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WORK AUTHENTICATION AND MONITORING SYSTEM WITH BLOCKCHAIN AND INTERNET OF THINGS (IOT)

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Abstract

In the Interconnected world, one of the major demands of developing counties like India is sanitary and hygienic public toilets, for becoming an Open Defecation Free (ODF) country. For this purpose, we came with the idea of a Work Monitoring and Authentication System (WMAS). In this research, an effort has been made to monitor and authenticate the services provided in the public toilets with the Technology of Blockchain and Internet of Things (IoT). In this study we collaborated the technical advantages of Internet of Things with the Blockchain Technology (Permissioned Blockchain). This study will help to reduce the cases of remissness in the operations involved in the cleanliness process of the public toilets.

1. Introduction

Swachh Bharat Mission (SBM) and Smart Cities Mission (SCM) is a nation-wide campaign in India that aims to clean up the streets, roads and infrastructure of India's cities, towns, urban and rural areas, and to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment. Under these campaigns Government of India (GoI), had built more than 110 million toilets for 6

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million people with 60 months [1] across India till date today. But till today there are 39.84% Or 524 million people [2] who defecate in open across the country. Reason behind such problems is, this huge infrastructure itself. It is quite difficult to manage, monitor and authenticate the authenticity of operations perform in such a huge infrastructure. And in today's digital world majority of the monitoring, reporting and authenticating work in such a huge infrastructure is done manually, that causes remissness.

With that note, we came up with the idea of Real-Time Work Monitoring and Authentication System (RTWMAS) for the real time monitoring of all the operations takes place in PUBLIC CONVENIENCE, like cleanliness of the toilets, availabilities of the required amenities, proper functioning of the human resource, etc. The idea is to make the public toilet smart enough to notify wherever any toilet starts getting insanitary and unhygienic, so that the cleaner can perform respective actions for on them. This system also facilities the toilets with user feedbacks system, that helps to improve the services. In collaboration of technology like Blockchain and Internet of Things (IoT), this system not only helps to monitor the activities of Public toilets in real time, but it also helps to authenticate the work done by the public servants.

Literature Survey

Toilet is one of public facilities, which is frequently used by people and located indoor. Therefore, maintaining good air quality in toilet is essential in order to keep it hygienic and sanitary. A study of Indoor Air Quality (IAQ) in toilets located Civil and Environmental Engineering building, University Tun Hussein Onns Malaysia (UTHM) was conducted to determine the level of gas pollutants exist in the toilets. The important IAQ parameters considered in this study are SO2, NO, and CO2. The measurements were conducted during break hour and taken using air quality monitoring. The existing SO2 concentrations on selected toilets found as a factor which could have adverse health effect such as asthmatic [3].

Table 1. Threshold Limit Value (TLV) of SO2 Components.

Gases	TLV (PPM)	Exposure via inhalation	Symptoms	*Ref

SO2	0.5	10 Minutes	Asthmatic	[4], [5]

*Ref: Reference

Municipal bodies use following model of operation, maintenances and monitoring of public toilets and CTCs. There are three major operations; Designing of the Toilet, Construction of the Toilets and Operation and Maintenance of the Toilet. [6]

And to perform those operations, there are three models:

(a) Model-1. here designing, construction and operations all are performed by the government bodies.

(b) Model-2. here designing, construction is performed by government bodies and operations are performed outsourced to the private agencies.

(c) Model-3. In this designing, construction and operations all are performed by the private agencies.

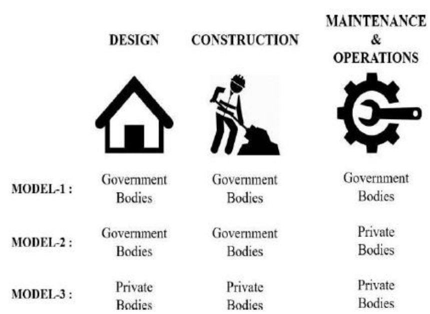

Figure 1. Working model of Municipalities of India.

2.1 Comparative Study on Existing e-Toilets

2.1.1 Delight e-Toilet. Delight was designed to ensure easy maintenance with the minimum of manual intervention, and substantial energy and water savings. It is based on an automatic system. The insertion of a coin opens the door for the user, switches on the light-thus saving energy-and even directs the user with audio commands. The toilets also feature power flushing, automatic closet washing and sterilization, and automatic platform cleaning mechanism, all backed by SMS alerts to inform the control room about the status of water tanks and bio-gas plants in the event of any errors or failures. The solid and liquid wastes are treated scientifically. A bio-membrane reactor is used to treat solid wastes and the water used is purified for reuse. Even Greater Chennai Corporation has also taken the initiatives towards building e-Toilet and came up with Chennai e-toilet [8]. The Delight e-Toilet is the perfect example of MODEL-3.

Figure 2. Delight e-Toilets.

2.1.2 Naaman e-Toilet. Naaman Toilet [9] [10] [11] is a modular toilet solution in India with urinals, hand-washing modules, accessible toilets, toilets for children, and toilet partitions for men and women. These can be applied to urban or rural areas, connected to electricity or installed with solar panels, connected to water systems or have an overhead tank, and connected to a sewage system or installed with a septic tank.

It cost approx.18, 700 USD (Rs.13 lakh) for a constructed complex (four toilet seats and urinals). It is developed under the Swatch Bharat Mission. Again it is an example of Model 3.

There are no solutions for Public Convenience which are developed under MODEL-1 and MODEL-2. It is identified that there is a huge gap to provide a solution that can authenticate the process of cleanliness of public convenience done either by Government bodies or Private bodies in real time and through secured method. We propose a solution that focuses on catering the solution based on Model 1 or Model 2. In this paper we have tried to propose a solution focusing on maintaining and working on the existing toilets without increasing the cost of building new infrastructures,

Figure 3. Naaman Toilet.

3. Proposed Solution

Idea is to develop a Permissioned Blockchain network of Supervisor of different areas/wards on a Municipal Corporation. Each node of the Permissioned Blockchain network represents the Supervisor's Application. Each Supervisor Application intern have several public toilets and CTCs (Community Toilet Complexes) and these public toilets and CTCs have their respective care taker and cleaning staff, which are connected to their Supervisor (24x7).

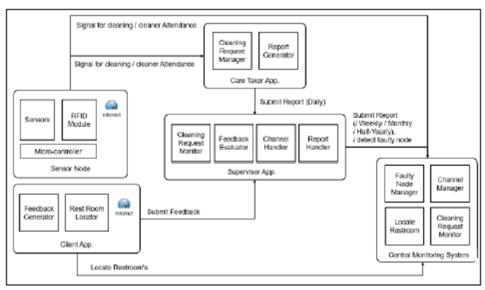

Figure 4. System Design.

Each public toilets and CTCs are equipped with the Sensor Node (IoT Devices) that send its real-time cleanliness status to the care taker and Supervisor. Each care taker has a Care Taker Application (Android/Web App.) to help send the report regarding its public toilet or CTC.

3.1. System Design. This is system is bifurcated into 5 major components, that are serving different services to 4 major stakeholder, named, the user (who access the toilet/restroom), care taker who physically look after the toilets/restrooms, the supervisor that manages the cluster of toilets/restrooms and the municipality itself that govern the whole system.

Those 5 components are; IoT NODE, Client's Application, Care Taker's Application, Supervisor's Application, and Central Monitoring System (CMS).

3.1.1. Client's Application. This application, will serves the users, who are using the toilet/restroom. It will empower users to give feedbacks regarding the services they had used in the toilets, and this can be done with the help of Feedback Generation Module (GRM).

User, who will access the toilets, can give their valuable feedbacks regarding the services provided by those particular toilets. Services will involve availability of water, soap, properly lilted place or not, foul order present or not.

3.1.2. Care Taker's Application. Care Taker's application will serve the care takers, who physically take cares of the toilets/restrooms. It provides two functionalities; notifying whenever toilet smells bad and helps to generate the cleanliness report of the toilet, and for providing these facilities, it has two different modules; one is Token Management Module (TMM) and other ire Report Generator Module (RGM).

3.1.2.1. Token Management Module (TMM). It will receive cleaning token form its respective restroom whenever it smells bad. When the application receives the token, it will display the details of cleaner who is the in-charge of cleaning that toilet at that working hour.

3.1.2.2. Report Generator Module (RGM). This component helps to generate cleanliness report of the restroom on hourly basis, in this report the care taker has to mark only those services that are not present or not working properly like availability of soap, availability of soap, and properly lilted or not, cleanliness of mirror, cleanliness of floor, disposable garbage bags empty or not, sink is clean or not, and send its respective supervisor.

[Note. restroom order will be automatically estimated and sent, at the time of report submission].

3.1.3. Supervisor's Application. This Application will serve the supervisor of cluster of toilets. It has many functionalities like; notify whenever toilet smells bad, validate cleanliness report sent by employee (care taker), work authenticity of the employee working under them. generate general reports for the blockchain, check general reports made of other supervisors, add block in the blockchain and for providing these facilities, it has following modules; Token Management Module (TMM), Feedback Management Module (FMM), Report Management Module (RMM-1), Distributed Network Management Module (DNMM) and Data Visualization Module (DVM).

3.1.3.1. Token Management Module (TMM). It will receive cleaning token form its respective restroom whenever the presence of Ammonia and Hydrogen Sulfide reaches to its threshold values. When the application receives the token, it displays the details of cleaner who is the in-charge of cleaning.

[Note. Cleanliness Request Manager (CRM) module of care taker application is a part of this module].

3.1.3.2. Feedback Management Module (FMM). It is used to manage the feedback send by user and cleanliness reports send by care taker. With the help of Feedback Evaluation Module (FEM), it will evaluate both the data and conclude whether a toilet is clean or not. It also runs that chaincode of the blockchain, that use to evaluates the toilet status toilets that comes under other supervisors.

3.1.3.3. Distributed Network Management Module (DNMM). This module is use to handle and manage the distributed network (permissioned blockchain) of which the application is part of. It will receive and send that data in the distributed network form other nodes (supervisors). It is also responsible for validating the reports send by them, create new block and add new block in the permissioned blockchain network.

3.1.3.4. Report Management Module (RMM-1). It is uses to generate and valid report (General Report) sent by the supervisor's on weekly basis. This module also consists of a sub module named, Data Visualization Module (DVM) that uses to make the municipalities official visualize the status of all resources engaged. Like number of clean-unclean toilets, vailed-invalid reports made by supervisor, care taker, improvement in sanitary rate week-by-week, month-by-month and year-by-year.

3.1.4. Central Monitoring System (CMS). This application will serve the municipality officials, to keep an eye on the operations and maintenances work of toilet/restrooms, work authenticity of their human resource etc. and for providing these facilities, it has it has following modules; Token Management Module (TMM), Resource Management Module (RMM-2), Distributed Network Management Module (DNMM), Data Visualization Module (DVM).

3.1.4.1. Token Management Module (TMM). It will receive cleaning token form its respective restroom whenever the presence of Ammonia and Hydrogen Sulfide reaches to its threshold values. When the application receives the token, it displays the details of cleaner who is the in-charge of cleaning.

[Note. Cleanliness Request Manager module of care taker application is a part of this module].

3.1.4.2. Distributed Network Management Module (DNMM). It is used to monitor and manage network of supervisors that comes under its jurisdiction. It will run the consensuses (Practical Byzantine Problem Consensuses). It manages the blockchain functionalities like creating channel, providing membership, providing e-certificates, faulty nodes (supervisor) etc.

3.1.4.3. Resource Management Module (RMM-2). It is use to manage all the resources of the public toilets, like Human Resources (Employee-care taker, cleaner, supervisor), Toilets, Users etc. perform all CRUD operation for them.

3.1.4.4. Data Visualization Module (DVM). It uses to make the municipalities official visualize the status of all resources engaged. Like number of clean-unclean toilets, vailed-invalid reports made by supervisor, care taker, improvement in sanitary rate week-by-week, month-by-month and year-by-year.

[Note. Data Visualization Module of supervisor application is a part of this module].

4. Methodology and Experimentation

4.1. Feedback Evaluation System (FES). It is sub-system of Feedback Management Module (FMM). This is module is used to evaluate the report sent by the employee (care taker) with the help of feedbacks send by the users for a particular toilet. This system has two phases;

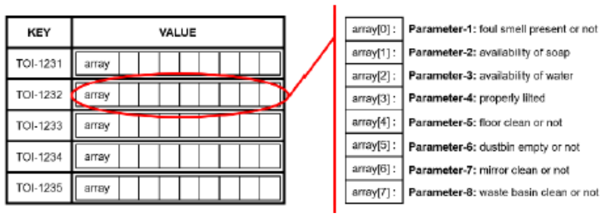

Figure 5. Hash Map Data Structure used in FES.

primary phase is known as Feedback Normalization Phase, and another phase is known as Feedback Evaluation Phase.

4.1.1. Feedback Normalization Phase. Here a three Map (hash table) data structure is used, where the key stores the toilet ID's in string format and value, stores an integer array of size eight, where each element of array signifies 8 different service (like foul smell, availability of water, availability of soap, etc.) and stores the count of user those are unsatisfied with those services.

1st hashap data structure (called as user rating) stores user entries, 2nd hashap data structure (called as importing) is used to store employee entries and 3rd hashap data structure (called as toilet list) use to used generalized entries concluded from other two hashap data structure.

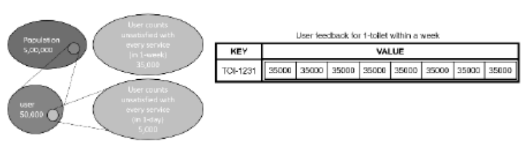

Figure 6. Data size of USER Feedbacks of 1 toilet within 1 week (before normalization).

According to Delhi Metro Rail Corporation (DMRC) [12], that on an average 0.5 million passengers used to travel from Rajiv Chowk Metro

Station, on daily bases. So, if we consider that only 10% of them (i.e. 50,0000 passengers daily), give feedbacks, and among that 50,000 user, only 10% of them are unsatisfied with each services then also, the count of every element will be of 5,000 for each element of array in one day, therefore within a week the count for each element of array will become 35,000.

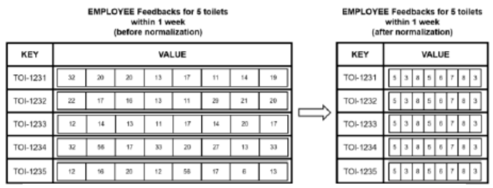

Figure 7. Employee reports for 5 toilets within 1 week (before and after normalization).

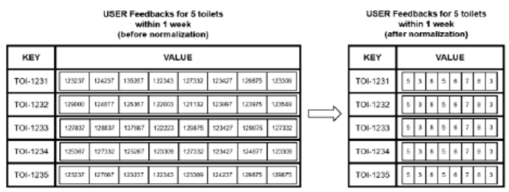

Figure 8. User Feedbacks for 5 toilets within 1 week (before and after normalization).

And in comparison, of that every day employee give reports 8 times, and among that they mark every service to be unsatisfactory for 3 times in a day, so within a week every service would be mark unsatisfactory for 21 times. So, to evaluate 35,000 user counts with 21 employee count, we need to normalized the elements of both the arrays and to do so, we had used max-min normalization to normalize user feedbacks and sometime employee report within the range of 0-10.

[Note. if the evaluation is done on daily basis, then there is no need to normalized then employee report].

Now these normalized user feedback and employee report went to the second phase where evaluation takes place.

4.1.2. Feedback Evaluation Phase. After Feedback Normalization Phase, normalized data went to Feedback Evaluation Phase, where a generalized entry will be given to each parameter of every toilet, which is concluded form normalized user feedbacks and employee report. These generalized entries will be in the range of -10 to +10.

Figure 9. assigning Data size of USER Feedbacks of a toilet within 1 week (before normalization).

Here employee entries for it-element from the integer array stored in user rating Map is subtracted by each user entries for it- element from the integer array stored in importing Map, and if the result is within the range of -3 and +3, then the entries for it- element from the integer array stored in toilet list Map is updated to 1 otherwise updated to 0. Now in order to check whether the employee report is vailed for a specific toilet or not. We will check first 4 elements of array.

```
if(-3<values[i] && values[i]<3 )
{
    ++accept;
    values[i] = 1;
}
else
{
     ++reject;
    values[i] = 0;
}
```

Figure 10. Logic-1.

If array [0] always equal to be 1, and among array [1], array [2] and array [3], any two of them should be equal to 1, then the employee report of that toilet would be considered as vailed report.

```
if(array[0]==1 && (array[1]==1 || array[2]==1 || array[3]==1))
{
    ++vailed;
}
else
{
    ++invailed;
}
```

Figure 11. Logic-2.

Like this, a list of toilets is generated along with the valid and invalid tags, produces by the Feedback Evaluation System (FES) as an output.

4.2. ROLE OF Internet of Things (IoT). The Internet of Things (IoT) is a network of physical objects-vehicles, machines, home appliances, and more-that use sensors and APIs to connect and exchange data over the Internet [13].

Employee (care taker) will generate a report using their care taker's application, telling about the condition of toilet on hourly basis. In that report there are 8 parameters, 4-major (shown in Figure 7) and 4-minor, among that major parameters are responsible to calibrate whether a Toilet is clean or not. among those four major parameters, first parameter is foul smell, and that parameter is calculate using IoT Module of this system called IoT NODE.

IoT NODE be equipped with different IoT devices, it has 3 major components; Sensor-component, RFID-component, and Communication-component.

Every WC/urinals of toilet are equipped with a Sensor- component, which is comprised of 2-Sensors, Sulfur Dioxide (SO2) Sensor to detect the presence of Sulfur Dioxide (SO2) Gas, along with that this sensor node will also equipped with DHT-11 for gathering the Temperature and Humidity status of the respective toilets.

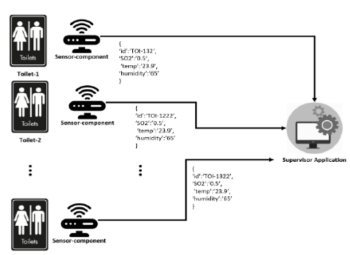

Figure 11. Logic-2.

Every toilet is equipped with a RFID-component, comprise of a RFID Reader, that is used to mark the attendance of cleaner and care taker. Cleaner has to punch its RFID-card whenever they came to clean the toilets, whereas care taker's attendance will be taken with the help of Geotagging, in which care taker has to upload a picture of the toilet at which they are deployed, at the time of submission of cleanliness report to the supervisor's application along with the report.

Every toilet would also equip with a communication component which is connected to the ethernet cable/Wi-Fi, that helps to transmit Digital Data Token (DDT-1) to care taker's application and supervisor's application.

4.3. Role of Blockchain. Blockchain is a decentralized computation and information sharing platform, that enables multiple authoritative domains, who may or may not know each other, to cooperate, coordinate and collaborate in a rational decision-making process.

List of toilets produces by the Feedback Evaluation System (FES) as an output will be added into the block of the blockchain (permissioned blockchain), as a single transaction by the Supervisor's Application. Basic Terminologies:

(a) Peer Node. supervior application, that can only validate the report and add new block to their blockchain.

(b) Admin Node. Central Monitoring System (CMS), that will monitor the blockchain transaction, validate legitatmate PEER NODEs, add/remove PEER NODEs, tackel DEFAULT NODE.

(c) Default Node: supervisor application, that has manipulated the employee report or provided invalid data.

(d) Committer Node: supervisor application, that can initiate the report validation process, validate reports, create block for the blockchain, notify report status to ADMIN NODE.

4.3.1. Transaction in Blockchain.

(a) Selecting COMMITTER NODE): ADMIN NODE with Distributed Network Management Module (DNMM), randomly makes a COMMITTER NODE among available PEER NODEs.

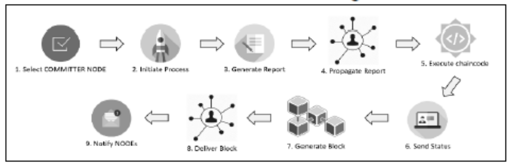

Figure 13. Transaction in the permissioned Blockchain.

(b) Initiate Process: COMMITTER NODE sends a message to all available PEER NODEs to start the validation process.

(c) Generate Data: every PEER NODE using Report Management Module (RMM) will evaluate the employee report send by care takers and creates a generalized report.

(d) Propagate Data: every PEER NODEs will distribute their individual generalized report and combination of user feedbacks and employee report, to all other active PEER NODEs along with COMMITTER NODE, using Distributed Network Management Module (DNMM).

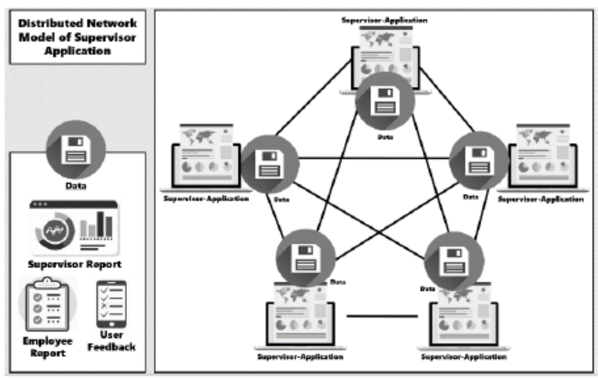

Figure 14. Data propagation in the Distributed Network of supervisor application.

(e) Execute Chaincode/Validate Data: after receiving the data from other PEER NODEs, a chaincode (Feedback Evaluation System) will run to validate.

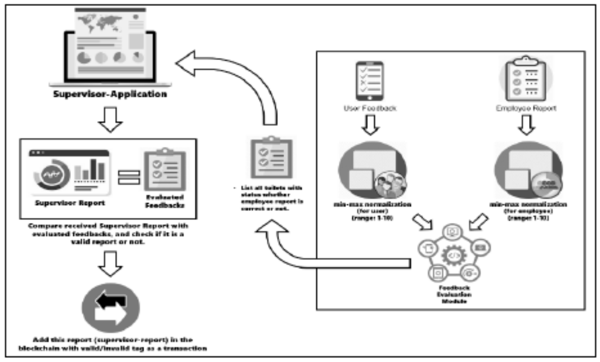

Figure 15. Chaincode of blockchain.

(f) Send Status: after validating the generalize report every supervisor application will send status (OK/ERROR) of those reports to the COMMITER NODE.

(g) Generate Block: COMMITTER NODE, will collect status of generalized report of supervisor from at least $(f+1)$ PEER NODEs. Check the status of the supervisor's generalized report. And then it will create the block, having generalized report of supervisor and their status.

(h) Deliver Block: now COMMITTER NODE will deliver this block to the PEER NODEs and ask them to add it in their respective blockchains.

(i) Notify Nodes. along with that, it also sends the notification to ADMIN NODE and PEER NODEs.

5. Performance Analysis

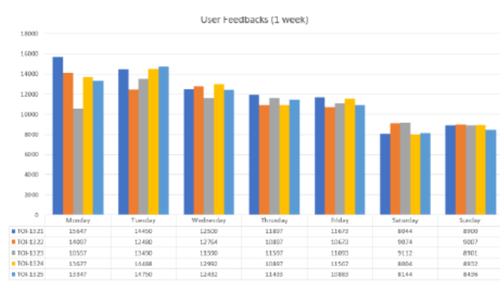

Figure 16. User feedbacks collected for 5 toilets in 1-week.

Figure 16 shows the feedbacks given by different users at different instance of time for 5 Toilets in 1 week. Different users send their feedback about the cleanliness and services of these toilets. The color variations represent different toilets.

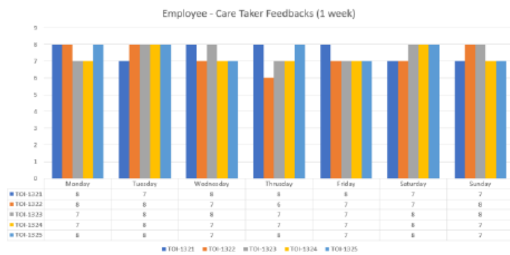

Figure 17. Employee Reports submitted for 5 toilets in 1-week.

Depending on the users feedback the evaluation of employee (care taker) report takes place and required action are performed to improve the services of the toilets, like cleaning.

Figure 17 shows the total no. of cleanliness report given by 5 different Employees (care taker) for their respective toilets in a week. Different colored bar represents different toilets. The employee (care taker) has to gives at total 8 cleanliness reports for the toilet within a day.

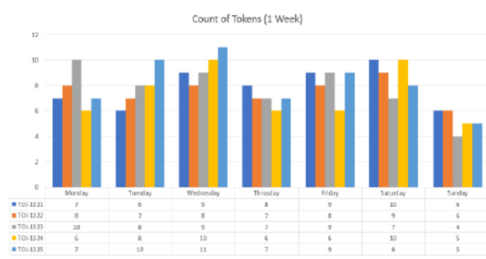

Figure 18. Count of tokens generated in 5-toilets 1-week.

Figure 18 represents the total count of tokens (DDT) generated for 5 different toilets, within the span of a week. Here also, different colored bar is used for different toilet. Different toilet gets different number of tokens each day, and from above data we can conclude that one an average, every toilet generates 7-DDT each day.

Figure 19. Count of tokens generated in toilet with ID: TOI-1324 in 1-week.

- **Profile of toilet ID: TOI-1324**

Figure19 displays line chart for total number of tokens (DDT) generated within the toilet ID, TOI-1324, in a week.

The Figure 20 describes the profile of toilet having toilet ID, TOI-1324, and it shows, how total number of token (DDT) decreases after using this system within a month (4 weeks). and Figure 21 shows comparative bar graph between total number of feedbacks send by the user for toilet ID TOI-1324, with total number of positive feedbacks given by the same users within a month (4 weeks).

Figure 20. Count of tokens generated in toilet with ID: TOI-1324 in 1-month.

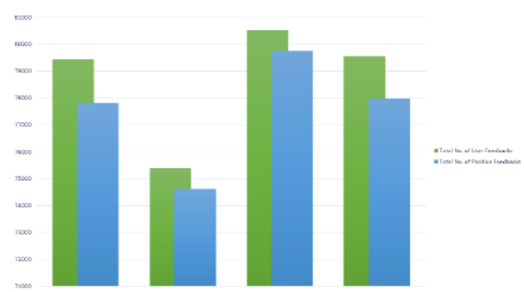

Figure 21. Comparison between total no. of user feedbacks submitted vs total number of positive feedbacks in 4-weeks.

5. Conclusion

In a country like India, personal hygiene in public toilets/CTCs/restrooms is a major concern, which has been tried to facilitate through different ideas and technologies, as we already discussed earlier at the chapter of literature survey. As discussed in this paper, the IoT Implementation at the places like public toilets/CTCs/restrooms in order to monitor the cleanliness and services provided in them is quite effective, and implementation of Blockchain (Permissioned Blockchain), and in order to authenticate the duties of the government conglomerate is also very impressive. And the capabilities of easy installation of this system with the existing infrastructures make it financially feasible to implement in a large scale.

6. Future Aspects

Future aspect is mainly concerned with uneducated audiences, or for those who doesn't have the access of a smartphone to give feedbacks. Idea is to integrate our system with a Feedback Generator Unit (FGU).

Figure 22. Feedback Generator Unit (FGU) Feedback UI.

Here between User and the Supervisor's Application, an electronic unit called, Feedback Generator Unit (FGU), is installed to get user feedbacks at real time.

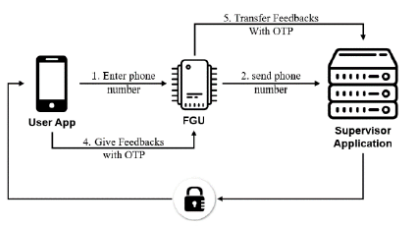

Figure 23. System Architecture of FGU.

It generates feedbacks in 5 simple steps, which are as follows;

1. User will enter his/her phone number, that he/she is carrying, into the FGU.
2. The FGU will send this phone number to its respective supervisor application
3. That supervisor application will generate an OTP against that phone number.
4. User will receive that OTP and enter into the FGU, along with his/her feedback.
5. And his/her feedback with OTP will be sent to the Supervisor's application

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