August 2020

Emergency-Only and Voice-Only Modes for Thermal Mitigation of Mobile Devices

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EMERGENCY-ONLY AND VOICE-ONLY MODES FOR THERMAL MITIGATION OF MOBILE DEVICES

Abstract

A mobile device experiencing excessive temperatures can be placed in an emergency-only mode in which on-going calls are ended, new incoming calls are rejected, and new outgoing calls are ended by the device as thermal mitigation measures to prevent additional heat generation by the device. Optionally, when the device is being used in hands-free mode, a user is provided with the choice to override the emergency mode to make and receive calls. Alternatively, less restrictive thermal mitigation measures may be taken to prevent damage to the mobile device, such as restricting the device to certain voice-only services and restricting data services.

Background

Heat management within mobile communication devices (e.g., smartphones) is increasingly relevant as more circuits, components, and subsystems are housed in smaller form factors, while also being configured to perform more functions. The performance of processors and other circuit components can decline with repeated or continuous exposure to excessive heat. For example, elevated temperatures within a device can affect the structural integrity of components and their physical connections, resulting in diminished performance or failure of components altogether. Mobile devices typically include thermal management modules that monitor the temperatures within the system and execute thermal mitigation procedures upon detecting high temperatures in order to mitigate the undesirable results which can occur due to excessive heat within the system. Thermal mitigation measures include, for example, reducing transmission power for the mobile device, reducing an operating frequency of a clock of the mobile device, and/or disabling data services.

Description

As mobile devices are configured with more features and greater functionality, the networks to which mobile devices connect need to support high rates of data transfer. Long Term Evolution (LTE) Carrier Aggregation is one of the primary techniques used to enable the very high data rates of fourth-generation (4G) networks to be achieved. By aggregating multiple channels together, a mobile network operator (carrier) can increase the total available bandwidth of a single transmission, and thereby increase the bitrate and capacity of the network. Mobile devices operating on LTE Carrier Aggregated networks can generate a significant amount of heat as a result of searching for network service on the multiple LTE bands or when performing high throughput data transfer. Thus, thermal mitigation is needed to maintain the temperature of the device at safe levels. Thermal mitigation can be performed at multiple stages by reducing the modem functionality based on the events observed in the modem or other components of the mobile device. In response to an increase in temperature, the mobile device may restrict voice activities, implement voice-only mode, and/or restrict cellular data applications in order to prevent the device from exceeding temperature thresholds for safe operation.

As illustrated in Figure 1 below, mobile devices generally include an application processor, a thermal manager, and a modem or communications processor. The application processor provides system capabilities needed to support a mobile device's applications, including memory management, graphics processing, and multimedia decoding. The thermal manager, which can be implemented as software, programmable logic, or hardwired circuitry, receives temperature data from components of the device and determines if mitigation actions should be initiated and, if so, which components will implement the actions. The

communications processor is responsible for establishing, maintaining, and controlling communications between a mobile device and the network to which it is connected.

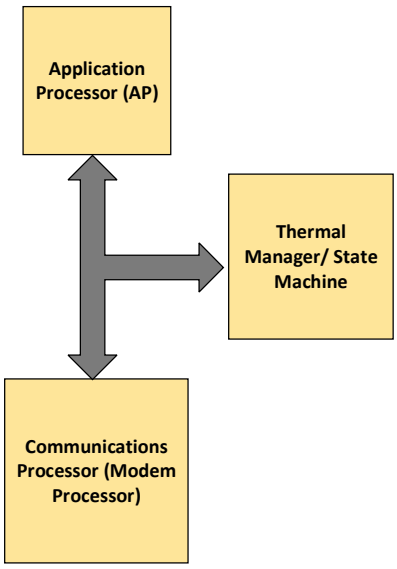

Figure 1

In a mobile device configured to implement voice activity restrictions as a thermal mitigation measure, the thermal manager receives temperature information from at least one temperature sensor within the device. The temperature information is compared to a threshold and, if the temperature information exceeds the threshold, the thermal manager sends an indication to the communications processor to initiate an "emergency-only" mode. Upon receiving the indication from the thermal manager that the device is to be placed in emergency-only mode, the communications processor checks whether the mobile device is currently engaged in call activity and, if so, the communications processor will end any voice calls and inform the telephony services via the radio interface layer (RIL) that the call was ended due to high temperatures. Once any voice calls are ended, the communications processor will enter emergency-only mode and send the mode preference to its tasks and components, including a non-access stratum (NAS) functional layer. In response to the emergency-only mode being

communicated to the NAS, the layer will stop the periodic timers and the Higher Priority Public Land Mobile Network (HPPLMN) timers. Alternatively, the mobile device can continue to reset the periodic and HPPLMN timers by a predetermined amount of time (e.g., ten seconds) when the timers expire and the mobile device is still in emergency-only mode.

If the mobile device receives notification of a mobile-terminated (MT) call (i.e., an incoming call) while in emergency-mode, the Internet Protocol Multimedia Subsystem (IMS) and/or circuit-switched (CS) upper layers of the device will note the information of the caller, reject the call, and inform the application processor and telephony service about the missed call. Further, if a user attempts to make a mobile-originated (MO) call (i.e., an outgoing call), the mobile device will notify the user of the restriction of voice services due to the thermal emergency and end the call. Accordingly, no signaling is received or sent by the mobile device when in emergency-only mode.

The method of restricting voice activity of a mobile device described above can be modified, as depicted in Figure 2 below, to allow for a user to override the restriction when using the device in hands-free mode. Once the communications processor has entered emergency-only mode and communicated this preference to its tasks and components, if the user attempts to initiate an MO call while using the mobile device in hands-free mode, the device will notify the user of the restriction, but allow the user to override the restriction and continue with the call. If the mobile device receives an MT call while in hands-free and emergency-only modes, the IMS and/or CS upper layers will notify the user that the call needs to be restricted due to thermal emergency, but allow the user to override the restriction to accept the incoming call.

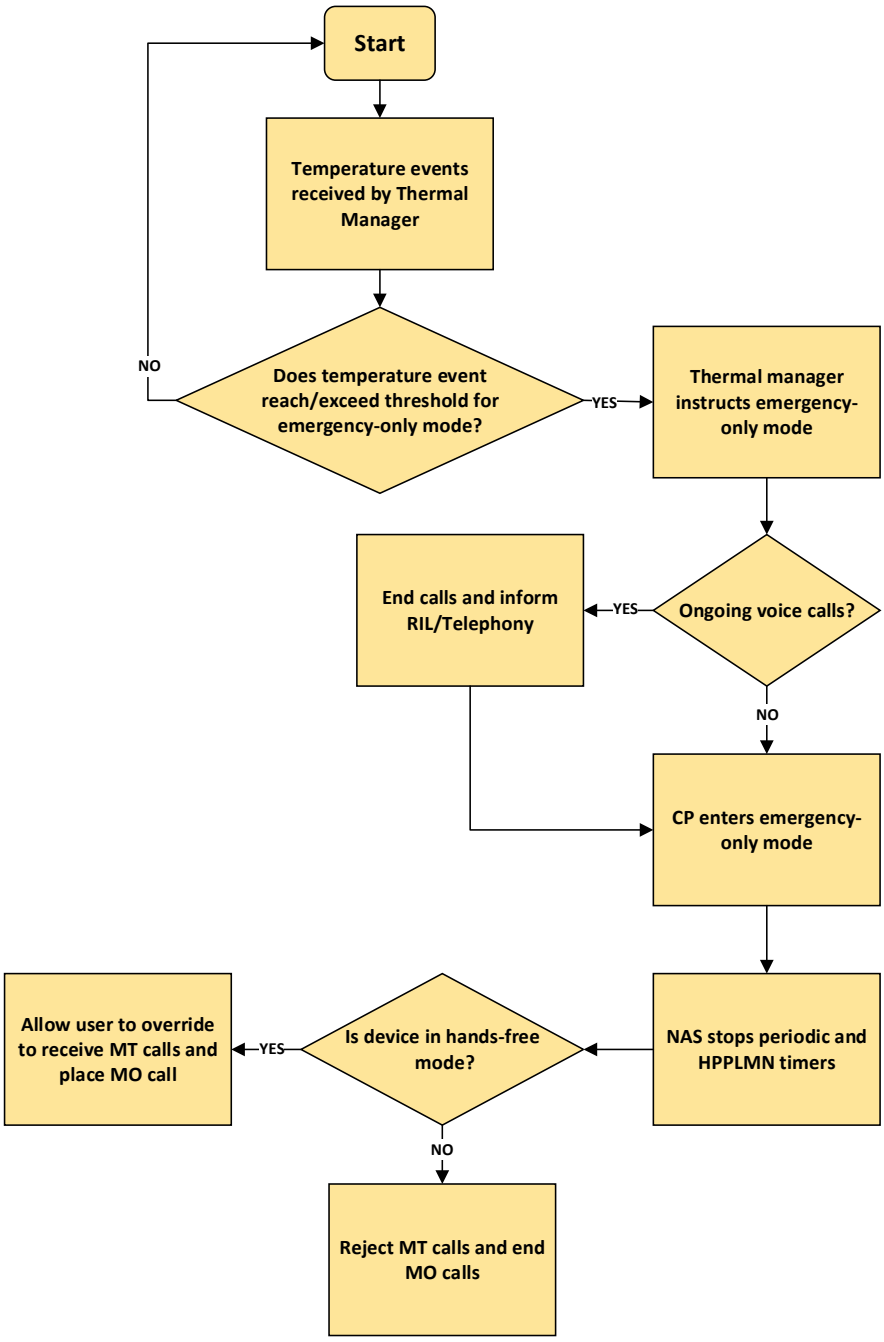

Figure 2

Another method of implementing thermal mitigation measures in a mobile device allows voice calls while restricting data usage. As illustrated below in Figure 3, if the thermal manager of the mobile device detects that a temperature threshold has been reached or exceeded, thermal mitigation mode is implemented. If the specific temperature threshold for implementing voice-

only mode is exceeded, the thermal manager will instruct the telephony application programming interface (API) to disable data services, noting the reason for doing so as thermal mitigation. Upon disabling data services, a data connection tracker can sever the internet public data network (PDN) and maintain the IMS PDN to enable the device to be used in voice-only mode without detaching from the network.

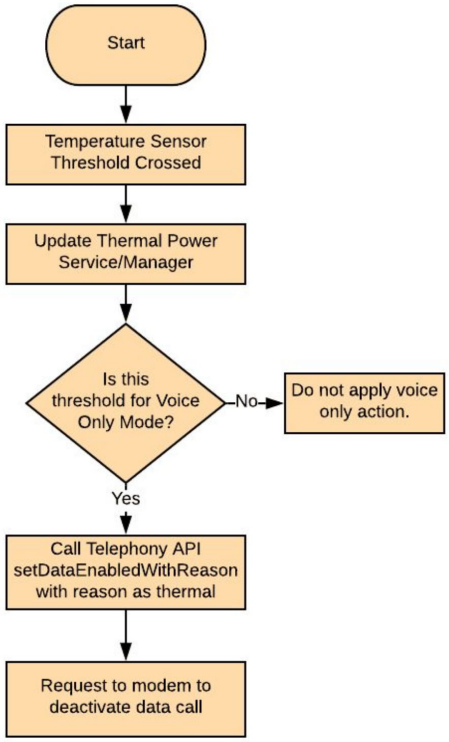

Figure 3

Figure 4 depicts a method of detaching packet switched (PS) service when in voice-only mode as a thermal mitigation measure. If the temperature threshold for voice-only mode is reached or exceeded, the thermal manager will implement voice-only mode for the mobile device and determine whether the device is currently using both PS service and circuit switched (CS) service. If the device is using PS+CS service, the thermal manager will change the service domain of the modem to CS-only and issue an instruction to detach from the PS service. In the event that no CS service is then found, the device will attempt connection to different CS radio

access technology (RAT) services, such as, for example, Global System for Mobile Communication (GSM), Wideband Code Division Multiple Access (WCDMA), Code Division Multiple Access (CDMA), or Time Division Synchronous Code Division Multiple Access (TD-SCDMA) services. If the mobile device is not using PS+CS service when placed in voice-only mode, an error will be sent to the thermal manager so that a next thermal mitigation measure can be processed.

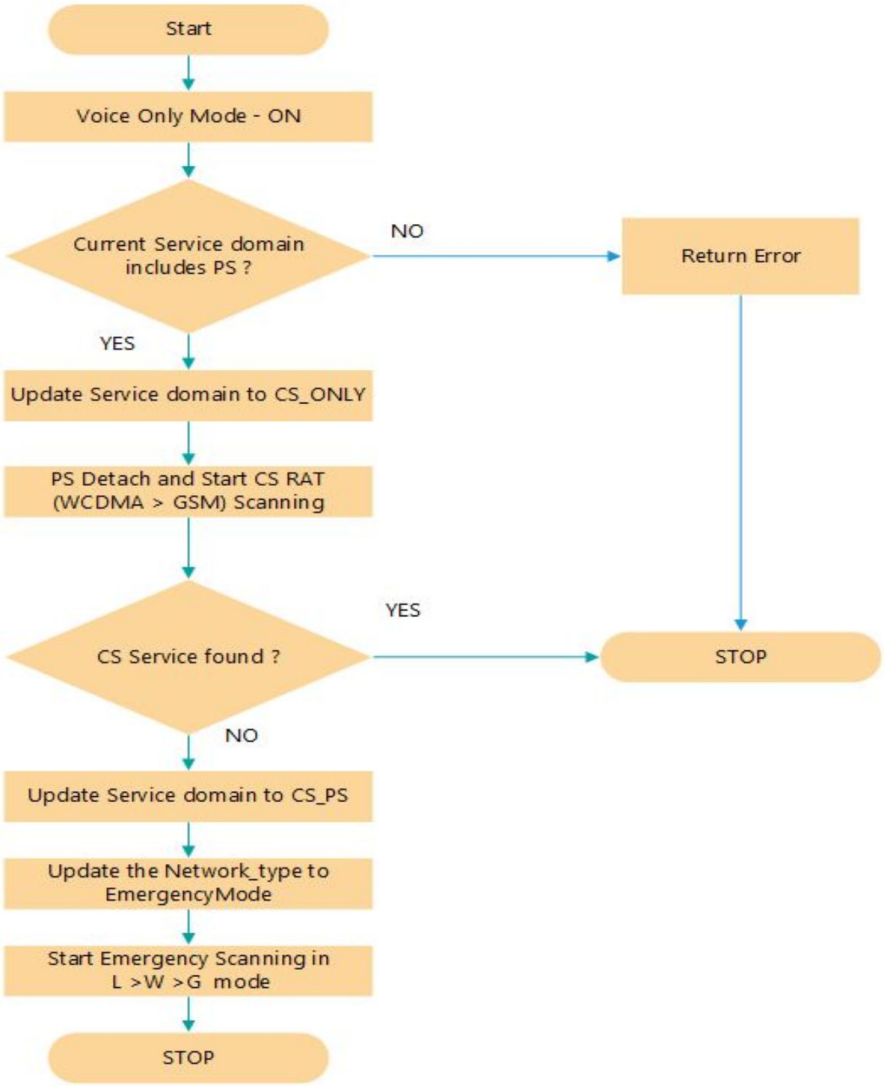

Figure 4

A mobile device that is implementing voice-only mode as a thermal mitigation measure might still be capable of making non-IMS calls, which can reduce the efficacy of the thermal mitigation provided by voice-only mode. Figure 5, below, illustrates a method of limiting the device to voice-over-LTE only in order to restrict non-IMS calls. The thermal manager of a mobile device operating in voice-only mode can check if the device is connected to an LTE network and whether there is an active IMS PDN and an active IMS registration for the device. If so, the modem is instructed to deactivate the internet PDN and end any active data calls. The mobile device is then allowed to continue on LTE service with only voice-over-LTE capabilities.

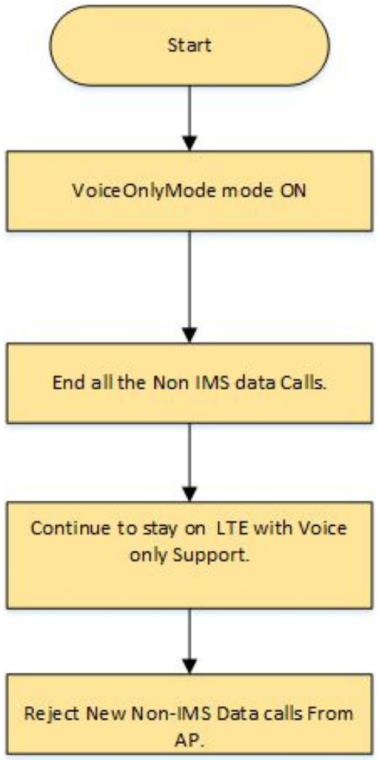

Figure 5

References

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3. U.S. Patent Application Serial No. 20160239057 (filed Feb. 17, 2015), incorporated by reference herein in its entirety.

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7. U.S. Patent Application Serial No. 20140366041A1 (filed Apr. 15, 2014), incorporated by reference herein in its entirety.