Arm® System Control and Management Interface

Platform Design Document

Non-Confidential

Version 3.0

arm

Document number: DEN0056C

Contents

Release information

The Change History table lists the changes that are made to this document.

Table R.1. Change history

Date	Issue	Confidentiality	Change
May 2017	Issue A	Non-confidential	Version 1.0, first external release
July 2019	Issue B	Non-confidential	Version 2.0. 1. Removed reference to specific document versions in section 1.1. 2. Replaced PSCA with the correct acronym (PCSA) for Power Control System Architecture in Section 2. 3. Added clarifications to SCMI status codes NOT_FOUND and NOT_SUPPORTED in Section 4.1.4. 4. Added clarifications on OSPM view in Section 4.3.5. 5. Added more context to the OUT_OF_RANGE and BUSY status codes. 6. Added guidance on usage of ACPI PCC channels for SCMI transport. 7. Added clarifying note on power costs of performance domains. 8. Added FastChannel support. 9. Added Power Domain Management pre-notification support. 10. Added Agent-specific Resource Isolation capability as a part of Base protocol. 11. Add agent_id self-discovery. 12. Added notes on agent-id management. 13. Replaced SCMI overview diagram. 14. Cleaned up description/grammar and typos at multiple places. 15. Extended System Power Management Protocol notifier to support Virtualized system implementations. 16. Added Reset Management Protocol. 17. Renamed Mailbox Transport to more appropriate Shared Memory based Transport and made changes to allow SMC/HVC based doorbells. 18. Added guidance on usage of ACPI PCC channels for SCMI transport. 19. Added more context to the OUT_OF_RANGE and BUSY status codes. 20. Added clarifications to SCMI status codes NOT_FOUND and NOT_SUPPORTED. 21. Added support for notifications to agents on performance level change events triggered by external factors. 22. Remove requirement for Statistics Regions to be reset after system suspend.

Nov. 2020	Issue C	Non-confidential	Version 3.0. 1. Fixed typographical errors and broken links. 2. Add multi-axis sensor support. 3. Allow reporting sensor resolution and configuring sensor update intervals, timestamps, and sensor state. 4. Add notification support for continuous sensor sampling. 5. Sensor value fields changed from uint32 to int32. 6. Add support for SENSOR_CONFIG_GET/SET and move sensor_update_interval field reporting. 7. Clarify usage of trip points for multi-axis sensors. 8. Change Sensor protocol version to 2.0. 9. Simplify sensor shared memory region by specifying Sensor Value Data Entry Table explicitly. 10. Add guidance in Section 4.1.2 to allow sending only the last notification in case of quick transitions for the same event. This replaces specific guidance in all notification descriptions. 11. Provide guidance of minimum message size to be supported by a transport in Section 5. 12. Remove 32-bit restriction for shared memory identifier for SMC/HVC based doorbells. 13. Broaden scope of COMMS_ERROR usage. 14. Fix pseudocode in BASE_DISCOVER_LIST_PROTOCOLS. 15. Clarify Sustained Performance Level in Performance Management Protocol to include external constraints. 16. Clarify that performance level power cost is per AP only when the domain includes APs. Also clarify that reporting power cost is optional. 17. Allow performance level change notifications to be sent to the agent requesting a level change to cater for the case when PERFORMANCE_LEVEL_SET returns asynchronously. 18. Introduce Voltage Domain Protocol. 19. Add agent_id field to RESET_ISSUED notification. 20. Change Reset domain protocol version to 2.0. 21. Specify that reset domain identifiers should be sequential and start from 0. 22. Specify that sensor identifiers should be sequential and start from 0. 23. Clarify CLOCK_DESCRIBE_RATES command to return only one segment in case a triplet is returned. 24. Mandate 64-bit alignment for statistics shared memory regions. 25. Add Match Sequence to Statistics Shared Memory Region to detect race conditions between write accesses by the platform and read accesses by the agent. 26. Change revision field of statistics tables in all protocols to 1.0. 27. Add POWER_STATE_CHANGE_REQUESTED notification attribute bit in POWER_DOMAIN_ATTRIBUTES command. 28. Change Power Domain Protocol version to 2.1

29. Add a clarificatory phrase in all command returns to allow a generic range of return types.
30. Update SCMI Overview diagram with Voltage Domain Protocol.

Arm Non-Confidential Document Licence ("Licence")

This Licence is a legal agreement between you and Arm Limited ("**Arm**") for the use of Arm's intellectual property (including, without limitation, any copyright) embodied in the document accompanying this Licence ("**Document**"). Arm licenses its intellectual property in the Document to you on condition that you agree to the terms of this Licence. By using or copying the Document you indicate that you agree to be bound by the terms of this Licence.

"**Subsidiary**" means any company the majority of whose voting shares is now or hereafter owner or controlled, directly or indirectly, by you. A company shall be a Subsidiary only for the period during which such control exists.

This Document is **NON-CONFIDENTIAL** and any use by you and your Subsidiaries ("Licensee") is subject to the terms of this Licence between you and Arm.

Subject to the terms and conditions of this Licence, Arm hereby grants to Licensee under the intellectual property in the Document owned or controlled by Arm, a non-exclusive, non-transferable, non-sub-licensable, royalty-free, worldwide licence to:

(i) use and copy the Document for the purpose of designing and having designed products that comply with the Document;

(ii) manufacture and have manufactured products which have been created under the licence granted in (i) above; and

(iii) sell, supply and distribute products which have been created under the licence granted in (i) above.

Licensee hereby agrees that the licences granted above shall not extend to any portion or function of a product that is not itself compliant with part of the Document.

Except as expressly licensed above, Licensee acquires no right, title or interest in any Arm technology or any intellectual property embodied therein.

THE DOCUMENT IS PROVIDED "AS IS". ARM PROVIDES NO REPRESENTATIONS AND NO WARRANTIES, EXPRESS, IMPLIED OR STATUTORY, INCLUDING, WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY, SATISFACTORY QUALITY, NON-INFRINGEMENT OR FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE DOCUMENT. Arm may make changes to the Document at any time and without notice. For the avoidance of doubt, Arm makes no representation with respect to, and has undertaken no analysis to identify or understand the scope and content of, third party patents, copyrights, trade secrets, or other rights.

NOTWITHSTANING ANYTHING TO THE CONTRARY CONTAINED IN THIS LICENCE, TO THE FULLEST EXTENT PETMITTED BY LAW, IN NO EVENT WILL ARM BE LIABLE FOR ANY DAMAGES, IN CONTRACT, TORT OR OTHERWISE, IN CONNECTION WITH THE SUBJECT MATTER OF THIS LICENCE (INCLUDING WITHOUT LIMITATION) (I) LICENSEE'S USE OF THE DOCUMENT; AND (II) THE IMPLEMENTATION OF THE DOCUMENT IN ANY PRODUCT CREATED BY LICENSEE UNDER THIS LICENCE). THE EXISTENCE OF MORE THAN ONE CLAIM OR SUIT WILL NOT ENLARGE OR EXTEND THE LIMIT. LICENSEE RELEASES ARM FROM ALL OBLIGATIONS, LIABILITY, CLAIMS OR DEMANDS IN EXCESS OF THIS LIMITATION.

This Licence shall remain in force until terminated by Licensee or by Arm. Without prejudice to any of its other rights, if Licensee is in breach of any of the terms and conditions of this Licence then Arm may terminate this Licence immediately upon giving written notice to Licensee. Licensee may terminate this Licence at any time. Upon termination of this Licence by Licensee or by Arm, Licensee shall stop using the Document and destroy all copies of the Document in its possession. Upon termination of this Licence, all terms shall survive except for the licence grants.

Any breach of this Licence by a Subsidiary shall entitle Arm to terminate this Licence as if you were the party in breach. Any termination of this Licence shall be effective in respect of all Subsidiaries. Any rights granted to any Subsidiary hereunder shall automatically terminate upon such Subsidiary ceasing to be a Subsidiary.

The Document consists solely of commercial items. Licensee shall be responsible for ensuring that any use, duplication or disclosure of the Document complies fully with any relevant export laws and regulations to assure that the Document or any portion thereof is not exported, directly or indirectly, in violation of such export laws.

This Licence may be translated into other languages for convenience, and Licensee agrees that if there is any conflict between the English version of this Licence and any translation, the terms of the English version of this Licence shall prevail.

Arm document reference: LES-PRE-21585 version 4.0

1 About this Document

This document describers an extensible operating system-independent software interface to perform various system control and management tasks, including power and performance management.

1.1 References

This document refers to the following documents.

Reference	Document Number	Title
[ACPI]		Advanced Configuration and Power Interface Specification. See https://uefi.org/specifications
[FDT]		Flattened Device Tree. See https://www.devicetree.org
[PSCI]	DEN0022	Power State Coordination Interface. See https://developer.arm.com/documentation/den0022/latest/
[PCSA]	DEN0050	Power Control System Architecture Specification.
[ARMTF]		Arm Trusted Firmware. See https://github.com/ARM-software/arm-trusted-firmware.
[ARM]	DDI 0487	Arm Architecture Reference Manual ARMv8, for ARMv8-A architecture profile.
[SMCCC]	DEN0028	Arm SMC Calling Convention.

1.2 Terms and abbreviations

This document uses the following terms and abbreviations.

Term	Meaning
ACPI	Advanced Configuration and Power Interface
Agent	Entity that sends commands to the platform using SCMI. For example, the OSPM running on an AP or an on-chip management controller.
AP	Application processor, that is a processor that is running the operating system and applications in the system.
ASL	ACPI Source Language. Interpreted language that is used by the boot firmware to describe methods and data for the Operating System to use to discover and configure system resources. Defined in [ACPI].
Channel	The transport link over which the agent communicates to the platform.
Command	A message that is sent from an agent to the platform.
Delayed response	A message that is sent from the platform to an agent to indicate completion of the work that is associated with an asynchronous command.
FastChannel	A FastChannel is a lightweight unidirectional channel that is dedicated to a particular SCMI message for controlling a particular platform resource.

FDT	Flattened Device Tree
Message	An individual communication from an agent to the platform or from the platform to an agent.
MMIO	Memory Mapped IO.
Notification	A message that is sent from the platform to an agent to alert of a change in state.
OSPM	Operating System-directed Power Management. Typically, this acronym refers to the software components of an Operating System that interact with the power management interfaces of the platform.
Platform	The set of system components that interpret the SCMI messages and provide the necessary functionality. An SCP is an example of a platform component that could implement the SCMI messages.
PSCI	Power State Coordination Interface.
SCMI	System Control and Management Interface, which is described in this specification.
SCP	System Control Processor, see [PCSA].

1.3 Feedback

Arm welcomes feedback on its documentation.

1.3.1 Feedback on this manual

If you have comments on the content of this manual, send an e-mail to errata@arm.com. Give:

- The title.
- The document and version number, DEN0056C.
- The page numbers to which your comments apply.
- A concise explanation of your comments.

Arm also welcomes general suggestions for additions and improvements.

2 Introduction

This document describes the *System Control and Management Interface* (SCMI), which is a set of operating system-independent software interfaces that are used in system management. SCMI is extensible and currently provides interfaces for:

- Discovery and self-description of the interfaces it supports.
- Power domain management, which is the ability to place a given device or domain into the various power-saving states that it supports.
- Performance management, which is the ability to control the performance of a domain that is composed of compute engines such as *application processors* (APs), GPUs, or other accelerators.
- Clock management, which is the ability to set and inquire rates on platform-managed clocks.
- Sensor management, which is the ability to read sensor data, and be notified of sensor value changes.
- Reset domain management, which is the ability to place a given device or domain into various reset states.
- Voltage domain management, which is the ability to configure and manage the voltage level of a domain that provides voltage supply to a group of components.

There is a strong trend in the industry to provide microcontrollers in systems to abstract various power, or other system management tasks, away from APs. These controllers usually have similar interfaces, both in terms of the functions that are provided by them, and in terms of how requests are communicated to them. The *Power Control System Architecture* (PCSA) describes how systems using this approach can be built. For detailed information about the PCSA, see [PCSA].

PCSA defines the concept of the *System Control Processor* (SCP), a processor that is used to abstract power and system management tasks from the APs. The SCP can take requests from APs and other system agents. It can coordinate these requests and place components in the platform into appropriate power and performance states. The SCMI interface is particularly relevant to these kinds of systems. The interface provides two levels of abstraction:

- **Protocols**
  Each group of related functions is referred to as a protocol. The SCMI interface structure is extensible, and therefore other protocols could be added in the future.
- **Transports**
  The protocols communicate through transports. A transport specification describes how protocol messages are communicated between agents using the interface and the platform components that implement the protocol messages.

The interface is intended to be described in firmware, using either the *Flattened Device Tree* (FDT) or *Advanced Configuration and Power Interface* (ACPI) specification. For more information, see [FDT] and [ACPI]. Because the protocols are intended to be generic, they result in generic kernel code to drive them. However, in the ACPI case, the interface can also be driven from ASL methods. This document is arranged into the following sections:

- Section 3 provides background into the interface structure.
- Section 4 describes protocols.
- Section 5 describes transports.

3 System Control and Management Interface structure

The SCMI is intended to allow agents such as an operating system to manage various functions that are provided by the hardware platform it is running on, including power and performance functions. As described in the introduction, SCMI provides two levels of abstraction: protocols and transports. Protocols define individual groups of system control and management messages. A protocol specification describes the messages that it supports. Transports describe the method by which protocol messages are communicated between agents and the platform. Arm strongly recommends that transports be operating system independent and capable of being virtualized.

Transports comply with the following rules:

- A transport might support multiple channels. Each agent has one or more dedicated channels. Channels cannot be shared between agents.
- Systems that use Arm TrustZone technology can have both Secure and Non-secure channels. Data in a Secure channel can only be read or written by Secure memory accesses. A Non-secure channel cannot be used to access or modify Secure platform resources. An agent can be Secure or Normal. Only a Secure agent can communicate over a Secure channel. A Normal agent cannot use a Secure channel.

It is intended that protocols and transports are developed independently.

The protocols that are described in this document are intended to be used by power and performance management agents such as an operating system, also referred to as *Operating System-directed Power Management* (OSPM). Typical agents are:

- An OSPM that operates in Non-secure Exception levels.
- Secure-world software that is running on an AP.
- A privileged entity like a hypervisor on virtualized systems.
- External entities in the system, such as a management controller in an enterprise system, or a modem in a mobile system.

The term *platform* is intended to describe the set of hardware components that interpret the messages and provide the necessary functionality. The term *agent* is used to describe the caller of the interface. Each agent that communicates with the platform must have its own set of dedicated channels. This requirement removes the need for creating locking primitives across agents that are running entirely different software stacks. For example, a management controller and an operating system. In addition, dedicated channels provide a method for the platform to identify which agent is sending a message.

Figure 1 below illustrates an example system that implements the SCMI interface. In this example, the platform includes an SCP that handles SCMI commands that are issued from APs. The latter communicates with the SCP through Secure and Non-secure channels. The figure also shows a device that uses SCMI protocols to manage its power and performance. As described in [PCSA], the SCP coordinates requests from all requesting agents and drives the hardware into appropriate power or performance states.

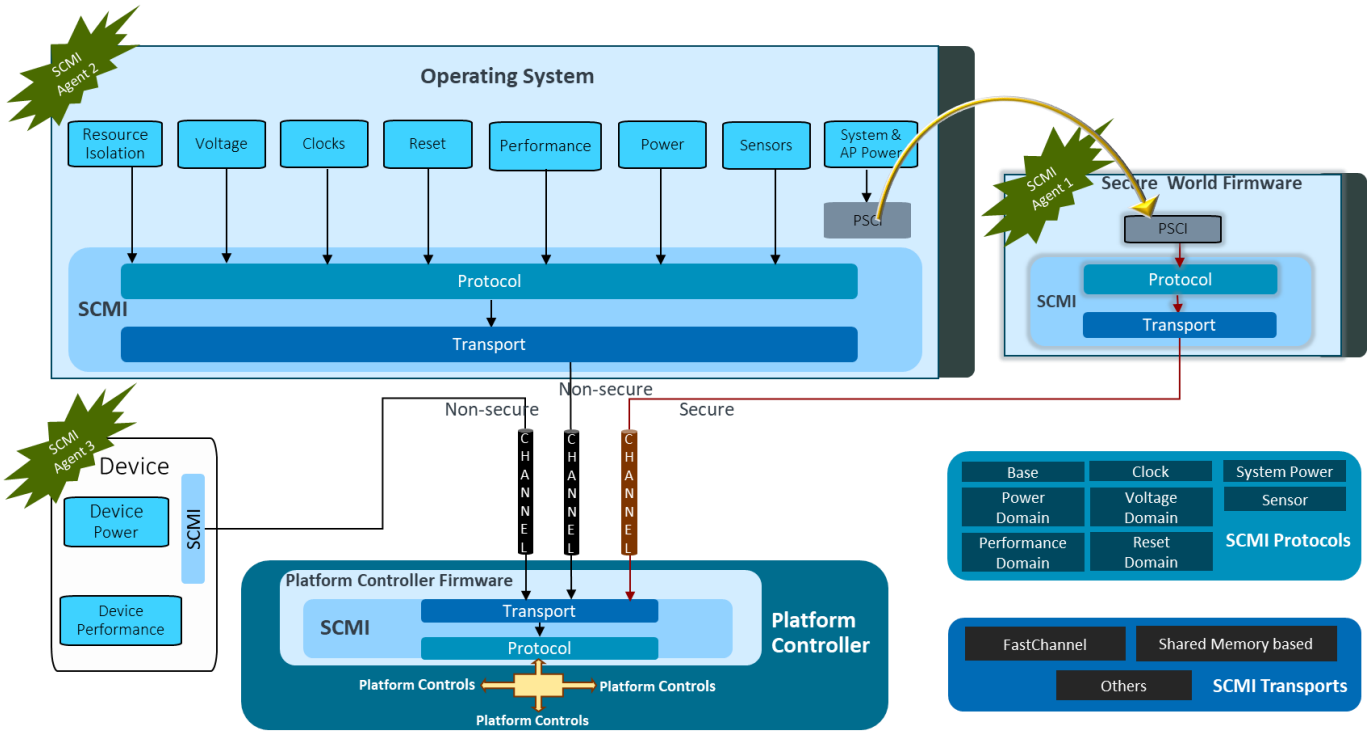

Figure 1 SCMI Overview

4 Protocols

4.1 Protocol structure

As described in section 3, a protocol is a group of messages. The following sections describe the message flow, the structure of messages, and protocol discovery.

4.1.1 Agents, messages and channels

The term agent is used to describe components that are clients of the SCMI interface. Agents have the following properties:

- Agents run a software stack with different privilege levels.
- Agent software stacks are independent from each other. This makes resource sharing, or the ability to write cross-agent locking primitives difficult. For example, one agent might be an operating system running on all APs, and another agent might be firmware running on a manageability controller.

Agents and the platform communicate over transport channels. A channel can be a dedicated SCMI FastChannel or a standard SCMI channel.

A FastChannel is a lightweight unidirectional channel that is dedicated to a single SCMI message type for controlling a specific platform resource. Unlike a standard channel, a FastChannel cannot be used to carry multiple message types, or to explicitly control multiple platform resources. A FastChannel cannot be shared among agents. The absence of multiple message types and their header requirements enables FastChannels to provide a potentially low latency mechanism for an agent to communicate with the platform. However, a FastChannel does not guarantee that the time taken by the platform to complete the requested operation is lower compared to a standard channel. Since FastChannels are protocol and message specific, their behavior is detailed in the respective Protocol sections. For this version of the specification, FastChannels are only supported for Performance management protocol and their properties are described in Section 4.5.1.1. Unless explicitly specified, the word ‘channel’ in the rest of the document will always refer to standard SCMI channels.

Figure 2 below describes how agents and the platform communicate over channels. The diagram shows multiple agents communicating with the platform.

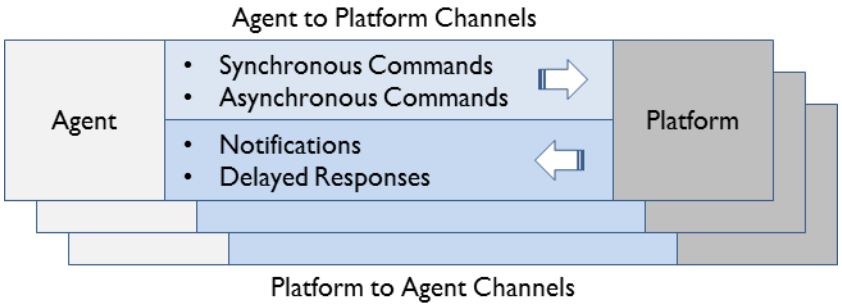

Figure 2 Messages and Channels

Each agent has dedicated channels, which are used to send messages to, and receive messages from, the platform. Each channel is a bidirectional communication pipe between the agent and the platform, except for FastChannels which are unidirectional. For a given channel either the agent or the platform is the master, or initiator, of communications. The master can place a message on a channel. At the other end, the slave processes the message, and if the channel is not a FastChannel, it might place return

data on the channel as a response. Depending on which entity is the master, a channel is one of two types:

- On **A**gent to **P**latform (A2P) channels, the agent is the master.
- On **P**latform to **A**gent (P2A) channels, the platform is the master.

Each agent can have one or more A2P channels and one or more P2A channels. However, these channels have to be dedicated to that specific agent and cannot be shared with other agents. Hence the maximum number of agents that can co-exist in a system at any given time can be no more than the number of available channels.

The platform considers that all communication over a channel is with a unique agent bearing a fixed agent identifier. This notion enables the platform to identify which agents are communicating with it. The platform statically assigns an agent identifier to every channel. An agent can discover the identifier assigned to it through the channel that the agent owns. This discovery is done using the Base protocol.

The properties of channels are specific to the transport that is used to send messages. An A2P transport might support interrupt-driven communication to send messages, where the platform generates an interrupt when it processes the message. The interrupt alerts the agent that the channel can now be used to send a further message. For a P2A transport, the agent might trigger an interrupt to the platform when it has processed the message sent by the platform. This informs the platform that the channel is now free and can be used to send a further message. Alternatively, a transport might only support polling-based communications. A transport can also support both methods and allow the agent to choose.

Messages are used by agents to make requests to the platform. The messages can carry various parameters, including an identifier for the requested operation. In turn, the platform carries out the requested operation, and might generate data in response to the message. From this point of view, messages are analogous to remote procedure calls, which can carry various parameters, and can also provide return data. The platform can also send messages to an agent, typically to indicate completion of a long job, or to notify of an event.

Messages that are sent by agents on A2P channels are known as commands and fall into two categories:

- **Synchronous**
  Commands that block the channel until the requested work has been completed. The platform responds to these commands over the A2P channel that was used to send them. Therefore, the channel cannot be used to send another command until the previous synchronous command has completed, and the channel is free to accept further commands.
- **Asynchronous**
  For these commands, the platform schedules the requested work to complete later in time. Therefore, these commands return almost immediately to the calling agent, freeing the channel for new commands. The response to an asynchronous command indicates the success or failure in the ability to schedule the requested work. When the work has completed, the platform can send an additional delayed response message to the client over a P2A channel.

Messages that the platform can send to an agent over P2A channels also fall into two categories:

- **Delayed response**
  Messages sent to indicate completion of the work that is associated with an asynchronous command.
- **Notifications**
  These messages provide notifications of events taking place in the platform. Events might include changes in power state, performance state, or other platform status.

FastChannels do not support synchronous commands, delayed responses or notifications.

4.1.2 Message format

Messages are analogous to remote procedure calls, and therefore must be representative of the particular operation being requested, and any parameters or return values thereof.

Each message carries a message header, which identifies the operation being requested. Each message belongs to a protocol. Therefore, the header of the message includes an 8-bit protocol identifier. This is known as the protocol_id. Within a protocol, each message is associated with a unique 8-bit identifier. This is known as the message_id.

A message can take several 32-bit arguments and can provide 32-bit return values. All parameters, message headers, and return arguments are expressed in little endian format. The endianness rule does not apply to strings. For all messages, any reserved field is set to zero.

Values for the protocol_id are described in Table 1.

Table 1 Protocol identifiers

protocol_id	Description
0x0 – 0xF	Reserved.
0x10	Base protocol.
0x11	Power domain management protocol.
0x12	System power management protocol.
0x13	Performance domain management protocol.
0x14	Clock management protocol.
0x15	Sensor management protocol.
0x16	Reset domain management protocol.
0x17	Voltage domain management protocol.
0x18-0x7F	Reserved for future use by this specification.
0x80-0xFF	Reserved for vendor or platform-specific extensions to this interface.

For all protocols and all transports using standard channels, messages are sent to the platform using a 32-bit message header, which is described in Table 2. FastChannels do not use a message header as they are specialized for a single message.

Table 2 Message header format

Field	Mnemonic	Description
Bits[31:28]	-	Reserved, must be zero.
Bits[27:18]	token	Token.

Bits[17:10]	protocol_id	Protocol identifier.
Bits[9:8]	message_type	Message type.
Bits[7:0]	message_id	Message identifier.

Commands

All commands, synchronous or asynchronous, have a message type of 0.

How the token field is used is entirely up to the caller. However, when a command returns, the platform must return the whole message header unmodified. The message header must always be the first parameter that is sent by an agent and returned by the platform.

In addition to the message header, commands return error status codes and can return more data. Any command that is sent with an unknown protocol_id or message_id must be responded to with a return value of NOT_SUPPORTED as the status code. FastChannels do not return any status codes since they are unidirectional. Status codes are provided in section 4.1.4.

Delayed responses

Delayed responses have a message type of 2.

Delayed response messages are sent by the platform to the agent to indicate completion of work that was requested by an asynchronous command. The message header that is associated with a delayed response uses the format that is described in Table 2. The message_id of a delayed response matches that of its associated asynchronous command. The token in the message header matches the token of the associated asynchronous command. The payload that is associated with a delayed response includes a status code, and additional data depending on the command.

Notifications

Notifications have a message type of 3.

Notifications provide a mechanism for the platform to inform agents about events taking place in the platform. Optionally, the implementation can provide information about which agent caused an event. To this end, a notification payload carries an agent identifier, agent_id, as its first parameter. The agent_id is an integer identifier that can be used to codify the agent that generated an event. The agent_id uses the following rules:

- A value of 0 identifies the platform itself.
- Where implemented, agent_ids are sequential and start from one.
- Agent identifiers and their mapping to other components are platform specific. Where necessary, this must be described to operating system through firmware table technologies such as FDT or ACPI.
- If agent identification is not supported, the implementation must set the agent_id to zero in notifications to indicate that the notification has been issued by the platform itself.

The platform is not required to guarantee sending a notification to an agent for every occurrence of the same event. In particular, if several events of the same type occur in quick succession, the platform is allowed to only issue a notification for the last occurrence of that event.

Message type 1 is reserved for future use by this specification.

4.1.3 Protocol discovery

This specification encompasses various protocols. However, not every protocol has to be present in an implementation, because not every protocol is relevant for every market segment. Furthermore, the platform chooses which protocols it exposes to a given agent. The only protocol that must be implemented is the Base protocol, which is described in section 4.2. The Base protocol is used by an agent to discover which protocols are available to it.

All protocols, whether they are generic or vendor specific, must mandatorily implement three special messages with message_ids of `0x0`, `0x1`, and `0x2` respectively, as described in Table 3.

Table 3 Required messages

message_id	Message	Description
`0x0`	PROTOCOL_VERSION	Returns the version of protocol.
`0x1`	PROTOCOL_ATTRIBUTES	Returns properties that are associated with the protocol implementation.
`0x2`	PROTOCOL_MESSAGE_ATTRIBUTES	Takes a message_id as a parameter and returns implementation details specific to that message.

Protocols might implement additional messages.

Protocol versioning uses a 32-bit unsigned integer, where the upper 16 bits are the major revision, and the lower 16 bits are the minor revision.

The following rules apply to the version numbering:

- Higher numbers denote newer versions.
- Different major revision values indicate possibly incompatible messages. For two protocol versions, A and B, which differ in major revision, and where B is higher than A, the following might be true:
    - B can remove messages that were present in A.
    - B can add new messages that were not present A.
    - B can modify the behavior or parameters of messages that are also present in A.
- Minor revisions allow extensions but must retain compatibility. For two protocol versions, A and B, that differ only in the minor revision, and where B is higher than A, the following must hold:
    - Every message in A must also be present in B, and work with compatible effect.
    - It is possible for revision B to have a higher message count than revision A.

4.1.4 SCMI status codes

Messages can return status codes to the sender. Negative 32-bit integers are used to return error status codes. Values 0 to -127 are reserved by this specification. Values below -127 can be used for vendor-specific errors.

Table 4 describes the error codes for SCMI messages.

Table 4 Status codes

Status code	Description
0	SUCCESS
-1	NOT_SUPPORTED
-2	INVALID_PARAMETERS
-3	DENIED
-4	NOT_FOUND
-5	OUT_OF_RANGE
-6	BUSY
-7	COMMS_ERROR
-8	GENERIC_ERROR
-9	HARDWARE_ERROR
-10	PROTOCOL_ERROR
-11 to -127	Reserved
< -127	Vendor specific

The specification of each SCMI message describes which error codes are appropriate to that message. However, unless otherwise specified, the following status codes apply to all command messages that are sent from an agent to the platform:

Code	Description
SUCCESS	Successful completion of the command.
NOT_SUPPORTED	The command or feature is not supported, or is supported but not within the calling agent's view of the platform.
INVALID_PARAMETERS	One or more parameters passed to the command are invalid or beyond legal limits.
DENIED	The caller is not permitted to perform the specific action, such as accessing a resource or feature that it is not allowed to use.

NOT_FOUND	The entity that is being accessed does not exist. Examples includes non-existent or invalid commands, resources such as power domains, clocks or sensors.
OUT_OF_RANGE	Requested settings are outside the legal range under the current operating state or condition. NOTE: Legal values can be different for different operating states of the system, hence a setting can be legal at a given point in time, and yet illegal at another. The operating state of the platform can change as a result of external factors.
BUSY	The platform is out of resources and thus unable to process a command. Arm strongly recommends that the implementation ensures that sufficient resources are available to the platform to handle the more frequently issued commands in order to guarantee availability of service. In particular, the platform must guarantee service for the following commands: • System power protocol commands • AP/domain power management commands. • Reset domain commands An agent receiving this status code must consider the system as non-functional and might attempt recovery through a system restart.
COMMS_ERROR	The message could not be correctly transmitted. Possible causes could include command buffer overflows as a result of flow control on the message transport. This error is a property of the transport.
GENERIC_ERROR	The command failed to be processed owing to an unspecified fault within the platform.
HARDWARE_ERROR	A hardware error occurred in a platform component during execution of a command.
PROTOCOL_ERROR	Returned when the receiver detects that the caller has violated the protocol specification.

4.2 Base protocol

This protocol describes the properties of the implementation and provides generic error management. The Base protocol provides commands to:

- Describe protocol version.
- Discover implementation attributes and vendor identification.
- Discover which protocols are implemented.
- Discover which agents are in the system.
- Register for notifications of platform errors.
- Configure the platform in order to control and modify an agent's visibility of platform resources and commands.

This protocol is mandatory.

4.2.1 Agent-specific permission configuration and reset

Where the system has multiple agents, the Base protocol provides commands that optionally allow a trusted agent to configure the access permissions of other agents. An agent should not be able to discover resources and commands that it does not have access to. If an agent tries to access resources that it does not have access to, the platform returns a DENIED or NOT_SUPPORTED response.

In a system comprising multiple agents, there is typically one trusted agent which has elevated privileges to configure and control the access rights of other agents in the system. Nominating a trusted agent is an implementation defined choice that must take into account the deployment use case. Arm recommends that only trusted agents have access to the Base Protocol commands to configure agent specific permissions. A trusted agent may be based in the Secure world or in the Normal world. Non-trusted agents should not be able to modify access permissions.

Platform resources can be Secure or Non-secure. Only a trusted agent based in the Secure world should be able to modify access permissions of Secure platform resources. The trusted agent might not always be resident in the Secure world. A trusted agent which is based in the Normal world should not be able to modify the access permissions of Secure platform resources.

The system boots with default permission configurations for each agent. Typically, this might ensure that Normal world agents do not have access to Secure platform resources. Thereafter, the trusted agent might setup additional access permissions. However, a Normal world agent, trusted or not, can never access Secure platform resources or modify access permissions of Secure platform resources.

In a virtualized system, a Virtual Machine (VM) is an example of a Normal world non-trusted agent, and the hypervisor is an example of a Normal world trusted agent. Using agent-specific permission configuration, the hypervisor can set up fine grained Non-secure resource access permissions for Virtual Machines. The hypervisor discovers the agent identifier of the channel that it wants to assign to a VM. The hypervisor then sets up access permissions of the agent identifier associated with that channel and assigns the channel to the VM. The VM can now discover the agent identifier, and only access those protocols and platform resources which have been permitted by the hypervisor.

4.2.1.1 Device specific access control

A platform usually includes a set of devices, or peripherals, for example Graphics Processing Units (GPUs), UART, or USB. If a platform has multiple agents, all agents might not have access to all the devices in the platform. The base protocol provides the BASE_SET_DEVICE_PERMISSIONS command to configure the devices that an agent has access to. A device, in this context, might also be

a logical aggregation of platform components. The definition of a device is the responsibility of the platform firmware and depends on the use case and the platform itself.

The platform must track all the resources that constitute a device. Platform resources refer to power domains, performance domains, clocks, sensors, reset domains and voltage domains. A device might span multiple domains. Also, multiple devices might share the same domain. An agent should be able to access resources associated with a device, only when the agent has permissions to access the device itself. When a resource is shared among multiple devices, the resource must be maintained in a state that fulfils the requirements of all the devices that share it.

4.2.1.2 Protocol specific access control

The Base protocol allows a trusted agent to restrict the protocols that non-trusted agents can use to access the platform resources that are associated with a specific device. This restriction is achieved by the BASE_SET_PROTOCOL_PERMISSIONS command. The platform should generate a DENIED or NOT_SUPPORTED response if an agent tries to use a restricted protocol to access the platform resources that are associated with the specific device.

4.2.1.3 Agent specific configuration reset

The Base protocol provides the BASE_RESET_AGENT_CONFIGURATION command to reset all the platform resource configurations that are requested by an agent and tracked by the platform. This command can also be used to reset agent-specific permission configurations to access devices and protocols.

A trusted agent might be allowed to reset the configuration of any agent in the system. However, a trusted agent that is based in the Normal world should not be allowed to reset Secure platform resource permissions or configurations. Non-trusted agents should not be allowed to reset the configuration of other agents. A non-trusted agent might only request configuration reset for itself.

Agent configuration reset should not be confused with system reset which is achieved through System power management protocol, or the reset of a domain which is achieved through the Reset domain management protocol. Agent specific configuration reset might typically be used in a scenario in which the trusted agent might want to remove an agent's access to all devices previously assigned to it. Agent specific configuration reset might also be useful when an agent has become unresponsive and the trusted agent needs to tell the platform to clean up that agent's resource configurations.

4.2.2 Commands

4.2.2.1 PROTOCOL_VERSION

This command returns the version of this protocol. For this version of the specification, the value that is returned must be `0x20000`, which corresponds to version 2.0.

message_id: `0x0`

protocol_id: `0x10`

This command is mandatory.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.

uint32 version	For this revision of the specification, this value must be `0x20000`.

4.2.2.2 PROTOCOL_ATTRIBUTES

This command returns the implementation details that are associated with this protocol.

message_id: `0x1`
protocol_id: `0x10`
This command is mandatory.

Return values

Name	Description	
int32 status	See section 4.1.4 for status code definitions.	
uint32 attributes	Bits[31:16]	Reserved, must be zero.
	Bits[15:8]	Number of agents in the system.
	Bits[7:0]	Number of protocols that are implemented, excluding the Base protocol.

If the platform does not support agent discovery, then it reports the number of agents in the system as zero, and all notifications carry a zero in the agent_id field.

4.2.2.3 PROTOCOL_MESSAGE_ATTRIBUTES

On success, this command returns the implementation details associated with a specific message in this protocol.

message_id: `0x2`
protocol_id: `0x10`
This command is mandatory.

Parameters

Name	Description
uint32 message_id	message_id of the message.

Return values

Name	Description

int32 status	One of the following: • SUCCESS: in case the message is implemented and available to use. • NOT_FOUND: if the message identified by message_id is not provided by this platform implementation. See section 4.1.4 for status code definitions.
uint32 attributes	Flags that are associated with a specific command in the protocol. For all commands in this protocol, this parameter has a value of 0.

4.2.2.4 BASE_DISCOVER_VENDOR

This command provides a vendor identifier ASCII string.

message_id: `0x3`
protocol_id: `0x10`
This command is mandatory.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.
uint8 vendor_identifier [16]	Null terminated ASCII string of up to 16 bytes with a vendor name.

4.2.2.5 BASE_DISCOVER_SUB_VENDOR

On success, this optional command provides a sub vendor identifier ASCII string.

message_id: `0x4`
protocol_id: `0x10`
This command is optional.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.
uint8 vendor_identifier [16]	Null terminated ASCII string of up to 16 bytes with a vendor name.

4.2.2.6 BASE_DISCOVER_IMPLEMENTATION_VERSION

This command provides a vendor-specific 32-bit implementation version. The format of the version number is vendor-specific, but version numbers must be strictly increasing so that a higher number indicates a more recent implementation.

message_id: `0x5`
protocol_id: `0x10`
This command is mandatory.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.
uint32 implementation_version	Format is vendor specific.

4.2.2.7 BASE_DISCOVER_LIST_PROTOCOLS

This command allows the agent to discover which protocols it is allowed to access. The protocol list returned by this call should be in numeric ascending order.

message_id: `0x6`
protocol_id: `0x10`
This command is mandatory.

Parameters

Name	Description
uint32 skip	Number of protocols to skip.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if a valid list of protocols is found. • INVALID_PARAMETERS: if skip field is invalid. See section 4.1.4 for more status code definitions.
uint32 num_protocols	Number of protocols that are returned by this call.
uint32 protocols[1+(num_protocols-1)/4]	Array of protocol identifiers that are implemented, excluding the Base protocol, with four protocol identifiers packed into each array element. The PROTOCOL_ATTRIBUTES command can be used to determine the number of protocols implemented.

The following pseudocode illustrates how this command can be used.

```
int status = 0;
int skip = 0;
int total_protocols = 0;
int num_protocols = 0;

uint32 attributes = 0;
uint32* protocols = NULL;
invoke_PROTOCOL_ATTRIBUTES(&status,&attributes);

if (status)
       goto clean_up_and_return;

total_protocols = (attributes & NUM_PROTOCOLS_MASK) >>
                           NUM_PROTOCOLS_SHIFT;

if (!total_protocols)
       goto clean_up_and_return;

do {
       invoke_BASE_DISCOVER_LIST_PROTOCOLS(skip,
              &status, &num_protocols, protocols);

       if (status)
              goto clean_up_and_return;


       for (int ix = 0; ix < num_protocols; ix++)
       {
              uint8 prot = protocols[ix/4] >> ((ix % 4) * 8);
              add_to_protocol_database(prot);
              skip++;
       }
} while (skip < total_protocols);
```

4.2.2.8 BASE_DISCOVER_AGENT

This optional command allows the caller to discover the name of an agent, described through an ASCII string of up to 16 bytes. A caller can discover if this command is implemented by issuing the PROTOCOL_MESSAGE_ATTRIBUTES command and passing the message_id of this command. If the command is implemented, PROTOCOL_MESSAGE_ATTRIBUTES returns SUCCESS (0).

Agent identifiers, agent_id, describe agents in the system that can use the SCMI protocols. Not every agent can use all protocols, and some protocols can offer different views to different agents. An agent_id of 0 is reserved to identify the platform itself. If the command is not implemented, the caller does not interpret agent identifiers in notifications, and the platform sets agent_id to zero in notifications. Where supported, agent_id values are sequential, start from one, and are limited by the number of agents that is reported through PROTOCOL_ATTRIBUTES.

If called with an agent_id of 0, the string returned in the name parameter must start with “platform”.

An agent can discover its own agent_id and name by passing agent_id of 0xFFFFFFFF. In this case, the command returns the agent_id and name of the calling agent.

message_id: `0x7`

protocol_id: `0x10`

This command is optional.

Parameters

Name	Description
uint32 agent_id	Identifier of the agent whose identification is requested.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: If a valid agent identifier is found. • NOT_FOUND: if agent_id does not point to a valid agent. See section 4.1.4 for more status code definitions.
uint32 agent_id	ID of the agent whose identity is requested. This field is: • populated with the agent_id of the calling agent, when the agent_id parameter passed via the command is 0xFFFFFFFF. • identical to the agent_id field passed via the calling parameters, in all other cases.
uint8 name[16]	Null terminated ASCII string of up to 16 bytes in length.

4.2.2.9 BASE_NOTIFY_ERRORS

An implementation can optionally provide notifications of errors in the platform to an agent that has registered through this command. A caller can discover if this command is implemented by issuing the PROTOCOL_MESSAGE_ATTRIBUTES command and passing the message_id of this command. If the command is implemented, PROTOCOL_MESSAGE_ATTRIBUTES returns SUCCESS.

Error notification is used to notify agents of commands that could not proceed due to unpredictable circumstances, such as internal hardware errors. Further information on the error notification and associated payload is provided in section 4.2.3.1, which describes the BASE_ERROR_EVENT notification.

message_id: `0x8`

protocol_id: `0x10`

This command is optional.

Parameters

Name	Description

uint32 notify_enable	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Notify enable: If this value is 0, the platform does not send any BASE_ERROR_EVENT messages to the calling agent. If this value is 1, the platform sends BASE_ERROR_EVENT messages to the calling agent when an error is detected. For more details on the BASE_ERROR_EVENT notification, see 4.2.3.1.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS. • INVALID_PARAMETERS: if notify_enable contains illegal or incorrect values. See section 4.1.4 for more status code definitions.

4.2.2.10 BASE_SET_DEVICE_PERMISSIONS

This command is used to indicate to the platform whether an agent has permissions to access devices, as specified by a device identifier. An agent can only operate on devices to which it has access, and by extension can only operate on the power, performance, clock, sensor, reset and voltage domains that are associated with that device. At system boot, the default device-specific access permission of an agent is IMPLEMENTATION defined. Arm recommends that only trusted agents in the system are given permission to invoke this command.

The Base protocol does not cover the discovery of device identifiers for devices in a platform. This information is provided to the caller by way of firmware tables in FDT or ACPI.

A caller can discover if this command is implemented by issuing the PROTOCOL_MESSAGE_ATTRIBUTES command and passing the message_id of this command. If the command is implemented, PROTOCOL_MESSAGE_ATTRIBUTES returns SUCCESS.

message_id: `0x9`

protocol_id: `0x10`

This command is optional.

Parameters

Name	Description
uint32 agent_id	Identifier of the Agent.
uint32 device_id	Identifier of the device.

uint32 flags	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Access Type: This bit defines the permissions of the agent to access platform resources associated with the device. If set to 0, deny agent access to the device. If set to 1, allow agent access to the device.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: in case the device permissions was set successfully for the agent specified by agent_id. • NOT_FOUND: if agent_id or device_id does not exist. • INVALID_PARAMETERS: if flags field is invalid. • NOT_SUPPORTED: if the command is not supported. • DENIED: if the calling agent is not allowed to set the permissions of the agent specified by agent_id. See section 4.1.4 for more status code definitions.

4.2.2.11 BASE_SET_PROTOCOL_PERMISSIONS

An agent can have access to multiple devices. The agent uses commands to access platform resources that are associated with those devices. The command BASE_SET_PROTOCOL_PERMISSIONS is used to indicate to the platform whether an agent has permissions to use a protocol to access the platform resources that are associated with a specific device. This command cannot be used to change the agent's permissions to access a device. This command only affects the protocols which the agent can use to access the platform resources that are associated with a particular device. At system boot, the default per-device protocol specific access permissions of an agent are IMPLEMENTATION defined.

Arm recommends that only trusted agents in the system are given permissions to invoke this command.

A caller can discover if this command is implemented by issuing the PROTOCOL_MESSAGE_ATTRIBUTES command and passing the message_id of this command. If the command is implemented, PROTOCOL_MESSAGE_ATTRIBUTES returns SUCCESS.

message_id: `0xA`

protocol_id: `0x10`

This command is optional.

Parameters

Name	Description

uint32 agent_id	Identifier of the Agent.	
uint32 device_id	Identifier of the device.	
uint32 command_id	Bits[31:8]	Reserved, must be zero.
	Bits[7:0]	Protocol ID: This field should not be set to 0x10, since it is mandatory to implement the Base protocol for all agents.
uint32 flags	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Access Type. This bit defines the permissions of the agent to use the protocol specified by command_id, to access platform resources that are a part of the device specified by device_id. If set to 0, deny agent access to the protocol. If set to 1, allow agent access to the protocol.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: in case the command permissions were set successfully. • NOT_FOUND: if any of agent_id, device_id or protocol_id does not exist. • INVALID_PARAMETERS: if flags field is invalid. • NOT_SUPPORTED: if the command is not supported. • DENIED: if the calling agent is not allowed to set the protocol permissions for the agent specified by agent_id. See section 4.1.4 for more status code definitions.

4.2.2.12 BASE_RESET_AGENT_CONFIGURATION

This command is used to reset platform resource settings that were previously configured by an agent. Platform resource settings refer to power domain, performance domain, clock, sensors and other settings associated with a device that the agent has access to. This command can also be used to reset agent-specific permission configurations to access devices and protocols.

When this command is received, the platform might need to flush all pending requests from the agent that is undergoing configuration reset. It might also need to wait for requests that are being processed on behalf of the agent to complete. Alternatively, the platform can choose to abort all agent-related transactions in flight and reset its configuration. The platform needs to revert the platform resources that are solely dedicated to the agent into their default state. Shared platform resources need to be moved

into a state that continues to meet the requirements of the remaining agents using that resource. Shared platform resources are those which are shared among and used by multiple agents. Agent configuration reset should not be confused with the reset of the platform or its components.

If the Permissions Reset flag is set, the platform resets all the device and protocol access permissions that are configured for the agent. When permission reset completes, IMPLEMENTATION defined platform-specific default permissions are restored for that agent.

Arm recommends that only trusted agents in the system are given permissions to invoke this command for other agents. An agent can invoke this command for itself.

A caller can discover if this command is implemented by issuing the PROTOCOL_MESSAGE_ATTRIBUTES command and passing the message_id of this command. If the command is implemented, PROTOCOL_MESSAGE_ATTRIBUTES returns SUCCESS.

message_id: `0xB`

protocol_id: `0x10`

This command is optional.

Parameters

Name	Description	
uint32 agent_id	Identifier of the Agent.	
uint32 flags	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Permissions Reset: If set to 0, maintain all access permission settings of the agent. If set to 1, reset all access permission settings of the agent.
	This command must always reset the platform resource settings configured by the agent specified by agent_id. Platform resource settings refer to Device, Power Domain, Performance Domain, Clocks, Sensors and other settings configured by the agent specified by agent_id.	

Return values

Name	Description

int32 status	One of, but not limited to, the following: • SUCCESS: in case the command is processed successfully. • NOT_FOUND: if the agent specified by agent_id does not exist. • INVALID_PARAMETERS: if the flags field is invalid. • NOT_SUPPORTED: if the command is not supported. • DENIED: if the calling agent is not allowed to reset the agent specified by agent_id. See section 4.1.4 for more status code definitions.

4.2.3 Notifications

4.2.3.1 BASE_ERROR_EVENT

These notifications are sent to any agent that has registered to receive them, provided the platform implements base error notifications.

Errors that are reported by the platform are one of two types:

- **Fatal error**
  Indicates that the platform is no longer able to process commands. The error might be accompanied by the list of messages that were being processed when the failure took place.
- **Non-fatal error**
  Indicates that the platform was not able to process some commands, but it is still operational. The error notification is accompanied by the list of commands that could not be processed.

By definition, fatal error notifications cannot be guaranteed, and the platform must not rely on these notifications as a mechanism to enable recovery.

Error notifications must not be used as mechanism to report that a command cannot be executed as requested due to constraints that arise in normal operation.

On initial boot of an agent, these notifications must be disabled by default to that agent.

message_id: `0x0`

protocol_id: `0x10`

This command is optional.

Parameters

Name	Description
uint32 agent_id	Identifier of the agent that caused this notification.

uint32 error_status	Bit[31]	Fatal. Set if error is fatal and platform cannot continue. Cleared if error is non-fatal but commands have failed.
	Bits[30:10]	Reserved, must be zero.
	Bits[9:0]	Command count, number of commands in the command list. A value of zero is possible if the error cannot be attributed.
{uint32 message_header unit32 status}[N]	Each entry in the command list is a tuple, where the first entry is the message header of the command, and second is an error status code that is associated with the command. The size of the list is specified by the command count sub-field.	

4.3 Power domain management protocol

This protocol is intended for management of power states of power domains.

The power domain management protocol provides commands to:

- Describe the protocol version.
- Discover implementation attributes.
- Set the power state of a domain.
- Get the current power state of a domain.
- Optionally get notifications when power domains change state or when an agent requests for a power domain state change.
- Optionally return statistics on residency and usage count of a given power state.

4.3.1 Power domain management protocol background

In this document, a power domain is defined as a group of components that are powered together. For example, a set of components that share a power source, and can only be turned ON or OFF as a group, form a power domain. Power domains have the following properties:

- They can include one or more devices.
- They must at least support the ON and OFF states but can support additional power states.
- In the ON state, the domain is operational and devices within it can run.
- In the OFF state, the domain has no power supplied to it. Devices within it cannot run and lose all context.

Domains can have dependencies on other domains. For example, a parent domain can include a child domain. In such a case, if the child domain is ON, the parent domain is also necessarily ON. Dependencies can also be implicit. For example, a slave domain that is in use by multiple agents in other power domains must be in a power state that can ensure service guarantees to those agents.

The protocol does not cover discovery of power states that are supported by a domain, or description of the properties of the states, for example associated latencies, context loss, or domain dependencies. This information is expected to be provided to the caller by way of firmware tables in FDT or ACPI.

Protocol commands take integer identifiers to identify the power domain that they apply to. The identifiers are sequential and start from 0.

The protocol can be used to manage the power state of application processors and devices in the system.

Operating systems that are running on application processors must not directly use SCMI to manage the power state of these processors. Instead, power states for domains that include APs must be managed using PSCI calls from the operating system. When the OSPM calls a PSCI function, the PSCI implementation, which is described in [PSCI, ARMTF], can communicate with the platform using this protocol over Secure channels. This protocol allows SCMI to provide an implementation for PSCI functions designed to manage the power of application processors, such as CPU_DEFAULT_SUSPEND, CPU_SUSPEND, CPU_FREEZE, CPU_ON and CPU_OFF. These functions map to various use cases including idle, secondary core boot, and hot plug. The list does not include system power state transitions such as system shutdown or reset, which are covered by the system power management protocol instead, as described in section 4.4.

Agents that are not running on application processors can register to receive notifications of power state changes to these power domains.

Non-secure channels can be used to manage power domains for devices that do not include application processors, and which are not used by Secure entities in the system. Any agent can register for power state change notifications for these domains.

An implementation can include devices that are intended for use only by Secure entities in the system such as a trusted OS. Power domains for such devices must be managed through Secure channels.

Agents other than the OSPM can manage power domains. In a multi-agent system with multiple domains, several scenarios are possible:

- A power domain is exclusive to an agent.
- A power domain can be shared by multiple agents.

In all of these cases, the agents can coordinate with the platform to access power domains, and to perform power management of the domains. For AP power domains, the coordination models are analogous to those described in [ACPI] and [PSCI]. For all combinations of power domains and agents, platform policy dictates which agents can access which power domains, and whether a power domain is shared or exclusive.

For all messages in this protocol, the interpretation of the power state parameter is specific to the combination of the agent and the power domain that it is managing. A power domain with Application Processors that is managed by a PSCI agent must support representation of the power state parameter based on definitions in [PSCI]. On the other hand, for power domains pertaining to devices, the power state parameter must minimally represent two pre-defined states, ON and OFF. Power state encoding for device power domains is described in Table 5.

Table 5: Power State Parameter Layout for Device Power Domains

Bit field	Description
31	Reserved. Must be zero.
30	StateType If set to 0, indicates that context is preserved. If set to 1, indicates that context is lost.
29:28	Reserved. Must be zero.
27:0	StateID A value of zero when StateType is set to 0 represents the ON state. A value of zero when StateType is set to 1 represents the OFF state. All other values are IMPLEMENTATION_DEFINED.

4.3.2 Commands

4.3.2.1 PROTOCOL_VERSION

On success, this command returns the Protocol version. For this version of the specification, the return value must be `0x21000`, which corresponds to version 2.1.

message_id: `0x0`
protocol_id: `0x11`
This command is mandatory.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.
uint32 version	For this revision of the specification, this value must be `0x21000`.

4.3.2.2 PROTOCOL_ATTRIBUTES

This command returns the implementation details associated with this protocol.

message_id: `0x1`
protocol_id: `0x11`
This command is mandatory.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.
uint32 attributes	Bits[31:16] Reserved, must be zero. Bits[15:0] Number of power domains.
uint32 statistics_address_low	The lower 32 bits of the physical address where the statistics shared memory region is located. This value should be 64-bit aligned. The address must be in the memory map of the calling agent. This field is invalid and must be ignored if the statistics_len field is set to 0. The statistics shared memory region is described in section 4.3.4.
uint32 statistics_address_high	The upper 32 bits of the physical address where the statistics shared memory region is located. The address must be in the memory map of the calling agent. This field is invalid and must be ignored if the statistics_len field is set to 0. The statistics shared memory region is described in section 4.3.4.

uint32 statistics_len	The length in bytes of the statistics shared memory region. A value of 0 in this field indicates that the platform doesn't support the statistics shared memory region.

4.3.2.3 PROTOCOL_MESSAGE_ATTRIBUTES

On success, this command returns the implementation details associated with a specific message in this protocol.

This command can be used to inquire if power state change notifications are supported, by passing POWER_STATE_NOTIFY or POWER_STATE_CHANGE_REQUESTED_NOTIFY message identifier to the call. If the platform returns SUCCESS, then it supports power state change notifications. Otherwise, if the platform returns NOT_FOUND, then it is an indication that notifications are not implemented, or that notifications are not available to the calling agent. The notifications commands are described in sections 4.3.2.7 and 4.3.3.1.

message_id: `0x2`

protocol_id: `0x11`

This command is mandatory.

Parameters

Name	Description
uint32 message_id	message_id of the message.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: in case the message is implemented and available to use. • NOT_FOUND: if the message identified by message_id is invalid or not implemented. See section 4.1.4 for more status code definitions.
uint32 attributes	Flags that are associated with a specific command in the protocol. In the current version of the specification, this value is always 0.

4.3.2.4 POWER_DOMAIN_ATTRIBUTES

This command returns the attribute flags associated with a specific power domain.

message_id: `0x3`

protocol_id: `0x11`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the domain. Domain identifiers are limited to 16 bits, and the upper 16 bits of this field are ignored by the platform.

Return values

Name	Description	
int32 status	One of, but not limited to, the following: • SUCCESS: if valid power domain attributes are returned. • NOT_FOUND: if domain_id pertains to a non-existent domain. See section 4.1.4 for more status code definitions.	
uint32 attributes	Bit[31]	Power state change notifications support. Set to 1 if power state change notifications are supported on this domain. Set to 0 if power state change notifications are not supported on this domain.
	Bit[30]	Power state asynchronous support. Set to 1 if power state can be set asynchronously. Set to 0 if power state cannot be set asynchronously.
	Bit[29]	Power state synchronous support. Set to 1 if power state can be set synchronously. Set to 0 if power state cannot be set synchronously.
	Bit[28]	Power state change requested notifications support. Set to 1 if power state change requested notifications are supported on this domain. Set to 0 if power state change requested notifications are not supported on this domain.
	Bits[27:0]	Reserved, must be zero.

uint8 name[16]	Null-terminated ASCII string of up to 16 bytes in length describing the power domain name.

For some agents, the platform might only allow registration and receipt of notifications for power domains and disallow setting of power states of those domains.

4.3.2.5 POWER_STATE_SET

This command allows an agent to set the power state of a power domain. Power domains can be managed synchronously or asynchronously:

- **Synchronous Mode**
  A call with valid parameters completes and frees the channel when the domain has transitioned to the desired power state.
- **Asynchronous Mode**
  The call completes immediately, and the caller can register for notifications if it wishes to observe the power state transition. These notifications are described in section 4.3.3.1.

When this command is used for power domains that include application processors, the Async flag is ignored. This call must return to the calling AP before that AP is powered down. Following this call, the AP executes some instructions before invoking a *Wait for Interrupt* (WFI) instruction [ARM]. The platform controller that implements SCMI begins the transition to the required power state when it observes the WFI. The method used by the platform controller to observe the WFI is IMPLEMENTATION DEFINED. For these power domains, this protocol can be used to implement PSCI CPU_SUSPEND, CPU_ON, CPU_FREEZE, CPU_DEFAULT_SUSPEND and CPU_OFF functions.

A power domain can contain other power domains. If the caller wants to change the state of a power domain and one of its parents, the power domain parameter must identify the child. The required power state for the child domain, and its parents, must be encoded in the power state parameter. How this is encoded in the power_state parameter is IMPLEMENTATION DEFINED.

message_id: `0x4`

protocol_id: `0x11`

This command is mandatory.

Parameters

Name	Description	
uint32 flags	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Async flag.
		Set to 1 if power transition must be done asynchronously.
		Set to 0 if power state transition must be done synchronously.
		The async flag is ignored for application processor domains.

uint32 domain_id	Identifier for the power domain.
uint32 power_state	Platform-specific parameter identifying the power state of the domain. For device power domains, this parameter is encoded as described in Table 5.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: for a power domain that can only be set synchronously, this status is returned after the power domain has transitioned to the desired state. For a power domain that is managed asynchronously, this status is returned if the command parameters are valid and the power state change has been scheduled. • NOT_FOUND: if the power domain identified by domain_id does not exist. • INVALID_PARAMETERS: if the requested power state does not represent a valid state for the power domain that is identified by domain_id. • NOT_SUPPORTED: if the request is not supported. • DENIED: if the calling agent is not allowed to set the state of this power domain. An example would be if this power domain is exclusive to another agent. See section 4.1.4 for more status code definitions.

4.3.2.6 POWER_STATE_GET

This command allows the calling agent to request the current power state of a power domain.

Note

It is possible for the power_state value returned by this command to be stale by the time the command completes, as another state change request could have been initiated and completed in the interim.

message_id: `0x5`

protocol_id: `0x11`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the power domain.

Return values	
Name	**Description**
int32 status	One of, but not limited to, the following: • SUCCESS: if the current power state is returned successfully. • NOT_FOUND: if domain_id does not point to a valid power domain. See section 4.1.4 for more status code definitions.
uint32 power_state	Platform-specific parameter identifying the power state of this domain. For device power domains, this parameter is encoded as described in Table 5.

4.3.2.7 POWER_STATE_NOTIFY

This command allows the caller to request notifications from the platform for state changes in a specific power domain. These notifications are sent using the POWER_STATE_CHANGED notification, which is described in section 4.3.3.1.

Notification support is optional, and PROTOCOL_MESSAGE_ATTRIBUTES must be used to discover whether this command is implemented.

These notifications must be disabled by default during initial boot of the platform.

message_id: `0x6` protocol_id: `0x11` This command is optional.		
Parameters		
Name	**Description**	
uint32 domain_id	Identifier for the power domain.	
uint32 notify_enable	Bits[31:1]	Reserved must be zero.
	Bit[0]	Notify enable. This bit can have one of the following values: 0, which indicates that the platform does not send any POWER_STATE_CHANGED messages to the calling agent. 1, which indicates that the platform does send POWER_STATE_CHANGED messages to the calling agent when a domain changes power state. See section 4.3.3.1 for more details about the POWER_STATE_CHANGED notification.

Return values	
Name	**Description**
int32 status	One of, but not limited to, the following: • SUCCESS. • NOT_FOUND: if domain_id does not point to a valid domain. • INVALID_PARAMETERS: if notify_enable specifies values that are either illegal or incorrect. See section 4.1.4 for more status code definitions.

4.3.2.8 POWER_STATE_CHANGE_REQUESTED_NOTIFY

This command allows the caller to receive notifications from the platform, when the platform receives a request from another agent to change the state of a power domain. These notifications are sent using the POWER_STATE_CHANGE_REQUESTED notification, which is described in section 4.3.3.2.

POWER_STATE_CHANGE_REQUESTED notifications are useful for the co-operative management of power domains that are shared among agents. When a power domain is shared among agents, the platform maintains the power domain in a state that meets the requirements of all the agents that are sharing it.

For example, the POWER_STATE_CHANGE_REQUESTED notification can be used when a request is made by one agent to turn off a shared power domain. The platform will not act on this request if other agents have requested the same power domain to be active. The platform will notify the other agents sharing the power domain through the POWER_STATE_CHANGE_REQUESTED notification, if the other agents have subscribed to it. This notification enables the other agents to allow the power state transition of the shared power domain, by voluntarily relinquishing the use of the shared power domain. The decision to voluntarily relinquish the use of a shared power domain is based on an implementation-defined policy.

Notification support is optional, and PROTOCOL_MESSAGE_ATTRIBUTES must be used to discover whether this command is implemented.

These notifications must be disabled by default during initial boot of the platform.

message_id: `0x7`

protocol_id: `0x11`

This command is optional.

Parameters	
Name	**Description**
uint32 domain_id	Identifier for the power domain.

uint32 notify_enable	Bits[31:1]	Reserved must be zero.
	Bit[0]	Notify enable. This bit can have one of the following values: 0, which indicates that the platform does not send POWER_STATE_CHANGE_REQUESTED messages to the calling agent. 1, which indicates that the platform sends POWER_STATE_CHANGE_REQUESTED messages to the calling agent when another agent requests for a change in the state of the power domain. See section 4.3.3.2 for more details about the POWER_STATE_CHANGE_REQUESTED notification.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS. • NOT_FOUND: if domain_id does not point to a valid domain. See section 4.1.4 for more status code definitions.

4.3.3 Notifications

4.3.3.1 POWER_STATE_CHANGED

If an agent has registered to receive power state change notifications for the power domain that is identified by domain_id, the platform sends these notifications to that agent when the power domain state changes, including transitions to an ON state.

Note that notified power states might not match those requested by the agent that is notified. The power state that is finally selected by the platform might differ from that requested by an agent, due to coordination with other requests on the same domain.

message_id: `0x0`

protocol_id: `0x11`

This command is optional.

Parameters

Name	Description
uint32 agent_id	Identifier of the agent that caused the power transition.

uint32 domain_id	Identifier of the power domain whose power state was changed.
uint32 power_state	The power state that the power domain transitioned to. These notifications take place when the transition has completed.

4.3.3.2 POWER_STATE_CHANGE_REQUESTED

An agent might have registered, via POWER_STATE_CHANGE_REQUESTED_NOTIFY, to receive notifications when the platform receives a request from a different agent to change the power state of a power domain. The platform sends this notification to the interested agent when such a request is received by it.

For more details on how POWER_STATE_CHANGE_REQUESTED notifications can be used, see section 4.3.2.8.

message_id: `0x1`

protocol_id: `0x11`

This command is optional.

Parameters

Name	Description
uint32 agent_id	Identifier of the agent that requested the power transition.
uint32 domain_id	Identifier of the power domain whose power state change is being requested.
uint32 power_state	The power state requested.

4.3.4 Power state statistics shared memory region

Optionally, the platform can provide a statistics shared memory region that is associated with the power state protocol. Whether support is present is indicated by the PROTOCOL_ATTRIBUTES command, which is described in section 4.3.2.2. The PROTOCOL_ATTRIBUTES command also provides the address and the size of the shared memory region. The region provides usage counts and residency information for each power state that is used by each power state domain. The memory must be accessible from the Non-secure world, and OSPM must map it as non-cached normal memory or device memory. For a given power domain, and for each power state in a domain, statistics in the shared memory region track the number of times the state has been used and the amount of time the domain has been in the state. The statistics must be updated regardless of the agent in the system that placed a domain into a given power state. After a system reset or shutdown, all the statistics must be initialized to zero. Time measurements are in microseconds.

The design of the statistics shared memory region allows the platform implementation to choose which power domains are included. However, if a domain is included, all its power states must be represented, including time that is spent in an ON state.

The format of the statistics shared memory region is described in Table 6.

Table 6 Power state statistics shared memory region

Field	Byte Length	Byte Offset	Description
Signature	0x4	0x0	0x504F5752 ('POWR').
Revision	0x2	0x4	For this revision, this field must be 0x1.
Attributes	0x2	0x6	For this revision, this field must be zero.
Number of domains	0x2	0x8	Number of domains for which statistics are collected.
Reserved	0x2	0xA	Must be zero.
Match Sequence	0x4	0xC	The match sequence populated by the platform as described in Section 4.3.4.1.
Power domain offset array	0x4 × (Total number of power domains)	0x10	For each power domain, this array provides a 4-byte offset, from the start of the shared memory area, to the memory location of the power domain entry in the data section. The entry is described in Table 7. A value of zero for the offset of a given power domain indicates that statistics are not collected for that domain.
Power domain data section	--	--	This area must start at an offset of 0x10 + 0x4 × (Number of power domains), or higher.

4.3.4.1 Match Sequence

Race conditions can arise between write accesses by the platform and read accesses by the agent during a statistics shared memory region update. This can lead to stale or invalid values being read by the agent. The match sequence is used to detect such race conditions.

The match sequence is a 4 byte non-zero unsigned value that is populated by the platform and is read by the agent. The match sequence should be an even number at boot. The sequence should be incremented by one, once at the start of, and once at the end of a statistics shared memory region update. This ensures that the match sequence is an odd number when the statistics shared memory region is being updated and is an even number otherwise. Care should be taken to handle the case when the match sequence wraps to zero. In such a scenario, the platform can choose to reset the match sequence to its boot time value.

A flow chart depicting the steps involved when the platform updates the statistics shared memory region is shown in Figure 3. The match sequence is an even number when the statistics shared memory region is not being updated. The platform increments the match sequence by one at the beginning of a statistics shared memory region update process. As a result, the match sequence becomes an odd number when the statistics shared memory region is being updated. The platform then updates the statistics shared memory region. When the platform has completed updating the statistics shared

memory region, it again increments the match sequence by one. As a result, the match sequence becomes an even number when the update process is complete. The match sequence before and after the update differ from each other. An odd value of the match sequence along with a mismatch of values can be used by an agent to detect invalid reads from the statistics shared memory region.

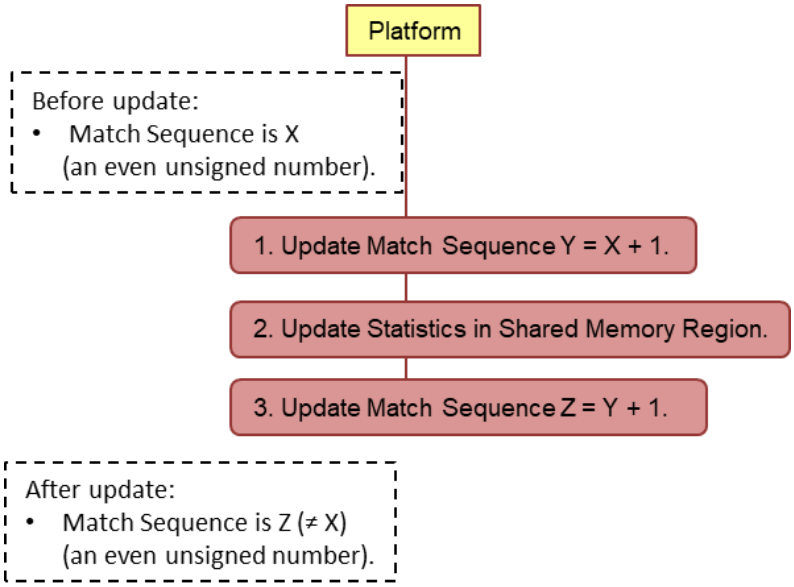

Figure 3 Statistics Shared Memory Region Update by Platform

A flow chart depicting the steps involved when an agent reads the statistics shared memory region is shown in Figure 4. The agent reads the match sequence before reading the statistics shared memory region. If the value read is odd, the agent aborts the read and retries till the match sequence read is an even number. The agent reads the match sequence again at the end of reading the statistics shared memory region. If the match sequences before and after the statistics shared memory region read are identical, the statistic was read successfully. Otherwise further reads must be done till the start match sequence and the end match sequence are equal and they are even numbers.

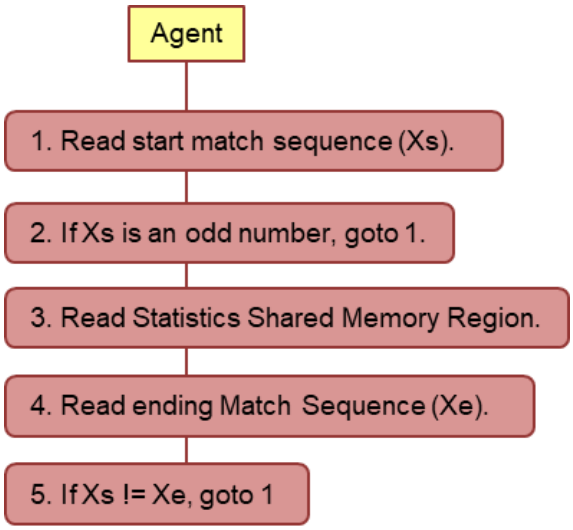

Figure 4 Statistics Shared Memory Region Read by Agent

4.3.4.2 Power domain data section

The power domain data section contains an entry for each power domain for which statistics are collected. The format for each entry is described in Table 7.

Table 7 Power domain entry

Field	Byte Length	Byte Offset	Description
Number of power states	0x2	0x0	Number of power state entries in the power state array.
Current power state Index	0x2	0x2	Index into power state array for current power state.
Reserved	0x4	0x4	Must be zero.
Time of last change	0x8	0x8	Timestamp in microseconds, from the beginning of the current boot, of the last power state transition, including to a running state.
Power state array	N × 0x18	0x10	Where N is the number of power states. Described in Table 8.

The format for each entry in the power state array is described in Table 8.

Table 8 Power state entry

Field	Byte Length	Byte Offset	Description
Power state	0x4	0x0	Identifier for the power state.
Reserved	0x4	0x4	Must be zero.
Usage count	0x8	0x8	Number of times this domain has entered the power state. This value must be updated when the domain transitions into the power state.
Residency	0x8	0x10	Amount of time in microseconds domain has been resident in the power state. This value must be updated when the domain transitions out of the power state.

4.4 System power management protocol

This protocol is intended for system shutdown, suspend and reset.

The system power protocol provides commands to:

- Describe the protocol version.
- Discover implementation attributes.
- Shut down the system.
- Suspend the system.
- Reset the system.
- Request a graceful shutdown or reset.
- Allow an agent to forcibly power down or reset the system.

4.4.1 System power management protocol background

The OSPM must be able to power down or reset the whole system it is running on. ACPI provides S states (S1-S5) for this purpose. In turn, PSCI provides SYSTEM_RESET, SYSTEM_RESET2, SYSTEM_SUSPEND and SYSTEM_OFF. On some systems, other agents might be required to initiate a system power down or reset. This protocol is designed to allow more than one agent to request these types of system power transitions. It is envisaged that, in the common case, there might be up to three agents:

- On application processors, a PSCI implementation. The PSCI implementation fulfills OSPM calls to SYSTEM_OFF, SYSTEM_SUSPEND, SYSTEM_RESET and SYSTEM_RESET2 functions. In order to do so, the PSCI implementation uses the SCMI protocol to request system power down or reset transitions.
- The management agent or privileged agent:
    - Particularly in enterprise systems, there might be a management agent that can request a shutdown or a reset, either gracefully through cooperation with the OSPM, or forcibly.
    - Virtualized systems might have a privileged agent, like a Hypervisor, that can request a shutdown or a reset, either gracefully through cooperation with the OSPM of the virtual machines, or forcibly.
    - Systems that deploy multiple Operating Systems running on different PE clusters within the same System-on-Chip might have a privileged agent. The privileged agent can request a shutdown or a reset, either gracefully through cooperation with the OSPM of the operating system entities in the different PE clusters, or forcibly in exceptional scenarios.
- The OSPM, which might receive notifications for a graceful shutdown request.

An agent can request the system to forcibly shut down or reset. The platform responds by performing the action that has been requested and then sending informational notifications to any remaining active agents in the system who have subscribed to the notification. An agent can also request a graceful shutdown or reset. In this case, the platform might send notifications to any subscribing OSPM agent, which can, in turn, initiate the requested action. To this end, the protocol allows an agent to request notifications of system power state transition requests generated by other agents. Table 9 describes the expected behavior for the various operations that are provided by this interface, depending on the calling agent.

Table 9 System power management operations, and expected responses depending on type of agent

Operation	Type of agent	Response
Request a forceful power state transition	OSPM	If the PE that the agent runs on supports PSCI, deny the request as NOT_SUPPORTED, as the calling agent is not in Secure world. Otherwise shutdown or reset as requested and send notifications.
	PSCI implementation on application processor	Shutdown or reset as requested and send notifications.
	Management agent or privileged agent	Shutdown or reset as requested and send notifications.
Request a graceful power state transition	OSPM	If the PE that the agent runs on supports PSCI, deny the request as NOT_SUPPORTED, as the calling agent is not in Secure world. Otherwise allow the request and send notifications to other subscribing agents.
	PSCI implementation on application processor	Allow the request and send notifications to other subscribing agents.
	Management agent or privileged agent	Allow the request and send notifications to other subscribing OSPM agents.
Request for notification of power state transition requests	OSPM	Allow, as this agent will initiate a shutdown or reset in response to the notification.
	Management agent or privileged agent	Allow, to enable the management or privileged agent to confirm that the OSPM has requested shutdown or reset.
	PSCI	Deny. NOT_SUPPORTED, because it is not required to handle notifications.

Notifications of system power state transitions are not propagated to the agent that requests the transition.

The protocol supports four kinds of system transitions:

- System powerup or shutdown.
- System suspend, as defined in PSCI for SYSTEM_SUSPEND, which is essentially a low-power system state. An example of a system suspend state is the suspend to RAM scenario that is analogous to S3 in ACPI.
- Architectural system resets, which are resets that are defined by this specification. These resets include system cold reset and system warm reset.
- Vendor defined transitions.

A system cold reset is equivalent to power cycling the system. All components in the system are powered down or held in reset. Components that are involved in the system boot are powered up or released from reset. In this context, the term cold boot refers to the expected boot flow after the first application of power to the system.

A system warm reset is one that preserves all memory that is visible to application processors. Similar to cold reset, all components in the system, except those involved in the provision of system memory to application processors, are powered down or held in reset. This definition of system memory does not extend to caches or to memory mapped I/O. As in the cold reset case, only those components that are involved in a system boot are powered up or released from reset.

System suspends could be of varying depths and wake latencies. Some suspend states could involve relatively large wake latencies, for example, suspend-to-RAM or SYSTEM_SUSPEND. Other suspend states, such as S0 idle states, could involve much lower wake latencies.

The view of the system that is affected by a system power state transition depends on the target segment and type of system being implemented. In some implementations, the system that is being powered down includes all the agents that can use this interface, as well as the platform controller that implements it. In this case this protocol is said to have a full-system view. However, for some platform implementations, the platform controller that implements this SCMI protocol might be in a dedicated always-on domain, such that it is not included in the system power transitions. In this case, this protocol is said to have an OSPM-system view, and the system power state transitions only affect those parts of the system that the OSPM controls. These parts are collectively called the OSPM world. In this latter kind of system, if an agent requests a system shutdown, the platform controller remains powered, so that it can service further commands, for example, a command to power up the system. Table 10 describes the expected behavior for the various forcible (non-graceful) operations that are provided by this interface, depending on the calling agent and the view of the system implemented.

Table 10 System power management forcible operations, and expected responses depending on view

System view	Operation (forcible)	Calling Agent	Expected behavior
OSPM	Shutdown or system suspend	PSCI on behalf of the OSPM	The OSPM world is shut down or suspended. System power state notifications to other agents are sent at the point at which it is possible to request a system power up.
		Management agent or privileged agent	Message returns at the point at which it is possible to request a system power up.
	Reset	PSCI on behalf of the OSPM	The OSPM world is reset. System power state notifications to other agents are sent when it is possible to request forcible system shutdown or reset.
		Management agent or privileged agent	The OSPM world is reset. The message returns when it is possible to request forcible system shutdown or reset.
	Power-up	PSCI on behalf of the OSPM	Not supported.
		Management agent or privileged agent	The OSPM world is powered up. The message returns at the point at which forcible system power state requests are possible.
		PSCI on behalf of the OSPM	Not supported.

	Get system power state	Management agent or privileged agent	Message returns system power state of OSPM world.
Full	Shutdown or suspend	PSCI on behalf of the OSPM	Whole system – or the full-system world – is shut down or suspended. System power state notifications to other agents are sent at the point at which PSCI makes its request.
		Management agent or privileged agent	Whole system – or the full-system world – is shut down or suspended. Notifications in this case are not required.
	Reset	PSCI on behalf of the OSPM	System is Reset. System power state notifications to other agents are sent at the point at which PSCI makes its request.
		Management agent or privileged agent	System is Reset. Notifications in this case are not required.
	Power up or get system state	PSCI on behalf of the OSPM	Not supported.
		Management agent or privileged agent	Not supported.

In both full and OSPM-system view implementations, the behavior towards a PSCI or an OSPM agent remains unchanged. The change in behavior is only visible to an external agent, such as a management agent or privileged agent. Commands to power up or get system state are only present in systems that implement the OSPM system view.

4.4.2 Commands

4.4.2.1 PROTOCOL_VERSION

On success, this command returns the version of this protocol. For this version of the specification, the value returned must be `0x10000`, which corresponds to version 1.0.

message_id: `0x0`

protocol_id: `0x12`

This command is mandatory.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.

uint32 version	For this revision of the specification, this must be `0x10000`.

4.4.2.2 PROTOCOL_ATTRIBUTES

This command returns the implementation details associated with this protocol.

message_id: `0x1`
protocol_id: `0x12`
This command is mandatory.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.
uint32 attributes	Bits[31:0] Reserved, must be zero.

4.4.2.3 PROTOCOL_MESSAGE_ATTRIBUTES

On success, this command returns the implementation details associated with a specific message in this protocol.

message_id: `0x2`
protocol_id: `0x12`
This command is mandatory.

Parameters

Name	Description
uint32 message_id	message_id of the message.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: in case the message is implemented and available to use. • NOT_FOUND: if the message identified by message_id is invalid or not provided by this platform implementation. • NOT_SUPPORTED: when message_id is set to the SYSTEM_POWER_STATE_NOTIFY command identifier and notifications are not supported. See section 4.1.4 for more status code definitions.

uint32 attributes	Flags associated with a specific command in the protocol. If message_id is for SYSTEM_POWER_STATE_SET, the attributes have the following format:	
	Bit[31]	System warm reset support. Set to 1 if system warm reset is supported. Set to 0 if system warm reset is not supported.
	Bit[30]	System suspend support. Set to 1 if system suspend is supported. Set to 0 if system suspend is not supported.
	Bits[29:0]	Reserved, must be zero. For all values of message_id, this value is zero.

4.4.2.4 SYSTEM_POWER_STATE_SET

This command is used to power down or reset the system.

System power-up must only be available to agents other than a PSCI implementation on systems that implement OSPM system view, as discussed in section 4.4.1.

message_id: `0x3`

protocol_id: `0x12`

This command is mandatory.

Parameters

Name	Description	
uint32 flags	This parameter has the following format:	
	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Graceful request. This flag is ignored for power up requests. Set to 1 if the request is a graceful request. Set to 0 if the request is a forceful request.

uint32 system_state	Can be one of:
	`0x0` System shutdown.
	`0x1` System cold reset.
	`0x2` System warm reset.
	`0x3` System power-up.
	`0x4` System suspend.
	`0x5` – `0x7FFFFFFF`
	Reserved, must not be used.
	`0x80000000` – `0xFFFFFFFF`
	Might be used for vendor-defined implementations of system power state. These can include additional parameters. The prototype for vendor-defined calls is beyond the scope of this specification.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • INVALID_PARAMETERS: if the requested power state is not valid. • NOT_SUPPORTED: if the requested state is not supported for the calling agent. • DENIED: for system suspend requests when there are application processors, other than the caller, in a running or idle state. See section 4.1.4 for more status code definitions.

4.4.2.5 SYSTEM_POWER_STATE_GET

This command must only be available to agents other than a PSCI implementation on systems that implement OSPM view, as discussed in section 4.4.1. The command is to get the power state of the system.

message_id: `0x4`

protocol_id: `0x12`

This command is mandatory in an OSPM view implementation.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.

uint32 system_state	Can be one of:	
	0x0	System shutdown.
	0x3	System power-up.
	0x4	System suspend.
	0x5 – 0x7FFFFFFF Reserved, must not be used.	
	0x80000000 – 0xFFFFFFFF Available for vendor-defined states.	

4.4.2.6 SYSTEM_POWER_STATE_NOTIFY

This command is used to request notification of system power state requests. This command might be used:

- By the OSPM to receive notifications of graceful system power state requests.
- By a management agent or a privileged agent to be notified that the OSPM requested a forceful transition.

On initial boot of an agent, these notifications must be disabled by default to that agent.

message_id: 0x5

protocol_id: 0x12

This command is mandatory in an OSPM view implementation.

Parameters

Name	Description	
uint32 notify_enable	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Notify enable: If this value is set to 0, the platform does not send any SYSTEM_POWER_STATE_NOTIFIER messages to the calling agent. If this value is set to 1, the platform does send SYSTEM_POWER_STATE_NOTIFIER messages commands to the calling agent. See section 4.4.3.1 for details about SYSTEM_POWER_STATE_NOTIFIER notifications.

Return values

Name	Description

int32 status	One of, but not limited to, the following: • SUCCESS • NOT_SUPPORTED: if notifications are not supported or available to the calling agent. • INVALID_PARAMETERS: if notify_enable specifies invalid or impermissible values. See section 4.1.4 for more status code definitions.

4.4.3 Notifications

4.4.3.1 SYSTEM_POWER_STATE_NOTIFIER

If an agent has registered for system power state notifications with SYSTEM_POWER_STATE_NOTIFY, the platform sends this notification to the agent. Typically, the agent is either:

- The OSPM that initiates a system power state transition in response to this notification. The OSPM needs this notification to become aware that a remote entity such as the management agent or the privileged agent is requesting a graceful power state transition.
- A management agent or a privileged agent that initiated a graceful power state transition and is waiting for the OSPM to perform a power state transition in response. The management agent or privileged agent needs this notification to confirm that the platform controller has successfully received the power state transition request from the PSCI agent, or from the OSPM for non-PSCI compliant systems.

message_id: `0x0`

protocol_id: `0x12`

This command is optional.

Parameters

Name	Description	
uint32 agent_id	Identifier for the agent that caused the system power state transition.	
uint32 flags	This parameter has the following format:	
	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Graceful request. Set to 1 if the notification indicates that a system power state transition has been gracefully requested. Set to 0 if the notification indicates that a system power state has been forcibly requested.

uint32 system_state	System power state that the system has transitioned to, or which has been requested.
	Can be one of:
	`0x0` System shutdown.
	`0x1` System cold reset.
	`0x2` System warm reset.
	`0x3` System power-up.
	`0x4` System suspend.
	`0x5` – `0x7FFFFFFF`
	Reserved, must not be used.
	`0x80000000` – `0xFFFFFFFF`
	Available for vendor-defined implementations of system power state. These can include additional parameters. The prototype for vendor-defined call is beyond the scope of this specification.

4.5 Performance domain management protocol

This protocol is intended for performance management of groups of devices or APs that run in the same performance domain. Performance domains must not be confused with power domains. A performance domain is defined by a set of devices that always have to run at the same performance level. For a given performance domain, there is a single point of control that affects all the devices in the domain, making it impossible to set the performance level of an individual device in the domain independently from other devices in that domain. For example, a set of CPUs that share a voltage domain, and have a common frequency control, is said to be in the same performance domain. The commands in this protocol provide functionality to:

- Describe the protocol version.
- Describe attribute flags of the protocol.
- Set the performance level of a domain.
- Read the current performance level of a domain.
- Return the list of performance levels supported by a performance domain, and the properties of each performance level.
- Optionally return statistics on residency and usage count of a performance level in performance domains.

4.5.1 Performance domain management protocol background

The performance domain management protocol command set operates on an abstract integer performance scale. The implementation can choose what this scale represents. For example, in some systems, the values in the scale might represent actual frequencies, while in others they might represent a percentage of the maximum performance of the domain. In all cases, the scale must be linear, meaning that a value of 2X delivers twice the performance as compared to a value of X.

Although this protocol uses an abstract scale to represent performance levels, the underlying implementation only provides a discrete set of performance levels.

Protocol commands take integer identifiers to describe which performance domain a given command applies to. The identifiers are sequential and start from 0.

In a multi-agent system, a given agent exclusively owns the performance of a set of domains. Agents are not allowed to directly change the performance of domains they do not own. However, an agent can request the platform to set limits on the performance of a domain it does not own. Agents are also allowed to read performance data or register for notifications issued on performance changes. The platform is responsible for resolution of limits when multiple agents send simultaneous request limits changes on the same power domain.

A performance domain can be characterized by three distinct levels that are advertised by the platform. These distinct levels are described in Table 11. The performance domain can support additional performance levels.

Table 11 Performance Domain Levels with Special Significance

Performance Level	Description
Highest Performance	This is the theoretical maximum performance level of the domain.
Sustained Performance	This is the maximum performance level that the domain can sustain under normal conditions taking into account all known external

	constraints like power budgeting and thermal constraints. All performance domains should be able to maintain their sustained performance level simultaneously. In exceptional circumstances, such as thermal runaway, the platform might not be able to guarantee this level.
Lowest Performance	This is the lowest performance level supported by the domain.

4.5.1.1 Power Cost

Each performance level has an associated power cost. If the performance domain includes APs, the power cost indicates the power consumption attributed to each AP in the performance domain. In all other cases, the power cost indicates the total power consumed by the performance domain when the domain is run at the given performance level. The performance domain protocol provides a command to discover performance levels and their associated power cost. The power can be expressed in mW or in an abstract scale. Vendors are not obliged to reveal power costs, but if power costs are reported then a linear scale should be used.

4.5.2 FastChannels

This section describes the properties of FastChannels for Performance Domain Management Protocol.

- Only PERFORMANCE_LIMITS_SET, PERFORMANCE_LIMITS_GET, PERFORMANCE_LEVEL_SET and PERFORMANCE_LEVEL_GET commands are supported over FastChannels.
- If FastChannel is supported, it needs to be unique for any combination of performance domain and performance domain management command. It is not necessary for every performance domain or every Performance Domain Management Command to support a FastChannel.
- FastChannels are discoverable via the PERFORMANCE_DESCRIBE_FASTCHANNEL command.
- Doorbell is not supported for PERFORMANCE_LEVEL_GET and PERFORMANCE_LIMITS_GET commands. If FastChannels are implemented for these commands, the last known valid performance level or performance limits must always available over the FastChannel without a doorbell trigger. This property reduces complexity due to latency considerations between doorbell trigger and the availability of return values over the FastChannel. For all other commands, Doorbell support is optional.

For more details on FastChannels, see Section 5.3.

4.5.2.1 Payload Requirements

The payload of a FastChannel should contain the message-specific parameters and exclude the domain_id. Since a FastChannel is domain_id and message_id specific, the domain_id or any other channel-specific and message-specific headers do not need to be included while using a FastChannel. For example, the payload of the PERFORMANCE_LEVEL_SET message should be ‘uint32 performance_level’.

4.5.3 Commands

4.5.3.1 PROTOCOL_VERSION

On success, this command returns the version of this protocol. For this version of the specification, the value returned must be `0x20000`, which corresponds to version 2.0.

message_id: `0x0`
protocol_id: `0x13`
This command is mandatory.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.
uint32 version	For this revision of the specification, this must be `0x20000`.

4.5.3.2 PROTOCOL_ATTRIBUTES

This command returns the attributes associated with this protocol.

message_id: `0x1`
protocol_id: `0x13`
This command is mandatory.

Return values

Name	Description	
int32 status	See section 4.1.4 for status code definitions.	
uint32 attributes	Bits[31:17]	Reserved, must be zero.
	Bit[16]	Power values expressed in mW: Set to 1 if the value described for a power consumption of performance level is expressed in mW. Set to 0 if the value described for a power consumption of performance level is expressed in a proprietary scale.
	Bits[15:0]	Number of performance domains.
uint32 statistics_address_low	The lower 32 bits of the physical address where the statistics shared memory region is located. This value should be 64-bit aligned. The address must be in the memory map of the calling agent. If the statistics_len field is 0, then this field is invalid and must be ignored. The statistics shared memory region is described in section 4.5.5.	

uint32 statistics_address_high	The upper 32 bit of the physical address where the shared memory region is located. The address must be in the memory map of the calling agent. If the statistics_len field is 0, then this field is invalid and must be ignored. The statistics shared memory region is described in section 4.5.5.
uint32 statistics_len	The length in bytes of the shared memory region. A value of 0 in this field indicates that the platform doesn't support the statistics shared memory region.

4.5.3.3 PROTOCOL_MESSAGE_ATTRIBUTES

On success, this command returns the implementation details associated with a specific message in this protocol.

This command can be used to enquire if performance level or limit change notifications are supported by the platform. This is achieved by passing message identifiers for the PERFORMANCE_NOTIFY_LEVEL or PERFORMANCE_NOTIFY_LIMITS messages to the call. The platform then returns a status code of NOT_FOUND to indicate that notifications are not implemented, or that they are not available to the calling agent. The notification commands are described in sections 4.5.3.10 and 4.5.3.11. This command can also be used to discover if FastChannels are supported for a command specified by message_id.

message_id: `0x2`

protocol_id: `0x13`

This command is mandatory.

Parameters

Name	Description
uint32 message_id	message_id of the message.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: in case the message is implemented and available to use. • NOT_FOUND: if the message identified by message_id is invalid or not provided by this platform implementation. See section 4.1.4 for more status code definitions.

uint32 attributes	Flags associated with a specific command in the protocol.	
	Bits[31:1]	Reserved, must be zero.
	Bit[0]	FastChannel Support. Set to 1 if there is at least one dedicated FastChannel available for this message. Set to 0 if this there are no FastChannels available this message.

4.5.3.4 PERFORMANCE_DOMAIN_ATTRIBUTES

This command returns attributes that are specific to a given domain.

message_id: `0x3`
protocol_id: `0x13`
This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the performance domain.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if valid performance domain attributes are found. • NOT_FOUND: if domain_id does not point to a valid domain. See section 4.1.4 for more status code definitions.

uint32 attributes	Bit[31]	Can set limits. Set to 1 if calling agent is allowed to set the performance limits on the domain. Set to 0 if a calling agent is not allowed to set limits on the performance limits on the domain.
	Bit[30]	Can set performance level. Set to 1 if calling agent is allowed to set the performance of a domain. Set to 0 if a calling agent is not allowed to set the performance of a domain. Only one agent can set the performance of a given domain.
	Bit[29]	Performance limits change notifications support. Set to 1 if performance limits change notifications are supported for this domain. Set to 0 if performance limits change notifications are not supported for this domain.
	Bit[28]	Performance level change notifications support. Set to 1 if performance level change notifications are supported for this domain. Set to 0 if performance level change notifications are not supported for this domain.
	Bit[27]	FastChannel Support. Set to 1 if there is at least one FastChannel available for this domain. Set to 0 if there are no FastChannels available for this domain.
	Bits[26:0]	Reserved and set to zero.
uint32 rate_limit	Bits[31:20]	Reserved and set to zero.
	Bits[19:0]	Rate Limit in microseconds, indicating the minimum time required between successive requests. A value of 0 indicates that this field is not supported by the platform. This field does not apply to FastChannels.

uint32 sustained_freq	Base frequency corresponding to the sustained performance level. Expressed in units of kHz.
uint32 sustained_perf_level	The performance level value that corresponds to the sustained performance delivered by the platform.
uint8 name[16]	Null terminated ASCII string of up to 16 bytes in length describing a domain name.

4.5.3.5 PERFORMANCE_DESCRIBE_LEVELS

This command allows the agent to ascertain the discrete performance levels that are supported by the platform, and their respective power costs. On success, the command returns an array that consists of several performance level entries, each of which describes an expected performance and power cost. The power cost can be expressed in milliwatts or in an abstract scale. How the numbers in that scale convert to the actual wattage is IMPLEMENTATION DEFINED, but the conversion must be linear, meaning that a power of 2X is twice the power of X. The size of the array, which is also returned, depends on the number of return values that a given transport can support. Therefore, it might not be possible to return information for all performance levels with just one call. To solve this problem, the interface allows multiple calls. The performance levels returned by this call should be in numeric ascending order.

message_id: `0x4`

protocol_id: `0x13`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the performance domain.
uint32 level_index	Index to the first level to be described in the return level array.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if valid performance levels are returned. • NOT_FOUND: if domain_id does not point to a valid domain. See section 4.1.4 for more status code definitions.
uint32 num_levels	Bits[31:16] Number of remaining performance levels. Bits[15:12] Reserved, must be zero. Bits[11:0] Number of performance levels that are returned by this call.

{uint32, uint32, uint32} perf_levels[N]	Array of performance levels, in numeric ascending order, to be described. N is specified by Bits[11:0] of num_levels field. Each array entry is composed of three 32-bit words with the following format:		
	uint32 entry[0]	Performance level value.	
	uint32 entry[1]	Power cost. A value of zero indicates that the power cost is not reported by the platform. Refer to Section 4.5.1.1 for more details.	
	uint32 entry[2]	Attributes	
		Bits[31:16]	Reserved, must be zero.
		Bits[15:0]	Worst-case transition latency in microseconds to move from any supported performance to the level indicated by this entry in the array.

The following pseudocode describes how the command can be used to discover information about every supported performance level for the performance domain:

```
uint16 level_index = 0;
int32 status = 0;
struct number_of_perf_levels {
        uint perf_levels_array_len:12;
        uint reserved: 4;
        uint remaining:16;
} num_levels = {0,0,0};

struct perf_level_data {
        uint32 perf_value;
        uint32 power;
        uint16 transition_latency;
        uint16 reserved;
};

struct perf_level_data perf_levels[];

do {
        invoke_PERFORMANCE_DESCRIBE_LEVELS (domain_id, level_index, &status,
                                            &num_levels, perf_levels);

        if (status)
```



```
                goto clean_up_and_return;

        add_levels_to_database (domain_id, level_index,
                                num_levels.perf_levels_array_len, perf_levels);

        level_index += num_levels.perf_levels_array_len;

} while(num_levels.remaining);
```

4.5.3.6 PERFORMANCE_LIMITS_SET

This command allows the caller to set limits on the performance level of a domain.

message_id: `0x5`

protocol_id: `0x13`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the performance domain.
uint32 range_max	Maximum allowed performance level.
uint32 range_min	Minimum allowed performance level.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if the command successfully set the limits of operation. If setting a limit requires modifying the current performance level of the domain, the command can return before this change has been completed. However, the change in performance level must still take place. • NOT_FOUND: if the performance domain identified by domain_id does not exist. • OUT_OF_RANGE: if the limits set lie outside the highest and lowest performance levels that are described by PERFORMANCE_DESCRIBED_LEVELS. • DENIED: if the calling agent is not permitted to change the performance limits for the domain, as described by PERFORMANCE_DOMAIN_ATTRIBUTES. See section 4.1.4 for more status code definitions.

4.5.3.7 PERFORMANCE_LIMITS_GET

This command allows the agent to ascertain the range of allowed performance levels. The returned value reflects the currently set limits for the performance domain. These limits might have been set implicitly by the platform, or explicitly by a preceding call to PERFORMANCE_LIMIT_SET.

On success, the range return value provides the minimum and maximum allowed performance level.

message_id: `0x6`

protocol_id: `0x13`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the performance domain.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if the performance limits are returned successfully. • NOT_FOUND: if domain_id does not point to a valid domain. See section 4.1.4 for more status code definitions.
uint32 range_max	Maximum allowed performance level.
uint32 range_min	Minimum allowed performance level.

4.5.3.8 PERFORMANCE_LEVEL_SET

This command allows the agent to set the performance level of a domain. This command can return before the domain has transitioned to the required performance level. The platform simply has to acknowledge that it has received the command. The agent can register for performance level notifications to ascertain whether a performance transition has taken place. For further details, see section 4.5.4.2.

message_id: `0x7`

protocol_id: `0x13`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the performance domain.

uint32 performance_level	Requested performance level.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if the platform has accepted the command and scheduled it for processing. • NOT_FOUND: if the domain_id parameter does not point to a valid domain. • OUT_OF_RANGE: if the requested performance level is outside the currently allowed range. • DENIED: if the calling agent is not permitted to change the performance level for a domain, as described by PERFORMANCE_DOMAIN_ATTRIBUTES. See section 4.1.4 for more status code definitions.

4.5.3.9 PERFORMANCE_LEVEL_GET

On success, this command returns the current performance level of a domain. Note the performance level value that is returned by this command might be stale by the time the command completes, as a subsequent performance change might have been initiated in the meantime.

message_id: `0x8`

protocol_id: `0x13`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the performance domain.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if the performance level is returned successfully • NOT_FOUND: if domain_id does not point to a valid domain. See section 4.1.4 for more status code definitions.
uint32 performance_level	Current performance level of the domain.

4.5.3.10 PERFORMANCE_NOTIFY_LIMITS

This command allows the agent to request notifications from the platform for changes in the allowed maximum and minimum performance levels. These notifications are sent using the PERFORMANCE_LIMITS_CHANGED command which is described in section 4.5.4.1.

If no domain supports limit notifications, the command can be omitted. The PROTOCOL_MESSAGE_ATTRIBUTES command, that is described in section 4.5.3.4, can be used to determine whether this command is implemented.

On initial boot of an agent, by default, these notifications must be disabled from being sent to that agent.

message_id: `0x9`

protocol_id: `0x13`

This command is optional.

Parameters

Name	Description	
uint32 domain_id	Identifier for the performance domain.	
uint32 notify_enable	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Notify enable: If this value is 0, the platform does not send any PERFORMANCE_LIMITS_CHANGED messages to the agent. If this value is set to 1, the platform does send PERFORMANCE_LIMITS_CHANGED messages to the agent. See section 4.5.4.1 for more details about PERFORMANCE_LIMITS_CHANGED notifications.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS. • NOT_FOUND: if domain_id does not point to a valid domain. • NOT_SUPPORTED: if notifications are not supported for the indicated performance domain. • INVALID_PARAMETERS: if notify_enable specifies values that are not legal or valid. See section 4.1.4 for more status code definitions.

4.5.3.11 PERFORMANCE_NOTIFY_LEVEL

This command allows the agent to request notifications from the platform when the performance level for a domain changes in value. These notifications are sent using the PERFORMANCE_LEVEL_CHANGED command which is described in section 4.5.4.2.

If no domains support level change notifications, the command can be omitted. The PROTOCOL_MESSAGE_ATTRIBUTES command, that is described in section 4.5.3.4, can be used to determine whether this command is implemented.

On initial boot of an agent, by default, these notifications must be disabled from being sent to that agent.

message_id: `0xA`

protocol_id: `0x13`

This command is optional.

Parameters

Name	Description	
uint32 domain_id	Identifier for the performance domain.	
uint32 notify_enable	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Notify enable: If this value is 0, the platform does not send any PERFORMANCE_LEVEL_CHANGED notifications to the agent. If this value is set to 1, the platform does send PERFORMANCE_LEVEL_CHANGED notifications to the agent. See section 4.5.4.2 for more details about the PERFORMANCE_LEVEL_CHANGED notification.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS. • NOT_FOUND: if domain_id does not point to a valid domain. • NOT_SUPPORTED: if notifications are not supported for the indicated performance domain. • INVALID_PARAMETERS: if notify_enable specifies illegal or unimplemented options. See section 4.1.4 for more status code definitions.

4.5.3.12 PERFORMANCE_DESCRIBE_FASTCHANNEL

This command allows the agent to discover the attributes of the FastChannel for the specified performance domain and the specified message.

The PERFORMANCE_DOMAIN_ATTRIBUTES command can be used to discover if a performance domain supports FastChannels. The PROTOCOL_MESSAGE_ATTRIBUTES command can be used to discover if a command, specified by message_id, supports FastChannels.

message_id: `0xB`

protocol_id: `0x13`

This command is optional.

Parameters

Name	Description
uint32 domain_id	Identifier for the performance domain for which the FastChannel is allocated.
uint32 message_id	Message-id for which the FastChannel is allocated.

Return values

Name	Description	
int32 status	One of, but not limited to, the following: • SUCCESS: If a valid FastChannel is found. • NOT_FOUND: if domain_id does not point to a valid domain or message_id does not point to a valid message. • NOT_SUPPORTED: if FastChannel is not supported for this domain or this message. See section 4.1.4 for more status code definitions.	
uint32 attributes	Bits[31:3]	Reserved. Should be zero in this version of the specification.
	Bits[2:1]	Doorbell Register width. This field is only valid if Doorbell Support is set to 1. If 0, then doorbell register is 8bits wide. If 1, then doorbell register is 16bits wide. If 2, then doorbell register is 32bits wide. If 3, then doorbell register is 64bits wide.
	Bit[0]	Doorbell Support. If 0, then the FastChannel does not have a doorbell register. If 1, then the FastChannel has a doorbell register.

uint32 rate_limit	Bits[31:20]	Reserved and set to zero.
	Bits[19:0]	Rate Limit in microseconds, indicating the minimum time required between successive requests. A value of 0 indicates that this field is not applicable or supported on the platform.
uint32 chan_addr_low	Lower 32 bits of the FastChannel address.	
uint32 chan_addr_high	Higher 32 bits of the FastChannel address.	
uint32 chan_size	Size of the FastChannel in bytes. The value of this field should be sufficient to accommodate the payload of the message this FastChannel is used for. For more details on payload requirements please refer Section 4.5.2.1.	
uint32 doorbell_addr_low	Lower 32 bits of the doorbell address. This field is not used if doorbell is not supported.	
uint32 doorbell_addr_high	Higher 32 bits of the doorbell address. This field is not used if doorbell is not supported.	
uint32 doorbell_set_mask_low	Contains a mask of lower 32 bits to set when writing to the doorbell register. If the doorbell register width, n, is less than 32 bits, then only n lower bits are considered from this mask. This field is not used if doorbell is not supported.	
uint32 doorbell_set_mask_high	Contains a mask of higher 32 bits to set when writing to the doorbell register. This field is only valid if the doorbell register width is 64 bits. This field is not used if doorbell is not supported.	
uint32 doorbell_preserve_mask_low	Contains a mask of lower 32 bits to preserve when writing to the doorbell register. If the doorbell register width, n, is less than 32 bits, then only n lower bits are considered from this mask. This field is not used if doorbell is not supported.	
uint32 doorbell_preserve_mask_high	Contains a mask of higher 32 bits to preserve when writing to the doorbell register. This field is only valid if the doorbell register width is 64 bits. This field is not used if doorbell is not supported.	

Bits which are set neither in set_mask nor in preserve_mask are to be cleared.

4.5.4 Notifications

4.5.4.1 PERFORMANCE_LIMITS_CHANGED

If an agent has registered for limit change notifications for the domain that is identified by domain_id, the platform sends this notification to the agent when the performance limits for that domain change.

message_id: `0x0`

protocol_id: `0x13`

This command is optional.

Parameters

Name	Description
uint32 agent_id	Identifier for the agent that caused the performance limit change.
uint32 domain_id	Identifier for the performance domain whose limit was changed.
uint32 range_max	Maximum allowed performance level.
uint32 range_min	Minimum allowed performance level.

4.5.4.2 PERFORMANCE_LEVEL_CHANGED

This notification is sent by the platform to an agent which has subscribed to receive performance level change notifications for the domain that is identified by domain_id. The platform sends this notification to a subscribing agent:

- when the performance level of the domain is changed by a different agent or entity in the system, including the platform itself.
- when the performance level of the domain is changed as a result of the subscribing agent issuing a PERFORMANCE_LEVEL_SET or PERFORMANCE_LIMITS_SET command.

The platform might autonomously change the performance level of the domain in order to apply thermal or power constraints. An external agent, such as a system management agent, can also request the platform to change the performance level. In each of these occurrences, the subscribing agent will be notified so that it can become aware of the change.

message_id: `0x1`

protocol_id: `0x13`

This command is optional.

Parameters

Name	Description
uint32 agent_id	Identifier for the agent that caused the performance level change.

uint32 domain_id	Identifier for the performance domain whose level was changed.
uint32 performance_level	The new performance level of the domain that results from the change.

4.5.5 Performance domain statistics shared memory region

Optionally, the platform can provide a statistics memory region that is associated with the performance domain management protocol. Whether support is present is indicated by the PROTOCOL_ATTRIBUTES command, which is described in section 4.5.3.2. This command also provides the address and size of the shared memory region. For a given performance domain, and for each performance level in that domain, statistics in the shared memory region track the number of times that the level has been used and the amount of time that the domain has been in that performance level. The statistics must be updated regardless of the agent in the system that placed a domain into a given performance level. After a system reset or shutdown, all the statistics must be initialized to zero when the system first starts up. Time measurements are in microseconds.

For APs, the shared memory must be accessible from the Non-secure world and must be mapped as non-cached normal memory or device memory. The format of the shared memory structure is described in Table 12.

Table 12 Performance level statistics memory region

Field	Byte Length	Byte Offset	Description
Signature	0x4	0x0	0x50455246 (‘PERF’).
Revision	0x2	0x4	For this revision, this value must be 0x1.
Attributes	0x2	0x6	For this revision, this value must be zero.
Number of domains	0x2	0x8	Number of domains for which statistics are collected.
Reserved	0x2	0xA	Must be zero.
Match Sequence	0x4	0xC	The match sequence populated by the platform as described in Section 4.3.4.1.
Performance domain offset array	0x4 × (Number of domains)	0x10	For each performance domain, this array provides a 4-byte offset, from the start of the shared memory area, to the memory location of the performance domain entry in the data section. The entry format is described in Table 13. A value of zero for the offset of a given performance domain indicates that statistics are not collected for that domain.

Performance domain data section	--	--	This area must start at an offset of 0x10 + 0x4 × (Number of performance domains), or higher.

The performance domain data section contains entries for each performance domain. The format for each entry is described in Table 13.

Table 13 Performance domain entry

Field	Byte Length	Byte Offset	Description
Number of performance levels	0x2	0x0	Number of performance level entries in the performance levels array.
Current performance level index	0x2	0x2	Index into performance level array for current performance level.
Extended statistics table offset	0x4	0x4	Contains the 4-byte offset, from the start of shared memory, to the start of the domain's Extended Statistics Table. This field is set to 0 if the Extended Statistics table is not supported. The Extended Statistics table definition is implementation specific.
Time of last change	0x8	0x8	Timestamp in microseconds since boot, of the last performance level transition.
Performance level array	N × 0x18	0x10	Performance level array, where N is the number of performance levels. Described in Table 14.

The format for each entry in the performance level array is described in Table 14.

Table 14 Performance level array entry

Field	Byte Length	Byte Offset	Description
Performance level	0x4	0x0	Performance level.
Reserved	0x4	0x4	Reserved, must be set to zero.
Usage count	0x8	0x8	Number of times this domain has used this performance level. This value must be updated when the domain transitions into the performance level.

Residency	0x8	0x10	This value represents the amount of time domain has been running at the performance level and is given in microseconds. This value must be updated every time the domain transitions to different performance level.

Accessing statistics can cause races between platform write accesses and agent read accesses. This problem and its solution are described in section 4.3.4.1.

4.6 Clock management protocol

This protocol is intended for management of clocks. It is used to enable or disable clocks, and to set rates. The protocol provides commands to:

- Describe the protocol version.
- Discover implementation attributes.
- Describe a clock.
- Enable or disable a clock.
- Set the rate of the clock synchronously or asynchronously.

4.6.1 Clock management protocol background

This protocol can be used for managing clock rates. It is not to be confused with the performance management protocol, which is used to manage the speed of compute engines such as application processors or GPUs. Examples of usage for the clock protocol might be setting rates for LCD clocks or I^2C buses.

The protocol does not cover discovery of the clock tree, which must be described through firmware tables instead.

Protocol commands take integer identifiers to describe which clock a given command applies to. The identifiers are sequential and start from 0.

4.6.2 Commands

4.6.2.1 PROTOCOL_VERSION

On success, this command returns the version of this protocol. For this version of the specification, the return value must be `0x10000`, which corresponds to version 1.0.

message_id: `0x0`

protocol_id: `0x14`

This command is mandatory.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.
uint32 version	For this revision of the specification, this value must be `0x10000`.

4.6.2.2 PROTOCOL_ATTRIBUTES

This command returns the implementation details associated with this protocol.

message_id: `0x1`

protocol_id: `0x14`

This command is mandatory.

Return values

Name	Description	
int32 status	See section 4.1.4 for status code definitions.	
uint32 attributes	Bits[31:24]	Reserved, must be zero.
	Bits[23:16]	Maximum number of pending asynchronous clock rate changes supported by the platform.
	Bits[15:0]	Number of clocks.

4.6.2.3 PROTOCOL_MESSAGE_ATTRIBUTES

On success, this command returns the implementation details associated with a specific message in this protocol.

message_id: `0x2`

protocol_id: `0x14`

This command is mandatory.

Parameters

Name	Description
uint32 message_id	message_id of the message.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: in case the message is implemented and available to use. • NOT_FOUND: if the message identified by message_id is invalid or not provided by this platform implementation. See section 4.1.4 for more status code definitions.
uint32 attributes	Flags that are associated with a specific command in the protocol. For all commands in this protocol, this parameter has a value of 0.

4.6.2.4 CLOCK _ATTRIBUTES

This command returns the attributes that are associated with a specific clock. An agent might be allowed access to only a subset of the clocks available in the system. The platform must thus guarantee that clocks that an agent cannot access are not visible to it.

message_id: `0x3`

protocol_id: `0x14`

This command is mandatory.

Parameters

Name	Description
uint32 clock_id	Identifier for the clock device.

Return values

Name	Description	
int32 status	One of, but not limited to, the following: • SUCCESS: if valid clock attributes are returned. • NOT_FOUND: if clock_id does not point to a valid clock device. See section 4.1.4 for more status code definitions.	
uint32 attributes	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Enabled/disabled. If set to 1, the clock device is enabled. If set to 0, the clock device is disabled.
uint8 clock_name[16]	A NULL terminated ASCII string with the clock name, of up to 16 bytes.	

4.6.2.5 CLOCK_DESCRIBE_RATES

This command allows the agent to ascertain the valid rates to which the clock can be set. On success, the command returns an array, which contains a number of rate entries. Sometimes it might not be possible to return the whole clock rate array with just one call. To solve this problem, the interface allows multiple calls. It also returns the number of remaining clock rates. The size of the array returned depends on the number of return values a given transport can support.

Clocks can support many rates and sometimes individually describing each rate might be too onerous. In such cases, the command can return only the lowest rate, the highest rate and the step size between two successive physical rates that the clock device can synthesize.

The clock rates returned by this call should be in numeric ascending order.

message_id: `0x4`

protocol_id: `0x14`

This command is mandatory.

Parameters

Name	Description
uint32 clock_id	Identifier for the clock device.
uint32 rate_index	Index to the first rate value to be described in the return rate array.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if valid clock rates were returned. • NOT_FOUND: if the clock identified by clock_id does not exist. • OUT_OF_RANGE: if the rate_index is outside of valid range. See section 4.1.4 for more status code definitions.
uint32 num_rates_flags	Descriptor for the rates supported by this clock. Bits[31:16] Number of remaining rates. This field should be 0 if Bit[12] is 1. Bits[15:13] Reserved, must be zero. Bit[12] Return format: If this bit is set to 1, the Rate Array is a triplet that constitutes a segment in the following form: rates[0] is the lowest physical rate that the clock can synthesize in the segment. rates[1] is the highest physical rate that the clock can synthesize in the segment. rates[2] is the step size between two successive physical rates that the clock can synthesize within the segment. If this bit is set to 0, each element of the Rate Array represents a discrete physical rate that the clock can synthesize. Bits[11:0] Number of rates that are returned by this call. This field should be 3 if Bit[12] is 1.

{uint32, uint32} rates [N]	Rate Array: If Bit[12] of the num_rates_flags field is set to 0, each array entry is composed of two 32-bit words and has the following format: Lower word: Lower 32 bits of the physical rate in Hertz. Upper word: Upper 32 bits of the physical rate in Hertz. If Bit[12] of the num_rates_flags field is set to 1, then each entry is a member of a segment {lowest rate, highest rate, step size} as described above. N is specified by Bits[11:0] of num_rates_flags field.

For an example of using this kind of API, see 4.5.3.5.

4.6.2.6 CLOCK_RATE_SET

This command allows the caller to select the clock rate of a clock synchronously or asynchronously.

The command returns when the clock rate has been changed.

message_id: `0x5`

protocol_id: `0x14`

This command is mandatory.

Parameters

Name	Description

uint32 flags	Bits[31:4]	Reserved, must be zero.
	Bits[3:2]	Round up/down: If Bit[3] is set to 1, the platform rounds up/down autonomously to choose a physical rate closest to the requested rate, and Bit[2] is ignored. If Bit[3] is set to 0, then the platform rounds up if Bit[2] is set to 1, and rounds down if Bit[2] is set to 0.
	Bit[1]	Ignore delayed response: If the Async flag, bit[0], is set to 1 and this bit is set to 1, the platform does not send a CLOCK_RATE_SET delayed response. If the Async flag, bit[0], is set to 1 and this bit is set to 0, the platform does send a CLOCK_RATE_SET delayed response. If the Async flag, bit[0], is set to 0, then this bit field is ignored by the platform.
	Bit[0]	Async flag: Set to 1 if clock rate is to be set asynchronously. In this case the call is completed with CLOCK_RATE_SET_COMPLETE message if bit[1] is set to 0. For more details, see section 4.6.3.1. A SUCCESS return code in this case indicates that the platform has successfully queued this command. Set 0 to if the clock rate is to be set synchronously. In this case, the call with return the clock rate setting has been completed.
uint32 clock_id	Identifier for the clock device.	
uint32 rate[2]	Lower word: Lower 32 bits of the physical rate in Hertz. Upper word: Upper 32 bits of the physical rate in Hertz.	

Return values

Name	Description

int32 status	One of, but not limited to, the following: • SUCCESS: if the clock rate was set successfully for a synchronous request or if the command was successfully enqueued for an asynchronous request. • NOT_FOUND: if the clock identified by clock_id does not exist. • INVALID_PARAMETERS: if the requested rate is not supported by the clock, or the flags parameter specifies invalid or illegal options. • BUSY: if there are too many asynchronous clock rate changes pending. The PROTOCOL_ATTRIBUTES command provides the maximum number of pending asynchronous clock rate changes supported by the platform. • DENIED: if the clock rate cannot be set because of dependencies, e.g. if there are other users of the clock. See section 4.1.4 for more status code definitions.

4.6.2.7 CLOCK_RATE_GET

This command allows the calling agent to request the current clock rate.

Note

If the clock rate is set asynchronously, the rate value that is returned by this command might be stale by the time the command completes.

message_id: `0x6`
protocol_id: `0x14`
This command is mandatory.

Parameters

Name	Description
uint32 clock_id	Identifier for the clock device.

Return values

Name	Description

int32 status	One of, but not limited to, the following: • SUCCESS: if the current clock rate was successfully returned. • NOT_FOUND: if the clock identified by clock_id does not exist. See section 4.1.4 for more status code definitions.
uint32 rate[2]	Lower word: Lower 32 bits of the physical rate in Hertz. Upper word: Upper 32 bits of the physical rate in Hertz.

4.6.2.8 CLOCK_CONFIG_SET

This command allows the calling agent to configure a clock device.

message_id: `0x7`
protocol_id: `0x14`
This command is mandatory.

Parameters

Name	Description	
uint32 clock_id	Identifier for the clock device.	
uint32 attributes	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Enable/Disable: If set to 1, the clock device is enabled. If set to 0, the clock device is disabled.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if the clock configuration has been set successfully. • NOT_FOUND: if the clock identified by clock_id does not exist. • INVALID_PARAMETERS, if the input attributes flag specifies unsupported or invalid configurations. See section 4.1.4 for more status code definitions.

4.6.3 Delayed responses

4.6.3.1 CLOCK_RATE_SET_COMPLETE

If the agent has changed the clock rate asynchronously through CLOCK_RATE_SET, the platform sends this delayed response to the agent when the clock rate changes.

message_id: `0x5`

protocol_id: `0x14`

This command is optional.

Parameters

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if clock rate was set successfully. • DENIED: if the request was denied because there are other users of the clock. Other vendor-specific errors can also be generated depending on the implementation. See section 4.1.4 for more status code definitions.
uint32 clock_id	Identifier for the clock device.
uint32 rate[2]	Value of the rate that the clock transitioned to. Lower word: Lower 32 bits of the physical rate in Hertz. Upper word: Upper 32 bits of the physical rate in Hertz.

4.7 Sensor management protocol

This protocol provides functions to manage platform sensors, and provides the following commands:

- Describe the protocol version.
- Describe the attribute flags of the protocol.
- Discover sensors that are implemented and managed by the platform.
- Read a sensor synchronously or asynchronously as allowed by the platform.
- Obtain and program sensor attributes, if applicable.
- Configure a sensor.
- Receive notifications on specific changes to sensor data, for example when a sensor value crosses a threshold.
- Receive continuous sensor updates through notifications.
- Specify a region of shared memory for conveying sensor values, if supported by the platform.

4.7.1 Sensor management protocol background

This protocol supports sensors which measure and report values along one or more axes like a 3-axis accelerometer. It also supports sensors which measure a scalar value like temperature. The protocol allows each axis of a multi-axis sensor to specify its own unit of measurement and other attributes. A sensor reporting uncalibrated values can report bias estimates as additional axes of measurement.

Protocol commands take integer identifiers to identify the sensor they apply to. The identifiers are sequential and start from 0.

The protocol supports accessing sensors through one of the following mechanisms:

- Synchronous Access – This method is recommended for sensors whose data is immediately available or is internally cached by the platform and can be returned immediately to the requesting agent. Examples include platform event counters, or sensor data samples that are stored in internal memory within the platform.
- Asynchronous Access – This method is recommended for sensors whose data is not cached by the platform or for sensors that are slow to read. An example of this could be an on-die thermal sensor.
- Event Notification – The agent can register for receiving notifications on specific sensor values, conditions, or states of interest. The agent can also register for receiving sensor values at a configured minimum update interval, if supported by the sensor.
- Shared Memory – In this scheme, the platform periodically updates the sensor value in an area of memory that is shared between agents and the platform.

Agents can discover the access mechanisms that are supported by a particular sensor by examining the attributes and descriptors that are advertised for the sensor. The platform can support multiple access mechanisms.

4.7.2 Commands

4.7.2.1 PROTOCOL_VERSION

On success, this command returns the version of this protocol. For this version of the specification, the return value must be `0x20000`, which corresponds to version 2.0.

message_id: `0x0`
protocol_id: `0x15`
This command is mandatory.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.
uint32 version	For this revision of the specification, this value must be `0x20000`.

4.7.2.2 PROTOCOL_ATTRIBUTES

This command returns the implementation details associated with this protocol.

message_id: `0x1`
protocol_id: `0x15`
This command is mandatory.

Return values

Name	Description	
int32 status	See section 4.1.4 for status code definitions.	
uint32 attributes	Bits[31:24]	Reserved, must be zero.
	Bits[23:16]	Maximum number of outstanding asynchronous commands that is supported by the platform.
	Bits[15:0]	Number of sensors that is present and managed by the platform.
uint32 sensor_reg_address_low	This value indicates the lower 32 bits of the physical address where the sensor shared memory region is located. This value should be 64-bit aligned. The address must be in the memory map of the calling agent. If the sensor_reg_len field is 0, then this field is invalid and must be ignored by the agent.	
uint32 sensor_reg_address_high	This value indicates the upper 32 bits of the physical address where the shared memory region is located. The address must be in the memory map of the calling agent. If the sensor_reg_len field is 0, then this field is invalid and must be ignored by the agent.	
uint32 sensor_reg_len	This value indicates the length in bytes of the shared memory region. A value of 0 in this field indicates that the platform does not implement the sensor shared memory.	

The sensor shared memory region is described in section 4.7.5.

4.7.2.3 PROTOCOL_MESSAGE_ATTRIBUTES

On success, this command returns the implementation details associated with a specific message in this protocol.

If the message is not supported or implemented by the platform, then this command returns a NOT_FOUND status code. This allows calling agents to comprehend which commands are supported on a platform and configure themselves accordingly.

message_id: `0x2`

protocol_id: `0x15`

This command is mandatory.

Parameters

Name	Description
uint32 message_id	message_id of the message.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: in case the message is implemented and available to use. • NOT_FOUND: if the message identified by message_id is not provided by this platform implementation. Other status codes according to section 4.1.4 might be returned for general error or status reporting.
uint32 attributes	Attributes that are associated with the message that is specified by message_id. Currently, this field returns the value of 0.

4.7.2.4 SENSOR_ DESCRIPTION_GET

This command can be used for sensor discovery on the platform. On success, it returns an array of Sensor Descriptors as described in 4.7.2.4.1.

message_id: `0x3`

protocol_id: `0x15`

This command is mandatory.

Parameters	
Name	**Description**
uint32 desc_index	Index of the first sensor descriptor to be read in the sensor descriptor array.

Return values		
Name	**Description**	
int32 status	See section 4.1.4 for status code definitions.	
uint32 num_sensor_flags	Bits[31:16]	Number of remaining sensor descriptors.
	Bits[15:12]	Reserved, must be zero.
	Bits[11:0]	Number of sensor descriptors that are returned by this current call.
SENSOR_DESC desc[N]	An array of sensor descriptors, of format described in 4.7.2.4.1.	

4.7.2.4.1 Sensor Descriptor

The SENSOR_DESC structure describes the sensor properties, such as the unique identifier for the sensor, its name, number of axes, reading types and other characteristics.

uint32	sensor_id	Identifier for the sensor.

uint32 sensor_attributes_low	Bit[31]	Asynchronous sensor read support: If this flag is set to 1, then this sensor can be read asynchronously through the SENSOR_READING_GET command, and its value is returned in the SENSOR_READING_COMPLETE delayed response. If this flag is set to 0, the sensor must be only be read using a synchronous call to SENSOR_READING_GET command.
	Bit[30]	Continuous sensor update notification support: If this flag is set to 1, the sensor supports continuous update notifications. The platform sends the SENSOR_UPDATE notification when an updated sensor value is available. The platform sends this notification only if the sensor is enabled and the agent has subscribed to the notification by calling SENSOR_CONTINUOUS_UPDATE_NOTIFY command. If this flag is set to 0, the sensor does not support continuous update notifications. The SENSOR_CONTINUOUS_UPDATE_NOTIFY command is not available for this sensor. The sensor values need to be read using the SENSOR_READING_GET command.
	Bits[29:15]	Reserved for future use.
	Bit[14:10]	Timestamp exponent: This field is represented in two's complement format. It is the power-of-10 multiplier that is applied to the sensor timestamps (timestamp x $10^{[\text{timestamp exponent}]}$) to represent it in seconds. This field is only valid if Bit[9] is set to 1.
	Bit[9]	Timestamp support: If this flag is set to 1, the sensor can provide timestamped values. If this flag is set to 0, the sensor cannot provide timestamped values. Timestamps should be derived from a monotonic time base. The selection of a time base is beyond the scope of this specification and should be agreed between the agent and the platform by other standard mechanisms.
	Bit[8]	Extended attributes support: If this flag is set to 1, the sensor reports extended attributes after the sensor_name field.

		If this flag is set to 0, the sensor does not report extended attributes. Fields beyond sensor_name are not allocated by the platform.
	Bits[7:0]	Number of trip points supported.
uint32 sensor_attributes_high	Bits[31:22]	Reserved for future use.
	Bits[21:16]	Number of axes: The number of axes of measurement the sensor supports. This field is valid only if Bit[8] is set to 1. This field must not be 0 if Bit[8] is set to 1.
	Bits[15:11]	Exponent: The power-of-10 multiplier in two's-complement format that is applied to the sensor unit specified by the SensorType field. This field is valid only if Bit[8] is set to 0. To obtain this field for sensors which report values along axes refer to 4.7.2.5.
	Bits[10:9]	Reserved.
	Bit[8]	Axis support: If this flag is set to 1, the sensor reports values along one or more axes. If this flag is set to 0, the sensor reports a scalar value like temperature.
	Bits[7:0]	SensorType: The type of sensor and the measurement system it implements, as described in Table 15. This field is valid only if Bit[8] is set to 0. To obtain this field for sensors which report values along axes refer to 4.7.2.5.
uint8 sensor_name[16]	A NULL terminated UTF-8 format string with the sensor name, of up to 16 bytes.	
uint32 sensor_power	This is an extended attribute field. It reports the average power consumed by the sensor in microwatts (uW) when it is active. Vendors are not obliged to report sensor power or be accurate in reporting it. If the power consumed is not reported, this field must be set to 0. This field is present only if Bit[8] of sensor_attributes_low is set to 1. This field reports the specification of the sensor and must not be used to return the actual measured power consumption of the sensor at runtime. Repeated calls to SENSOR_DECRIPTION_GET for the same sensor must return the same values.	

uint32 sensor_resolution	Bits[31:27] Exponent: The power-of-10 multiplier in two's-complement format that is applied to the Res field. Bits[26:0] Res: The resolution of the sensor. This is an extended attribute field. It reports the resolution of the sensor. The representation is in [res] x $10^{[exponent]}$ format, in units specified by SensorType. SensorType is reported by Bits[7:0] of sensor_attributes_high field. If the sensor does not report its resolution, this field must be set to 0x0. This field is present only if: • Bit[8] of sensor_attributes_high is set to 0 which indicates that the sensor reports scalar values, and • Bit[8] of sensor_attributes_low is set to 1. To obtain this field for sensors which report values along axes refer to 4.7.2.5.
int32 sensor_min_range_low	This is an extended attribute field. It reports the lower 32 bits of the minimum sensor value that can be measured by the sensor. If the sensor does not report its minimum range, this field must be set to 0x0. This field is present only if: • Bit[8] of sensor_attributes_high is set to 0 which indicates that the sensor reports scalar values, and • Bit[8] of sensor_attributes_low is set to 1. To obtain this field for sensors which report values along axes refer to 4.7.2.5.
int32 sensor_min_range_high	This is an extended attribute field. It reports the higher 32 bits of the minimum sensor value that can be measured by the sensor. If the sensor does not report its minimum range, this field must be set to 0x80000000. This field is present only if: • Bit[8] of sensor_attributes_high is set to 0 which indicates that the sensor reports scalar values, and • Bit[8] of sensor_attributes_low is set to 1. To obtain this field for sensors which report values along axes refer to 4.7.2.5.

	This is an extended attribute field. It reports the lower 32 bits of the maximum sensor value that can be measured by the sensor. If the sensor does not report its maximum range, this field must be set to 0xFFFFFFFF.
int32 sensor_max_range_low	This field is present only if: • Bit[8] of sensor_attributes_high is set to 0 which indicates that the sensor reports scalar values, and • Bit[8] of sensor_attributes_low is set to 1. To obtain this field for sensors which report values along axes refer to 4.7.2.5.
	This is an extended attribute field. It reports the higher 32 bits of the maximum sensor value that can be measured by the sensor. If the sensor does not report its maximum range, this field must be set to 0x7FFFFFFF.
int32 sensor_max_range_high	This field is present only if: • Bit[8] of sensor_attributes_high is set to 0 which indicates that the sensor reports scalar values, and • Bit[8] of sensor_attributes_low is set to 1. To obtain this field for sensors which report values along axes refer to 4.7.2.5.

Table 15 Sensor Type Enumerations[1:]

Enum	Sensor Unit Description	Enum	Sensor Unit Description	Enum	Sensor Unit Description
0	None	**33**	Cubic Meters	**66**	Pascals
1	Unspecified	**34**	Liters	**67**	Counts
2	Degrees C	**35**	Fluid Ounces	**68**	Grams
3	Degrees F	**36**	Radians	**69**	Newton-meters
4	Degrees K	**37**	Steradians	**70**	Hits
5	Volts	**38**	Revolutions	**71**	Misses
6	Amps	**39**	Cycles	**72**	Retries
7	Watts	**40**	Gravities	**73**	Overruns/Overflows
8	Joules	**41**	Ounces	**74**	Underruns

9	Coulombs	**42**	Pounds	**75**	Collisions
10	VA	**43**	Foot-Pounds	**76**	Packets
11	Nits	**44**	Ounce-Inches	**77**	Messages
12	Lumens	**45**	Gauss	**78**	Characters
13	Lux	**46**	Gilberts	**79**	Errors
14	Candelas	**47**	Henries	**80**	Corrected Errors
15	kPa	**48**	Farads	**81**	Uncorrectable Errors
16	PSI	**49**	Ohms	**82**	Square Mils
17	Newtons	**50**	Siemens	**83**	Square Inches
18	CFM	**51**	Moles	**84**	Square Feet
19	RPM	**52**	Becquerels	**85**	Square Centimeters
20	Hertz	**53**	PPM (parts/million)	**86**	Square Meters
21	Seconds	**54**	Decibels	**87**	Radians per second
22	Minutes	**55**	DbA	**88**	Beats per Minute
23	Hours	**56**	DbC	**89**	Meters per second squared
24	Days	**57**	Grays	**90**	Meters per second
25	Weeks	**58**	Sieverts	**91**	Cubic meter per second
26	Mils	**59**	Color Temperature Degrees K	**92**	Millimeters of Mercury
27	Inches	**60**	Bits	**93**	Radians per second squared
28	Feet	**61**	Bytes	**-**	All others – reserved
29	Cubic Inches	**62**	Words (data)		
30	Cubic Feet	**63**	Doublewords		
31	Meters	**64**	Quadwords		
32	Cubic Centimeters	**65**	Percentage	**255**	OEM Unit

[1:] This table is derived from the sensorUnits enumeration Table of Distributed Management Task Force (DMTF) specification number DSP 0248 (Platform Level Data Model for Platform Monitoring and Control Specification). It is however not an exact replica of the sensorUnits enumeration Table.

4.7.2.5 SENSOR_ AXIS_DESCRIPTION_GET

This command is used for the discovery of the sensor axis properties. On success, it returns an array of Sensor Axis Descriptors as described in 4.7.2.5.1. Sensor axis descriptors should be reported in the normative order of axes. For example, a triaxial accelerometer should return its axis descriptors ordered as x, y, and z.

message_id: `0x7`

protocol_id: `0x15`

This command is mandatory for sensors providing measurements along axis only.

Parameters

Name	Description
uint32 sensor_id	Identifier for the sensor.
uint32 axis_desc_index	Index of the first sensor axis descriptor to be read in the sensor axis descriptor array.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if valid sensor axis descriptors were returned. • NOT_FOUND: if sensor_id does not point to a valid sensor. • NOT_SUPPORTED: if the sensor does not report values along axis. See section 4.1.4 for more status code definitions.
uint32 num_axis_flags	Bits[31:26] Number of remaining sensor axis descriptors. Bits[25:6] Reserved, must be zero. Bits[5:0] Number of sensor axis descriptors that are returned by this current call.
SENSOR_AXIS_DESC desc[N]	An array of sensor axis descriptors of format described in 4.7.2.5.1. N is specified by Bits[5:0] of num_axis_flags field.

4.7.2.5.1 Sensor Axis Descriptor

The SENSOR_AXIS_DESC structure describes the sensor axis properties, such as the axis identifier for the sensor, its name, reading types and other characteristics.

uint32 axis_id	Identifier for the axis of the sensor.	
uint32 axis_attributes_low	Bits[31:9]	Reserved.
	Bit[8]	Extended attributes support: If this flag is set to 1, the sensor reports extended attributes for this axis after the name field. If this flag is set to 0, the sensor does not report extended attributes for this axis. Fields beyond name are not allocated by the platform.
	Bits[7:0]	Reserved.
uint32 axis_attributes_high	Bits[31:16]	Reserved.
	Bits[15:11]	Exponent: The power-of-10 multiplier in two's-complement format that is applied to the sensor unit specified by the SensorType field.
	Bits[10:8]	Reserved.
	Bits[7:0]	SensorType: The type of sensor axis and the measurement system it implements, as described in Table 15.
uint8 name[16]	A NULL terminated UTF-8 format string with the sensor axis name, of up to 16 bytes. It is recommended that the name ends with '_' followed by the axis of the sensor in uppercase. For example, the name for the x-axis of a triaxial accelerometer could be "acc_X" or "_X".	
uint32 axis_resolution	Bits[31:27]	Exponent: The power-of-10 multiplier in two's-complement format that is applied to the Res field.
	Bits[26:0]	Res: The resolution of the sensor axis.
	This is an extended attribute field. It reports the resolution of the sensor axis. The representation is in [res] x $10^{[exponent]}$ format, in units specified by SensorType. SensorType is reported by Bits[7:0] of axis_attributes_high field. If the sensor does not report the resolution for this axis, this field must be set to 0x0. This field is present only if Bit[8] of axis_attributes_low is set to 1.	

int32	axis_min_range_low	Lower 32 bits of the minimum value that can be measured by this axis. If the sensor does not report the minimum range for this axis, this field must be set to 0x0. This field is present only if Bit[8] of axis_attributes_low is set to 1.
int32	axis_min_range_high	Higher 32 bits of the minimum value that can be measured by this axis. If the sensor does not report the minimum range for this axis, this field must be set to 0x80000000. This field is present only if Bit[8] of axis_attributes_low is set to 1.
int32	axis_max_range_low	Lower 32 bits of the maximum value that can be measured by this axis. If the sensor does not report the maximum range for this axis, this field must be set to 0xFFFFFFFF. This field is present only if Bit[8] of axis_attributes_low is set to 1.
int32	axis_max_range_high	Higher 32 bits of the maximum value that can be measured by this axis. If the sensor does not report the maximum range for this axis, this field must be set to 0x7FFFFFFF. This field is present only if Bit[8] of axis_attributes_low is set to 1.

4.7.2.6 SENSOR_LIST_UPDATE_INTERVALS

This command allows the agent to ascertain the update intervals supported by the sensor. On success, the command returns an array, which contains a number of update interval entries. Sometimes it might not be possible to return all the sensor update intervals with just one call. To solve this problem, the interface allows multiple calls. It also returns the number of remaining update intervals. The size of the array returned depends on the number of return values a given transport can support.

Sensors can support many update intervals and sometimes individually describing each update interval might be too onerous. In such cases, the command can return only the lowest update interval, the highest update interval and the step size between two successive update intervals that the sensor supports.

The sensor update intervals returned by this call should be in numeric ascending order.

message_id: `0x8`
protocol_id: `0x15`
This command is optional.

Parameters

Name	Description
uint32 sensor_id	Identifier for the sensor.
uint32 index	Index to the first update interval value to be described in the return interval array.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if sensor update intervals were returned successfully. • NOT_FOUND: if the sensor identified by sensor_id does not exist. • OUT_OF_RANGE: if the index is outside of valid range. • NOT_SUPPORTED: if the sensor does not support update intervals. See section 4.1.4 for more status code definitions.
uint32 flags	Descriptor for the update intervals supported by this sensor. Bits[31:16] Number of remaining update intervals. This field should be 0 if Bit[12] is 1. Bits[15:13] Reserved, must be zero. Bit[12] Return format: If this bit is set to 1, the Interval Array is a triplet that constitutes a segment in the following form: interval[0] is the lowest update interval that the sensor can support in the segment. interval[1] is the highest update interval that the sensor can support in the segment. interval[2] is the step size between two successive update intervals that the sensor can support within the segment. If this bit is set to 0, each element of the Interval Array represents a discrete sensor update interval. Bits[11:0] Number of update intervals that are returned by this call. This field should be 3 if Bit[12] is 1.

	Interval Array: Each array entry has the following format: Bits[31:21] Reserved. Bits[20:5] sec – Seconds. Bits[4:0] exponent – two's complement format representing the power-of-10 multiplier that is applied to the sec field.
uint32 intervals[N]	The representation is in [sec] x $10^{[exponent]}$ format, in units of seconds. If Bit[12] of the flags field is set to 0, each array entry is a discrete sensor update interval. If Bit[12] of the flags field is set to 1, then each entry is a member of a segment {lowest update interval, highest update interval, step size}. N is specified by Bits[11:0] of flags field.

For an example of using this kind of API, see 4.5.3.5.

4.7.2.7 SENSOR_TRIP_POINT_NOTIFY

This command is used by the agent to globally control generation of notifications on cross-over events for the trip-points that have been configured using the SENSOR_TRIP_POINT_CONFIG command.

message_id: `0x4`

protocol_id: `0x15`

This command is optional.

Parameters

Name	Description
uint32 sensor_id	Identifier for the sensor.

		Bits[31:1]	Reserved.
		Bit[0]	Globally controls generation of notifications on crossing of configured trip-points pertaining to the specified sensor. If this bit is set to 1, notifications are sent whenever the sensor value crosses any of the trip-points that have been configured using the SENSOR_TRIP_POINT_CONFIG command. If this bit is set to 0, no notifications are sent for any of the trip-points.
uint32	sensor_event_control		

Return values

Name		Description
int32	status	One of, but not limited to, the following: • SUCCESS. • NOT_FOUND: if sensor_id does not point to an existing sensor. • INVALID_PARAMETERS: if the input sensor_event_control flag contains invalid or illegal settings. • NOT_SUPPORTED: if the platform does not support trip point event notifications for the sensor. See section 4.1.4 for more status code definitions.

4.7.2.8 SENSOR_TRIP_POINT_CONFIG

This command is used for selecting and configuring a trip-point of interest. Following the successful completion of this command, the platform generates the SENSOR_TRIP_POINT_EVENT event whenever the sensor value crosses the programmed trip point value, provided notifications have been enabled for trip-points globally using the SENSOR_TRIP_POINT_NOTIFY command.

Sensors which report values along multiple axes can optionally support trip points only if all the axes report the same sensor units. In such a case, the SENSOR_TRIP_POINT_EVENT event is generated when any axis crosses the configured threshold.

An agent can use this command for various use-cases. For example:

- The agent can invoke this command twice to program the upper and lower values of a hysteresis band, respectively.
- For a counter-type sensor that is required to fire a notification on reaching a certain count, the agent can issue this command to program the count value.

message_id: `0x5`

protocol_id: `0x15`

This command is mandatory if at least one of the implemented sensors in the platform supports trip points.

Parameters

Name	Description	
uint32 sensor_id	Identifier for the sensor.	
uint32 trip_point_ev_ctrl	Bits[31:12]	Reserved.
	Bits[11:4]	trip_point_id: Identifier for the selected trip point. This value should be equal to or less than the total number of trip points that are supported by this sensor as advertised in its descriptor.
	Bits[3:2]	Reserved for future use.
	Bits[1:0]	Event control for the trip-point: If set to 0, disables event generation for this trip-point (this is the default state). If set to 1, enables event generation when this trip-point value is reached or crossed in a positive direction. If set to 2, enables event generation when this trip-point value is reached or crossed in a negative direction. If set to 3, enables event generation when this trip-point value is reached or crossed in either direction.
uint32 trip_point_val_low	Lower 32 bits of the sensor value corresponding to this trip-point. The default value is 0.	
uint32 trip_point_val_high	Higher 32 bits of the sensor value corresponding to this trip-point. The default value is 0.	

Return values

Name	Description

int32 status	One of, but not limited to, the following: • SUCCESS: if the sensor trip point was set successfully. • NOT_FOUND: if sensor_id does not point to an existing sensor. • INVALID_PARAMETERS: if the input parameters specify incorrect or illegal values. • NOT_SUPPORTED: if the platform does not support trip point event notifications for the sensor. See section 4.1.4 for more status code definitions.

4.7.2.9 SENSOR_CONFIG_GET

This command is used to read the sensor configuration. It returns the configured sensor update interval, the sensor state and if timestamping is enabled.

message_id: `0x9`

protocol_id: `0x15`

This command is mandatory.

Parameters

Name	Description
uint32 sensor_id	Identifier for the sensor.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if the sensor configuration was returned successfully. • NOT_FOUND: if sensor_id does not point to an existing sensor. See section 4.1.4 for more status code definitions.

	Bits[31:11]	sensor_update_interval:
		Bits[31:16] sec – Seconds.
		Bits[15:11] exponent – two's complement format representing the power-of-10 multiplier that is applied to the sec field.
		The time duration between successive updates of the sensor value. The representation is in the [sec] x $10^{[exponent]}$ format, in units of seconds.
uint32 sensor_config		This field is set to 0 if the sensor does not require or support an update interval.
	Bits[10:2]	Reserved.
	Bit[1]	Timestamp reporting:
		Set to 1 if the sensor value provided by the platform is timestamped.
		Set to 0 if the sensor value provided by the platform is not timestamped.
	Bit[0]	Sensor State:
		Set to 1 if the sensor is enabled.
		Set to 0 if the sensor is disabled.

4.7.2.10 SENSOR_CONFIG_SET

This command is used to configure the sensor update interval and to enable the timestamping of sensor values. This command can also be used to enable or disable the sensor.

If the sensor has been enabled, sensor values can be read using the SENSOR_READING_GET command or notified by the platform through the SENSOR_UPDATE notification. The platform generates the SENSOR_UPDATE notification only if the agent subscribes to this notification by calling SENSOR_CONTINUOUS_UPDATE_NOTIFY as described in 4.7.2.12. The platform generates this notification only for sensors which support continuous update notifications.

message_id: `0xA`

protocol_id: `0x15`

This command is mandatory.

Parameters

Name	Description
uint32 sensor_id	Identifier for the sensor.

uint32 sensor_config	Bits[31:11]	sensor_update_interval:	
		Bits[31:16]	sec – Seconds.
		Bits[15:11]	exponent – two's complement format representing the power-of-10 multiplier that is applied to the sec field.
		The time duration between successive updates of the sensor value. The representation is in the [sec] x $10^{[exponent]}$ format, in units of seconds.	
		This field should be set to 0 if the sensor update interval does not need to be updated or if the sensor does not support configuring the sensor update interval.	
	Bits[10:9]	Round up/down:	
		If Bit[10] is set to 1, the platform rounds up/down autonomously to choose a sensor update interval closest to the requested update interval, and Bit[9] is ignored.	
		If Bit[10] is set to 0, then the platform rounds up if Bit[9] is set to 1, and rounds down if Bit[9] is set to 0.	
	Bits[8:2]	Reserved.	
	Bit[1]	Timestamp reporting:	
		Set to 1 if the sensor value provided by the platform should be timestamped.	
		Set to 0 if the sensor value provided by the platform should not be timestamped.	
		If the sensor does not support timestamp reporting or its configuration, this bit should be set to 0.	
	Bit[0]	Sensor State:	
		Set to 1 if the sensor should be enabled.	
		Set to 0 if the sensor should be disabled.	

Return values

Name	Description

int32 status	One of, but not limited to, the following: • SUCCESS: if the sensor configuration was set successfully. • NOT_FOUND: if sensor_id does not point to an existing sensor. • INVALID_PARAMETERS: if the input parameters specify incorrect or illegal values. • NOT_SUPPORTED: if the configuration requested by this command is not supported by the sensor. See section 4.1.4 for more status code definitions.

4.7.2.11 SENSOR_READING_GET

This command requests the platform to provide the current value of the sensor that is represented by sensor_id. The sensor should be in enabled state before using this command. For synchronous mode of access, the platform provides the sensor reading in the response to this command itself. For asynchronous accesses, the platform returns the sensor value in the SENSOR_READING_COMPLETE delayed response.

When the platform notices failure or fault conditions in the sensor or its associated logic or circuitry, it returns the HARDWARE_ERROR status. Other errors pertain to the interface itself and are enumerated in 4.1.4.

Agents should assess the sensor attributes to determine the optimal mode of access for the sensor. A slow sensor like a temperature sensor can be more optimally read asynchronously, while a shared memory-based sensor can be read synchronously.

message_id: `0x6`

protocol_id: `0x15`

This command is mandatory.

Parameters

Name		Description
uint32	sensor_id	The identifier for the sensor to be read.
uint32	flags	Bits[31:1] Reserved. Bit[0] Async flag: Set to 1 if the sensor is to be read asynchronously. Set to 0 to if the sensor is to be read synchronously.

Return values

Name	Description

int32 status	One of, but not limited to, the following: • SUCCESS: if the reading was successfully returned for a synchronous request or if the command was successfully enqueued for an asynchronous request. • NOT_FOUND: if sensor_id does not point to an existing sensor. • INVALID_PARAMETERS: if the flags input specifies illegal or invalid settings. • PROTOCOL_ERROR: if the command is used to read updates from a disabled sensor. See section 4.1.4 for more status code definitions. If this is an asynchronous call, then the returned status code pertains to this command itself, and any error that occurs during the actual sensor read operation is reported subsequently with the SENSOR_READING_COMPLETE delayed response.
SENSOR_READING readings[N]	An array of sensor readings of format described in 4.7.2.11.1, where N is: • 1 for sensors which measure scalar values. • the number of sensor axes for sensors which report values along axes. All axes should be reported in order.

4.7.2.11.1 Sensor Reading Descriptor

The SENSOR_READING structure provides the sensor readings and the timestamp when they were collected.

int32 sensor_value_low	Lower 32 bits of the sensor value. This value is invalid if an error status is returned.
int32 sensor_value_high	Higher 32 bits of the sensor value. This value is invalid if an error status is returned.
uint32 timestamp_low	Lower 32 bits of the timestamp when the sample was captured. If no timestamp is collected, this field should be set to 0.
uint32 timestamp_high	Higher 32 bits of the timestamp when the sample was captured. If no timestamp is collected, this field should be set to 0.

4.7.2.12 SENSOR_CONTINUOUS_UPDATE_NOTIFY

This command allows the agent to request notifications from the platform if a sensor has values to report. These notifications are sent using the SENSOR_UPDATE command which is described in section 4.7.4.2.

The SENSOR_UPDATE notification is sent only when the sensor is enabled. This notification could be generated at every sensor update interval or whenever the sensor values change by a specific margin depending on the sensor characteristics.

The sensor must support continuous update notifications for this command to be used.

If no sensor in the platform supports continuous update notifications, this command can be omitted. The PROTOCOL_MESSAGE_ATTRIBUTES command, that is described in section 4.7.2.3, can be used to determine whether this command is implemented.

On initial boot of an agent, by default, these notifications must be disabled from being sent to that agent.

message_id: `0xB`

protocol_id: `0x15`

This command is optional.

Parameters

Name	Description	
uint32 sensor_id	Identifier for the sensor to be read.	
uint32 notify_enable	Bits[31:1]	Reserved, must be zero.
	Bit[0]	Notify enable: If this value is 0, the platform does not send any SENSOR_UPDATE notifications to the agent. If this value is set to 1, the platform sends SENSOR_UPDATE notifications to the agent. See section 4.7.4.2 for more details about the SENSOR_UPDATE notification.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS. • NOT_FOUND: if sensor_id does not point to a valid domain. • NOT_SUPPORTED: if continuous update notifications are not supported for the indicated sensor. • INVALID_PARAMETERS: if notify_enable specifies illegal or unimplemented options. See section 4.1.4 for more status code definitions.

4.7.3 Delayed Responses

4.7.3.1 SENSOR_READING_COMPLETE

This response is the delayed response to an asynchronous SENSOR_READING_GET command issued by an agent. When the platform determines that there are certain failure conditions in the sensor itself, such as a fault in the sensor hardware or related circuitry or logic, it returns HARDWARE_ERROR to report that condition to the caller. Other errors apply to the interface itself and are enumerated in 4.1.4.

message_id: `0x6`

protocol_id: `0x15`

This response is mandatory and is generated if the caller used the asynchronous method to read the sensor.

Return Values

Name	Description
int32 status	An appropriate status code, as described in section 4.1.4.
uint32 sensor_id	Identifier for the sensor.
SENSOR_READING readings[N]	An array of sensor readings of format described in 4.7.2.11.1, where N is the number of sensor axes. All axes should be reported in order.

4.7.4 Notifications

4.7.4.1 SENSOR_TRIP_POINT_EVENT

This notification is issued by the platform when a sensor crosses a specific trip point that the agent had requested event notification for, by using the SENSOR_TRIP_POINT_CONFIG command.

The platform might read sensors periodically using polling, or program sensors to generate interrupts on trip points, depending on implementation. If the sensor value changes such that it crosses several trip-points between successive reads by the platform, then the platform might minimally send only one notification to the agent to represent the multiple cross-over condition.

Message_id: `0x0`

protocol_id: `0x15`

This notification is optional.

Return Values

Name	Description

uint32 agent_id	Refers to the agent that caused this event. For the current version of the specification, this field is set to 0 to indicate that the platform is the generator of all sensor events.	
uint32 sensor_id	Identifier for the sensor that has tripped.	
uint32 trip_point_desc	Bits[31:17]	Reserved.
	Bit[16]	Direction. If set to 1, indicates that the trip point was reached or crossed in the positive direction. If set to 0, indicates that the trip point was reached or crossed in the negative direction.
	Bits[15:8]	Reserved for future use.
	Bits[7:0]	trip_point_id. The identifier for the trip point that was crossed or reached.

4.7.4.2 SENSOR_UPDATE

The SENSOR_UPDATE notification is issued by the platform to provide a sensor reading. This notification is sent to an agent which had requested continuous update notifications from a sensor using the SENSOR_CONTINUOUS_UPDATE_NOTIFY command.

The SENSOR_UPDATE notification is sent only when the sensor is enabled. This notification could be generated at every sensor update interval or whenever the sensor values change by a specific margin depending on the sensor characteristics.

The notification is generated at a rate no faster than the configured sensor update period. The platform is allowed to generate the notification at a rate slower than the configured sensor update period if the agent or the platform cannot cope with the rate of generation of notifications due to hardware constraints. However, the platform should always provide the latest sensor values in the SENSOR_UPDATE notification.

The platform does not need to implement this notification if no sensors support continuous update notifications.

message_id: `0x1`

protocol_id: `0x15`

This notification is mandatory if at least one sensor supports continuous update notifications.

Return Values

Name	Description

uint32 agent_id	Refers to the agent that caused this event. For the current version of the specification, this field is set to 0 to indicate that the platform is the generator of all sensor events.
uint32 sensor_id	Identifier for the sensor.
SENSOR_READING readings[N]	An array of sensor readings of format described in 4.7.2.11.1, where N is: • 1 for sensors which measure scalar values. • the number of sensor axes for sensors which report values along axes. All axes should be reported in order.

4.7.5 Sensor Values Shared Memory

Optionally, the platform might provide sensor values through the shared memory region that is associated with the sensor management protocol. Whether support is present is indicated by the PROTOCOL_ATTRIBUTES command, which is described in section 4.7.2.2. This command also provides the address and the size of the shared memory region. The memory must be accessible from the Non-secure world, and OSPM must map it as non-cached normal memory or device memory.

Accessing multi-word values might cause races between platform write accesses and the read accesses by agents in the system. This problem and its solution are described in section 4.3.4.

The format of the sensor shared memory region is described in Table 16.

Table 16 Sensor shared memory region

Field	Byte Length	Byte Offset	Description
Signature	0x4	0x0	0x53454E53 (‘SENS’).
Revision	0x2	0x4	For this revision, this value must be 0x1.
Attributes	0x2	0x6	For this revision, this value must be zero.
Number of sensors	0x2	0x8	Number of sensors.
Reserved	0x2	0xA	Must be zero.
Match Sequence	0x4	0xC	The match sequence populated by the platform as described in Section 4.3.4.1.
Sensor domain offset array	0x4 × Number of sensors	0x10	For each sensor, this array provides a 4-byte offset, from the start of the shared memory area, to the memory location of the sensor value data entry in the data section. The array is indexed by sensor_id. The sensor value data entry format is described in Table 17.

			A value of 0 indicates that the sensor value is not reported through shared memory.
Sensor values data section	--	--	This area must start at an offset of `0x10` + `0x4` × (Number of sensors), or higher.

The sensor values data section contains entries for each sensor value. The format for each sensor value data entry is described in Table 17.

Table 17 Sensor value data entry

Field	Byte Length	Byte Offset	Description
Sensor Value	`0x10 × N`	`0x0`	The sensor value is stored on a 64-bit aligned boundary in the format specified by section 4.7.2.11.1 where N is: • 1 for sensors which measure scalar values. • the number of sensor axes for sensors which report values along axes. All axes should be reported in order.

Accessing statistics can cause races between platform write accesses and agent read accesses. This problem and its solution are described in section 4.3.4.1.

4.8 Reset domain management protocol

This protocol is intended for control of reset capable domains in the platform. The reset management protocol provides commands to:

- Describe the protocol version.
- Discover the attributes and capabilities of the reset domains in the system.
- Reset a given domain.
- Receive notifications when a given domain is reset.

4.8.1 Reset domain management protocol background

Devices that can be collectively reset through a common reset signal constitute a reset domain. A reset domain can be reset autonomously or explicitly. When autonomous reset is chosen, the firmware is responsible for taking the necessary steps to reset the domain and to subsequently bring it out of reset. When explicit reset is chosen, the caller has to specifically assert and then de-assert the reset signal by issuing two separate RESET commands.

Reset State encoding for reset domains is described below in Table 18.

Table 18: Reset State Parameter Layout

Bit field	Description
31	Reset Type If set to 0, indicates Architectural Reset. If set to 1, indicates IMPLEMENTATION defined Reset.
30:0	Reset ID

The two distinct reset types possible are architectural reset and IMPLEMENTATION defined reset. Reset Types and Reset IDs are described in Table 19.

Table 19: Reset Type and Reset ID Description

Reset Type	Reset ID	Description
Architectural Reset	0x0	COLD_RESET. Full loss of context of all devices in the domain.
	0x1-0x7FFFFFFF	Reserved for future use. Lower values indicate greater context loss.
IMPLEMENTATION defined Reset	0x0-0x7FFFFFFF	IMPLEMENTATION defined Resets. All values represent resets that result in varying levels of context loss. Lower values indicate greater context loss.

Reset domains are not the same as power domains, although they can be the same. There could be multiple reset domains within a given power domain. There could also be reset domains that straddle multiple power domains.

Resets might impose the requirement that devices in the affected reset domain are in a state of quiescence before the reset is issued. Support for such quiescence might be provided by the reset domain. In the absence of such a support, it is the calling agent's responsibility to ensure quiescence prior to invocation of the reset.

Protocol commands take integer identifiers to identify the reset domain they apply to. The identifiers are sequential and start from 0.

4.8.2 Commands

4.8.2.1 PROTOCOL_VERSION

On success, this command returns the version of this protocol. For this version of the specification, the value returned must be `0x20000`, which corresponds to version 2.0.

message_id: `0x0`
protocol_id: `0x16`
This command is mandatory.

Return values

Name	Description
int32 status	See section 4.1.4 for status code definitions.
uint32 version	For this revision of the specification, this must be `0x20000`.

4.8.2.2 PROTOCOL_ATTRIBUTES

This command returns the implementation details associated with this protocol.

message_id: `0x1`
protocol_id: `0x16`
This command is mandatory.

Return values

Name	Description	
int32 status	See section 4.1.4 for status code definitions.	
uint32 attributes	Bits[31:16]	Reserved, must be zero.
	Bits[15:0]	Number of reset domains.

4.8.2.3 PROTOCOL_MESSAGE_ATTRIBUTES

On success, this command returns the implementation details associated with a specific message in this protocol.

message_id: `0x2`
protocol_id: `0x16`
This command is mandatory.

Parameters

Name	Description
uint32 message_id	message_id of the message.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: in case the message is implemented and available to use. • NOT_FOUND: if the message identified by message_id is not provided by this platform implementation. See section 4.1.4 for more status code definitions.
uint32 attributes	Reserved, must be zero.

4.8.2.4 RESET_DOMAIN_ATTRIBUTES

This command returns attributes of the reset domain specified in the command.

message_id: `0x3`
protocol_id: `0x16`
This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the reset domain.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if valid reset domain attributes were returned.

	• NOT_FOUND: if domain_id pertains to a non-existent domain. See section 4.1.4 for more status code definitions.	
uint32 attributes	Bit[31]	Asynchronous reset support. Set to 1 if this domain can be reset asynchronously. Set to 0 if this domain can only be reset synchronously.
	Bit[30]	Reset notifications support. Set to 1 if reset notifications are supported for this domain. Set to 0 if reset notifications are not supported for this domain.
	Bits[29:0]	Reserved, must be zero.
uint32 latency	Maximum time (in microseconds) required for the reset to take effect on the given domain. A value of 0xFFFFFFFF indicates this field is not supported by the platform.	
uint8 name[16]	Null-terminated ASCII string of up to 16 bytes in length describing the reset domain name.	

4.8.2.5 RESET

This command allows an agent to reset the specified reset domain. If the reset request is issued as an asynchronous call, the platform must return immediately upon receipt of the request. The platform might need to ensure that the domain and all dependent logic have reached a state of quiescence before performing the actual reset, although this is not mandatory.

When the reset is done, the platform should then send a RESET_COMPLETE delayed response, described in section 4.8.3.1.The platform has the option to inform agents other than the caller of the reset incident, using the RESET_ISSUED notification that is described in section 4.8.4.1.

message_id: `0x4`

protocol_id: `0x16`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the reset domain.

uint32 flags	This parameter allows the agent to specify additional conditions and requirements specific to the request, and has the following format: Bits[31:3] Reserved, must be zero. Bit[2] Async flag. Only valid if Bit[0] is set to 1. Set to 1 if the reset must complete asynchronously. Set to 0 if the reset must complete synchronously. Bit[1] Explicit signal. This flag is ignored when Bit[0] is set to 1. Set to 1 to explicitly assert reset signal. Set to 0 to explicitly de-assert reset signal. Bit[0] Autonomous Reset action. Set to 1 if the reset must be performed autonomously by the platform. Set to 0 if the reset signal shall be explicitly asserted and de-asserted by the caller.
uint32 reset_state	The reset state being requested. The format of this parameter is specified in Table 18.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if the operation was successful. • NOT_FOUND: if the reset domain identified by domain_id does not exist. • INVALID_PARAMETERS: if an illegal or unsupported reset state is specified or if the flags field is invalid. • GENERIC_ERROR: if the operation failed, for example if there are other active users of the reset domain. • DENIED: if the calling agent is not allowed to reset the specified reset domain. See section 4.1.4 for more status code definitions.

4.8.2.6 RESET_NOTIFY

This command allows the caller to request notifications from the platform when a reset domain has been reset. If reset has been explicitly signaled, the platform generates this notification when the reset

signal has been asserted. These notifications are sent using the RESET_ISSUED notification, which is described in section 4.8.4.1.

Notification support is optional, and PROTOCOL_MESSAGE_ATTRIBUTES must be used to discover whether this command is implemented.

These notifications must be disabled by default during initial boot of the platform.

message_id: `0x5`

protocol_id: `0x16`

This command is optional.

Parameters

Name	Description	
uint32 domain_id	Identifier for the reset domain.	
uint32 notify_enable	Bits[31:1]	Reserved must be zero.
	Bit[0]	Notify enable. This bit can have one of the following values: 1, which indicates that the platform should send RESET_ISSUED notifications to the calling agent when the domain is reset. 0, which indicates that the platform should not send any RESET_ISSUED notifications to the calling agent.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS. • NOT_FOUND: if domain_id does not point to a valid domain. • INVALID_PARAMETERS: if notify_enable specifies values that are either illegal or incorrect. See section 4.1.4 for more status code definitions.

4.8.3 Delayed Responses

4.8.3.1 RESET_COMPLETE

The platform sends this delayed response to the caller that requested an asynchronous reset of the specified domain.

message_id: `0x4`

protocol_id: `0x16`

This command is optional.

Parameters

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if reset was successful. • GENERIC_ERROR: if the operation failed, for example if there were other users of the reset domain, or if the domain could not be brought to a state of quiescence preparatory to the reset. Other vendor-specific errors can also be generated depending on the implementation. See section 4.1.4 for more status code definitions.
uint32 domain_id	Identifier for the reset domain.

4.8.4 Notifications

4.8.4.1 RESET_ISSUED

The platform sends this notification to an agent that has registered to receive notifications when the reset domain identified by domain_id has been reset. The notification might not be received if the agent is affected as a result of the reset.

message_id: `0x0`

protocol_id: `0x16`

This command is optional.

Parameters

Name	Description
uint32 agent_id	Identifier of the agent that caused the reset of the domain.
uint32 domain_id	Identifier of the reset domain.
uint32 reset_state	The reset state issued on the domain. The format of this parameter is specified in Table 18.

4.9 Voltage domain management protocol

This protocol is intended for the management of configuration and voltage levels of voltage domains. The voltage domain management protocol provides commands to:

- Describe the protocol version.
- Discover implementation attributes.
- Discover the voltage levels supported by a domain.
- Get the configuration and voltage level of a domain.
- Set the configuration and voltage level of a domain.

4.9.1 Voltage domain management protocol background

In this document, a voltage domain is defined as a group of components that are supplied by a single voltage source. A voltage domain is different from a power domain which is a collection of elements within a voltage domain that share common power control. A voltage domain can be partitioned into one or more power domains.

Voltage domain protocol can be used for managing voltage supply to standard components like embedded multi-media cards, USB and others which specify a standard operating voltage.

Voltage domains have the following properties:

- They can include one or more devices.
- Their voltage supply can be scaled or removed for power management.

Protocol commands take integer identifiers to identify the voltage domain they apply to. The identifiers are sequential and start from 0.

—— Note ——————————————————————

Voltage domain management protocol should not be used:

- to control the performance of application processors or devices.
- if one or more clock rates need to be adjusted as a direct consequence of changing the voltage level of a voltage domain.

The Performance domain management protocol should be used in all the above cases.

———————————————————————————

An implementation can include devices that are intended for use only by Secure entities in the system such as a trusted OS. Voltage domains for such devices must be managed through Secure channels.

Non-secure channels can be used to manage voltage domains for devices which are not used by Secure entities in the system.

In a multi-agent system with multiple domains, several scenarios are possible:

- A voltage domain is exclusive to an agent.
- A voltage domain can be shared by multiple agents.

In both these cases, the agents can coordinate with the platform to access voltage domains, and to perform voltage management of the domains. For all combinations of voltage domains and agents, platform policy dictates which agents can access which voltage domains, and whether a voltage domain is shared or exclusive.

Voltage domains can operate in different modes are described below in Table 20. It is not necessary for a voltage domain to support all the modes of operation.

Table 20: Voltage Domain Mode Parameter Layout

Bit field	Description
3	Mode Type If set to 0, indicates Architectural Mode. If set to 1, indicates IMPLEMENTATION defined Mode.
2:0	Mode ID

The two distinct voltage domain mode types possible are architectural mode and IMPLEMENTATION defined mode. Mode Types and Mode IDs are described in Table 21.

Table 21: Mode Type and Mode ID Description

Mode Type	Mode ID	Description
Architectural Mode	0x0	OFF. Voltage supply to the domain is disabled.
	0x1-0x6	Reserved for future use.
	0x7	ON. Voltage supply to the domain is active. The components supplied by the voltage domain can operate normally.
IMPLEMENTATION defined Mode	0x0-0x7	IMPLEMENTATION defined Modes.

4.9.2 Commands

4.9.2.1 PROTOCOL_VERSION

On success, this command returns the protocol version. For this version of the specification, the return value must be `0x10000`, which corresponds to version 1.0.

message_id: `0x0`
protocol_id: `0x17`
This command is mandatory.

Return values

Name	Description

int32 status	See section 4.1.4 for status code definitions.
uint32 version	For this revision of the specification, this value must be `0x10000`.

4.9.2.2 PROTOCOL_ATTRIBUTES

This command returns the implementation details associated with this protocol.

message_id: `0x1`
protocol_id: `0x17`
This command is mandatory.

Return values

Name	Description	
int32 status	See section 4.1.4 for status code definitions.	
uint32 attributes	Bits[31:16]	Reserved, must be zero.
	Bits[15:0]	Number of voltage domains.

4.9.2.3 PROTOCOL_MESSAGE_ATTRIBUTES

On success, this command returns the implementation details associated with a specific message in this protocol.

message_id: `0x2`
protocol_id: `0x17`
This command is mandatory.

Parameters

Name	Description
uint32 message_id	message_id of the message.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: in case the message is implemented and available to use. • NOT_FOUND: if the message identified by message_id is invalid or not implemented. See section 4.1.4 for more status code definitions.

uint32 attributes	Flags that are associated with a specific command in the protocol. In the current version of the specification, this value is always 0.

4.9.2.4 VOLTAGE_DOMAIN_ATTRIBUTES

This command returns the attribute flags associated with a specific voltage domain.

message_id: `0x3`

protocol_id: `0x17`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the domain. Domain identifiers are limited to 16 bits, and the upper 16 bits of this field are ignored by the platform.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if valid voltage domain attributes were returned. • NOT_FOUND: if domain_id pertains to a non-existent domain. See section 4.1.4 for more status code definitions.
uint32 attributes	Bits[31:0] Reserved, must be zero.
uint8 name[16]	Null-terminated ASCII string of up to 16 bytes in length describing the voltage domain name.

4.9.2.5 VOLTAGE_DESCRIBE_LEVELS

This command allows the agent to ascertain the voltage levels supported by a voltage domain. On success, the command returns an array, which contains a number of voltage level entries. Sometimes it might not be possible to return the whole array with just one call. To solve this problem, the interface allows multiple calls. It also returns the number of remaining voltage levels. The size of the array returned depends on the number of return values a given transport can support.

Voltage domains can support many voltage levels and sometimes individually describing each voltage level might be too onerous. In such cases, the command can return only the lowest voltage level, the highest voltage level and the step size between two successive voltage levels that the voltage domain supports.

The voltage levels returned by this call should be in numeric ascending order.

For an example of using this kind of API, see 4.5.3.5.

message_id: `0x4`

protocol_id: `0x17`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the voltage domain.
uint32 level_index	Index of the first voltage level to be described in the return voltage array.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if the voltage levels are returned successfully. • NOT_FOUND: if the domain identified by domain_id does not exist. • OUT_OF_RANGE: if the level_index is outside of valid range. • NOT_SUPPORTED: if the request is not supported. • DENIED: if the calling agent is not allowed to get the voltage levels supported for this voltage domain. An example would be if this voltage domain is exclusive to another agent. See section 4.1.4 for more status code definitions.

uint32 flags	Descriptor for the voltage levels supported by this domain.	
	Bits[31:16]	Number of remaining voltage levels. This field should be 0 if Bit[12] is 1.
	Bits[15:13]	Reserved, must be zero.
	Bit[12]	Return format: If this bit is set to 1, the Voltage Array is a triplet that constitutes a segment in the following form: voltage[0] is the lowest voltage level that the domain supports. voltage[1] is the highest voltage level that the domain supports. voltage[2] is the step size between two successive voltage levels that the domain supports. If this bit is set to 0, each element of the Voltage Array represents a discrete voltage level that the voltage domain supports.
	Bits[11:0]	Number of voltage levels that are returned by this call. This field should be 3 if Bit[12] is 1.
int32 voltage [N]	Voltage Array expressed in microvolts (uV): If Bit[12] of the flags field is set to 0, each array entry represents a discrete voltage level. If Bit[12] of the flags field is set to 1, then each entry is a member of a segment {lowest voltage level, highest voltage level, step size} as described above. N is specified by Bits[11:0] of flags field.	

4.9.2.6 VOLTAGE_CONFIG_SET

This command allows an agent to set the configuration of a voltage domain. It allows to enable or disable the domain.

message_id: `0x5`

protocol_id: `0x17`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the voltage domain.

uint32 config	Bits[31:4]	Reserved, must be zero.
	Bits[3:0]	Mode: The operating mode the voltage domain should be set to, as described in Table 20.

Return values

Name	Description
int32 status	One of, but not limited to, the following: • SUCCESS: if the voltage domain configuration has been set successfully. • NOT_FOUND: if the voltage domain identified by domain_id does not exist. • INVALID_PARAMETERS: if the requested configuration is not supported by the voltage domain. • NOT_SUPPORTED: if the request is not supported. • DENIED: if the calling agent is not allowed to set the configuration of this voltage domain. An example would be if this voltage domain is exclusive to another agent. See section 4.1.4 for more status code definitions.

4.9.2.7 VOLTAGE_CONFIG_GET

This command allows the calling agent to request the configuration of a voltage domain.

message_id: `0x6`
protocol_id: `0x17`
This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the voltage domain.

Return values

Name	Description

int32 status	One of, but not limited to, the following: • SUCCESS: if the voltage domain configuration was successfully returned. • NOT_FOUND: if domain_id does not point to a valid voltage domain. • NOT_SUPPORTED: if the request is not supported. • DENIED: if the calling agent is not allowed to get the configuration of this voltage domain. An example would be if this voltage domain is exclusive to another agent. See section 4.1.4 for more status code definitions.	
uint32 config	Bits[31:4]	Reserved, must be zero.
	Bits[3:0]	Mode: The operating mode of the voltage domain, as described in Table 20.

4.9.2.8 VOLTAGE_LEVEL_SET

This command allows an agent to set the voltage level of a voltage domain.

message_id: `0x7`

protocol_id: `0x17`

This command is mandatory.

Parameters

Name	Description	
uint32 domain_id	Identifier for the voltage domain.	
uint32 flags	Bits[31:0]	Reserved, must be zero.
int32 voltage_level	The voltage level, in microvolts (uV), to set the domain to.	

Return values

Name	Description

int32 status	One of, but not limited to, the following: • SUCCESS: if the voltage domain has been set to the desired level. • NOT_FOUND: if the voltage domain identified by domain_id does not exist. • INVALID_PARAMETERS: if the requested voltage level is not supported by the voltage domain. • NOT_SUPPORTED: if the request is not supported. • DENIED: if the calling agent is not allowed to set the voltage level of this voltage domain. An example would be if this voltage domain is exclusive to another agent. See section 4.1.4 for more status code definitions.

4.9.2.9 VOLTAGE_LEVEL_GET

This command allows the calling agent to request the current voltage level of a voltage domain.

Note

It is possible for the voltage_level value returned by this command to be stale by the time the command completes, as another voltage level change request could have been initiated and completed in the interim.

message_id: `0x8`

protocol_id: `0x17`

This command is mandatory.

Parameters

Name	Description
uint32 domain_id	Identifier for the voltage domain.

Return values

Name	Description

int32 status	One of, but not limited to, the following: • SUCCESS: if the voltage level of the domain was returned successfully. • NOT_FOUND: if domain_id does not point to a valid voltage domain. • NOT_SUPPORTED: if the request is not supported. • DENIED: if the calling agent is not allowed to get the voltage level of this voltage domain. An example would be if this voltage domain is exclusive to another agent. See section 4.1.4 for more status code definitions.
int32 voltage_level	The voltage level, in microvolts (uV), that the domain is set to.

5 Transports

Transports describe how messages are exchanged between agents and the platform. The transport should allow the agent and the platform to exchange the largest possible message described in this specification. If the platform supports messages which return data elements iteratively, like SENSOR_LIST_UPDATE_INTERVALS as described in Section 4.7.2.6, the transport should allow at least one data element to be returned.

5.1 Shared Memory based Transport

This form of transport relies on the use of shared memory between the platform and the agents.

The transport optionally supports interrupt-based communication, where, on completion of the processing of a message, the caller receives an interrupt. Polling for completion is also supported.

The transport can be used to provide an agent to platform, or a platform to agent channel. Each channel in the transport includes:

- **Shared memory area**
  This is an area of memory that is shared between the caller and the callee. At any point in time, the shared memory is owned by the caller or the callee. The ownership is reflected by a **channel status** word in the shared memory area. The channel is said to be free when the memory area is owned by the caller, and busy when it is passed to the callee. When a channel is free, the caller can write a message and associated payload to this shared memory area. After this, the caller updates the status field, thereby relinquishing ownership of the shared memory and marking the channel as busy. The callee can then use the shared memory to pass return values that are associated with the processing of the message. When the callee has completed processing the message, it updates the channel status field to indicate that the channel is now free. The layout of the memory area is described in section 5.1.2.
- **Doorbell**
  This is a mechanism that the caller can use to alert the callee of the presence of a message.

  Typically, this mechanism is implemented as a register in caller, which, when written, raises an interrupt on the callee. In case the callee chooses to poll over the ‘Channel free’ bit in the Channel status field of the shared memory area in order to discover new messages from the caller, then the doorbell support is optional.

  The doorbell can also be implemented through Secure Monitor Call (SMC) or Hypervisor Call (HVC) instructions if the callee is resident in the Secure world or at a different exception level.
- **Completion interrupt**
  This transport supports polling or interrupt driven modes of communication. In interrupt mode, when the callee completes processing a message, it raises an interrupt on the caller. Hardware support for completion interrupts is optional.

5.1.1 Message communications flow

A flow chart for sending a message from the caller to the callee using interrupt mode is shown in Figure 5. The steps are as follows:

1. The caller must ensure that the channel is free.
2. The caller populates the shared memory area with the message and its payload.
3. The caller marks the channel as busy by updating the channel status.

4. The caller rings the doorbell. This signals the callee that a pending message is in the shared memory area.
5. The callee processes the command in shared memory area.
6. Optionally, the callee updates the shared memory area with any return data that are associated with the message processing.
7. The callee marks the channel as free by updating the channel status.
8. The callee issues a completion interrupt to the caller.
9. Optionally the caller processes the contents of the shared memory area.

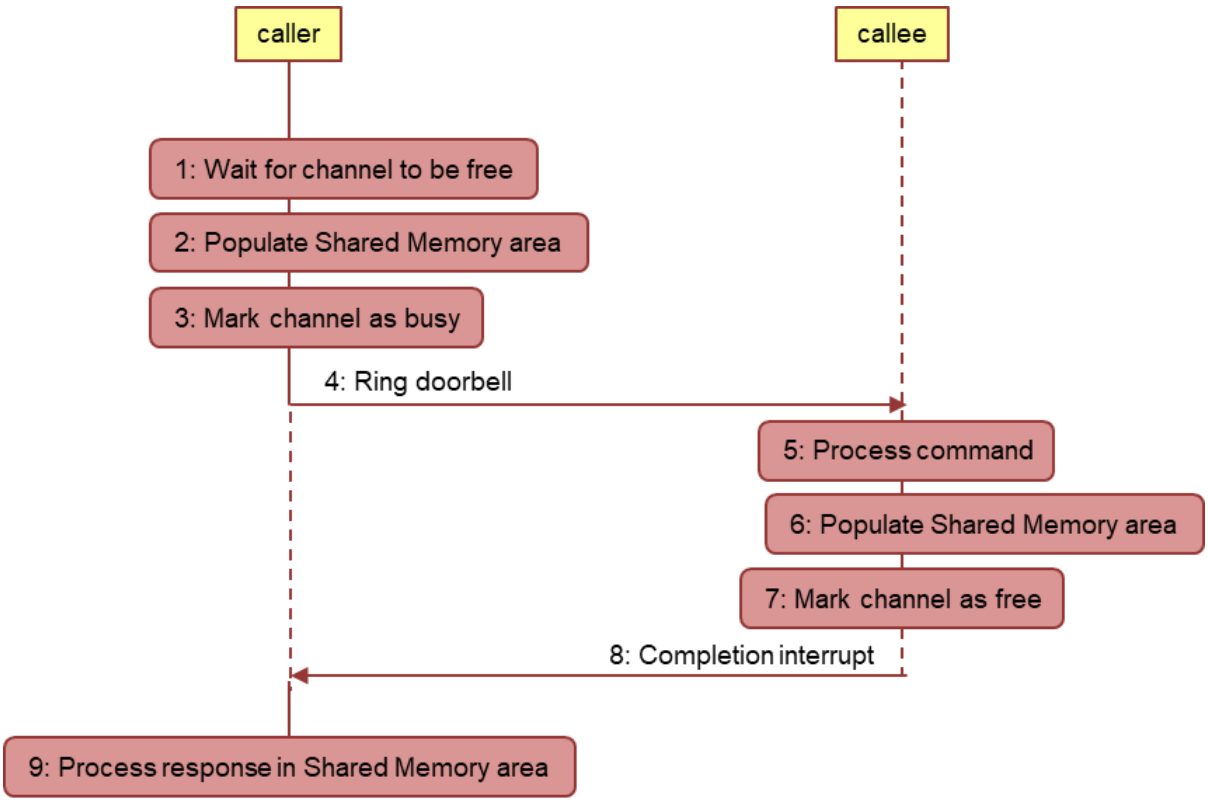

Figure 5 Interrupt-driven Communications flow

A flow chart for sending a message using polling mode is shown in Figure 6. The main difference is that the caller has to poll for command completion by checking the status of the channel, as there is no completion interrupt.

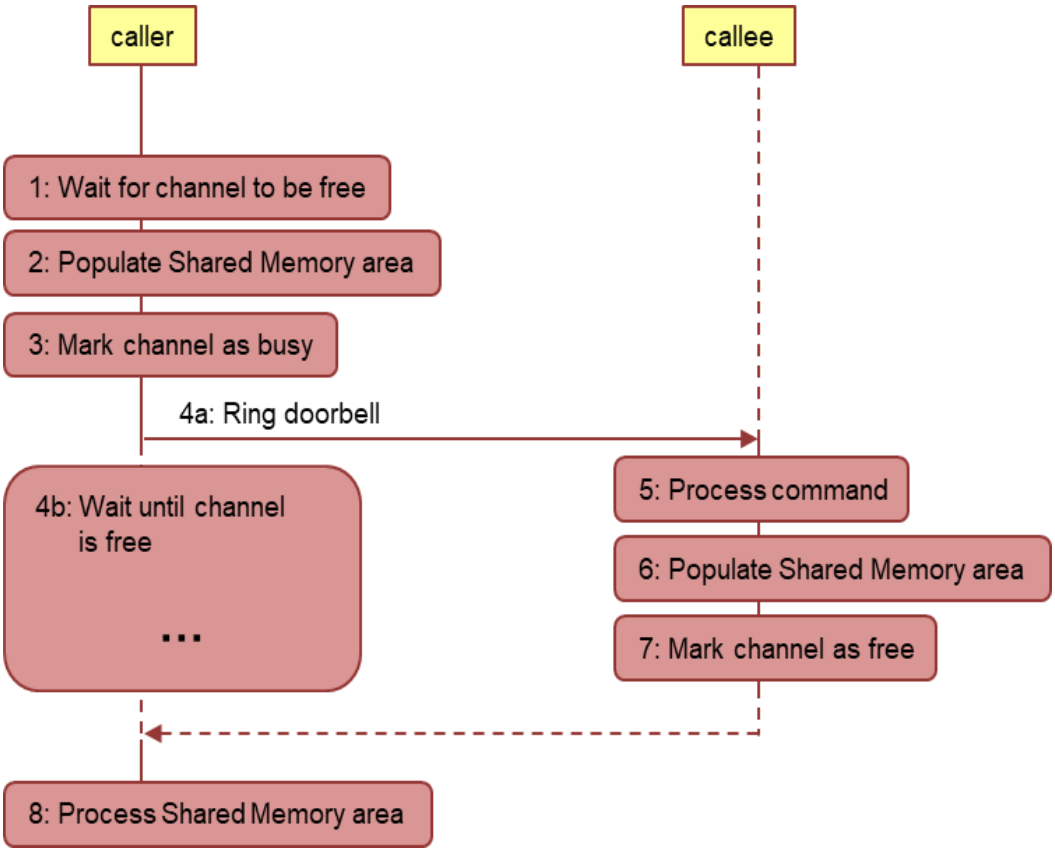

Figure 6: Polling based Communication Flow

The caller must ensure the appropriate ordering of memory operations so that all updates to the shared memory must be visible to the callee before ringing the doorbell. Equally, the callee must ensure that all shared memory changes are visible to the caller before updating the status.

If the caller contains multiple processing elements that can share a transport channel, then appropriate locking must be put in place to ensure that only one processing element can use the channel at any one time. The channel must be locked until the message processing completes and the results are processed by the caller.

5.1.2 Shared memory area layout

For a given channel, the layout of the memory that is shared between the agent and platform is described in Table 22.

Table 22 Layout of the shared memory area

Field	Byte Length	Byte Offset	Description
Reserved	0x4	0x0	Reserved, must be zero.

Channel status	0x4	0x4	The field has the following format: Bits[31:2] Reserved, must be zero. Bit[1] Channel error This bit is set to 1 if the previous message was not transmitted due to a communications error. The caller must clear it when it has ownership of the channel. Bit[0] Channel free This bit is set to 1 if the channel is free. This bit is cleared to 0 if the channel is busy.
Reserved	0x8	0x8	IMPLEMENTATION DEFINED field.
Channel flags	0x4	0x10	Channel flags are described in Table 23.
Length	0x4	0x14	Length in bytes of the Message header and Payload areas (4+N). If the message length does not match the message, the payload must contain the PROTOCOL_ERROR status as the first return value upon completion of message processing. Status codes are described in detail in section 4.1.4.
Message header	0x4	0x18	Message header field as described in section 4.1, Table 2.
Message Payload	N	0x1C	Array of 32-bit values that are used to hold any parameters or return values. The arguments are sent out in the same order they are declared in a protocol command. Return values are sent back in the same order as they are declared in a protocol command. If a message is not known to the callee, the payload must contain NOT_SUPPORTED as the first return value. Status codes are described in detail in section 4.1.4.

When interrupt driven communication is supported, the transport allows the caller to choose between interrupt and polling driven communications. This can be done on any transfer and is useful when the caller wants to operate in a fire and forget fashion, without having to handle interrupts. To make the choice, the channel flags are used. The format of the flags is described in Table 23.

Table 23 Channel flags

Field	Description
Bits[31:1]	Reserved, must be zero.
Bit[0]	Interrupt communication enable: Set to 1 if the command should complete via an interrupt. Set to 0 if the command should not result in an interrupt assertion.

5.1.3 Shared memory based transport firmware representation guidelines

An operating system on an agent needs a description of the shared memory based transport and its properties before using it. Arm recommends using firmware technologies such as FDT and ACPI for this purpose. This section details the properties that are required to be defined for each channel.

5.1.3.1 Doorbell

For agent to platform channels, a doorbell is required to alert the platform that a message is present in the shared memory area. In case the doorbell is a register, writing to it requires a read-modify-write sequence. Firmware tables can be used to describe the properties of the register to an OSPM running on the AP. The properties that must be described are shown in Table 24.

Table 24 Properties of the doorbell register

Field	Description
Register address	Physical address of the register that is written to, to issue a command to the platform.
Preserve Mask	Mask of bits that must be preserved when modifying the doorbell register to issue a command.
Modify Mask	Mask of bits that must be set when modifying the doorbell register to issue a command.

Channels can share a register address for the doorbell, but in this case must have unique preserve and modify masks. If the callee chooses to poll over the ‘Channel free’ bit in the Channel status field of the shared memory area in order to discover new messages from the caller, then doorbell support is optional.

If the doorbell is SMC or HVC based, it should follow the SMC Calling Convention [SMCCC]. The doorbell needs to provide the identifier of the Shared Memory area that contains the payload. The Shared Memory area containing the payload is updated with the SCMI return response when the call returns.

For platform to agent channels, a message interrupt can be described. This interrupt is raised by the platform on notification or delayed response messages. Not describing this interrupt implies that that platform messages have to be polled by agents.

5.1.3.2 Shared memory area address and size

The physical address of the shared memory area, and its size, must be described to the OSPM.

5.1.3.3 Completion interrupt

For agent-to-platform channels where interrupt mode is supported, the properties of the completion interrupt, if present, must be described by agent firmware. The properties of the completion interrupt to be described are covered in Table 25.

Table 25 Properties of the completion interrupt

Field	Description
Interrupt identifier	Identifier for the interrupt asserted by the platform on command completion.
Interrupt properties	Whether interrupt is level or edge triggered.
Register address	If the interrupt is level sensitive, the physical address of the interrupt clearing register that must be written to, to clear the interrupt.
Preserve Mask	If the interrupt is level sensitive, mask of bits that must be preserved when accessing the register to clear the interrupt.
Modify Mask	If the interrupt is level sensitive, mask of bits that must be set when accessing the register to clear the interrupt.

If the interrupt is level-sensitive, it can be shared by more than one channel. In this case, the preserve- and modify-masks must be unique for each channel.

5.2 ACPI-based Transport

ACPI-based implementations can leverage SCMI protocols to provide platform services using standard ACPI methods. For example, a device may be power managed by an ACPI-aware OS using the standard ACPI control methods that are described in [ACPI]. These ACPI methods can internally send SCMI Power Management Protocol requests to the platform to transition the power state of the device. In such an implementation, the platform is an ACPI-compliant platform controller as defined by Chapter 14 of [ACPI]. The SCMI transport is represented as a standard ACPI Platform Communications Channel (PCC) of Type 3. SCMI transports that follow the format outlined in section 5.1 are compatible with PCC type 3 channel definition. Also, ACPI version 6.3 introduces the concept and use of PCC operation regions. This enables ACPI methods that rely on underlying SCMI services to access the SCMI transport through PCC operation regions.

5.3 Shared Memory or MMIO based Transport for FastChannels

FastChannels might rely on the use of shared memory between the platform and the agents. Alternatively, FastChannels can be MMIO based. Any MMIO or shared memory based FastChannel must be visible and readable by both the caller and the callee. However, only the caller or the callee, but not both, must have write permissions to enforce unidirectionality. FastChannels must be mapped as non-cached device memory.

A FastChannel:

a) must be the same width as the payload requirements of the message for which the FastChannel is used. The payload layout of the FastChannel is described in the relevant Protocol sections.

b) can have optional doorbell support. The doorbell can be used to inform the platform that the agent has posted a new request over the FastChannel. If doorbell support is absent, the platform might need to poll over the FastChannel for any messages from the agent.

The discovery of the FastChannel is described in the relevant Protocol sections.

