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Battery Cell Health Self-Test

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ABSTRACT

This disclosure describes techniques for self-testing of battery health of electronic devices. Per techniques of this disclosure, a battery cell health state is determined by performing a self-test that emulates high power-draw and/or critical usage scenarios. The self-test is conducted at a likely inactive time for the device use based on user-permitted contextual factors. During the test, device charging is disabled so that the battery cell is isolated from its power source. The battery voltage is lowered to a predetermined voltage that is representative of a low state of charge by utilizing a power virus. Battery health parameters such as power consumption, state of charge, current being drawn from battery, battery voltage during the test, etc., are recorded. Based on the battery health parameters measured during the self-test, usage parameters are adjusted to mitigate brownout risk.

KEYWORDS

- Brownout
- Power aggressor
- Battery cell health
- Lithium ion battery
- Power virus
- Charge cycle
- Smartwatch
- Wearable device
- Battery self-test

BACKGROUND

Electronic devices such as wearable devices commonly include lithium ion battery cells which have high energy density, and thereby enable thin and light device form factors. However, lithium ion cells have a limited lifespan that is characterized by their rated number of charge cycles - the number of times that the cell can be charged, e.g., from 0 to 80% (or other percentage) of design capacity. As lithium ion cells age, their maximum usable capacity and attained voltage at full charge decreases and less energy can be stored and retrieved from the cell during each cycle.

Power intensive computing operations, such as installing a software update, downloading large files over a WiFi or mobile (e.g., LTE) network, processing large batches of data, etc., can rapidly drain a battery. In addition, if the load on the power bus of the device is greater than what the cell can provide, it can cause the power bus to drop below a critical voltage level. When the power bus voltage drops below a critical level, certain device components may not have the necessary voltage to stay powered, and can shut off. If multiple critical subsystems of the device were to shut off, the device can experience a brownout, which would appear to the user as a random power cycle of the device. Brownouts can pose a risk to electronic devices, and particularly to older devices with poor battery health.

DESCRIPTION

This disclosure describes techniques for self-testing of battery health and automatic adjustment of device usage parameters based on the determined battery cell health. Per techniques of this disclosure, a battery cell health state is characterized (determined) by performing a self-test that emulates high power-draw and/or critical usage scenarios. Based on the determined battery health state, usage parameters are automatically adjusted to mitigate the risk of a brownout during high power-draw and/or critical usage scenarios.

Two categories of high power-draw and critical usage scenarios are commonly considered:

Installation of updates

Updates are pushed to a device, e.g., a smartwatch via Bluetooth Low Energy (BLE) or via WiFi when the device is placed on a charger. The updates are installed when the device battery is above a specific state of charge threshold (e.g., above 20%). However, in some cases, the user may remove the device from the charger after the update has commenced. If the update takes a long time, or if the device enters a state of error while not being charged, a high power drain can cause a brownout before completion of the update. In some situations, the operating system may become corrupted, rendering the device unusable.

General usage

Certain device operations consume high electrical power and are termed power aggressors. Running multiple power aggressors in parallel can cause system brownouts when the battery has aged cells that have reduced capacity. Example power aggressors in a wearable device include tracking a run using GPS while also utilizing a photoplethysmography (PPG) based heart rate sensor, participating in a VoLTE phone call, using the watch display at a high level of brightness, receiving notifications that trigger haptic feedback to the user, etc.

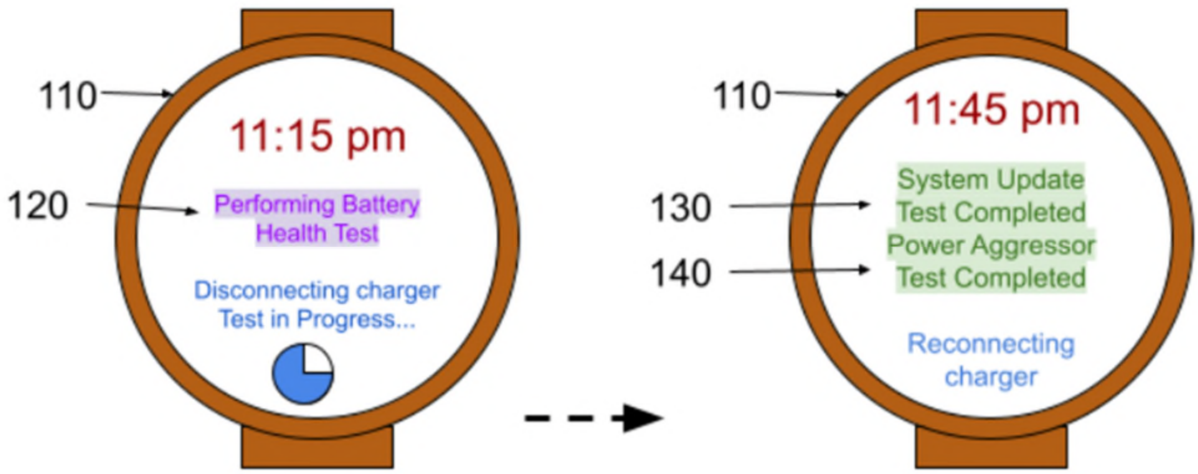

Fig. 1: A battery health test is performed to determine battery health parameters

Fig. 1 depicts an example battery health test being performed (120) for a wearable device (110), per techniques of this disclosure. In this illustrative example, with user permission, it is determined based on context and prior usage patterns, that the device is in a state where it is unlikely to be utilized for a period of time. It is additionally determined that the device is plugged in for charging.

The device is temporarily disconnected from the charger and the battery health self-test is performed. The battery health test can include system update tests (13), whereby battery parameters are logged based on a simulated system (software) update and simulated power aggressor tests (14) during which battery parameters are measured and logged based on simultaneous operation of multiple power-intensive tasks performed by the device. Upon test completion, usage parameters are updated based on the measured battery performance and the device is reconnected for charging.

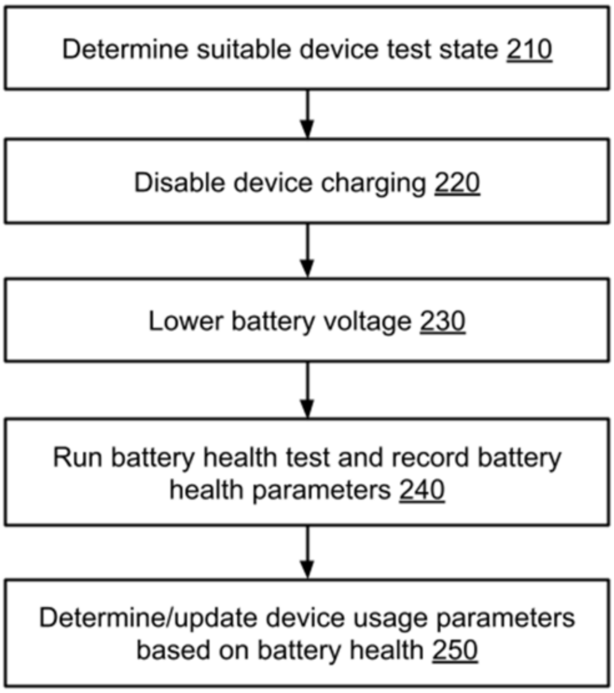

Fig. 2: Battery cell health parameters determined via a self-test are utilized to adjust usage parameters

Fig. 2 depicts an example workflow for adjusting usage parameters and/or thresholds based on determined battery cell health, per techniques of this disclosure. A suitable time for a self-test is determined (210) for the device, e.g., when the device is connected to (e.g., placed on) a charger and with a low likelihood of being picked up by the user. Battery cell health parameters are determined based on a self-test performed at a time that is determined to be a likely inactive time for the device use. For example, the self-test may be performed at a particular time based on determination that the probability of the device being picked up, used, or worn is minimal during the particular time period. This can be determined or inferred based on user permitted contextual data, e.g., user charging patterns such as at night, when many users take off their wearable device and place it for charging. In some implementations, it is determined that the device has been in a state of inactivity on the charger for a threshold period of time.

To perform the self-test, the device charging is disabled (220) so that the battery cell can be isolated from its power source. If the device is being charged by wired, contact-based charging, device charging can be disabled via the contacts. If the device is being charged wirelessly using a wireless charger, amplitude shift keying (ASK) or frequency shift keying (FSK) can be utilized to disable wireless charging.

The battery voltage is lowered (230) to a predetermined voltage that is representative of a low state of charge, e.g., by utilizing a power virus. The power virus can include simultaneous operation of a set of power aggressors, e.g., processing large batches of random data, operating the radios on the device, etc.

When the cell reaches a predetermined state of charge, a battery health test is performed (240). During the battery health test, parameters such as power consumption, state of charge, current being drawn from battery, battery voltage during the test, etc., are recorded. Power consumption is measured by utilizing current sense resistors that are included in power rails associated with various components and/or subsystems. Based on the battery health parameters measured during the self-test, usage parameters are adjusted (250) to mitigate brownout risk. The battery health test can include update installation tests and/or general usage tests.

- **Update Installation Test:** Simulation of a system update is performed by downloading a simulated file with a file size that matches previously downloaded system update files. For example, the simulated update file size can be selected to be an average file size or a maximum file size of previously downloaded system update files. Installation of a system update is simulated by running one or more power aggressors and measuring peak power consumption and average power consumption.
- **General Usage Test:** Simulation of general usage is performed by running multiple power aggressors in a sequential manner. For example, an application processor may be operated at its peak load, and other subsystems, e.g., a GPS subsystem, haptic feedback subsystem, etc., are also operated. Subsystems that can inadvertently disturb the user, e.g., turning on a display or a speaker in the middle of the night, are not utilized, in the event that the test is performed at a user location (as opposed to a factory self-test).

Update Installation Parameters

If a device brownout is detected during the simulated update test, one or more threshold parameters associated with device system updates are adjusted based on the state of the charge and voltage measured at the time of the device brownout. The threshold parameters are utilized, for example, to specify a battery level below which a system update cannot be performed (to minimize brownout risk during the update). For example, a threshold state of charge for the device (e.g., a battery charge level percentage) to perform a system update is adjusted (increased) to account for a possible lower voltage state at a given battery state of charge for an older battery cell when compared to a newer battery cell. A magnitude of the threshold adjustment may be based on the measured battery characteristics associated with the type of battery cell in use. In some implementations, the magnitude of threshold adjustment may also be based on an age of the battery cell.

General Usage Parameters

If a device brownout is detected during the general usage test, a battery cell voltage and a system power load on the system bus at a time of brownout are recorded. A peak power demand threshold that determines a maximum allowable power demand on the battery is adjusted by adding a buffer to the system power load at the time of brownout.

During subsequent device use, the peak power demand threshold is utilized to regulate power consumption of device components and/or device subsystems. For example, when a new component or subsystem comes online, e.g., a user starts a voice call on their wearable device while on a run that is being tracked via GPS, other subsystems are scaled back in terms of their power usage to avoid brownout if the total power demand approaches the peak power demand threshold. In such a scenario, a haptic intensity level may be scaled back, display brightness may be reduced, other active measurements or sampling may be reduced or duty cycled, etc., to keep the power demand below the peak power demand threshold.

CONCLUSION

This disclosure describes techniques for self-testing of battery health of electronic devices. Per techniques of this disclosure, a battery cell health state is determined by performing a self-test that emulates high power-draw and/or critical usage scenarios. The self-test is conducted at a likely inactive time for the device use based on user-permitted contextual factors.

During the test, device charging is disabled so that the battery cell is isolated from its power source. The battery voltage is lowered to a predetermined voltage that is representative of a low state of charge by utilizing a power virus. Battery health parameters such as power consumption, state of charge, current being drawn from battery, battery voltage during the test, etc., are recorded. Based on the battery health parameters measured during the self-test, usage parameters are adjusted to mitigate brownout risk.

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