Two Tier Communication Architecture for Smart Meter

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Abstract—Construction of the smart grid network infrastructure is in the process of being laid out worldwide with the goal of energy efficiency from power generation to distribution. Making a smart grid work requires an array of enabling technologies, one of them being an integrated communications system. Smart meter plays a vital role in this communication system. Apart from sending and receiving regular billing/consumption related messages, the smart meter must be able to send so-called last gasp message in case of power outage in a very short time. In this paper, we propose novel two-tier communication architecture for smart meters that can choose which radio to use depending upon the message to be communicated. In the proposed architecture, the smart meter will be able to send a message directly to the control center in case of power-down, reducing the latency of the system.

Keywords—Smart Grid, Smart meter, Last gasp, WiMAX.

I. INTRODUCTION

The increasing dependence on electricity and power by the society has created a need for automated and interoperable version of power grid called the smart grid. The power grid aims to address problems such as demand supply mismatch, grid failures, inaccurate load forecasting and lack of control flow information. The challenges faced in addressing these problems include lack of a stable and reliable infrastructure capable of handling the two way communications and interoperability between the units involved. It is well known that power cannot be saved and must be consumed as soon as it is produced [1], which necessitates an efficient demand-supply match between the producers and the consumers.

Reliable communication between the units in the power grid plays an important role in management of any emergency situations in the grid. Early handling of stress conditions such as the grid failure over smaller areas is important in preventing catastrophic failures. The major parts involved in smart grid are power generation, distribution, consumption and communication among these entities. The communication domain includes smart meters, HAN/NAN concentrator, WAN aggregator and the control center. Exchanged information consists of data about metering, power consumption messages from the homes, aggregators and transmission units to the control centers. Since messages at each step have different size, frequency of dispersal and format, there is no standard allowing single ubiquitous communication link linking all the units [1]. A blend of communication technologies including zigbee, PLC, Wi-Fi, LTE etc. have been used and tested at different levels to create robust communication architecture for the smart grid.

For the regular periodic exchange of power consumption related messages, the communication path consists of three steps, from the smart meter to the HAN/NAN concentrator to WAN aggregator and then to the control center. The control center is linked with the power generating and distribution units and is the center for intelligent decision making regarding demand/supply calculations, billing etc. All the regular as well as emergency data from generators as well as consumers must reach control centers. The regular data may be processed at each intermediate unit and aggregated before it finally reaches the control center [1].

Job of metering and monitoring control information is spread over a vast network area. Though divided into smaller networks, the frequency of message creation and dispersal is extremely high. Assuming that approximately 10,000 smart meters generate message(s) every 10 minutes, highly scalable and reliable communication architecture is necessary to cater to the varying demands of power and communication [1].

The essence of reliable communication in smart grids starts and ends with the smart meter which acts as the intermediate between the consumer and the utility. The smart meter passes the demand and control information from the consumer side as well as pricing and control messages from utilities side thus acting like a gateway between the two. One of the design requirements of the smart meter is when power is lost, it must be able to send a so-called “last gasp” message to the control center within short time duration. This time duration is determined by the charge holding ability of the back-up capacitor used at the smart meter. It is possible to equip the smart meters with batteries but just as in smoke detectors, customers can not be relied to make sure the batteries are fresh and working. As a result, a charge capacitor is used and the capacitor charge is expected to last for about few milli-seconds and this define the time frame within which the last-gasp message must be sent. The three step communication described earlier will suffice for regular communication but not for the last-gasp message due to the latencies involved in crossing gateways, processing, queuing and transfer of message. Emergency message will not have this much time to live [2].

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So, the last gasp message needs to be communicated directly from the smart meters to the control center to reduce the possibility of message dying off in the route itself.

The idea addressed in this paper is based on the belief that effective communication architecture will help in faster dissemination of control information, which can allow the grid to take intelligent decisions and prevent series of other failures by implementing islanding situations. The emergency direct link from smart meters to control center may involve the use of any 4G technology or (wired) optical fiber network. In this work, we have proposed usage of 4G radio due to its range and flexibility. The smart meter must be enabled with a 4G radio and other radio technology for regular exchange of message with the concentrator as shown in the diagram. In addition, the smart meter must be equipped with cognitive intelligence to choose between the two communications technologies as per functional requirements.

II. SYSTEM MODEL

The system model consists of networks at different levels connected to each other in a serial manner. Link1 comprises of connection between the smart meter and the nearest BAN/NAN (around 250-500 meters [3]). The smart meters are periodically polled by the BAN/NAN aggregator to collect the data from the meters. Since the meters are periodically polled by the aggregator, primary outage can be reported from there itself in case meters do not respond to the regular ping. However, the reporting delay in this case will be closely tied to polling period, assuming the BAN/NAN aggregator has not lost its power. Different technologies such as zigbee, Wi-Fi, PLC, cellular communications etc. are deployed and tested in various countries for communication between smart meters and BAN/NAN.

Figure1: Traditional and Emergency Flow of Information in Smart Grid

Link2 comprises of connection between BAN/NAN aggregator to the WAN aggregator. Around 16-20 aggregators from the BAN/NAN area collect and periodically send the data to the WAN aggregator [3]. The processed data must traverse much larger area than the previous link. The range comprises of tens of kilometers [1]. Communication technologies such as Ethernet, microwave, 3G/LTE, fiber optic links are some of the options for the link2. Link3 is the collection of 2-3 WAN aggregators to the control center. The control center is also called the Meter Data Management System (MDMS). It comprises of units such as CIS (Customer Information System), GIS (Geographic Information System), OMS (Outage Management System) and DMS (Distributed Management System) [4]. All the information from the smart meters and aggregators reach the control center and it takes the decision over pricing, billing, supply-demand mismatch etc. The area from the WAN aggregators to the control centers is relatively large with 10,000 or more smart meters. The system model is shown in figure 1.

III. PROPOSED MODEL

In case of broad power blackout, all devices are expected to be cut off from the main power supply and need to communicate using backup source such as charged capacitor. In that case, the smart meters must directly communicate with the control center instead of following the regular flow. For such a large number of smart meters (around 10,000) to directly connect to the control centers either wired or wireless mode can be tested. Wired communication in the form of PLC is efficient but not reliable since the particular power-line may be down resulting in loss of power as well as communication break-down. Since notification of power loss at correct time may allow the control center to make decisions that may prevent broad blackout, a loss or delay cannot be tolerated in communicating the last gasp signal. So, the ubiquitous connection from the smart meters to the control centers with any of the 4G techniques has to be looked upon for emergency situations in addition to the regular three step link.

The proposed two tier radio architecture for the smart meter is enabled with two radios for different scenarios (normal communication flow and the emergency scenario). In addition, there must be cognitive intelligence which will allow the smart meter to make decision between the two radios as and when required.

IV. CONCLUSION AND FUTURE WORK

A two radio enabled smart meter is needed for the effective working and management of the smart meter and to cater to the needs of the smart grid. In addition to the radio, there has to be a cognitive intelligence to choose between the radios.

REFERENCES