Smart IoT Communication: Circuits and Systems

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Abstract

In a smart IoT system, multi-sensing at a field node is a typical scenario. The examples considered in this study are pollution monitoring and smart energy metering. In such applications, energy sustainability and communication and storage resource usage optimization are two of the key issues of interest. In this study, on one hand it is intended to develop indigenous beyond state of the art multi-sensing boards with the inherent smartness in energy replenishment and sensing/communication activities. On the other hand, smart data collection and processing at the end node (fog node or edge node) is of interest primarily from efficient communication bandwidth usage perspective.

On the first exercise towards energy sustainable IoT sensing and communication board design, we have designed a prototype for a 5G capable environmental air pollution monitoring system. The system measures concentrations of NO2, ozone, CO and SO2 using semiconductor sensors. Further, the system gathers other environmental parameters like temperature, humidity, PM1, PM2.5 and PM10. The prototype is equipped with a GPS sub-system for accurate geo-tagging. The board communicates through Wi-Fi and NB-IoT. The board is also equipped with energy harvesting power management, and is powered through solar energy and battery backup.

On the second exercise, a working model of a smart IoT device with a data pruning subsystem is designed, where a smart energy meter is considered for an example application. As a proof of concept we plan to demonstrate data compression at the edge to save bandwidth required for data transmission to a remote cloud. At each smart meter, sparsity of data is exploited to devise an adaptive data reduction algorithm using compressive sampling technique such that the bandwidth requirement for smart meter data transmission is reduced with minimum loss of information. The Smart Energy Meter is WiFi and NB-IoT enabled. This meter is capable of logging multiple energy consumption parameters.

The overall objective has been demonstrating the ability of beyond state of the art circuits and system design for IoT communications, wherein context specific intelligence is applied at the at the node. The broad philosophy in this study can be readily extended to any chosen IoT application.

1. Demo Part A: Energy Harvesting Enabled Multi-Sensing in Smart IoT Applications: A Test Case of Air Pollution Monitoring

1.1 Motivation

The main reason for air contamination is industries and also extensive use of vehicles adds more to it. Air quality is menial in metropolitan cities like Delhi, Mumbai and Kolkata. This degraded air pollution imposes a drastic effect on humans as well as on the environment. Numerous air pollution monitoring systems are being developed by researchers from the past few years.

Various industrial air pollution monitoring systems are available which are integrated with GSM, Bluetooth, ZigBee etc. as its communication protocol. This system can be deployed to the industries to monitor carbon monoxide (CO), sulphur dioxide (SO2) and dust concentration. But these are very power hungry and also does not have any energy harvesting technique inside them. Gas chromatography (GC), a Conventional air quality monitoring system is limited with respect to expense, time and installation sites. Opsis, Codel, Urac and TAS-Air metrics are some available pollutant monitoring systems which are typically expensive and has installation limitations.

The system, shown in Fig. 1, consists of Alphasense Gas sensor (AFE) module and Alphasense OPC N3 to sense carbon monoxide (CO), Sulphur dioxide (SO2), Nitrogen dioxide (NO2), Ozone (O3), PM1, PM2.5 and PM10 respectively. Temperature and humidity are sensed using DHT11 sensor. It is using NB IoT and/or Wi-fi as the communication protocol. This NB IoT consumes a very low power (in microwatts) in its active mode. The fabricated board and some results are shown in Figs. 2, 3, and 4.

1.2 System Overview

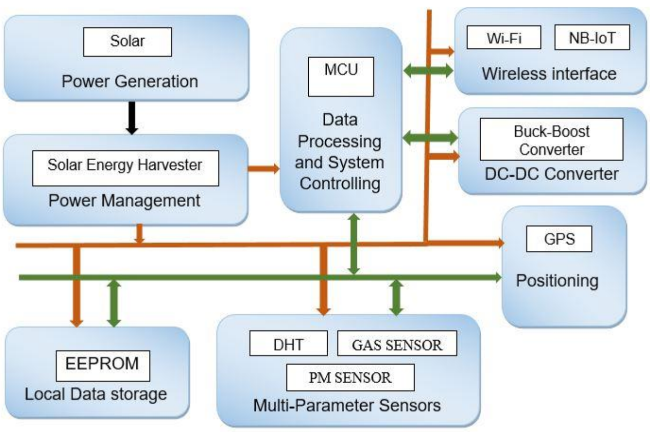

Fig1. Block diagram of the system.

Fig2. 5G Enabled Designed Prototype.

1.3 Results

Fig3. (a) Temperature and (b) Humidity graph in cloud.

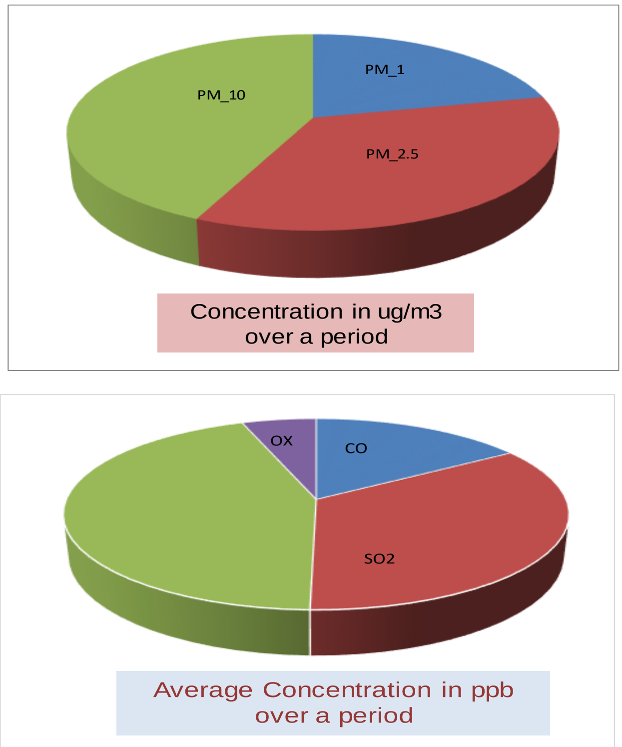

Fig. 4. Gas sensor and PM sensor data at a particular instance.

2. Demo Part B: Context Specific Data Pruning in Smart IoT Applications: An Implementation Case Study on Smart Energy Meter

2.1 Motivation

Advanced Metering in Smart Grid has emerged as a powerful paradigm to enable bi-directional information flow between utility and consumers in the electricity distribution network. Unlike their analog counterparts, smart meters follow a rapid data logging approach to generate loads of fine grained electricity consumption data. Typically, Smart Meters implement two modules, which are measurement and communication. Hence, each Smart Meter has two subsystem **Metrology and Communication**, respectively. Data collected by the Smart Meter is a combination of measured parameters along with Unique identifier and the current timestamp. Though smart metering is useful for understanding and modeling of energy usage patterns, efficient communication and storage of this massive data remains a challenge. Due to limitation in handling big data, strategies for smart meter data reduction need to be employed. However, Data Driven Resource Optimization techniques have not been incorporated in Smart Meters. It is therefore proposed to incorporate a **Data Pruning Subsystem** in Smart Meters.

The proposed software architecture is shown in Fig. 5, and the hardware system snapshot is shown in Fig. 6. Live data pruning performance screenshots are shown in Fig. 7.

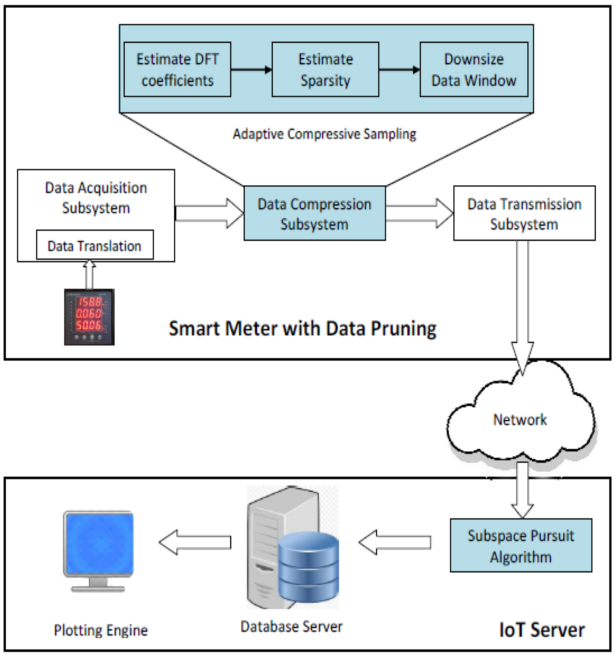

Fig. 5. Smart Metering: Proposed Software Architecture.

Fig. 6. Smart Energy Meter with Data Pruning Subsystem.

2.2 Results

Fig. 7. Time-series of Reconstructed Samples along with Real-time BW Saving.