Smart Water Quality Monitoring and Metering Using Lora for Smart Villages

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Abstract— **Water is the basic need and elixir of life. Our daily water supply is through water tanks and dams which are constructed to store water for future usage. From there water crosses many stages through pipes to reach our homes. At each level, source water is prone to mix and get polluted from the environment and humans. Excessive water overflow and pollution are the major cause of the depletion of water. The objective of the work is to monitor water quality, distribution, usage in Potable water and Chemical leakage detection in rivers, etc using M2M-LoRa. LoRa is a new type of wireless connectivity in the unlicensed 433MHz and 868MHz used for long-range transmission upto 15Kms. The proposed work is mainly for Smart Village Projects. The LoRa mote along with sensors will be placed in water tanks (200 locations) at villages and within corporation limits. The system will continuously monitors the quality and level of water in all tanks and displayed in a common place where the entire water distribution system can be controlled from one place. The distribution system saves the water and monitoring system controls the distribution of polluted water. Finally, the potentiality of the smart meters for water distribution is discussed.**

Keywords- Smart Village; M2M; LoRa; LoRaWAN; Smart Meter; Water Quality; Water Level.

I. Introduction

Smart Village: There is no unique definition or Framework for smart Village. Based on the requirements, each country and state defines their own definition for smart Village according to the geographical Location, their requirements and the economical conditions. In Indian villages, the distribution of electricity, water is done manually. Innovative technologies are applied in Public Work Department (PWD)-water section to optimize the consumption and reduce the wastage. These solutions can be used in smart irrigation, water supply plans in village and cities, industries, even to improve fish production, Rupsa G et.al provided Energy efficient and street lamps solution through automation for saving energy in smart villages. [1]. IEEE smart village development is going on in Himalayan Expedition and Nigeria to provide clean energy, education where the projects were undertaken by IEEE smart Village partners and entrepreneurs [2]. Sanjeev K have explored Information ad Communication Technologies to develop a Smart Village and a possible framework for implementation with solutions [3]. Pritesh says the development of smart villages reduces the migration of people from village to urban areas as well increases the population flow from urban to rural areas [4]. Current reviews and researches says that there is lack of consideration of water in smart village projects. Hence our research and product development concentrates on water which is an important thing for human life. The distribution of quality water in Urban and rural areas to consumers, general public are a challenging task. Since the water have to travel through different areas and prone to get polluted from the environment. The requirements of water quality for agriculture, maximum concentration on irrigation water and saline water for livestock and poultry are discussed in [5]. J.Pasecho et.al introduced an IoT security Framework to integrate Smart water system with IOT and focused in cyber-attacks targeting smart cities [6]. R. Rediana and B. Pharmasetiawan developed a business model for confirming the technology, business aspect, integrating commercial and social purposes by combining the four models: quality, quantity, continuity, and connectivity [7]. M. Razaghi and M. Finger discussed the technological innovations in urban systems which provide new opportunities to improve the performance of cities and addressed the changes in the sociopolitical culture of societies [8].

C K Wu et.al proposed a time-synchronized ZigBee building network to collect the sensed data from the building and transfer to the backend server for water management [9]. Gaurav Gosavi discussed about the demand management, asset management, and leakage management in water management system [10]. Kunwar P. S et.al used multivariate statistical techniques to get the water quality from the large data sets and designed a monitoring network for management of water resources [11]. Malche T and Maheshwary P proposed an IOT based water level monitoring system using arduino with ethernet for internet connectivity. Since the proposed system can be suitable for prototype and cannot handle huge amount of traffic from more number of systems. Also this system requires internet where the net connection is not available in most of the villages [12].The distribution of water and monitoring the quality of water is also done manually. Due to the manual process, huge man power is required and wastage of water in lots of place. In order to make the system automatic without the human intervention and to save the water an automated using Machine-to-Machine (M2M) with LoRa communication is proposed.

Machine-to-Machine (M2M) communication is a communication paradigm which involves communication between nodes without direct human intervention [13]. LoRa is a novel wireless technology developed by Semtech corporation which enables transmission of low data rate for long distances which will support for M2M [14]. LoRa uses chirp modulation. LoRa is one of the wireless networks which provides services for Smart city applications and hence finds commercial interest all over the world. Smart city requires an existing cellular network like 4G/LTE/VoLTE for accessing internet to provide connectivity among the M2M devices. Machine Identification Module (M2M sim card) provides services to the M2M network from existing Mobile operators. Recent Research says 50billion devices will be connected in India by 2022 for smart city/village and smart home projects. The existing cellular network cannot provide service for this application. Marco et.al [15] introduced a new approach to provide connectivity in the M2M, LoRa and LPWANs are inherently different from usual IoT architectures, which are typically characterized by short-range links and mesh topology can be used long range links in smart city applications.

The rest of the paper is organized as follows: Section II discusses the M2M, LoRa and its parameters. Smart metering and smart water quality is discussed in Section III. Section IV discusses the Data acquisition process. Finally section V concludes our paper.

II. M2M-LoRa and Its Parameters

A sensor node in Sensor network, monitors physical parameters and transmit to the end user. The communication range is limited based on the devices like Bluetooth, wifi, Zigbee used. A M2M area Network (M2MAN) where M2M communication allows edges/nodes to communicate each other and do certain actions base without human intervention. An M2M network uses the existing network like cellular networks to transfer the data's in any part of the world. Typically Machine Type Devices (MTD) transmits/receives small amount of data. Requirement for the design of MTD to build a M2M network are Small size, Small Processing unit, Low memory, Low power and Low Data rate. LoRa is one of the alternate communication modules which provide services to M2M network even without the existence of networks like 3G/4G.

A. LoRa

LoRa is a physical layer modulation which uses Chirp Spread spectrum(CSS) with Forward Error Correction. LoRa operates in different frequencies based on the region. In India it operates at 433 MHz and 868MHz. A LoRa receiver can decode the data with 19.5db below the Noise Floor. The maximum Over the Air Data rate is 10.9 kbps in LoRa modulation.

LoRa devices Classes: LoRa network operates LoRa device is in three classes: Class A(all), Class B(Beacon) , Class C(continuous listen/Talk).

LoRa is a proprietary and LoRaWAN is open for development and developed by LoRa alliance, led by Semtech, Microchip, and IBM. The LoRa network is connected in Stars of star topology where the end nodes are interconnected through single hop Link to one or many gateways which in turn connected to network server and application server. The gateway act as relay and simply forward the packets to network server. The LoRa node may send the data to two different nearby gateways for requesting a service from Application server. While in return, the Network server determines the gateway which is closer to the LoRa node location and sends the acknowledgment/ service through one gateway only.

B. LoRa Parameter

A LoRa Transceiver mote can be configured to tune the receiver by varying following radio parameters.

- RF Transmission Power (TxP): RF Txp is the maximum power that can be selected to transmit the packets on air. TxP on a LoRa radio can be adjusted from - 4 dBm to 20 dBm, but because of limitation hardware implementation, the range is often limited to 10d dBm on 433MHz and 14dBm in 868MHz.
- Carrier Frequency (CF):The frequency at which the LoRa module Transmits at CF in different Channels The LoRa Module operates in two bands 863-870MHz and 433.050- 434.790MHz.
- Spreading Factor (SF) : In LoRa modulation, a chirp signal that continuously varies in frequency is used to spread the spectrum of the original data. In this case the time and frequency offset between the Transmitter and receiver are same. As well as the frequency bandwidth of this chirp and the spectral bandwidth of the signal are same. The data signal is modulated onto the chirp signal chipped at a higher data rate and SF ranges from 7 to 12. Simply saying, SF 7 says the ratio of the modulated signal to unmodulated signal bandwidth is 7.
- Bandwidth (BW) The radio Bandwidth (BW) of the LoRa Module takes any of the three values125KHz, 250 KHz, and 500 KHz.
- Coding Rate (CR) 4/5, 4/6/, 4/7.

The LoRa mote can be connected to other LoRa mote in point to point mode. The data are transmitted in plain form an intruder can easily access the data transmitted and inject the data as legitimate sender. Though the intended receiver will receive the data from the intruder as legitimate user. In this case security have to considered in point to point mode where as in LoRaWAN, the gateway take care of the security by issuing the keys for the LoRa mote registered or requested service from the gateway.

III. Smart Metering

Smart Meters are utility meters used in electricity, gas, water, heat meters used to measure the utilized amount and estimated the bills and provide the meter readings to customers and energy distributors and suppliers. Smart metering uses the intelligent meter installed at clients residence, offices and, process the data and gives feedback to the clients The objective of this smart metering is to save the water. Clients can make smart decisions by analyzing their water usage. The requirements of LoRa Application server for smart metering are:

- Must handle large number of LoRa and huge amount of data.
- Maintain high Quality of service and reliability.
- Efficient protocols are required

In order to save the water, Smart City-India- project have implemented a new regulation for water consumption. The objective is: by the year 2020, atleast 20%reduction in usage, 20% effective utilization of water by proper segregation of water based on their qualities. This can be easily achieved by smart water quality metering. Also smart metering finds attraction among the people.

A. Smart Water Quality Monitoring

In recent years, due to climatic change, air pollution, scarcity of water and human power for agriculture has threatened for human life. Water Quality monitoring ensures the quality of surface water or underground water both for human being and plants/animals. The water in the pond or lake may act as two different bodies with different densities as one floating one over the other. The surface water receives more sunlight than the lower layer and physically separated from the atmosphere. As a result of this the lower level water may have decreased oxygen when compared to the upper layer. The groundwater quality the composition of the recharge water, the interactions between the water and the soil, soil-gas and rocks with which it comes into contact in the unsaturated zone. Water for human consumption like drinking and cooking purposes includes treated or untreated (natural) supplied by any means for human consumption from any source must comply with the requirements shown in table1 [17] [18]. A water quality analysis in the District named Coimbatore, India says Nitrate is found in excess in about 80 percent samples due to the use of fertilizers for agriculture and other improper waste disposal [19].

Smart Water involves in water quality monitoring, water distribution and usage. M2M communication opens up completely for new possible applications in smart water quality monitoring system. The parameters to be monitored are turbidity, pH, Electrical Conductance (EC), Dissolved Oxygen (DO), Nitrate, Arsenic, Fluoride. Water quality monitoring involves analyzing water properties in rivers, dams, lakes and underground water reservoir.

- Water Quality: Turbidity, pH, Electrical conductance, Dissolved O2.
- Water Distribution: Pressure Level, Detection in leakage (if any).
- Water Usage: Remote Monitoring of water meters (usage), control of irrigation in farms.

Ion Monitoring for Various Applications:

- Drinking water quality control: Calcium ($Ca2^{+)}$, Iodide (I^{-}), Chloride (Cl^{-}), Nitrate (NO3), pH.
- Agriculture water monitoring: Calcium ($Ca2^{+}$), Nitrate ($NO3^{-}$), pH.
- Swimming pools: Bromide (Br), Chloride (Cl^{-}), Fluoride (F^{-}), pH.
- Waste water treatment: Cupric ($Cu2^{+}$), Silver/Sulfide ($Ag^{+}/S2^{-}$), Lead ($Pb2^{+}$), Fluoroborate ($BF4^{-}$), pH

TABLE I. WATER QUALITY STANDARDS

Standard	Technique	Data Rate
pH Value	6.5-8.5	No relaxation
Turbidity,NTU	1	5
Aluminium(Al) mg/l	0.03	0.2
Ammonia mg/l	0.5	No relaxation
Barium(BA) mg/l	0.7	No relaxation
Calcium (Ca) mg/l	75	200
Chloride(Cl) mg/l	250	1000
Copper(Cu) mg/l	250	1000
Fluoride (F) mg/l	1.0	1.5
Iron(fe) mg/l	0.3	No relaxation
Nitrate (No3) mg/l	45	No relaxation
Aluminum(Al) mg/l	0.03	0.2

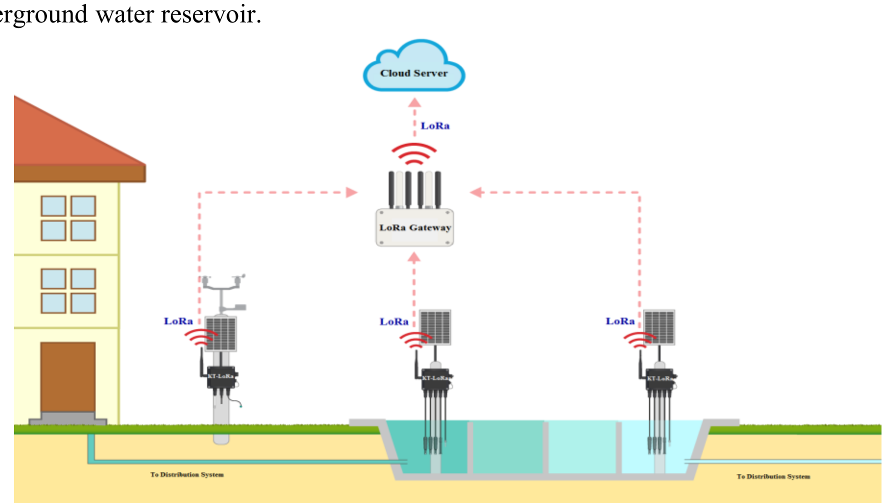

Figure 1. Water Quality Monitoring Network using LoRa.

Fig. 1 shows the water quality monitoring network using LoRa. Along with water quality sensors, Level sensors and Flow sensors are placed to quantify the incoming and outgoing water. Through this accountability, we can monitor the purposeful usage of water and save situations like “Overflow, Leakage, Excessive incoming and outgoing.” Another thing which can be observed is the period of water staying in the tank. Making the water stagnant for a long time even make it loses its property and get polluted.

IV. Data Acquisition And Processing Using LoRa And LoRaWAN

Sensors send the data about the quantity and quality of water to Application server. To transport sensor data, traditional communication protocols like Zigbee, Wi-Fi, Bluetooth are not suitable for remote locations, while they can be used in house hold water monitoring system. Data processing can be done at Edge nodes (saves the over the air time and network latency). The central location may be a local base station or a cloud based server or an edge device.

A perfect combination for Long range, Low data rate, and Personal Area Network is provided by LoRa WAN Technology. LoRa provides an optimal solution for monitoring water tanks in a radius up to 15kms, where several water tanks, pipelines, and water taps can be inter connected to make efficient use of water.

LoRa is an independent standard requires separate infrastructure. It can form a local network and can communicate to other nodes directly or through Gateway. The networking radius may be 15km in free Line of Sight propagation and 10Km in urban areas.

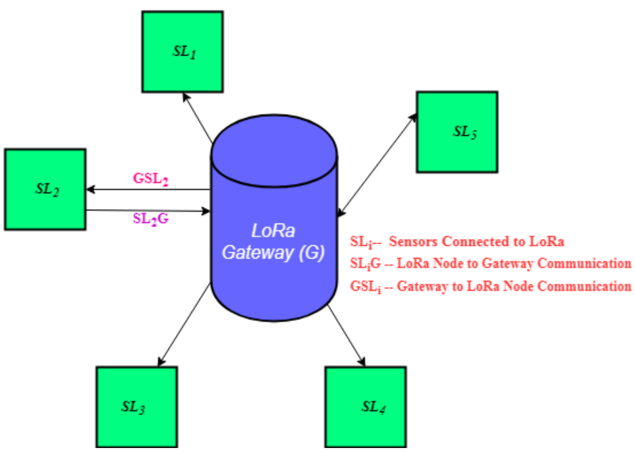

Figure 2. LoRA to Gateway Communication.

Fig. 2 shows the Communication between LoRa mote (L_i) placed in Water tanks and Lora gateway(G).In this scheme the link L_i-G and G-L_j can be activated simultaneously. The LoRa mote sends the data to Gateway through G_i.

The transmission power, data rate and other parameters are selected in the LoRa mote based on the Channel State Information and link outage requirements. LoRa to LoRa (L2L) thereby gateway link may be used if the LoRa mote is not with coverage link. The Gateway can manage the link and line up the power and data rate for transmission.

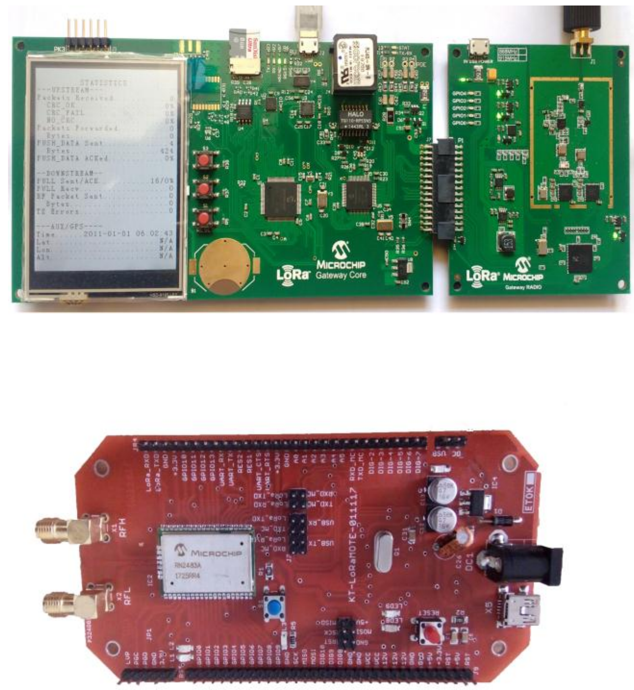

Figure 3. KT-LoRa Mote and Microchip Gateway.

Fig. 3 shows the KT-LoRa mote that uses Microchip RN2483 and Atmega328 processor is designed for this application. Microchip LoRaWAN Gateway core board with radio daughter card at 868MHz is used as gateway.

Non contact water level Ultrasonic Sensor is used to measure the water level of the tank. This sensor is best suitable for measuring open channel flow in larger flumes like the level of river, lake and tank. The Sensors for monitoring the quality, quantity, level are connected to the KT-LoRa mote through GPIOs. The processor is programmed to continuously monitor these parameters. Based on the quality, the Village Panchayat can take decision to refresh, refill pure water or can take necessary steps to clean the water. Based on the quantity and level, the Panchayat can take decision to refill the water on time and reduce the water scarcity.

Fig. 4 shows the coverage area of each gate way and the number of gateways estimated to cover the entire city considering 20Km of length each side approx. Testing results shows each gateway covers nearly 4Km in Urban area and in worst case it covers 2.5Km. Based on these analyses, the number of gateways required to cover the entire city is only 16. The gateway requirement is less than the no of cell sites required to provide service. This confirms that the network is cost effective.

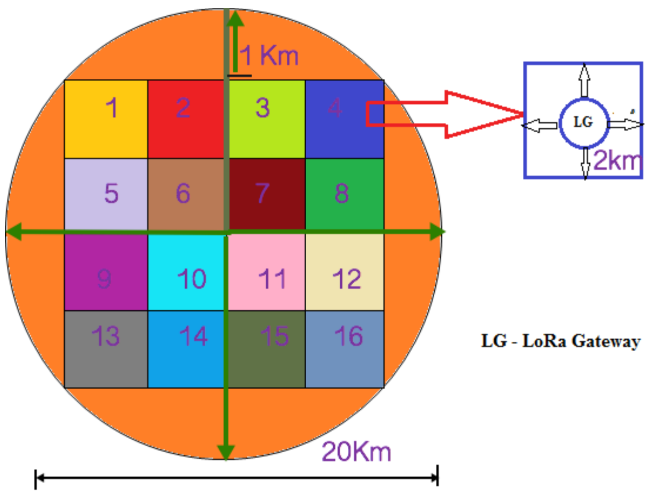

Figure 4. Coverage Area using LoRa Gateway.

V. Conclusion

In this paper a survey is done on the recent researches in Smart villages. Water distribution and monitoring the quality of water in Villages as well as cities is a challenging task. The solution for smart water distribution and quality monitoring in smart villages is discussed and solution is provided using LoRa and LoRaWAN. LoRaWAN provides a alternate solution for networking where cellular network is not available. These LoRaWAN is suitable in forest areas and mountains where the cellular network is not available as well in cities where the cellular network couldn't provide service to these type of applications. The proposed system will save water and provide good quality of water to people. The calculation says that the water can be saved atleast by 20% which is large in number. Our future work is to provide solution to nearby cities and villages and also to provide smart meters to individual house where they can monitor and control the usage of water.

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