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# Maximizing the usable battery capacity in WSN with load harmonization

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**Abstract-** Wireless sensor nodes are mainly battery powered, thus having restricted amounts of energy. A WSN should be autonomous and self-sustainable, able to function for several years with a battery power supply. A node's lifetime is defined as the node's operating time without the need for any external intervention, like battery replacement. A WSN lifetime can be defined as the lifetime of the shortest living node in the network, but, depending on the application, density of the network and possibilities of reconfiguration, it can be defined as the lifetime of some other (main or critical) node. In the present paper we have presented the load harmonizing in wireless sensor node which will help increase the longevity of the wireless sensor node by enhancing the usable battery capacity.

## 1. INTRODUCTION

A Wireless Sensor Network (WSN) consists of a large number of small devices with very limited capabilities, called wireless sensor nodes, each of which integrates one or more sensors, a processing subsystem and a short range transceiver. These nodes collect information from the environment, process the information, locally make decisions and wirelessly communicate with other nodes in the network. However, when considered individually, each node is a simple device; the components that make up its subsystems are commonplace, off-the-shelf components. . A WSN lifetime can be defined as the lifetime of the shortest living node in the network, but, depending on the application, density of the network and possibilities of reconfiguration, it can be defined as the lifetime of some other (main or critical) node.

Anyway, in order to prolong a WSN lifetime, it is required to reduce the energy consumption of the nodes as much as possible and form an energy- and context-aware system. The problem of energy consumption has been addressed in two different ways in the literature. In the first, a large number of energy-efficient communication protocols – most significantly, MAC, routing and self-organization protocols that take the peculiarities of wireless sensor networks into account have been proposed. In the second, local dynamic power management (DPM) strategies are developed to recognize and minimize the impact of wasteful and inefficient activities within an individual node. Wasteful and inefficient activities can be accidental side effects or results of non-optimal software and hardware configurations.

This paper attempts to explain the load harmonization to maximize the usable battery capacity by harmonizing the battery consumption to continuous and uniform discharge rates by dynamically altering the operating Voltage and Frequency with the goal to complete the tasks just in time.

The remaining part of the paper is organized as follows: In Section II, an overview of the Li-ion battery properties and information dissemination techniques in WSN are discussed to set the context for the topic of this paper. In Section III, generation of harmonization co-efficients is discussed which will be used to determine the weighted timings for the experimental wireless sensor node. In Section IV, load harmonization technique is discussed. Finally, in Section V, some outstanding research issues are discussed and concluding remarks are given.

## 2. BATTERY

A brief overview of the properties of lithium-ion batteries is given below to set the context for explaining the proposed usable battery capacity maximization.

The usable capacity of a battery is mainly affected by two factors: the load power and the intermittence of discharge [1]. Batteries are specified by a rated current capacity, C, expressed in Ampere-Hour. This quantity describes the maximum amount of energy that can be withdrawn from a battery under a specified discharge rate and temperature. Most portable batteries are rated at 1C, which means a 1000mAh battery provides 1000mA for one hour, if it is discharged at a rate of 1C. Ideally, the same battery can discharge at a rate of 0.5C, providing 500mA for two hours; and at 2C, 2000mA for 30 minutes and so

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on. 1C is often referred to as a one-hour discharge. Likewise, a 0.5C would be a two-hour discharge and a 0.1C a ten-hour discharge [3].

In reality, batteries perform at a rate below the prescribed rate. Often, the Peukert Equation [2] is applied to quantify the capacity offset.

$$C_p = I^k t$$

where $C_p$ is the Peukert Capacity expressed in Ampere-Hours; I is the discharge current in Ampere; k is a dimensionless constant that refers to the internal resistance of the battery (known as the Peukert constant). This value indicates how well a battery performs under continuous heavy currents. A value close to 1 indicates that the battery performs well; the higher the number, the more capacity is lost when the battery is discharged at high currents. k is determined empirically. For example, for lead acid batteries, the number is typically between 1.3 and 1.4. Finally, t is the discharge time expressed in hours.
Drawing current at a rate greater than the discharge rate results in a current consumption rate higher than the rate of diffusion of the active elements in the electrolyte. If this process sustains for a long time, the electrodes run out of active material even though the electrolyte has not yet completely exhausted the active material. This situation can be overcome by intermittently drawing current from the battery.

The discharge rate has a non-linear impact on the total amount of power a battery can deliver. A typical lithium-ion battery has the following characteristics [1,4].

| Discharge Rate | Usable Battery Capacity ( Normalized to 1C discharge rate) |
|---|---|
| C/5 | 107% |
| C/2 | 104% |
| 1C | 100% |
| 2C | 94% |
| 5C | 86% |

A high discharge rate (e.g., >4C) can lower the usable battery capacity to 70%-80%. Additionally the usable battery capacity can be shortened by an intermittent load. Duty cycles of 25% can reduce the usable capacity by 40% compared to a continuous load with the same average power [1,3].

Due to the influence of discharge rate and load intermittence on the battery capacity, our scheduling algorithm should consider both effects and should throttle the system activity in a way that establishes continuous load of a modest level by altering the bias voltage and operating frequency. Sporadic high loads should be avoided.

## 3. INFORMATION DISSEMINATION

There are four established techniques for information dissemination in WSNs:

### 3.1 Continuous/periodic dissemination

The sensor node continuously reports data following a periodic schedule. In this way, packets are proactively pushed from the network (and an energy cost incurred) even when the sensed parameter has not significantly changed, hence containing little useful information since the previous transmission.

### 3.2 Query-driven dissemination

The user or application initiates data transfer by querying data from the network. Qualifying nodes reply to these queries with packets.

### 3.3 Event-driven dissemination

The intelligent' sensor node decides for itself what data are worth reporting to a sink node. In that way, redundant transmissions can be minimized (using the principle that: 'it is not news if one can predict it').

### 3.4 hybrid dissemination

Algorithms that are an amalgamation of the above techniques.

In continuous reporting, the choice of period duration has a considerable effect on network performance. If a short period is chosen, a large proportion of the packets are likely to be redundant (containing little useful information), while still consuming energy. If a long period is chosen, the network is likely to suffer from latency issues and the missing of events. While the missing of events can be avoided by locally aggregating the average-max-min sensed values (when using a sampling rate that is greater than the dissemination rate), this does not avoid the issues with latency or the information smoothing that aggregation introduces. Hence, while continuous dissemination is suited to applications with random or uncharacterizable signals, in most cases it does not maximize energy consumption or information throughput. Event driven dissemination approaches provides more suitable techniques.
[5].

Event driven systems can be classified into two categories: those that report only the 'digital' occurrence of an event (such as smoke or motion detectors), and those that detect the occurrence and magnitude of an event (such as a seismograph which reports the magnitude of any vibration above a

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certain threshold) [6]. Event-driven algorithms require a form of intelligence inside the network, however simple, to ascertain when events occur. Rule-based approaches generate events whenever specific criteria are fulfilled or features detected in the sensed environment.

## Generate initial harmonizing co-efficients

It is observed that there is considerable different in the cost and latency of the operation between different types of sensor nodes based on their hardware and software configuration as well as the intended application. Therefore it is impossible to device a load harmonizing mechanism without knowing the actual values of the supported operating voltages, frequency steps and power & latency to perform an operation at different operating voltage and frequency points.

Based on the complexity of the of the selected wireless sensor node, which depends on its hardware, software configuration and the complexity of the application it designed for the overall functionality of the sensor node is divided into a set of operations. While doing this care should be taken that we do not divide them into to small atomic operations as it may increase the complexity of the load harmonizing and may result in consuming more energy than we save. In our case we have divided into three macro operations, viz. sampling/sensing, processing the collected samples and communicating the processed result to the desired destination node. In reality it might go upto 5 to 7 operations based on the data aggregation, In node processing strategies as well as the sleep and wakeup schedules controlled by used mac protocols and network topologies.

Once we have decided upon the macro operations, traces are added to output the execution latency of each of these macro operations and the trace data is collected by exercising these macro operations multiple times and a simple linear average is taken. This is repeated for all the supported voltages and frequencies.

For a WSN supporting 2 operating voltage and frequency points the table might look like this

| Voltage/Frequency | Sensing | Processing | Communicating |
|---|---|---|---|
| $V_F F_F$ | $T_{SF}$ | $T_{PF}$ | $T_{CF}$ |
| $V_H F_H$ | $T_{SH}$ | $T_{PH}$ | $T_{CF}$ |

To minimize the variations between the same type of nodes and also to compensate for the variations due to temperature, while taking the multiple samples, different nodes can be used and tested at different temperatures.

## Load Harmonizing

Wireless sensor networks are predominantly event driven and the events occur infrequently; and nodes experience non-uniform workload. Hence, the main goal of a Load harmonizing strategy is to harmonize these spikes to create a continuous and uniform work load. This entails determining the type and timing of the load based on the system's history, workload, and performance constraints.

In an event driven environment, a node follows a sleep-wakeup-sample-compute-communicate cycle, where the majority of the cycle is spent in the low power sleep state. This is due to the common requirement in WSNs that they do not require continuous sampling or communication (WSNs are often defined by their low data-rate and communication frequency); hence, active cycles of 1–2 % are common [7]. This implies that most of the nodes spend around 98% of the time either in sleep state or idle. Load Harmonization works by reducing this sleep/idle time to around 97% by increasing the active time But a Lower operating Voltage and Frequency point. By doing this there will not be any saving or change in the energy consumption as Energy consumption per operation remains constant for different operating Voltage and Frequency points. The actual saving comes from the usable battery capacity as distributing the load over a longer period at uniform level will result in twin advantages of reduction in number of duty cycles as well as keeps the drawing current at lesser rate. Sensor nodes will have prior information about the start of the operation like Sensing, processing and Communication. As Sampling/sensing period is pre-defined and processing is normally triggered by a preceding Sensing operation or a preceding communication operation in case of data aggregation. And communication start times are controlled by mac protocols and can be obtained from the mac protocol in use. Load harmonizing is done by making use of the start time of the next operation in sequence which is already available with the sensor node and the latency required to complete the current operation (harmonizing co-efficient) determined in section 3.

At the start of each of the macro operation, load harmonizing function will be triggered to set the node to the optimal operating voltage & frequency. Load harmonizer will then compare the latency of the

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current macro operation for each of the available operating VF point with the operation start time of the next scheduled macro operation and selects the least VF point with which the operation can be completed before the start of the next macro operation. In this way Load optimizer will distribute the load to a continuous uniform level from. Load harmonizer will also update the harmonizing co-efficients based on the execution latencies each time it completes the macro operation to take care of any minor deviations that may occur because of aging etc.

## 4. Conclusion & future scope

As part of this paper we have presented the load harmonizing in wireless sensor node which will help increase the longevity of the wireless sensor node by enhancing the usable battery capacity. Studies need to be continued on how the power consumption is affected in the specific cases where remaining time after harmonized operation is less than the time required to allow the system to enter the sleep state. And accordingly load harmonization algorithm needs to be updated to either carry on the operation at higher operational voltage frequency point and enter the sleep or carry on at lower VF point and remain in idle.

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