APPENDIX C

ACPI System States

Power optimization of computer systems has become very important. There are many governing bodies (like the California Energy Commission) that mandate a certain level of power efficiency in computing devices. In a computer system, there are multiple pieces of hardware and software that all need to be in sync. Therefore, a mechanism is needed for these pieces to pass information around. The Advanced Configuration and Power Interface Special Interest Group (ACPI SIG) developed such a standard, named after the group, ACPI.

ACPI provides an open standard that system firmware (BIOS) and operating systems use to discover, configure, and carry out system-specific operations. ACPI replaces the multiple earlier standards like Advanced Power Management (APM), MultiProcessor Specification, and the Plug and Play (PnP) BIOS Specification. ACPI defines a hardware abstraction interface across system firmware, computer hardware components, and operating systems. ACPI is the key element in operating system–directed configuration and power management (OSPM). In 2013, the ACPI SIG agreed to transfer the specification to the UEFI Forum, which now owns the specification.

ACPI defines standard operating states for systems, devices, and processors, among other things. Figure C-1 shows the various states defined by ACPI and transitions between them. In the following sections, we talk about these states and explain what they all mean.

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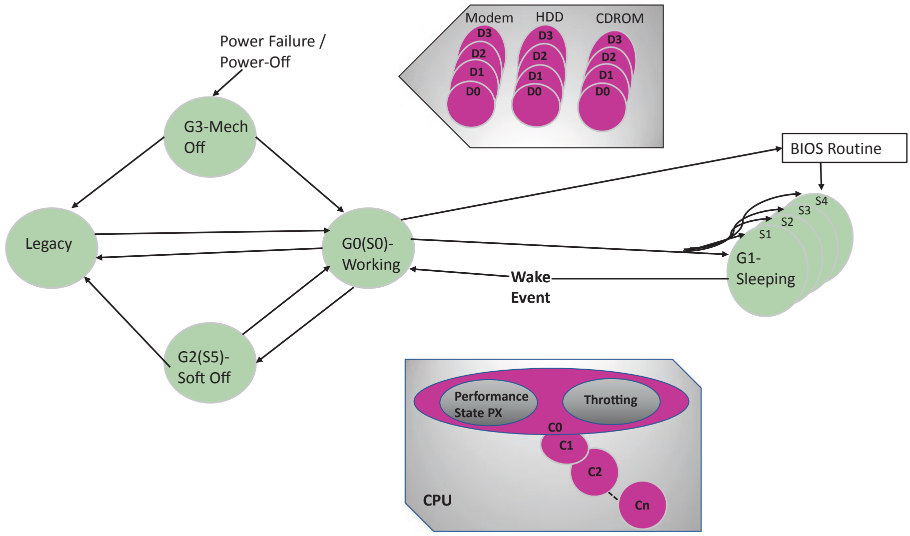

Figure C-1. *Global and System Power States and Transitions*

Global and System States

ACPI defines four global states and six system states. The global states are marked G0–G3, while the system states are marked as S0–S5. It must be noted, however, that some motherboard documents reference S6, which is not an ACPI-defined state. If you come across this, you can safely map this to G3.

ACPI defines a mechanism to transition the system between the working state (G0) and the sleeping state (G1) or the soft-off state (G2). During transitions between the working and sleeping states, the operating system will maintain your context, so you don't lose information on such transitions. ACPI defines the level of the G1 sleeping state by defining the system attributes of four types of ACPI sleeping states (S1, S2, S3, and S4). Each sleeping state is defined to allow implementations to trade-off cost, power, and wake latencies:

- G0/S0: In the G0 state, work is being performed by the OS/application software and the hardware. The CPU or any particular hardware device could be in any one of the defined power states (more on the device and CPU power states in a later section); however, some work will be taking place in the system.

    a. S0: System is in a fully working state.

- G1: In the G1 state, the system is assumed to be doing no work. Prior to entering the G1 state, OSPM will place devices in a device power state compatible with the system sleeping state to be entered; if a device is enabled to wake the system, then OSPM will place these devices into the lowest D*x* state from which the device supports wake.

    a. S1: The S1 state is defined as a low wake latency sleeping state. In this state, the entire system context is preserved with the exception of CPU caches. Before entering S1, OSPM will flush the system caches.

    b. S2: The S2 state is defined as a low wake latency sleep state. This state is similar to the S1 sleeping state where any context except for system memory may be lost.

    c. S3: Commonly referred to as Standby, Sleep, or Suspend to RAM (STR). The S3 state is defined as a low wake latency sleep state. From the software viewpoint, this state is functionally the same as the S2 state. The operational difference is that some power resources that may have been left ON in the S2 state may not be available to the S3 state. As such, some devices may be in a lower-power state when the system is in the S3 state than when the system is in the S2 state. Similarly, some device wake events can function in S2 but not S3.

d. S4: Also known as Hibernation or Suspend to Disk. The S4 sleeping state is the lowest-power, longest wake latency sleeping state supported by ACPI. In order to reduce power to a minimum, it is assumed that the hardware platform has powered off all devices. Because this is a sleeping state, the platform context is maintained. Depending on how the transition into the S4 sleeping state occurs, the responsibility for maintaining system context changes between OSPM and BIOS. To preserve context, in this state all content of the main memory is saved to non-volatile memory such as a hard drive and is powered down. The contents of RAM are restored on resume. All hardware is in the off state and maintains no context.

- G2/S5: Also referred to as Soft Off. In G2/S5, all hardware is in the off state and maintains no context. OSPM places the platform in the S5, soft-off, state to achieve a logical off. The S5 state is not a sleeping state (it is a G2 state), and no context is saved by OSPM or hardware, but power may still be applied to parts of the platform in this state, and as such, it is not safe to take the system apart. Also, from a hardware perspective, the S4 and S5 states are nearly identical. When initiated, the hardware will sequence the system to a state similar to the off state. The hardware has no responsibility for maintaining any system context (memory or I/O); however, it does allow a transition to the S0 state due to a power button press or a remote start.

- G3: Mechanical Off. Same as S5. Additionally, the power supply is isolated. The computer's power has been totally removed via a mechanical switch, and no electrical current is running through. This is the only state that the system can be worked on without damaging the hardware.

Device States

In addition to global and system states, ACPI defines various device states ranging from D0 to D3. The exact definition or meaning of specific device states depends on the device class. A device class describes a type of device – for example, audio, storage, network, and so on:

- D0: This state is assumed to be the highest level of functionality and power consumption. The device is completely active and responsive and is expected to remember all relevant contexts.
- D1: Many device classes may not support D1. In general, D1 is expected to save less power and preserve more device context than D2. D1 may cause the device to lose some context.
- D2: Many device classes may not support D2. In general, D2 is expected to save more power and preserve less device context than D1 or D0. D2 may cause the device to lose some context.

- D3 Hot: Devices in the D3 Hot state are required to be software enumerable. In general, D3 Hot is expected to save more power and optionally preserve device context. If device context is lost when this state is entered, the OS software will reinitialize the device when transitioning back to D0.
- D3 Cold: Power has been fully removed from the device. The device context is lost when this state is entered, so the OS software will have to fully reinitialize the device when powering it back on. Devices in this state have the longest restore times.

Processor States

ACPI defines the power state of system processors while in the G0 working state as being either active (executing) or sleeping (not executing). Processor power states are designated as C0, C1, C2, C3, … Cn. The C0 power state is an active power state where the CPU executes instructions. The C1–Cn power states are processor sleeping states where the processor consumes less power and dissipates less heat than leaving the processor in the C0 state. While in a sleeping state, the processor does not execute any instructions. Each processor sleeping state has a latency associated with entering and exiting that corresponds to the power savings. In general, the longer the entry/exit latency, the greater the power savings is for the state. To conserve power, OSPM places the processor into one of its supported sleeping states when idle. While in the C0 state, ACPI allows the performance of the processor to be altered through a defined "throttling" process and through transitions into multiple performance states (P states). A diagram of processor power states (not to be confused with performance states) is provided in Figure C-2.

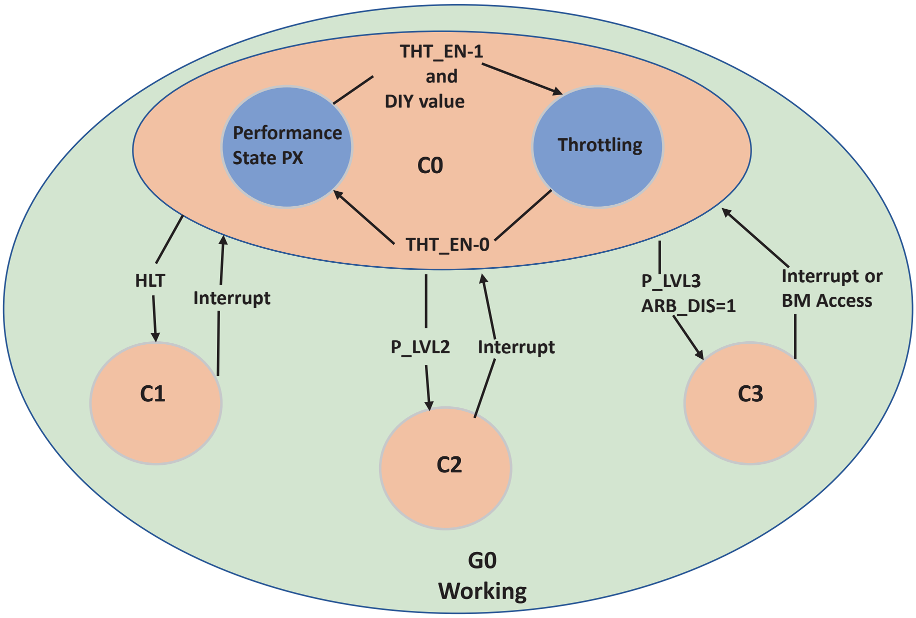

Figure C-2. *Processor Power States*

In summary, one of the main goals of OSPM is to save power/energy when the workload allows it, and detecting inactivity and putting the devices and the system (if possible) in their low-power states forms the heart of power management software.