interface diagram of micro-controller system is shown in Fig 5.6. 8-bits of Port C are configured as digital inputs ports and in our case, their statuses depend on the position of corresponding dip switch. 6 bits of Port D (PD2 – PD7) and two higher bits of Port B (PB6 – PB7) are configured as digital outputs and corresponding LEDs indicate their status (ON for logic ‘0’). Lower 6 bits of Port B are connected to 2 × 16 characters LCD display in 4-bit data length mode.

In this application, mobile 6610 is connected to micro-controller based system through RS-232C data link cable. Internally RxD and TxD are connected to 9-pin RS232 female connector through MAX 232 IC for TTL-RS232C signal translation. PA0 bit is connected to potential divider circuit to provide variable analog voltage at its input. The crystal of 1.8432 MHz is chosen for generating baud rate of 115.2 kbps for serial communication with mobile.

Two types of spoken command phrases selected as valid text message for this application are shown in Table 5.1. Thirteen words namely alpha, device, one, two, three, four, five, six, seven,
eight, on, off and status are used for recognition of commands. Initially all possible words in the selected command phrase are spoken and stored as speech templates and features are extracted. These features are used as inputs to Learning Vector Quantization (LVQ) based neural network for training. After successful completion of training, the system is tested for recognition of spoken words.

TABLE 5.1 FORMAT OF SPOKEN COMMAND PHRASES

<table>
<thead>
<tr>
<th>No.</th>
<th>Password</th>
<th>Option</th>
<th>Parameter 1</th>
<th>Parameter 2</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Alpha</td>
<td>Device</td>
<td>1/2/3/4/5/6/7/8</td>
<td>ON/OFF</td>
<td>Select Device &amp; switch it ON or OFF</td>
</tr>
<tr>
<td>2.</td>
<td>Alpha</td>
<td>Status</td>
<td>----------</td>
<td>----</td>
<td>Read status of inputs</td>
</tr>
</tbody>
</table>

The block diagram of the feature extraction and processing for speech recognition is shown in Fig. 5.7.

Fig. 5.7 Block Diagram of Speech Extraction & Processing

![Block Diagram of Speech Extraction & Processing](image-url)

Fig. 5.8 Plot of Spoken phrase 'Alpha Device Six ON' and its energy

![Energy Plot](image-url)
Fig. 5.8 shows the speech signal waveform for a spoken command phrase “Alpha Device Six On” and its energy. Fig. 5.9 shows the plot of MFCC coefficients \( \{C_{\text{mel}}(1), C_{\text{mel}}(2), C_{\text{mel}}(3), C_{\text{mel}}(4)\} \) for the spoken word “Alpha”.

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].

**5.4 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.

The Block Diagram of the scheme is shown in Fig. 5.10. 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 micro-controller based system through decoder. This device offers voice recording, non-volatile storage, and playback.
capability up to 60 seconds. 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. In this application, basic format for DTMF based commands are: “*<xx>” or “*<b>”

Where * is predefined character for valid command and xx indicates desired temperature and b = 0 indicates relay to be switched OFF while b = 1 indicates relay to be switched ON.

![Microcontroller System Interfacing](image)

Interfacing diagram of micro-controller system is shown in Fig. 5.11. Whenever control system mobile receives SMS, it sends unsolicited result code along with text message to the
microcontroller through serial interface. Microcontroller interprets the text message and carries out the specified command. For temperature measurement, microcontroller carries out sequence of transactions using 1-wire protocols with temperature sensor DS18S20. Whenever temperature reaches desired limits, microcontroller sends SMS to user mobile through control system mobile using “AT + CMGS” command to inform fulfillment of command. It checks for SMS delivery unsolicited result code for specified time. If it does not receive intimation, it proceeds with the voice call by sending ‘ATD<no>;;’ and then selects appropriate recorded message number and activates voice chip APR9600 message pin. It now sends ‘ATH’ command to switch mobile modem to voice mode. After specific time interval for playing selected recorded message, microcontroller sends AT +CHUP command to terminate the voice call. It continues to maintain temperature within specified limits by activating/ deactivating relay till the receipt of new command. It also sends SMS / voice call to user indicating error if temperature fails to change within specified interval after the relay switching.

The block diagram of the feature extraction and processing for speech recognition is similar to the earlier scheme shown in Fig. 5.7.

Three types of spoken command phrases selected as valid text message for this application are shown in Table 5.2. Ten words namely alpha, temperature, seventy, eighty, ninety, hundred, five, on, off and status are used for recognition of commands. Initially all possible words in the selected command phrase are spoken and stored as speech templates and features are extracted. These features are used as inputs to LVQ based neural network for training. After successful completion of training, the system is tested for recognition of spoken words.

**TABLE 5.2 FORMAT OF SPOKEN COMMAND PHRASES**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Code</th>
<th>Parameter</th>
<th>Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Alpha</td>
<td>Temp.</td>
<td>70/75/80/85/90/95/100</td>
<td>Set temp. 70 to 100 °C</td>
</tr>
<tr>
<td>2.</td>
<td>Alpha</td>
<td>Temp.</td>
<td>ON/OFF</td>
<td>Switch ON/OFF heater bulb</td>
</tr>
<tr>
<td>3.</td>
<td>Alpha</td>
<td>Temp.</td>
<td>Status</td>
<td>Read temp. value</td>
</tr>
</tbody>
</table>
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.

5.5 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 labor cost and more effective utilization of labor 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.

The Block diagram of the scheme is shown in Fig. 5.14. 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.
Fig. 5.15 shows the interfacing of microcontroller system. 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.

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

After carrying out trial of the system developed in section 5.5, 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 (Fig. 5.14 & Fig. 5.15). 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 5.3. Similarly, user cell phone sends commands to system cell phone by making specified number of miscalls as shown in Table 5.4. 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>
<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>
<tr>
<td>04</td>
<td>Resumption after normal condition restoration</td>
</tr>
</tbody>
</table>

<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>
<tr>
<td>04</td>
<td>Stop Task</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 (available on IEEE Xplore) 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 5.16 shows the interfacing diagram of microcontroller system for implementation.

![Microcontroller System Interfacing Diagram](image-url)
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 PD₃ bit and waits for reception of echo burst. Echo burst is received after filtering and signal processing on capture input of timer1 (PD₂) 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.

5.7 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.

Fig. 5.17 System Block Diagram

The Block diagram of the scheme is shown in Fig. 5.17. For providing Bluetooth connectivity to the microcontroller system, Bluetooth Serial Port Adaptor (SPA) from Connect Blue cB-OEMSPA312 was chosen (Refer section 4.2.4). 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 microcontroller. Bluetooth SPA is connected to AVR Microcontroller board through RS232C serial interface. SPA needs to be properly configured before it can start data communication with other Bluetooth devices (Refer section 4.2.4).

Fig. 5.18 Microcontroller System Interfacing
Interfacing diagram of microcontroller is shown in Fig. 5.18. 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 to power down 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 (http://jcp.org/jsr/detail/82.jsp).

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. 5.19. 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.

Fig. 5.19. Screen shots of some processes (a) Bluetooth Devices searching (b) List of Discovered Devices (c) Service discovered with connection url (d) Sending command to SPA from cell phone

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 (NSI-35) at VTU, Belgaum, 5-7 Jan 2011 and published in Journal of Instrument Society of India, Vol. 41, No.1, March 2011, pp 13-15.

5.8 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. 5.20 shows system block diagram.

![System Block Diagram](image)

Fig. 5.20 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 no 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. 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 5.6) involving usage of number of miscalls with substantial decrease in utilization 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 5.5. Similarly, user cell phone sends commands to system cell phone by making miscall for specified duration as shown in Table 5.6.

**Table 5.5 Message based on Miscalls 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 5.6 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></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</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 with damage display 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.

This work has been presented in IEEE International Conference on Communication Systems & Networking Technologies (CSNT 2011), pp 419-422, 3-5 June 2011, SMVDU, Katra, J&K, India (available on IEEE Xplore)

### 5.9 Novel Ultra Low Cost Remote Monitoring System for Home Automation using Cell Phone

Home automation systems have been developed by many researchers (Srikanthan and Karande, 2002; Delgado et al., 2006, Tam et al., 2007, Atukorala et al., 2009). However, the installation and operational cost of such system is relatively high. In this work, development of two remote monitoring systems using cell phone with a major focus on cost reduction to allow wider
utilization even in undeveloped and developing countries are discussed. Cell phone is gradually emerging as powerful tool for many commercial applications like train reservation booking, banking, etc. With availability of latest cell phone models with exquisite features like touch screen UI, high resolution display, high resolution camera, rich music quality etc., there is constant migration of people towards acquisition of higher end models. So, simple Java-enabled cell phone models with medium resolution camera are available at throwaway prices. Such models can be easily adapted for remote monitoring purpose. These models can perform the function of GSM modem at a lower cost and with additional functionalities like microphone, camera, Bluetooth interface, networking facilities like SMS, MMS, GPRS; Java based applications downloading, etc.

Two systems were developed for remote monitoring of household devices using cell phone with focus on low cost solutions. The first system (I) has relatively simple features and has been designed primarily with the objective of keeping very low operational cost while the second system (II) is having greater security features including image capture for intrusion detection.

Fig. 5.21 shows the Block Diagram of the System I. The parameters of system are set by the keyboard or received in form of duration of miscall from user cell phone. Based on commands received and present sensor conditions, µc system send signals through its ports to switch on/off appliances like AC, garage door, lights, fan, siren, etc. The sensors used in the system are microphone, temperature sensor and two sets of LED-infrared intrusion detectors. Recent generation of cell phone have USB and/or Bluetooth based data link. Since many simple and conventional systems do not support USB interface, Bluetooth Serial Port Adaptor (SPA) from ConnectBlue cB-OEMSPA312 with RS232C connectivity is used.

**Table 5.7 Message Coding based on Miscall from System Cell Phone**
The system cell phone is designed to send miscall for specified duration to user cell phone to report various conditions as shown in Table 5.7. Similarly, user cell phone sends commands to system cell phone by making miscall for specified duration as shown in Table 5.8. This novel concept of miscalls results in substantial savings without compromising the utility of system.

For implementing miscall based control, CLIP command is used to activate indication of received cell phone number. On receipt of first unsolicited code RING along with CLIP, $\mu c$ checks incoming number with user cell phone. If match is found, then $\mu c$ waits for maximum 1 minute duration to check total number of RING responses and carries out specified task after no further miscalls are received within period of two minutes. Similarly $\mu c$ carries out voice call from control system cell phone to user cell phone for specified time duration using ATD command. During the voice call progress, if BUSY or ERROR result codes are received, $\mu c$
retries this operation and if there is no success, it tries SMS mode to inform user. It also tries SMS mode when there is no acknowledgment of the message from user through miscall within specific time interval.

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 by activating the key presses of right soft key, left soft key, 5-way navigation(4 arrows and selection key), call creation and termination keys (control keys) through ports of µc system using analog controlled switches. 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 creation and termination keys for direct voice call and termination of present application.

Fig. 5.22 shows the control keys of a general cell phone model. For dedicated remote control application, selected cell phone was opened and contacts of control keys were soldered and brought out to external connector.
The Block diagram of the system II is shown in Fig. 5.23. External microphone is coupled to speaker of cell phone model and audio signals are sent to input of tone decoder circuit. Tone decoder circuit is set according to dominant messaging standard tone frequency of selected cell phone and output is connected to one input port bit of μc.

Four output port bits are connected to control pins of analog controlled switches through BCD to decimal decoder IC to ensure activation of single control key press. Table 5.9 shows the code for activation of control keys based on decimal code received.

**Table 5.9 Coding for Control keys of Cell Phone**
<table>
<thead>
<tr>
<th>Decimal Code</th>
<th>Control Key Activation</th>
</tr>
</thead>
<tbody>
<tr>
<td>'0'</td>
<td>Selection key - Navigation</td>
</tr>
<tr>
<td>'1'</td>
<td>← (Leftwards Arrow) - Navigation</td>
</tr>
<tr>
<td>'2'</td>
<td>↑(Upwards Arrow) - Navigation</td>
</tr>
<tr>
<td>'3'</td>
<td>→(Rightwards Arrow) - Navigation</td>
</tr>
<tr>
<td>'4'</td>
<td>↓(Downwards Arrow) - Navigation</td>
</tr>
<tr>
<td>'5'</td>
<td>Right Soft Key</td>
</tr>
<tr>
<td>'6'</td>
<td>Left Soft Key</td>
</tr>
<tr>
<td>'7'</td>
<td>Call Creation Key</td>
</tr>
<tr>
<td>'8'</td>
<td>Call Termination Key</td>
</tr>
<tr>
<td>&gt; '8'</td>
<td>No action</td>
</tr>
</tbody>
</table>

The selected cell phone model is loaded with applications relating Bluetooth serial communication and messaging using Java ME APIs. Whenever incoming message is received, standard messaging alert tone is generated which causes tone decoder circuit to provide active output. \( \mu c \) detects this signal and sends BCD code corresponding to '0' through BCD to decimal decoder to analog controlled switches to activate navigation selection key. As a result, application is executed by the cell phone which causes message to be read if it matches with port id and then message is transferred to micro-controller system through Bluetooth and \( \mu c \) interprets the message and carries out the desired activity.

Many powerful functions of cell phone like camera image capturing, sound recording, sending MMS, etc can be called through sequence of control keys activation by \( \mu c \). For example, the algorithm for capturing image using camera of system cell phone and transmitting this image to user cell phone is as follows:

1. BCD code ‘8’ is sent to decoder. This activates call termination key to terminate any previous application.
2. After delay of 0.5 seconds, BCD code ‘2’ is sent. This activates ↑ arrow key which causes camera application to be opened on system cell phone.
3. After delay of 2 second, ‘0’ is sent. This activates selection navigation key which causes application to capture image.
4. After delay of 5 seconds, ‘0’ is again sent. This causes selection of send option of application.
5. After delay of 0.5 seconds, selection key is again activated by sending ‘0’ code. This action results in message option being selected by the camera application.

6. After delay of 5 seconds, activation of selection key causes add option by application to select the address.

7. After delay of 0.5 seconds, activation of selection key causes various options to be displayed by application.

8. After delay of 0.5 seconds, activation of ↓ arrow key results in ‘recent’ to be selected.

9. After delay of 0.5 seconds, activation of selection key causes list of recent addresses to be displayed.

10. After delay of 0.5 seconds, activation of selection key causes image to be sent as multimedia message to user cell phone by the camera application.

11. After delay of around 30 seconds, μc sends BCD code ‘8’ to terminate the application and also sends miscall to user cell phone to indicate image was sent.

Fig. 5.24 shows screen shot of image of door of home captured by system cell phone for intrusion detection during trial of automated response using μc system.

There can be some variations depending on the cell phone model. The exact algorithm can be determined by carrying out the entire procedure manually using keypads (control keys only) of cell phone and noting the sequence of key hits required for the process. It is possible to extend this procedure to any cell phone by evaluating the control key hits sequence for desired function operation.

Interfacing diagram of μc system is shown in Fig. 5.25. The dashed portion shows the optional blocks needed for implementation of System II.
Analog input ADC0 is used to detect sound generated in the room through microphone. The signal conditioning circuit consists of amplifier, rectifier and filter. Whenever sound level
exceeds predetermined threshold, μc sends miscall/ SMS to user cell phone indicating possible intrusion. Similarly analog channel ADC1 is used to measure temperature. When system receives temperature regulation command, the voltage at this channel is sensed at regular intervals and AC is switched ON and OFF based on upper and lower limits of regulation range. 2×16 character LCD display is interfaced to μc system in 4-bit data mode while 4×4 matrix is interfaced to 4 input (columns) ports PA₄- PA₇ and 4 output (rows) ports PC₄-PC₇ of the system. Appliances like AC, Lights, Fans, Siren are switched through relays controlled through driver circuits from output ports PC₃, PD₂-PD₃ and PB₆-PB₇. RxD and TxD pins are connected through MAX 232 IC to Bluetooth SPA through 9-pin RS232 female connector. LED Infrared sensor pair set-up is used to detect intrusion near door in two regions. Whenever LED rays are obstructed by intrusion, there is change in state of Infrared sensor causing change in input ports (ADC2-ADC3) of μc. The system sends miscall/ message to user cell phone indicating intrusion. If no response is obtained from user cell phone within specified time, the system triggers siren and random switching of lights to confound intruders. Real Time Calendar (RTC) chip is connected through I²C interface using SCL and SDA pins of μc. The clock/calendar provides seconds, minutes, hours, day, date, month, and year information. Initially with the help of keyboard and LCD display, present date and time are written into corresponding internal memory locations of this IC using IC protocol.

For system II implementation, external microphone is coupled to speaker of system cell phone to pick up message alert tones for automated operation. The output of microphone is connected to input of tone decoder circuit. Whenever standard message alert tone is received, tone decoder output is activated. μc system responds to this input and sends code corresponding to selection key activation of system cell phone to run the Java ME application to receive incoming message and send it to μc system through Bluetooth serial port if there is match of port ID otherwise this message is ignored by cell phone. Output BCD code (4-bit) is sent through BCD to decimal decoder to selected control pin of analog controlled switch to activate the corresponding control key of system cell phone for automated response of system cell phone.

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.
The Wireless Messaging API (JSR-205) specification supports functions to compose, send, and receive SMS, MMS, and CBS messages through Java™ applications (MIDlets). Messages can be sent using this API via client or server type MessageConnections. When a message identifying a port number is sent from a server type MessageConnection, the originating port number in the message is set to port number of MessageConnection. This allows the recipient to send a response to the message that will be received by this MessageConnection. The basic URL starts with sms://.

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.

Eclipse version 4.2.2 with Java ME plug-in was used to develop program in Java ME (http://www.eclipse.org/platform). Sun Wireless Tool Kit for CLDC WTK2.2 was used for simulation and debugging of Java code (http://java.sun.com/products/sjwtoolkit/) and Nokia PC Suite software was used to download generated file with extension .jar into cell phone (http://www.nokia.com/pcsuite).

Fig 5.26(a) shows the screen shot of searching of Bluetooth devices in the neighborhood by system cell phone. Fig 5.26(b) shows screen shot of list of discovered devices. Fig 5.26(c) shows screen shot of user cell phone sending command to switch ON light1 whereas Fig. 5.26(d) shows the screen shot of received message alert on the system cell phone.
Thus two systems were developed for remote monitoring of household appliances using cell phone with major focus on minimizing the cost of the system. 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. There can be drastic reduction in house breaking incidents by installation of this system. Low installation and operating cost of this system will permit wide spread use even in low income groups.

The major attractions of system I are capability to use any cell phone model, ease of use compared to typing of messages and ultra low operating cost through the novel concept of miscall. It was observed that even cell phone with damaged display can be utilized as system cell phone if 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.
System I based on concept of miscalls 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.

System II provides greater flexibility and user friendliness by incorporating SMS and MMS based approach also. Moreover, it fully utilizes functional capabilities of cell phone by using camera, multimedia messaging and Java applications. It allows users to minimize cost by using miscall concept during normal conditions and also permits user to obtain images through MMS services at time of intrusion.

This work has been submitted to International Conference CICN 2011 to be held in October 2011.