May 2023

Enabling Extreme Low Power Mode Based on Bluetooth Quality Reports

Feng-Jui Kuo

Follow this and additional works at: https://www.tdcommons.org/dpubs_series

Enabling Extreme Low Power Mode Based on Bluetooth Quality Reports

ABSTRACT

Unchecked power consumption at low battery levels can hasten the shutdown of a device, causing inconvenience to the user. This disclosure describes an extreme low power mode for devices that have Bluetooth capabilities. At low battery levels, statistics of recent activities and current consumption of the Bluetooth controller, as obtained from Bluetooth quality reports (BQR), are used to adaptively select energy appropriate Bluetooth modes. In the extreme low power mode, the audio codec can be switched to one that minimizes current consumption; the frequency of Bluetooth/BLE advertising and scanning can be reduced; the frequency of BLE advertising reports can be limited; the radio-frequency transmission power can be reduced; etc. BQR, used traditionally for debugging and performance optimization, is repurposed to enhance user experience.

KEYWORDS

- Bluetooth low energy (BLE)
- Advanced audio distribution profile (A2DP)
- Bluetooth synchronous-connection oriented (SCO) link
- Bluetooth quality report (BQR)
- Bluetooth controller
- Bluetooth advertising
- Bluetooth scanning
- Low power mode
- Link supervision timeout (LSTO)

BACKGROUND

Unchecked power consumption at low battery levels can hasten the shutdown of a device, causing inconvenience to the user. The Bluetooth quality report (BQR) is a mechanism by which the Bluetooth controller reports energy consumption, link statistics, and quality-related events to host software. BQR includes:

- energy-monitoring, a feature to monitor the activities, current consumption, etc. of the Bluetooth controller; and

- quality-event reporting, a feature to report link quality, a lack of received packets for longer than half the link supervision timeout (LSTO), choppy audio (due to issues in A2DP or SCO connectivity), etc.

BQR is commonly used by hardware and software engineers to debug Bluetooth and to optimize its performance.

DESCRIPTION

This disclosure describes an extreme low-power mode for Bluetooth. At low battery levels, statistics of recent activities and current power consumption of the Bluetooth controller, as obtained from Bluetooth quality reports (BQR), are used to adaptively select energy appropriate Bluetooth modes. BQR, a facility designed for debugging and for performance optimization, is repurposed to enhance user experience.
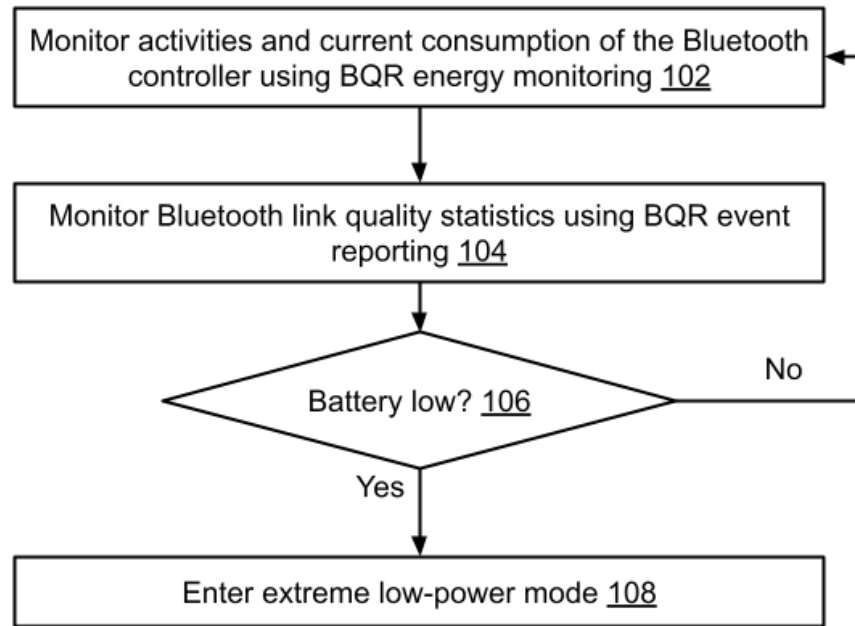
Fig. 1: Entering extreme low-power mode based on Bluetooth quality reports

Fig. 1 illustrates a process to selectively enter extreme low-power mode in Bluetooth based on Bluetooth quality reports (BQR). The activities and the current consumption of the Bluetooth controller of a device are monitored using the BQR energy-monitoring (102). The Bluetooth link statistics are monitored using BQR event-reporting (104), e.g., in regard to adaptive selection of Bluetooth bit rates, etc. If the device battery is low (106) (the energy level falls below a threshold), Bluetooth and associated processes enter the extreme low-power mode (108).

In extreme low-power mode, one or more of the following actions can be taken to reduce power consumption:

- Selection of an audio codec that minimizes current consumption.

- Reducing the frequency of Bluetooth/BLE advertising and scanning.

- Limiting the scheduling frequency of Bluetooth/BLE advertising and scanning on the Bluetooth controller and firmware

● Limiting the frequency of BLE advertising reports from the Bluetooth controller/firmware

● Reducing the radio frequency transmission power to a lower yet acceptable level.

The described techniques can be incorporated into any Bluetooth capable device, such as a smartphone, smartwatch, or other device. Providing an extreme low power mode can enable the device to continue supporting Bluetooth features while also extending available battery life and usable time of the device when the battery level is low.

CONCLUSION

This disclosure describes an extreme low power mode for devices that have Bluetooth capabilities. At low battery levels, statistics of recent activities and current consumption of the Bluetooth controller, as obtained from Bluetooth quality reports (BQR), are used to adaptively select energy appropriate Bluetooth modes. In the extreme low power mode, the audio codec can be switched to one that minimizes current consumption; the frequency of Bluetooth/BLE advertising and scanning can be reduced; the frequency of BLE advertising reports can be limited; the radio-frequency transmission power can be reduced; etc. BQR, used traditionally for debugging and performance optimization, is repurposed to enhance user experience.

REFERENCES

[1] "HCI requirements," available online at

https://source.android.com/docs/core/connect/bluetooth/hci_requirements, accessed Mar. 3, 2023.