USenSewer: Ultrasonic Sensor and GSM-Arduino based Automated Sewerage Management

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***Abstract*—This paper presents the design and prototype implementation of USenSewer, an automated sewerage management system that uses Arduino microcontroller coupled with an ultrasonic sensor, a NRF module and a GSM module to automate the routine checkup and removal of drain blockage vital for the continuous waste water flow in the big cities. The proposed system consists of three main components; the blockage detection system which is placed inside the drain, the blockage removal system which is placed above the ground level and a control center which controls and coordinates the collection of waste materials placed by the first two components. Several pilot installations of the system in the city of Dhaka have shown that the proposed system significantly outperforms the state-of-the-art manual systems prevailing in the city from the scalability, flexibility and economic point of view.**

I. Introduction

Sewer and drain management system is a fundamental part of city management. This is also important to prevent congestion of dirty water, rain water etc. We have chosen the sewerage system of Dhaka, the capital city of Bangladesh to design USenSewer, our proposed automated sewerage management system. Bangladesh is one of the most populated countries in the world where the sanitation problem is acute in the urban areas especially in the big cities like Dhaka, the capital of Bangladesh and a city with 20 million inhabitants. The sewerage management of a city like Dhaka is not an easy task and requires enormous efforts to manage the drainage system to keep the city suitable for living [1]. Moreover, there exists numerous challenges such as flooding, poor service quality, groundwater depletion, inadequate sanitation, polluted river water, unplanned urban development, and the existence of large slums where more than one third of its population lives, a good example being the city of Dhaka. Residents of Dhaka enjoy one of the lowest sewerage tariffs in the world, which limits the authority's capacity to invest in sewerage management. The service area of Dhaka Water Supply and Sewer Authority (DWASA) covers more than 360 square km with a population of about 12 million [2]. But unfortunately, the drainage management system of this capital city is not well planned and not at all organized [3]. Most of the drains of Dhaka city are congested in many places and as a result the flow in the drain is obstructed heavily. This often results in the overflow of the drain water over the roads and residential areas causing a serious problem in the daily life of the city dwellers. Moreover, the city of Dhaka was particularly hit by the floods of past several years, some of which such as the ones in 1988 and 1998 were catastrophic with flood levels of up to 4.5m in parts of the city. Particularly, about 56 percent of the city was inundated during the 1998 flood which shows the poor sewerage system of the city [4]. The government has taken several projects to improve the sewerage system in the capital and bring other big cities like Chittagong and Khulna under similar system of sewerage network, but these initiatives fell short to cope with the problems existing in those cities [5], [6]. Additionally, there is a lack of sufficient resources and manpower in the city corporation authority to check the drain blockage and remove the obstructions from the jammed points [7]. Although routine checkup and removal of drain blockage is needed for continuous waste water flow, it turns out to be expensive and tedious for authorities with limited resources. In this perspective, it is impossible to manage the drain system manually with the help of insufficient resources of the city corporation. Our motivation is to develop a microcontroller based automatic system to manage the drainage system of the city so that the obstructions in the citys drains can be removed automatically.

This paper aims to automate blockage detection and temporary waste removal process to reduce workload and ensure proper water flow. Researchers have tried to design automatic drain water monitoring and analysis technology [8], investigated applying of SPC (Statistical Process Control) in the sewage treatment system [9], tried vacuum sewer system management by IP sensing [10], proposed a network of controllable sewage sumps having pumps and level detection equipment to permit controlled flow of sewage to a central treatment facility [11] or used event-driven model predictive control of sewage pumping stations [12]. However, only a few of the above mentioned methods achieved the desired

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success. None of the researchers proposed microcontroller based solution coupled with an ultrasonic sensor, NRF module and GSM module to automate the routine checkup and removal of drain blockage. To the best of our knowledge, this paper is the first attempt to use a microcontroller based solution to design a fully automated sewerage management system.

Our Contributions. This paper presents the following contributions:

- **Automatic blockage detection system**. Design and implement an automatic blockage detection system that is placed inside the drain.
- **Automatic blockage removal system**. Design and implement an automatic blockage removal system that is placed above ground level outside the drain.
- **GSM based coordination and control**. Design and implement a GSM based coordination and control mechanism that is vital for the management of sewerage system by the city authority.
- **Pilot installation and evaluation**. Install some pilot prototypes in various points of the sewerage system of Dhaka city and evaluate the performance of the proposed solution against the state-of-the-art manual system.

The rest of the paper is organized as follows. Section II describes the background of the work. Section III describes the Stochastic Game Petri Net (SGPN). Section IV analyzes the previous works. Section V shows how SGPN is represented. Section VI and VII present the attack modeling and defense modeling respectively. Section VIII evaluates our proposed models and analyze the findings. Finally, Section IX concludes the paper with a highlight on the scope of future work.

II. Related Work

Several techniques on management of sewerage system have been proposed in recent years. Müller et al. [13] report of the development of an automatic control strategy to manage the wastewater flow to a WwTP according to its actual treatment capacity. Brandstetter et al. [14] present a comprehensive mathematical model (Urban Wastewater Management Model) to continuously simulate time-varying wastewater flows and qualities in complex metropolitan combined sewerage systems. Guo-ping et al. [15] presents the automatic monitoring and supervision system for pollution sources.

Much work has been done on detection of moving obstacles using ultrasonic sensors on both air medium and water medium. Petillot et al. [16] describe the tracking of underwater objects and motion estimation by proposing a new framework for segmentation of sonar images. They apply this framework to the design of an obstacle avoidance and path planning system for underwater vehicles based on a multibeam forward looking sonar sensor. Similarly, Ohya et al. [17] design autonomous mobile robot which can detect moving obstacles in air medium with ultrasonic sensors. Crowley, Borenstein and Elfes [18]–[20] design sonar-based mapping and navigation system for autonomous mobile robot operating in unknown and unstructured environments.

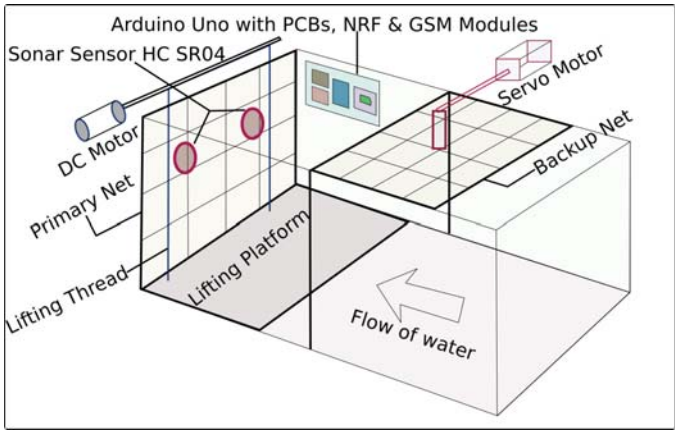

Fig. 1. System Diagram

Some works have been done on the automation of manual systems using Arduino microcontroller and GSM. Adriansyah and Baraka [21], [22] propose design of smart home automation system based on Arduino. Teslyuk et al. [23] present the structure of control system of Arduino microcontroller and Android device based greenhouse, describe features of developed software and physical model based on the Arduino microcontroller using Android device. Wensi et al. [24] present a new system for remote monitoring using GSM wireless data transmission system. Kumar et al. [25] designs an Arduino based wireless intrusion detection using IR sensor and GSM.

Zaghloul [26] presents the practical design and implementation of professional tool using GSM-GPRS Arduino Shield (GS-001) with SIM 900 chip module in wireless data transmission system for data acquisition and control of power induction melting furnace. Several other researchers use GSM-GPRS Arduino for smart energy metering and billing system [27], design of a communication system [28] and data acquisition system [29].

However, the aforementioned technologies suffer various shortcomings and are not sufficient enough to deal with the numerous challenges that exist with the sewerage management of a city like Dhaka. A comprehensive yet modern approach is needed to deal with the existing problems. This paper proposes a new approach to use a microcontroller based solution to design a fully automated sewerage management system.

III. System Model

The mechanical body of USenSewer consists of a primary net responsible for filtering the waste materials coming with the drain water, a lifting platform responsible for storing and removing the waste materials and a backup net to temporarily hold the waste materials from passing through while the lifting platform is busy with removing the already accumulated waste materials. The primary net is placed vertically with the ground where a waterproof ultrasonic sensor is attached in a desired height up to which we want the wastes to accumulate. The lifting platform is placed horizontally in the ground making

an angle of 90 degree with the primary net. The backup net is placed horizontally above the ground which is attached with a servo motor. There is a pair of lifting thread that are attached with the lifting platform which are responsible for moving the lifting platform upwards and downwards by the help of a DC motor. An Arduino Uno board with PCBs, NRF module and GSM module are placed above the ground which work for the automation of the system. In summary, we have used the following materials in order to implement our system.

- Arduino Uno
- NRF module 24L01
- Waterproof Ultrasonic Sensor HC SR04
- Servo Motor
- DC motor
- GSM module Sim 900
- 9V battery
- Wires

A. System Components

USenSewer consists of three main components; the blockage detection system which is placed inside the drain, the blockage removal system which is placed above the ground level and a control center which controls and coordinates the collection of waste materials placed by the first two components. We now detail each of the components.

Blockage Detection System. The blockage detection system consists of an Arduino Uno board coupled with a NRF module, an ultrasonic sensor and a servo motor along with its power supply. The waste water flows through the drain and the waste materials coming with the water are accumulated in the lifting platform. The ultrasonic sensor is mounted on the primary net at a threshold height which measures the distance of the object in front it in almost real time by the pulse-echo techniques. As the waste material piles up and crosses a certain height, the ultrasonic Sensor detects the waste obstruction and triggers the NRF module and the servo motor. The NRF module then transfers the blockage data to the blockage removal system while the servo motor drives the backup net to place vertically so that further waste doesn't get onto the lifting platform. After the platform removes the waste, the backup net is moved back to its original horizontal position to open up the flow path again.

Blockage Removal System. The blockage removal system consists of a GSM module and a DC motor. The blockage detection circuit receives the data from the NRF module whenever the waste material piles up and crosses a certain height. The DC motor, guided by a track lifts the platform containing waste materials to ground level with the help of lifting thread and pours the wastage on a waste container placed outside the drain. The lifting platform is moved back to its position after the removal of the wastes is complete. Finally, the GSM module sends a text message informing the control center that a pile of wastes has been removed.

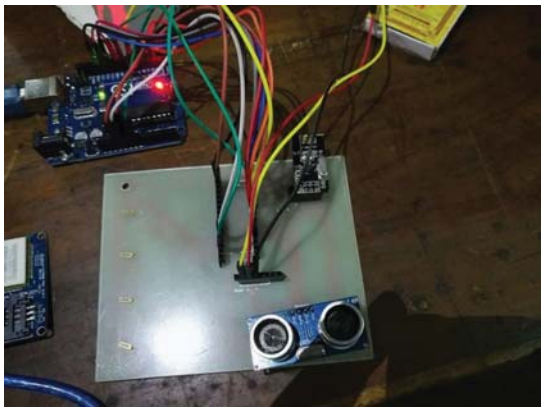

Fig. 2. Blockage detection system circuit

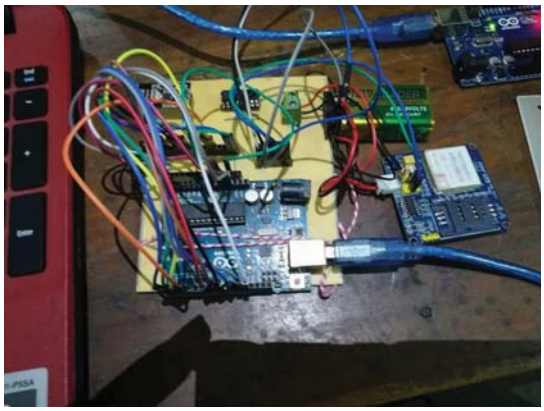

Fig. 3. Blockage removal system circuit

Control Center. The control center has the people working for the city authority who receives the text message sent by the GSM module. The manpower from the city corporation is then informed and they collect and remove the waste materials from the waste container.

IV. Circuit Diagrams and Arduino Codes

A. Blockage Detection

Blockage Detection Arduino Code

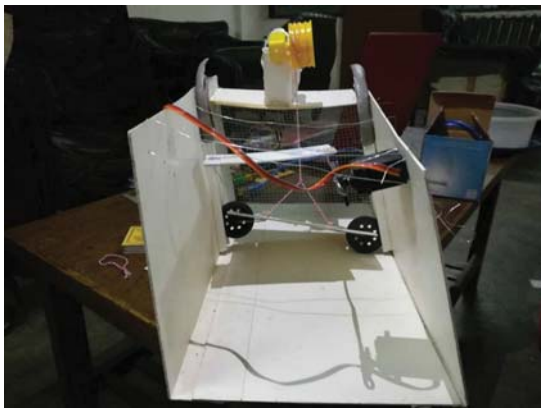

Fig. 4. USenSewer prototype

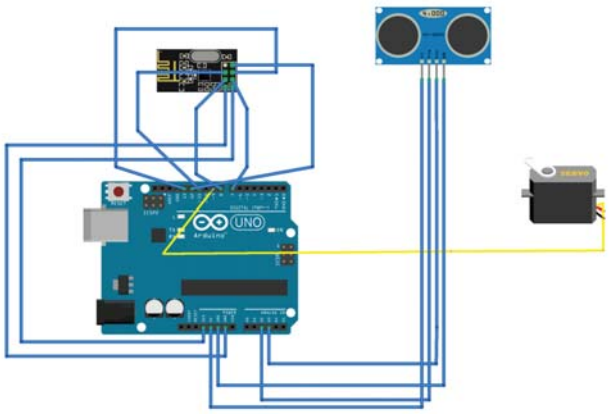

Fig. 5. Blockage detection circuit

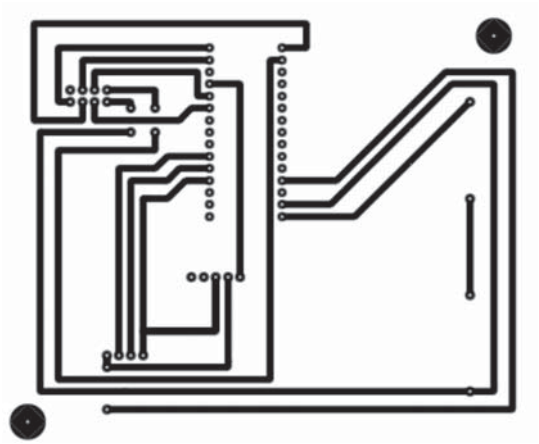

Fig. 6. Blockage detection PCB layout

```
// BlockageDetection.c
//NRF Transmitter
#include <Servo.h>
#include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>
RF24 radio(7, 8);
const byte rxAddr[6] = "00001";
unsigned long flag=0;
//Sonar
const int trigpin=2;
const int echopin=3;
long duration;
int distance;
Servo myservo;
int pos1=0;
void setup() {
// put your setup code here, to run once:
pinMode(trigpin,OUTPUT);
pinMode(echopin,INPUT);
Serial.begin(9600);
myservo.attach(9);
radio.begin();
radio.setRetries(15, 15);
radio.openWritingPipe(rxAddr);
radio.stopListening();
}
void loop() {
```

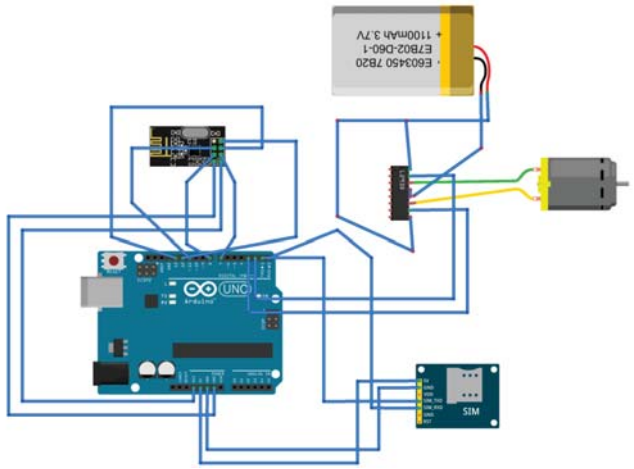

Fig. 7. Blockage removal circuit

```
// put your main code here, to run repeatedly:
digitalWrite(trigpin,LOW);
delayMicroseconds(2);
digitalWrite(trigpin,HIGH);
delayMicroseconds(10);
digitalWrite(trigpin,LOW);
duration = pulseIn(echopin,HIGH);
distance = duration*.034/2;
Serial.print("Distance: ");
Serial.println(distance);
if (distance <=5 && distance >=0)
{
const char text[] = "Hello World";
flag=1;
//radio.write(&text, sizeof(text));
radio.write(&flag, sizeof(unsigned long));
delay(5000);
for(pos1 = 0 ; pos1 <90 ; pos1=pos1+1)
{
myservo.write(pos1);
delay(10);
}
delay(10000);
for(pos1=90 ; pos1 >0 ; pos1=pos1-1)
{
myservo.write(pos1);
delay(10);
} } }
```

B. Blockage Removal

Blockage Removal Arduino Code

```
// BlockageRemoval.c
#include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>
RF24 radio(7, 8);
const byte rxAddr[6] = "00001";
int timesTosend = 1;
int count = 0;
char phoneno[]="0123456789";
int led=13;
const int Forward =2;
const int Backward=3;
```

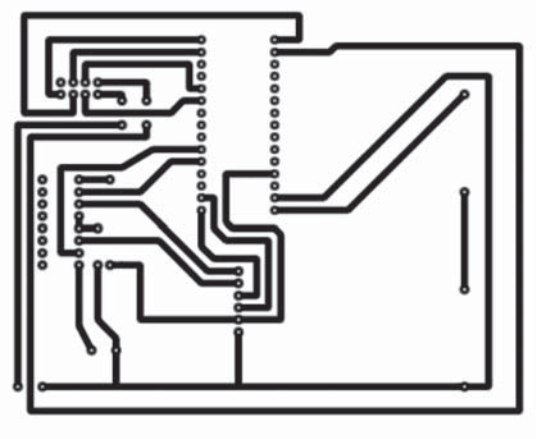

Fig. 8. Blockage removal PCB layout

```
void setup() {
// put your setup code here, to run once:
while (!Serial);
Serial.begin(9600);
radio.begin();
radio.openReadingPipe(0, rxAddr);
radio.startListening();
Serial.begin(9600);
delay(2000);
delay(2000);
}
void loop() {
// put your main code here, to run repeatedly:
if (radio.available())
{
char text[32] = {0};
char text2[32]="Hello World";
unsigned long flag=0;
//radio.read(&text, sizeof(text));
radio.read(&flag, sizeof(unsigned long));
Serial.println(flag);
if(flag)
{
pinMode(led,OUTPUT);
digitalWrite(led,HIGH);
delay(500);
digitalWrite(led,LOW);
delay(500);
// while(count < timesTosend)
//{
Serial.println("AT+CMGF=1");
delay(1500);
Serial.print("AT+CMGS=\"");
Serial.print(phoneno);
Serial.println("\"");
while(Serial.read()!='>');
{
Serial.print("hello");
//delay(500);
Serial.write(0x1A);
Serial.write(0x0D);
Serial.write(0x0A);
delay(5000);
}
// count++;
//}
delay(3000);
digitalWrite(Forward,HIGH);
digitalWrite(Backward,LOW);
delay(20000);
digitalWrite(Forward,LOW);
digitalWrite(Backward,LOW);
delay(20000);
digitalWrite(Forward,LOW);
digitalWrite(Backward,HIGH);
delay(20000);
digitalWrite(Forward,LOW);
digitalWrite(Backward,LOW);
delay(20000);
}
else
{
Serial.println("USenSewer");
digitalWrite(Forward,LOW);
digitalWrite(Backward,LOW);
delay(2000);
}}}
```

V. Evaluation

We have implemented the prototype of USenSewer and installed it at several points in the Dhaka city's sewerage system. The average cost for the implementation of the system was around 3,500 BDT (approximately 43 USD) and cost of maintenance of the system was also very low (see table I). We have also used a temporary control center which simulated the action of the actual control center being used in the city. The system has run successfully without any major drawbacks. Our research suggests that we need to install 20 systems to cover per square km area which would cost approximately 70,000 BDT, most of which is an one time cost. After the initial installation is complete, we only need the maintenance cost which would be much negligible in comparison to the installation cost. On the other hand, the state-of-the-art manual system that now exists in the city would cost at least 30,000 BDT monthly to maintain the same city area we mentioned [30]. A quick calculation shows us that our system will outperform the manual system just in over 2 months. After that point, our system will continue to save the expenditure that would otherwise be needed if there were the manual system.

Moreover, our system is very flexible to replace or reposition in any time based on the current need. It is possible to replace any defective system very quickly without causing much interruption in the sewerage management system. Additionally, the system is very much scalable as we can use as many system as needed without bothering the capacity of the control center. Overall, our system outperforms the existing manual system over many folds in various dimensions.

VI. Conclusions

Our proposed USenSewer is a starting prototype of the actual system as time and resource constraints limited the primary model set up. The waste detection system might be upgraded to create a 2D or 3D mapping compared to the 1D mapping used in this case. The lifting platform can be powered by a much powerful motor and the sluice gate may

Item	Unit	Price	Cost
Arduino Uno	2	600	1200
Sonar Sensor	1	150	150
NRF Module	2	350	700
Servo Motor	1	250	250
DC Motor	1	80	80
PCB	2	300	600
9V Battery	2	45	90
Connecting Wires	250	1	250
Others			180
Total			**3500**

TABLE I
COST ESTIMATION FOR USENSEWER IMPLEMENTATION (IN BDT)

be designed to improve primary waste filtering. The overall system needs to be rugged and water resistant for use in all sorts of environments. For continuous standalone power supply, a solar panel setup may be added as using battery cell might require routine maintenance.

VII. ACKNOWLEDGMENT

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