

2nd International Conference on Intelligent Computing, Communication & Convergence
(ICCC-2016)

Srikanta Patnaik, Editor in Chief

Conference Organized by Interscience Institute of Management and Technology

Bhubaneswar, Odisha, India

Framework for a smart water management system in the context of smart city initiatives in India

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Abstract

The Internet, invention of the century, has completely revolutionized the world and brought people closer to each other than ever before. The advancement in technologies of computing, communication brings the next generation of Internet, Internet of Things. As the population and urbanization increases, the cities have to transform to Smart Cities which can be achieved with the help of Internet of Things. Water is one of the vital resource for existence of human life and so Smart water management system has a key role in smart city. The paper reviewed different technologies and platforms that are required for a smart environment. An architecture design for Smart water management is proposed and an implementation detail of Smart water monitoring system is discussed.

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Peer-review under responsibility of the Organizing Committee of ICC 2016

Keywords: Internet of Things; Smart City; Smart Water;

1.Introduction

The Internet, invention of the century, has completely revolutionized the world and brought people closer to each other than ever before. The introduction of mobile devices and the influence of internet not only changed the way we do business but changed our lifestyle too.

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Internet of Things, can be considered as the next generation of Internet. There has been drastic advancement in technologies of computing, mobile communication, wireless communication, ubiquitous computing and this opens the door for Internet of Things. Internet of Things is a network of connected devices, where the devices can be a sensor, cell phone, actuator, RFID systems or anything that can transmit and receive information, over a communication channel. The device can be stationary or transit and are uniquely identified by their address and will be communicated either by wired or wireless technology. This connected objects and accessibility from anywhere at any point of time and value added services provided by them brings a better world for human being. The Internet of Things advances to the extent that number of 'Things' connected is far more than the total population of the world. As these many devices are connecting and sharing information, massive amount of data will be generated. This data will be meaningful only if we are able to draw insights from it. There comes the importance of analytics. The Internet of Things along with predictive analytics helps to realize the concept of Smart City.

Smart City initiatives in India: As per the Census report in 2011, 63% of India's GDP comes from the urban areas and only 31% of India's population is residing there. Population residing in rural areas started shifting to urban area for a better lifestyle. By 2030, country is expecting 40% of population will be there in cities and that will contribute 75% of India's GDP. For accommodating this urbanization, development in infrastructures in terms physical, economic and social are mandatory. Both government and private sectors already initiated some program by investing in this areas [1]. In 2014-15 Budget, Government of India allotted 70.6 billion for smart city projects. Smart Solutions for a Smart city can be categorized based on the service sectors. Water and Energy management are the key areas of focus. Smart Meters (which can monitor and manage the consumption and distribution), water quality monitoring, leakage identifications etc. are few challenging solutions in Indian scenario. Smart grids, renewable source energy management, green building etc. are some solutions coming under Energy management. Smart Parking, intelligent traffic management, integrated multi-modal transport can bring Smart transportation to the city. Smart waste management, air quality monitoring and noise monitoring system can add more values to smart environment.

Smart Water Management: Water is one of the vital resources for human life. The dramatic change in climate and increase in the population made water insufficient compared to demand. As the consumption of water is increasing, water management becomes a big challenge for both the government and water companies. The challenge also includes providing quality water at minimum cost and energy use. Water management have role in many aspects of human lives like water consumption, agriculture, food production, environment etc. [2]. Water is required for generating energy and energy is needed to provide water.

Existing systems spend more time for gathering data and concentrate less on insights that can be drawn from data. The water level in tanks has to be collected manually. In a delivery system, reading from flow meter and pressure meters are taken manually. Water quality is checked by taking samples which is then tested from labs and also this will take few days to get the result. Smart water analytics can bring a change for this by bringing the real-time data in front so that the analyst can spend time on analysis and actions in short time and at low cost. Smart water management systems include real-time monitoring of water levels, identifying leaks in distribution systems, monitoring and maintaining water quality.

The rest of the paper is organized as follows. Section 2 discuss the literature survey in which different architecture and technologies used in Internet of Things, various cloud platforms for IoT, and components for IoT. Design of the proposed system is discussed in section 3 and section 4 briefs the implementation details and the results. Conclusion and future enhancement is discussed in section 5.

2. Literature Survey

Smart Water Management is mainly concentrating in reducing the challenges facing in the water sector. Information and communication Technologies (ICT) plays a major role in Smart Water Management (SMW) [3]. SMW can maximize the social and economic welfare by integrating ICT products and can be effectively used for continuous monitoring, finding anomalies and the data can be used for optimizing the water distribution network. SMW includes data acquisition and integration using sensor networks or smart meter, data distribution using WiFi or internet, data processing and storage using cloud technologies, modelling and analytics and visualization and

decision support using web based tools.

The basic three tier architecture for Internet of Things is discussed in [4]. The bottom tier consists of variety of ‘things’ or ‘objects’ such as sensors, mobile phones, actuators etc. The middle tier is the network tier which can be wireless or wired for a reliable transfer of information generated/collected by the ‘things’. Application layer is the top layer where the data is processed, analysed and made available to end users as knowledge rather than information. Different technologies like RFID, Wireless sensors, addressing schemes etc that can be used in implementing IoT have been discussed and a comparative study on different wireless technologies like Bluetooth, Wi-Fi and XBee is made in [5]. The comparison is made based on the factors like operating band, coverable distance, power consumption etc. XBee has lot of advantages over the other two which includes larger distance coverage, lower power requirement, better latency etc. Also XBee takes only 15 ms to wake up from sleeping mode where the Bluetooth require 3–4 secs. The XBee technology uses protocols such as ACL or AES which exhibits a high three tier security. The challenges facing in the data transmission and power are discussed in [6]. Device to device communication (Personal area network), Wi-Fi, mobile broadband, satellite communications are the options for wireless communication. A mesh network design is suggested [7] when there is regularity in spacing between the sensing devices. Each device can act as a communication hub for the next device. Another challenge in the transmission is the power required for the device that uses wireless technology/protocol. The need and advantage of using IPv6 addressing schema is discussed in [15]. As the number of devices that connect to internet increases and also each of these devices need a unique address, we are forced to adopt IPv6 addressing schema. We can address 2^{128} devices by using this schema where as it is possible to address only 2^{32} devices by IPv4 schema.

The proposed IoT system make use of Raspberry Pi and Arduino for data collection. A comparison is made between Raspberry Pi and Arduino in [9]. Raspberry Pi is low cost full functional computer where Arduino is single component of a computer (microcontroller). Raspberry Pi is step ahead of Arduino when comparing in terms of software applications, but in terms of hardware projects Arduino is much better. Arduino can be used in places where real-time and analog data has to be captured and can work with any kind of sensors and chips, whereas Raspberry pi don't have this feature. Arduino can be used where places need a single process to run for a long time and Raspberry Pi can be used where more processing and computer functionalities are needed. ESP8266 WiFi Chip [8] is a self-contained Wi-Fi module that can provide Wi-Fi capability to any microcontroller. Arduino or other microcontrollers will communicate to this chip over UART whereas sensors or application specific devices communicate via GPIO pins.

In the cloud era, the application platform is delivered as a service, often described as Platform as a Service (Paas). A ‘Platform as a service’ is an environment that allows developers to deploy applications with minimum overhead where the underlying infrastructure is invisible to them. IBM Bluemix[9], Ubidots[10], Carriots[11], Nimbits[12], Thingspeak[13] are leading cloud platforms that support IoT. A comparison of few more platforms is discussed in [14] and a summary of the same is formulated in Table 1

Table 1. Comparison of Cloud platforms for Internet of Things

Name	Description	Supporting Hardware	Operating System	Programming	Advantage/ Disadvantage
Xively	Offers features in Enterprise level	Raspberry Pi, Arduino, Beaglebone	Embedded C/C++, Arduino, Linux	MQTT, C, JAVA, Ruby	Adv: Supported hardware/OS are open sources
Thingsquare	Special OS for IoT and wireless sensor network. It supports IPv6.	Texas Instruments TI-CC2538, MSP 430, Atmel R21, Atmel D20	Contigi OS	C, Websocket	Adv: online IDE, Full AES128 Encryption Disadv: Supported hardwares are limited
Thingworx	Platform for business and enterprise level Supports ERP, CRM and Bigdata analytics	Digigateway, Eurotech, Libelium	GNU/Linux	Python, Java, MQTT, C, Websocket	Adv: Can be used in industries like medical, manufacturing, smart cities etc

3. Proposed Smart Water Management System

Water is a scarce resource which has to be monitored efficiently, and also measures have to be taken for efficient supply and distribution. This work aims at proposing a design for this through a Smart Water Management System using the techniques of sensors (Internet of Things) and Analytics. Towards realizing this, we are in a process of implementing this in our campus. Currently all the data collection and analysis is done manually. We are trying to provide an IoT based solution for this. The solution includes collecting water level from the tanks using sensors, transmitting it to a centralized server using Arduino and Raspberry Pi, visualizing the data through a web interface and also in the cloud using Ubidots cloud Platform. The solution also includes SMS and email alert system.

The systems comprises of the following

- **Point of Use** : Point of Use (PoU) are the places where water level sensors has to be deployed. There are two types of PoUs , Sumps and over head tanks (OHT). 4 sensors to be deployed in every PoUs at levels 20%, 40%, 60% and 80%. The sensors will give a TRUE if water is present at corresponding level and FALSE otherwise. One Arduino board with BLE has been used at every PoUs for data collection.
- **Echo Module** : The PoUs may or may not be in the range of Wi-Fi. An arduino board with BLE can be used as echo module. This module can be treated as a hop. Number of such hopes required depends on the distance between PoUs and the place having Wi-Fi range. The receiving module, Push module (i.e the hop in the Wi-Fi range) designed as arduino with Bluetooth in software serial and Wi-Fi in hardware serial port. This arduino will push the data to a file in local server.
- **Data processing and Integration** : A Raspberry Pi, low cost full functional computer ,with Wi-Fi connectivity can be used as the central system. Data from the local server will be fetched by the central system and can start processing. Raspberry Pi has to be configured in such way that it has to perform the following functionalities.
 - Populate the data to corresponding tables for visualization
 - Populate the data to cloud
 - Trigger Email/SMS alert when water level goes below threshold
 - Trigger Email with different reports in daily/monthly/yearly basis

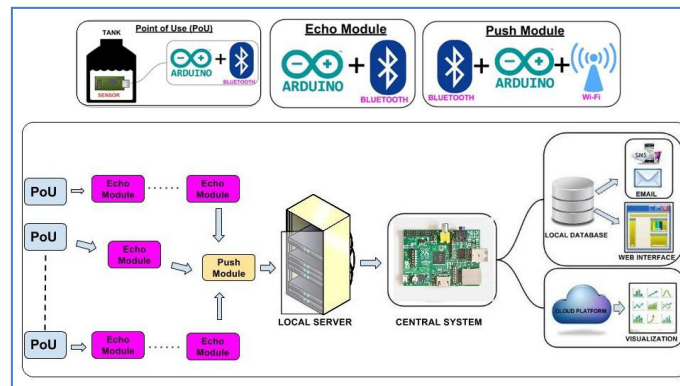


Fig. 1. Proposed architecture diagram for a SMW system

4. Implementation and Results

The implementation of the Smart Water Management system is done in two stages. One is processing the strings/data from PoUs and populating the necessary data to database. Second is the pulling the data from database and made available for visualization, alert systems etc. Raspberry Pi is configured so as to function it as a central system. Installed debian Operating system, lampserver for web server and MySQL database. cron jobs are used for scheduled running of scripts that will generate reports in daily/monthly/year.

A. Data Processing

Sensors are deployed in PoUs. Each PoUs contain 4 sensors at different levels. Sensors will give a TRUE if water is there at that level else return FALSE. One Arduino board is deployed for each PoUs. Arduino board is configured to capture the data from sensors and then encode it in the form of #<tanktype><tankID>_<T/F><T/F><T/F><T/F>#. Example of the string is #S105_TTFF# which indicates, it is the data from the sump which has id 105 and have water level above 40% and below 60%. For the ease of calculation we are assuming there will be 50% water. All PoUs will send the string to the local centralized server from which the processing starts.

Algorithm for Data population

1. MasterScript – This script will execute Process_file script in every 5 minutes
2. Process_file
 - Copy all strings from the file to a temporary file for processing and flush the file in server for next batch to come
 - Read each string from the temporary file and do the following (Eg : #S105_TTFF)
 - Validate the string and split the string as Tank Type - S , Tank ID - 105 , Level - 2
 - If the type = 'O' (overtank) execute upd_consum and upd_exus procedures
 - execute upd_waterlevel(type,tank_id, lvl)
 - if ((type=S and level<2)or(type=O and level<1) execute sms_alert(tank_loc,level)

Upd_consum

- Will check if there is record in that day for that tank_id
 - If yes and the prev_level is > current level
 - Add quantity consumed in that interval to the existing quantity
 - Else if prev_level is < current level { Increment refill count by one }
- If no record, add a new record with that tank_id and date

Upd_exus

- If (Prev_level -current_level) >=2 and time difference between the records is greater than 5 mins
 - Insert record to Excess use table – which is further used for analytics

Upd_waterlevel

- Update the WATERLEVEL table with current level, data and time

B. Visualization and alert system

Water Level			Consumption			Excess Use			Missed Packets			Visualization		
Priority	Location	Capacity/Available/Level	Priority	Location	Capacity/Available/Level	Priority	Location	Capacity/Available/Level	Priority	Location	Capacity/Available/Level	Indicator	Level	Percentage
1	Academic Block 1	250000 / 125000	1	AC BLK1 OHT2	Academic Block 1	80000 / 40000	1	Nachi OHT2	Nachiketas Bhavanam	70000 / 63000	1	●	4	>80%
1	Quarters Nr CIR	200000 / 60000	1	Nachi OHT1	Nachiketas Bhavanam	70000 / 7000	1	Gargi OHT1	Gargi Bhavanam	80000 / 40000	1	●	2.3	>60%
1	Gargi Bhavanam	250000 / 175000	1	AC BLK1 OHT1	Academic Block 1	80000 / 40000	1	YB Hostel	YB Hostel	70000 / 21000	1	●	0.1	<40%
2	Gautham Bhavan	150000 / 105000	2	CIR	Quarters Nr CIR	70000 / 35000	2	PG Mess Hall	YB Hostel	70000 / 21000	2	●		
2	Vyasa Mahirishi Bhavan	150000 / 75000	2	ASB	Quarters Nr CIR	70000 / 49000	2	YB Hostel	YB Hostel	70000 / 21000	2	●		
2	YB Hostel	200000 / 100000	2	YB Annex	YB Hostel	70000 / 63000	2	Vyasa OHT	Vyasa Mahirishi Bhavan	80000 / 24000	2	●		
2	Nachiketas Bhavanam	160000 / 80000	2	Mythreyi OHT2	Mythreyi Bhavanam	60000 / 54000	2	Vassista OHT1	Vassista Bhavanam	60000 / 18000	2	●		
2	Academic Block 2	125000 / 37500												
2	Academic Block 3	175000 / 52500												
2	Vassista Bhavanam	250000 / 125000												
3	Agasthya Bhavanam	150000 / 45000												
3	Mythreyi Bhavanam	150000 / 75000												

Fig. 2. Screenshot of Web Interface for Smart monitoring system

The visualization is achieved in two ways. A webpage has been developed using HTML and PHP. The page has multiple tabs like Water level, Consumption details, Excess Usage, Inactive/out of order PoUs. The water level

tab will be refreshed automatically in every 5 mins and will display the individual sump/overtank capacity, quantity available and a RGB visualization of the current level. Also this tab will give the summary of total capacity, quantity available and quantity required for both sump and overtank. The Consumption tab will provide the details of quantity of water consumed, frequency of refilling in daily, weekly, monthly or yearly basis. This data will help to give a warning / notification to the corresponding authorities so that the consumption in coming days can be reduced. Other way of visualization is done through Ubidot cloud. The services provided includes an alert system which will trigger alerts like sms, email when the sensor value hits a threshold. For each user an API key will be provided. One variable for each PoU is created in the dashboard. The unique ID provided for that variable is used to assign values. Using Raspberry Pi data is collected and Python script is used to integrate the device with Ubidots cloud and push the data to cloud.

Alert System

Mail alert : Excess water consumption details will be captured from the exus table and will send as mail to the concerned person/group. smtp library in python is used for sending mail alert. Thexlswriter package is used to generate excel files from the tables and can be sent as attachments

SMS Alert : SMS alert system is implemented in such a way that SMS will be triggered to corresponding lorry drivers when the level of water in tank goes below a threshold. Txtweb is used for this service. 20 APIs are created for this project for sending SMS to concerned persons.

5. Conclusion and Future Enhancement

A detailed study on emerging technology, Internet of Things and Predictive Analytics is made and its relevance in the context of Smart City has been discussed. Different technologies that can be used for a Smart water management system is also discussed. A study has been made on various IoT based cloud platforms. A design for a cost effective Internet of Things based Smart water management system has been proposed. The implementation details of smart water monitoring system in Amrita campus is discussed. The implementation is done for few tanks and in future it can be extended to all tanks and the data collected can be used for further analytics like consumption forecasting, water leakage detection etc.

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