SOC Module for IOT Based Smart Water Monitoring

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Abstract— The Internet of Things (IoT) has provided promising opportunities to create powerful industrial and domestic applications. One of its main applications is smart metering. The existing analogue meter in residential area requires consistent human monitoring, which leads to computational errors. Huge labor force, their negligence and money invested are the drawback of such meters. Therefore, a cost effective and low power smart-meter that can monitor the daily consumption of water in residential area need to be developed, in order to conserve water. Here in this research, SOC based smart water meter is developed to provide cost effective solution. Further, the developed system is implemented in real time to investigate the reliability and feasibility.

Keywords- *IoT, smart meter, SOC,water consumption and residential.*

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I. INTRODUCTION

Water being the necessity of life may pose greatest challenge of its increased use in fore coming years. In order to overcome the water stress in near future, new infrastructural facilities have to be constructed to monitor the water flow. Based on the investigation for payment of water charges in Chennai city, it has been found that the residential pipelines are monitored by means of an analogue water meter. But the readings from those water meters are manually obtained by means of a water monitoring staff [1]. This reading method has many disadvantages, such as human negligence, slow and inaccurate processing of information. Thus, the precision in obtaining the information is reduced to a greater extend. By reading the water meter accurately on time, the water resources can be conserved effectively and efficiently. In the proposed research, an attempt to automate the domestic water end-use classification process using a robust hybrid model is developed. The research employs ZigBee and event based techniques for transmission and data processing.

The organization of the paper is as follows: Section II elaborates the state of art related to the proposed work. Section III describes the proposed methodology. The results obtained are discussed in section IV. Finally, section V concludes the paper with the future research direction.

II. LITERATURE SURVEY

This section presents the various literatures existing related to the proposed research.

In [1], the authors have made an analysis to transit into a water-metering based system to determine the effects of water metering on household consumers. The analysis on short-term effects of water metering is conducted for a single urban area where data is available. The study of long-term effects using a dataset of water utility level observations is made. It has been observed that the water usage is decreased three to four times when compared with the normative water use of 200–250 liters per person per day.

In [2], the authors have developed a general framework for the classification of residential water demand modeling. This paper formulates a correct taxonomy for water meter modeling to be followed at both the back and front end. The data gathering is followed by end-user characterization, User modeling Design and implementation of personalized WDMS (Water Demand Management Strategies). The findings conclude that smart meter data can be exploited to differentiate the price variations in relation to different uses (e.g., outdoor and indoor water consumption).

In [3], the authors have designed a water meter simulation model for the Tsumeb East area. The developed model is tested under different conditions of dead meters and idle meters using the Link layer model in TOSSIM. Furthermore, distance based mechanism and meter density based mechanisms are used to place the Data Acquisition Points (DAPS) in the network. From both mechanisms, it is evident that network performance rapidly decreases as the number of dead meters and idle meters increases.

In [4], the authors have developed an intelligent water meter, to store the data and analyze it over the IoT cloud. The measured water flow and temperature information is sent to the IoT cloud via Wi-Fi (IEEE 802.11). The developed system uses STUF-280T ultrasonic water meter, which gives data in M-Bus protocol. The data in M-Bus protocol is converted to TCP/IP and sent to the IoT cloud via Wi-Fi. This system notifies client about the flow rate via mail if it exceeds a specific threshold value.

In [5], the authors have designed the water management system based on wireless sensor networks (WSN). The system uses the IEEE 802.15.4 standard embedded in ContikiOS Lib CoAP as an open-source application. The developed system provides the user with a real-time monitoring system for water consumption. It can also be used for other services such as leakage detection and localization. It has been observed that the monitoring system can help users monitor their water usage and reduce water consumption, as well as to identify and fix abnormal water consumption.

In [6], the authors have developed a wireless intelligent remote water meter system to achieve the high-precision data collection of water meters in high-rise buildings. The functions like data collection, routing and the placement of nodes are redefined and the communication protocol is recombined. In this way, the real- time reading of the water meter can be improved especially in high-rise residential building,

In [7], the authors have analyzed the wide choices of wireless communication methods in automatic water metering system. It focuses on residents in living areas, villages and enterprises zones, where the signal interference is severe. Based on the observations, Satellite communications have high stability and interference immunity. The mobile communications networks are mainly concentrated in the crowded places, and the signal is stronger. Moreover, smaller amount of data is suitable to be transmitted through GSM; on the contrary, larger amount of data fits GPRS or CDMA.

In [8], the authors have suggested an alternate way to measure the water meter reading. It specifies a way of using image processing to monitor the water meter readings. The analog meter showing reading is captured and compared with the previous image to determine the amount of water flown for a particular time. The water flow from the traditional analogue needle meter is continuously monitored using two cameras. One for capturing the current position of needle. The other for collecting the data over continuous time to a database for history.

From the literature survey, it is clear that, most of the existing systems requires a new smart meter to be replaced with the existing analogue meter. This, significantly, increases the cost incurred to develop the infrastructure of the automated system. Moreover, the existing smart meter systems are targeted only for large water consuming units, which are quite dedicated and expensive.

III. PROPOOSED METHODOLOGY

This section explains the architecture and working of the proposed system. It also describes the water meter setup and the hardware components used in the research.

A. Architecture

The architecture of the proposed system is shown in Fig.1. It consists of three sections:

1. Device deployment in user area
2. ZigBee based data routing
3. Server side data collection and billing

1. Device deployment in user area:

This block consists of analogue water meter (WM) with a Hall Effect sensor and microcontroller. Pulses are produced in accordance to the flow rate. In the proposed work, on an average, 265 pulses are produced per litre of water. These pulses are used to determine volume of water consumption in litters. Enhancement in accuracy is achieved by determining an accurate calibration factor.

Calibration factor = number of pulse per litre/60

*Flow Rate = (pulse Count) *60/ calibration Factor*

2. Zigbee based data routing :

The nodes are connected to the local server through a coordinator. The coordinator collects the water consumption information from every node present in the apartment. In the proposed system, ZigBee protocol is used to transmit data from the nodes to the coordinator respectively.

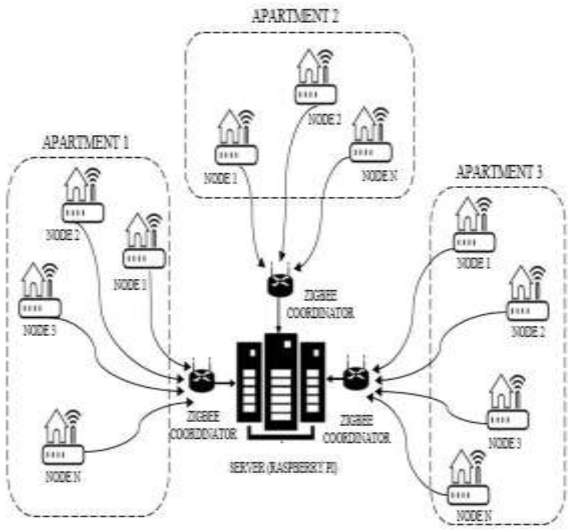

Figure 1. Proposed system architecture

Every node uses a ZigBee transmitter which transmits the data to the ZigBee coordinator. The long range and the high node connectivity of the XBees, along with the low power consumption, make it ideal to be used for the transmission of real time data faster and efficient. A ZigBee module is capable of connecting 62000 nodes on an average of 80 m in coverage.

3. Server side data collection and billing:

The ZigBee coordinator is connected to a local server running on a Raspberry pi 3. The Raspberry pi runs an Apache web server, and a MySQL database which log the water consumption data from the individual nodes. The logged data is presented to the individual users of the apartment using a web interface. From the user interface, the water consumption can be viewed and monitored. The bill amount corresponding to the quantity of water consumed by the individual is calculated as per the tariff rate per liter. The webpage collects the data from the database using a php script and displays it in the form of HTML to the end user.

B. Design flow:

The flowchart shown in Fig. 2 represents the design flow of the proposed work. The pulses arriving from the signal conditioning circuit of the Hall-effect sensor is sampled. Then it is checked whether the pulse count function has received any pulses. If so, it is converted into quantity of water consumed and accumulates it to the total water consumption so far. The accumulated value is sent to the ZigBee transmitter for data logging. The control unit provides an event based trigger to calculate and send the data. The Timer library triggers the calculate function once in every second, to reduce the pulse error. The sendValue() function is triggered once in every 120 seconds, which sends the data to a ZigBee transmitter.

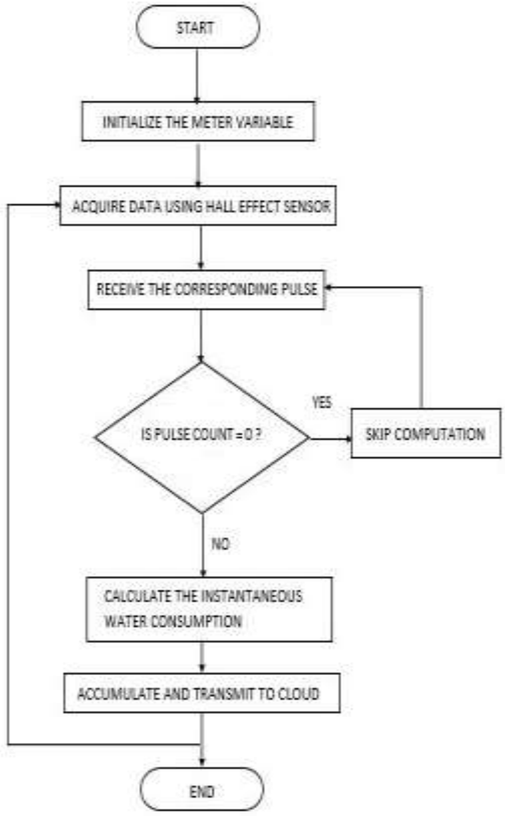

Figure 2. Process Flow

C. Hardware Setup:

Fig.3 shows the test bed of the developed node. The node is placed on a meter, which is connected to the outlet of a rooftop tank. The outlet of the water meter is then connected to the pipelines that are in turn connected to the taps of a particular house in the apartment. The Hall Effect sensor is then placed inside the cavity of the water meter, so that the Hall Effect sensor captures the magnetic variations efficiently. The developed embedded device to which the Hall Effect sensor is connected. The developed device is connected to the programmer, through which the Hexadecimal files can be uploaded. The power to the embedded device is provided by means of a power bank for experimental purposes.

1. *Hall effect sensor:*

The 44E Hall effect sensor captures the magnetic variations present in the magnetic drive water meter and converts them into corresponding pulses. It is powered by a 5V DC supply. When the polarity of the magnet inside the water meter is changed, The Hall effect sensor switches to logic high. The sensor remains in logic high state until the magnet returns back to the original polarity. Thus, the mechanical motion is converted into electric pulses using Hall-effect sensor.

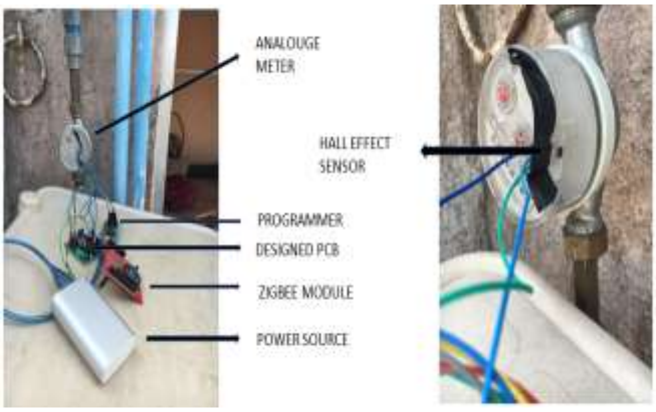

Figure 3. Real time experimental set up - Residential

2. *XBee module:*

ZigBee is a low cost, long range communication module, widely used to transmit data from the nodes. The non-beacon mode of ZigBee is exploited in the current scenario, resulting in low power consumption. The end device in this network is connected to the ZigBee transmitter, which communicates the information to the ZigBee receiver. Thus, the consumption data is transmitted wirelessly over a long range, when compared to other communication modules such as Wi-Fi and Bluetooth.

3. Designed PCB:

The microcontroller, amplifier and the XBee is powered by a 9V battery, which is regulated to 5V by means of a switching regulator. The output from the Hall-effect sensor is then fed into the inverting input of the LM358 amplifier. The output of the amplifier is connected to PCINT port of Atmega328P-PU, which is a dedicated interrupt pin to handle the interrupt requests. The XBee Din and Dout pins are cross coupled with the RXD and TXD pins of the microcontroller. A 16 MHz crystal oscillator is connected to the microcontroller to provide a variety of clock frequency, right from 16 MHz till 1 MHz. The Hexadecimal file is uploaded to the flash memory of microcontroller via the programmer pins. The program is uploaded to the microcontroller by means of a programmer board running on an Atmega8A controller, thus serving as an interface between the computer and the target microcontroller.

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865 – 870

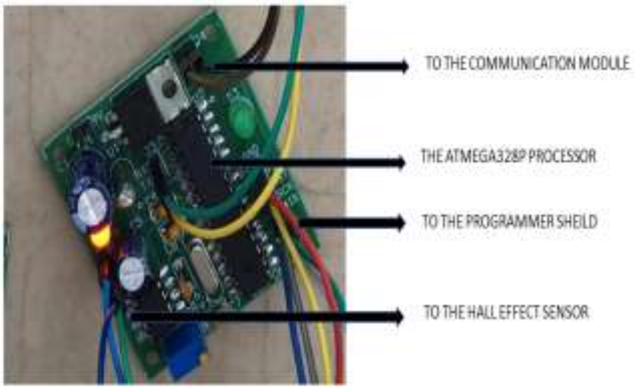

Figure 4. Fabricated PCB

IV. RESULTS AND DISCUSSIONS

The developed system is currently placed in user apartment to attain the real-time water consumption.

1. Range test:

Since the communication between XBee modules takes place over the air, the quality of the wireless signal can be affected by many factors such as absorption, reflection of waves, line-of-sight issues, antenna style and location. The range test of ZigBee modules, which are used as the transmitter and receiver is carried out using the Digi XCTU software [12]. Based on the successful reception of data packets by the receiver, the range of the XBees used is analysed. In the considered scenario, based on the environment there are two types of placement of nodes (indoor and outdoor). Since the performance of a ZigBee module in terms of range can be determined differently for user customized area, the range can vary depending upon the environment.

Figure 5. Indoor range analysis

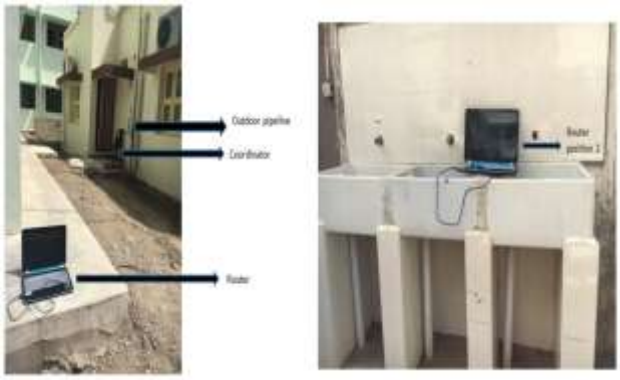

Figure 6. Outdoor range analysis

On sending a constant fixed packet of 100, the reception of successful packets is measured using Digi XCTU software.

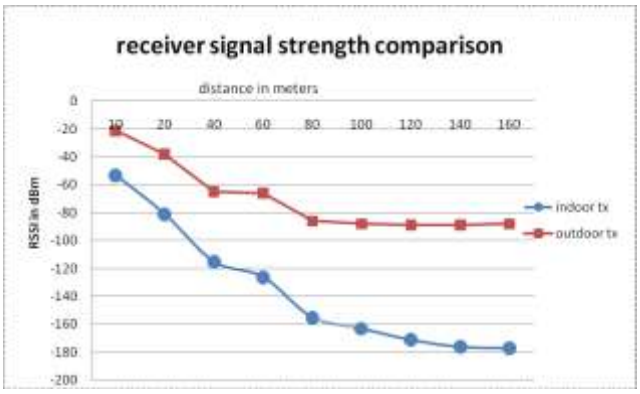

Figure 7. Signal strength -range analysis of receiver

Having a constant number of packets to be 100, the efficiency of reception along with signal strength is measured for different distances. The distance between transmitter and receiver is increased at a constant rate.Fig.9 and Fig.10 shows the graph representing the number of successful packet received by the receiver with respect to the distance between the transmitter and receiver ZigBee units.

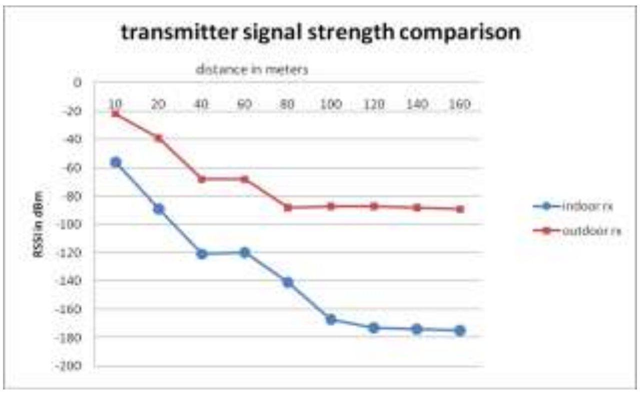

Figure 8. Signal strength -range analysis of transmitter

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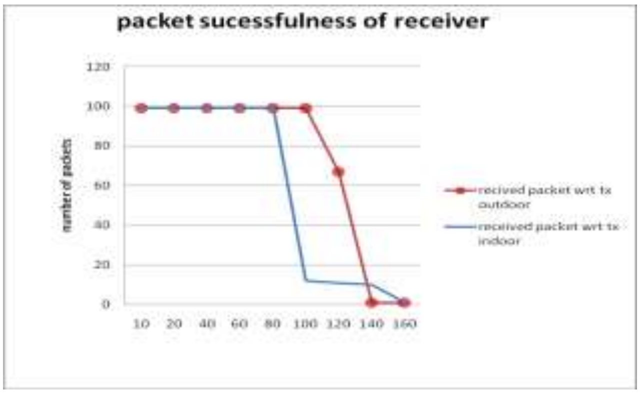

Figure 9. Packet efficiency -range analysis of receiver

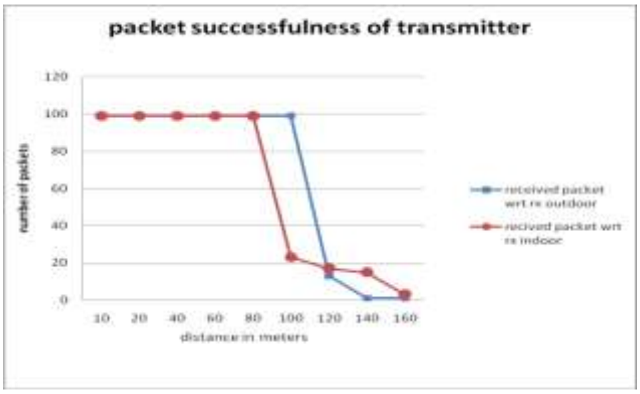

Figure 10. Packet efficiency -range analysis of receiver

From the above graphs, it is clear that the packet efficiency remains to be 99%, if the distance between transmitter and receiver does not exceed 80 meters in case if the units are placed indoor and 100 meters in case of outdoor. The signal strength at the transmitting and receiving antenna can be measured to determine the quality of a communication link. The RSSI [13]in relation to distance is,

$$Rssi[dbm] = -(10n \log 10(d) - A)$$

n=constant value that factors in terrain (3.2 to 4.0),
d= distance in meters A= offset value the offset value of the considered residential terrain is 0.4. The offset value is selected based on the Altitude

2. Data logging and billing :

The web server uses MariaDB database to store the data from the ZigBee coordinator. The connection between ZigBee and MariaDB is established by means of python programming. The database uses ID as a primary key. It also has a built-in timestamp, which logs the date and time, whenever the data is logged into the database.

The variable "value" holds the quantity of water consumed by the individual. The server uses Apache 2.4.2 for hosting the server. The Apache and MariaDB is maintained using phpMyAdmin[14, 15]. The phpMyAdmin serves as a platform to create users, grant access to the tables in the database corresponding to the user and manages the table columns and its variables.

Fig.11 shows a dynamic webpage which displays the quantity of water consumed by the consumer along with the amount to be paid as per the tariff rate. The user can log into the webpage by means of the credentials provided to the individual user. The credentials include a username and a unique password. A new user installed with new smart water meter of the same network is provided the access of web page using the registration page.

V. CONCLUSION AND FUTURE WORK

In this research, a wireless embedded device to monitor the water consumption is developed. It consists of a Custom-design PCB board where the data is transmitted by means of a ZigBee transmitter. The major contributions made in the developed system is that it can be embedded on the existing analogue meter. Thus, it reduces the replacement costs of the meter. Moreover, the powerconsumption table specified, shows that the developed PCB consumes low power when compared to the other development boards. This implies that the developed device ncreases the longevity of the battery life. Similarly, around 62000 nodes can be connected to a single XB24C coordinator, reducing the complex architecture.

Figure 11. Water consumption and billing page

The future works involves integration of various water quality monitoring sensors in addition to the developed quantity monitoring system. The developed system can be extended to a metropolitan level, by moving the local server to a server enabled with public IP and port forwarding. The dynamic webpage can be further enhanced by using a mobile friendly Graphical User Interface (GUI). The functionality of the device can be further enhanced by developing a leakage detection algorithm in addition to the developed system.

REFERENCES

[1] Naira Harutyunyan, "Metering drinking water in Armenia: The process and impacts", Elsevier International Journal on Sustainable Cities and Society, ISSN: 2210-6707, Volume 14, February 2015, pp.no 351-358.

[2] A.Cominola, M.Giuliani, D.Piga, A.Castelletti and A.E.Rizzoli, "Benefits and challenges of using smart meters for advancing residential water demand modelling and management: A review", Elsevier International Journal on Environmental Modelling & Software, ISSN: 1364-8152, Volume 72, October 2015, pp.no 198-213.

ISSN: 2321-8169
865 – 870

[3] Neeharika Cherukutota and Shraddha Jadhav, "Architectural Framework of Smart Water Meter Reading System In IoT Environment", International Conference on Communication and Signal Processing, April 6-8, 2016, India, pp.no 791-794.

[4] Linda N. Shitumbapo and Clement N. Nyirenda, "Simulation of a Smart Water Metering Network in Tsumeb East, Namibia", IEEE International Conference on Emerging Trends in Networks and Computer Communications (ETNCC), 17-20 May 2015, Namibia, pp.no 44-49.

[5] Young-Woo Lee, Seongbae Eun and Seung-Hyueb Oh, "Wireless Digital Water Meter with Low Power Consumption for Automatic Meter Reading ", IEEE International Conference on Convergence and Hybrid Information Technology, 28-30 Aug 2008, Seoul, pp.no. 639-645.

[6] Mduduzi John Mudumbe and Adnan M. Abu-Mahfouz, "Smart Water Meter System for User-Centric Consumption Measurement", IEEE 13th International Conference on Industrial Informatics (INDIN), 22-24 July 2015, United Kingdom, pp.no 993-998.

[7] Yuzhu Sun and Dapeng Wu, "Application of Long-distance Wireless Communication Technologies in Automatic Water Metering System", 7th International Conference on Wireless Communications, Networking and Mobile Computing, 23-25 Sept. 2011, China, pp.no 1-4.

[8] Chang O, Pruna E., Pilatasig M., Escobar I. and Mena L., "Calibration of Residential Water Meters by Using Computer Vision", CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON), 28-30 Oct.2015, Chile, pp.no 351-356.

[9] http://www.explainthatstuff.com/hall-effect-sensors.html

[10] https://www.digi.com/products/xbee-rf-solutions/embedded-rf-modulesmodems/xbee-802-15-4

[11] http://html.alldatasheet.com/htmlpdf/555052/ETC2/XB24CZ7RISB003/103/1/XB24CZ7RISB003.pdf

[12] https://www.digi.com/resources/documentation/digidocs/PDFs/90001458-13.pdf

[13] Qian Dong and Waltenegus Dargie "Evaluation of the Reliability of RSSI for Indoor Localization",2012 International Conference on Wireless Communications in Underground and Confined Areas, 28-30 Aug. 2012,France ,pp.no 1-4.

[14] http://iiti.ac.in/people/~tanimad/JavaTheCompleteReference.pdf

[15] https://www.sap.com/india/solution/internet-of-things.html