Methods to Maximize IoT Battery Life

A Technical Paper prepared for SCTE/ISBE by

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1. Introduction

Addressing Internet of Things (IoT) energy consumption has a number of potential benefits, from the obvious environmental value of reducing the number of disposed batteries, to the customer experience benefits and resource savings that can be associated with fewer service calls. The concurrent migration to smaller devices requires action to extend the sensor battery life; chief among these is to improve battery selection techniques.

On the surface, choosing a battery for an IoT sensor may seem like a simple task, but in reality it involves a complex process of discovery, selection, and testing as outlined in this paper. Typically, replaceable lithium coin cell, cylindrical alkaline, and lithium batteries are utilized, as are other flat battery designs. While some IoT sensors use special high-cost chemical or rechargeable batteries, this paper is focused on maximizing battery life for low-cost wireless IoT sensors with replaceable batteries, deployed by the cable industry.

Simulated implementation for both performance and economic aspects are evaluated. Among important factors are assessing subscriber and system operator experiences from time, cost-savings, safety, and disposal perspectives. Recommendations are proposed to identify product design and deployment opportunities for Multiple System Operators (MSOs).

2. Battery Procurement

The objective for choosing a battery for an IoT sensor design is to find either the lowest-cost battery or, in some instances, to find a name-brand battery that meets your requirements. Battery manufacturers consistently advertise that their battery is superior and longer lasting, but the reality may be that there is only a marginal improvement of one over another. Also, often what is advertised differs drastically from what is delivered.

There are four false assumptions about procuring batteries: (1) major manufacturers have the highest-quality batteries; (2) lithium batteries are more powerful than alkaline batteries; (3) brand-name batteries cost more than no-name batteries; and (4) buying batteries from major vendor websites or distributors is good enough.

2.1. Origin of Manufacture

Major battery manufacturers may procure their batteries from their own factories or from third-party factories. From either source, the case and look of the battery can be identical. There are two methods to determine the quality of the battery. The first is to contact the battery vendor directly, which is usually performed under a non-disclosure agreement (NDA), and ask in what factory (or factories) the battery in question is manufactured and which factory carries out quality control; then confirm the country of manufacture on the battery label. If the battery manufacturer has multiple factories in China, for example, modify the procurement agreement to state that only batteries of this type are acceptable from this factory, unless notified and agreed to otherwise.

2.2. Pricing

Typically, information on battery pricing is found on bulk battery distributors' websites, but this pricing does not reflect the discounts that a large company would be provided for volume purchasing for a new IoT device and other products for which the company is currently procuring. Public website pricing is typically higher than what can be negotiated by a bulk customer, so it is suggested that pricing should become an exercise of discussions between major battery manufacturers and, in some cases, lower-cost manufacturers for cost comparison. Major manufacturers may sometimes charge the same price or a price within a couple of cents per unit as a lower-cost manufacturer, so that cost difference becomes a less important factor than other considerations when deciding on which battery to use.

2.3. Storage

Vendors must be able to provide documentation that their batteries are stored at a temperature close to 70 °F in a humidity-controlled environment, and that the batteries provided are fresh and not from dated warehouse stock. For manufacturer devices shipped, it is strongly suggested to require batteries be dated no more than 3 months from the date of manufacture as battery capacity generally degrades about 10% per year (see Figure 3). Recently, battery manufacturers have been marking batteries with an expiration date rather than a date of manufacture. For example, in 2016, a battery with a 2022 expiration date and a 10-year shelf life is likely to be 4 years old, and thus have an estimated 40% reduction in capacity. Battery manufacturers that have fully automated factories usually have less contamination; as a result, non-manual production and a better level of quality therefore exists. Battery contamination during manufacture, such as a dielectric marred by micro-pinholes, will result in a shorter battery lifespan than rated.

3. Battery Internal Resistance

All batteries will have some amount of internal resistance (IR; see battery schematic in the figure below). For example, a CR2450 cell will have an IR of 20 Ω or less. IR can be measured by calculation or using a test meter.

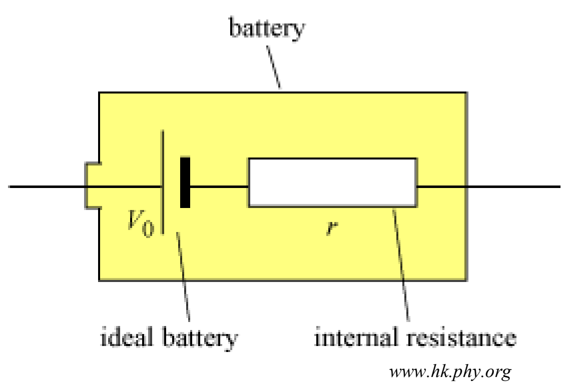

Figure 1 – Battery Schematic Illustrating Internal Resistance

Internal resistance generally varies as the inverse of the battery voltage drop over the life of the battery, as shown in the below diagram. Battery charts such as those shown below typically show “light loading” over time, while IoT devices on transmission, for example, exhibit a high level of instantaneous current draw which results in a lower voltage provided by the battery, depending on the battery maximum current draw specification and the internal resistance of the battery. Hence, there is a need to select device circuits with the lowest current draw for a max-loading operation such as wireless transmissions. For example, for a 50 mA instantaneous draw, a 3 V lithium coin cell may drop 400 mV, while two 1.5 V AA alkaline batteries in series (i.e., 3 V) may only drop 100 mV, mostly due to the much lower internal resistance of the alkaline battery.

In some cases, depending on current drawn, alkaline batteries can outperform lithium coin cell batteries. Performing a load test with both lithium and alkaline batteries is an improved method to determine the best battery for a particular application.

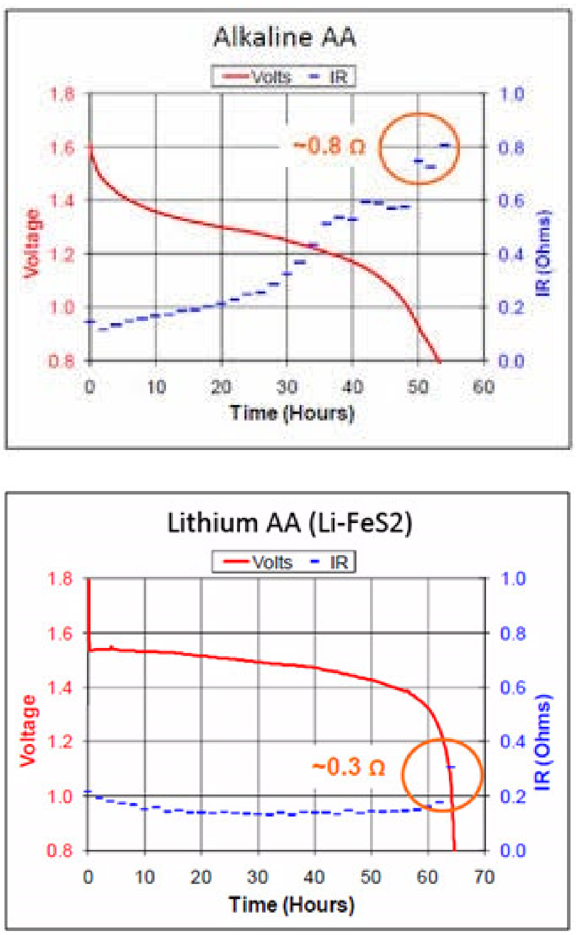

Figure 2 – Variation of Voltage and IR over Time for Alkaline (top) and Lithium (bottom) Batteries

4. Advanced Battery Designs

New battery chemistries are more resilient against degradation over time, particularly in a high-heat environment. However, these batteries have the trade-offs of smaller capacity and slightly higher cost. Modern smoke alarms are using such batteries for a sealed 10-year life span. (Note: While the battery life of these devices is longer than that of standard batteries, the 10-year life span assumes a life spent in standby. Battery life is shortened when alarms occur.) Taking into account customer satisfaction, truck-roll costs, and disposal related to battery replacement, utilizing the new chemistry, longer-life batteries is well worth the small increase in cost.

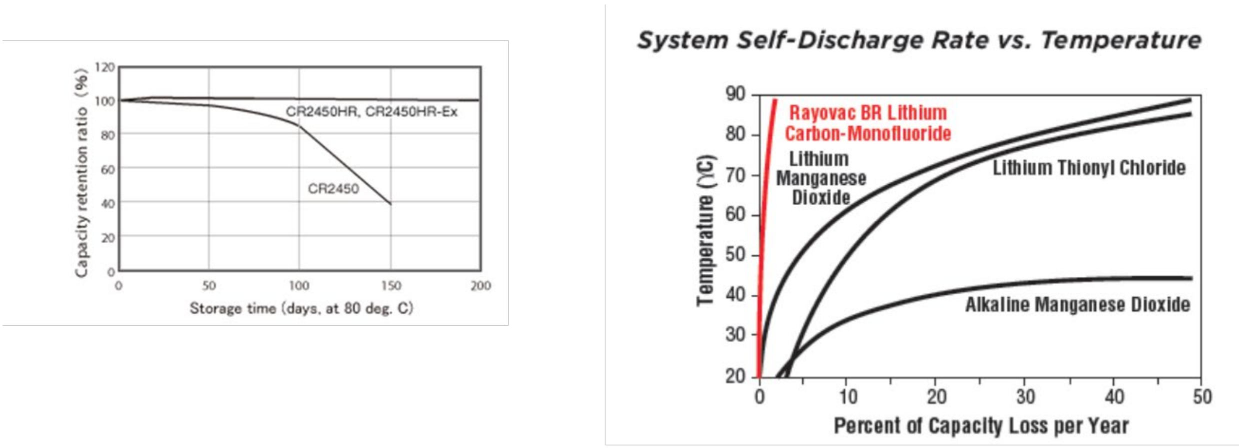

Figure 3 – Analysis of Battery Capacity over Time for Different Manufacturers/Products

5. Storage and Disposal

It is suggested that only a limited number of batteries and devices with batteries be carried in trucks and that stock be regularly turned over, as trucks exposed to the extreme summer heat will reduce battery life. (Extreme heat degrades batteries; cold preserves batteries as long as the temperature is not at or below the manufacturer's extreme cold battery rating.)

Batteries removed from IoT sensors should be wrapped/stored as recommended by the battery manufacturer and returned for recycling or proper disposal as advised by the battery manufacturer. One benefit of battery recycling is that some new batteries are composed of a small amount of recycled battery material, and are marked as such. Thus, battery recycling is encouraged to promote a "greener" environment for battery usage.

6. Safety

Accidental shorting of batteries must always be a consideration. Some battery types, but not all manufacturers within that type, incorporate a built-in positive temperature coefficient (PTC) circuit for additional protection. Other recommended protective measures include: the addition of battery protection circuits in the device design, mechanical reverse battery protection, and wrapping the batteries individually in plastic by the manufacturer. It is strongly suggested to contact the battery manufacturer for their complete list of battery safety recommendations.

7. Summary

To maximize IoT battery life the following steps are required:

1. Select device designs with the lowest battery cut-off voltage, lowest sleep current, lowest max-load draw, and adequate low equivalent series resistance (ESR) capacitance across the battery circuit.
2. Review the battery candidate's data sheets and select advanced battery chemistries with the lowest internal resistance, widest operating temperature range, largest capacity, and lowest capacity loss over storage time.
3. Pre-screen a large sample of batteries to find the product with the most consistent and lowest internal resistance.
4. Test and compare candidate batteries over a temperature range, loading down to the cut-off voltage of the device.
5. Follow the procurement procedures in this paper for the final battery vendor selection criteria.

When the steps above are taken for the IoT design and battery selection, the result will be optimal battery life (reduced overall battery change-out cost), fewer service calls (reduced operator cost), and increased customer satisfaction (customer retention benefit).

To truly maximize IoT device battery life beyond this paper's recommendations, device designers must employ smart software to conserve battery life: sleep the device for the maximum time the application will allow and ensure device functions take as little time as possible.

8. Abbreviations

ESR	equivalent series resistance
IoT	Internet of Things
IR	internal resistance
PTC	positive temperature coefficient