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Cloud-based Internet of things for Smart Water Consumption Monitoring System

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Abstract - The levels at which groundwater is depleting around the world is alarming and there is an impending necessity to be judicious with water usage. This led to the formulation of a consolidated architecture to monitor water consumption at the household level. Internet of Things (IoT) is combined with the Thingspeak Cloud Computing platform and Android Studio to facilitate an efficient dashboard for consumers. The proposed model aims at imbibing a sense of responsibility in the citizens as it helps keep a track of water usage periodically using visually appealing charts, lays down the monthly water utility costs as well as provides tips with all in the form of a compact android application in their phones that is needed to be proactive and conserve resources. This paper presents a tested prototype and the pipeline connecting the hardware and software components responsible for streamlining the process of data transfer from IoT to cloud and from cloud to the android application. An overview of the promising technologies and frameworks that have been orchestrated in the development of the system as well as results obtained are thus provided.

Keywords - Water Consumption Monitoring System, Internet of Things(IoT), Thingspeak Cloud, Android Studio

I. INTRODUCTION

Water is one of the primary sources of survival for all life forms on earth. A lot of our day to day activities such as bathing, cooking, washing is dependent on the use of water. The community needs water for various activities beginning with the production of food [6] and irrigation. But now the world is heading towards a water crisis due to the excessive and uneconomical use of water by the large human population[8]. The World Economic Forum has announced in 2015 that the water crisis ranks the eighth global risk with the highest likelihood of occurring within 10 years[4]. This has left many fearing that the shortage of water is probably going to be the most important cause of conflict in the coming years[1]. The importance of groundwater conservation practices has undergone a gradual increase as it can lessen wastewater discharge which can further result in improved water quality. They also diminish the necessity to search for or create new water sources, leaving them in reserve for future use. Hence it is extremely important to conserve groundwater by constantly monitoring and regulating usage starting at the individual household level. The designated system strives to achieve just that. One of the main objectives of the system is to imbibe a sense of responsibility in the citizens by preaching the importance of water and its conservation. The monitoring dashboard provides tips for being conservative with the daily usage consumption and also allows them to set limits on the same. Once the limit is approached or has reached, the consumer receives an alert regarding the same, leaving room for usage reduction.

Some of the real-time applications of the system in the domestic/household-front include -

i. Track units of water consumed hourly/daily/weekly/monthly.
ii. View live analysis of consumption statistics in the form of interactive charts.
iii. Set limits on water consumption and receive alerts when the limit approaches or has reached.
iv. Receive monthly water utility cost bills and log reports based on the units consumed.
v. Be mindful of the usage by receiving tips on conservation timely.
vi. Educate residents as well as house help personnel.

The organization of the rest of the paper is as follows. Section II briefly overviews the technology involved in putting the system together, while section III highlights the consolidated system architecture and implementation. Results of the end application are produced in section IV, before concluding the article in section V.

II. WATER CONSUMPTION MONITORING SYSTEM

A. *Internet of Things*

Internet of Things or IoT, in short, is a paradigm popularly used for giving "things" like actuators, sensors, mobiles and other devices the ability to interact with each other and transfer data seamlessly. IoT is widely used for digitization of machines and home automation[2]. It is a multidisciplinary concept where any real or virtual object(thing) that can be assigned an IP address[5] can be hosted over the network for transfer of data. Here, mobile on which the application is installed, water flow rate meters and Raspberry Pi 3B are the things, where Pi is responsible for assigning IP addresses and further computation involving retrieving data from the water sensors installed.

a. Raspberry Pi

Raspberry Pi is a credit-card-sized full-fledged computer that can run applications when connected to peripheral devices like the keyboard, mouse, display, power supply and micro SD card with Linux environment[7]. There have been three generations of Raspberry Pis: Pi 1, Pi 2 and Pi 3 and there has generally been a Model A and a Model B of most generations. Raspberry pi 3 model B, being used throughout is a third-generation Pi, with Quad-core 64-bit CPU, wireless LAN and even bluetooth[13]. The popularity of Pi grew when CS enthusiasts grasped the fact that Pi is a cheaper alternative to a computer, that runs Linux operating system and provides a set of GPIO(General Purpose Input/Output) pins that allow one to control electronic components for physical computing, data transfer, communication and signalling among others.

b. Water flow meter YF-S201

The flow and flow rate of water through the pipes is measured using YF-S201 water meter with the Raspberry Pi. This water flow sensor has only three wires and it can be easily interfaced between any microcontroller, microprocessor or even Arduino board[12]. It requires only +5V Vcc through the red wire, while the black wire is connected to the ground(GND) and gives pulse output signal through the yellow wire when tightly fitted between the water pipelines. The mechanism underlying these meters is Hall effect[3] and hence they are also known as hall effect sensors.

Figure 1. YF-S201 water flow meter

Following are the technical specifications of the water meter used for measuring water in the proposed solution:
i. Model - YF-S201 water flow meter
ii. Sensor type - Hall effect
iii. Working voltage - 5 to 18 volts DC
iv. Max current draw - 15mA @5V
v. Size - 2.5'' x 1.4'' x 1.4''
Connections of the wires and interfacing are as follows:
i. Red wire - +5V
ii. Black wire - GND
iii. Yellow wire - PWM output

B. Household Faucet Model

A prototype of household outlet faucets has been soldered together to demonstrate the usage of the monitoring system. Two model outlet taps, one for the kitchen and one for the washroom tap have been installed, along with a water motor, for the water to be reused. Water meters with installed hall-effect sensors are fitted along the individual pipelines, which record the flow in litres as well as the flow rate every second as the water flows through the rotors. This data is then sent to the Raspberry Pi console to which the meters are interfaced through jumper cables a General PCB board soldered at the back (alternative to a breadboard).

Figure 2. Household Faucet Model

This arrangement, however, is just a prototype of the household water system, developed for testing the application on water usage. To scale the product to a community of households, this arrangement needs to be approved for large-scale production and real-time testing with more outlets and a group of channels.

C. Thingspeak Cloud Platform and Communication APIs

Thingspeak is an IoT enabled cloud service that allows one to analyze, aggregate and visualize live streams of data and host it on the cloud[11]. Its services can be put to use by signing up on the platform and creating a free account to host data remotely. However, if the usage and the volume of data sensed increases exponentially, i.e., to expand the product to a community(large-scale), it is needed to subscribe to a suitable plan that suits the business needs out of a range of plans that Thingspeak provides. Thingspeak also provides read and write communication APIs to import and export the data to/from the cloud channel in the form of JSON/XML/Excel to other platforms like Android studio for development and production purposes [10]. Using the REST API calls such as GET, POST, PUT and DELETE, one can create a channel, update its feed, update an existing channel, clear feed, or delete a channel.

Read Data	Read data from all fields in a channel using HTTP GET
Read Field	Read data from a single field of channel using HTTP GET
Read Status	Read status field of a channel using HTTP GET
Read Last Entry	Read last entry in a channel using HTTP GET
Read Last Field Entry	Read last entry in a field of a channel using HTTP GET
Read Last Status	Read the last status of a channel using HTTP GET

Figure 3. Thingspeak API calls

D. Android Studio

Android Studio is a new Android development environment based on IntelliJ IDEA[14]. Similar to Eclipse with the ADT Plugin, Android Studio provides integrated Android developer tools for development and debugging. At the core of Android Studio is an intelligent code editor capable of advanced code completion, refactoring, and code analysis[14]. Here, Android studio is used for the development of an interactive application in the form of a dashboard for the consumer to track usage, view analysis, tips and billing reports. Java is used as the language for development as the default android toolchain and SDK allow for Java 8 bytecode transformations with an in-built javac compiler. Android Studio also provides terminal support for debugging through lines of code.

III. SYSTEM ARCHITECTURE AND IMPLEMENTATION

The water consumption monitoring system has been designed with many intricate components that contributed to the overall functionality. The system, as shown in Figure 4, starts with the water flow sensors with an intrusive mechanism, that are installed at the individual pipelines. These sensors start measuring the water flowing through the pipes and send the data to the Raspberry Pi console. The thingspeak read/write communication APIs are then used to host the live measuring data on the Thingspeak cloud. MATLAB is used to perform statistical analysis on the same and interactive charts and graphs on consumption are generated. Meanwhile, the page layouts and action listeners are to be developed on the Android studio, so that the application is ready to receive timely data from the cloud. Once the data is received, tips and utility cost bills and reports are generated. Along with these, the application also provides the feature of setting limits to daily consumption and receiving push notifications when the limit approaches.

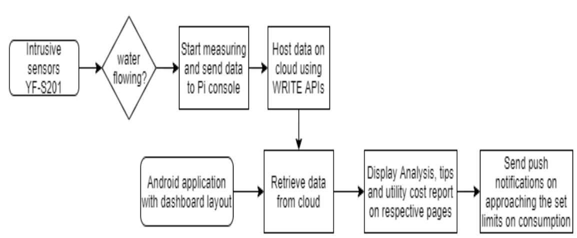

Figure 4. System design

The system has been designed, keeping in mind the interaction required between hardware and software components and the role played by network connectivity to get them to communicate with each other, to streamline the whole process of transfer of data from one medium to another. Cloud communication APIs played a major role in this transfer of data from IoT to cloud and from cloud to the mobile application and a good internet connectivity plays a pivotal role in making the transfer seamless.

IV. END APPLICATION RESULTS

The system designed for timely monitoring of water consumption has been tested and measured real-time, transmitted on a per-second basis and stored time-to-time in the central database provided by Thingspeak and can be obtained by appending requirements to the GET/POST urls.

Shown in Figure 5 is one such example of water flow rate of both the taps dated February 15, 2020.
The screenshot displays the usage tracking channel that allows users to switch between water outlets i.e., Washroom tap or kitchen tap as shown to know individual usage..
On choosing a channel, the consumer can then view the water flow and flow rate details that keep updating with the water flow along with the timestamp.

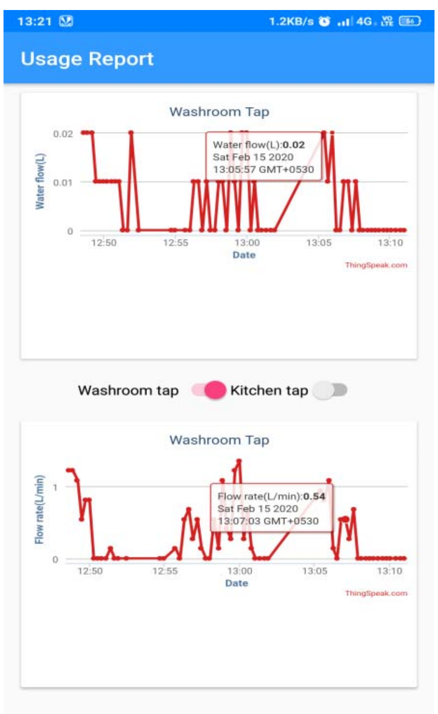

Fig 5 Consumption Statistics

Fig 6. Utility report

Figure 6 shows the utility billing reports for a particular month, that displays the total units of water consumed in either outlets as well as computes the total bill for the month using a standard formula used by the union ministry of water and resources, including the VAT and other taxes added up.

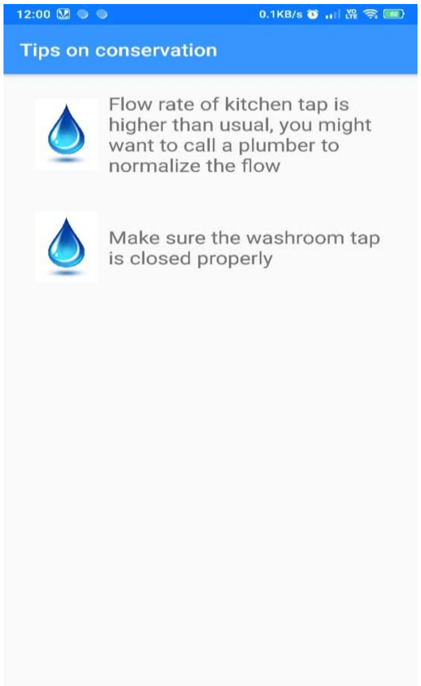

Fig 7. Tips for conservation

Figure 7 as shown, generates customised tips based on the consumption that would help consumers prevent unwanted leakages and overconsumption in any part of the household.
The tips generated, if followed by the consumers, have the power to bring about even the slightest change in the overall consumption and prevent groundwater depletion.

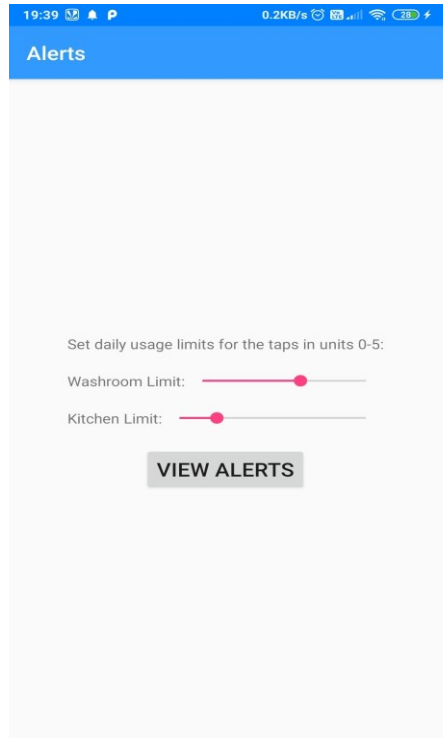

Fig 8. Alert setting page

Figure 8 above, is an alert setting page that allows the consumers to set limits on daily consumption in the form of water units and receive alerts in the form of push notifications, when the limits exceed.

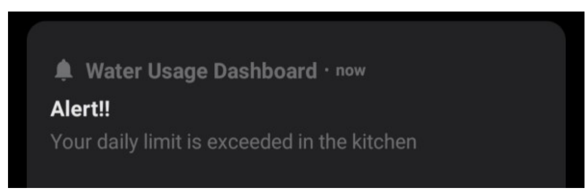

Fig 9. Push Notification

Shown in figure 9 is an example of the kind of notifications the user will be receiving on exceeding the usage limits. Here, the user had set the limit of usage in the kitchen as low as 1 water unit, and hence received an alert when the set limit exceeded.

V. CONCLUSION

In conclusion, this paper reports a system that utilises live water usage data from water flow meters at household prototype level and draws useful inferences from it. Combined with a mobile application with an interactive UI, this system helps users understand where the maximum water is being consumed/wasted and helps one take judicious decisions concerning water usage. Considering the current water crisis globally, this product can be launched at a household level, or at a community level. It can even be monetised by introducing it in small-scale infrastructure and housing projects in construction, by installing the meters in every household in the block. The only limitation is that it does not provide leakage detection and has currently been tested only on two pipes, but these aspects can be overcome in the near future with the right technology and robust mechanisms. It can be further expanded to provide smart solutions on rainwater harvesting, smart home energy planning overhead tank-level monitoring and leakage detection systems etc.

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