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Vision and Strategy for India's Electricity Metering Infrastructure of the future

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Abstract
In the country like India with over millions of kilometers of transmission lines and billions of consumers, task of collecting information related to energy consumption of every consumer is a critical job. The meter reader has to travel a long distance and take reading manually to collect the data. This reading is then feed in a central database. Then the bill gets generated later with help of software. This project intends to reduce this tedious work by automating the process of collecting data from consumer's electricity meter. This would be done by implementing Advanced Metering Infrastructure that unites all the various metering devices of a building in one network and provides the metering data in real-time, locally and from remote. Here, AMI uses ZigBee to build up high-rise building area network of connected metering devices.
Keywords: Advanced Metering Infrastructure (AMI), Automatic Meter Reading (AMR), Wireless Sensor Network (WSN), Wireless Personal Area Network (WPAN), ZIGBEE, ZIGBEE Device Objects (ZDO).

I. INTRODUCTION

Meter reading and billing for consumption of electricity, water and gas is done by human operator from house to house and building to building since a long time back. It requires huge number of labour operators and long time working hour to achieve complete data reading and billing of a particular area. Reading error is a common cause of human operator billing. Sometimes the billing job is also slowed down due to bad weather condition. There are many such problems in the billing system which causes inconvenience to the power provider as well as the consumers. And this problem is increasing with the development of residential housing and commercial building in the developing countries. This has, in turn, resulted in increase of power provider billing cost. In order to reduce billing cost and overcome the above mentioned problems, AMI system is introduced. An AMI consists of a "two-way fixed network and associated systems for providing advanced metering data and energy management capability. And it provides the capabilities to improve data tracking above and beyond AMR with the goal of influencing energy usage." The Smart Meters of an AMI can be accessed and controlled from remote at any time. They are able to communicate among each other, record data and provide it in real-time, handle events and alarms, send diagnostic information, detect leaks or tampering, handle pricing information and come with extensive logging and monitoring features. Such an Infrastructure i.e. AMI opens the door for new services such as in-house energy visualisation terminals, prepayment, outage control.

II. EXISTING TREND

In India today, Meter reading and billing for consumption of electricity, water and gas is done by human operator from house to house and building to building since a long time back. It requires large number of labour operators and long time working hours to achieve complete data reading and billing of a particular area. Reading error is a common cause of human operator billing. Sometimes the billing job is also slowed down due to bad weather condition. There are many such problems in the billing system which causes inconvenience to the power provider as well as the consumers. And this problem is increasing with the development of residential housing and commercial building in India. This has, in turn, resulted in increase of power provider billing cost. And also, when the human operator comes to give monthly bills at a particular house, he just throws away the bill in the compound of a house or hangs it somewhere in the compound. But, if suppose, the bill is misplaced the loss is of the consumer.

III. PROPOSED METHOD (VISION)

Here, in this project our vision is to develop an Advanced Metering Infrastructure using ZigBee i.e. a WSN that has been widely adopted in industrial automation which transmitted the data over large areas using its multi-hopping ability.

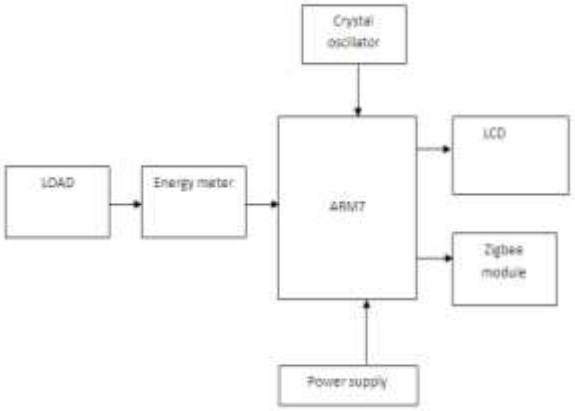

Fig. 1. First and Second Floor Flat

We would be implementing a system hardware for two floor and two apartments i.e. we are considering only one apartment on each floor with energy metering hardware interfaced to the ZigBee module. And, the third hardware would be receiver i.e. server for collecting data from the apartments showing the usage reading. ZigBee consists of a receiver; actually "ZigBee is a transreciever." Here we are just creating a database of the collected data in the PC which can then be taken up by the MSEB for calculating the monthly usage and billing. We even would be using ZigBee router so that it should not go out of range.

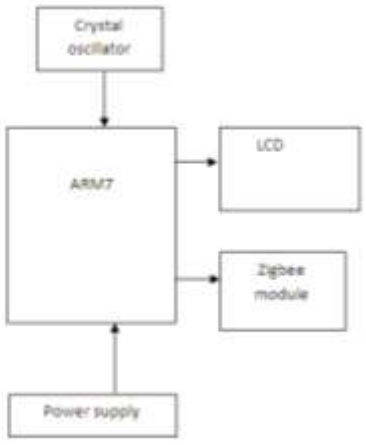

Fig. 3. Main Receiver Unit

IV. ADVANCE METERING INFRASTRUCTURE (AMI)

An advanced metering infrastructure (AMI) ties up various metering devices of a building in a single network and provides metering data in real-time and also it opens the door for advanced energy management.

An AMI utilises ZigBee to build up home area networks of connected metering devices. An AMI consists of a "two-way fixed network and associated systems for providing advanced metering data. And it provides the capabilities to improve data tracking above and beyond AMR with the goal of influencing energy usage". The Smart Meters of an AMI can be accessed and controlled from remote at any time.

They are able to communicate among each other, record data and provide it in real-time, handle events and alarms, send diagnostic information, detect leaks or tampering, handle pricing information and come with extensive logging and monitoring features.

V. HIGH LEVEL FEATURES OF AMI

Metering: The core feature of any AMI is to get the information out of meters. It is possible to get metering data from multiple commodities such as electricity, gas, water, and thermal (sub metering, multi energy metering). The system should be flexible enough to support different measuring units and modernisation. An AMI must provide state of the art measurement types including load profiles, summation etc. Further, metering data (consumption/production) should be available in real-time and recorded in a history for later use. Data can be retrieved locally on-site and from remote. The network incorporates mains powered and battery driven devices. Selected data can be accessed from the utility, a technician or the customer with sensible restrictions and privacy. Legacy support for already available and powerful metering protocols must be guaranteed

Demand Response and Load Control: This ability of the system is to control energy consuming and generating devices depending on inputs from the utility and/or the customer. This includes management and scheduling of multiple events, the ability to individually or simultaneously target specific groups of devices (HVACs, water heaters, lighting etc.), randomisation of start and end times and so on.

Pricing: It is possible to distribute, visualise and process tariff based on the spot market prices for energy (real-time pricing) or the much higher "Critical Peak Prices" etc. Smart Appliances are able to access this pricing information publicly and act accordingly. A flexible architecture supports different international units, currencies and a variety of rates, rate based services and multiple providers within the same system.

Customer Information Services: Features like the distribution of simple informational text messages between devices or new types of devices such as special in-house units. The text messages allow informing the customer about

energy usage alerts, errors, system states, billing information, rates, current energy consumption, value added services such as weather forecasts etc. In-house units visualise metering data and text messages and allow interaction of the customer with the load curtailment services

VI. ZIGBEE

- ZigBee is a specification for suite of high level communication protocols using the small, low-power digital radios based on an IEEE 802 standard for wide personal area networks.
- ZigBee devices are often used in mesh network form to transmit data over large distances, passing data through intermediate devices to reach more distant ones .
- Any ZigBee device can be tasked with a running network.
- ZigBee is targeted for applications that require a low data rate, long battery life, and secure networking.
- Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that requires short-range wireless transfer of data at relatively low rates.
- The technology defined by the ZigBee specification is meant to be simpler and less expensive than other WPANs, such as Bluetooth.
- ZigBee is a low-cost, low-power, wireless mesh network standard. The low cost allows the technology to be widely used in wireless control and monitoring applications.
- Low power-usage allows longer life with smaller batteries. Mesh networking provides high reliability and more extensive range.
- ZigBee has the defined rate of 250 kbps.
- ZigBee operates in the industries at 2.4 GHz in most parts.
- Data transmission rates vary from 20 to 900 kilobits/second.
- The ZigBee network layer natively supports both star and tree typical networks, and generic mesh networks.
- Every network must have one coordinator device, tasked with its creation, the control of its parameters and basic maintainance.
- Both trees and meshes allows use of ZigBee routers to extend communication at the network level.
- ZigBee builds upon physical layer and medium access control defined in IEEE standard 802.15.4 for low-rate WPANs.
- The specification goes on to complete the standard by adding four main components: network layer, application layer, *ZigBee device objects* (ZDOs) and manufacturer-defined application objects which allow for customization and favor total integration.
- ZigBee protocols are meant for embedded applications requiring low data rates and low power consumption.

VII. ZIGBEE SMART ENERGY FEATURES

The ZigBee Smart Energy was developed for the energy management and efficiency optimization, in applications like Net Metering, Advanced Metering Infrastructure, Demand Response.

¬ **Metering Support:**

- Meter swap outs
- Multiple commodities including electric, and thermal
- Multiple units measure for international support
- Battery or mains powered
- Multiple measurement types such as load profile, power factor, summation, demand, and tiers
- Real-time information
- Historical information (previous day, today, etc.)
- Status indicators including tampering
- Ability to record both generation (delivered) and consumption (received)

¬ **Demand Response and Load Control Support:**

- Scheduling of multiple events
- Auditing of event enrollment, participation, and other actions
- Ability to individually or simultaneously target specific groups of devices including HVACs, water heaters, lighting, electric vehicles, and generation systems.
- Multiple control methods including temperature set points and offsets, criticality levels (such as emergency signals) and duty cycling
- Ability to randomize start and end times to avoid spikes

¬ **Pricing Support:**

- Block tariffs (inclining/declining block rates)
- Prepayment
- Multiple commodities including electric, gas, water, and thermal
- Multiple units measure for international support

- Multiple currencies for international support (using ISO 4217)
- Unregistered devices allowed to request and receive pricing information
- Support for multiple providers and rates in a single location
- Support for price ratios and price tiers
- Support for separate generated (delivered) and consumed (received) prices

¬ **Text Message Support:**
- Scheduling and canceling of messages
- Ability to request message confirmation
- Unregistered devices allowed to request and receive messages
- Multiple urgency levels
- Optional message duration for short-lived messages
- Support for multiple international character sets

¬ **Preliminary Device Support:**
- Meter-integrated or standalone energy service portals
- In-premise displays including low-cost, standalone devices such as refrigerator magnets and energy orbs
- Programmable communicating thermostats (PCT)
- Generic load control devices for appliances such as water heaters. lights and pool pumps
- Smart appliances
- Electric vehicles and plug-in hybrid electric vehicles
- Energy management systems
- Range extenders

¬ **Security:**
- Support for utility registration and utility-only networks
- Automatic, secure network registration using either pre-installed keys or ECC certificate exchange
- Support for ECC public key infrastructure for authentication and mobility
- Data encryption

¬ **Other:**
- Tunneling of manufacturer specific protocols
- Over-the-air updates
- Backwards compatible with ZigBee Smart Energy version 1.0 ZigBee Certified products
- Time Synchronization provided by ESP
- Designed for easy upgrade and adaptability within version 1.x

VIII. NETWORK ARCHITECTURE

- ZigBee knows the notion of a PAN (Personal Area Network) that addresses one ZigBee network.
- In the AMI domain one can differentiate between a HAN (Home Area Network), BAN (Building Area Network) and a NAN (Neighborhood Area Network).
- Besides pure AMI networks, there could be other ZigBee networks around (e.g. a Home Automation or a Commercial Building Automation netwrok).
- Security is an important (and mandatory) feature in an AMI environment.
- Networks are secured with ZigBee network security features.
- In most cases, the network will be private with keys only known to the utility.
- If there are other HANs in a building, they all belong to the same ZigBee PAN.
- Privacy between neighbours is again assured over ZigBee's application security features.
- There exists a requirement to involve devices which are not part of the highly secured AMI network (e.g. to send pricing information or text messages to insecure HA devices).
- ZigBee routers are not made to route messages between PAN networks5. In the literature this issue is addressed under the term "inter-PAN" communication.
- One can try to build a ZigBee bridging device that consists out of two separate physical routers that join two PAN networks and transfer their data between them.

IX. EXPERIMENTAL SET UP AND RESULT

Fig. 4. Experimental Set Up

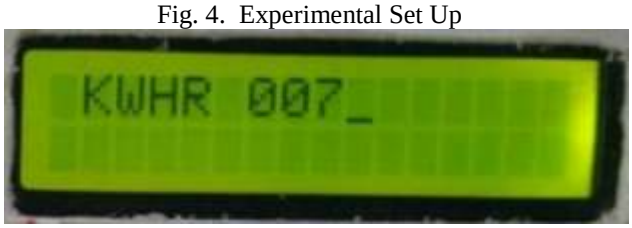

Fig. 5. Automatic Meter Reading

Fig 4 indicates the experimental set up of proposed system which is limited for two flats on different floors. For experimental purpose we have taken 10 watts loads. Fig 5 indicates the actual meter reading of a particular flat displayed on LCD, here KWHR is the unit decided for measuring the energy consumption i.e Kilo Watt Per Hour. In this way multiple readings of different flats can be taken and the same data can be forwarded to the main receiver and further to the service provider.

X. CONCLUSION

We have presented a basic wireless sensor network based on IEEE 802.15.4 on ZigBee alliance standards, with emphasis to requisite used in the development of a wireless sensing network for automation of energy meter. ZigBee is the best option for low data rate sensor network with small size low power requirement. ZigBee technology is a new wireless protocol that widely used in various areas for its excellent performance in reliability, capability, flexibility and cost.

REFERENCES

[1] Gerhard P. Hancke, Senior Member, IEEE, and Kim Fung Man, "The Generic Design of a High-Traffic Advanced Metering Infrastructure Using ZigBee", IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, VOL. 10, NO. 1, FEBRUARY 2014.

[2] N.C. Batista, R. Melício and J.C.O. Matias, J.P.S. Catalão, "ZigBee Standard in the Creation of Wireless Networks for Advanced Metering Infrastructures" 978-1-4673-0784-0/12/2012IEEE

[3] Velin Kounev, David Tipper, "Advanced Metering and Demand Response Communication Performance in Zigbee based HANs", 2013 IEEE INFOCOM Workshop on Communications and Control for Smart Energy Systems.

[4] Vinod Namboodiri, Surya Narayan Mohapatra, Ward Jewell, "Toward a Secure Wireless-Based Home AreaNetwork for Metering in Smart Grids", IEEE SYSTEMS JOURNAL, VOL. 8, NO. 2, JUNE 2014

[5] Slawomir Nowak, Mateusz Nowak, Krzysztof Grochla, "Properties of Advanced Metering Infrastructure Networks' Topologies", 978-1-4799-0913-1/14/2014 IEEE

[6] Monontsi Nthontho, S.P.Chowdhury, Simon Winberg, "Smart Communication Network Standards for Smart Energy Management", 978-1-4577-1250-0/11/2011 IEEE.