AMI Mesh Networks – A Practical Solution, Performance Evaluation and Power Management

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ABSTRACT
In this paper, we describe the development of smart meter using Advanced Metering Infrastructure (AMI). This entails transport of metering data from energy consumer's premises to the data management systems of energy provider using a practical mesh networking solution to realize metering communication. When the demand in the grid increases with decreased amount of power generated, this in turn leads to insufficient availability of power at the consumer premises. The proposed work employs a ZigBee based digital power meter in which prioritization of appliances are employed. If the power is less on the grid, the power will be automatically managed using the controller embedded in the digital meter. Constant uninterrupted power is fed to the higher priority appliances connected to the meter, while the lower priority appliances receive power according to the power availability on the grid. The power usage of consumer is monitored through a Graphical User Interface (GUI) by the energy provider, in order to prevent the power theft.

General Terms
Smart metering, power management, wireless communication.

Keywords
AMI, measurements, smart grid, mesh networking, smart meter.

1. INTRODUCTION
In many countries the increase in demand is growing at a faster rate than transmission capacity. And the cost of providing power is also increasing due to higher fuel prices and increases in the cost of construction and capital expenses. The energy sector in recent years has led to greater competition along with consumer demand for more control over power usage and costs. This has forced to rethink traditional supply and billing practices. AMI puts control into the hands of both utilities and consumers by giving them more detail information about consumption this allows utilities to better regulate the supply and to refine their pricing structure based on demand cycles. It also gives consumers immediate feedback about the feedback of their usage allowing them to reduce their consumption.

There are several communication technologies such as cellular, broadband, Power Line Communication (PLC), and wireless mesh networks. Each of these technologies has its own pros and cons. In case of cellular, the utility provider will have to sort out agreements with the cellular operator which may have cost implications. Moreover, the utility provider will have to travel through a third party network. Cellular penetration may be another factor that has to be considered to ensure adequate coverage. Broadband technology is another alternative where data can be securely tunneled over the broadband network. However, broadband penetration issues need to be considered to ensure coverage. PLC appears like an attractive choice given the seamless of penetration of power lines in the consumer premises. However, regulatory requirements could mean limited deployments. Also, the underlying medium will not be available during power outages. Rolling out mesh networks comprising low power and low cost could be a compelling alternative especially because the utility provider will have complete control over the infrastructure. If the network management can be simplified, the cost and complexity associated with the deployments are reduced.

The focus of this paper is to show how advanced metering infrastructure (AMI) can be realized deploying a wireless mesh network and also how the meter effectively delivers the power in the consumer premises. The meter at consumer premises augmented with a wireless radio, can discover and connect to the "concentrator" deployed in each neighborhood. The concentrator can aggregate data from several meter nodes within the neighborhood and forward it to the utility provider's data management system using a wide area link. The topology of the concentrator's network can be visualized like a tree with smart meter nodes feeding into root node (concentrator) such type of network can self-configure and adapt automatically.

2. MESH NETWORKS FOR REALIZING AMI

2.1 Typical deployment and related challenges
The topology of the mesh network based smart metering communications solution can be visualized as several trees each rooted at a different concentrator with each concentrator serving the smart meters in the neighborhood. In a large scale network there could be hundreds of networks serving several tens of smart meters. There would be concentrator in each neighborhood which could either be deployed in a planned or unplanned manner. In former case the utility provider could assign a non-overlapping channel to each concentrator for it to operate on. In the latter case, there may be requirement for the concentrators to identify the channels used by other concentrators operating in their vicinity and avoid using the radio interference with the neighbors. Whether the deployment is planned or unplanned manner, there is still clear to meet with dynamics that may arise with the networks. As an example, smart meter nodes that power on will need to automatically identify the connectivity with the concentrator.

Some nodes not within the range may have to identify smart meter nodes through which they may be able to reach the multi-hop link. A self-organizing solution can be very useful in such circumstances.

2.2 Discovery of nodes and initialization of meter

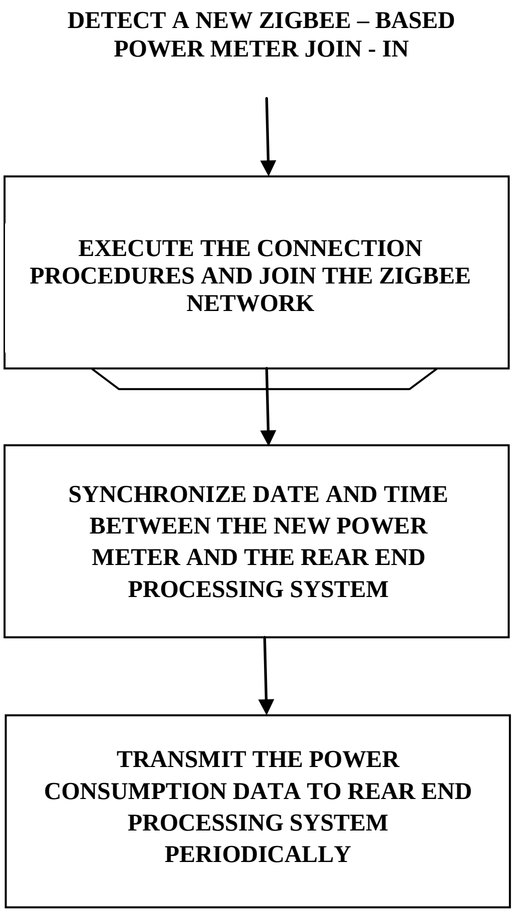

Fig 1: Power meter initialization

From Fig. 1, it can be seen that while a new ZigBee based smart power meter is detected; the node will execute the initialization and connection procedures to let the meter join in the ZigBee network. The power meter will then execute the date/time synchronization; afterward, the power meter will have the correct time information and can transmit the power consumption and event data to rear-end processing system periodically. If the date/time synchronization with the rear-end processing system was accomplished successfully, the procedure for power consumption data can be carried out periodically

3. SYSTEM ARCHITECTURE

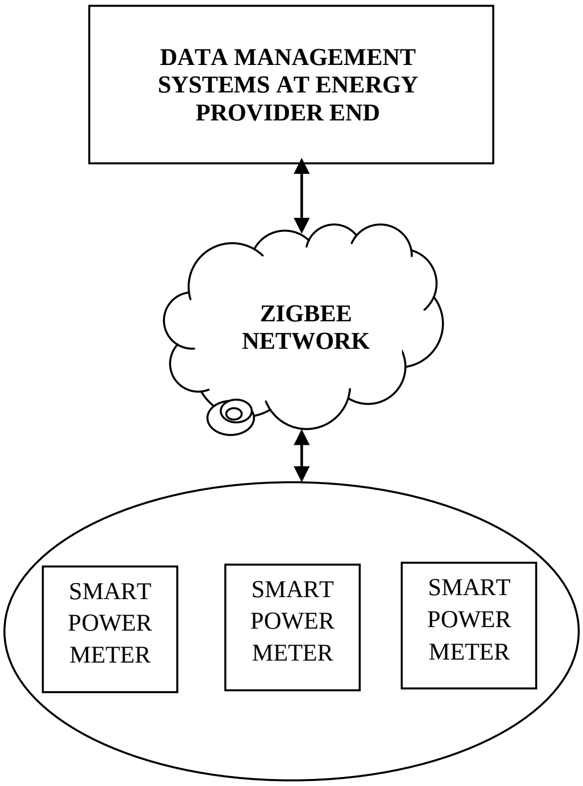

Fig 2: System architecture

Fig. 2 shows the system architecture of the proposed ZigBee based smart power meter system. The full system can be divided into three parts: the smart power meter, ZigBee network and the rear end processing system. First the voltage and current values of loads are acquired by the data acquisition modules they are then converted into digital signal using an ADC module of controller unit in the smart meter. The rear end processing system is composed of a ZigBee coordinator and the software is designed for the proposed smart meter. The software of the proposed rear end processing system is used to establish power consumption databases and offer inquiry of power consumption data recorded in the proposed smart meter.

3.1 Power management

Demand for power is the recent problem, where power generated is not sufficient to meet the power demand. We are now in a position where power is one of the essential one in our daily day life. When the power in the grid reduces, the power distributed to the consumers is interrupted. Sometimes this problem goes even more severe leading for the interruption period to last for a long duration. In this paper we have made a solution for the management of power when the power in the grid reduces. This can be made as a solution in residential power distribution. We have divided the distribution of power in our home into three lines they are of higher priority, medium priority and least priority. The priority of devices is fixed as per the power consumed by the appliances. A higher priority appliance are those that are of very few watts for e.g. fan, light etc., medium priority appliance are those which consume power which consume more power than higher priority appliance for e.g. motor pump, mixers, etc., and least priority appliance are those that consume more power than the other two, for e.g. air coolers etc. the prioritized appliance receive power through the relay arrangement in the smart power meter. Where the highest priority appliances receive constant uninterrupted power whereas the other appliances receive power based on the power availability on the grid. The power management is carried over by the energy provider side, where the power in the grid is monitored and distributed to the consumers is also monitored through a Graphical User Interface (GUI) at the power provider side. A simple control mechanism is been developed by simply sending the control signals that trips the relay ON/OFF according to the signal received from the power provider side. The transfer of signal is made through ZigBee nodes from the power provider side to the consumer side. The consumer usage of power is also carefully monitored, hence if any power theft is been performed by interconnecting the appliance makes the relay to be tripped off as a penalty again to restore receiving power, can only be done in triggering from power provider end. Thus the power can be efficiently handled whenever power in the grid decreases.

3.2 Smart meter characteristics

The meter displays the power consumed information along with the cost of power is to be displayed for a regular period of time. There are various LED placed in meter that represents the power to the line that is being currently delivered through the meter (higher/medium/least priority). The display of usage promotes the consumers to reduce their power consumptions. A buzzer is used to warn the consumer during power theft, along with a visual warning at GUI interface in the power provider side also indicates the power theft that is being carried over at specific residence. This enables the power provider to disconnect the power to the specific consumer if the theft prevails even after the warning being made at the consumer end.

4. SIMULATION RESULTS

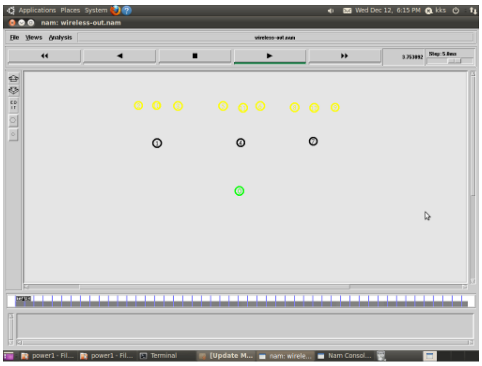

Fig 3: Initial stages of nodes

The various nodes in the figures 3, 4, 5 and 6 depicts the following properties: Yellow nodes: These nodes represent the various priorities of nodes connected to the digital power meter, Black nodes: These nodes represent ZigBee digital power meters, Green node: This node represent the main feeder power supply system.

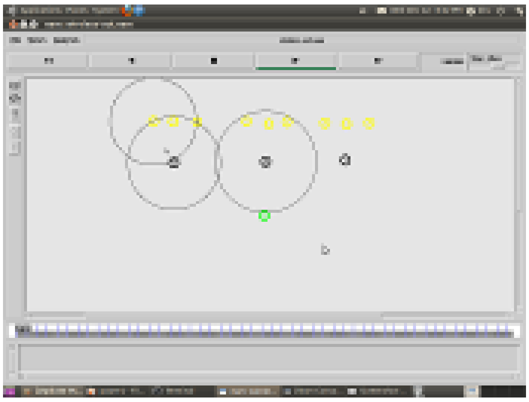

Fig 4: All nodes receiving power

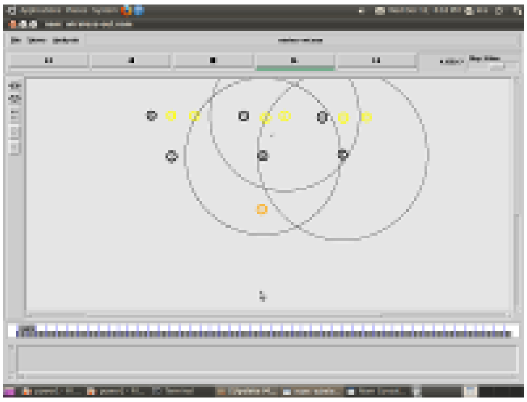

Fig 5: Two nodes of higher priority receiving power

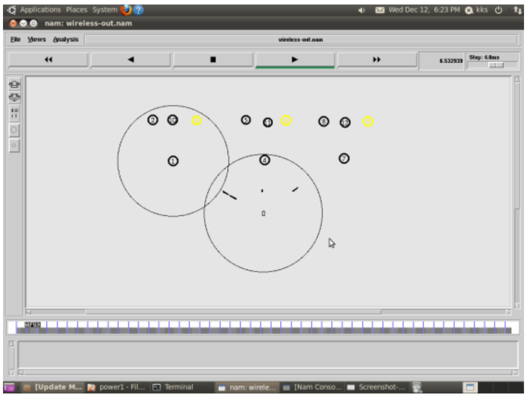

Fig 6: Only the highest priority node receiving power

Studying the proposed mechanisms in realistic scenarios with simulation results we move one step further by proposing various enhancements for smart metering. These results also make us provide valuable guidelines for deployment.

In summary, we have mainly focused on applying some of the existing mesh networking concepts and algorithms in new application of smart metering. This is not trivial, as AMI has posed some new challenges in terms of scalability, ease of deployment and cost efficiency. By combining careful protocol engineering and practical system design, our work shows an effective solution to AMI that achieves optimal system performance with standard compliance and robustness.

5. CONCLUSION

A ZigBee based smart power meter was designed and implemented in this paper. The rear end processing system used to acquire the power consumption data and store these data in rear end data base was also accomplished. Simulation results demonstrated the validity of the proposed system and showed that the proposed system can be effectively integrated to AMI. In addition, the proposed ZigBee smart power meter also does power management whenever the demand rises with production decreases in the grid and therefore, a really "Ubiquitous computing" can be created.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] Liting Cao; Jingwen Tian; Yanxia Liu; "Remote Real Time Automatic Meter Reading System Based on Wireless Sensor Networks", 3rd International Conference on Innovative Computing Information and Control, June 2008, pp.591-591

[2] P.Kulkarni, S.Gormus, Z.Fan and B.Motz,"A self-organizing mesh networking solution based on enhanced RPL for smart metering communications", in Proc.IEEE hotmesh workshop, Lucca, Italy, Jun.2011

[3] S.Subramani, Z.Fan, S.Gomus, P.Kulkarni, M.Sooriyabandara and W.H.Chin,"Wisemen:White space for smart metering", in Proc.IEEE Innov.Smart Grid Technol.(ISGT) Conf., Washington DC, Jan 2012.

[4] I.Akyildiz, X.Wang and W.Wang, "W#ireless mesh networks: A survey", Comput.Netw., vol. 47, pp.445-487

[5] T.Iwao, K.Yamada, M.Yura, Y.Nakaya, A.Cardenas, S.Lee and R.Masuoka,"Dynamic data forwarding in wireless mesh networks", in Proc.IEEE Smart Grid Commun. Conf., Gaithersburg, MD, Oct.2010.

[6] Microchip corporation, http://www.microchip.com/

[7] Vojdani.A: "Smart Integration", IEEE Power and Energy Magazine, Vol. 6, Issue 6, Nov.-Dec. 2008, pp.71-79

[8] EU Smart Grid Framework "Electricity Networks of Future 2020 and Beyond"

[9] Hart.D.G;"Using AMI to Realize the Smart Grid", IEEE PES General meeting, July 2008, pp.1-2

[10] Ian.F.Akyildiz and Xudong Wang, "A survey on Wireless Mesh Networks", IEEE Communications Magazine, vol.43, Sept.2005.