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Automated Water Billing and Leak Detection System Control Strategy Development for Smart Water Management in Smart Cities

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***Abstract*— Water leakage is a significant factor in overall water losses, and effective metering can help identify and locate leaks, raising consumer awareness about water usage. An automated water billing and leak detection system in smart cities aims to address these issues by employing advanced technologies. Metering not only helps in tracking consumption but also plays a crucial role in detecting leaks, thus allowing utilities to automate their water systems and identify problem areas early. The development of such a system provides numerous benefits, including proactive leak detection, enhanced customer tools for monitoring water use, and more accurate billing rates. By integrating message and Wi-Fi (IoT) technology, the system can automatically collect consumption data, diagnose issues, and gather status information from energy meters. This automation saves utilities the cost and effort of periodic trips to physical locations for meter readings, streamlining the process and making it more efficient. One of the key advantages of this smart water management system is its ability to base billing on near real-time consumption rather than on estimates or historical data. This approach not only makes the billing process faster and more accurate but also helps in reducing water wastage. By providing customers with real-time data, they can be more mindful of their water usage, thereby contributing to overall water conservation efforts in smart cities.**

***Index Terms*— Leakage detection, IoT, Arduino IDE Leakage**

I. INTRODUCTION

As Water loss during distribution is considered a major waste. It has been observed that a large amount of water loss happens close to the source of purified water, even before the distribution network. Measurements of per capita water availability indicate that India is currently water stressed; future projections indicate that India may have water scarcity by year 2050. In this scenario, leakages in the water distribution system can have a huge impact on the water availability [4]. Water flow conservation encompasses the policies, strategies and activities to manage fresh water as a sustainable resource, to protect the water environment, and to meet current and future human demand. It also deals with digitally "noting" the energy meter reading(s). This process eliminates the traditional

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“paper and pen” and the errors associated with manual reading/recording/processing of the meter data. AMR came into existence since energy meters turned intelligent which dates back to the deployment of microcontrollers in energy meters [1].
Automatic Meter Reading also makes the data recording fast and saves on time and hence complies with the definition of automation. Water is the renewable and an abundantly available natural resource on the earth. Water covers 70% of the Earth‟s surface. Out of this, only 3% of the water is portable. Water has its utility in domestic purposes, industrial usage, agricultural field etc. Population growth causes insufficient and uneven distribution of drinking water [3]. Earth consists of 97% of salt water and 3% of fresh water in total. Of this 3% of fresh water, 68.7% constitutes of ice caps and the glaciers. 30.1% consists of ground water, 0.9% of other water and 0.3% of surface water. Of this 0.3%, 87% consists of lake water, 2% of river water and 11% for swamps [5]. The rapid development of science and technology improved the sensors and flow meter designs to achieve proper water supply through storage tanks, pipes etc To facilitate the domestic and industrial water supply needs, government has formed water boards which monitor the proper supply of water throughout the nation. It acts as the regulating body abided by the rules framed by the government [2].
Water acts as a primary source in the industries; hence, there arises a need of accurate measurement of water flow. In the domestic sector, water is used for all household activities. Excessive usage of water needs to be avoided and a system is required to monitor the over usage of water. This paper aims at developing a meticulous water management system at a city level that will guarantee measured, recorded and continuous supply of water with 24x7 supply of water, overcoming the major issues of unaccounted supply to entities and Non- Revenue Water (NRW). Instead of providing unregulated water for a limited period i.e. a time based water system (currently deployed in many parts of India), a quota-based system is proposed wherein water will be provided all day. The quantity relegated to every element will be chosen powerfully dependent on different organic market parameters [5].

II. Literature Survey

Paper 1 : A proposed approach for automatic supply of purified water along with bill generation in context of bangladesh
By turning off id.Water crisis and pollution are two major existing problems in current state of Bangladesh. Some traditional water level indicator along with notification system and purification arrangement is available in this context. However, the indication and purification system is not fully automated and there needs a lot of maintenance overhead. In this paper, a novel model is proposed to conduct an automatic indication and two-layer purification process for home water.The automated indication system is necessary to stop the probable scarcity of drinking water, wastage of water in various levels and purification system is needed for safe drinking water. Proposed system can also maintain the proper distribution of water during hot and humid weather by sensing temperatures and humidity. Finally, this system will generate automatic bill depending on the exact amount of usages of water by individuals.
Paper 2: Automated household water supply monitoring & billing system
The paper describes our research in household water supply monitoring & billing. Arduino mega 2560 was utilized in this project along with double relay for automation of the switching feature and water level sensors and water flow sensors was used to detect the level and the amount of water used respectively. The feature of this project is automatic switching of the DC water motor based on the level of water present in reservoir along with display of the amount of water used in each block. For the display, an LCD Alphanumeric display was used. We have also included a set capacity of usage for each floor and billing according to usage
Paper 3: Smart water meter using power line communications (PLC) approach for the measurement of accurate water consumption and billing process
Data transmission methods have been evolved drastically with the development of internet. Data transmission methods are of two types. One is wired and the other one is wireless networks. Power line communication is considered as one of the tools that are used for power transmission using special type of modems that takes the data with known frequencies. The paper proposes smart water meter that uses flow sensor that collects household water consumption. The proposed system will be set to a threshold limit where the water is cut-off using electronic valve. The collected data will be sent to data center for data analysis through grid power line using PLC modem. The data center further forwards the water billing department for billing purposes through SMS and then it will be sent to user mobile number. The proposed work aims at increasing accuracy of reading and collection process. The benefit of this work is reduced human intervention and measuring tools

Paper 4: Smart water monitoring system for real-time water quality and usage monitoring
This paper aims at designing a Smart Water Monitoring System (SWMS) for real-time water quality and usage monitoring. It consists of two parts: Smart Water Quantity meter and Smart Water Quality meter. The objective of designing Smart Water Quantity Meter is to ensure water conservation by monitoring the amount of water consumed by a household, notifying the same to the consumer and the authority. A three-slab billing system generates consumption bill according to the quantity consumed. The Smart Water Quality meter checks the purity of portable water that the consumer receives, by measuring five qualitative parameters of water viz. pH, temperature, turbidity, dissolved oxygen and conductivity. The system ensures to prevent any health hazards or potential threats caused due to accidental seepage of sewage or farm release into the portable water. An online monitoring system is to provide these data on the cloud in real-time. Any violations in either the usage limit or water quality is immediately notified to the consumer and authority via SMS and an alert signal generated by the system.
Paper 5 : Optimization of water consumption using dynamic quota based smart water management system
Water is a vital resource for life and for the economy. Nowadays, one of the most serious challenges to solve is to manage water scarcity. As the importance of water usage optimization in monetary point of view is not that pronounced, we lack the incentive to in implementing technologically advanced systems for organized distribution of water. This paper describes the development of a meticulous water distribution system at a city level that will guarantee a continuous supply of water, overcoming some major issues like unaccounted supply to entities and Non- Revenue Water (NRW). A centralized control room equipped with a local computing machine and a Human Machine Interface (HMI) to monitor and control the city's water system is proposed. A smart tariff system should be exercised with an IoT- enabled mobile-friendly web portal developed for accessing various water usage statistics accompanied with an option of paying water bills online. In this volumetric, limit based model, the quota assigned to each entity is decided dynamically based on various supply and demand parameters including the availability of water with changing seasons. Adaptive learning through machine learning algorithms was used for the same. Unbilled, unauthorized consumption, apparent losses (water theft and metering inaccuracies) and transportation losses was curbed by monitoring from a remote location via IoT. Higher degree of theft and leakage was concluded using loss detection technique using the differential flow data. Here, a novel, cost-effective, real-time monitor able and controllable system is proposed with an analysis on a model simulation being performed for optimal water distribution.

III. System Architecture

The prototype for the flow conservation is to measure inflow and outflow of water. Water supplied from water distribution authority is stored in ground level reservoirs and overhead tanks and is further distributed to rest of the consumers. This project installs flow measurement sensors at the input and then measure water volume in the water reservoirs [6]. The volume of water inside the reservoir would give the accumulated difference between inflow and outflow of water. Hence, then the outflow can be calculated. If the volume of the water crosses the threshold level, the system will automatically stop the water supply. The water supply can start as soon as the leakage is rectified [7]. Advances in water meter technology can automatically record and report leakage within customer owned portion of the plumbing by detecting a constant flow of water. Automatic Reading and Management using Mobile Agents can be of great importance for municipalities and energy distribution companies so as to minimize the number of traditional visits required by the distribution company, hence decreasing the number of employees used in performing this traditional time consuming and high cost work. Such technology not only helps to conserve water, but helps the customer avoid unnecessarily high water bills. AMR system is divided into four basic units. These are: Reading unit, Communication unit & leakage detection, Data receiving and processing unit, billing unit [8].

IV. Arduino Uno

Arduino / Genuino Uno is a microcontroller board based on theATmega328P [9]. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0 [10]. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino , now evolved to newer releases. The Uno board is the first in a series of USB

Arduino boards, and the reference model for the Arduino platform, for an extensive list of current, past or outdated boards see the Arduino index of boards [11].

V. LCD DISPLAY

A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome [12]. LCDs are available to display arbitrary images (as in a general- purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and 7-segment displays, as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements. are, however, susceptible to image persistence [13].

VI. FLOW SENSOR

Sensors play a very crucial role in today‟s automatic systems. Being a small, low cost and reliable device, sensors are easy to embed with larger electronics. Today we can find various types of sensors in the market. With the advance in technology, sensors are also evolved in their functioning and size [14]. From the early size of cm units, size of sensors has shrunk to the scale of nm. Sensors have also solved many challenges of electronic and electrical engineering such as finding the intensity of ambient light, determining the temperature in the furnace, calculating humidity of surrounding, etc. Water flow sensor gives an amazing solution for measuring the flow rate of liquids [15].

VII. SOLENOID VALVE

12V DC Solenoid Water Air Valve Switch (Normally Closed) – 1/2″ controls the flow of fluid (liquid or air) and acts as a valve between high-pressure fluid. This liquid valve would make a great addition to your robotic gardening project [16]. There are two ½” (Nominal NPT) outlets. Normally, the valve is closed. When a 12V DC supply is applied to the two terminals, the valve opens and water can push through. The valve works with the solenoid coil which operates electronically with DC 12 volt supply. As it is a normally closed assembly, it opens flow of fluids as soon as it is powered ON & stops/blocks the flow when supply voltage removed [17].

VIII. NODE MCU

The NodeMCU is a development board built around the ESP8266 system-on-chip (SoC), renowned for its embedded Wi-Fi capabilities [18]. Leveraging the ESP8266's powerful computing capabilities and integrated Wi-Fi connectivity, the NodeMCU facilitates seamless integration of wireless communication into Internet of Things (IoT) projects. Featuring a compact form factor and an onboard Wi-Fi antenna, the NodeMCU is engineered to enable rapid prototyping and development of IoT applications requiring remote monitoring and control. Its compatibility with the Arduino Integrated Development Environment (IDE) provides developers with access to a rich ecosystem of libraries and tools, streamlining the development process. Equipped with GPIO pins and analog inputs, the NodeMCU offers extensive interfacing capabilities, allowing for seamless integration with sensors, actuators, and other peripheral devices.

IX. WORKING PRINCIPLE

- *Flow Sensors*: Flow sensors are placed along the water pipelines to measure the flow rate of water passing through them. This data is crucial for calculating water consumption.
- *Arduino Uno*: Arduino Uno serves as the main controller of the system. It collects data from the flow sensors and controls the valves based on user commands or detection of water leakage.
- *NodeMCU*: NodeMCU is used for internet connectivity.It enables the system to send data to the cloud or communicate with other devices, such as smartphones, via Wi-Fi.
- *Valves*: Valves are used to control the flow of water. Arduino Uno controls these valves to shut off the watersupply in case of leakage or based on user commands received through the Telegram platform.
- *LCD Display*: An LCD display is integrated to provide real-time information about water consumption, leakage detection, and other relevant data.
- *Arduino IDE and Embedded C*: Arduino IDE is used for programming the Arduino Uno and NodeMCU. Embedded C is the programming language used to write the code for the microcontrollers.

- *Telegram*: Telegram is utilized as a platform for users to interact with the system remotely. Users can receive notifications about water usage, detect leaks, and even control the valves through commands sent via Telegram.

X. METHODOLOGY ADOPTED

- Flow sensors continuously monitor the water flow rate.
- Arduino Uno collects data from the flow sensors andprocesses it.
- If abnormal flow patterns indicative of a leak are detected, Arduino Uno sends a notification via Telegram.
- Users receive notifications and can take action by remotelycontrolling the valves through Telegram commands.
- Additionally, users can monitor their water consumption inreal-time through the LCD display or via the Telegram interface.
- Valves are automatically shut off by Arduino Uno in case of detected leaks, preventing further water wastage until the issue is resolved.
- NodeMCU enables the system to connect to the internet, facilitating communication with the Telegram platform for remote monitoring and control.

In this project, initially the system should be reset after some amount of water has been received by the client. The valves are automatically turned OFF and the usage data will be sent to the client that the minimum amount of water required has been transmitted. If the client requires extra amount of water the device sends request for the if YES the extra water transmitted to the clients and the bill is generated for both the number of water. If the minimum amount of water is enough for client the bill is generated only for this amount of water. The flow of water is observed in both SENDER and RECEIVER part through the flow sensors. If any difference in the reading observed the device alerts the SENDER that water has been leaked. This project works on request basis where the minimum required amount of water is first sent to the consumer, but if extra water is needed then the consumer requests for extra water through Telegram. When the request is given then the water is distributed to the consumer with accurate amount of water with the help of Flow sensor. If the requested amount of water is not provided then it sends a signal to the provider that there is a leakage. The consumer is asked to pay for only the extra water when requests.

XII. RESULTS & OUTCOMES

Fig. 1 : Implemented project photograph - 1

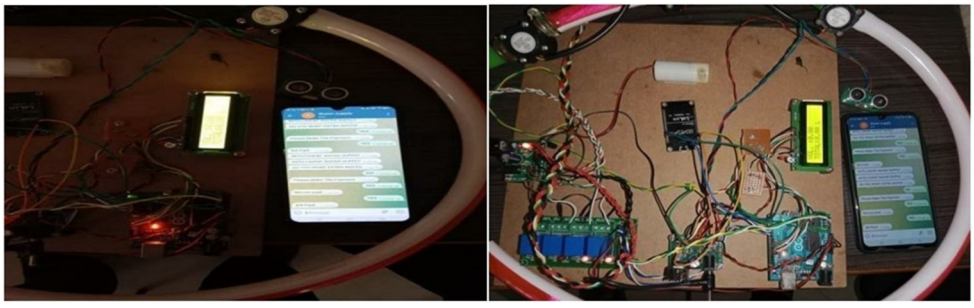

Fig. 2 : Implemented project photograph - 2

The above figures shows the working of the project model. Fig. 1 and 2 shows the connection and the hardware used and the circuit are rig up. Here we can see all the components used and the connections are made according to the needs and then the program is dumped to the hardware using Arduino Uno software. We can see the water

flow sensors connected to the pipe where it is used to measure the amount of water which flows from the sender to the consumer. The Figs 1 & 2 shows the amount of water consumed by the consumer using the 16 x 2 display and the mobile is connected to the hardware and the communication takes place using Telegram. So, if any extra mount of water is required then the consumer asks the amount of water needed and the payment should be done right after the water is sent. The Figs 1 & 2 shows the overall working of the project where all the process are seen and observed.

XII. Conclusions & Future Enhancements

As discussed in this project, leak detection plays an increasingly important role in water conservation. Thus, adopting water conservation methods and technologies that support water preservation and management is an area of increased priority. By investing in such technologies and systems now, communities can significantly reduce consumption and ease the strain on our nation's water supplies. The paper describes the design and working of Smart Energy Meter and represents how Smart Energy Meter can be used for Automatic Meter Reading. It is the most economical implementation to develop mankind in this era of technology. Detecting leaks helps saving water resources, cost and energy. More water is available to consumers and can be billed. Water recontamination after centralized treatment is less likely to happen in the pipes. With the present enhancement in the use of technology to facilitate mankind, it is an efficient and practical utilization of present networks. This paper also shows that how customer can manage the load by using Smart Energy Meter. It provides ease in taking the meter readings, accuracy, and detection of faulty readings. The leakage control can be enhanced by incorporating sensors at the line connecting each and every house to detect the leakage. Provisions can be provided to the customers to send an alert message to the authority in case of any faults or damage occurs to the meter or the pipe can be reported to the utility providers by sending an alert message which will stop the water connection to that particular house.

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