Bringing IoT closer to carbon neutrality

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***Abstract*—Internet of things (IoT) is present in our daily lives in a variety of forms, including wearable devices, smart home appliances, smart sensors and actuators, healthcare, and smart mobility. The IoT market is anticipated to reach $3,352.97 billion by 2030. IoT devices are primarily battery-powered, so power management is the primary concern. In 2012, author had his first experience with power consumption and energy measurement through a collaborative project with the Institute of Horticulture. Since then, author has been striving to make the Internet of Things more energy-efficient. This abstract summarizes the results of the ongoing work this area.**

***Keywords*—IoT, WSN, TestBed, GHG, Carbon footprint**

I. Introduction

Carbon footprint, sometimes referred to as climate footprint, is an estimation of ecological impact, often in relation to global warming, often estimated as the sum of all greenhouse gas (GHG) emissions of a specific process [1]. In the world of Internet of Things (IoT), calculating GHG is difficult because no one knows the total quantity of GHG emitted by an IoT device due to the complex calculations required [2]. The total quantity can only be speculated and estimated by factoring in the footprint of each chip, the manufacturing of the device itself, the energy costs of software development, the energy efficiency of the device while running, its overall life expectancy before replacement, impact of deployment, etc.

Author is concentrating on the energy efficiency portion of the IoT carbon footprint because it is a variable that can be measured and influenced by certain actions, such as selection of specific hardware components, software component optimization, duty cycle adjustments, etc. The author has been acutely aware of the carbon footprint issues of IoT devices ever since the the development of their first Wireless Sensor Network (WSN) node - SADmote [3], described in Section II. After developing this node, the author commenced work on a real-time energy consumption measurement system for WSN [4] described in Section III, which was subsequently incorporated into WSN TestBed [5] described in Section IV. Finally the current results and future work are shortly discussed in Section V.

II. SADmote

SAD was the first project in which the author was challenged to create a node that could withstand harsh environments and capture data for an extended periods of time [3]. Author created a sensor node dubbed SADmote, whose primary purpose was to collect data on environmental factors such as temperature, humidity, and available light. This node needed to be effective enough to collect data and transmit it throughout the network. The sensor network of these nodes was deployed in an orchard owned by the Institute of Horticulture. The primary goal of this network was to collect environmental data that would aid researchers in boosting crop yield and combating horticultural issues such as insufficient water or sunlight. The author was tasked with developing this device's circuitry from the ground up, during which the author identified the need for current measurements to enhance the field dependability of WSN nodes.

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III. Real time energy consumption measurement device

As part of a term paper [4], the author began working on a superior method for measuring the energy consumption of WSN nodes following the development of SADmote. The device was required to be both dependable and simple to use with terminal or USB connections. The idea arose after using instrument-based energy consumption measurements [6], which included a multimeter and occasionally an oscilloscope to gather the measurements. The devised device was able to automatically collect energy consumption data with an error rate of up to 13.44%.

IV. Wireless Sensor Network TestBed

The subsequent step was to increase the scale and introduce the capability of real-time energy consumption measurements to multiple WSN nodes at once. The energy consumption measurement device was created in EDI TestBed [5], a facility that enables users to develop, test, and debug the WSN as a whole, not just its individual components. The error rate of this measuring instrument was reduced to 0.5% through its enhancement. Afterwards, energy measurement capabilities were added to mobile EDI TestBed workstations [7] so that this functionality could be used outside of laboratory constraints and directly in the target environment. The next stage is to enhance EDI TestBed's overall functionality [8]. The measurement of energy consumption is one of the most crucial aspects of a refined and debugged IoT system. The TestBed v2 has ambitious requirements, but they are not unreachable.

A. TestBed v2 current measurement requirements

The requirements are set as follows:

- Current measurement range 2nA - 3A
- Current measurement frequency 1MHz