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Towards the Future of Public Restrooms: A Smart Toilet System for Cleanliness and User Satisfaction

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Abstract : It is a well-known fact that sanitation is a major issue in our country India. The issue of poor sanitation is not only limited to rural areas but it has made its way to urban, metropolitan cities as well. Although infrastructural coverage is progressively getting better, it has so far been unable to keep up with the increase of urbanization. Our government has invested a lot of time, money, and effort into keeping the public restrooms clean and orderly, yet the hygiene is terribly lacking. People's lack of interest in maintaining clean public sanitation systems in comparison to their degree of concern for maintaining clean restrooms at their houses is the primary cause of the current state of sanitation, wasting government resources and efforts. Maintaining hygiene and cleanliness in public washrooms is a challenging task that requires continuous monitoring and upkeep. To address this issue, we have developed a Smart Toilet System that uses various sensors and an app-based interface to facilitate efficient washroom management. Our solution implements an automated system that will keep track of the air quality and cleanliness of the public restrooms in order to solve this issue. Smart Toilet System offers an innovative approach to washroom management that utilizes technology to enhance efficiency and hygiene. The system can be easily integrated into existing washroom infrastructure and can provide valuable insights into the washroom's usage patterns. We believe that the Smart Toilet System has the potential to revolutionize washroom management practices and improve public health and hygiene. This project's major objective is to demonstrate how our system will track various cleaning metrics and alert the cleaner when the condition of the toilet deteriorates past a certain threshold.

IndexTerms **- Internet of Things; MQ-135 sensor, Smart toilet System, App development.**

I INTRODUCTION

This project aims to make the public restrooms self-cleaning using an automated system which uses various IoT sensors such as MQ-135 sensor, LDR sensor. Due to negligence of the public, majority of public restrooms are unclean and difficult to use because of the unpleasant smell. Citizens believe that if they touch the flush button or tap, their hands will get diseased or unclean, hence they avoid flushing. Because of this mindset, a lot of unclean waste material is retained in those toilets, and slowly, various germs are discharged in the surrounding environment, causing many ailments. As a result, public health issues are consequently getting worse. India has the highest rate of exposure to human waste, according to UNICEF data. It is estimated that 625 million people lack access to restrooms. TABLE I. gives the information of the Diseases linked directly or indirectly to sanitation [11]. In the absence of well-maintained restrooms for all, families and communities are more vulnerable to illness, stress, and aggression. While maintaining and managing this public restroom can be costly. FIGURE I shows Poor sanitation has a substantial financial cost in every region, but it is especially high in South Asia and sub-Saharan Africa. So, to overcome this problem we have developed a system that will sense the environment and apply necessary cleaning measures. Using a well-developed system, this software/App will provide a water level indicator, NH3 data display, last cleaned info, customer feedback. The system will also alert the Ease of Use cleaner to check the public toilet to see if the air quality is constantly bad even after providing cleaning measures.

Disease	**Deaths**	**Dalys (1,000S)**	**Population -Attributable Function**
Diarrhoeal diseases	828,651	49,774	0.60
Soil-transmitted helminth infections	6,248	3,431	1

Malnutrition	28,194	2,995	0.16
Trachoma	Less than 10	244	1
Schistosomiasis	10,405	1,096	0.43
Lymphatic filariasis	Less than 10	782	0.67
Total other diseases	**44,848**	**8,548**	**NA**

TABLE I. Disease burden associated with inadequate sanitation, either directly or indirectly, 2016 [11]

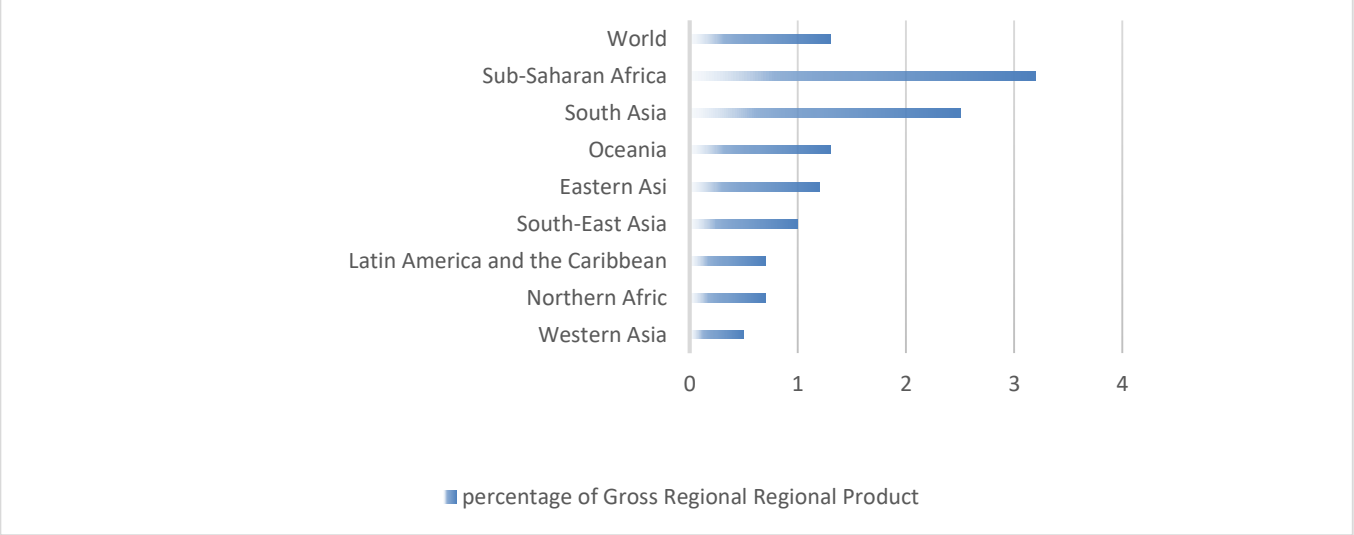

FIGURE I. Regional Economic Losses Associated with Inadequate Sanitation, as a Share of GDP, 2012 [11]

I.1 Problem Statement :

Keeping public restrooms clean and hygienic can be difficult, especially in places with heavy traffic like airports, malls, and office buildings. This problem affects not just the overall experience of users but also the cleaning crew, who find it difficult to effectively oversee several restrooms dispersed over a wide area. Our goal is to solve this issue by creating a complete self-monitoring toilet system and an intuitive mobile application that will increase cleaner productivity and user satisfaction with cleaner restrooms.

I.2 Background:

Public restrooms are essential locations that host a lot of people every day. Ensuring cleanliness and hygiene is crucial for both public health and user comfort. But when it comes to giving cleaning staff real-time information and direction, conventional cleaning techniques frequently fall short. This leads to inefficiencies, a slow reaction time to spills or shortages of supplies, and inadequate restroom conditions.

I.3 Objectives:

I.3.1 Boost Cleaner Productivity:

This project's main objective is to give cleaning personnel a cutting-edge system that automates monitoring, sends out alerts, and gives them access to real-time data on restroom conditions. Our goal in doing this is to increase cleaning staff productivity to a great extent.

I.3.2 Enhance User Experience:

I.3.3 Encouraging restroom users to have a pleasant and hygienic experience is an equally important goal. The system can guarantee a higher standard of restroom hygiene and thereby increase user satisfaction by proactively addressing cleanliness issues.

I.3.4 Control Odor Levels:

To proactively identify and eliminate offensive smells, integrate a smart odor management system into the self-monitoring toilet system. When necessary, the system will activate ventilation or deodorizing mechanisms based on sensor readings of the air quality. Through efficient odor control, this goal seeks to maintain public restrooms that are not only clean but also enjoyable to use.

II LITERATURE SURVEY

This project's purpose is to design and create a semi-automated flushing system for railroad restrooms. The design of the system will prevent water from passing through it until the passenger has opened and closed the door. The flush system will be activated by a piston installed on the door after the reciprocating action in this process. Potential advantages include effective water use using the

least amount of water, which lowers water waste. The pressure of the flushing system needs to be increased to improve cleaning effectiveness. The results of this paper [1] study could reduce water waste and enhance cleanliness in public restrooms. Cleanliness is one of the requirements for a sound and stable economy. Based on data from a late-2018 survey that re-examined households from the 2014 survey in four states—Bihar, Madhya Pradesh, Rajasthan, and Uttar Pradesh—Paper [2] suggests that open defecation is fairly common in Indian States. From roughly 70% of rural respondents in the 2014 survey to 40–50% in 2018, this percentage declined. The construction of new latrines is largely to blame for the decline in open defecation. Although, the Swachh Bharat Mission encouraged people to construct publics restrooms there was still a major lack of public awareness and interest in sanitation and hygiene. Coercive measures should be discontinued, latrine use promoted, and social attitudes that have made open defecation so common and difficult to address in the past changed in order to eradicate it from rural India. The goal of the research paper [3] is to decrease water waste through the development of water-saving devices. It used water level detection to save water. To reduce water waste, it recommends developing a water-saving device with an automated mechanism that opens and closes the water-tab. After the bathtub is filled with water, the smart house will determine to turn off the water supply automatically. It makes use of an ultrasonic sensor to gauge the water level. When the sensor detecting the water surface gets close to the ultrasonic sensor, it will alert the user to a rising water level and turn off the water supply before a flood happens. Researchers in [4] discuss the application of cutting-edge technologies, including the use of an Arduino Uno, a GSM module, an IR sensor, a turbidity sensor, and a gas sensor. In this study, they offer a strategy for ensuring that restrooms are kept clean, monitoring the work of the sweeper, and prohibiting the use of unclean facilities. The use of intelligent and automated technologies has been recommended for "Smart Toilets with Turbidity Sensor. Modern technologies such as solar energy to generate electricity can be used to build intelligent public restrooms. If the facilities are kept clean and well-maintained, more people will use them, which will help keep the area clean. In the research paper [5], the suggested approach is to develop a Mobile Toilet which can also be used during emergencies when people cannot access their public restrooms safely. To create a transportable flush toilet self-contained in electricity, water, and drainage is this study's goal. Moreover Furthermore, this toilet design may be utilized in less developed countries with limited infrastructure. Paper [6] talks about creating a smart toilet system for maintaining cleanliness in the railways with the help of IoT using automation. The proposed solution uses a robotic arm to autonomously clean the squat toilet. It uses a sequential algorithm for cleaning. A brush attached to the robotic arm's end effector is used, and water jets are available. Stem uses extraordinarily little water and electricity. To prevent human interference during system operation, an automatic door locking mechanism is offered. To maintain the periodicity of the cleanliness level, a variety of sensor types are used, such as the MQ-135 sensor, which detects the stench of the toilet. Wi-Fi is used to maintain a database that delivers all notifications to the Railway Authority's cleaning department via an Android application and a webpage. TABLE II gives details about related Papers and their Overview.

Sr. No	Title of paper	Date	Overview
1.	**Smart Toilet System using IOE**	15-06-2020	Providing clean restrooms and creating a universally usable toilet that is sustainable and can be effectively utilized by people from all socioeconomic backgrounds are the goals of the initiative.
2.	**Smart Public Toilet Health Check System**	02-06-2020	We have employed sensors to monitor water levels in tanks, water consumption, and human presence in the restroom. Our system forecasts the cleanliness of restrooms using sensor data. The Raspberry Pi is interfaced with the sensors, and after processing the data from the sensors, it is uploaded to the cloud. Pi starts the necessary action.
3.	**Deep-Learning-Driven Proactive Maintenance Management of IoT-Empowered Smart Toilet**	12-10-2022	The framework consists of two parts: (1) An Internet of Things (IoT) monitoring system that gathers time-series data on the ambient and operating conditions of the equipment. (2) A hybrid deep learning model that forecasts the ambient and operating conditions using the time-series data it has collected. The model is called the convolutional bidirectional long short-term memory (CBLM) model.
4.	**Smart Toilet Based on IoT**	29-08-2019	The objective of this project is to make sure the toilet seats are clean. The proposed system "Smart Toilet" is based on IoT, smell sensor, IR sensor, sonic sensor, RFID sensor.
5.	**A mountable toilet system for personalized health monitoring via the analysis of excreta**	07-05-2020	**The system uses excretion data, including urinalysis, urodynamics, stool form and defecation timing, stored in a cloud server. This smart toilet system has the potential to provide useful information to characterize symptoms of patients with bowel dysfunction or defecatory disorders.**
6.	**A smart toilet for personalized health monitoring**	02-06-2020	Describe easily deployable hardware and software for the long-term analysis of a user's excreta through data collection and models of human health. The 'smart' toilet, which is self-contained and operates autonomously by leveraging pressure and motion sensors, analyses the user's urine using a standard-of-care colorimetric assay that traces red–green–blue values from images of urinalysis strips, calculates the flow rate and volume of urine using computer vision as a uroflowmeter, and classifies stool according to the Bristol stool form scale using deep learning, with performance that is comparable to the performance of trained medical personnel.

Table II. Literature Survey of related research papers and their overview.

III METHODOLOGY

This research project aims to evaluate the effectiveness and functionality of a sensor-based smart toilet system equipped with water level sensors, ammonia detection sensor, and motion sensors in enhancing the hygiene, efficiency, and user experience of public restrooms. FIGURE II shows the whole visual of the Suggested System.

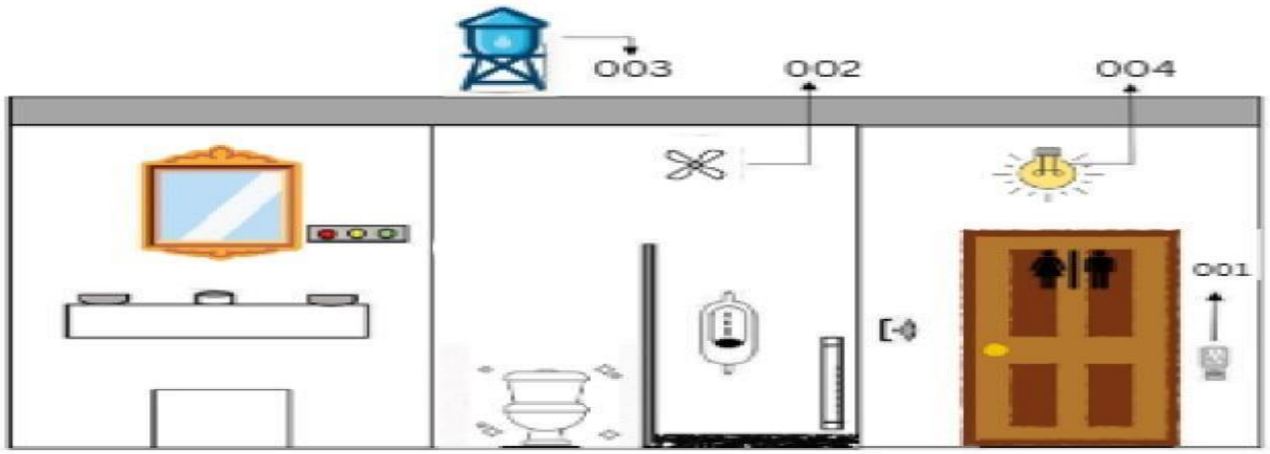

FIGURE II. Diagram of the Suggested system

In FIGURE II The Following 001 -MQ-135 sensor 002- MV (mixing ventilation) 003- Water Tank 004- Automatic Lights.

The methodology for this research can be divided into several key steps, each playing a crucial role in assessing the overall impact and performance of the sensor-based smart toilet system:

III.1 IoT Sensors to Check the Ammonia Content and Water Level:

Our project makes use of a sensor which checks the content of ammonia gas in the air. It is known as the MQ-135 IoT sensor. The smell coming from the toilet is caused by ammonia. Only at a concentration of 5 parts per million can the stench of ammonia be detected (parts per million). When the ammonia level in the toilet reaches the predetermined threshold of ppm, the ventilation system in the restroom is automatically turned on but when the ammonia content is below 5ppm there is no effect. The water sensor is used to keep track of the amount of water in the tank that supplies the toilet. It is the most suitable sensor that displays the threshold status and also takes corresponding action. There is a luminosity sensor too for regulating the brightness in the toilet. All of the sensors communicate data to the Database or Cloud.

III.2 Cleaning Process:

The cleaning process is dynamically tailored to ensure a well-maintained and pleasant restroom environment, based on the data collected by the various IoT sensors deployed in this project. This is a more thorough explanation of the cleaning procedure:

III.2.1*Air purification and ventilation:*

The ventilation system is automatically activated when pollutants or elevated levels of odor are detected by the ammonia detection sensors or other air quality sensors. To enhance the quality of the air in the restroom, the system starts air purification procedures. To attain the best possible air quality, this can entail turning on exhaust fans, releasing deodorizers, or even modifying the airflow. By taking these steps, restroom users should experience a more enjoyable and healthful environment.

III.2.2Notice to Maintenance Staff:

The system instantly alerts the service staff if the data gathered by the sensors shows that the restroom is dirty or if specific problems (like overflowing water or low supplies) are noticed. The cleaning staff receives these alerts via their mobile app, which gives them comprehensive details about the problem's location and nature. Alerts in real time facilitate prompt action and effective resource distribution.

III.2.3Adaptive Cleaning Procedures:

Cleaning procedures are modified in response to the information received from IoT sensors. For example, the cleaning staff is instructed to deal with the water-related issue first if the water level sensor detects an overflow. In a similar vein, the cleaning procedure might give priority to thoroughly cleaning and deodorizing the impacted areas if the ammonia detection sensors pick up on an increase in odor levels. With this flexible strategy, cleaning resources are effectively allocated to the most urgent issues.

III.2.4Schedules for Cleaning Based on Data:

By creating data-driven cleaning schedules based on real-time sensor feedback and historical data, the cleaning process is further optimized. When deciding when to perform routine maintenance, cleaning staff can make use of user feedback and information about when the restroom was last cleaned. By taking this proactive approach, restroom users are less likely to experience disruptions and cleaning is done when it is most needed.

In conclusion, the cleaning procedure that reacts to data from IoT sensors is a dynamic, data-driven, and user-centered strategy that guarantees that public restrooms are kept clean, hygienic, and enjoyable to use. It increases cleaning staff productivity while also establishing a proactive and responsive system that eventually serves the interests of the general public as well as the service personnel in charge of maintaining restrooms.

III.3 Data Processing and Display on the App:

The smart toilet system relies heavily on the data gathered by the Internet of Things sensors, and efficient restroom management is made possible by the way the data is processed and presented on the app. This is a more thorough description of the procedure:

III.3.1 Data Aggregation and Analysis:

The system's backend first aggregates and processes the data gathered from the various IoT sensors, such as motion sensors, water level sensors, and ammonia detectors. After that, this data is examined to find important trends and insights. These analyses comprise, but do not restrict to:

- **Water Levels:** The data from the water level sensor is processed to monitor the availability of water and to detect any anomalies like water overflow or low water levels in the overhead tank.
- **Motion Sensing:** The data from motion sensors provides useful information on restroom occupancy, usage frequency, and dwell times. It aids in understanding usage patterns and optimizing cleaning schedules.
- A**mmonia Levels:** The data from the ammonia detection sensors is analysed to monitor air quality and detect any spikes in odor levels. The system can differentiate between normal fluctuations and potentially problematic situations.

III.3.2 Alerts and Notifications in Real Time:

The system's real-time alerts and notifications are triggered by the processed data. For instance, the system instantly alerts the cleaning crew via the app when the ammonia detection sensor notices a noticeable increase in odor levels. In a similar vein, maintenance staff members get a notification on their mobile devices if the water level sensor detects a possible overflow. These notifications are essential for prompt and proactive problem solving.

III.3.3 Washroom Availability Information:

The app displays real-time restroom availability information. This feature is especially helpful for users because it allows them to check the availability of restrooms before they visit, saving time and improving their overall experience.

III.3.4 App Interface That Is Easy to Use:

The app displays the processed data in an easy-to-use interface that is accessible to both the general public and cleaning staff. Before visiting the facility, users can easily access information about the cleanliness and availability of restrooms. The app provides a dashboard for cleaning staff that displays sensor data, alerts, and cleaning schedules. This ensures that the information is easily accessible and understandable to those in charge of restroom maintenance.

IV IMPLEMENTATION

Certainly, putting in place a sensor-based smart toilet system with the features and functionalities described in the preceding sections is a complicated process involving numerous components. Here's an overview of the key steps involved in putting such a system in place:

IV.1 Design and Selection of a System:

Begin by designing the smart toilet system, which includes selecting appropriate IoT sensors (such as water level, ammonia detection, and motion), actuators, and microcontrollers. Select components that are compatible with the intended environment and project scope. FIGURE III shows the Data flow of the System.

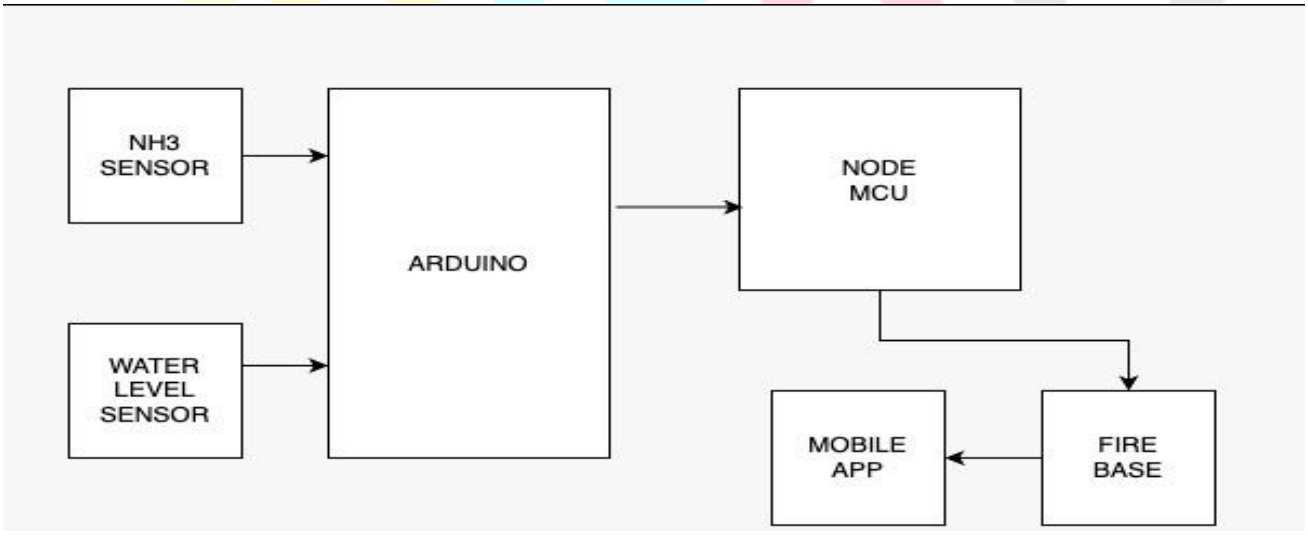

FIGURE III. Data Flow of the Proposed System

IV.2 Hardware Development:

A sensor-based smart toilet system is designed, assembled, and deployed by strategically placing hardware components such as water level sensors, ammonia detectors, motion sensors, microcontrollers, and actuators within restroom environments. These components collect data, which is then processed and analyzed in real time to monitor and control various restroom functions. The system is interfaced with a user-friendly mobile app, which allows the general public to access real-time information about restroom availability and conditions while also allowing cleaning staff to receive alerts, view cleaning schedules, and integrate user feedback. To ensure reliability and functionality, the hardware is subjected to rigorous testing, calibration, and validation, and quality assurance measures are implemented to ensure longevity and compliance with safety and security standards. The successful integration of the hardware into restroom infrastructure, aided by the app's user-friendly interface, results in a cleaner, more efficient, and user-friendly public restroom experience.

IV.2.1 Hardware Used:

- ***Arduino:***

Designed and manufactured in the United States, Arduino is an open-source hardware and software company, project, and user community that produces single-board microcontrollers and microcontroller kits used in the construction of digital devices.

- **MQ 135 Sensor:**

The MQ-135 Gas sensor is capable of detecting smoke, other hazardous gases, ammonia (NH3), sulfur (S), benzene (C6H6), and CO2. Additionally, this sensor has an analog and digital output pin. The digital pin becomes elevated when the airborne concentration of these gases surpasses a predetermined threshold. The on-board potentiometer can be used to set this threshold value. An analog voltage that can be used to estimate the concentration of these gases in the atmosphere is produced by the analog output pin. The MQ135 air quality sensor module uses about 150mA and runs at 5V.

- **Water Level Depth Sensor Module:**

An instrument called a water level sensor determines whether the liquid level in a fixed container is too high or too low. By measuring the volume of droplets or water through a series of parallel wires with exposed traces, the Water Level Sensor is an affordable, user-friendly high level/drop recognition sensor.

- **Node MCU WIFI Module:**

The NodeMCU (Node Microcontroller Unit) is an open-source environment for developing hardware and software that is based on the ESP8266, a low-cost System-on-a-Chip (SoC).

- **Hardware Connectivity Diagram:**

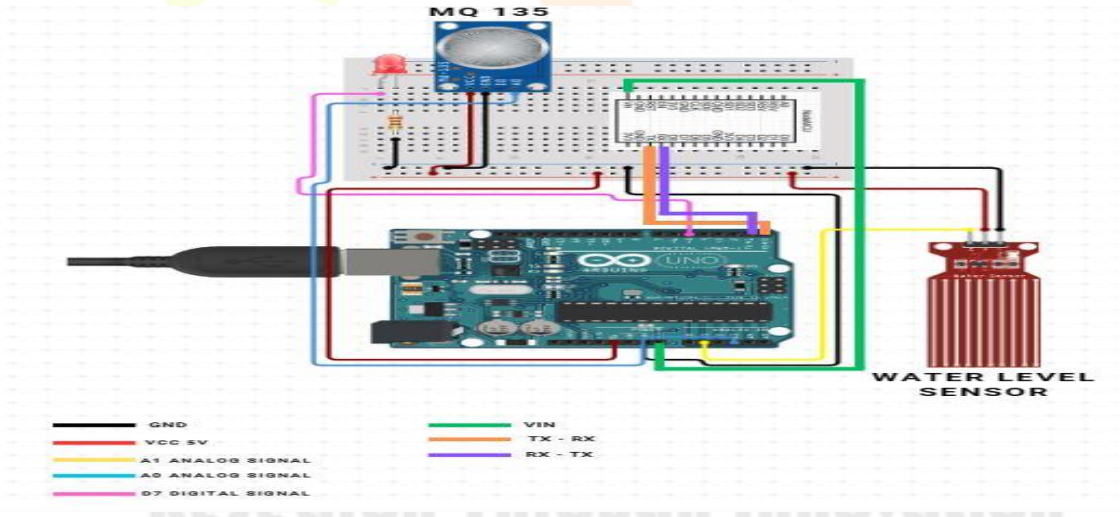

FIGURE IV. Hardware Connectivity diagram of the System.

IV.3 User-Friendly App Development:

User-centric design, intuitive navigation, responsive and accessible features, real-time data display, customization options, interactive feedback submission, multi-language support, offline functionality, rigorous testing, data security, scalability, and ongoing updates are all required when developing a user-friendly app for a sensor-based smart toilet system. The app improves user satisfaction and efficiency by prioritizing user needs and ensuring a visually appealing, easy-to-navigate interface for both the general public and cleaning staff to access real-time restroom information, submit feedback, and engage with the system's features, ultimately contributing to improved restroom management and user experience. FIGURE IV Shows the Front End of the System application.

IV.3.1 Software Tools:

- **Flutter:**

Flutter is a Google open-source UI framework that simplifies cross-platform app development by allowing developers to create high-performance, visually appealing mobile, web, and desktop apps with a single codebase. It's well-known for its "hot reload" feature, expressive UI components, and strong community support, which make it an efficient and popular choice for developing natively compiled apps with a native look and feel.[16]

- **Firebase:**

Google offers a suite of backend cloud computing services and platforms for developing applications called Firebase. It supports many different applications, such as Android, iOS, JavaScript, Node.js, Java, Unity, PHP, and C++, and hosts databases, services, authentication, and integration for them.

- **Arduino IDE**

The Arduino Integrated Development Environment (Arduino IDE) is a free and open-source software platform for programming and creating applications for Arduino microcontroller boards. It offers a simple interface for writing, compiling, and uploading code to Arduino hardware. The IDE provides a simplified programming environment that allows users to create and test a wide variety of electronic projects, making it ideal for beginners and hobbyists in the field of embedded systems and electronics. FIGURE VI shows a sample code wrote using Arduino IDE for MQ135 Gas sensor.

- **Front end:**

FIGURE V. Front End of the Proposed Application

```
#include <MQ2.h>
#define MQ2pin (A0)

float sensorValue;

void setup()
{

 Serial.begin(9600);
 Serial.println("Sensor Warming up")
  delay(20000);
}

void loop(){

   sensorValue = analogRead(MQ2pin);
   Serial.print("Sensor Value: ");
   Serial.print(sensorValue);

   if(sensorValue > 5)
   {
     Serial.print("| Smoke Detected");
   }

     Serial.println("");
delay(2000);

   }
```

FIGURE VI. Sample Code for MQ 135 Gas Sensor.

V RESULTS

The sensor-based Smart Toilet System was implemented with promising results, improving public restroom hygiene, efficiency, and user experience. The system monitored and responded to real-time sensor data effectively, triggering alerts for maintenance staff when issues arose, resulting in proactive and efficient restroom maintenance. User participation and feedback were actively encouraged, fostering a sense of collaboration and ultimately improving the restroom experience. Cleaning protocols were optimized using data-driven decision-making, resulting in resource allocation that was cost-effective. Furthermore, the system improved public perception by providing cleaner and more pleasant restrooms, ultimately transforming how these facilities are managed and perceived.

VI CONCLUSION

Because of this project, we were able to create a commercially feasible solution to the issue of unhygienic public restrooms. The mobile app is easy to install and acts as a conduit for communication between users, maintenance staff, and public restrooms. Modern public restrooms with this technology aid in maintaining their cleanliness and hygienic conditions. The mobile app is much simpler to use because the data display is up to par. The Internet of Things gadget is portable and reasonably priced. The use of advanced sensors to produce more accurate data could enhance this work in the future. With the analysis of sample data and the collection of additional test data, machine learning increases prediction accuracy. The public restroom situation in India will greatly improve once this strategy is widely implemented.

VII ACKNOWLEDGMENT

We would like to express our gratitude and acknowledge our debt of gratitude to Professor Dr. Ganesh Pathak, our project guide, for making this work possible. His kind counsel and knowledgeable counsel have been quite helpful at every turn of the project. His in-depth conversations and insightful recommendations have made a significant impact on the research paper's enhancement.

VIII REFERENCES

[1] S Mohamed Ashiq, K Karthikeyan, S Karthikeyan. ”Fabrication of Semi- Automated Pressurized Flushing System in Indian Railway Toilet”, International Journal of Engineering and Advanced Technology(IJEAT),Volume-2, Issue-3,February 2013

[2] Gupta et al., "Open Defecation in Rural North India: 2014- 2018," IZA Discussion Paper No. 12065.

[3] Teddy Mantoro, Wirawan Istiono. “Saving Water with Water Level Detection in a Smart Home Bathtub Using Ultrasonic Sensor and Fuzzy Logic”

[4] Mithya V, Divya Prabha N. SismaSamlein S, Madhumitha M, “Smart Toilets using Turbidity Sensor” International Journal of Innovative Technology and Exploring Engineering. Vol-8, Issue5S, March 2019.

[5] Soshino, Yasuhiro et al. “Design and Development of the Red Cross Mobile Flush Toilet Toward the Smart Design Shelter." 2018 IEEE Global Humanitarian Technology Conference (GHTC) (20/8): 1-6.

[6] Dharmesh Katariya, Pratik Parik, Akshay Pincha, Gauri Lodha and Anita Borse, “Smart Toilet”, International Journal of Electrical, Electronics and Data Communication, Vol, Issue5, May 2018

[7] D. Taibi, V. Lenarduzzi. “On the Definition of Microservice Bad Smells” IEEE Software. Vol 35, Issue 3, May/June 2018.

[8] P Banait et al., "Automatic Washroom Cleaning System," Scientific Research in Computer Science. Engineering and Information Technology (USRCSEIT), ISSN : 2456- 3307, Volume 5, Issue 2, pp.37-39, March-April-2019.

[9] E.Elakiya, K.Elavarasi, R.P.Kaaviya priya , "Implementation of Smart Toilet (Swachh Shithouse) Using IOT Embedded Sensor Devices", International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES), Volume 4, Issue 4, April-2018, pp 65 – 74.

[10] W. Cai, N.Chou, M. Tsai and Y. Lin, "Intelligent Toilet Management System with Internet of Things Technology." 2019 IEEE International Conference on Consumer Electronics -Taiwan(ICCETW), 2019,pp. 1-2.

[11] State-of-the-world's-sanitation-2020.pdf (unicef.org)

[12] Rahman, Mohammad Moshiur, Gahangir Hossain, Rajab Challoo, and Maher Rizkalla. "iRestroom: a smart restroom cyberinfrastructure for elderly people." Internet of Things 19 (2022): 100573.

[13] PREMKUMAR, M., S. KANIMOZHI, V. KRSIHIKA, and KORRAPATI SINDHUPRIYA. "SMART LAVATORY WITH AUTOMATIC CLEANSING SYSTEM AND LIVE HYGIENE MAINTENANCE FOR PUBLIC." (2020).

[14] Sai, Kinnera Bharath Kumar, Somula Rama Subbareddy, and Ashish Kumar Luhach. "IOT based air quality monitoring system using MQ135 and MQ7 with machine learning analysis." Scalable Computing: Practice and Experience 20, no. 4 (2019): 599-606.

[15] Rombang, Ivanno Alexander, Lukas Bambang Setyawan, and Gunawan Dewantoro. "Perancangan Prototipe Alat Deteksi Asap Rokok dengan Sistem Purifier Menggunakan Sensor MQ-135 dan MQ-2." Techné: Jurnal Ilmiah Elektroteknika 21, no. 1 (2022): 131-144.

[16] Flutter (software) - Wikipedia

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