# A Novel Smart Water-Meter based on IoT and Smartphone App for City Distribution Management

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***Abstract*—A novel approach to performing automated water-meter reading for update of consumption information from field to the Utilityoffice is described in this paper. The smart metering approach proposed differs from existing commercial methodologies by making use of low cost IoT hardware and smartphone app. This scheme permits both Meter Reader as well as individual domestic / industrial consumers to use regular smartphones to perform meter reading and update to utility's portal / database for billing and payment. The proposed scheme reduces overheads on Utilities in handling meter reading and billing for water distribution in metropolitan and large urban conglomerates.**

***Keywords—AMR, IoT, customer relations and billing, smartphone, water-meter, water distribution system, Municipal Utilities, smart cities.***

## I. INTRODUCTION

The world is increasingly looking forward to adaptation and use of new technologies to improve quality of life as well as reduce impact of human activities and consumption patterns on environment. Availability of clean water, its increasing demand from urbanization[1] and growing population in cities, cost for management of water transmission, storage, treatment, distribution and billing for consumption are serious issues in underdeveloped and developing countries. Rapid changes in lifestyle and increased paying capacity have impacted use of water and related overheads on sewerage requirements.

Water Utilities have traditionally looked at managing water distribution as a sensitive task with humanitarian approach which sometimes result in uneconomically high cost of water management and skewed cost-sharing arrangements among different categories of consumers.The main revenue for water utilities have been through Billing for consumption. Utilities try to meet most of their expenditure on Capital for new installations, operations, maintenance, etc. from consumption metering and billing. The use of communication and IT infrastructure for Customer Relations and Billing Management (CRBM) [2] have been attempted by Utilities during the past decade. The CRBMs normally do not receive live data on consumption from the vast population of water-meters.

This paper proposes implementation of smart water distribution metering approach especially suited to third-work countries with limited investments in infrastructure and burgeoning populations and amoeboid expansions to urban habitats. The prototype system relies on the use of simple Internet of Things (IoT) approach for Water-metering in conjunction with a custom built Smartphone App. Metering data communication and update to CRBM, logging of complaints, dynamic checks for water leakages at consumer-end and Utility monitoring of hourly consumption from individual or group of meters for suspected leakages / tampering, etc. are potential advantages using this approach. The paper describes a novel Smart meter implementation architecture that permits both online and offline methods especially for areas with poor / unreliable cellular network coverage.

## II. SMART METERING AND CRBMS

### A. *CRBMs for Water Distribution*

MunicipalWater Supply utilities implementCRBMs[3] to improve revenues, to improve operations and maintenance, to cut down on non-revenue water costs including leakages, losses, unmetered discharges, etc.[4]. Besides billing functions, a well-designed CRBM assistsin utilization of consumption data for Analytics and planning [5],[6]. Dynamic and real-time updates to CRBMs help in reduction of billing periods (e.g. 3- or 2-month billing cycle to 1-month cycle) [7], improve response to customer complaints, help respond faster to incidents such as pipeline leakages and breakdowns [8], achieve re-organization of water traffic in case of unforeseen disruptions[9], etc. Real time update of metering data to CRBMs call for optimized infrastructure and methodologies in bringing remote meter data to Utility Office through a secure, reliable, cost-effective approach.

### B. *Automated Metering and Smart Meters*

Traditionally, Smart Water meters implied use of electronics interface to the Consumption Register module on the Water-meters to capture information such as

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Consumption, Register Tamper (Tamper-proof Flag Status), unique ID of meter, etc.

The Electronics Module is sometimes housed atop the Water-meter Register (or as an integral unit with Meter-Register) with sensors, battery, CPU and Memory. The other approach is to have electronics module with battery as a separate Unit external to the Water-meter that records consumption based on signal output from built-in magnetic Reed-switch in the Register as it gets activated by motion of a tiny embedded magnet in a register wheel.

Smart metering have been looked upon as Automated Meter Reading (AMR) to cater to Billing requirements of the Utility [10]. Hence AMRs have seen use of Handheld Data capture devicescarried by Meter Readers who move to the site of each water-meter. Alternate techniques of AMR rely on the use of handheld radio or vehicle mounted radio (RF Transceivers) that poll the water meters for consumption and meter integrity data. Such AMR water-meters have electronic modules designed with built-in RF transceivers and long-life Battery or alternate mechanisms to top-up charge from kinetic energy of flow [11]. The Query Command from handheld or portable radio wakes up the transceiver from low-power mode and in response it provides information to the remote radio device. The handheld or vehicle mount AMR devices accumulate responses received from the queried RF-Water-meters, filters and sorts the received information to compute consumption based on pre-stored Meter-register values from previous billing cycle. The data are ported to Utility Office computer for CRBM update and generation of Billing. The Billing calculations could alternatively be performed on the handheld and Bill hardcopy produced with built-in thermal printer for handing to consumer.

There have been smart-meter variants introduced around a decade back such as Prepaid Water-meters,similar to pre-paid energy-meters [12]. These meters are fundamentally Water-meters with an ON/OFF Solenoid Valve and Electronic module that records consumption as well as reads Pre-paid Card (serial EPROM/ *SmartCard* /RFID Card) as well as drives the Valve OPEN or CLOSE. These are stand-alone units usually at remote locations catering to water supply to domestic or public taps. In case of private consumption, the prepaid value is stored into the Meter memory till exhausted when the Valve gets closed. For public taps, the Prepaid Card is required to be inserted into the Reader and a pre-selected volume is dispensed. The value for volume dispensed is reduced from the respective Pre-Paid Card used. A variant of meter reading based on SMS messaging over GSM has been attempted especially for bulk water-meters [13].

One commercial implementation of Meter Reading comprises AMR modules on each water-meter communicating by RF to a Data Concentrator Unit (DCU) that accumulates data from upto 16 to 32 Meters. The DCU in turn communicates to Utility through GSM network.An alternate approach makes use of wired connection from Meters to the DCUs which are connected to Utility network over broadband / Cable.

## III. The Smart Metering System

The proposed Smart Meter System comprises of hardware component called the Electronic Interface Module (EIM) that resides in conjunction with the basic water-meter.The EIM is designed around a low-cost CPU board with features such as interface for meter-register and tamper-switch, Real-Time Clock and Flash memory for date-time stamped Data log, Ethernet Stack and port for interface to TCP/IP network or Wi-Fi or GSM/3G/4G Router, built-in battery and charging adaptor.

The prototype Smart Watermeter constructed,is a regular water-meter but with magnet-reed switch pick-off and embedded tiny magnet on a wheel which together generates pulses corresponding to rotation of the wheel. Recording of these pulses indicatethe water consumption.

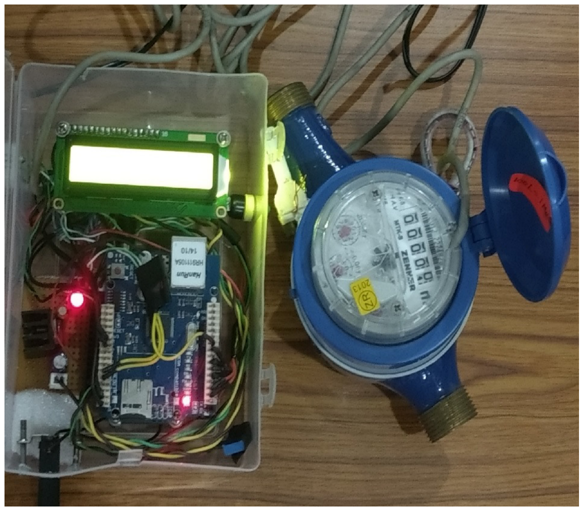


*Fig. 1. Smart-meter prototype with external EIM*

For the prototype system, an external EIM designed around an Arduino SBC board with Ethernet Stack and additional Flash Memory, as shown in Fig. 1has been used.

The tamper-flag is fundamentally a combination of spring-loaded switch that detects forceful detachment of pick-off from the water-meter, and a secondary sensing by Hall-effect device to detect presence / shift of strong external magnetic field in the meter vicinity. Tampering by use of an external magnet typically causes locking of pulse output signal stream from meter register. The interrupt signal to the microprocessor arriving from the tamper-switch is used to toggle a Boolean Flag in the EIM memory log and is registered with Date/Time stamp. Meter-Reader when assessing consumption also reads the state of Tamper Flag in memory and can identify the specific date(s)/time(s) at which tampering had occurred. The EIM has two tamper Flags, one corresponding to Register-tamper (cut-off of pulse signal) due to forceful mechanical tampering and the other corresponding to Tamper signal from Hall-effect based sensor that senses a strong external magnetic field (due to use of an external magnet).

The EIM used in the study is a proof-of-concept case for large-scale implementation through IoT. The use of low cost high life rechargeable batteries for power, ability to run diagnostics periodically for both operation of meters as well as meter related data analytics for leak detection and evaluation of consumption patternare the expected advantages to the consumers as well as water utilities.

### *A. Smart Metering Architecture*

The schematic of proposed Smart-Meter system architecture for water distribution operations and CRBM comprises of following different options. A schematic of the smart-meter architecture is shown in Fig. 2.

a. Meters with EIM transmitting data to Smartphone (over Wi-Fi or Bluetooth). The smartphone Metering App is responsible for sending query to poll the meter reading information including date-time stamped consumption, tamper flag and meter ID. The EIMs with smartphone communication features (e.g. Wi-Fi or Bluetooth) will require periodic charging of its battery. Typically the use of high power batteries would add to both the initial cost as well as maintenance costs. Hence this type of system is typically recommended for standalone Bulk Watermeters used for large consumption metering or distribution branch pipeline flow monitoring.

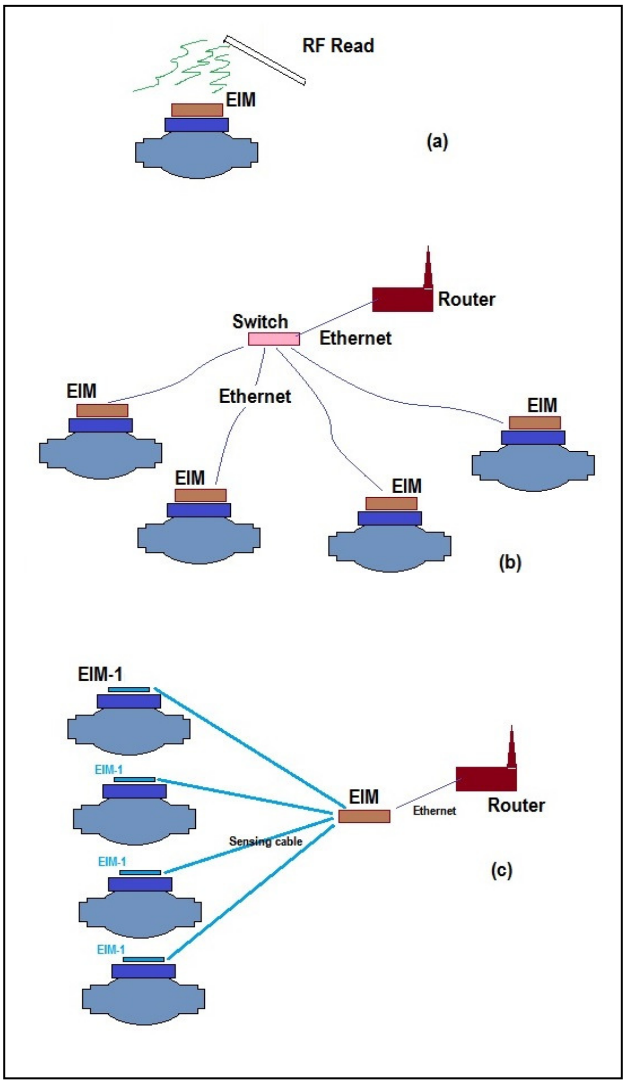



*Fig. 2. Architecture of the Smart meter scheme*

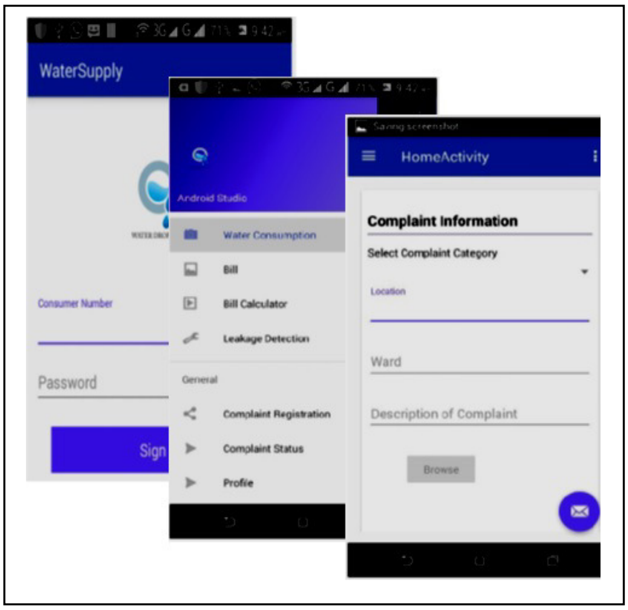
b. Meters with EIM connecting over Ethernet to Router. Regular Routers for GSM/3G/4G or Optic-fiber could be used for connectivity to Utility over Internet. No separate expensive Data Concentrator module required. In this approach a smartphone App is not essential for metering operations. The date-time stamped consumption, tamper flag and meter ID from individual EIMs are polled by the remote computer.Meter EIMs of this type would be wired to communicate digital serial data over two wires (proprietary protocol).

c. Meters with EIM variant that interface to multiple Meters. Date-time stamped Consumption measurement from multiple Meters are made available to remote CRBM system via Ethernet Router / Gateway to Internet. This approach is different from DCUs in that the EIM directly interfaces to the multiple water-meters to read their consumption records which are stored as date-time stamped records for individual meters. These data are accessed by remote CRBM by remote access. The EIM is configured during installation of water-meters with the meter-ID and individual tamper-flag sensors.This EIM system connecting to a bank of watermeters would normally run on any standard power source near its vicinity. It is therefore not generally subject to scarcity of power for its batteries.

The methodology applied for water-metering may be extended for piped natural-gas city distribution systems as well as for Energy-meter reading systems for domestic and industrial consumers.

### *B. Smartphone App for Metering and Diagnostics*

The Smart Meter reading and diagnostics application has been developed using Android SDK and Java. It is prepared as a multiple screen application that permits user to configure and tag the associated Water-meter with the Consumer ID and Address details at the CRBM system. Fig. 3 shows screenshots from the developed smartphone



App.

*Fig. 3. Smartphone App screenshots for Meter reading*

Once the installation details have been verified at the CRBM, the phone number registration is completed.The App thereafter permits interaction with EIM for running meter diagnostics to check / identify Date-Time information, Unique ID of meter, Status of tamper-flags, save a copy of live consumption record, retrieve periodic log (hourly stored data) and history, etc. from the EIM

The smartphone App permits update of meter consumption record to the CRBM after secure login access to the CRBM, view consumption records pertaining to previous Billing cycle, etc. The App permits access to CRBM record on Monthly consumption for the Registered Meter to help reveal consumption trends of the individual user. This data may help consumer to assess losses, over-limit consumption, etc. to help plan his/her conservation and maintenance programs.

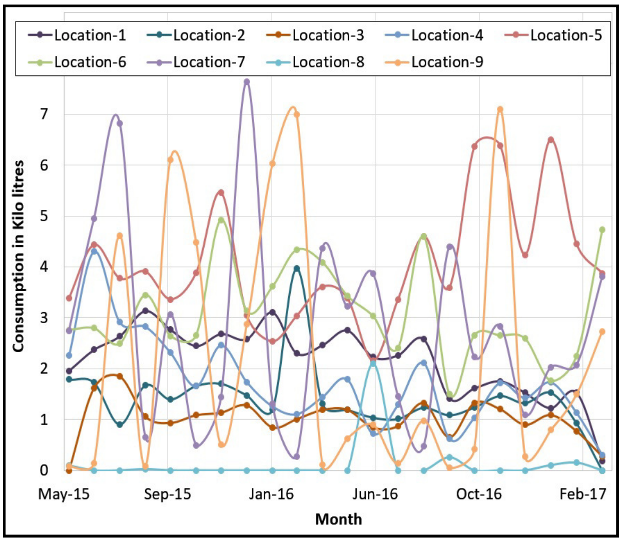



*Fig. 4 Average daily consumption for each month at a few locations in a 4"NB distribution line*

## IV. Assessment of Water Consumption and Losses

A preliminary assessment on water loss evaluation and conservation was undertaken on a small section of water distribution network at the Institute campus. The measurement logs pertaining to received water quantities were assessed against individual consumption at the different locations within the geographical area. The water loss on account of various factors such as pipeline joint leakages underground, faulty water-meters, defective faucets and water-taps, overflow water loss due to aged / broken float-valves, dripping losses through garden water hoses, etc. were identified during the assessment survey. The amount of water saved by corrective actions, replacements and revised operations was of the order of about 14% of water receipts.

The consumption data on water-metering at a few branch locations in 4"NB mains is shown in Fig.4. The monthly consumption for a small population of water-meters in a small community network is shown in Fig. 5. Analyses of these yielded information on water loss, enabled steps to be taken for improving water conservation measures, etc. within the small community.

The present study is being extended to incorporate consumption pattern based algorithms to enable substantial value addition to consumers as well as saving of treated water. Data Analytics at the CRBM would provide information such as consumption patterns for each type of consumers, identify and evaluate changes in these patterns, look for trends in consumer demands, verify consumption data for suspect consumers and conduct audit to identify avoidable leakages, pipeline pilferages and breaks, etc.

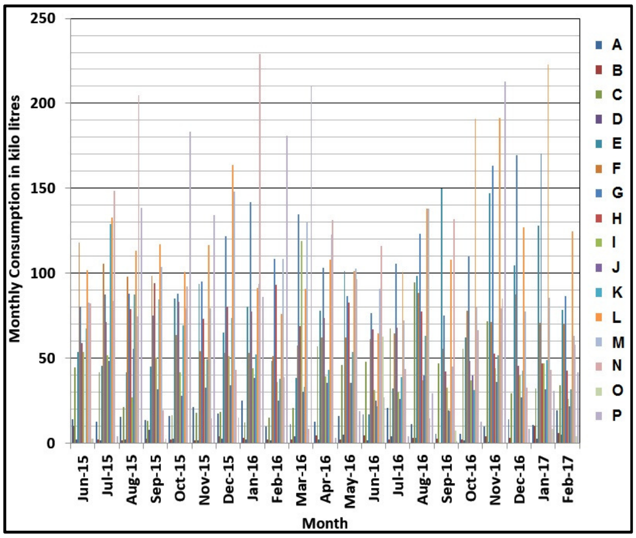



*Fig. 5Snapshot of Monthly consumption from water-meters at 16 locations in a zone in the distribution network*

## Conclusion

A novel system for implementing an economic and reliable smart water distribution metering using IoT based hardware and smartphone App is discussed. The features of prototype system and the benefits are discussed. The novel approach overcomes disadvantages in certainsmart-meter systems such as tampering in pre-paid water-meters that often go undetected due to standalone nature of pre-paid meters; tampering or unauthorized Top-Up updates to pre-paid meter smartcards using hacking software, etc. The proposed architecture also overcomes connectivity issues typically seen in DCU architectures when DCUs are installed near Meter banks in basements or areas with poor / unreliable cellular signal strengths.The work is being extended to cover a range of Distribution metering and Unaccounted for Water issues faced by utilities while giving direct and intangible gains to the consumers in the changing smart infrastructure scenario in urban areas.

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