Reducing Power Consumption in System-on-a-Chip Devices

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REDUCING POWER CONSUMPTION IN SYSTEM-ON-A-CHIP DEVICES

ABSTRACT

Disclosed herein is an improved mechanism for reducing power consumption in System-on-a-Chip (SoC) devices. The mechanism can include causing user-space applications executing on a main portion of a processor of a device to be suspended while causing a voice recognition application to continue executing in a Trusted Execution Environment (TEE) space of the processor. The voice recognition application can detect a spoken command included in audio data received by a microphone of the device. In response to detecting the spoken command, the device can cause one or more user-space applications executing on the main portion of the processor to be resumed. The device can then cause an action corresponding to the detected spoken command to be executed by the one or more user-space applications.

BACKGROUND

System-on-a-Chip devices are common, for example, in mobile devices, wearable electronic devices, virtual assistant devices, streaming media devices, etc. Such an SoC device may include a microphone and a voice recognition application, where the device can respond to a spoken keyword or a spoken command of multiple words. For example, in the case of a virtual assistant device, the device may perform an action (e.g., execute a search query, begin presenting a particular media content item, answer a call, etc.) in response to detecting a corresponding spoken command. In order to detect this spoken command, the voice recognition application must be executing on the device at all times. However, executing a voice recognition application at all times using the main operating system of the device leads to high power consumption and generally undesirable power requirements.
One approach to reduce the power consumption in these SoC devices is to add an external co-processor that is configured to run the voice recognition application. Upon detecting a corresponding spoken command, the voice recognition application that is always executing on the external co-processor wakes up the main SoC from a low-power or sleep state to perform an action. The problem with such an approach is the additional cost and configuration of the co-processor.

Thus, there is a need for an improved mechanism for reducing power consumption in System-on-a-Chip devices.

DESCRIPTION

The systems and techniques described in this disclosure relate to reducing power consumption in System-on-a-Chip devices. The system can be implemented on a user device, such as a mobile device, a wearable electronic device, a virtual assistant device, a streaming media device, and/or any other suitable user device. FIG. 1 illustrates an example process for reducing power consumption in System-on-a-Chip devices. In particular, FIG. 1 illustrates an example process for executing a voice recognition application or a keyword recognition application outside of the user-space applications, thereby allowing the device to reduce the amount of executing processes to only those needed for keyword recognition. This can also allow the device to enter a low-power mode in which unnecessary subsystems that are not used in the voice recognition process of FIG. 1 can be shut down.
At 102, the device can cause execution of user-space applications to be suspended while executing a voice recognition application in a trusted execution environment space of the device. In some instances, the user-space applications can include any suitable applications that execute on the device in connection with a main operating system of the device. For example, in some instances, the user-space applications can include any suitable applications associated with presenting media content using the device, executing search queries by the device, receiving or transmitting messages using any suitable messaging applications on the device, and/or any other suitable applications. In some instances, the voice recognition application can be any suitable application that receives audio data from a microphone associated with the device and that
determines whether the audio data includes one or more spoken words corresponding to a keyword. For example, in some instances, the voice recognition application can determine whether received audio data includes a wake-up word associated with the device, a command for the device to perform a particular action (e.g., begin presenting a particular media content item, execute a particular search query, and/or perform any other suitable action).

It should be noted that the device can suspend execution of the user-space applications in any suitable manner. For example, in some instances, the device can cause any threads associated with the user-space applications to be frozen or paused. In some instances, the device can cause the voice recognition application to execute in the trusted execution environment space in any suitable manner. For example, the device can cause any suitable threads associated with the voice recognition application to execute in the trusted execution environment space. It should also be noted that the trusted execution environment space can be any suitable portion or area of the processor of the device.

It should further be noted that, upon suspending execution of the user-space applications, the device can have power consumption savings by reducing System-on-a-Chip core frequencies and/or by turning off unnecessary cores. For example, the main processor of the device, which may include multiple central processing unit cores, can be configured to enter a low-power mode when idle. In such a low-power mode, the main processor may draw less voltage, and/or operate at a lower clock rate, than when in a high-power mode. Thus, when the main processor is not executing user-space applications as they are frozen or paused, the main processor may use less power than it otherwise would. Additionally for multiple-core processors, upon suspending execution of the user-space applications, one or more cores can transition into idle mode.
independently from the other cores. Thus, reducing the load on the main processor may result in power consumption savings.

At 104, the device can detect a spoken command that includes a keyword using the voice recognition application executing in the trusted execution environment space. As described above, the spoken command can include any suitable keyword(s), such as a wake-up word associated with the device, a keyword that indicates an action to be performed by the device (e.g., to begin presenting a particular media content item, to execute a particular search query, etc.). For example, in some instances, a keyword that corresponds to a wake-up word associated with the device can be a name assigned to the device. As another example, in some instances, a keyword that corresponds to a command to begin presenting a media content item can include the word "PLAY" and a name or other identifier of the media content item. Note that, in some instances, the spoken command can include any suitable combination of multiple keywords, such as a wake-up word combined with an action to be performed, and/or any other suitable combination.

At 106, the device can, in response to detecting the spoken command, cause one or more of the user-space applications to resume. In some instances, the device can cause one or more of the user-space applications to resume using any suitable technique or combination of technique(s). For example, in some instances, the voice recognition application executing in the trusted execution environment space can cause an interrupt to be transmitted to the main operating system, thereby causing any paused or frozen threads associated with the user-space applications to be resumed. In another example, in some instances, the voice recognition application executing in the trusted execution environment space can determine which of the user-space applications correspond to the detected spoken command. In continuing this
example, the voice recognition application can cause the determined user-space application to wake up from a low-power mode or sleep state and allow the remaining user-space applications to remain in a low-power mode or sleep state.

At 108, the device can cause one or more actions to be performed by the user-space applications based on the spoken command. For example, as described above, in an instance in which the spoken command includes a command to begin presenting a particular media content item, the device can begin presenting the media content item in any suitable manner, such as by presenting audio content associated with the media content item using one or more speakers associated with the device, by presenting video content associated with the media content item using a display associated with the device, and/or in any other suitable manner. Note that, in some instances, the device can cause the media content item to begin being presented on a second screen device that has been paired with the device that received the spoken command (e.g., paired speakers, a paired television, and/or any other suitable type of paired device). As another example, in an instance in which the spoken command includes a command to execute a search query, the device can cause the search query to be executed by the device. Note that, in some instances, results of the search query can be presented by the device in any suitable manner, such as on a display associated with the device, as spoken results presented using a speaker associated with the device, and/or in any other suitable manner.

It should be noted that, in some implementations, the device can loop back to 102 and can cause the user-space applications to be suspended. For example, in some instances, in response to determining that more than a predetermined duration of time has elapsed (e.g., more than a minute, more than five minutes, more than thirty minutes, etc.) since any actions have been
performed by the user-space applications, the device can cause the user-space applications to be suspended.

It should also be noted that, although the implementation described herein generally relates to executing a voice recognition application or a keyword recognition application outside of the user-space applications, thereby allowing the device to reduce the amount of executing processes to only those needed for keyword recognition, this is merely illustrative and any suitable application can be configured to execute from a trusted execution environment space while the user-space applications are suspended in a low-power or sleep state.

Accordingly, a mechanism for reducing power consumption in System-on-a-Chip devices is provided.