UrJar: A device to address energy poverty using e-waste

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ABSTRACT

A significant portion of the population in India does not have access to reliable electricity. At the same time, there is a rapid penetration of Lithium Ion battery-operated devices such as laptops, both in the developing and developed world. This generates a significant amount of electronic waste (e-waste), especially in the form of discarded Lithium Ion batteries. In this work, we present *UrJar*, a device which uses re-usable Lithium Ion cells from discarded laptop battery packs to power low energy DC devices. We describe the construction of the device followed by findings from field deployment studies in India. The field trial participants appreciated the long duration of backup power provided by the device to meet their lighting requirements. Through our work, we show that *UrJar* has the potential to channel e-waste towards the alleviation of energy poverty, thus simultaneously providing a sustainable solution for both problems. More details of this work is provided in [3].

Keywords

computing for development; e-waste; sustainability; discarded laptop battery; lighting device; energy poverty

Categories and Subject Descriptors

B.0 [**Hardware**]: General

1. INTRODUCTION

There is a significant portion of the world, where grid-based electricity has either not permeated down yet, or is unavailable for significant durations every day. For example, 44.7% of rural households in India do not have any access to electricity [6]. Most of these people cannot afford expensive power backup solutions, thus necessitating a dependence on kerosene oil which has adverse health, safety, economic and environmental implications [1]. On the other hand, a large amount of electronic waste (e-waste) is created around the world daily, both in developed and developing regions of the world. In India, it is estimated that more than 8,00,000 tons of e-waste is generated every year [2]. Lithium Ion (Li-Ion) batteries, which power portable devices such as laptops and mobile phones, form a key constituent of e-waste. In 2013, the India operations of just one large multinational IT company resulted in more than 10 tons of discarded laptop batteries[1]. Recycling of Li-Ion batteries is a complex, labour-intensive and costly process, and hence is not commercially viable.

Battery packs used in laptops consist of Li-Ion cells arranged in a series-parallel configuration. Studies undertaken by us revealed that one or more Li-Ion cells in discarded battery packs can still provide a satisfactory terminal voltage level, suggesting that when a battery pack is discarded, not all of its constituent cells are 'dead'. Moreover, a study on 32 discarded laptop batteries undertaken by us revealed that on average these batteries still had 64% of the design capacity remaining indicating that often, the complete battery pack can be reused directly after removing the battery conditioning circuit. Therefore, discarded laptop battery cells have reuse potential which has not been hitherto exploited.

Used laptop battery collection services around the world and in India have had limited success so far, with an estimated collection rate of less than 5% [5]. Therefore, most discarded laptop batteries today end up in landfills or incinerators, which results in an adverse environmental impact. Novel use cases of discarded laptop batteries can alleviate their environmental impact by creating an ecosystem that has a demand for such batteries. We present one such attempt, a backup power device - called *UrJar* - that seeks to simultaneously address the problems of proliferation of laptop battery e-waste, and the prevalence of energy poverty in developing countries. It uses discarded but still usable laptop battery cells to power low-energy DC appliances. The device is aimed at 'bottom-of-the-pyramid[2]' users, especially people in rural or semi-urban parts with access to intermittent power. The device is primarily aimed at powering a DC light bulb, since lighting represents an essential load for this population. Moreover, it also has provision to power secondary loads such as a DC fan and a mobile charger. To develop this device, we first conducted a survey of lighting solutions being used currently by our target end users in India based on which we identified the design considerations for *UrJar*. We then developed a few prototypes of *UrJar* and evaluated them through real world deployments. The key benefits offered by *UrJar* are: (i) a means to addess the proliferation of Li-Ion e-waste, (ii) a mechanism to meet the essential energy requirements (such as lighting) of bottom-of-the-pyramid population in developing regions, and (iii) enablement of an ecosystem to electrify rural areas.

2. DESCRIPTION OF URJAR

* This work was done when the author was employed at IBM Research, India

[1]Data communicated through sources inside the organization.

[2]A country's poorest socio-economic group

A few protypes of *UrJar* were built (Fig. 1) based on design considerations identified via a study involving 25 participants in India, belonging to the underprivileged community in India, with no direct access to the grid. These considerations were derived by understanding the limitations of the current lighting solutions employed by these participants.

UrJar prototypes were built following these steps:

Step 1: Source used laptop battery packs from e-waste.

Step 2: Disassemble packs to extract individual Li-Ion cells that can still deliver power.

Step 3: Connect re-usable cells to build a refurbished battery pack.

Step 4: Build a box which contains a charging circuit for the refurbished pack, step-up/step-down converters and other electronics to power extrenal devices such as a LED light bulb, a DC fan, and a mobile charger.

These prototypes have the following features:

Appliances: The prototypes power a DC light bulb (LED), a DC fan and a mobile charger.

Refurbished battery packs: Refurbished battery packs were built by extracting Li-Ion cells from discarded laptop batteries exhibiting terminal voltages of more than 3.7 V. The cells were arranged in a 3S2P configutation, and the refurbished pack delivers DC power at around 12 V.

Battery charger: A 6W charger based on FSEZ1216 IC from Fairchild Semiconductor [4] is used as the off-line battery charger. The IC uses primary-side sensing which reduces the number of components enabling a compact design. The IC was chosen from a readily available inventory since it provides Constant Voltage and Constant Current control which is ideal for battery charging. The charging efficiency is close to 75%. Charging current is limited to 500 mA to ensure that batteries are not damaged due to higher charging currents. Since these batteries are not new, their ability to handle abuse is reduced and therefore, charging cut-off is kept between 4.0 to 4.1 V per cell.

Mobile charger: A sychronous DC-DC buck converter operating at 1 MHz is used for conversion from battery voltage to 5 V needed for mobile charging. The output is a constant 5 V output with a maximum current of 1 A. Since the current is small, a sychronous regulator with internal MOSFETs is used. This reduced the footprint for the mobile charger. Operating at 1 MHz reduced the power inductor size and current handling requirements. The efficiency of conversion was close to 90%.

Fan: Brushless DC motor based personal table fan is used. A similar buck converter topology, with higher current is used.

Light: A buck regulator in continuous conduction mode is used for buck regulation. The regulator uses a current sense of 100 mV to precisely regulate LED current. High Power, high efficiency LEDs with 120 degree beam width is used. A frosted shell minimises glare. The regulator output drives three 1 W LED bulbs in series, housed in a 3 W LED bulb enclosure, at 100 mA. A single LED driver at 350 mA could be used to lower costs further.

Cost: At a volume of 1000 pieces, we estimate the bill of material cost for each of these protoypes to be around INR 600. The pricing includes the enclosure, electronics, and a 3 W LED light bulb.

To understand the usability of *UrJar* in a real-world scenario, prototypes were handed to five participants to be used in unsupervised settings for one week or more. Overall, the participants mentioned that UrJar is safer, cheaper, and easier to use, compared to their existing solutions. The major benefit of UrJar mentioned by participants was long lighting hours after a single recharge.

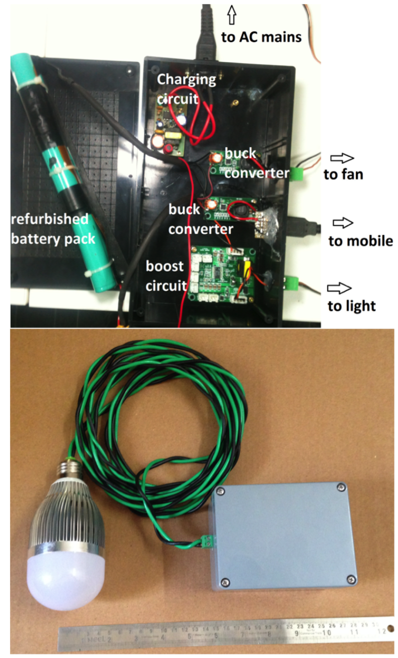

Figure 1: Component details of an *UrJar* prototype built using discarded laptop batteries.

3. CONCLUSIONS

In this work, we proposed a low-cost solution, *UrJar* to the problem of unreliable or unavailable electrical power in developing regions of the world. The novelty of this solution lies in the use of discarded lithium ion batteries as the source of energy. These batteries are employed to power lights, and additionaly fans and mobile chargers for the bottom-of-the-pyramid community in developing countries. We developed *UrJar* prototypes and conducted real world field deployments. We found that the participants were generally satisfied with *UrJar*. Future work shall focus on addition of other features such as direct solar charging, inclusion of other types of battery packs, e.g. cellphone batteries, and inclusion of additional DC devices.

4. REFERENCES

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