IoT based SCADA Integrated with Fog for Power Distribution Automation

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Abstract—**Electrical Grid we have is more than 50 years old. The integration of information technology to the electric grid system is expected to address many shortcomings of the current and traditional electrical grids that have resulted in Smart Grid which is gaining lot of interest and momentum. In Smart Grid, Power Distribution is one part which requires monitoring and control. Lot of technologies and have been applied in Smart grid towards sensing and action. Supervisory Control and Data Acquisition (SCADA) system is very well proven within the substation region. There has been very less monitoring done on the distribution side due to the geographical distribution. Currently, Internet of Things has paved way for connecting huge number of devices to the Internet which would be very much effective and beneficial for power distribution and Automation. So accordingly, an IoT based SCADA integrated with Fog for Distribution Automation system has been proposed which takes care of the consumer utilization, outage management, power quality control and pole transformer health. This is supported by fog computing which does real-time streaming analytics. This helps in reducing the internet bandwidth and latency for immediate control action.**

Keywords—IoT; SCADA; Fog Computng; Distribution automation; Smart Grids.

I. INTRODUCTION

The electric Grid that we have is half a century old. To meet the demands, reduce losses and transport electricity effectively, the present grid needs to be updated.

The integration of information technology to the electric grid system is expected to address many shortcomings of the current and traditional electrical grids that have resulted in Smart Grid which is gaining lot of interest and momentum [1]. These smart grids integrate advance sensing technologies employing sensors, Control systems and communication systems into the current electricity grids. This improves the generation, storage alternatives, optimizing assets and operational efficiency [2,3]. The smart grid has a vision which incorporates a broad set of applications, comprising software and hardware technologies that allow utilities to participate, interface with, and intelligently control the present electric grid.

Power Distribution Automation (DA) which is a part of smart grid refers to automation of the entire distribution system operation and covers functions from protection of SCADA and associated information technology applications. Distribution Automation has the ability to mix local automation, remote control of switching devices, and central decision making into a cohesive, flexible, and cost effective operating architecture for power distribution systems maintaining the Integrity of the Specifications

One of the major problem for the lack of Distribution Automation system in India is the investment for installing sensors, Remote Terminal Units (RTUs) and creating a communication infrastructure. India has a lot to do with improving the DA infrastructure as it will be beneficial for the reduction of the Aggregate Technical and Commercial (AT & C) losses and providing better quality supply.

Cloud Computing has helped in bringing IoT to a reality. But not every IoT system can get the advantages of cloud computing. Industrial IoT systems require high speed control actions by immediately processing the data obtained from sensors. The delay caused by cloud in IoT System can cause damage to the systems that require instant processing of the data stream and quick feedback. This has resulted in a new method of computing called Fog computing.

Fog computing has the characteristics of the cloud computing at the edge, but at the same time relies on the Cloud for huge level of historical data processing. It forms a bridge between the edge devices and the cloud. Fog computing got lot of advantages over cloud computing like reduced latency, less processing delay and low bandwidth.

So for addressing the issue of power distribution automation, we here propose an IoT based SCADA integrated with Fog Router and Cloud. The rest of paper is organized as follows. Section II gives a complete literature survey pertaining to technologies in power distribution and automation. Section III talks on IoT based SCADA integrated with Fog architecture and its functionalities for power distribution and automation. Section IV is Conclusion and Future work.

II. Literature Review

In this section, we will be talking in brief on various technologies pertaining to smart grid like wireless sensors, IoT protocols and also about Fog computing .

A. Wireless Sensor technologies in Smart Grid

Wireless sensors help Smart Grids to obtain its maximum efficiency. Wireless Sensor Network (WSN) as "smart sensing peripheral information" play a vital role in smart grid technology development. WSN technology in the smart grid will also further promote the industrial development of WSNs [4,5,6]. These WSNs got lot of technical advantages pertaining to online monitoring system with timely warning for catastrophes, locating the position of faults and shorten the time of fault recovery and thereby improve the quality of power supply.

WSN have proved to be a very supporting technology for realizing Smart Grids (SG), especially in areas of power generation, transmission, metering infrastructure, providing cost effective control mechanisms [7, 8].

In [9], they use SG for green communication and other information communication (ICTs). The overview of SG and its communication and security challenges have been presented in [10].

Also, the study in [11] provides a reference architecture of the SG communication system and its major components. In addition, that survey discusses the four major SG applications, which are used to identify the key requirements for smart grid communication systems.

Various, diverse range power grid applications from Home area Network (HAN) to power Transmission and Distribution (T&D) monitoring have been developed and used allowing for robust and energy efficient monitoring and control in a SG [12,13].

B. IoT in Distribution Automation

Cloud-based SCADA is a small, highly specialized research area with only a few literatures. They define cloud-based SCADA architectures, but focus on implementing a solution from the ground up, as opposed to utilizing pre-existing SCADA solutions [14, 15].

Liu, et al. presents a generalized overview of clouds and SCADA, and propose the possibility of running SCADA in the cloud [16].

Gligor and Turc in [17] recommend exposing each SCADA component as a service and deploying them through a Local Directory Service (LDS). This approach is very flexible; allowing users to extend the SCADA system by adding new functionalities to existing services or define new ones in accordance with needs and formulated requirements towards a web-based SCADA system on Rackspace cloud resources.

Goose et al. presented a secure SCADA cloud framework called SKYDA [18]. This SCADA system is designed to take advantage of the scalability and reliability offered by a cloud-based infrastructure. They focused on providing a high level understanding of SCADA replication using clouds, moving all SCADA components (except the field devices) as a single service.

C. 6LoWPAN based sensor nodes:

6LoWPAN (IPv6 Low-power wireless Personal Area Network) is a new set of standards made by the Internet Engineering Task Force (IEFT) for IPv6 over low power embedded devices. The routing over low power lossy Network (RoLL) work group has come up with a new protocol called Routing Protocol for Low-power Lossy Networks (RPL) defined in the RFC 6550. Thus using sensors which are 6LoWPAN can ensure that the real-time monitoring and control demands of the industrial system can be achieved.

III. IoT based SCADA integrated with Fog Architecture

The overall system architecture for an IoT based SCADA integrated with Fog for Power Distribution Automation system been presented. The Distribution Automation sensing area is divided into the following 1) Smart Metering for monitoring and controlling the home supply. 2) Line sensors for monitoring the voltage and the current supply in the lines. 3) Intelligent Electronic Devices (IEDs) monitor the parameters like temperature, loading, voltage, current and power supplied. So towards monitoring the Transformers, Power lines and Smart meters, Fog router is placed in between the Pole Transformer and Consumer side. Pole mounted Fog router are placed in such a way that Pole Transformer's IED's use single hop to reach Fog router for better efficiency.

The smart meters that are to be installed in individual homes shall use 6LoWPAN standard. Since this is an IP based communication built upon the IEEE 802.15.4, every energy meter gets an individual IP address. This forms the Neighborhood Area Network based on 6LoWPAN. These collect voltage, current and Power consumption data from homes and send it to Fog Routers. IEDs fixed on the Pole Transformers also use 6LoWPAN based communication capability. These 6LoWPAN based sensors and meters are connected to 6LoWPAN aggregator and use multi hop communication to reach the Fog Router. The Fog routers act as the 6LoWPAN gateway, where the data from smart meters, line sensors, IEDs are collected in real time for analytics and use Backbone network like 3G/4G for communicating to Cloud. These Fog routers supports heterogeneity, cloud integration and distributed data analytics as we take the advantage of the low latency with a wide and dense geographical distribution. This also reduces the network traffic, Latency and provides Scalability. DA helps in improving reliability of the Grid. It helps in improving the efficiency of the operation and also extending the asset life.

A. Functionalities of IoT System

The IoT based SCADA integrated with Fog architecture for Power Distribution Automation takes care of outage management which is one of the basic functionality that the fog router will help us achieve by locating the location of faults by querying the smart meters for Voltage and Current.

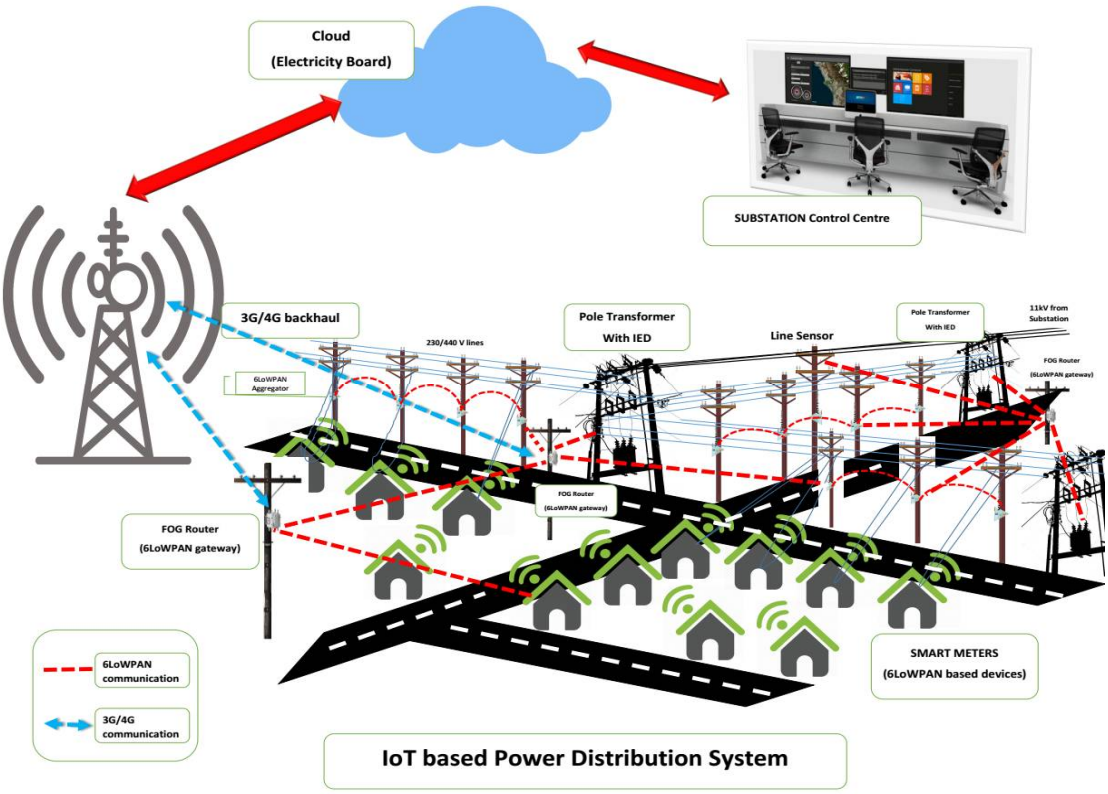

Fig.1 IoT based SCADA integrated with Fog Architecture

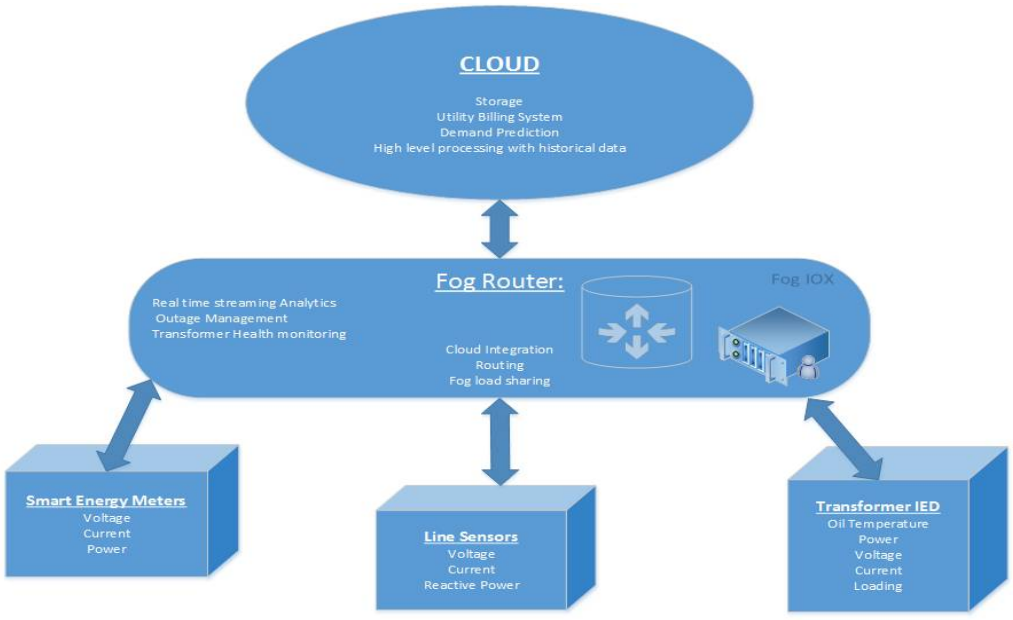

Fig.2 System Flow Diagram for IoT based Distribution Automation System

Analytical algorithms are deployed at pole mounted fog router for analyzing power quality, outages and usage patterns. In terms of Pole Transformer, Intelligent Electronic Devices called IED are deployed which is 6LoWPAN based communication. In here power consumption, supply voltage, Current, Temperature of distribution transformer would be monitored by Fog router real time. At the distribution line, Voltage and Reactive power be monitored periodically by deploying analytical algorithm at the fog router for voltage regulation by changing the tapping of capacitor banks.

Lastly the SCADA system at the substation would be upgraded for power distribution monitoring with a HMI which is provided as Software as a Service so that operating personnel can view alerts from anywhere.

IV. Conclusion and Future Work

In conclusion, we have seen that lot of sensing technologies been applied in Smart Grid for providing better power delivery and efficiency.

With the upcoming of Internet of things which connects all devices to internet, we here have developed an IoT based SCADA integrated with Fog Architecture for Power Distribution Automation integrated with Fog and Cloud. These Pole Transformer IEDs, Power Line sensors and Smart Meters are wireless enabled enabling 6LoWPAN communication. SCADA HMI be provided as Software as a Service.

In future, the proposed architecture be validated towards reliable routing protocol in IoT for power distribution and Automation for efficient communication of data. Also the system will be developed with proper analytical algorithm with Machine learning and so for analysis and same validated too. Thus proving the effectiveness of IoT based architecture for Distribution Automation.

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