SMART TOILET: An IoT Implementation for Optimization of Resources

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ABSTRACT

In this era, the emerging technologies have no doubt influenced almost every sector around the world. As the part of technology, Internet of Things (IoT) played an important role and became very popular to emphasize the vision of global infrastructures. The utilization of IoT become an opportunity for developing the smart city, where the citizens are given access to the real-time environment for future planning and decision. This paper presents the implementation of an IoT in Smart Toilet for Optimization of Resources. Proposed an architecture shows how the development has been done. Two major things that are taken into consideration which are optimizing the resources in terms of manpower and using the cloud technology for this implementation to have more flexibility. This implementation involves the complete IoT system from sensory level to data management system with Cloud-based Integration.

Keywords: smart toilet, Internet of Things, Optimization of resources.

I INTRODUCTION

The Internet of Things (IoT) represents a worldwide network of heterogeneous cyber-physical objects for instance sensors, actuators, smart devices, smart objects, RFID, embedded computers (Fortino et al., 2014) (Akkaya et al.,2015). There is a sign of energy saving using IoT to implement smart homes. The smart home products range from home security for example motion detector, CCTV cameras etc., environmental controls such as temperature, light, humidity etc., to voice activated device controls (Kodeswaranet et al., 2016). According to ioi-analaytics.com, there top 10 industries that use IoT to improve performance which are Smart Homes, Wearable, Smart City and others. The priority has been given to Smart City as it has a wide variety of use cases, from traffic supervision to water supply, to waste management, city security and environmental monitoring. Its popularity is powered by the fact that many Smart City solutions promise to alleviate real pains of people living in cities these days. IoT solutions in Smart City solve traffic congestion problems, reduce noise and pollution and help make cities safer. All the approaches of IoT are used to save energy and resources. This project does share the same objective, which to save resources.

In this paper, we will be presenting the architecture of Smart Toilet (ST) which does not focus only on a bowl or the wash basin but entire toilet cleaning frequency. We have proposed an architecture which is able to optimize the resources usage specifically Janitors used in every building. There large number janitors being assigned to clean toilets which are already clean at the same time limited janitors given to clean to the toilet which has a high frequency of usage. So, we have come up with an architecture which will be able to provide the right number of janitors to be used, and companies will be able to optimize their janitor usage.

The paper is organized such as Section II, discusses all the IoT methods used for Smart City and Smart building development. Section III introduced the idea of ST and presented the proposed architecture. Section IV explains the methodology of ST, and Finally, Section IV is the conclusion of the entire paper and presented our future work.

II TYPES OF INTERNET OF THINGS APPLICATION

With the current technology of IoT in buildings and residential areas, the environment can be monitored in real time. Such case, by retrieving the real-time data may also save the survivors during emergencies (Akkaya et al.,2015). Enabling monitoring capabilities and improving energy consumptions is the goal of this study. At the same time, it may also use to enhance the security surveillance and improve the deployment of wireless communication. Disadvantages such as precision, cost, intrusiveness and privacy also been pointed out. Deploying additional devices and increase the accuracy, at the same time it will increase intrusiveness which will increase the cost. Two major challenges faced by the author are 1) to achieve occupancy monitoring in a minimally intrusive way and 2) to develop effective data fusion techniques for improving occupancy monitoring accuracy. Jin et al., (2014), mentioned the urbanization breaking the 50% barrier; it is of importance to understand the demand to increase the efficiency of the city management. The author also claims that, the highly developed sensing and

capability of technology able to gather and evaluate the real-time data which able to convert into useful information.

According to Fortino et al. (2014), management with the cyber-physical object is complex due to the integration with real application. Thus, he proposed "Cloud-assisted and Agent-Based IoT (CA-IoT)" to embed the cyber-physical environment which is based on multi-agents and cloud integration. Based on Kodeswaran et al. (2016), automated detection for Activities of Daily Living (ADL) is achieved. A smart home that is instrumented with sensors and being monitored at the opening and closing of the house utilization, for example, microwave, fridge and cabinets.

Smart home not only growing towards technologies, but it's beyond the basic convenience of daily life. According to Mao, J.et al., (2018), smart home functionalities' such an automatic light adjustment, and door locker also provide benefits such as energy saving. it is also efficient recourses usage with the water flow sensing and smart meter optimization also achieving home security, for instance, connecting to IP Based cameras and motion sensors integration. Vulnerabilities to smart home hacking are the drawback that the author points out.

According to Malche & Maheshwary (2017), a smart home or building should have the following functions such as alert, monitor, control system and some intelligence. This improves the living style, and able save energy. The proposed system by Malche & Maheshwary (2017), is on lights where the lights of the house will be on based on motion in the selected area. This helps to save energy by auto switching of the light when there is no one around in the specific area.

Rathinavel & Manisa (2017), have proposed a building automation system which can control the remote environment. They also agree that IoT system should have a remote control rather than the manual functions. This leads to a lot of security issues. There is a limitation in implementing too much of security features as encrypting and decrypting the data during the transfer takes a lot of energy. Although the data is secured, the goal of using IoT is to save energy. They have encouraged to use low cost and low power microcontroller such raspberry pi for the development.

Medina, Perez & Trujillo (2017), also agreed on implementation on IoT will making a smart city in term of improving the quality of services provided, better use of public resources and reducing the operation cost for the public. Our proposed idea will also reflect these criteria on reducing the operation cost on management. Medina et al., (2017), also emphasize on the data collected which can be processed and retrieve knowledge about the citizen behaviour. This idea will be adopted as well on ST. By process, this data, future development on the toilet can be predicted on the most preferred toilet by the user.

According to Kientopf, Raza, Lansing & Güneş (2017), challenges such as scalability interoperability, lthe atency for timely providing services lead to cthe oncept of cloud computing. By implementing cloud computing will save the cost as well easy management. Also, since we are implementing cloud based mobile application ,it will reduce the phone resources as well (Kanesaraj, Chua, & Haw, 2015).

A smart automatic urinal flushing system is proposed by Osathanunkul, K. et al., (2016). Water management system is one of the most important aspects of the geological department. This automated flushing system is implemented in most of the public toilet. It will help to control the amount of water running in the toilet. He also mentioned that this implementation also reduces the chance of cross-infection from pushing a flushing button. However, the drawback of them this system, its only able to manage the frequency of cleaning the bowl. The smart toilet should be a system which covers entire toilet such as the environment itself, not just the bowl.

Duta et al., (2017), encourages the use of cloud for the smart city or for any IoT applications. They also agree that the use of cloud server for IoT application is very inexpensive as well as flexible. Besides that, it also provides real-time control to all the appliance available in a smart building. They have proved with their lab prototype that the proposed cloud-based architecture for an IoT application is low cost and it works for the smart green building. Their test also includes videos and audio.

As we are also agreed on the statement by Madinat et al., (2017), by implementing IoT, it will also save resources and improve the quality of service offered to the public. In this paper, its more to the university students who pay their fees deserve a cleaner toilet while the resources are optimized.

III SMART TOILET

Smart Toilet (ST) is an efficient way that can be implemented at common places such as universities, shopping malls, high rise buildings and public toilets. This implementation will be used for optimization resources in terms of manpower such as janitors and use cloud technology to have more flexibility. This implementation involves the

complete IoT system from sensory level to data management system with Cloud-based Integration. Furthermore, ST also helps to check the availability of the occupancy of the toilet. The technique for cleaning toilets requires janitors to clean on schedule basis for the whole premises. For instance, every 2 hours once the janitor will need to clean the whole washroom no matter it is used or not. In this case, implementation ST will improvise current traditional method in terms of efficiency and effectiveness.

As discussed earlier, ST will solve several issues that have been pointing out. Firstly, on the resources. By implementing ST, directly we can optimized resource such as number of janitors required. There is no necessity for janitors to clean the toilet every day even there is no usage. Janitor will only require cleaning the toilet only if it is being used for several times. The janitor will be instructed by the leader or manager who able to view the report on many users for every toilet. Figure 1 below, shows the mobile application interface on manager's screen. The odometer will show the number of users of every toilet. When it reaches the targeted number, the manager will be notified and needs to assign the janitor to clean the toilet. The red colour indicates the toilet is ready to clean meanwhile the green colour indicates the toilets are clean. The manager also will receive the notification if the toilet is ready to clean.

Figure 1. Proposed View for Manager on the cleanliness of toilets.

As per recommended by both Malche & Maheshwary, (2017) and Rathinavel & Manisa, (2017), every IoT system should have a system controller. This mobile application plays the role of the system controller. The manager will be able to view the status of the toilet and instruct the janitors to clean it if it is in a critical condition.

On the other hand, the management able to view the following report as shown in Figure 2.

i) Average time per user spend in the toilet
This allows the management to decide which floors will need more toilets and which floor or which wing of the building does not require the toilet to be kept open. Keeping a toilet in operation with a very small amount of usage is not sufficient for the janitors and energy used in the toilet for one whole day.

ii) Average time every toilet in the building being used on the monthly basis
This gives an overview of toilet usage on a monthly basis. This is specifically useful for schools and universities. During the semester break and school holidays, not all toilets are used. This data will help the management to determine which batch or floor of toilets can be scheduled for maintenance or even close to saving resources for a specific month only.

iii) Average time janitors take to clean the toilet after the dirty notification is release
This information can work as the key performance indicator (KPI) for the janitors. This will encourage the janitors to clean the toilet faster as soon as the notification is released.

Figure 2. Proposed View for Management on Analysis Report.

Furthermore, the end user can check the availability of toilet as shown in Figure 3 below. Before the user goes to the toilet, users are capable of checking whether the toilet is occupied or not. In such case, they either find the alternative way to find another available toilet on another floor. This will reduce the number of the queue or waiting list in the toilets. Additionally, if the users are taking a long time in the toilet, there will be sent an email to Security department to take further action. This is just to alert if the user faint in the toilet or any first aid is needed.

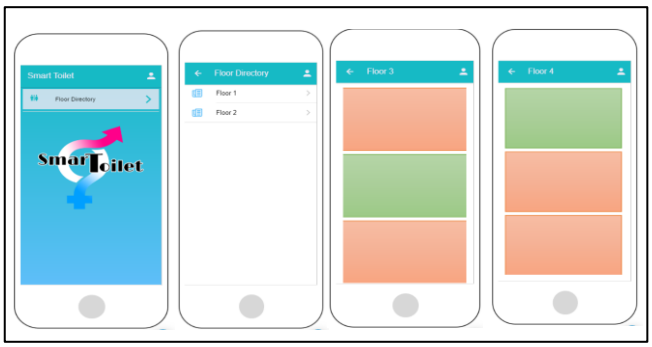

Figure 3. Proposed View for End User

IV IV METHODOLOGY

Figure 4, shows the activities that were carried out to conduct our research.

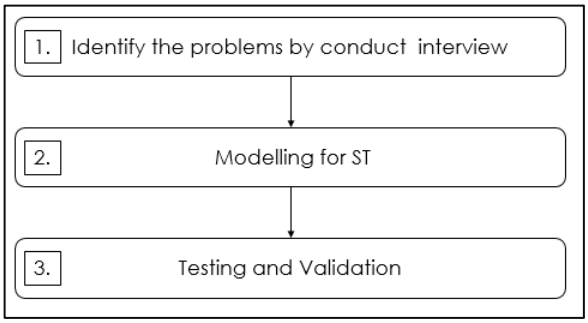

Figure 4. Flow of the Activity

1. Identifying the problems by Interview.

Based on the interview conducted, the problem is being identified such as cleanliness, long queue etc.

2. Modelling for Smart Toilet

Problem identified in 1), will be considered in developing ST. The prototype and architecture of ST will be discussed next, which is capable of solving the problem occurred at most of the places especially shopping malls.

Figure 5 below, shows the prototype of the actual toilet. For each toilet there will be one motion sensor will be placed on the top. This motion sensor will identify if there is any motion inside the toilet. The sensor will send the data to the cloud when motion is detected and every second to ensure the availability of the toilet. This data will be transferred to our cloud database through microcontroller which in this case Raspberry Pi 3 Model B will be used. Using the wireless connection within the campus, the data will be uploaded. Alerts and push notification will be initiated using the cloud application service.

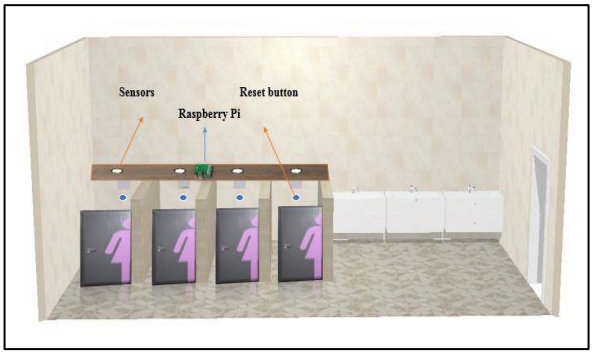

Figure 5. Proposed Prototype For The Actual Toilet

Figure 6 below, shows the architecture how the system is designed. The data collected from the sensors will be transferred to the cloud database. All the processing will happen in the cloud database before it's made available to the application to read. The mobile application services will retrieve the data and push the notification service will be handled by the application service from the cloud and update the views for the user in real time.

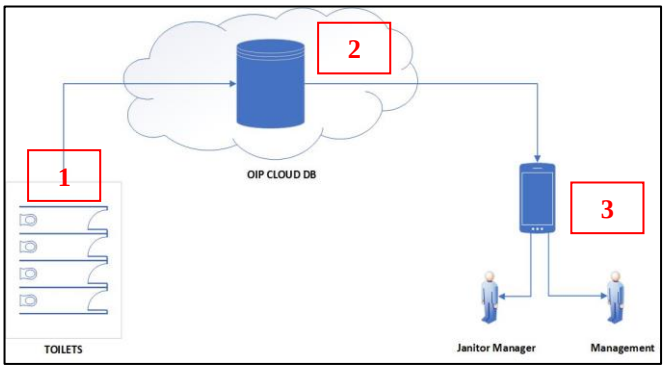

Figure 6. Smart Toilet System Architecture

Algorithm 1 below, shows the total time taken for per person in the toilet. This algorithm will be used to generate our analysis chart for each toilet to identify the usage of toilets in monthly basis. In this flow, once the person enters the toilet the current time is recorded. Then once the person leaves the toilet that time is recorded. Then the difference between begin and end time is calculated to identify the total time spent in the toilet.

Algorithm 1. Calculate Time Taken In The Toilet

```
BEGIN
    For Each Toilet
        MSen = Obtain the motion trigger
        CurrTime = Obtain Current date and time
        IF (Msen ==  False) Then
          ETime =  Obtain Current date and time
        End IF
       TotalTime =  ETime – CurrTime
       StoreInDatabase(TotalTime)
    End For Each
END
```

Algorithm 2, shows the calculation of time taken by the janitor to clean. This will indicate the performance of the janitors. The time is calculated from the dirty warning which is triggered by the manager and the time is stopped by janitors once the cleaning process is done. The indication of cleaning is completed triggered by the janitors by clicking the push button which is being placed in the toilet itself. There might be some questions raised if the janitors can hit the button without cleaning the toilet. In this work, we assume all janitors are ethical in their work.

Algorithm 2. Calculate the total time taken by janitors to clean

```
BEGIN
notifyTime = obtain the time during the dirty notification
    mpush = obtain the push button status
    IF(mpush == true) then
      curtime = obtain current time
      totaltime= curtime – mnots
      storeInDatabase(totaltime)
    END IF
END
```

There are three (3) main phases of this ST implementation. Firstly, sensory phase (1), Then, cloud management (2) and lastly, mobile development phase for monitoring purposes. (3). Table 1 shows the description and tools used in three phases.

3. Testing and Validation

To ensure the sensors are working accurately, the data from web service will be observed through a mobile application.

Table 1.The functionality and description of each phase in ST.

Phase	Tools
Sensory Phase	In this phase, the sensors are in the toilet as shown in Figure 4 above. This sensor will monitor the real-time environment and send the data to the database to store the monitored value to process in next stage. 1. Raspberry Pi Zero W will be used as a microcontroller or main device which collects and transfer the data through a wireless connection. 2. PIR Motion Sensor: This sensor will be used to detect the range approximately 1 meter from the sensor located. In ST, this sensor will be used to for detect the person in the toilet in and out. 3. Push-to-Off-Button is a button which will be placed in the toilet to for the janitors to indicate the cleaning process is completed after the dirty notification is alerted.
Cloud Management Phase	In this phase, we will be using a cloud database to store the data and the system process as well. All the data will be accumulated from the sensors will be stored in a cloud database. As recommended by the other researchers, using cloud database able to save energy and ability to provide the flexibility in a future enhancement. As for this project, we plan to use TM R&D OIP Cloud server. Besides this server, we can also use Microsoft Azure or Amazon Web Service (AWS) IoT server which provides almost same functionality for IoT implementation.
Mobile Development Phase	Mobile Development is the last stage in this development where the data from cloud management will be monitored here with a better user interface(UI). We will be using Xamarin as our development tool. This allows us to build all platform application using the same code in a native environment. As we will be able to use the application for both iOS and Android.

V CONCLUSION

In general, Smart Toilet is part of the initiative of a smart building. There are many works has been done for smart building in saving energy. The efforts which have been done for the smart toilet is only for the toilet bowls cleansing. This only focus on one area, meanwhile cleaning of a toilet is general where it should always remain dry floor. In this effort, we are more in focus on saving the resources in manpower used for the cleaning service. This application can be used in all high-rise buildings. As for the future work, we would like to implement this concept and prove the optimization of resources can be done through an IoT application. Besides that, this smart toilet system should also further have improved by having a water pressure sensor to identify whether there is water in the specific toilet. It is common to have in the same building, but only certain floors will have a water supply due to maintenance reason. With this upgrade, the users can determine which floor to go

rather got to the toilet and found out there is no water.

REFERENCES

kkaya, K., Guvenc, I., Aygun, R., Pala, N., & Kadri, A. (2015, March). IoT-based occupancy monitoring techniques for energy-efficient smart buildings. In Wireless Communications and Networking Conference Workshops (WCNCW), 2015 IEEE (pp. 58-63). IEEE.

Centenaro, M., Vangelista, L., Zanella, A., & Zorzi, M. (2016). Long-range communications in unlicensed bands: The rising stars in the IoT and smart city scenarios. IEEE Wireless Communications, 23(5), 60-67.

Coates, A., Hammoudeh, M., & Holmes, K. G. (2017, July). Internet of Things for Buildings Monitoring: Experiences and Challenges. In Proceedings of the International Conference on Future Networks and Distributed Systems (p. 38). ACM.

Dutta, J., & Roy, S. (2017, January). IoT-fog-cloud based architecture for smart city: Prototype of a smart building. In Cloud Computing, Data Science & Engineering-Confluence, 2017 7th International Conference on (pp. 237-242). IEEE.

Fortino, G., Guerrieri, A., Russo, W., & Savaglio, C. (2014, May). Integration of agent-based and cloud computing for the smart objects-oriented IoT. In Computer Supported Cooperative Work in Design (CSCWD), Proceedings of the 2014 IEEE 18th International Conference on (pp. 493-498). IEEE.

Jin, J., Gubbi, J., Marusic, S., & Palaniswami, M. (2014). An information framework for creating a smart city through internet of things. IEEE Internet of Things Journal, 1(2), 112-121.

Keles, C., Karabiber, A., Akcin, M., Kaygusuz, A., Alagoz, B. B., & Gul, O. (2015). A smart building power management concept: Smart socket applications with DC distribution. International Journal of Electrical Power & Energy Systems, 64, 679-688.

Kientopf, K., Raza, S., Lansing, S., & Güneş, M. (2017, October). Service management platform to support service migrations for IoT smart city applications. In Personal, Indoor, and Mobile Radio Communications (PIMRC), 2017 IEEE 28th Annual International Symposium on (pp. 1-5). IEEE.

Kodeswaran, P. A., Kokku, R., Sen, S., & Srivatsa, M. (2016, June). Idea: A system for efficient failure management in smart iot environments. In Proceedings of the 14th Annual International Conference on Mobile Systems, Applications, and Services (pp. 43-56). ACM.

Malche, T., & Maheshwary, P. (2017, February). Internet of Things (IoT) for building smart home system. In I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC), 2017 International Conference on (pp. 65-70). IEEE.

Mao, J., Lin, Q., & Bian, J. (2018). Application of learning algorithms in smart home IoT system security. Mathematical Foundations of Computing, 1(1), 63-76.

Medina, C. A., Pérez, M. R., & Trujillo, L. C. (2017, June). IoT paradigm into the smart city vision: a survey. In Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), 2017 IEEE International Conference on (pp. 695-704). IEEE.

Osathanunkul, K., Hantarkul, K., Pramokchon, P., Khoenkaw, P., & Tantitharanukul, N. (2016, December). Design and implementation of an automatic smart urinal flusher. In Computer Science and Engineering Conference (ICSEC), 2016 International (pp. 1-4). IEEE.

Ramasamy, R. K., Chua, F. F., & Haw, S. C. (2015). Adaptive and Dynamic Service Composition for Cloud-Based Mobile Application. In Advanced Computer and Communication Engineering Technology (pp. 963-973). Springer, Cham.

Rathinavel, K., Pipattanasomporn, M., Kuzlu, M., & Rahman, S. (2017, April). Security concerns and countermeasures in IoT-integrated smart buildings. In Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT), 2017 IEEE (pp. 1-5). IEEE.

Rocha, P., Siddiqui, A., & Stadler, M. (2015). Improving energy efficiency via smart building energy management systems: A comparison with policy measures. Energy and Buildings, 88, 203-213.

Thramboulidis, K., & Foradis, T. (2016). From Mechatronic Components to Industrial Automation Things-An IoT model for cyber-physical manufacturing systems. arXiv preprint arXiv:1606.01120.