Document Identifier: DSP0274

Date: 2020-03-18

Version: 1.1.0b

Security Protocol and Data Model (SPDM) Specification

Information for Work-in-Progress version:

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Supersedes: 1.1.0a

Document Class: Normative

Document Status: Work In Progress

Document Language: en-US

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1 Foreword

The Platform Management Components Intercommunication (PMCI) working group of the DMTF prepared the *Security Protocol and Data Model (SPDM) Specification* (DSP0274). DMTF is a not-for-profit association of industry members that promotes enterprise and systems management and interoperability. For information about the DMTF, see https://www.dmtf.org.

2 Acknowledgments

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3 Abstract

The *Security Protocol and Data Model (SPDM) Specification* defines *messages*, data objects, and sequences for performing message exchanges between *devices* over a variety of transport and physical media. The description of message exchanges includes *authentication* of hardware identities, measurement for firmware identities and session key exchange protocols to enable confidentiality and integrity protected data communication. The SPDM enables efficient access to low-level security capabilities and operations. Other mechanisms, including non-PMCI- and DMTF-defined mechanisms, can use the SPDM.

3.1 Scope

This specification describes how to use messages, data objects, and sequences to exchange messages between two devices over a variety of transports and physical media. This specification contains the message exchanges, sequence diagrams, message formats, and other relevant semantics for such message exchanges, including authentication of hardware identities and firmware measurement.

Other specifications define the mapping of these messages to different transports and physical media. This specification provides information to enable security policy enforcement but does not specify individual policy decisions.

3.2 Normative references

The following documents are indispensable for the application of this specification. For dated or versioned references, only the edition cited, including any corrigenda or DMTF update versions, applies. For references without a date or version, the latest published edition of the referenced document (including any corrigenda or DMTF update versions) applies.

- *ISO/IEC Directives, Part 2, Principles and rules for the structure and drafting of ISO and IEC documents - 2018 (8th edition)*
- DMTF DSP0004, *Common Information Model (CIM) Metamodel*, https://www.dmtf.org/sites/default/files/standards/documents/DSP0004_3.0.1.pdf
- DMTF DSP0223, *Generic Operations*, https://www.dmtf.org/sites/default/files/standards/documents/DSP0223_1.0.1.pdf
- DMTF DSP0236, *MCTP Base Specification 1.3.0*, https://dmtf.org/sites/default/files/standards/documents/DSP0236_1.3.0.pdf
- DMTF DSP0239, *MCTP IDs and Codes 1.6.0*, https://www.dmtf.org/sites/default/files/standards/documents/DSP0239_1.6.0.pdf
- DMTF DSP0240, *Platform Level Data Model (PLDM) Base Specification*, https://www.dmtf.org/sites/default/files/standards/documents/DSP0240_1.0.0.pdf

- DMTF DSP0275, *Security Protocol and Data Model (SPDM) over MCTP Binding Specification*, https://www.dmtf.org/dsp/DSP0275
- DMTF DSP1001, *Management Profile Usage Guide*, https://www.dmtf.org/sites/default/files/standards/documents/DSP1001_1.2.0.pdf
- *ISO/IEC Directives, Part 2, Principles and rules for the structure and drafting of ISO and IEC documents*, https://isotc.iso.org/livelink/livelink.exe?func=ll&objId=4230456&objAction=browse&sort=subtype
- IETF RFC5234, *Augmented BNF for Syntax Specifications: ABNF*, January 2008
- *USB Authentication Specification Rev 1.0 with ECN and Errata through January 7, 2019*
- *TCG Algorithm Registry, Family "2.0", Level 00 Revision 01.27*, February 7, 2018
- **ASN.1 — ISO-822-1-4**
  - ITU-T X.680, 08/2015
  - ITU-T X.681, 08/2015
  - ITU-T X.682, 08/2015
  - ITU-T X.683, 08/2015
- **DER — ISO-8825-1**
  - ITU-T X.690, 08/2015
- **X.509 — ISO-9594-8**
  - ITU-T X.509, 08/2015
- **ECDSA**
  - Section 6, The Elliptic Curve Digital Signature Algorithm (ECDSA) in FIPS PUB 186-4 Digital Signature Standard (DSS)
  - Appendix D: Recommended Elliptic Curves for Federal Government Use in FIPS PUB 186-4 Digital Signature Standard (DSS)
- **RSA**
  - Table 3 in *TCG Algorithm Registry Family “2.0" Level 00 Revision 01.22*, February 9, 2015
- **SHA2-256**, **SHA2-384**, and **SHA2-512**
  - FIPS PUB 180-4 Secure Hash Standard (SHS)
- **SHA3-256**, **SHA3-384**, and **SHA3-512**
  - FIPS PUB 202 SHA-3 Standard: Permutation-Based Hash and Extendable-Output Functions
- **Transport Layer Security 1.3**
  - TLS 1.3 RFC 8446

3.3 Terms and definitions

In this document, some terms have a specific meaning beyond the normal English meaning. This clause defines those terms.

The terms "shall" ("required"), "shall not", "should" ("recommended"), "should not" ("not recommended"), "may", "need not" ("not required"), "can" and "cannot" in this document are to be interpreted as described in ISO/IEC Directives, Part 2, Clause 7. The terms in parenthesis are alternatives for the preceding term, for use in exceptional cases when the preceding term cannot be used for linguistic reasons. Note that ISO/IEC Directives, Part 2, Clause 7 specifies additional alternatives. Occurrences of such additional alternatives shall be interpreted in their normal English meaning.

The terms "clause", "subclause", "paragraph", and "annex" in this document are to be interpreted as described in ISO/IEC Directives, Part 2, Clause 6.

The terms "normative" and "informative" in this document are to be interpreted as described in ISO/IEC Directives, Part 2, Clause 3. In this document, clauses, subclauses, or annexes labeled "(informative)" do not contain normative content. Notes and examples are always informative elements.

The terms that DSP0004, DSP0233, DSP0236, DSP0239, DSP0275, and DSP1001 define also apply to this document.

This specification uses these terms:

Term	Definition
application data	Data that is specific to the application and whose definition and format is outside the scope of this specification. Application data usually exist at the application layer, which is, in general, the layer above SPDM and the transport layer.
authentication	Process of determining whether an entity is who or what it claims to be.
authentication initiator	Endpoint that initiates the authentication process by challenging another endpoint.
byte	Eight-bit quantity. Also known as an *octet*.
certificate	Digital form of identification that provides information about an entity and certifies ownership of a particular asymmetric key-pair.
certificate authority (CA)	Trusted third-party entity that issues certificates.
certificate chain	Series of two or more certificates. Each certificate is signed by the preceding certificate in the chain.
component	Physical entity similar to the PCI Express specification’s definition.
device	Physical entity such as a network controller or a fan.
DMTF	Formerly known as the Distributed Management Task Force, the DMTF creates open manageability standards that span diverse emerging and traditional information technology (IT) infrastructures, including cloud, virtualization, network, servers, and storage. Member companies and alliance partners worldwide collaborate on standards to improve the interoperable management of IT.
endpoint	Logical entity that communicates with other endpoints over one or more transport protocol.
intermediate certificate	Certificate that is neither a root certificate nor a leaf certificate.

Term	Definition
leaf certificate	Last certificate in a certificate chain.
measurement	Representation of firmware/software or configuration data on an endpoint.
message	See SPDM message.
message body	Portion of a SPDM message that carries additional data.
message originator	Original transmitter, or source, of a SPDM message.
message transcript	The concatenation of a sequence of messages in the order in which they are sent and received by an endpoint. The final message included in the message transcript may be truncated to allow inclusion of a signature in that message which is computed over the message transcript. If an endpoint is communicating with multiple peer endpoints concurrently, the message transcripts for the peers are accumulated separately and independently.
most significant byte (MSB)	Highest order *byte* in a number consisting of multiple bytes.
Negotiated State	Set of parameters that represent the state of the communication between a corresponding pair of Requester and Responder at the successful completion of the `NEGOTIATE_ALGORITHMS` messages. These parameters may include values provided in `VERSION` , `CAPABILITIES` and `ALGORITHMS` messages. Additionally, they may include parameters associated with the transport layer. They may include other values deemed necessary by the Requester or Responder to continue or preserve communication with each other.
nibble	Computer term for a four-bit aggregation, or half of a byte.
nonce	Number that is unpredictable to entities other than its generator. The probability of the same number occurring more than once is negligible. Nonce may be generated by combining a pseudo random number of at least 64 bits, optionally concatenated with a monotonic counter of size suitable for the application.
payload	Information-bearing fields of a message. These fields are separate from the fields and elements, such as address fields, framing bits, checksums, and so on, that transport the message from one point to another. In some instances, a field can be both a payload field and a transport field.
physical transport binding	Specifications that define how a base messaging protocol is implemented on a particular physical transport type and medium, such as SMBus/I^2C, PCI Express™ Vendor Defined Messaging, and so on.
Platform Management Component Intercommunications (PMCI)	Working group under the DMTF that defines standardized communication protocols, low-level data models, and transport definitions that support communications with and between management controllers and management devices that form a platform management subsystem within a managed computer system.
record	A record is a unit or chunk of data that is either encrypted and/or authenticated.

Term	Definition
Requester	Original transmitter, or source, of a SPDM request message. It is also the ultimate receiver, or destination, of a SPDM response message.
Responder	Ultimate receiver, or destination, of a SPDM request message. It is also the original transmitter, or source of a SPDM response message.
root certificate	First certificate in a certificate chain, which is self-signed.
session keys	Session Keys are any secrets, derived cryptographic keys or any cryptographic information bound to the session.
Session-Secrets-Exchange	This term denotes any SPDM request and their corresponding response that initiates a session and provides initial cryptographic exchange. Examples of such requests are `KEY_EXCHANGE` and `PSK_EXCHANGE` .
Session-Secrets-Finish	This term denotes any SPDM request and their corresponding response that finalizes a session setup and provides the final exchange of cryptographic or other information before application data can be securely transmitted. Examples of such requests are `FINISH` and `PSK_FINISH` .
secure session	A secure session is a session that provides either or both of encryption or message authentication for communicating data over a transport.
SPDM message	Unit of communication in SPDM communications.
SPDM message payload	Portion of the message body of a SPDM message. This portion of the message is separate from those fields and elements that identify the SPDM version, the SPDM request and response codes, and the two parameters.
SPDM request message	Message that is sent to an endpoint to request a specific SPDM operation. A corresponding SPDM response message acknowledges receipt of a SPDM request message.
SPDM response message	Message that is sent in response to a specific SPDM request message. This message includes a `Response Code` field that indicates whether the request completed normally.
trusted computing base (TCB)	Set of all hardware, firmware, and/or software components that are critical to its security, in the sense that bugs or vulnerabilities occurring inside the TCB might jeopardize the security properties of the entire system. By contrast, parts of a computer system outside the TCB must not be able to misbehave in a way that would leak any more privileges than are granted to them in accordance to the security policy. Reference: https://en.wikipedia.org/wiki/Trusted_computing_base

3.4 Symbols and abbreviated terms

The abbreviations defined in DSP0004, DSP0223, and DSP1001 apply to this document.

The following additional abbreviations are used in this document.

Abbreviation	Definition
CA	*certificate authority*
MAC	Message Authentication Code
DMTF	Formerly the *Distributed Management Task Force*
MSB	*most significant byte*
PMCI	*Platform Management Component Intercommunications*
SPDM	Security Protocol and Data Model
TCB	*trusted computing base*
AEAD	Authenticated Encryption with Associated Data

3.5 Conventions

The following conventions apply to all SPDM specifications.

3.5.1 Document conventions

- Document titles appear in *italics*.
- The first occurrence of each important term appears in *italics* with a link to its definition.
- ABNF rules appear in a monospaced font.

3.5.2 Reserved and unassigned values

Unless otherwise specified, any reserved, unspecified, or unassigned values in enumerations or other numeric ranges are reserved for future definition by the DMTF.

Unless otherwise specified, reserved numeric and bit fields shall be written as zero (`0`) and ignored when read.

3.5.3 Byte ordering

Unless otherwise specified, for all SPDM specifications *byte* ordering of multi-byte numeric fields or multi-byte bit fields is "Little Endian"(that is, the lowest byte offset holds the least significant byte, and higher offsets hold the more significant bytes).

3.5.4 SPDM data types

The SPDM data types table lists the abbreviations and descriptions for common data types that SPDM message fields and data structure definitions use. These definitions follow DSP0240.

SPDM data types

Data type	Interpretation
`ver8`	Eight-bit encoding of the SPDM version number. Version encoding defines the encoding of the version number.
`bitfield8`	Byte with eight bit fields. Each bit field can be separately defined.
`bitfield16`	Two-byte word with 16-bit fields. Each bit field can be separately defined.

3.5.5 Version encoding

The `SPDMVersion` field represents the version of the specification through a combination of *Major* and *Minor* nibbles, encoded as follows:

Version	Matches	Incremented when
Major	Major version field in the `SPDMVersion` field in the SPDM message header.	Protocol modification breaks backward compatibility.
Minor	Minor version field in the `SPDMVersion` field in the SPDM message header.	Protocol modification maintains backward compatibility.

EXAMPLE:

Version 3.7 → `0x37`

Version 1.0 → `0x10`

Version 1.2 → `0x12`

An *endpoint* that supports Version 1.2 can interoperate with an older endpoint that supports Version 1.0 only, but the available functionality is limited to what SPDM specification Version 1.0 defines.

An endpoint that supports Version 1.2 only and an endpoint that supports Version 3.7 only are not interoperable and shall not attempt to communicate beyond `GET_VERSION`.

The detailed version encoding that the `VERSION` response message returns contains an additional byte that indicates specification bug fixes or development versions. See the Successful VERSION response message table.

3.5.6 Notations

SPDM specifications use the following notations:

Notation	Description
`M:N`	In field descriptions, this notation typically represents a range of byte offsets starting from byte `M` and continuing to and including byte `N` (`M ≤ N`). The lowest offset is on the left. The highest offset is on the right.
`[4]`	Square brackets around a number typically indicate a bit offset. Bit offsets are zero-based values. That is, the least significant bit.
`[M:N]`	A range of bit offsets where M is greater than or equal to N. The most significant bit is on the left, and the least significant bit is on the right.
`1b`	A lowercase `b` after a number consisting of `0` s and `1` s indicates that the number is in binary format.
`0x12A`	A leading `0x` indicates that the number is in hexadecimal format.
`N+`	This indicates a variable length byte range that starts at byte offset N.
`{ Payload }`	Used mostly in figures, this notation indicates the payload specified in the enclosing curly brackets is encrypted and/or authenticated by the keys derived from one or more major secrets. The specific secret used is described throughout this specification. For example, `{ HEARTBEAT }` shows that the Heartbeat message is encrypted and/or authenticated by the keys derived from one or more major secrets.
`{ Payload }::[[`S_X`]]`	Used mostly in figures, this notation indicates the payload specified in the enclosing curly brackets is encrypted and/or authenticated by the keys derived from major Secret X. For example, `{ HEARTBEAT }::[[`S_2`]]` shows that the Heartbeat message is encrypted and/or authenticated by the keys derived from major secret S_2.

4 SPDM message exchanges

The message exchanges defined in this specification are between two endpoints and are performed and exchanged through sending and receiving of SPDM messages defined in SPDM messages. The SPDM message exchanges are defined in a generic fashion that allows the messages to be communicated across different physical mediums and over different transport protocols.

The specification-defined message exchanges enable Requesters to:

- Discover and negotiate the security capabilities of a Responder.
- Authenticate the identity of a Responder.
- Retrieve the measurements of a Responder.
- Securely establish cryptographic session keys to construct a secure communication channel for the transmission or reception of application data.

These message exchange capabilities are built on top of well-known and established security practices across the computing industry. A brief overview for each of the message exchange capabilities is described in the following clauses. Some of the message exchange capabilities are based on the security model defined in USB Authentication Specification Rev 1.0.

4.1 Security capability discovery and negotiation

This specification defines a mechanism for a Requester to discover the security capabilities of a Responder. For example, an endpoint could support multiple cryptographic hash functions that are defined in this specification. Furthermore, the specification defines a mechanism for a Requester and Responder to select a common set of cryptographic algorithms to use for all subsequent message exchanges before another negotiation is initiated by the Requester, if an overlapping set of cryptographic algorithms exists that both endpoints support.

4.2 Identity authentication

In this specification, the authenticity of a Responder is determined by digital signatures using well-established techniques based on public key cryptography. A Responder proves its identity by generating digital signatures using a private key, and the signatures can be cryptographically verified by the Requester using the public key associated with that private key.

At a high-level, the authentication of a Responder's identity involves these processes:

- **Identity provisioning**

  The process followed by device vendors during or after hardware manufacturing. A trusted root *certificate* *authority (CA)* generates a *root certificate* (*RootCert*) that is provisioned to the *authentication initiator*. The authentication initiator uses this certificate to verify the validity of certificate chains. A device carries a *certificate chain*, which has the RootCert as the root of the certificate chain and a device certificate (*DeviceCert*) as the *leaf certificate* of the certificate chain. The device certificate contains the public key that corresponds to the device private key.

Through the certificate chain, the root CA indirectly endorses the per-device public/private key pair in the DeviceCert, where the private key is provisioned to or generated by the endpoint.

- **Runtime authentication**

  The process by which an authentication initiator (Requester) interacts with a Responder in a running system. The authentication initiator can retrieve the certificate chain(s) from the Responder and send a unique challenge to the Responder. The Responder then signs the challenge with the private key. The authentication initiator verifies the signature using the public key of the Responder as well as any intermediate public keys within the certificate chain using the root certificate as the trusted anchor.

4.3 Firmware and configuration measurement

A measurement is a representation of firmware/software or configuration data on an endpoint. A measurement is typically a cryptographic hash value of the data, or the raw data itself. The endpoint optionally binds a measurement with the endpoint identity through the use of digital signatures. This binding enables an authentication initiator to establish the identity and measurement of the firmware/software or configuration running on the endpoint.

4.4 Secure Session

Many devices communicate to other devices and the data they exchange may require protection. In this specification, the device-specific data that is communicated is generically referred to as application data. The application data's protocol usually exists at a higher layer and it is outside the scope of this specification.

To protect the application data as it is traverses over a physical medium, this specification arranges for initial cryptographic information exchange and derivation of secrets in order to establish a protected channel of communication. This protection is achieved through the use of encryption and message authentication. For more details, please see the Session section.

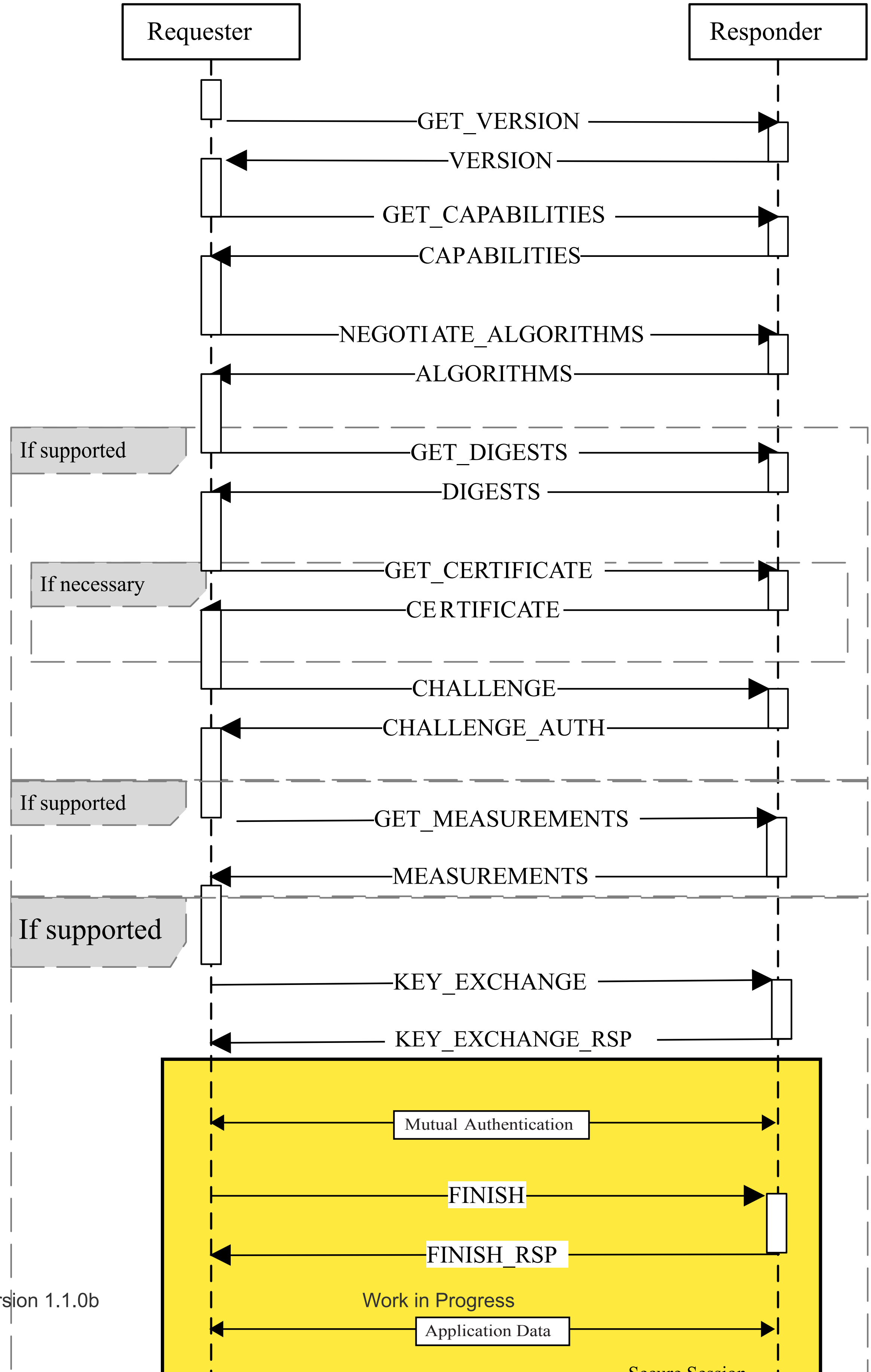
Lastly, but not the least, many SPDM requests and their corresponding responses are also afforded the same protection. Thus, these requests and responses are only allowed to be sent in a secure session. See the SPDM Request and Response Validity Table and SPDM Request and Response Code Issuance Allowance section for more details.

The SPDM messaging protocol flow gives a very high level view on when the secure session actually starts.

5 SPDM messaging protocol

The SPDM messaging protocol defines a request-response messaging model between two endpoints to perform the message exchanges outlined in SPDM message exchanges. Each SPDM request message shall be responded to with a SPDM response message as defined in this specification unless otherwise stated in this specification.

The SPDM messaging protocol flow depicts the high-level request-response flow diagram for SPDM. An endpoint that acts as the *Requester* sends a SPDM request message to another endpoint that acts as the *Responder*, and the Responder returns a SPDM response message to the Requester.


Requester
Responder
GET_VERSION
VERSION
GET_CAPABILITIES
CAPABILITIES
NEGOTIATE_ALGORITHMS
ALGORITHMS
If supported
GET_DIGESTS
DIGESTS
If necessary
GET_CERTIFICATE
CERTIFICATE
CHALLENGE
CHALLENGE_AUTH
If supported
GET_MEASUREMENTS
MEASUREMENTS
If supported
KEY_EXCHANGE
KEY_EXCHANGE_RSP
Mutual Authentication
FINISH
FINISH_RSP
Application Data

All SPDM request-response messages share a common data format, that consists of a four-byte message header and zero or more bytes message payload that is message-dependent. The following clauses describe the common message format and SPDM messages details each of the request and response messages.

The Requester shall issue `GET_VERSION`, `GET_CAPABILITIES`, and `NEGOTIATE_ALGORITHMS` request messages before issuing any other request messages. The responses to `GET_VERSION`, `GET_CAPABILITIES`, and `NEGOTIATE_ALGORITHMS` may be saved by the requester so that after reset the requester may skip these requests.

5.1 SPDM Bits to Bytes Mapping

All SPDM fields, regardless of size or endianness, map the highest numeric bits to the highest numerically assigned byte in monotonically decreasing order until the the least numerically assigned byte of that field. The following two figures illustrate this mapping.

One-Byte Field Bit Map

Example: A One-Byte Field

Byte 1							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

Two-Byte Field Bit Map

Example: A Two-Byte Field

Byte 3								Byte 2							
Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

5.2 Generic SPDM message format

Table 3 defines the fields that constitute a generic SPDM message, including the message header and payload.

Table 3 — Generic SPDM message field definitions

Byte	Bits	Length (bits)	Field name	Description
`0`	`[7:4]`	4	SPDM Major Version	The major version of the SPDM Specification. An endpoint shall not communicate by using an incompatible SPDM version value. See Version encoding.
`0`	`[3:0]`	4	SPDM Minor Version	The minor version of the SPDM Specification. A specification with a given minor version extends a specification with a lower minor version as long as they share the major version. See Version encoding.
`1`	`[7:0]`	8	Request Response Code	The request message code or response code, which are enumerated in Table 4 and Table 5. `0x00` through `0x7F` represent response codes and `0x80` through `0xFF` represent request codes. In request messages, this field is considered the request code. In response messages, this field is considered the response code.
`2`	`[7:0]`	8	Param1	The first one-byte parameter. The contents of the parameter is specific to the Request Response Code.
`3`	`[7:0]`	8	Param2	The second one-byte parameter. The contents of the parameter is specific to the Request Response Code.
`4`	See Description	Variable	SPDM message payload	Zero or more bytes that are specific to the Request Response Code.

5.3 SPDM request codes

The SPDM request codes table defines the SPDM request codes. The **Implementation Requirement** column indicates requirements on the Requester.

All SPDM-compatible implementations shall use the following SPDM request codes.

Unsupported request codes shall return an `ERROR` response message with `ErrorCode=UnsupportedRequest`.

SPDM request codes

Request	Code value	Implementation requirement	Message format
`GET_DIGESTS`	`0x81`	Optional	See the GET_DIGESTS request message table.
`GET_CERTIFICATE`	`0x82`	Optional	See the GET_CERTIFICATE request message table.
`CHALLENGE`	`0x83`	Optional	See the CHALLENGE request message table.

Request	Code value	Implementation requirement	Message format
`GET_VERSION`	`0x84`	Required	See the GET_VERSION request message table.
`GET_MEASUREMENTS`	`0xE0`	Optional	See the GET_MEASUREMENTS request message table.
`GET_CAPABILITIES`	`0xE1`	Required	See the GET_CAPABILITIES request message table.
`NEGOTIATE_ALGORITHMS`	`0xE3`	Required	See the NEGOTIATE_ALGORITHMS request message table.
`KEY_EXCHANGE`	`0xE4`	Optional	See the KEY_EXCHANGE request message table.
`FINISH`	`0xE5`	Optional	See the FINISH request message table.
`PSK_EXCHANGE`	`0xE6`	Optional	See the PSK_EXCHANGE request message table.
`PSK_FINISH`	`0xE7`	Optional	See the PSK_FINISH request message table.
`HEARTBEAT`	`0xE8`	Optional	See the HEARTBEAT request message table.
`KEY_UPDATE`	`0xE9`	Optional	See the KEY_UPDATE request message table.
`GET_ENCAPSULATED_REQUEST`	`0xEA`	Optional	See the GET_ENCAPSULATED_REQUEST request message table.
`DELIVER_ENCAPSULATED_RESPONSE`	`0xEB`	Optional	See the DELIVER_ENCAPSULATED_RESPONSE request message table.
`END_SESSION`	`0xEC`	Optional	See the END_SESSION request message table.
`RESPOND_IF_READY`	`0xFF`	Required	See the RESPOND_IF_READY request message table.
`VENDOR_DEFINED_REQUEST`	`0xFE`	Optional	See the VENDOR_DEFINED_REQUEST request message table.
Reserved	`0x80` , `0x85` - `0xDF` , `0xE2` , `0xED` - `0xFD`	SPDM implementations compatible with this version shall not use the reserved request codes.	

5.4 SPDM response codes

The Request Response Code field in the SPDM response message shall specify the appropriate response code for a request. All SPDM-compatible implementations shall use the following SPDM response codes.

On a successful completion of a SPDM operation, the specified response message shall be returned. Upon an unsuccessful completion of a SPDM operation, the `ERROR` response message shall be returned.

The SPDM response codes table defines the response codes for SPDM. The **Implementation Requirement** column indicates requirements on the Responder.

SPDM response codes

Response	Value	Implementation requirement	Message format
`DIGESTS`	`0x01`	Optional	See the GET_DIGESTS request message table.
`CERTIFICATE`	`0x02`	Optional	See the GET_CERTIFICATE request message table.
`CHALLENGE_AUTH`	`0x03`	Optional	See the CHALLENGE request message table.
`VERSION`	`0x04`	Required	See the Successful VERSION response message table.
`MEASUREMENTS`	`0x60`	optional	See the GET_MEASUREMENTS request message table.
`CAPABILITIES`	`0x61`	Required	See the Successful CAPABILITIES response message table.
`ALGORITHMS`	`0x63`	Required	See the Successful ALGORITHMS response message table.
`KEY_EXCHANGE_RSP`	`0x64`	Optional	See the KEY_EXCHANGE_RSP response message table.
`FINISH_RSP`	`0x65`	Optional	See the FINISH_RSP response message table.
`PSK_EXCHANGE_RSP`	`0x66`	Optional	See the PSK_EXCHANGE_RSP response message table.
`PSK_FINISH_RSP`	`0x67`	Optional	See the PSK_FINISH_RSP response message table.

Response	Value	Implementation requirement	Message format
`HEARTBEAT_ACK`	`0x68`	Optional	See the HEARTBEAT_ACK response message table.
`KEY_UPDATE_ACK`	`0x69`	Optional	See the KEY_UPDATE_ACK response message table.
`ENCAPSULATED_REQUEST`	`0x6A`	Optional	See the ENCAPSULATED_REQUEST response message table.
`ENCAPSULATED_RESPONSE_ACK`	`0x6B`	Optional	See the ENCAPSULATED_RESPONSE_ACK response message table.
`END_SESSION_ACK`	`0x6C`	Optional	See the END_SESSION_ACK response message table.
`VENDOR_DEFINED_RESPONSE`	`0x7E`	Optional	See the VENDOR_DEFINED_RESPONSE response message table.
`ERROR`	`0x7F`		See the ERROR response message table.
Reserved	`0x00` , `0x05` - `0x5F` , `0x62` , `0x6D` - `0x7D`	SPDM implementations compatible with this version shall not use the reserved response codes.	

5.5 SPDM Request and Response Code Issuance Allowance

The SPDM Request and Response Validity Table describes the conditions under which a request and response can be issued.

The **Session** column describes whether the respective request and response can be sent in a session. If the value is *"Allowed"*, the issuer of the request and response shall only send it in a secure session; thereby, affording them the protection of a secure session. If the value is "*Prohibited*" in the **Session** column, the issuer shall be prohibited from sending the respective request and response in a secure session.

The column, **Outside of a Session**, indicates which requests and responses are allowed to be sent free and independent of a session; thereby lacking the protection of a secure session. An *"Allowed"* in this column shall require the respective request and response to only be sent outside the context of a secure session. Likewise, a *"Prohibited"* in this column shall prohibit the issuer from sending the respective request or response outside the context of a session.

A request and its corresponding response can have an *"Allowed"* in both the **Session** column and **Outside of a**

Session column, in which case, they are allowed to be sent and received in both scenarios but may have additional restrictions. See the respective request and response section for further details.

Finally, the **Session Phases** column describes which phases of a session the respective request and response shall be issued when they are allowed to be issued in a session.

Please see the Session Section for further session details.

SPDM Request and Response Validity Table

Request	Response	Session	Outside of a Session	Session Phases
`FINISH`	`FINISH_RSP`	Allowed	Prohibited	Session Handshake
`PSK_FINISH`	`PSK_FINISH_RSP`	Allowed	Prohibited	Session Handshake
`HEARTBEAT`	`HEARTBEAT_ACK`	Allowed	Prohibited	Application Phase
`KEY_UPDATE`	`KEY_UPDATE_ACK`	Allowed	Prohibited	Application Phase
Not Applicable	`ERROR`	Allowed	Allowed	All Phases
`GET_ENCAPSULATED_REQUEST`	`ENCAPSULATED_REQUEST`	Allowed	Allowed	All Phases
`DELIVER_ENCAPSULATED_RESPONSE`	`ENCAPSULATED_RESPONSE_ACK`	Allowed	Allowed	All Phases
`VENDOR_DEFINED_REQUEST`	`VENDOR_DEFINED_RESPONSE`	Allowed	Allowed	Application Phase
All Others	All others	Prohibited	Allowed	Not Applicable

For `ERROR` response in Session Handshake or Application Phase of a session, the Requester is only allowed in certain situations to send the ERROR response.

5.6 Concurrent SPDM message processing

This clause describes the specifications and requirements for handling concurrent overlapping SPDM request messages.

If an endpoint can act as both a Responder and Requester, it shall be able to send request messages and response messages independently.

5.7 Requirements for Requesters

A Requester shall not have multiple outstanding requests to the same Responder, with the exception of `GET_VERSION` addressed in GET_VERSION request message and VERSION response message. If the Requester has sent a request to a Responder and wants to send a subsequent request to the same Responder, then the Requester shall wait to send the subsequent request until after the Requester completes one of the following actions:

- Receives the response from the Responder for the outstanding request.
- Times out waiting for a response.
- Receives an indication, from the transport layer, that transmission of the request message failed.

A Requester may send simultaneous request messages to different Responders.

5.8 Requirements for Responders

A Responder is not required to process more than one request message at a time.

A Responder that is not ready to accept a new request message shall either respond with an `ERROR` response message with `ErrorCode=Busy` or silently discard the request message.

If a Responder is working on a request message from a Requester, the Responder may respond with `ErrorCode=Busy`.

If a Responder enables simultaneous communications with multiple Requesters, the Responder is expected to distinguish the Requesters by using mechanisms that are outside the scope of this specification.

6 Timing requirements

The Timing specification for SPDM messages table shows the timing specifications for Requesters and Responders.

If the Requester does not receive a response within **T1** or **T2** time accordingly, the Requester may retry a request message. A retry of a request message shall be a complete retransmission of the original SPDM request message.

The Responder shall not retry SPDM response messages. It is understood that the transport protocol(s) may retry, but that is outside of the SPDM specification.

6.1 Timing measurements

A Requester shall measure timing parameters, applicable to it, from the end of a successful transmission of a SPDM request to the beginning of the reception of the corresponding SPDM response. A Responder shall measure timing parameters, applicable to it, from the end of the reception of the SPDM request to the beginning of transmission of the response.

6.2 Timing specification table

The **Ownership** column in the Timing specification for SPDM messages table specifies whether the timing parameter applies to the Responder or Requester.

Timing specification for SPDM messages

Timing parameter	Ownership	Value	Units	Description
RTT	Requester	See the description.	us	Worst case round-trip transport timing. The maximum value shall be the worst case total time for the complete transmission and delivery of a SPDM message round trip at the transport layer(s). The actual value for this parameter is transport- or media-specific. Both the actual value and how an endpoint obtains this value are outside the scope of this specification.
ST1	Responder	100,000	us	Shall be the maximum amount of time the Responder has to provide a response to requests that do not require cryptographic processing, such as the `GET_CAPABILITIES`, `GET_VERSION`, or `NEGOTIATE_ALGORITHMS` request messages.
T1	Requester	RTT + ST1	us	Shall be the minimum amount of time the Requester shall wait before issuing a retry for requests that do not require cryptographic processing. For details, see `ST1`.

Timing parameter	Ownership	Value	Units	Description
CT	Responder	$2^{CTExponent}$	us	The `CAPABILITIES` message reports the cryptographic timeout, in microseconds. `CTExponent` is reported in `GET_CAPABILITIES`. This timing parameter shall be the maximum amount of time the Responder has to provide any response requiring cryptographic processing, such as the `GET_MEASUREMENTS` or `CHALLENGE` request messages.
T2	Requester	RTT + CT	us	Shall be the minimum amount of time the Requester shall wait before issuing a retry for requests that require cryptographic processing. For details, see `CT`.
RDT	Responder	$2^{RDTExponent}$	us	Recommended delay, in microseconds that the Responder needs to complete the requested cryptographic operation. When the Responder is unable to complete cryptographic processing response within the `CT` time, it shall provide `RDTExponent` as part of the `ERROR` response. See the ResponseNotReady extended error data table for the `RDTExponent` value. For details, see `ErrorCode=ResponseNotReady` in the ResponseNotReady extended error data table.
WT	Requester	RDT	us	Amount of time that the Requester should wait before issuing the `RESPOND_IF_READY` request message. The Requester shall measure this time parameter from the reception of the `ERROR` response to the transmission of `RESPOND_IF_READY` request. The Requester may take into account the transmission time of the `ERROR` from the Responder to Requester when calculating `WT`. For details, see `RDT`.
WT_{Max}	Requester	(RDT * RDTM) - RTT	us	Maximum wait time the Requester has to issue `RESPOND_IF_READY` request unless the Requester issued a successful `RESPOND_IF_READY` request message earlier. After this time the Responder is allowed to drop the response. The Requester shall take into account the transmission time of the `ERROR` from the Responder to Requester when calculating `WT` Max. The `RDTM` value appears in the ResponseNotReady extended error data. The Responder should ensure that `WT` Max does not result in less than `WT` in determination of `RDTM`. For details, see `ErrorCode=ResponseNotReady` in the ResponseNotReady extended error data table.

Timing parameter	Ownership	Value	Units	Description
HeartbeatPeriod	Requester and Responder	Variable	s	See HEARTBEAT Request and HEARTBEAT_ACK Response for detail.

7 SPDM messages

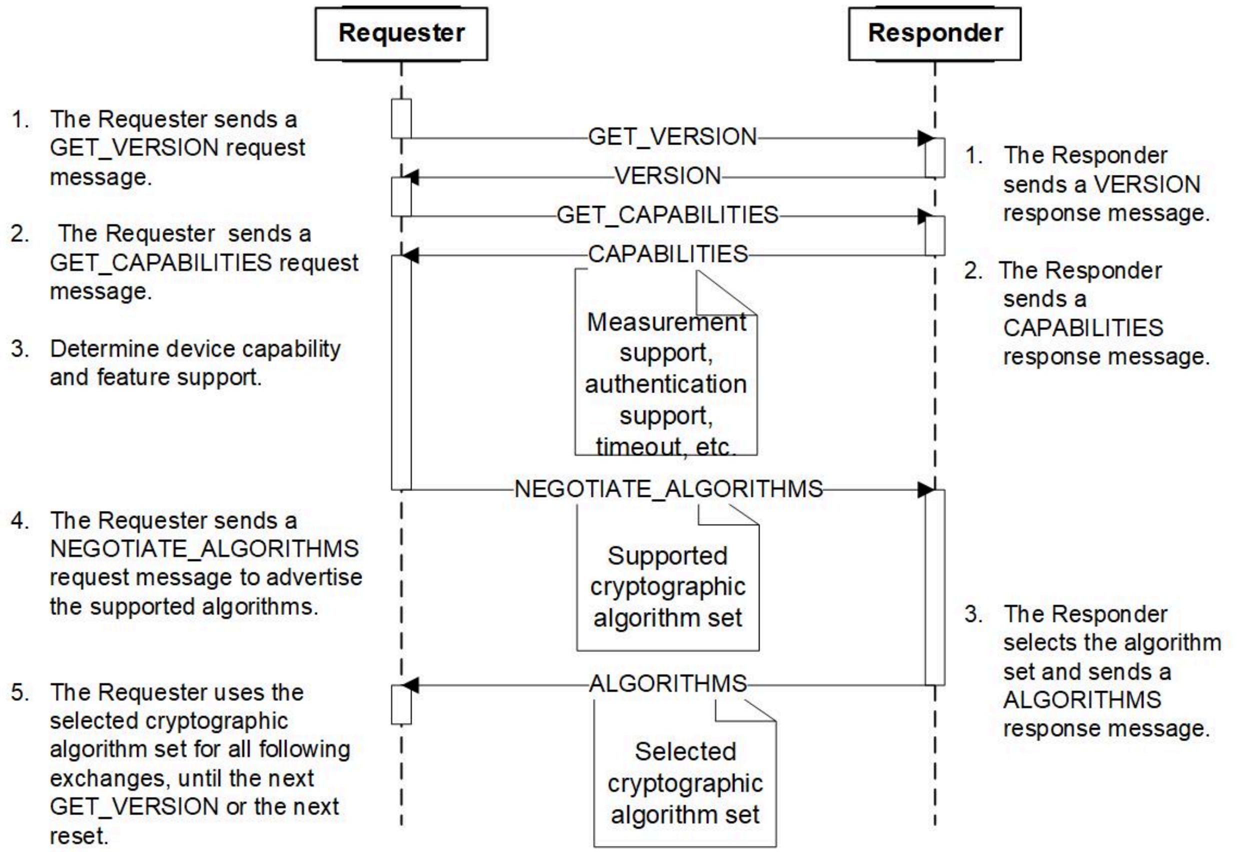
SPDM messages can be divided into the following categories, supporting different aspects of security exchanges between a Requester and Responder:

- Capability discovery and negotiation
- Responder identity authentication
- Firmware measurements
- Key agreement for secure channel establishment

7.1 Capability discovery and negotiation

All Requesters and Responders shall support `GET_VERSION` , `GET_CAPABILITIES` and `NEGOTIATE_ALGORITHMS` .

The Capability discovery and negotiation flow shows the high-level request-response flow and sequence for the capability discovery and negotiation:



7.2 GET_VERSION request message and VERSION response message

This request message shall retrieve an endpoint's SPDM version. The GET_VERSION request message table shows the `GET_VERSION` request message format and the Successful VERSION response message table shows the `VERSION` response message format.

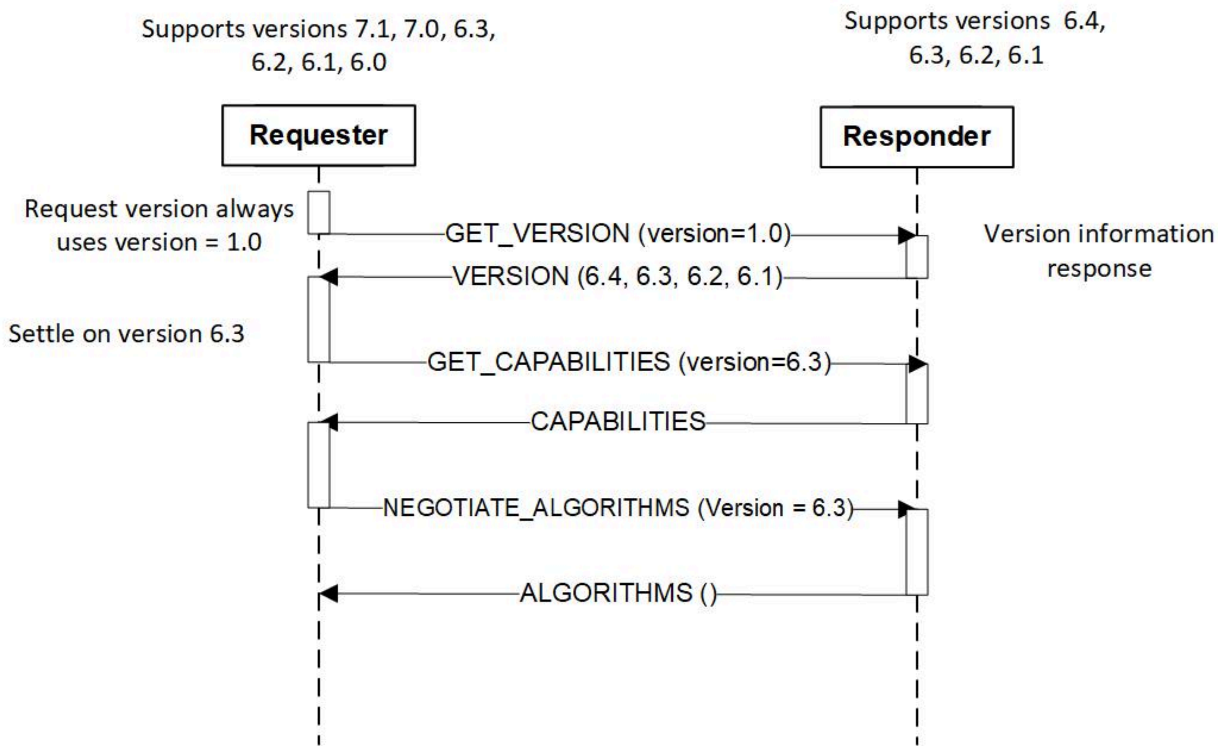
In all future SPDM versions, the `GET_VERSION` and `VERSION` response messages will be backward compatible with all previous versions.

The Requester shall begin the discovery process by sending a `GET_VERSION` request message with major version 0x1. All Responders must always support `GET_VERSION` request message with major version `0x1` and provide a `VERSION` response containing all supported versions, as the GET_VERSION request message table describes.

The Requester shall consult the `VERSION` response to select a common supported version, which is typically the latest supported common version. The Requester shall use the selected version in all future communication of other requests. A Requester shall not issue other requests until it receives a successful `VERSION` response and identifies a common version that both sides support. A Responder shall not respond to the `GET_VERSION` request message with `ErrorCode=ResponseNotReady`.

A Requester may issue a `GET_VERSION` request message to a Responder at any time, which is as an exception to Requirements for Requesters for the case where a Requester must restart the protocol due to an internal error or reset.

After receiving a `GET_VERSION` request, the Responder shall cancel all previous requests from the same Requester. Additionally, this message shall clear or reset the previously *Negotiated State*, if any, in both the Requester and its corresponding Responder.



GET_VERSION request message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x84=GET_VERSION`
2	`Param1`	1	Reserved
3	`Param2`	1	Reserved

Successful VERSION response message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x04=VERSION`
2	`Param1`	1	Reserved
3	`Param2`	1	Reserved
4	`Reserved`	1	Reserved
5	`VersionNumberEntryCount`	1	Number of version entries present in this table (=n).
6	`VersionNumberEntry1:n`	2 * n	16-bit version entry. See the GET_VERSION request message table.

VersionNumberEntry definition

Bit	Field	Value
`[15:12]`	`MajorVersion`	Version of the specification with changes that are incompatible with one or more functions in earlier major versions of the specification.
`[11:8]`	`MinorVersion`	Version of the specification with changes that are compatible with functions in earlier minor versions of this major version specification.
`[7:4]`	`UpdateVersionNumber`	Version of the specification with editorial updates but no functionality additions or changes. Informational; possible errata fixes. Ignore when checking versions for interoperability.
`[3:0]`	`Alpha`	Pre-release work-in-progress version of the specification. Backward compatible with earlier minor versions of this major version specification. However, because the `Alpha` value represents an in-development version of the specification, versions that share the same major and minor version numbers but have different `Alpha` versions may not be fully interoperable. Released versions must have an Alpha value of zero.

7.3 GET_CAPABILITIES request message and CAPABILITIES response message

This request message shall retrieve an endpoint's SPDM capabilities.

The GET_CAPABILITIES request message table shows the `GET_CAPABILITIES` request message format.

The Successful CAPABILITIES response message table shows the `CAPABILITIES` response message format.

The Flag fields definitions table shows the flag fields definitions.

A Responder shall not respond to `GET_CAPABILITIES` request message with `ErrorCode=ResponseNotReady`.

GET_CAPABILITIES request message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0xE1=GET_CAPABILITIES`
2	`Param1`	1	Reserved
3	`Param2`	1	Reserved
4	`Reserved`	1	Reserved
5	`CTExponent`	1	Shall be exponent of base 2, which is used to calculate `CT`. See the Timing specification for SPDM messages table. The equation for `CT` shall be $2^{CTExponent}$ microseconds (us). For example, if `CTExponent` is 10, `CT` is 2^{10}=1024 us.
6	`Reserved`	2	Reserved
8	`Flags`	4	See the Requester Flag fields definitions table.

Successful CAPABILITIES response message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x61=CAPABILITIES`
2	`Param1`	1	Reserved
3	`Param2`	1	Reserved
4	`Reserved`	1	Reserved
5	`CTExponent`	1	Shall be the exponent of base 2, which used to calculate `CT`. See the Timing specification for SPDM messages table. The equation for `CT` shall be $2^{CTExponent}$ microseconds (us). For example, if `CTExponent` is 10, `CT` is 2^{10}=1024 us.

Offset	Field	Size (bytes)	Value
6	`Reserved`	2	Reserved
8	`Flags`	4	See the Responder Flag fields definitions table.

Requester Flag fields definitions

Byte	Bit	Field	Value
0	`0`	`Reserved`	Reserved
0	`1`	`CERT_CAP`	If set, Requester supports `DIGESTS` and `CERTIFICATE` response messages.
0	`2`	`CHAL_CAP`	If set, Requester supports `CHALLENGE_AUTH` response message.
0	`4:3`	`MEAS_CAP`	The Requester's `MEASUREMENT` response capabilities. • `00b` . The Requester does not support `MEASUREMENTS` response capabilities. • `01b` . The Requester supports `MEASUREMENTS` response but cannot perform signature generation. • `10b` . The Requester supports `MEASUREMENTS` response and can generate signatures. • `11b` . Reserved
0	`5`	`MEAS_FRESH_CAP`	• `0` . As part of `MEASUREMENTS` response message, the Requester may return `MEASUREMENTS` that were computed during the last Requester's reset. • `1` . The Requester can recompute all `MEASUREMENTS` in a manner that is transparent to the rest of the system and shall always return fresh `MEASUREMENTS` as part of `MEASUREMENTS` response message.
0	`6`	`ENCRYPT_CAP`	If set, Requester supports message encryption. If set, one or more of `PSK_CAP` or `KEY_EX_CAP` fields shall be specified accordingly to indicate support.
0	`7`	`MAC_CAP`	If set, Requester supports message authentication. If set, one or more of `PSK_CAP` or `KEY_EX_CAP` fields shall be specified accordingly to indicate support.
1	`0`	`MUT_AUTH_CAP`	If set, Requester supports mutual authentication.
1	`1`	`KEY_EX_CAP`	If set, Requester supports `KEY_EXCHANGE` messages. If set, one or more of `ENCRYPT_CAP` and `MAC_CAP` shall be set.
1	`3:2`	`PSK_CAP`	Requester's `Pre-Shared Key` capabilities. • `00b` . Requester does not support `Pre-Shared Key` capabilities. • `01b` . Requester supports `Pre-Shared Key` • `10b` and `11b` . Reserved. If supported, one or more of `ENCRYPT_CAP` and `MAC_CAP` shall be set.

Byte	Bit	Field	Value
1	4	ENCAP_CAP	If set, Requester supports GET_ENCAPSULATED_REQUEST , ENCAPSULATED_REQUEST , DELIVER_ENCAPSULATED_RESPONSE and ENCAPSULATED_RESPONSE_ACK messages. If mutual authentication is also supported by the Requester, this field shall be set also.
1	5	HBEAT_CAP	If set, Requester supports HEARTBEAT messages.
1	6	KEY_UPD_CAP	If set, Requester supports KEY_UPDATE messages.
1	7	HANDSHAKE_IN_THE_CLEAR_CAP	if set, Requester supports Delayed verified data capability during KEY_EXCHANGE messages. If set, KEY_EX_CAP shall be set.
2	7:0	Reserved	Reserved
3	7:0	Reserved	Reserved

Responder Flag fields definitions

Byte	Bit	Field	Value
0	0	CACHE_CAP	If set, the Responder supports the ability to cache the *Negotiated State* across a reset. This allows the Requester to skip reissuing the GET_VERSION , GET_CAPABILITIES and NEGOTIATE_ALGORITHMS requests after a reset. The Responder shall cache the selected cryptographic algorithms as one of the parameters of the Negotiated State. If the Requester chooses to skip issuing these requests after the reset, the Requester shall also cache the same selected cryptographic algorithms.
0	1	CERT_CAP	If set, Responder supports DIGESTS and CERTIFICATE response messages.
0	2	CHAL_CAP	If set, Responder supports CHALLENGE_AUTH response message.
0	4:3	MEAS_CAP	The Responder's MEASUREMENT response capabilities. • 00b . The Responder does not support MEASUREMENTS response capabilities. • 01b . The Responder supports MEASUREMENTS response but cannot perform signature generation. • 10b . The Responder supports MEASUREMENTS response and can generate signatures. • 11b . Reserved
0	5	MEAS_FRESH_CAP	• 0 . As part of MEASUREMENTS response message, the Responder may return MEASUREMENTS that were computed during the last Responder's reset. • 1 . The Responder can recompute all MEASUREMENTS in a manner that is transparent to the rest of the system and shall always return fresh MEASUREMENTS as part of MEASUREMENTS response message.
0	6	ENCRYPT_CAP	If set, Responder supports message encryption. If set, one or more of PSK_CAP or KEY_EX_CAP fields shall be specified accordingly to indicate support.

Byte	Bit	Field	Value
0	`7`	`MAC_CAP`	If set, Responder supports message authentication. If set, one or more of `PSK_CAP` or `KEY_EX_CAP` fields shall be specified accordingly to indicate support.
1	`0`	`MUT_AUTH_CAP`	If set, Responder supports mutual authentication.
1	`1`	`KEY_EX_CAP`	If set, Responder supports `KEY_EXCHANGE` messages. If set, one or more of `ENCRYPT_CAP` and `MAC_CAP` shall be set.
1	`3:2`	`PSK_CAP`	Responder's `Pre-Shared Key` capabilities. • `00b` . Responder does not support `Pre-Shared Key` capabilities. • `01b` . Responder supports `Pre-Shared Key` but does not provide ResponderContext for session key derivation. • `10b` . Responder supports `Pre-Shared Key` and provides ResponderContext for session key derivation. • `11b` . Reserved If supported, one or more of `ENCRYPT_CAP` and `MAC_CAP` shall be set.
1	`4`	`ENCAP_CAP`	If set, Responder supports `GET_ENCAPSULATED_REQUEST` , `ENCAPSULATED_REQUEST` , `DELIVER_ENCAPSULATED_RESPONSE` and `ENCAPSULATED_RESPONSE_ACK` messages. If mutual authentication is also supported by the Requester, this field shall be set also.
1	`5`	`HBEAT_CAP`	If set, Responder supports `HEARTBEAT` messages.
1	`6`	`KEY_UPD_CAP`	If set, Responder supports `KEY_UPDATE` messages.
1	`7`	`HANDSHAKE_IN_THE_CLEAR_CAP`	if set, Responder supports Delayed verified data capability during `KEY_EXCHANGE` messages. If set, `KEY_EX_CAP` shall be set
2	`7:0`	`Reserved`	Reserved
3	`7:0`	`Reserved`	Reserved

7.4 NEGOTIATE_ALGORITHMS request message and ALGORITHMS response message

This request message shall negotiate cryptographic algorithms. A Requester shall not issue a `NEGOTIATE_ALGORITHMS` request message until it receives a successful `CAPABILITIES` response message.

A Requester shall not issue any other SPDM requests, with the exception of `GET_VERSION` until it receives a successful `ALGORITHMS` response message.

A Responder shall not respond to `NEGOTIATE_ALGORITHMS` request message with `ErrorCode=ResponseNotReady` .

The NEGOTIATE_ALGORITHMS request message table shows the `NEGOTIATE_ALGORITHMS` request message format.

The Successful ALGORITHMS response message table shows the `ALGORITHMS` response message format.

NEGOTIATE_ALGORITHMS request message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0xE3=NEGOTIATE_ALGORITHMS`
2	`Param1`	1	Number of Algorithms Structure Tables in this request using ReqAlgStruct
3	`Param2`	1	Reserved
4	`Length`	2	Length of the entire request message, in bytes. Length shall be less than or equal to 128 bytes.
6	`MeasurementSpecification`	1	Bit mask. The `MeasurementSpecification` field of the GET_MEASUREMENTS request message and MEASUREMENTS response message shall define the values for this field. The Requester may set more than one bit to indicate multiple measurement specification support.
7	`Reserved`	1	Reserved
8	*BaseAsymAlgo*	4	Bit mask listing Requester-supported SPDM-enumerated asymmetric key signature algorithms for the purposes of signature verification. • Byte 0 Bit 0. TPM_ALG_RSASSA_2048 • Byte 0 Bit 1. TPM_ALG_RSAPSS_2048 • Byte 0 Bit 2. TPM_ALG_RSASSA_3072 • Byte 0 Bit 3. TPM_ALG_RSAPSS_3072 • Byte 0 Bit 4. TPM_ALG_ECDSA_ECC_NIST_P256 • Byte 0 Bit 5. TPM_ALG_RSASSA_4096 • Byte 0 Bit 6. TPM_ALG_RSAPSS_4096 • Byte 0 Bit 7. TPM_ALG_ECDSA_ECC_NIST_P384 • Byte 1 Bit 0. TPM_ALG_ECDSA_ECC_NIST_P521 All other values reserved.

Offset	Field	Size (bytes)	Value
12	*BaseHashAlgo*	4	Bit mask listing Requester-supported SPDM-enumerated cryptographic hashing algorithms. • Byte 0 Bit 0. TPM_ALG_SHA_256 • Byte 0 Bit 1. TPM_ALG_SHA_384 • Byte 0 Bit 2. TPM_ALG_SHA_512 • Byte 0 Bit 3. TPM_ALG_SHA3_256 • Byte 0 Bit 4. TPM_ALG_SHA3_384 • Byte 0 Bit 5. TPM_ALG_SHA3_512 All other values reserved.
16	*ExtAsymCount*	1	Number of Requester-supported extended asymmetric key signature algorithms (=A). A + E + R + S + L shall be less than or equal to 20.
17	*ExtHashCount*	1	Number of Requester-supported extended hashing algorithms (=E). A + E + R + S + L shall be less than or equal to 20.
18	`Reserved`	2	Reserved
20	*ExtAsym*	4*A	List of Requester-supported extended asymmetric key signature algorithms. The Extended algorithm field format table describes the format of this field.
20 + 4*A	*ExtHash*	4*E	List of the extended hashing algorithms supported by Requester. The Extended algorithm field format table describes the format of this field.
20 + 4*A + 4*E	*ReqAlgStruct*	AlgStructSize	See Request AlgStructure field

AlgStructSize is the sum of the size of all Algorithm structure tables enumerated below. The algorithm structure table need be present only if the requester supports that AlgType.

Request Algorithm structure table

Offset	Field	Size (bytes)	Value
0	*AlgType*	1	Type of algorithm. 0 = DHE, 1 = AEADCipherSuite, 2 = ReqBaseAsymAlg, 3 = KeySchedule, 4 to 255 reserved

Offset	Field	Size (bytes)	Value
1	*AlgCount*	1	Requester supported fixed algorithms. • Bit [7:4]. Number of Bytes required to describe Requester supported SPDM-enumerated fixed Algorithms (= M). M + 2 must be a multiple of 4 • Bit [3:0] Number of Requester supported extended algorithms (= L).
2	*AlgSupported*	M	Bit mask listing Requester-supported SPDM-enumerated algorithms.
2 + M	*AlgExternal*	4*L	List of Requester-supported extended algorithms. The Extended algorithm field format table describes the format of this field.

The tables for each of the individual type with the associated fixed fields are described below.

DHE structure table

Offset	Field	Size (bytes)	Value
0	*AlgType*	1	Type of algorithm 0 = DHE
1	*AlgCount*	1	Bit [7:4] = 2
2	*AlgSupported*	2	Bit mask listing Requester-supported SPDM-enumerated cryptographic Diffie-Hellman algorithms. • Byte 0 Bit 0. ffdhe2048 • Byte 0 Bit 1. ffdhe3072 • Byte 0 Bit 2. ffdhe4096 • Byte 0 Bit 3. secp256r1 • Byte 0 Bit 4. secp384r1 • Byte 0 Bit 5. secp521r1 All other values reserved.

AEAD structure table

Offset	Field	Size (bytes)	Value
0	*AlgType*	1	Type of algorithm 1 = AEAD
1	*AlgCount*	1	Bit [7:4] = 2

Offset	Field	Size (bytes)	Value
2	*AlgSupported*	2	Bit mask listing Requester-supported SPDM-enumerated cryptographic Encryption Cipher Suite algorithms. • Byte 0 Bit 0. AES-128-GCM • Byte 0 Bit 1. AES-256-GCM • Byte 0 Bit 2. CHACHA20_POLY1305 All other values reserved.

ReqBaseAsymAlg structure table

Offset	Field	Size (bytes)	Value
0	*AlgType*	1	Type of algorithm 2 = ReqBaseAsymAlg
1	*AlgCount*	1	Bit [7:4] = 2
2	*AlgSupported*	2	Bit mask listing Requester-supported SPDM-enumerated asymmetric key signature algorithms for the purposes of signature generation. • Byte 0 Bit 0. TPM_ALG_RSASSA_2048 • Byte 0 Bit 1. TPM_ALG_RSAPSS_2048 • Byte 0 Bit 2. TPM_ALG_RSASSA_3072 • Byte 0 Bit 3. TPM_ALG_RSAPSS_3072 • Byte 0 Bit 4. TPM_ALG_ECDSA_ECC_NIST_P256 • Byte 0 Bit 5. TPM_ALG_RSASSA_4096 • Byte 0 Bit 6. TPM_ALG_RSAPSS_4096 • Byte 0 Bit 7. TPM_ALG_ECDSA_ECC_NIST_P384 • Byte 1 Bit 0. TPM_ALG_ECDSA_ECC_NIST_P521 All other values reserved.

KeySchedule structure table

Offset	Field	Size (bytes)	Value
0	*AlgType*	1	Type of algorithm 3 = KeySchedule
1	*AlgCount*	1	Bit [7:4] = 2

Offset	Field	Size (bytes)	Value
2	*AlgSupported*	2	Bit mask listing Requester-supported SPDM-enumerated Key Schedule algorithms. • Byte 0 Bit 0. HMAC-HASH. All other values reserved.

Successful ALGORITHMS response message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x63=ALGORITHMS`
2	`Param1`	1	Number of Algorithms Structure Tables in this request using RespAlgStruct
3	`Param2`	1	Reserved
4	`Length`	2	Length of the response message, in bytes.
6	`MeasurementSpecificationSel`	1	Bit mask. The Responder shall select one of the measurement specifications supported by the Requester. Thus, no more than one bit shall be set. The `MeasurementSpecification` field of the Measurement block format table defines the values in this field.
7	`Reserved`	1	Reserved

Offset	Field	Size (bytes)	Value
8	`MeasurementHashAlgo`	4	Bit mask listing SPDM-enumerated hashing algorithm for measurements. M represents the length of the measurement hash field in measurement block structure. See the CHALLENGE request message table. The Responder shall ensure the length of measurement hash field during all subsequent `MEASUREMENT` response messages to the Requester until the next `ALGORITHMS` response message is M. • Bit 0. Raw Bit Stream Only, M=0 • Bit 1. TPM_ALG_SHA_256, M=32 • Bit 2. TPM_ALG_SHA_384, M=48 • Bit 3. TPM_ALG_SHA_512, M=64 • Bit 4. TPM_ALG_SHA3_256, M=32 • Bit 5. TPM_ALG_SHA3_384, M=48 • Bit 6. TPM_ALG_SHA3_512, M=64 If the Responder supports `GET_MEASUREMENTS` , exactly one bit in this bit field shall be set. Otherwise, the Responder shall set this field to `0` . A Responder shall only select bit 0 if the Responder supports raw bit streams as the only form of measurement; otherwise, it shall select one of the other bits.
12	`BaseAsymSel`	4	Bit mask listing the SPDM-enumerated asymmetric key signature algorithm selected. A Responder that returns `CHAL_CAP=0` and `MEAS_CAP!=2` shall set this field to `0` . Other Responders shall set no more than one bit.
16	`BaseHashSel`	4	Bit mask listing the SPDM-enumerated hashing algorithm selected. A Responder that returns `CHAL_CAP=0` and `MEAS_CAP!=2` shall set this field to `0` . Other Responders shall set no more than one bit.
20	`ExtAsymSelCount`	1	Number of extended asymmetric key signature algorithms selected. Shall be either `0` or `1` (=A'). A Requester that returns `CHAL_CAP=0` and `MEAS_CAP!=2` shall set this field to `0` .
21	`ExtHashSelCount`	1	The number of extended hashing algorithms selected. Shall be either `0` or `1` (=E'). A Requester that returns `CHAL_CAP=0` and `MEAS_CAP!=2` shall set this field to `0` .
22	`Reserved`	2	Reserved.
24	`ExtAsymSel`	4*A'	The extended asymmetric key signature algorithm selected. Responder must be able to sign a response message using this algorithm and Requester must have listed this algorithm in the request message indicating it can verify a response message by using this algorithm. The Responder shall use this asymmetric signature algorithm for all subsequent applicable response messages to the Requester. The Extended algorithm field format table describes the format of this field.

Offset	Field	Size (bytes)	Value
24 + 4*A'	`ExtHashSel`	4*E'	Extended hashing algorithm selected. The Responder shall use this hashing algorithm during all subsequent response messages to the Requester. The Requester shall use this hashing algorithm during all subsequent applicable request messages to the Responder. The Extended algorithm field format table describes the format of this field.
24 + 4*A' + 4*E'	*RespAlgStruct*	AlgStructSize	See Response AlgStructure field

AlgStructSize is the sum of the size of all Algorithm structure tables enumerated below. The algorithm structure table need be present only if the requester requested that AlgType.

Response Algorithm structure table

Offset	Field	Size (bytes)	Value
0	*AlgType*	1	Type of algorithm. 0 = DHE, 1 = AEADCipherSuite, 2 = ReqBaseAsymAlg, 3 = KeySchedule, 4 to 255 reserved
1	*AlgCount*	1	Bit mask listing Responder supported fixed algorithm requested by the Requester. • Bit [7:4]. Number of Bytes required to describe Requester supported SPDM-enumerated fixed Algorithms (= M). M + 2 must be a multiple of 4 • Bit [3:0] Number of Requester supported extended algorithms (= L).
2	*AlgSupported*	M	Bit mask listing Requester requested, Responder selected fixed algorithm. Responder shall set at most one bit to 1.
2 + M	*AlgExternal*	4*L	List of Requester-supported Responder supported extended algorithm. Responder shall select at most one external algorithm. The Extended algorithm field format table describes the format of this field.

The tables for each of the individual type with the associated fixed fields are described below.

DHE structure table

Offset	Field	Size (bytes)	Value
0	*AlgType*	1	Type of algorithm 0 = DHE
1	*AlgCount*	1	Bit [7:4] = 2

Offset	Field	Size (bytes)	Value
2	*AlgSupported*	2	Bit mask listing Responder selected, Requester requested, cryptographic Diffie-Hellman algorithm. A Responder that returns `ENCRPT_CAP=0` and `MAC_CAP=0` shall set this field to `0`. • Byte 0 Bit 0. ffdhe2048 • Byte 0 Bit 1. ffdhe3072 • Byte 0 Bit 2. ffdhe4096 • Byte 0 Bit 3. secp256r1 • Byte 0 Bit 4. secp384r1 • Byte 0 Bit 5. secp521r1 All other values reserved.

AEAD structure table

Offset	Field	Size (bytes)	Value
0	*AlgType*	1	Type of algorithm 1 = AEADCipherSuite
1	*AlgCount*	1	Bit [7:4] = 2
2	*AlgSupported*	2	Bit mask listing Responder selected Requester requested cryptographic Encryption Cipher Suite algorithm. • Byte 0 Bit 0. AES-128-GCM • Byte 0 Bit 1. AES-256-GCM • Byte 0 Bit 2. CHACHA20_POLY1305 All other values reserved.

ReqBaseAsymAlg structure table

Offset	Field	Size (bytes)	Value
0	*AlgType*	1	Type of algorithm 2 = ReqBaseAsymAlg
1	*AlgCount*	1	Bit [7:4] = 2

Offset	Field	Size (bytes)	Value
2	*AlgSupported*	2	Bit mask listing Responder selected, Requester requested, asymmetric key signature algorithm for the purposes of signature generation. • Byte 0 Bit 0. TPM_ALG_RSASSA_2048 • Byte 0 Bit 1. TPM_ALG_RSAPSS_2048 • Byte 0 Bit 2. TPM_ALG_RSASSA_3072 • Byte 0 Bit 3. TPM_ALG_RSAPSS_3072 • Byte 0 Bit 4. TPM_ALG_ECDSA_ECC_NIST_P256 • Byte 0 Bit 5. TPM_ALG_RSASSA_4096 • Byte 0 Bit 6. TPM_ALG_RSAPSS_4096 • Byte 0 Bit 7. TPM_ALG_ECDSA_ECC_NIST_P384 • Byte 1 Bit 0. TPM_ALG_ECDSA_ECC_NIST_P521 All other values reserved.

KeySchedule structure table

Offset	Field	Size (bytes)	Value
0	*AlgType*	1	Type of algorithm 3 = KeySchedule
1	*AlgCount*	1	Bit [7:4] = 2
2	*AlgSupported*	2	Bit mask listing Responder selected, Requester requested, SPDM-enumerated Key Schedule algorithm. • Byte 0 Bit 0. HMAC-HASH. All other values reserved.

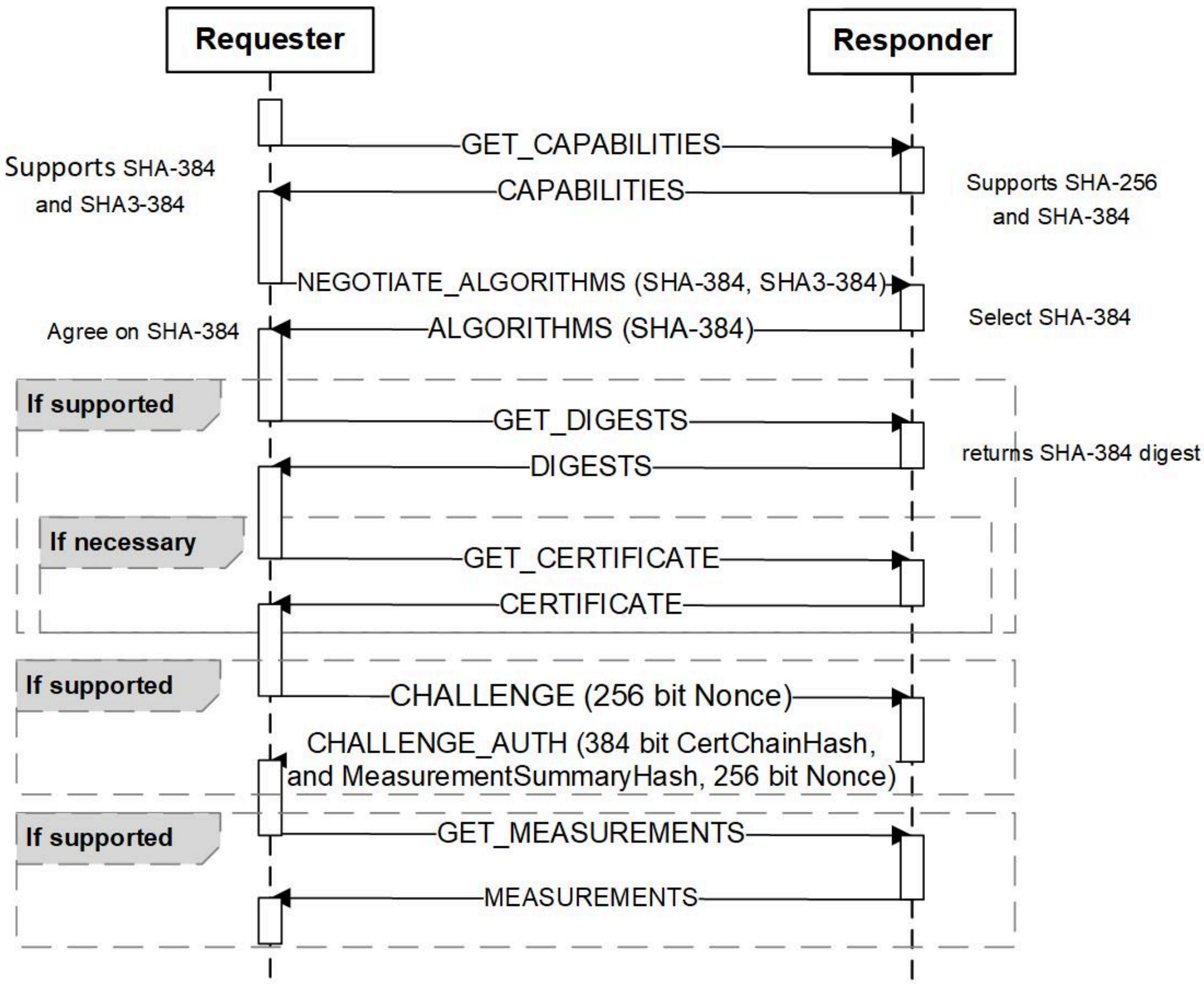
Extended algorithm field format

Offset	Field	Description
0	Registry ID	Shall represent the registry or standards body. The **ID** column in the Registry or standards body ID table describes this field's value.
1	Reserved	Reserved
[2:3]	Algorithm ID	Shall indicate the desired algorithm. The registry or standards body owns the value of this field. For details, see the Registry or standards body ID table.

A Responder shall not select both a SPDM-enumerated asymmetric key signature algorithm and an extended asymmetric key signature algorithm. A Responder shall not select both a SPDM-enumerated hashing algorithm and an extended hashing algorithm.

Hashing algorithm selection: Example 1 illustrates how two endpoints negotiate a base hashing algorithm.

In Hashing algorithm selection: Example 1, endpoint A issues `NEGOTIATE_ALGORITHMS` request message and endpoint B selects an algorithm of which both endpoints are capable.

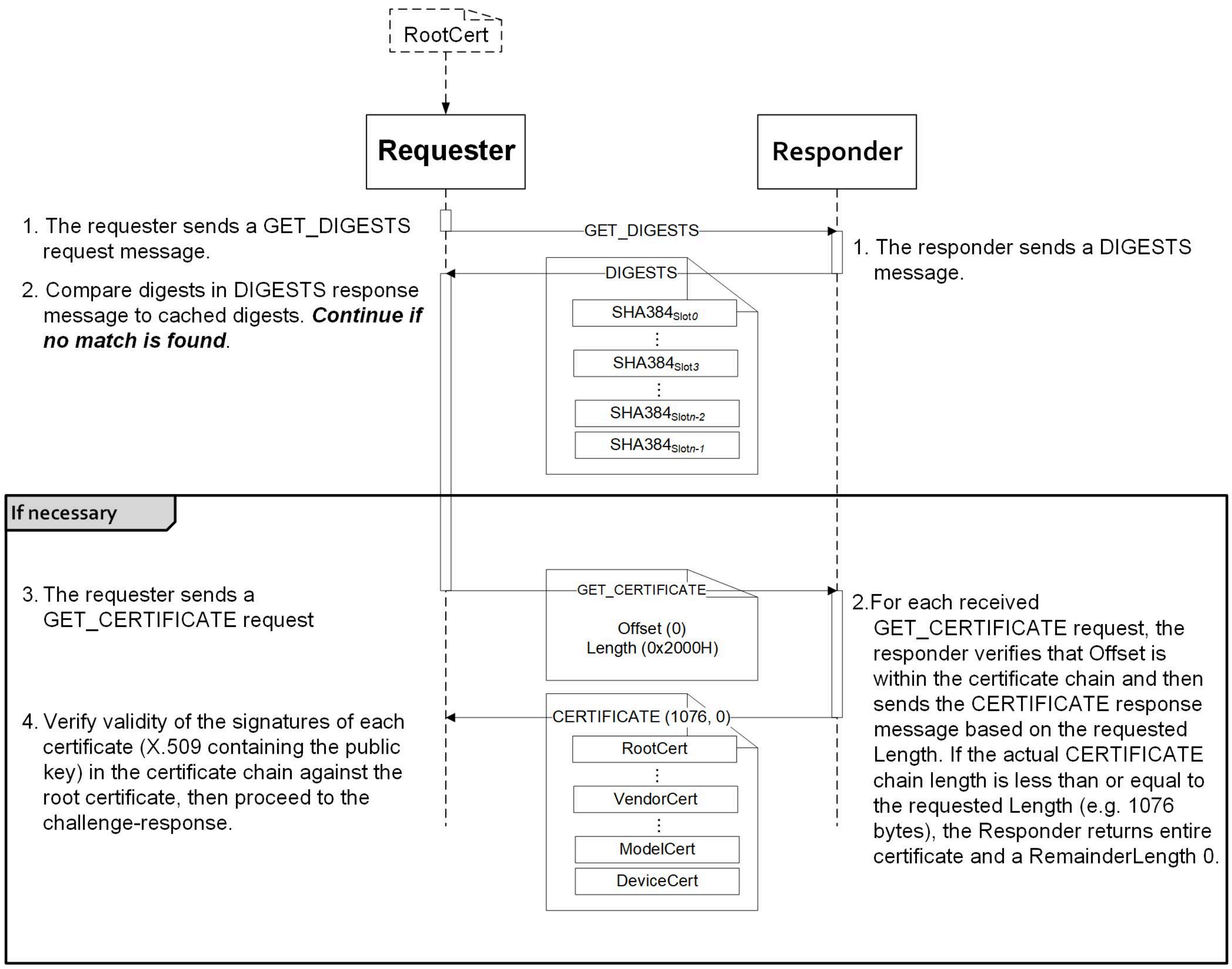


The SPDM protocol accounts for the possibility that both endpoints may issue `NEGOTIATE_ALGORITHMS` request messages independently of each other. In this case, the endpoint A Requester and endpoint B Responder communication pair may select a different algorithm compared to the endpoint B Requester and endpoint A Responder communication pair.

7.5 Responder identity authentication

This clause describes request messages and response messages associated with the Responder's identity authentication operations. The GET_DIGESTS and GET_CERTIFICATE messages shall be supported by a Responder that returns `CERT_CAP` =1 in the CAPABILITIES response message. The CHALLENGE message defined in this clause shall be supported by a Responder that returns `CHAL_CAP` =1 in the CAPABILITIES response message.

The Responder authentication: Example certificate retrieval flow shows the high-level request-response message flow and sequence for *certificate* retrieval.



The `GET_DIGESTS` request message and `DIGESTS` response message may optimize the amount of data required to be transferred from the Responder to the Requester, due to the potentially large size of a certificate chain. The cryptographic hash values of each of the certificate chains stored on an endpoint is returned with the `DIGESTS` response message, such that the Requester can cache the previously retrieved certificate chain hash values to detect any change to the certificate chains stored on the device before issuing the `GET_CERTIFICATE` request message.

For the runtime challenge-response flow, the signature field in the `CHALLENGE_AUTH` response message payload shall be signed by using the device private key over the hash of the message transcript. See the Request ordering and message transcript computation rules for M1/M2 table.

This ensures cryptographic binding between a specific request message from a specific Requester and a specific response message from a specific Responder and enables the Requester to detect the presence of an active adversary attempting to downgrade cryptographic algorithms or SPDM versions.

Furthermore, a Requester-generated nonce protects the challenge-response from replay attacks, whereas a Responder-generated nonce prevents the Responder from signing over arbitrary data that the Requester dictates. The message transcript generation for the signature computation is restarted with the latest `GET_VERSION` request received.

7.5.1 Certificates and certificate chains

Each Responder that supports identity authentication shall carry at least one certificate chain. A certificate chain contains an ordered list of certificates, presented as the binary (byte) concatenation of the fields that the Certificate chain format shows.

Each certificate shall be in ASN.1 DER-encoded X.509 v3 format. The ASN.1 DER encoding of each individual certificate can be analyzed to determine its length. The minimum number of certificates within a chain shall be one, in which case the single certificate is the device-specific certificate. The Responder shall contain a single public-private key pair per supported algorithm for its hardware identity, regardless of how many certificate chains are stored on the device. The Responder selects a single asymmetric key signature algorithm per Requester.

Certificate chains are stored in locations called slots. Each slot shall either be empty or contain one complete certificate chain. A device shall not contain more than eight slots. Slot 0 is populated by default. Additional slots may be populated through the supply chain such as by a platform integrator or by an end user such as the IT administrator. A slot mask identifies the certificate chains from the eight slots.

In this document, `H` refers to the output size, in bytes, of the hash algorithm agreed upon in `NEGOTIATE_ALGORITHMS`.

Certificate chain format

Offset	Field	Size	Description
0	`Length`	2	Total length of the certificate chain, in bytes, including all fields in this table. This field is little endian.
2	`Reserved`	2	Reserved.

Offset	Field	Size	Description
4	`RootHash`	H	Digest of the Root Certificate. Note that Root Certificate is ASN.1 DER-encoded for this digest. This field shall be big endian.
4 + H	`Certificates`	Length - (4 + H)	One or more ASN.1 DER-encoded X.509 v3 certificates where the first certificate is signed by the Root Certificate or is the Root Certificate itself and each subsequent certificate is signed by the preceding certificate. The last certificate is the *leaf certificate*. This field shall be big endian.

7.6 GET_DIGESTS request message and DIGESTS response message

This request message shall be used to retrieve the certificate chain digests.

The GET_DIGESTS request message table shows the `GET_DIGESTS` request message format.

The Successful DIGESTS response message table shows the `DIGESTS` response message format.

The digests in the Successful DIGESTS response message table shall be big endian.

GET_DIGESTS request message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x81=GET_DIGESTS`
2	`Param1`	1	Reserved
3	`Param2`	1	Reserved

Successful DIGESTS response message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x01=DIGESTS`
2	`Param1`	1	Reserved

Offset	Field	Size (bytes)	Value
3	`Param2`	1	Slot mask. The bit in position K of this byte shall be set to 1b if and only if slot number K contains a certificate chain for the protocol version in the SPDMVersion field. (Bit 0 is the least significant bit of the byte.) The number of digests returned shall be equal to the number of bits set in this byte. The digests shall be returned in order of increasing slot number.
4	`Digest[0]`	H	Digest of the first certificate chain.
...	...	...	...
4 + (H * (n -1))	`Digest[n-1]`	H	Digest of the last (n^{th}) certificate chain.

7.7 GET_CERTIFICATE request message and CERTIFICATE response message

This request message shall retrieve the certificate chains.

The GET_CERTIFICATE request message table shows the `GET_CERTIFICATE` request message format.

The Successful CERTIFICATE response message table shows the `CERTIFICATE` response message format.

The Requester should, at a minimum, save the public key of the leaf certificate and associate it with each of the digests returned by `DIGESTS` message response. The Requester sends one or more `GET_CERTIFICATE` requests to retrieve Responder's certificate chain.

GET_CERTIFICATE request message

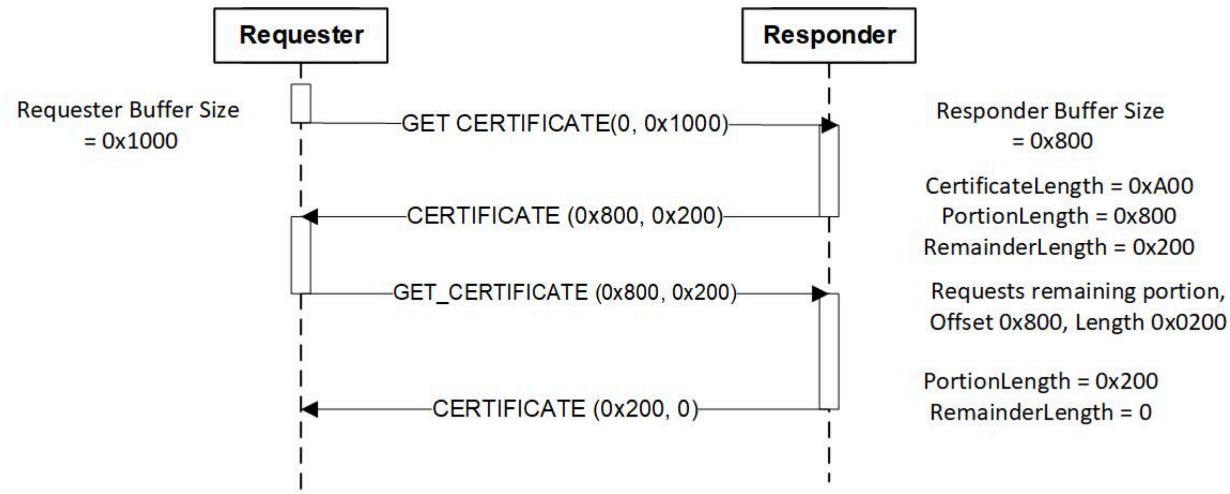
Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x82=GET_CERTIFICATE`
2	`Param1`	1	Slot number of the target certificate chain to read from. The value in this field shall be between 0 and 7 inclusive.
3	`Param2`	1	Reserved

Offset	Field	Size (bytes)	Value
4	`Offset`	2	Offset in bytes from the start of the certificate chain to where the read request message begins. The Responder should send its certificate chain starting from this offset. For the first `GET_CERTIFICATE` request, the Requester must set this field to 0. For non-first requests, Offset is the sum of PortionLength values in all previous `GET_CERTIFICATE` responses.
6	`Length`	2	Length of certificate chain data, in bytes, to be returned in the corresponding response. Length is an unsigned 16-bit integer. This value is the smaller of the following values: • Capacity of Requester's internal buffer for receiving Responder's certificate chain. • The `RemainderLength` of the preceding `GET_CERTIFICATE` response. For the first `GET_CERTIFICATE` request, the Requester should use the capacity of the Requester's receiving buffer. If `offset=0` and `length=0xFFFF`, the Requester is requesting the entire chain.

Successful CERTIFICATE response message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x02=CERTIFICATE`
2	`Param1`	1	Slot number of the certificate chain returned.
3	`Param2`	1	Reserved.
4	`PortionLength`	2	Number of bytes of this portion of certificate chain. This should be less than or equal to `Length` received as part of the request. For example, the Responder might set this field to a value less than `Length` received as part of the request due limitations on the Responder's internal buffer.
6	`RemainderLength`	2	Number of bytes of the certificate chain that have not been sent yet after the current response. For the last response, this field shall be 0 as an indication to the Requester that the entire certificate chain has been sent.
8	`CertChain`	`PortionLength`	Requested contents of target certificate chain, formatted in DER. This field is big endian.

The Responder unable to return full length data flow shows the high-level request-response message flow for Responder response when it cannot return the entire data requested by the Requester in the first response.



7.7.1 Leaf certificate

The SPDM endpoints for authentication must be provisioned with DER-encoded X.509 v3 format certificates. The leaf certificate must be signed by a trusted CA and provisioned to the device. For endpoint devices to verify the certificate, the following required fields must be present. In addition, to provide device information, use the `Subject Alternative Name` certificate extension `otherName` field.

Required fields

Field	Description
`Version`	Version of the encoded certificate shall be present and shall be `3` or `2` .
`Serial Number`	CA-assigned serial number shall be present with a positive integer value.
`Signature Algorithm`	Signature algorithm that CA uses shall be present.
`Issuer`	CA distinguished name shall be specified.
`Subject Name`	Subject name shall be present and shall represent the distinguished name associated with the leaf certificate.
`Validity`	Certificate may include this attribute. If the validity attribute is present, the value for `notBefore` field should be assigned the generalized `19700101000000Z` time value and `notAfter` field should be assigned the generalized `99991231235959Z` time value.
`Subject Public Key Info`	Device public key and the algorithm shall be present.

Field	Description
`Extended Key Usage`	Shall be present and key usage bit for digital signature shall be set.

Optional fields

Field	Description
`Basic Constraints`	If present, the CA value shall be `FALSE`.
`Subject Alternative Name otherName`	In some cases, it might be desirable to provide device specific information as part of the device certificate. DMTF chose the `otherName` field with a specific format to represent the device information. The use of the `otherName` field also provides flexibility for other alliances to provide device specific information as part of the device certificate.

Definition of otherName using the DMTF OID

```
DMTFOtherName ::= SEQUENCE {
    type-id   DMTF-oid
    value [0] EXPLICIT ub-DMTF-device-info
}
-- OID for DMTF device info --
id-DMTF-device-info  OBJECT IDENTIFIER ::= { 1 3 6 1 4 1 412 274 1 }
DMTF-oid                                 ::= OBJECT IDENTIFIER (id-DMTF-device-info)

-- All printable characters except ":" --
DMTF-device-string                       ::= UTF8String (ALL EXCEPT ":")

-- Device Manufacturer --
DMTF-manufacturer                        ::= DMTF-device-string

-- Device Product --
DMTF-product                             ::= DMTF-device-string

-- Device Serial Number --
DMTF-serialNumber                        ::= DMTF-device-string

-- Device information string  --
ub-DMTF-device-info                      ::= UTF8String({DMTF-manufacturer":"DMTF-product":"DMTF-serialNumber})
```

ANNEX B - Leaf certificate example shows an example leaf certificate.

7.8 CHALLENGE request message and CHALLENGE_AUTH response

message

This request message shall initiate authenticating a Responder through the challenge-response protocol.

The CHALLENGE request message table shows the `CHALLENGE` request message format.

The Successful CHALLENGE_AUTH response message table shows the `CHALLENGE_AUTH` response message format.

CHALLENGE request message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x83=CHALLENGE`
2	`Param1`	1	Slot number of the Responder's certificate chain that shall be used for authentication.
3	`Param2`	1	Requested measurement summary hash Type: • `0x0` . No measurement summary hash. • `0x1=TCB` . Component measurement hash. • `0xFF` . All measurements hash. All other values reserved. When Responder does not support any measurements, Requester shall set this value to `0x0` .
4	`Nonce`	32	The Requester should choose a random value.

Successful CHALLENGE_AUTH response message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x03=CHALLENGE_AUTH`
2	`Param1`	1	Shall contain the slot number in the `Param1` field of the corresponding `CHALLENGE` request. The Requester can use this value to check that the certificate matched what was requested.

Offset	Field	Size (bytes)	Value
3	`Param2`	1	Slot mask. The bit in position K of this byte shall be set to `1b` if and only if slot number K contains a certificate chain for the protocol version in the `SPDMVersion` field. Bit 0 is the least significant bit of the byte.
4	`CertChainHash`	H	Hash of the certificate chain used for authentication. The Requester can use this value to check that the certificate chain matches the one requested. This field is big endian.
4 + H	`Nonce`	32	Responder-selected random value.
36 + H	`MeasurementSummaryHash`	H	When the Responder does not support measurement or requested `Param2` =0, the field shall be absent. When the requested `Param2` =1, this field shall be the combined hash of Measurements of all measurable components considered to be in the TCB required to generate this response, computed as hash(Concatenation(MeasurementBlock[0].Measurement, MeasurementBlock[1].Measurement, ...)) where MeasurementBlock[x].Measurement is a measurement in TCB. When the requested `Param2` =1 and there are no measurable components in the TCB required to generate this response, this field shall be `0` . When requested `Param2=0xFF` , this field is computed as the hash(Concatenation(MeasurementBlock[0].Measurement, MeasurementBlock[1].Measurement, ..., MeasurementBlock[n].Measurement)) of all supported measurements.
36 + 2H	`OpaqueLength`	2	Size of the `OpaqueData` field. The value shall not be greater than 1024 bytes.
38 + 2H	`OpaqueData`	`OpaqueLength`	Free-form field, if present. The Responder may include Responder-specific information and/or information defined by its transport.
38 + 2H + `OpaqueLength`	`Signature`	S	S is the size of the asymmetric-signing algorithm output that the Responder selected through the last `ALGORITHMS` response message to the Requester. The CHALLENGE_AUTH signature generation and CHALLENGE_AUTH signature verification clauses, respectively, define the signature generation and verification processes.

7.8.1 CHALLENGE_AUTH signature generation

To complete the `CHALLENGE_AUTH` signature generation process, the Responder shall complete these steps:

1. The Responder shall construct M1 and the Requester shall construct M2 message transcripts. See the Request ordering and message transcript computation rules for M1/M2 table.

where:

`Concatenate()` is the standard concatenation function that is performed only after a successful completion response on the entire request and response contents.

- If a response contains `ErrorCode=ResponseNotReady` :

  Concatenation function is performed on the contents of both the original request and the response received during `RESPOND_IF_READY` .

- If a response contains an `ErrorCode` other than `ResponseNotReady` :

  No concatenation function is performed on the contents of both the original request and response.

2. The Responder shall generate:

```
Signature = Sign(SK, Hash(M1));
```

where:

- `Sign`

  Asymmetric signing algorithm that the Responder selected through the last `ALGORITHMS` response message that the Responder sent.

  The Successful ALGORITHMS response message table describes the `BaseAsymSel` and `ExtAsymSel` fields.

- `SK`

  Private Key associated with the Responder's leaf certificate in `slot=Param1` of the `CHALLENGE` request message.

- `Hash`

  Hashing algorithm the Responder selected through the last `ALGORITHMS` response message that the Responder sent.

  The Successful ALGORITHMS response message table describes the `BaseHashSel` and `ExtHashSel` fields.

7.8.2 CHALLENGE_AUTH signature verification

Modifications to the previous request messages or the corresponding response messages by an active person-in-the-middle adversary or media error result in `M2!=M1` and lead to verification failure.

To complete the `CHALLENGE_AUTH` signature verification process, the Requester shall complete this step:

1. The Requester shall perform:

   ```
   Verify(PK, Hash(M2), Signature);
   ```

   where:

   - `Verify`

     Asymmetric verification algorithm that the Responder selected through the last `ALGORITHMS` response message that the Requester received.

     The Successful ALGORITHMS response message table describes the `BaseAsymSel` and `ExtAsymSel` fields.

   - `PK`

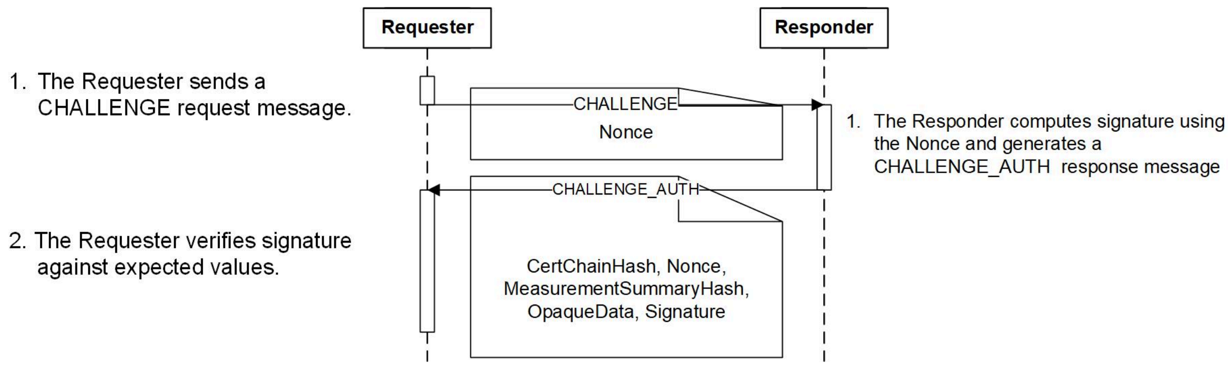
     Public key associated with the leaf certificate of the Responder with `slot=Param1` of the `CHALLENGE` request message.

   - `Hash`

     Hashing algorithm the Responder selected through the last sent `ALGORITHMS` response message as received by the Requester.

     The Successful ALGORITHMS response message table describes the `BaseHashSel` and `ExtHashSel` fields.

The Responder authentication: Runtime challenge-response flow shows the high-level request-response message flow and sequence for Responder's authentication for runtime challenge-response.



7.8.2.1 Request ordering and message transcript computation rules for M1 and M2

The Request ordering and message transcript computation rules for M1/M2 table defines how the message transcript is constructed for M1 and M2, which are used in signature calculation and verification in the `CHALLENGE_AUTH` response message.

The possible request orderings after reset leading up to and including `CHALLENGE` are:

- `GET_VERSION` , `GET_CAPABILITIES` , `NEGOTIATE_ALGORITHMS` , `GET_DIGESTS` , `GET_CERTIFICATE` , `CHALLENGE` (A1, B1, C1)
- `GET_VERSION` , `GET_CAPABILITIES` , `NEGOTIATE_ALGORITHMS` , `GET_DIGESTS` , `CHALLENGE` (A1, B3, C1)
- `GET_VERSION` , `GET_CAPABILITIES` , `NEGOTIATE_ALGORITHMS` , `CHALLENGE` (A1, B2, C1)
- `GET_DIGESTS` , `GET_CERTIFICATE` , `CHALLENGE` (A2, B1, C1)
- `GET_DIGESTS` , `CHALLENGE` (A2, B3, C1)
- `CHALLENGE` (A2, B2, C1)

The possible request orderings after reset without `CHALLENGE` are:

- `GET_DIGESTS` (A2, B3, C2)
- `NULL` (A2, B2, C2)

After the Requester receives a successful `CHALLENGE_AUTH` response or the Requester sends a `GET_MEASUREMENTS` request, M1 and M2 shall be set to null. Immediately after reset, M1 and M2 shall be null. If a Requester sends a `GET_VERSION` message, the Requester and Responder shall reset M1 and M2 to null and recommence construction of M1 and M2 starting with the new `GET_VERSION` message.

Request ordering and message transcript computation rules for M1/M2

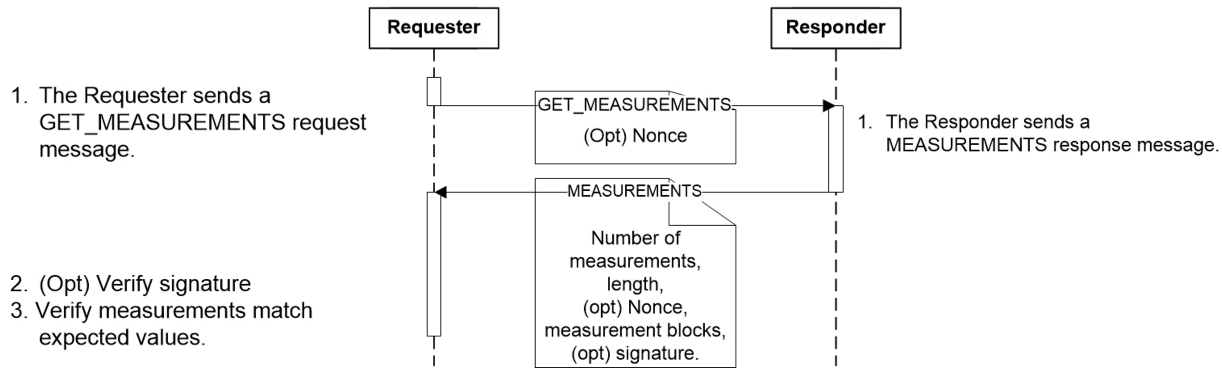
Requests	Implementation requirements	M1/M2=Concatenate (A, B, C)
Reset	NA	M1/M2=null

Requests	Implementation requirements	M1/M2=Concatenate (A, B, C)
`GET_VERSION` issued	Requester issued this request to allow the Requester and Responder to determine an agreed upon Negotiated State. A Requester may detect out of sync condition typically on first power on, or when the signature verification fails or the Responder provides an unexpected error response.	M1/M2=null
`GET_VERSION` , `GET_CAPABILITIES` , `NEGOTIATE_ALGORITHMS` Issued	Requester shall always issue these requests in this order.	`A1=Concatenate(GET_VERSION, VERSION, GET_CAPABILITIES, CAPABILITIES, NEGOTIATE_ALGORITHMS, ALGORITHMS)`
`GET_VERSION` , `GET_CAPABILITIES` , `NEGOTIATE_ALGORITHMS` Skipped	Requester skipped issuing these requests after a new reset if the Responder has previously indicated `CACHE_CAP=1` . In this case, the Requester and Responder shall proceed with the previously Negotiated State.	`A2=null`
`GET_DIGESTS` , `GET_CERTIFICATE` issued	Requester issued these requests in this order after `NEGOTIATE_ALGORITHMS` request completion or immediately after reset, if it chose to skip the previous three requests.	`B1=Concatenate(GET_DIGEST, DIGEST, GET_CERTFICATE, CERTIFICATE)`
`GET_DIGESTS` , `GET_CERTFICATE` skipped	Requester skipped both requests after a new reset since it could use previously cached response to these requests.	`B2=null`
`GET_DIGESTS` issued, `GET_CERTIFICATE` skipped	Requester skipped `GET_CERTIFICATE` request after a new reset since it could use the previously cached `CERTIFICATE` response.	`B3=(GET DIGESTS, DIGEST)`
`CHALLENGE` issued	Requester issued this request to complete security verification of current requests and responses. The Signature bytes of `CHALLENGE_AUTH` shall not be included in C.	`C1=(CHALLENGE, CHALLENGE_AUTH\Signature)` . See the CHALLENGE request message table.
`CHALLENGE` completion	Completion of `CHALLENGE` resets M1 and M2.	`M1/M2=null`
`CHALLENGE` skipped	Requester skipped this request and forwent security verification of previous requests and responses. Requester may typically skip `CHALLENGE` when it issues `GET_DIGESTS` directly after reset.	`C2 = M1\M2 unchanged`
Other issued	If the Requester issued `GET_MEASUREMENTS` or `KEY_EXCHANGE` or `FINISH` or `PSK_EXCHANGE` or `PSK_FINISH` or `KEY_UPDATE` or `HEARTBEAT` or `GET_ENCAPSULATED_REQUEST` or `DELIVER_ENCAPSULATED_RESPONSE` or `END_SESSSION` request(s) and skipped `CHALLENGE` completion, M1 and M2 are reset to `null` .	`M1/M2=null`

7.9 Firmware and other measurements

This clause describes request messages and response messages associated with endpoint measurement. All request messages in this clause shall be supported by an endpoint that returns `MEAS_CAP=01b` or `MEAS_CAP=10b` in `CAPABILITIES` response.

The Measurement retrieval flow shows the high-level request-response flow and sequence for endpoint measurement. If `MEAS_FRESH_CAP` bit in the `CAPABILITIES` response message returns 0, and the Requester requires fresh measurements, the Responder must be reset before `GET_MEASUREMENTS` is resent. The mechanisms employed for resetting the Responder are outside the scope of this specification.



7.10 GET_MEASUREMENTS request message and MEASUREMENTS response message

This request message shall retrieve measurements in the form of measurements blocks. A Requester should not send this message until it has received at least one successful `CHALLENGE_AUTH` response message from the responder. The successful `CHALLENGE_AUTH` response may have been received before the last reset.

The GET_MEASUREMENTS request message table shows the `GET_MEASUREMENTS` request message format.

The GET_MEASUREMENTS request attributes table shows the `GET_MEASUREMENTS` request message attributes.

The Successful MEASUREMENTS response message table shows the `MEASUREMENTS` response message format.

GET_MEASUREMENTS request message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0xE0=GET_MEASUREMENTS`
2	`Param1`	1	Request attributes. See the GET_MEASUREMENTS request attributes table.

Offset	Field	Size (bytes)	Value
3	`Param2`	1	Measurement operation. • A value of 0x0 shall query the Responder for the total number of measurement blocks available. • A value of `0xFF` shall request all measurement blocks. • A value between `0x1` and `0xFE` , inclusively, shall request the measurement block at the index corresponding to that value.
4	`Nonce`	32	The Requester should choose a random value. This field is only present if a signature is required on the response. See the GET_MEASUREMENTS request attributes table.

GET_MEASUREMENTS request attributes

Bits	Value	Description
`0`	`1`	If the Responder can generate a signature as shown in `CAPABILITIES` message, this bit's value shall indicate to the Responder to generate a signature. The Responder shall generate a signature in the corresponding response. The `Nonce` field shall be present in the request.
`0`	`0`	Responders that cannot generate a signature as shown in the `CAPABILITIES` message shall use this bit's value. For Responders that can generate signatures, this bit's value shall indicate that the Requester does not want a signature. The Responder shall not generate a signature in the response. The `Nonce` field shall be absent in the request.
`[7:1]`	Reserved	Reserved

Successful MEASUREMENTS response message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x60=MEASUREMENTS`
2	`Param1`	1	When `Param2` in the requested measurement operation is `0` , this parameter shall return the total number of measurement indices on the device. Otherwise, this field is reserved.
3	`Param2`	1	Reserved

Offset	Field	Size (bytes)	Value
4	`NumberOfBlocks`	1	Number of measurement blocks (N) in `MeasurementRecord` . Shall reflect the number of measurement blocks in `MeasurementRecord` . If Param2 in the requested measurement operation is `0` , this field shall be `0` .
5	`MeasurementRecordLength`	3	Size of the `MeasurementRecord` field in bytes. If `Param2` in the requested measurement operation is `0` , this field shall be `0` .
8	`MeasurementRecord`	L= `MeasurementRecordLength`	Concatenation of all measurement blocks that correspond to the requested Measurement operation. Measurement block defines the measurement block structure.
8 + L	`Nonce`	32	The Responder should choose a random value.
40 + L	`OpaqueLength`	2	Size of the `OpaqueData` field in bytes. The value shall not be greater than 1024 bytes.
42 + L	`OpaqueData`	`OpaqueLength`	Free-form field, if present. The Responder may include Responder-specific information and/or information defined by its transport.
42 + L + `OpaqueLength`	`Signature`	S	Signature of the `GET_MEASUREMENTS` request and `MEASUREMENTS` response messages, excluding the Signature field and signed using the device private key. The Responder shall use the asymmetric signing algorithm it selected during the last `ALGORITHMS` response message to the Requester, and S is the size of that asymmetric signing algorithm output.

7.10.1 Measurement block

Each measurement block that the `MEASUREMENTS` response message defines shall contain a four-byte descriptor, offsets 0 through 3, followed by the measurement data that correspond to a particular measurement index and measurement type. The blocks are ordered by `Index` .

The Measurement block format table shows the format for a measurement block:

Measurement block format

Offset	Field	Size (bytes)	Value
0	`Index`	1	Index. Shall represent the index of the measurement.

Offset	Field	Size (bytes)	Value
1	`MeasurementSpecification`	1	Bit mask. The value shall indicate the measurement specification that the requested `Measurement` follows and shall match the selected measurement specification in the `ALGORITHMS` message. See the Successful ALGORITHMS response message table. Only one bit shall be set in the measurement block. • Bit 0=DMTF, as specified in the Measurement field format when MeasurementSpecification field is Bit 0 = DMTF table. All other bits are reserved.
2	`MeasurementSize`	2	Size of `Measurement` , in bytes.
4	`Measurement`	MeasurementSize	The `MeasurementSpecification` defines the format of this field.

7.10.1.1 DMTF specification for the Measurement field of a measurement block

The present clause is the specification for the format of the `Measurement` field in a measurement block when the `MeasurementSpecification` field selects Bit 0=DMTF. This format is specified in Measurement field format when MeasurementSpecification field is Bit 0 = DMTF.

Measurement field format when MeasurementSpecification field is Bit 0 = DMTF

Offset	Field	Size (bytes)	Value
0	`DMTFSpecMeasurementValueType`	1	Composed of: • Bit [7] indicates the representation in `DMTFSpecMeasurementValue`. • Bits [6:0] indicate what is being measured by `DMTFSpecMeasurementValue`. These values are set independently and are interpreted as follows: • `[7]=0b`. Hash. • `[7]=1b`. Raw bit stream. • `[6:0]=00h`. Immutable ROM. • `[6:0]=0x1`. Mutable firmware. • `[6:0]=02h`. Hardware configuration, such as straps, debug modes. • `[6:0]=03h`. Firmware configuration, such as, configurable firmware policy. All other values reserved.
1	`DMTFSpecMeasurementValueSize`	2	Size of `DMTFSpecMeasurementValue`, in bytes. When `DMTFSpecMeasurementValueType[7]=0b`, the `DMTFSpecMeasurementValueSize` shall be derived from the measurement hash algorithm that the `ALGORITHM` response message returns.
3	`DMTFSpecMeasurementValue`	`DMTFSpecMeasurementValueSize`	`DMTFSpecMeasurementValueSize` bytes of cryptographic hash or raw bit stream, as indicated in `DMTFSpecMeasurementType[7]`.

7.10.2 MEASUREMENTS signature generation

To complete the `MEASUREMENTS` signature generation process, the Responder shall complete these steps:

1. The Responder shall construct L1 and the Requester shall construct L2 over their observed messages:

```
L1/L2 = Concatenate(GET_MEASUREMENTS_REQUEST1, MEASUREMENTS_RESPONSE1, ...,
                    GET_MEASUREMENTS_REQUESTn-1, MEASUREMENTS_RESPONSEn-1,
                    GET_MEASUREMENTS_REQUESTn, MEASUREMENTS_RESPONSEn)
```

where:

- `Concatenate()`

  Standard concatenation function.

- `GET_MEASUREMENTS_REQUEST1`

  Entire first `GET_MEASUREMENTS` request message under consideration, where the Requester has not requested a signature on that specific `GET_MEASUREMENTS` request.

- `MEASUREMENTS_RESPONSE1`

  Entire `MEASUREMENTS` response message without the signature bytes that the Responder sent in response to `GET_MEASUREMENTS_REQUEST1`.

- `GET_MEASUREMENTS_REQUESTn-1`

  Entire last consecutive `GET_MEASUREMENTS` request message under consideration, where the Requester has not requested a signature on that specific `GET_MEASUREMENTS` request.

- `MEASUREMENTS_RESPONSEn-1`

  Entire `MEASUREMENTS` response message without the signature bytes that the Responder sent in response to `GET_MEASUREMENTS_REQUESTn-1`.

- `GET_MEASUREMENTS_REQUESTn`

  Entire first `GET_MEASUREMENTS` request message under consideration, where the Requester has requested a signature on that specific `GET_MEASUREMENTS` request.

  n is a number greater than or equal to `1`.

  When *n* equals `1`, the Requester has not made any `GET_MEASUREMENTS` requests without signature prior to issuing a `GET_MEASUREMENTS` request with signature.

- `MEASUREMENTS_RESPONSEn`

  Entire `MEASUREMENTS` response message without the signature bytes that the Responder sent in response to `GET_MEASUREMENTS_REQUESTn`.

Any communication between Requester and Responder other than a `GET_MEASUREMENTS` request or response resets L1/L2 computation to null.

2. The Responder shall generate:

```
Signature = Sign(SK, Hash(L1));
```

where:

- `Sign`

  Asymmetric signing algorithm that the Responder selected through the last `ALGORITHMS` response message that the Responder sent.

  The Successful ALGORITHMS response message table describes the `BaseAsymSel` and `ExtAsymSel` fields.

- `SK`

  Private key associated with the Responder's slot 0 leaf certificate.

- `Hash`

  Hashing algorithm that the Responder selected through the last `ALGORITHMS` response message that the Responder sent.

  The Successful ALGORITHMS response message table describes the `BaseAsymSel` and `ExtAsymSel` fields.

7.10.3 MEASUREMENTS signature verification

To complete the `MEASUREMENTS` signature verification process, the Requester shall complete this step:

1. The Requester shall perform:

```
Verify(PK, Hash(L2), Signature)
```

where:

- `PK`

  Public key associated with the slot 0 certificate of the Responder.

  `PK` is extracted from the `CERTIFICATES` response.

- `Verify`

Asymmetric verification algorithm that the Responder selected through the last `ALGORITHMS` response message that the Requester received.

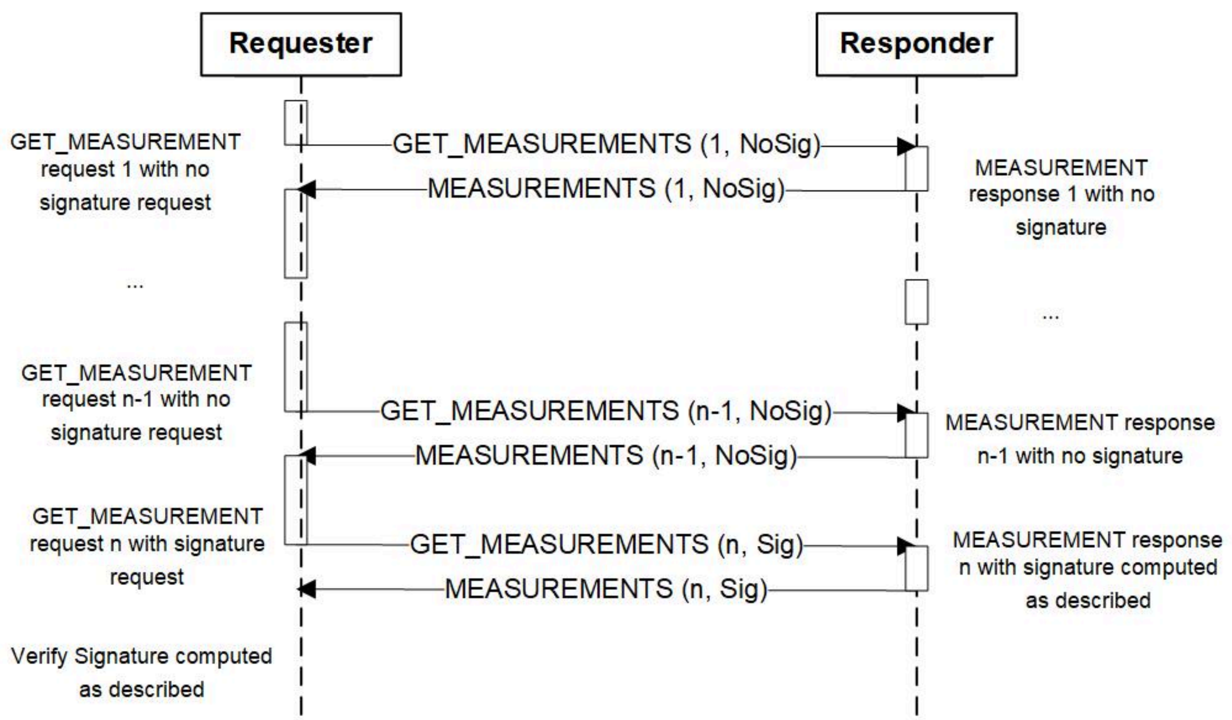
The Successful ALGORITHMS response message table describes the `BaseAsymSel` and `ExtAsymSel` fields.

- `Hash`

  Hashing algorithm the Responder selected through the last sent `ALGORITHMS` response message that the Requester sent.

  The Successful ALGORITHMS response message table describes the `BaseAsymSel` and `ExtAsymSel` fields.

The Measurement signature computation example shows an example of a typical Requester Responder protocol where the Requester issues 0 to *n*-1 `GET_MEASUREMENTS` requests without a signature, followed by a single `GET_MEASUREMENTS` request *n* with a signature.



7.11 ERROR response message

For a SPDM operation that results in an error, the Responder shall send an `ERROR` response message to the Requester.

The ERROR response message table shows the `ERROR` response format.

The Error code and error data table shows the detailed error code, error data, and extended error data.

The ResponseNotReady extended error data table shows the `ResponseNotReady` extended error data.

The Registry or standards body ID table shows the registry or standards body ID.

The ExtendedErrorData format definition for vendor or other standards-defined ERROR response message table shows the `ExtendedErrorData` format definition for vendor or other standards-defined `ERROR` response message.

ERROR response message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x7F=ERROR`
2	`Param1`	1	Error Code. See Error code and error data.
3	`Param2`	1	Error Data. See Error code and error data.
4	`ExtendedErrorData`	0-32	Optional extended data. See Error code and error data.

Error code and error data

Error code	Value	Description	Error data	ExtendedErrorData
Reserved	`0x00`	Reserved	Reserved	Reserved
`InvalidRequest`	`0x01`	One or more request fields are invalid	`0x00`	No extended error data is provided.
`InvalidSession`	`0x02`	The record layer used an invalid session ID.	This shall be the invalid session ID.	Reserved
`Busy`	`0x03`	The Responder received the request message and the Responder decided to ignore the request message, but the Responder may be able to process the request message if the request message is sent again in the future.	`0x00`	No extended error data is provided.
`UnexpectedRequest`	`0x04`	The Responder received an unexpected request message. For example, `CHALLENGE` before `NEGOTIATE_ALGORITHMS`.	`0x00`	No extended error data is provided.

Error code	Value	Description	Error data	ExtendedErrorData
`Unspecified`	`0x05`	Unspecified error occurred.	`0x00`	No extended error data is provided.
`DecryptError`	`0x06`	The receiver of the record cannot decrypt the record or verify data during the session handshake.	Reserved	Reserved
`UnsupportedRequest`	`0x07`	The `RequestResponseCode` in the request message is unsupported.	`RequestResponseCode` in the request message.	No extended error data is provided
`RequestInFlight`	`0x08`	The Responder has an delivered a request to which it is still waiting for the response.	Reserved	Reserved
`InvalidResponseCode`	`0x09`	The Requester delivered an invalid response for an encapsulated response.	Reserved	Reserved
`SessionLimitExceeded`	`0x0A`	Reserved	Reserved	Reserved
Reserved	`0x0b` - `0x40`	Reserved	Reserved	Reserved
`MajorVersionMismatch`	`0x41`	Requested SPDM Major Version is not supported.	`0x00`	No extended error data provided.
`ResponseNotReady`	`0x42`	See the RESPOND_IF_READY request message.	`0x00`	See the ResponseNotReady extended error data table.
`RequestResynch`	`0x43`	Responder is requesting Requester to reissue `GET_VERSION` to resynchronize.	`0x00`	No extended error data provided.
Reserved	`0x44` - `0xFE`	Reserved	Reserved.	Reserved
Vendor/Other Standards Defined	`0xFF`	Vendor or Other Standards defined	Shall indicate the registry or standard body using one of the values in the **ID** column in the Registry or standards body ID table.	See the ExtendedErrorData format definition for vendor or other standards-defined ERROR response message table for format definition.

ResponseNotReady extended error data

Offset	Field	Size (bytes)	Value
0	`RDTExponent`	1	Exponent expressed in logarithmic (base 2 scale) to calculate `RDT` time in uS after which the Responder can provide successful completion response. For example, the raw value 8 indicates that the Responder will be ready in 2^8=256 uS. Responder should use `RDT` to avoid continuous pinging and issue the `RESPOND_IF_READY` request message after `RDT` time. For timing requirement details, see the Timing specification for SPDM messages table.
1	`RequestCode`	1	The request code that triggered this response.
2	`Token`	1	The opaque handle that the Requester shall pass in with the `RESPOND_IF_READY` request message.
3	`RDTM`	1	Multiplier used to compute WT_{Max} in uS to indicate the response may be dropped after this delay. The multiplier shall always be greater than 1. The Responder may also stop processing the initial request if the same Requester issues a different request. For timing requirement details, see the Timing specification for SPDM messages table.

Registry or standards body ID

For algorithm encoding in extended algorithm fields, unless otherwise specified, consult the respective registry or standards body.

ID	Vendor ID length (bytes)	Registry or standards body name	Description
`0x0`	0	DMTF	DMTF does not have a Vendor ID registry. At present, DMTF does not have any algorithms defined for use in extended algorithms fields.
`0x1`	2	TCG	Vendor is identified by using TCG Vendor ID Registry. For extended algorithms, see TCG Algorithm Registry.
`0x2`	2	USB	Vendor is identified by using USB's vendor ID.
`0x3`	2	PCI-SIG	Vendor is identified using PCI-SIG Vendor ID.
`0x4`	4	IANA	Vendor is identified by using the Internet Assigned Numbers Authority's Private Enterprise Number (PEN).
`0x5`	4	HDBaseT	Vendor is identified by using HDBaseT HDCD entity.

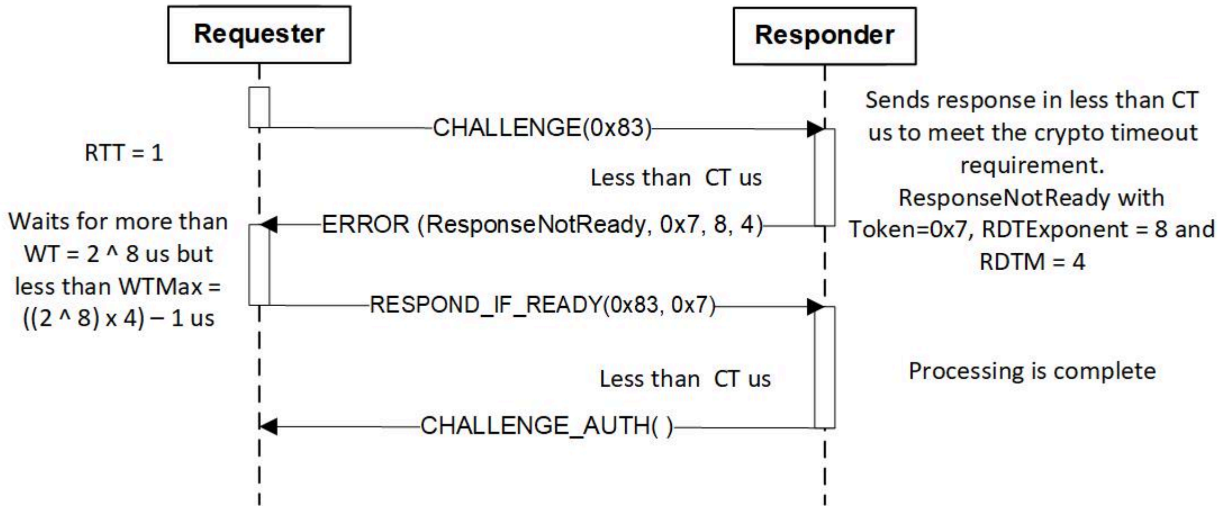
ID	Vendor ID length (bytes)	Registry or standards body name	Description
`0x6`	2	MIPI	Vendor is identified by using MIPI's Manufacturer ID.

ExtendedErrorData format definition for vendor or other standards-defined ERROR response message

Byte offset	Length	Field name	Description
0	1	Len	Length of the `VendorID` field. If the `ERROR` is vendor defined, the value of this field shall equal the `Vendor ID Len`, as the Registry or standards body ID table describes, of the corresponding registry or standard body name. If the `ERROR` is defined by a registry or a standard, this field shall be zero (`0`), which also indicates that the `VendorID` field is not present. The `Error Data` field in the `ERROR` message indicates the registry or standards body name, such as `Param2`, and is one of the values in the **ID** column in the Registry or standards body ID table.
1	Len	VendorID	The value of this field shall indicate the Vendor ID, as assigned by the registry or standards body. The Registry or standards body ID table describes the length of this field. Shall be in little endian format. The registry or standards body name in the `ERROR` is indicated in the `Error Data` field, such as `Param2`, and is one of the values in the **ID** column in the Registry or standards body ID table.
1 + Len	Variable	OpaqueErrorData	Defined by the vendor or other standards.

7.12 RESPOND_IF_READY request message

This request message shall ask for the response to the original request upon receipt of `ResponseNotReady` error code. If the response to the original request is ready, the Responder shall return that response message. If the response to the original request is not ready, the Responder shall return the `ERROR` response message, set `ErrorCode` = `ResponseNotReady` and return the same token as the previous `ResponseNotReady` response message.



The RESPOND_IF_READY request message table shows the `RESPOND_IF_READY` request message format.

RESPOND_IF_READY request message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0xFF=RESPOND_IF_READY`
2	`Param1`	1	The original request code that triggered the `ResponseNotReady` error code response. Shall match the request code returned as part of the `ResponseNotReady` extended error data.
3	`Param2`	1	The token that was returned as part of the `ResponseNotReady` extended error data.

7.13 VENDOR_DEFINED_REQUEST request message

A Requester intending to define a unique request to meet its need can use this request message. The VENDOR_DEFINED_REQUEST request message table defines the format.

The Requester should send this request message only after sending `GET_VERSION` , `GET_CAPABILITIES` and `NEGOTIATE_ALGORITHMS` request sequence.

The VENDOR_DEFINED_REQUEST request message table shows the `VENDOR_DEFINED_REQUEST` request message format.

VENDOR_DEFINED_REQUEST request message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0xFE=VENDOR_DEFINED_REQUEST`
2	`Param1`	1	Reserved
3	`Param2`	1	Reserved
4	`StandardID`	2	Shall indicate the registry or standards body by using one of the values in the **ID** column in the Registry or standards body ID table.
6	`Len`	1	Length of the `Vendor ID` field. If the `VendorDefinedRequest` is standard defined, Len shall be `0`. If the `VendorDefinedRequest` is vendor-defined, Len shall equal `Vendor ID Len`, as the Registry or standards body ID table describes.
7	`VendorID`	Len	Vendor ID, as assigned by the registry or standards body. Shall be in little endian format.
7 + Len	`ReqLength`	2	Length of the `VendorDefinedReqPayload`.
7 + Len + 2	`VendorDefinedReqPayload`	ReqLength	The standard or vendor shall use this field to send the request payload.

7.13.1 VENDOR_DEFINED_RESPONSE response message

A Responder can use this response message in response to `VENDOR_DEFINED_REQUEST`. The VENDOR_DEFINED_RESPONSE response message table defines the format.

The VENDOR_DEFINED_RESPONSE response message table shows the `VENDOR_DEFINED_RESPONSE` response message format.

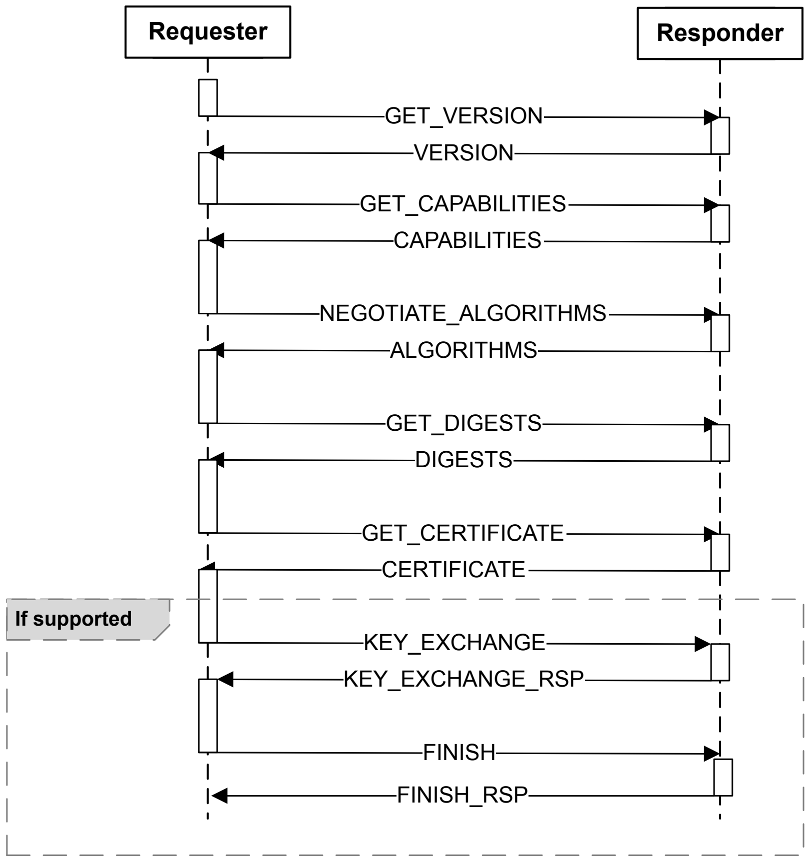
VENDOR_DEFINED_RESPONSE response message

Offset	Field	Size (bytes)	Value
0	`SPDMVersion`	1	`V1.0=0x10`
1	`RequestResponseCode`	1	`0x7E=VENDOR_DEFINED_RESPONSE`
2	`Param1`	1	Reserved
3	`Param2`	1	Reserved

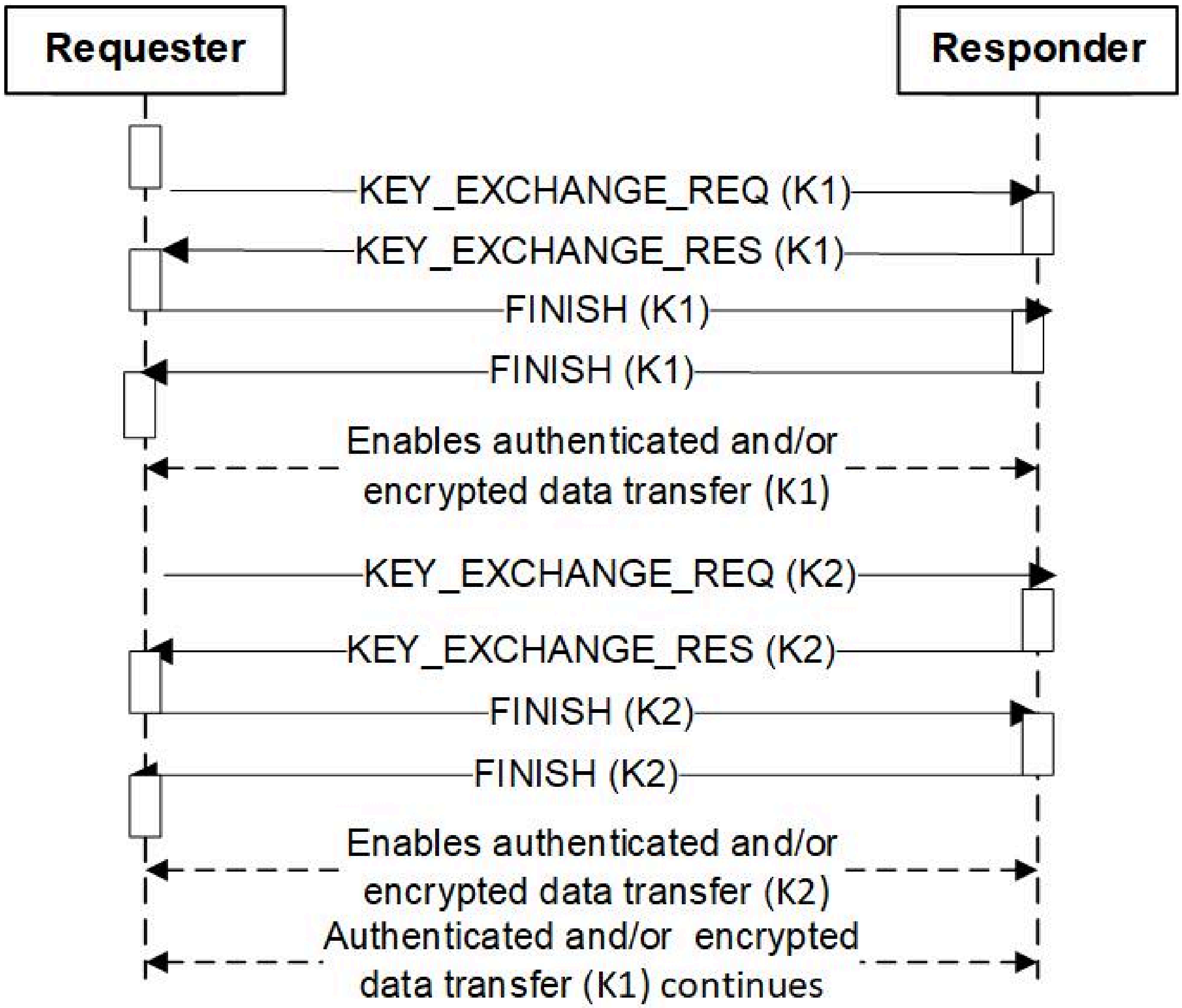
Offset	Field	Size (bytes)	Value
4	`StandardID`	2	Shall indicate the registry or standard body using one of the values in the **ID** column in the Registry or standards body ID table.
6	`Len`	1	Length of the `Vendor ID` field. If the `VendorDefinedRequest` is standards-defined, length shall be `0`. If the `VendorDefinedRequest` is vendor-defined, length shall equal `Vendor ID Len`, as the Registry or standards body ID table describes.
7	`VendorID`	Len	Shall indicate the Vendor ID, as assigned by the registry or standards body. Shall be in little endian format.
7 + Len	`RespLength`	2	Length of the `VendorDefinedRespPayload`
7 + Len + 2	`VendorDefinedRespPayload`	ReqLength	Standard or vendor shall use this value to send the response payload.

7.14 KEY_EXCHANGE request and KEY_EXCHANGE_RSP response messages

This request message shall initiate a handshake between Requester and Responder intended to authenticate the Responder (or optionally both parties), negotiate cryptographic parameters (in addition to those negotiated in the last `NEGOTIATE_ALGORITHMS` / `ALGORITHMS` exchange), and establish shared keying material. The KEY_EXCHANGE request message table shows the `KEY_EXCHANGE` request message format and the KEY_EXCHANGE_RSP response message table shows the `KEY_EXCHANGE_RSP` response message format. The handshake is completed by the successful exchange of the `FINISH` request and `FINISH_RSP` response messages, presented in the next section, and depends on the tight coupling between the two request/response message pairs.


Requester
Responder
GET_VERSION
VERSION
GET_CAPABILITIES
CAPABILITIES
NEGOTIATE_ALGORITHMS
ALGORITHMS
GET_DIGESTS
DIGESTS
GET_CERTIFICATE
CERTIFICATE
If supported
KEY_EXCHANGE
KEY_EXCHANGE_RSP
FINISH
FINISH_RSP

The figure below provides an example of multiple sessions using two independent sets of root session keys coexisting at the same time. The specification does not require a specific temporal relationship between the second KEY_EXCHANGE request message and first FINISH response message. However a Responder may generate an `ErrorCode=Busy` response to second KEY_EXCHANGE request message until first FINISH response message is complete in order to simplify implementation.



KEY_EXCHANGE request message

Offset	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0xE4 = KEY_EXCHANGE`
2	Param1	1	Requested measurement summary hash Type: • `0x0` . No measurement summary hash. • `0x1=TCB` . Component measurement hash. • `0xFF` . All measurements hash. All other values reserved. When Responder does not support any measurements, Requester shall set this value to `0x0` .
3	Param2	1	The slot number of the target certificate chain that the Responder will use for authentication. The value in this field shall be between 0 and 7 inclusive to identify a valid certificate slot.
4	DHE_Named_Group	4	• Byte 0 Bit 0 – Finite Field ffdhe2048 (D = 256) – RFC 7919 Appendix A.1 • Byte 0 Bit 1 – Finite Field ffdhe3072 (D = 384) – RFC 7919 Appendix A.2 • Byte 0 Bit 2 – Finite Field ffdhe4096 (D = 512) – RFC 7919 Appendix A.3 • Byte 0 Bit 3 – ECDHE secp256r1 (D = 64, C = 32) – RFC 8446 Section 4.2.8.2 • Byte 0 Bit 4 – ECDHE secp384r1 (D = 96, C = 48) – RFC 8446 Section 4.2.8.2 • Byte 0 Bit 5 – ECDHE secp521r1 (D = 132 C = 66) – RFC 8446 Section 4.2.8.2 All other values reserved. NOTE: This field is a duplicate of that found in the NEGOTIATE_ALGORITHMS/ALGORITHMS commands. This is included for early error detection and must be the same algorithm as selected in NEGOTIATE_ALGORITHMS/ALGORITHMS
8	RandomData	32	Requester-provided random data.
40	ExchangeData	D	If the selected DHE_Named_Group is finite field, then ExchangeData represents the computed public information. If the selected DHE_Named_Group is ECDHE, the exchange data represents the X and Y values in network byte order. Specifically, X is [0: C - 1] and Y is [C : D – 1]. In both cases the size of D (and C for ECDHE) is derived from the selected DHE_Named_Group.
40 + D	L	2	Length of the OpaqueData to follow.
40 + D + L	OpaqueData	L	If present, OpaqueData sent by the Requester. Used to indicate any parameters that Requester wishes to pass to the Responder for key schedule and/or usage.

Successful KEY_EXCHANGE_RSP response message

Offset	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0x64 = KEY_EXCHANGE_RSP`
2	Param1	1	HeartbeatPeriod The value of this field shall be zero if Heartbeat is not supported. Otherwise, the value shall be in units of seconds.
3	Param2	1	Session ID. The Responder shall choose a session ID. It should be different from the 5 previous sessions or active sessions to the same endpoint.
4	Length	2	Length of the entire request in bytes.
6	Mut_Auth_Requested	1	• Bit 0 – If set, Responder is requesting a Mutual Authentication flow. Requester shall initiate a GET_ENCAPSULATED_REQUEST request. • Bit 1 - If set, Responder is requesting a Mutual Authentication flow with implicit GET_DIGESTS request. Requester shall initiate a DELIVER_ENCAPSULATED_RESPONSE request which encapsulates DIGESTS response. Bit [7:2] reserved.
7	Reserved	1	reserved.
8	RandomData	32	Responder-provided random data.
40	ExchangeData	D	If the selected DHE_Named_Group is finite field, then ExchangeData represents the computed public information. If the selected DHE_Named_Group is ECDHE, the exchange data represents the X and Y values in network byte order. Specifically, X is [0: C - 1] and Y is [C : D – 1]. In both cases the size of D (and C for ECDHE) is derived from the selected DHE_Named_Group.

Offset	Field	Size in bytes	Value
40+D	`MeasurementSummaryHash`	H	When the Responder does not support measurement or requested `Param1` =0, the field shall be absent. When the requested `Param1` =1, this field shall be the combined hash of Measurements of all measurable components considered to be in the TCB required to generate this response, computed as hash(Concatenation(MeasurementBlock[0].Measurement, MeasurementBlock[1].Measurement, ...)) where MeasurementBlock[x].Measurement is a measurement in TCB. When the requested `Param1` =1 and there are no measurable components in the TCB required to generate this response, this field shall be `0` . When requested `Param1=0xFF` , this field is computed as the hash(Concatenation(MeasurementBlock[0].Measurement, MeasurementBlock[1].Measurement, ..., MeasurementBlock[n].Measurement)) of all supported measurements.
40+D+H	Signature	S	Signature over the transcript hash. S is the size of the asymmetric signing algorithm output the Responder selected via the last `ALGORITHMS` response message to the Requester. The construction of the transcript hash is defined in Transcript Hash for `KEY_EXCHANGE_RSP` signature.
40+D+H+S	ResponderVerifyData	O	Conditional field. If both the requester and responder support `HANDSHAKE_IN_THE_CLEAR_CAP` this field is absent with length 0. (O=0). In this mode the entire handshake until FINISH_RSP is carried out in the clear. If either requester or responder do not support `HANDSHAKE_IN_THE_CLEAR_CAP` field this field is of length H (O = H) and it equals HMAC of the transcript hash using a MAC key derived from the shared session keys generated by the Requester and Responder. The construction of the transcript hash is defined in Transcript Hash for `KEY_EXCHANGE_RSP` HMAC.

7.15 FINISH request and FINISH_RSP response messages

This request message shall complete the handshake between Requester and Responder initiated by a `KEY_EXCHANGE` request. The purpose of the `FINISH` request and `FINISH_RSP` response messages is to provide key confirmation, bind each party's identity to the exchanged keys and protect the entire handshake against manipulation by an active attacker. The FINISH request message table shows the `FINISH` request message format and the FINISH_RSP response message table shows the `FINISH_RSP` response message format.

FINISH request message

Offset	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0xE5 = FINISH`
2	Param1	1	Bit 0 – If set, the Signature field is included. This bit shall be set when mutual authentication occurs. All other bits reserved.
3	Param2	1	Slot ID. Only valid if Param1= 0x01, otherwise reserved. Slot number of the target Certificate Chain being authenticated in signature field. The value in this field shall be between 0 and 7 inclusive.
4	Signature	S	Signature over the transcript hash. S is the size of the asymmetric signing algorithm output the Responder selected via the last `ALGORITHMS` response message to the Requester. S is zero and field not present if Param1 = 0x00. The construction of the transcript hash is defined in Transcript Hash for `FINISH` request signature, mutual authentication.
4+S	VerifyData	H	An HMAC of the transcript hash using a MAC key derived from the shared session keys generated by the Requester and Responder. The construction of the transcript hash is defined in Transcript Hash for `FINISH` request HMAC, Responder-only authentication and Transcript Hash for `FINISH` request HMAC, mutual authentication.

Successful FINISH_RSP response message

Offset	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0x65 = FINISH_RSP`
2	Param1	1	Reserved.
3	Param2	1	Reserved.
4	ResponderVerifyData	O	Conditional field. If either the requester or the responder do not support `HANDSHAKE_IN_THE_CLEAR_CAP` this field is absent with length 0. (O = 0). If both the requester and responder support `HANDSHAKE_IN_THE_CLEAR_CAP` field this field is of length H (O = H) and it equals HMAC of the transcript hash using a MAC key derived from the shared session keys generated by the Requester and Responder. The construction of the transcript hash is defined in Transcript Hash for `FINISH_RSP` response HMAC and Transcript Hash for `FINISH_RSP` request HMAC, mutual authentication.

7.15.1 Transcript Hash calculation rules

The Transcript Hash is calculated by concatenating the prescribed full messages or message fields in order. In the following, the notation: `[${message_name}]`.`${field_name}` is used, where:

- `${message_name}` is the name of the request or response message.
- `${field_name}` is the name of the field in the request or response message. The asterisk (`*`) means all fields in that message.

Transcript Hash for `KEY_EXCHANGE_RSP` signature:

```
1.  [GET_VERSION].*
2.  [VERSION].*
3.  [GET_CAPABILITIES].*
4.  [CAPABILITIES].*
5.  [NEGOTIATE_ALGORITHMS].*
6.  [ALGORITHMS].*
7.  The specified certificate chain in DER format(i.e. KEY_EXCHANGE Param2)
8.  [KEY_EXCHANGE].*
9.  [KEY_EXCHANGE_RSP].SPDM Header Fields
10. [KEY_EXCHANGE_RSP].Length
11. [KEY_EXCHANGE_RSP].Mut_Auth_Requested
12. [KEY_EXCHANGE_RSP].Reserved
13. [KEY_EXCHANGE_RSP].RandomData
14. [KEY_EXCHANGE_RSP].ExchangeData
```

Transcript Hash for `KEY_EXCHANGE_RSP` HMAC:

```
1.  [GET_VERSION].*
2.  [VERSION].*
3.  [GET_CAPABILITIES].*
4.  [CAPABILITIES].*
5.  [NEGOTIATE_ALGORITHMS].*
6.  [ALGORITHMS].*
7.  The specified certificate chain in DER format (i.e. KEY_EXCHANGE Param2)
8.  [KEY_EXCHANGE].*
9.  [KEY_EXCHANGE_RSP].SPDM Header Fields
10. [KEY_EXCHANGE_RSP].Length
11. [KEY_EXCHANGE_RSP].Mut_Auth_Requested
12. [KEY_EXCHANGE_RSP].Reserved
13. [KEY_EXCHANGE_RSP].RandomData
14. [KEY_EXCHANGE_RSP].ExchangeData
15. [KEY_EXCHANGE_RSP].Signature
```

Transcript Hash for `FINISH` signature, mutual authentication:

```
1.  [GET_VERSION].∗
2.  [VERSION].∗
2.  [GET_CAPABILITIES].∗
3.  [CAPABILITIES].∗
4.  [NEGOTIATE_ALGORITHMS].∗
5.  [ALGORITHMS].∗
6.  The specified certificate chain in DER format (i.e. KEY_EXCHANGE Param2)
7.  [KEY_EXCHANGE].∗
8.  [KEY_EXCHANGE_RSP].∗
9.  The specified certificate chain in DER format (i.e. FINISH Param2)
10. [FINISH].SPDM Header Fields
```

Transcript Hash for `FINISH` HMAC, Responder-only authentication:

```
1.  [GET_VERSION].∗
2.  [VERSION].∗
3.  [GET_CAPABILITIES].∗
4.  [CAPABILITIES].∗
5.  [NEGOTIATE_ALGORITHMS].∗
6.  [ALGORITHMS].∗
7.  The specified certificate chain in DER format (i.e. KEY_EXCHANGE’s request Param2)
8.  [KEY_EXCHANGE].∗
9.  [KEY_EXCHANGE_RSP].∗
10. [FINISH].SPDM Header Fields
```

Transcript Hash for `FINISH` HMAC, mutual authentication:

```
1. [GET_VERSION].∗
2. [VERSION].∗
3.  [GET_CAPABILITIES].∗
4.  [CAPABILITIES].∗
5.  [NEGOTIATE_ALGORITHMS].∗
6.  [ALGORITHMS].∗
7.  The specified certificate chain in DER format (i.e. KEY_EXCHANGE’s request Param2)
8.  [KEY_EXCHANGE].∗
9.  [KEY_EXCHANGE_RSP].∗
10. The specified certificate chain in DER format (i.e. FINISH’s Param2).
11. [FINISH].SPDM Header Fields
12. [FINISH].Signature
```

Transcript Hash for `FINISH_RES` HMAC, Responder-only authentication:

```
1.  [GET_VERSION].∗
2.  [VERSION].∗
```

```
3.  [GET_CAPABILITIES].*
4.  [CAPABILITIES].*
5.  [NEGOTIATE_ALGORITHMS].*
6.  [ALGORITHMS].*
7.  The specified certificate chain in DER format (i.e. KEY_EXCHANGE's request Param2)
8.  [KEY_EXCHANGE].*
9.  [KEY_EXCHANGE_RSP].*
10. [FINISH].* Fields
11. [FINISH_RSP].SPDM Header fields
```

Transcript Hash for `FINISH_RES` Response HMAC, mutual authentication:

```
1. [GET_VERSION].*
2. [VERSION].*
3.  [GET_CAPABILITIES].*
4.  [CAPABILITIES].*
5.  [NEGOTIATE_ALGORITHMS].*
6.  [ALGORITHMS].*
7.  The specified certificate chain in DER format (i.e. KEY_EXCHANGE's request Param2)
8.  [KEY_EXCHANGE].*
9.  [KEY_EXCHANGE_RSP].*
10. The specified certificate chain in DER format (i.e. FINISH's Param2).
11. [FINISH].*
12. [FINISH_RSP].SPDM Header fields
```

When multiple session keys are being established between the same Requester and Responder pair, Signature over Transcript HASH during FINISH request is computed using only the corresponding KEY_EXCHANGE, KEY_EXCHANGE_RSP and FINISH request parameters.

7.16 PSK_EXCHANGE request and PSK_EXCHANGE_RSP response messages

The Pre-Shared Key (PSK) key exchange scheme provides an option for a Requester and a Responder to perform mutual authentication and session key establishment with symmetric-key cryptography. This option is especially useful for endpoints that do not support asymmetric-key cryptography or certificate processing. This option can also be leveraged to expedite the session key establishment, even if asymmetric-key cryptography is supported.

This option requires the Requester and the Responder to have prior knowledge of a common PSK before the handshake. Essentially, the PSK serves as a mutual authentication credential and the base of the session key establishment. As such, only the two endpoints and potentially a trusted third party that provisions the PSK to the two endpoints may know the value of the PSK.

A Requester may be paired with multiple Responders. Likewise, a Responder may be paired with multiple

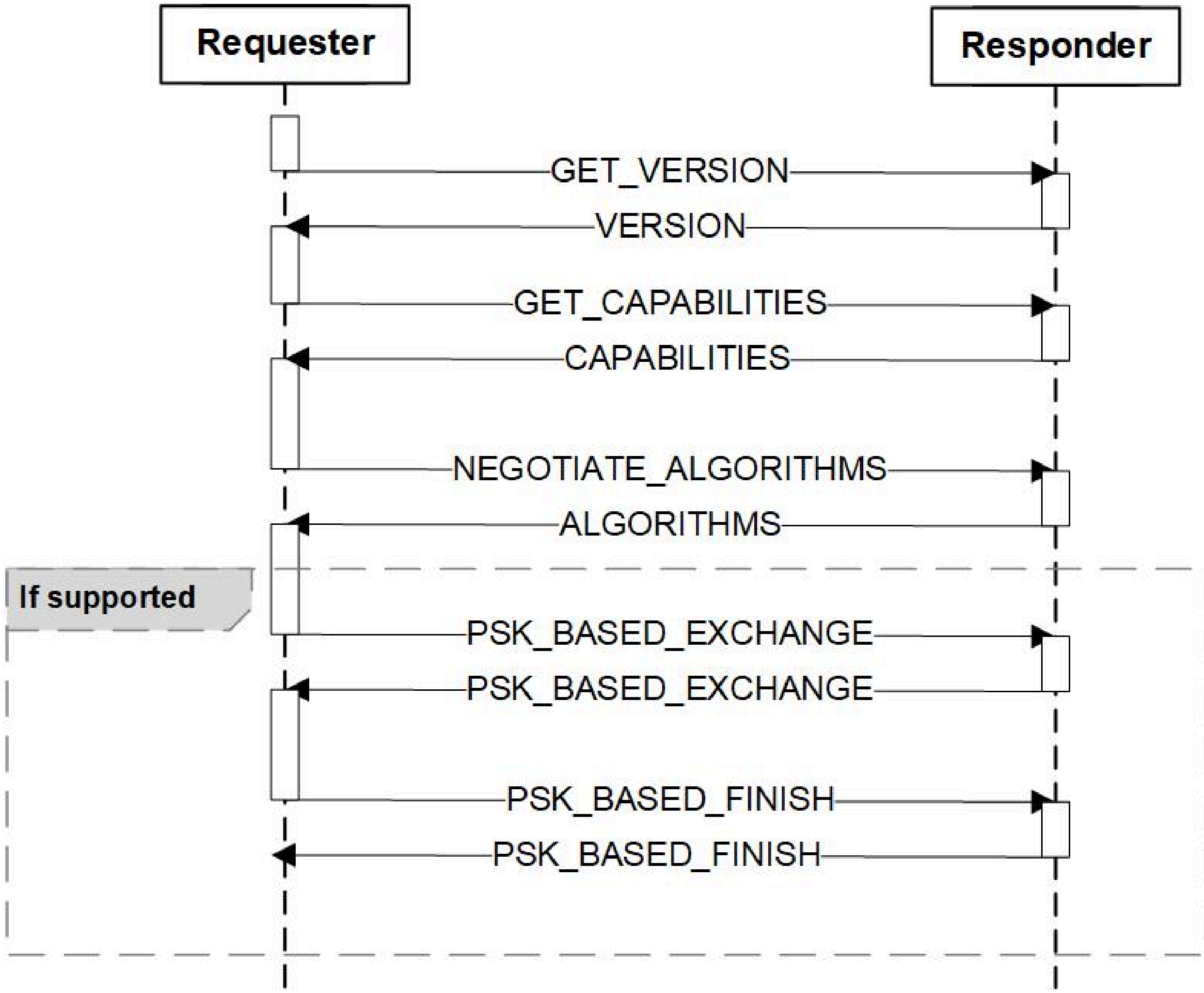
Requesters. A pair of Requester and Responder may be provisioned with one or more PSKs. An endpoint may act as a Requester to one device and simultaneously a Responder to another device. It is the responsibility of the transport layer to identify the peer and establish communication between the two endpoints, before the PSK-based session key exchange starts.

The PSK may be provisioned in a trusted environment, for example, during the secure manufacturing process. In an untrusted environment, the PSK may be agreed upon between the two endpoints using a secure protocol. The mechanism for PSK provisioning is out of scope of this specification. The size of the provisioned PSK is determined by the requirement of security strength of the application, but should be at least 128 bits and recommended to be 256 bits or larger. During PSK provisioning, an endpoint's capabilities and supported algorithms may be communicated to the peer. Therefore, SPDM commands `GET_CAPABILITIES` and `NEGOTIATE_ALGORITHMS` are not required during session key establishment with the PSK option.

Two message pairs are defined for this option: PSK_EXCHANGE/PSK_EXCHANGE_RSP and PSK_FINISH/PSK_FINISH_RSP.

The PSK_EXCHANGE message carries three responsibilities:

1. Prompts the Responder to retrieve the specific PSK.
2. Exchanges contexts between the Requester and the Responder.
3. Proves to the Requester that the Responder knows the correct PSK and has derived the correct session keys.



PSK_EXCHANGE request message

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0xE6 = PSK_EXCHANGE`

Offsets	Field	Size in bytes	Value
2	Param1	1	Requested measurement summary hash Type: • `0x0` . No measurement summary hash. • `0x1=TCB` . Component measurement hash. • `0xFF` . All measurements hash. All other values reserved. When Responder does not support any measurements, Requester shall set this value to `0x0` .
3	Param2	1	Reserved
4	P	2	Length of the OpaquePSKData.
6	R	1	Length of the RequesterContext. R must be equal to or greater than H, where H is the size of the underlying MAC used in key derivation.
7	Reserved	1	Reserved
8	RequesterContext	R	Requester's context. Must include random nonce and optionally Requester's information.
8+R	OpaquePSKData	P	Opaque data required by the Responder to retrieve the PSK. Optional.

The field OpaquePSKData is optional (absent if P is set to 0). It is introduced to address two scenarios:

- The Responder is provisioned with multiple PSKs and stores them in secure storage. The Requester uses OpaquePSKData as an ID to specify which PSK will be used in this session.
- The Responder does not store the value of the PSK, but can derive the PSK using OpaquePSKData. For example, if the Responder has an immutable UDS (Unique Device Secret) in fuses, then during provisioning, a PSK may be derived from the UDS or its derivative and a non-secret salt provided by the Requester. During session key establishment, the same salt is sent to the Responder in OpaquePSKData of PSK_EXCHANGE. This mechanism allows the Responder to support any number of PSKs, without consuming secure storage.

The RequesterContext is the Requester's contribution to session key derivation. It must contain a random nonce to make sure the derived session keys are ephemeral for this session only to mitigate against replay attacks. It may also contain other information from the Requester.

Upon receiving PSK_EXCHANGE request, the Responder:

1. Acquires PSK from OpaquePSKData, if necessary.
2. Generates ResponderContext, if supported.
3. Derives the Responder's finished_key by following Key Schedule.
4. Constructs PSK_EXCHANGE_RSP response message and sends to the Requester.

PSK_EXCHANGE_RSP message

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0x66 = PSK_EXCHANGE_RSP`
2	Param1	1	HeartbeatPeriod The value of this field shall be zero if Heartbeat is not supported. Otherwise, the value shall be in units of seconds.
3	Param2	1	Session ID. The Responder shall choose a session ID. It should be different from the 5 previous sessions or active sessions to the same endpoint.
4	Q	1	Length of ResponderContext in bytes. Must be multiple of 4 and should be at most 64.
5	Reserved	3	Reserved
8	ResponderContext	Q	Responder's context. Optional. If present, must include a nonce and/or Responder's information.
8+Q	`MeasurementSummaryHash`	H	When the Responder does not support measurement or requested `param1` =0, the field shall be absent. When the requested `param1` =1, this field shall be the combined hash of Measurements of all measurable components considered to be in the TCB required to generate this response, computed as hash(Concatenation(MeasurementBlock[0].Measurement, MeasurementBlock[1].Measurement, ...)) where MeasurementBlock[x].Measurement is a measurement in TCB. When the requested `param1` =1 and there are no measurable components in the TCB required to generate this response, this field shall be `0` . When requested `param1=0xFF` , this field is computed as the hash(Concatenation(MeasurementBlock[0].Measurement, MeasurementBlock[1].Measurement, ..., MeasurementBlock[n].Measurement)) of all supported measurements.
8+Q+H	ResponderVerifyData	H	Data to be verified by the Requester using the Responder's finished_key.

The ResponderContext is the Responder's contribution to session key derivation. It should contain a nonce (random number or monotonic counter) and other information of the Responder. Because the Responder may be a constrained device that is not able to generate nonce, ResponderContext is optional. However, the Responder is required to use ResponderContext if it can generate a nonce.

It should be noted that the nonce in ResponderContext is critical for anti-replay. If a nonce is not present in

ResponderContext, then the Responder is not challenging the Requester for real-time knowledge of PSK. Such a session is subject to replay attacks - a man-in-the-middle attacker could record and replay prior PSK_EXCHANGE and PSK_FINISH messages and set up a session with the Responder. But the bogus session would not leak secrets, so long as the PSK or session keys of the prior replayed session are not compromised.

If ResponderContext is present in the response (i.e., `PSK_CAP` in Responder's `CAPABILITIES` is `10b`), then the Requester must send PSK_FINISH with requester_verify_data to prove that it has derived correct session keys. However, if ResponderContext is absent (i.e., `PSK_CAP` in Responder's `CAPABILITIES` is `01b`), then the Requester is not required to send PSK_FINISH, as the session keys are solely determined by the Requester. In other words, if the Responder demands session key verification, then it must use ResponderContext, even if a nonce is not included, to signal the Requester to send PSK_FINISH request.

To calculate ResponderVerifyData, the Responder calculates a MAC. The MAC key is the Responder's finished_key. The data is the concatenation of all data sent so far between the Requester and the Responder:

1. `[GET_VERSION].*` (if issued)
2. `[VERSION].*` (if issued)
3. `[GET_CAPABILITIES].*` (if issued)
4. `[CAPABILITIES].*` (if issued)
5. `[NEGOTIATE_ALGORITHMS].*` (if issued)
6. `[ALGORITHMS].*` (if issued)
7. `[PSK_EXCHANGE].*`
8. `[PSK_EXCHANGE_RSP].SPDMVersion`
9. `[PSK_EXCHANGE_RSP].RequestResponseCode`
10. `[PSK_EXCHANGE_RSP].Param1`
11. `[PSK_EXCHANGE_RSP].Param2`
12. `[PSK_EXCHANGE_RSP].responder_context`

Upon receiving PSK_EXCHANGE_RSP, the Requester:

1. Derives the Responder's finish key by following Key Schedule.
2. Verify ResponderVerifyData by calculating the MAC in the same manner as the Responder. If verification fails, the Requester aborts the session.
3. If the Responder contributes to session key derivation (`PSK_CAP` in Responder's `CAPABILITIES` is `10b`), construct PSK_FINISH request and send to the Responder.

7.17 PSK_FINISH request and PSK_FINISH_RSP response messages

The PSK_FINISH request proves to the Responder that the Requester knows the PSK and has derived the correct session keys. This is achieved by a MAC value calculated with the Requester's finished_key and messages of this session. The Requester is required to send the PSK_FINISH only if ResponderContext is present in PSK_EXCHANGE_RSP. Otherwise, PSK_FINISH is optional.

PSK_FINISH request message

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0xE7 = PSK_FINISH`
2	Param1	1	Reserved.
3	Param2	1	Reserved.
4	RequesterVerifyData	H	Data to be verified by the Responder using the Requester's finished_key.

To calculate RequesterVerifyData, the Requester calculates a MAC. The key is the Requester's finished_key, as described in Key Schedule. The data is the concatenation of all data sent so far between the Requester and the Responder:

1. `[GET_VERSION].*` (if issued)
2. `[VERSION].*` (if issued)
3. `[GET_CAPABILITIES].*` (if issued)
4. `[CAPABILITIES].*` (if issued)
5. `[NEGOTIATE_ALGORITHMS].*` (if issued)
6. `[ALGORITHMS].*` (if issued)
7. `[PSK_EXCHANGE].*`
8. `[PSK_EXCHANGE_RSP].*`
9. `[PSK_FINISH].SPDMVersion`
10. `[PSK_FINISH].RequestResponseCode`
11. `[PSK_FINISH].Param1`
12. `[PSK_FINISH].Param2`

Upon receiving PSK_FINISH request, the Responder derives the Requester's finished_key and calculates the MAC independently in the same manner and verifies the result matches RequesterVerifyData. If verified, then the Responder constructs PSK_FINISH_RSP response and sends to the Requester. Otherwise, the Responder sends ERROR response message to the Requester.

PSK_FINISH_RSP response message

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0x67 = PSK_FINISH_RSP`
2	Param1	1	Reserved.
3	Param2	1	Reserved.

7.18 HEARTBEAT Request and HEARTBEAT_ACK Response

This request shall keep a session alive if `HEARTBEAT` is supported by both the Requester and Responder. The `HEARTBEAT` request shall be sent periodically as indicated in `HeartbeatPeriod` in either `KEY_EXCHANGE_RSP` or `PSK_EXCHANGE_RSP` response messages. The Responder shall terminate the session if a `HEARTBEAT` request is not received in twice `HeartbeatPeriod`. Likewise, the Requester shall terminate the session if a `HEARTBEAT_ACK` response or `ERROR` response is not received in twice `HeartbeatPeriod`. If an `Error` with `ErrorCode=InvalidSessionID` Response is received, the Requester shall terminate the session. The Requester may retry `HEARTBEAT` requests. The Requester shall wait `ST1` time for the response before retrying.

The timer for the Heartbeat period shall start at the transmission, for Responders, or reception, for Requester, of either the `FINISH_RSP` or `PSK_FINISH_RSP` response messages. When determining the value of HeartbeatPeriod, the Responder should ensure this value is sufficiently greater than `RTT`.

For further details of session termination, see Session Termination Handling.

The HEARTBEAT Request Message Format Table describes the format for the Heartbeat Request.

HEARTBEAT Request Message Format

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0xE8 = HEARTBEAT` Request
2	Param1	1	Reserved.
3	Param2	1	Reserved.

The HEARTBEAT_ACK Response Message Format Table describes the format for the Heartbeat Response.

HEARTBEAT_ACK Response Message Format

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0x68 = HEARTBEAT_ACK` Response
2	Param1	1	Reserved.
3	Param2	1	Reserved.

7.18.1 Heartbeat Additional Information

The transport layer may allow the `HEARTBEAT` request to be sent from the Responder to the Requester. This is recommended for transports capable of asynchronous bidirectional communication.

7.19 KEY_UPDATE Request and KEY_UPDATE_ACK Response

To update session keys, this request shall be used. There are many reasons for doing this but an important one is when the per-record nonce will soon reach its maximum value and rollover. The KEY_UPDATE request can be issued by the Responder as well using the GET_ENCAPSULATED_REQUEST mechanism. A KEY_UPDATE request shall update session keys in the direction of the request only. Because the Responder can also send this request, it is possible that two simultaneous key updates, one for each direction, can occur. However, only one KEY_UPDATE request for a single direction shall occur. Until the session key update synchronization successfully completes, subsequent KEY_UPDATE request for the same direction shall be considered a retry of the original KEY_UPDATE request.

KEY_UPDATE Request Message Format

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0xE9 = KEY_UPDATE` Request
2	Param1	1	Key Operation. See KEY_UPDATE Operations Table.
3	Param2	1	Tag. This field shall contain a unique number to aid the responder in differentiating between the original and retry request. A retry request shall contain the same tag number as the original.

KEY_UPDATE_ACK Response Message Format

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0x69 = KEY_UPDATE_ACK` Response
2	Param1	1	Key Operation. This field shall reflect the Key Operation field of the request.
3	Param2	1	Tag. This field shall reflect the Tag number in the `KEY_UPDATE` request.

KEY_UPDATE Operations Table

Value	Operation	Description
0	Reserved	Reserved
1	UpdateKey	Update the single-direction key.
2	UpdateAllKeys	Update keys for both directions.
3	VerifyNewKey	Ensure the key update is successful and the old keys can be safely discarded.
4 - 255	Reserved	Reserved

7.19.1 Session Key Update Synchronization

For clarity, in the key update process, the term, sender, means the SPDM endpoint that issued the `KEY_UPDATE` request and the term, receiver, means the SPDM endpoint that received the `KEY_UPDATE` request, acted upon and responded to it accordingly. Furthermore, the sender only updates session keys in the sending direction and similarly, the receiver updates keys in the receiving direction.

To ensure the key update process is seamless while still allowing the transmission and reception of records, both sender and receiver shall follow the prescribed method described in this section.

The Session Key Update Synchronization process shall start with the responsibility on the sender to quiesce all application data traffic to the receiver. If `UpdateAllKeys` is the selected operation, the receiver shall also quiesce all application data traffic to the sender. If `UpdateKey` is the selected operation, the receiver may also quiesce application traffic to the sender but this is unnecessary. The actual method used by Requester or Responder to quiesce the flow of application traffic in either direction is outside the scope of this specification. Once the sender has quiesced the transportation of application data to the receiver, the sender shall, then, send a `KEY_UPDATE` request with `UpdateKey` or `UpdateAllKeys` operation.

When the sender sends the `KEY_UPDATE` request with one of the key update operations, the sender should, at the same time, derive the new session key for the sending direction. If the selected operation is `UpdateAllKeys` , the sender should also, at the same time, derive the new session key for the receiving direction. However, the sender shall not use the new session keys yet. Likewise, after the successful reception of the `KEY_UPDATE` request with `UpdateKey` operation, the receiver shall derive the new session keys for the receiving direction. If the selected operation is `UpdateAllKeys`, the receiver shall also derive the new session keys for the sending direction and it shall immediately use this key for the `KEY_UPDATE_ACK` and subsequent messages. Both the sender and the receiver shall derive the new keys as detailed in Major Secrets Update. Only upon the reception of the `KEY_UPDATE_ACK` response, the sender shall immediately use the new session keys. If the sender has not received `KEY_UPDATE_ACK`, the sender may retry or end the session. The sender shall not proceed to the next step until successfully receiving the corresponding `KEY_UPDATE_ACK`.

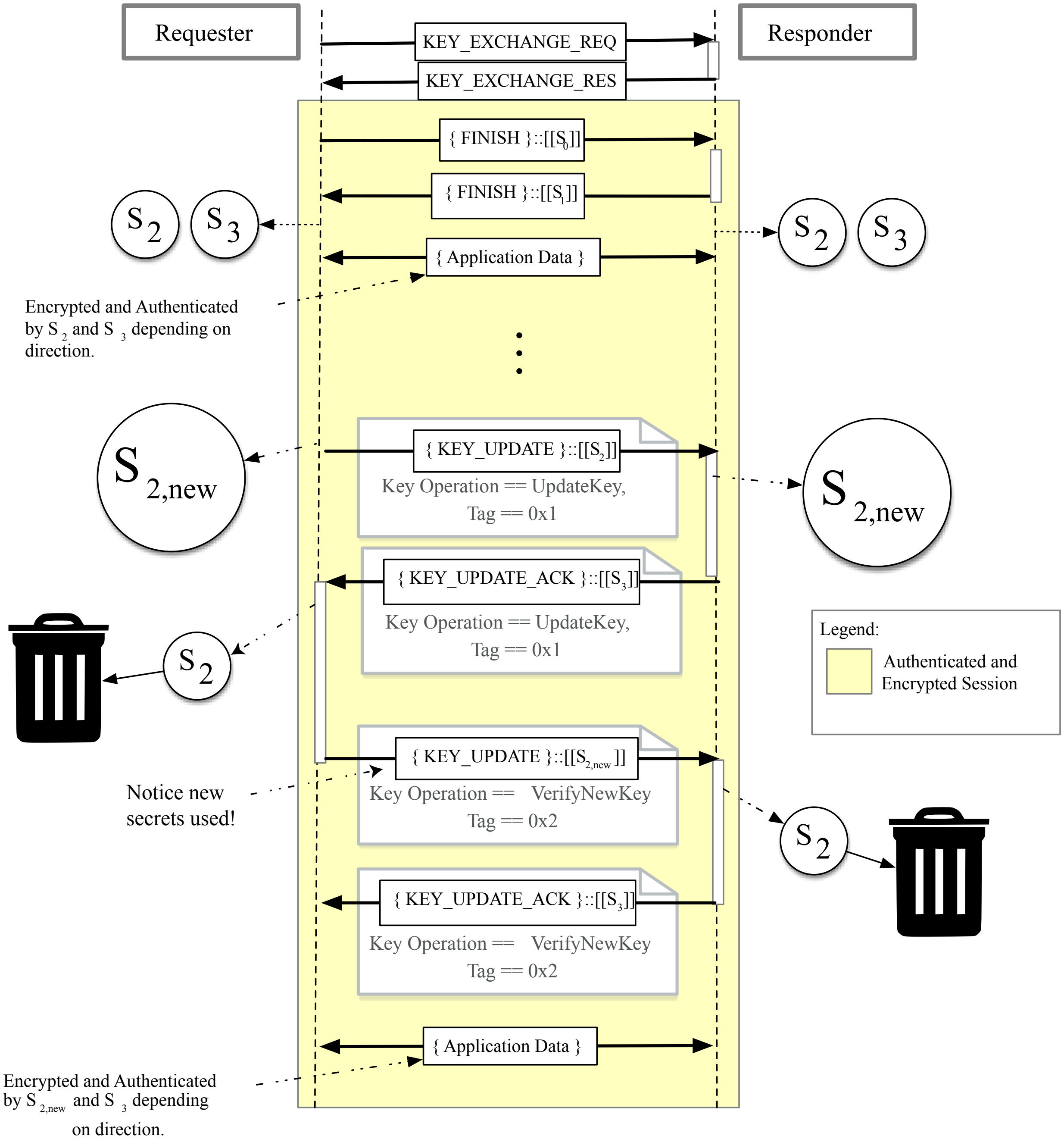
At this time, best practices recommends the sender discards the old session keys. Even though the receiver has transmitted the `KEY_UPDATE_ACK` response, the receiver shall use both the the current session keys and the new session keys for the direction of data traffic from the sender. If the selected operation is `UpdateAllKeys`, then the receiver may discard the old session key for the direction of data traffic towards the sender.

Upon the successful reception of the `KEY_UPDATE_ACK`, the sender shall have *ST1* time to transmit a `KEY_UPDATE` request with `VerifyNewKey` operation using the new session keys. The sender may retry until the corresponding `KEY_UPDATE_ACK` response is received. However, the sender shall be prohibited, at this point, from restarting this process or going back to a previous step. Its only recourse in error handling is either to retry the same request or to terminate the session. Upon successful reception of the `KEY_UPDATE` with `VerifyNewKey` operation, the receiver can now discard the old session keys. After the sender successfully receives the corresponding `KEY_UPDATE_ACK`, transportation of application data may resume. Also, at this point, the transportation of the application data shall now use the new session keys accordingly.

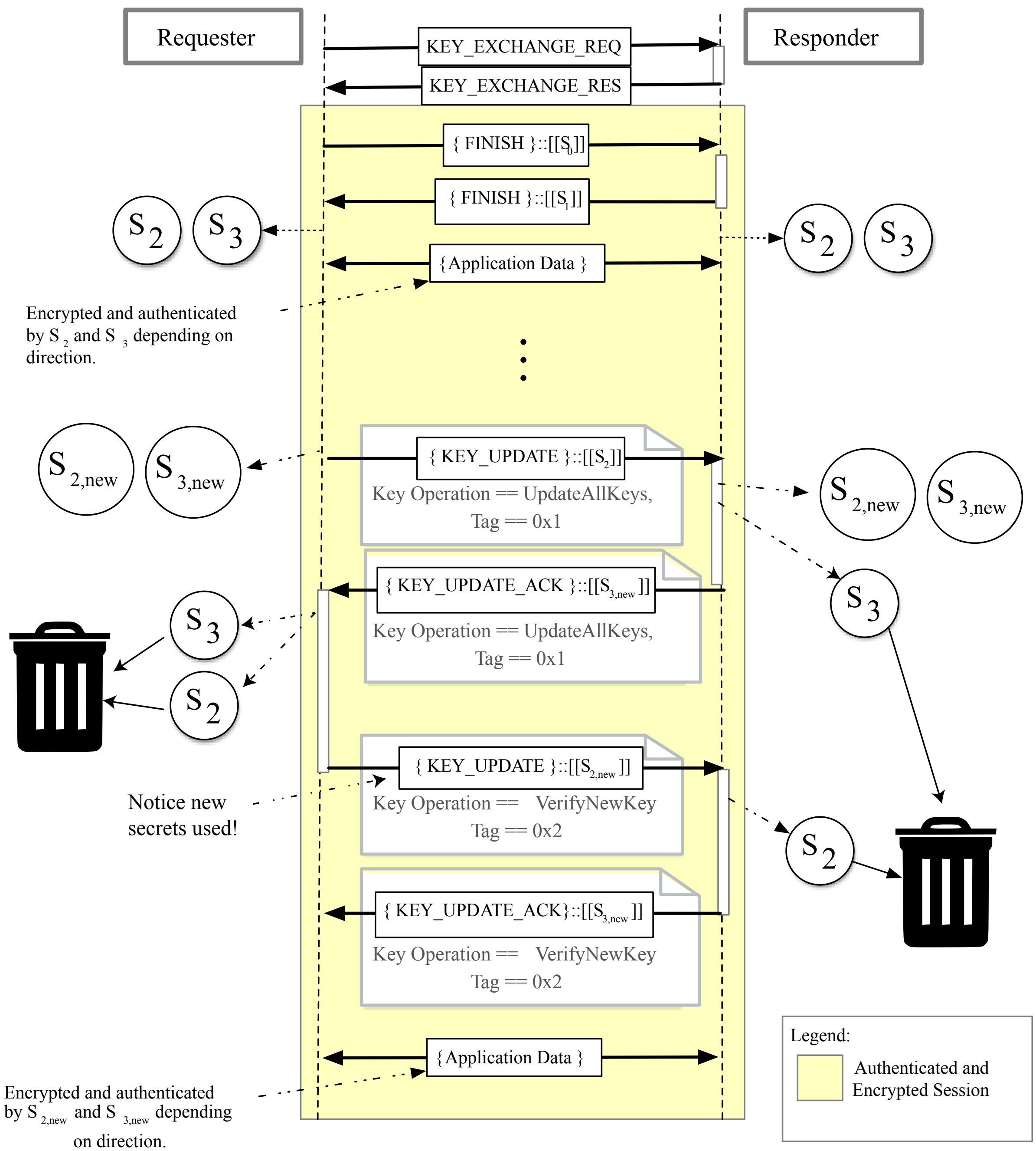
In certain scenarios, the receiver may need additional time to process the `KEY_UPDATE` request such as processing data already in its buffer. Thus, the receiver may reply with an `ERROR` message with `ErrorCode=Busy`. The sender should retry the request after a reasonable period of time with a reasonable amount of retries to prevent premature session termination.

Finally, it bears repeating that a key update in one direction can happen simultaneously with a key update in the opposite direction. Still, the aforementioned synchronization process still works and occurs independently but simultaneously for each direction.

The Key Update Protocol Example Flow figure illustrates a typical key update initiated by the Requester to update its secret. In this example, the Responder and Requester are both capable of message authentication and encryption.



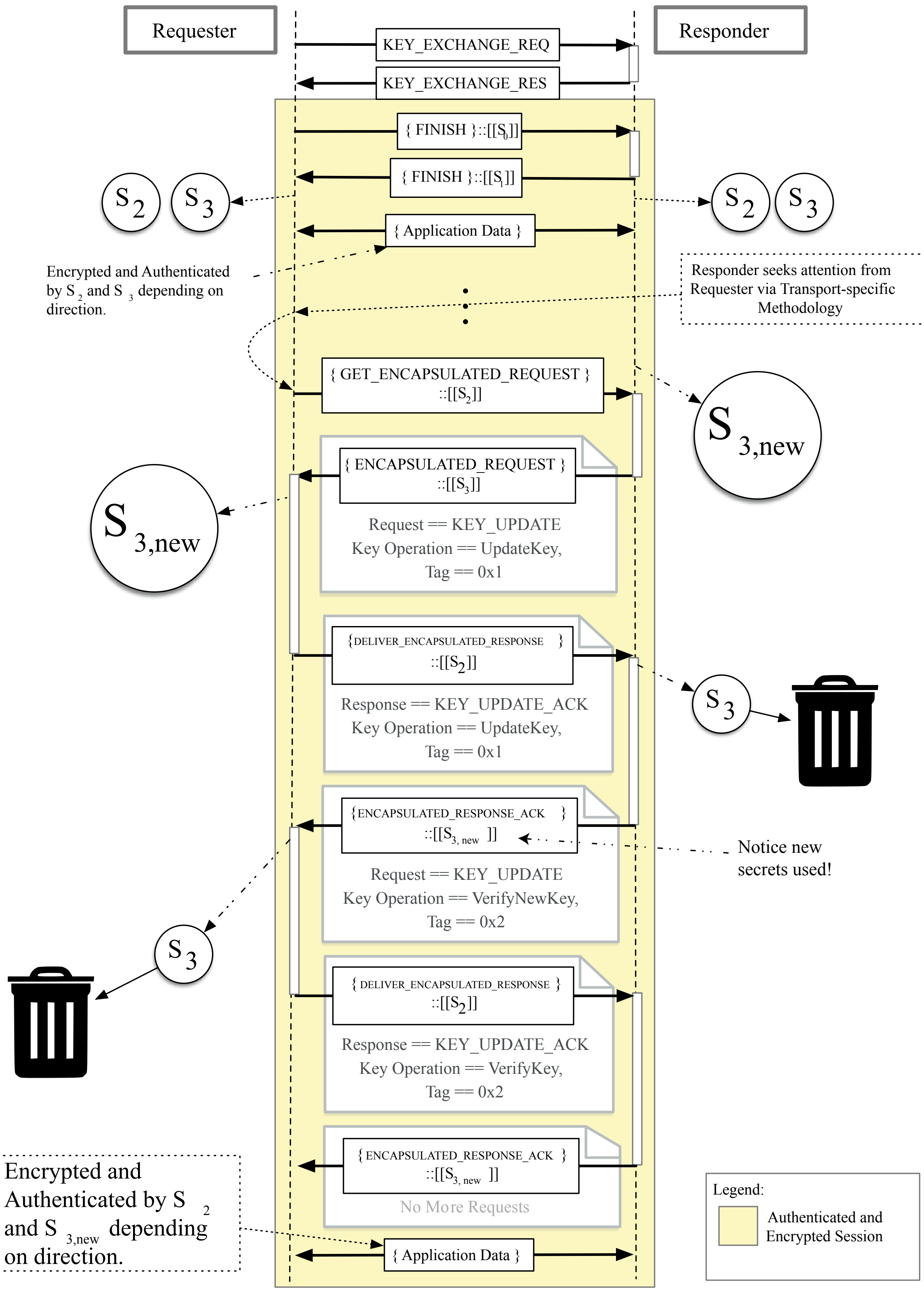
The Key Update Protocol Change All Keys Example Flow figure illustrates a typical key update initiated by the Requester to update all secrets. In this example, the Responder and Requester are both capable of message authentication and encryption.



7.19.2 KEY_UPDATE Transport Allowances

On some transports, bidirectional communication can occur asynchronously. On such transports, the transport may allow or disallow the `KEY_UPDATE` to be sent asynchronously without using the `GET_ENCAPSULATED_REQUEST` mechanism. The actual method to use should be defined by the transport and is outside the scope of this specification.

The Key Update Protocol Example Flow 2 figure illustrates a key update over a physical transport that has a limitation where by only a single device (often called the master) is allowed to initiate all transactions on that bus. This physical transport specifies that a Responder must alert the Requester via a sideband mechanism and to utilize the `GET_ENCAPSULATED_REQUEST` mechanism to fulfill SPDM-related requirements. Also, in this same example, the Requester and Responder are both capable of encryption and message authentication.

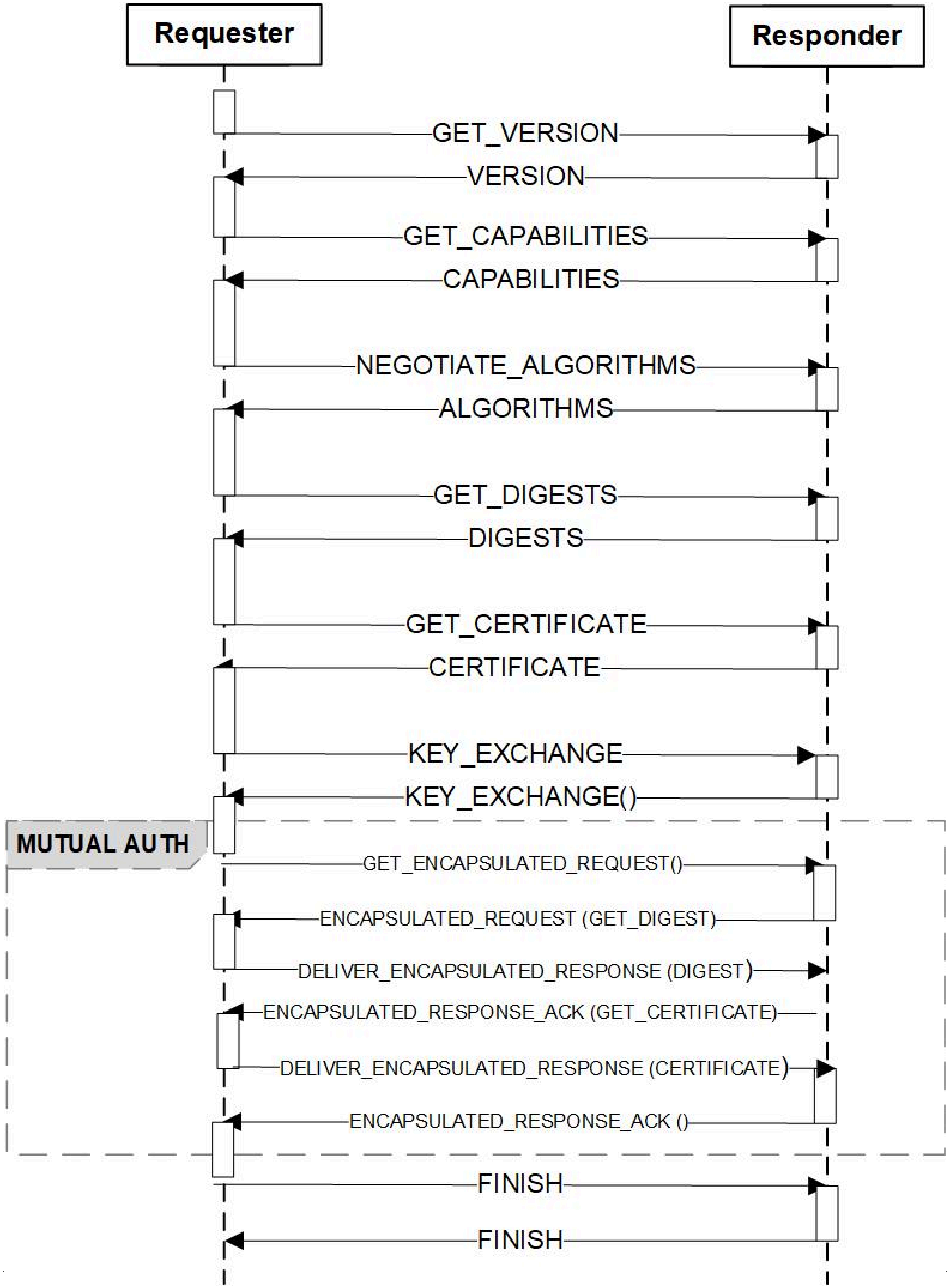

Requester
Responder
KEY_EXCHANGE_REQ
KEY_EXCHANGE_RES
{ FINISH }::[[S0]]
{ FINISH }::[[S1]]
S2
S3
{ Application Data }
Encrypted and Authenticated by S2 and S3 depending on direction.
Responder seeks attention from Requester via Transport-specific Methodology
{ GET_ENCAPSULATED_REQUEST } ::[[S2]]
S3,new
{ ENCAPSULATED_REQUEST } ::[[S3]]
Request == KEY_UPDATE
Key Operation == UpdateKey,
Tag == 0x1
{DELIVER_ENCAPSULATED_RESPONSE } ::[[S2]]
Response == KEY_UPDATE_ACK
Key Operation == UpdateKey,
Tag == 0x1
{ENCAPSULATED_RESPONSE_ACK } ::[[S3, new]]
Notice new secrets used!
Request == KEY_UPDATE
Key Operation == VerifyNewKey,
Tag == 0x2
{ DELIVER_ENCAPSULATED_RESPONSE } ::[[S2]]
Response == KEY_UPDATE_ACK
Key Operation == VerifyKey,
Tag == 0x2
{ ENCAPSULATED_RESPONSE_ACK } ::[[S3, new]]
No More Requests
Encrypted and Authenticated by S2 and S3,new depending on direction.
{ Application Data }
Legend:
Authenticated and Encrypted Session

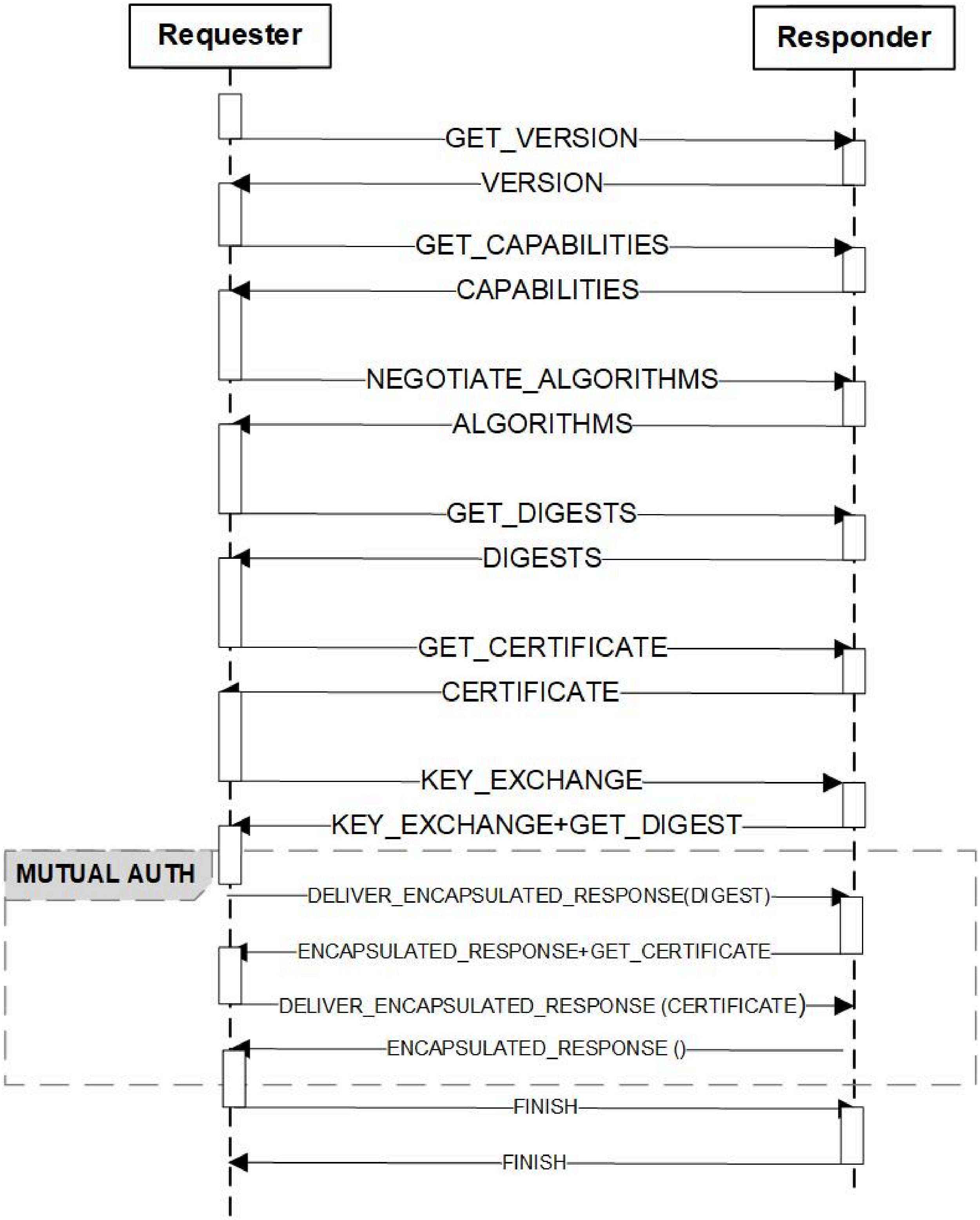
7.20 GET_ENCAPSULATED_REQUEST Request and ENCAPSULATED_REQUEST Response

This request retrieves an SPDM request message from the Responder. This request is only allowed in certain scenarios. See Session clauses for details.

The response for this message encapsulates an SPDM request message as if the Responder was a Requester. The request message format is described in `GET_ENCAPSULATED` Request Format Table. The Responder shall use the same SPDM version the Requester used.

Except for this request and `DELIVER_ENCAPSULATED_RESPONSE`, the Requester shall not send any other SPDM request message until successfully fulfilling the Responder's request. If a Responder receives a request other than `DELIVER_ENCAPSULATED_RESPONSE` or `GET_ENCAPSULATED_REQUEST` after the Responder already has provided a request to the Requester to which it has not received a response, the Responder shall respond with `ErrorCode=RequestInFlight`.


Requester
Responder
GET_VERSION
VERSION
GET_CAPABILITIES
CAPABILITIES
NEGOTIATE_ALGORITHMS
ALGORITHMS
GET_DIGESTS
DIGESTS
GET_CERTIFICATE
CERTIFICATE
KEY_EXCHANGE
KEY_EXCHANGE()
MUTUAL AUTH
GET_ENCAPSULATED_REQUEST()
ENCAPSULATED_REQUEST (GET_DIGEST)
DELIVER_ENCAPSULATED_RESPONSE (DIGEST)
ENCAPSULATED_RESPONSE_ACK (GET_CERTIFICATE)
DELIVER_ENCAPSULATED_RESPONSE (CERTIFICATE)
ENCAPSULATED_RESPONSE_ACK ()
FINISH
FINISH


Requester
Responder
GET_VERSION
VERSION
GET_CAPABILITIES
CAPABILITIES
NEGOTIATE_ALGORITHMS
ALGORITHMS
GET_DIGESTS
DIGESTS
GET_CERTIFICATE
CERTIFICATE
KEY_EXCHANGE
KEY_EXCHANGE+GET_DIGEST
MUTUAL AUTH
DELIVER_ENCAPSULATED_RESPONSE(DIGEST)
ENCAPSULATED_RESPONSE+GET_CERTIFICATE
DELIVER_ENCAPSULATED_RESPONSE (CERTIFICATE)
ENCAPSULATED_RESPONSE ()
FINISH
FINISH

GET_ENCAPSULATED_REQUEST Request Message Format

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0xEA = GET_ENCAPSULATED_REQUEST`
2	Param1	1	Reserved.
3	Param2	1	Reserved.

The ENCAPSULATED_REQUEST Response Format Table describes the format this response.

ENCAPSULATED_REQUEST Response Format Table

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0x6A = ENCAPSULATED_REQUEST` Response
2	Param1	1	Request ID. This field should be unique to help the Responder match response to request.
3	Param2	1	Reserved.
4+	Encapsulated Request	Variable	SPDM Request Message. The value of this field shall represent a valid SPDM request message. The length of this field is dependent on the SPDM Request message. The field shall start with the `RequestResponseCode` field. Both `GET_ENCAPSULATED_REQUEST` and `DELIVER_ENCAPSULATED_RESPONSE` shall be invalid requests and the Requester shall respond with `ErrorCode=UnexpectedRequest` if these requests are encapsulated.

7.20.1 GET_ENCAPSULATED_REQUEST Attention

Once a session has been established, the Responder may wish to send a request asynchronously such as a `KEY_UPDATE` request but cannot due to the limitations of the physical bus or transport protocol. In such a scenario, the transport and/or physical layer is responsible for defining an alerting mechanism for the Requester. Upon receiving the alert, the Requester shall issue a GET_ENCAPSULATED_REQUEST to the Responder.

7.21 DELIVER_ENCAPSULATED_RESPONSE Request and

ENCAPSULATED_RESPONSE_ACK Received Message

In order to provide a response to a Responder's request, this request shall be used. This request delivers the response to the Responder's request which was encapsulated in the previous `ENCAPSULATED_REQUEST` response message.

Furthermore, if there are additional requests from the Responder, the Responder shall provide the next request in the `ENCAPSULATED_RESPONSE_ACK` response message.

As with the `GET_ENCAPSULATED_REQUEST` message, the Requester shall not send any other requests with the exception of `DELIVER_ENCAPSULATED_RESPONSE` until successfully delivering the response to the current request from the Responder. If a Responder receives a request other than `DELIVER_ENCAPSULATED_RESPONSE` after the Responder already has provided a request to the Requester to which it has not received a response, the Responder shall respond with `ErrorCode=RequestInFlight`.

The timing parameters for the response shall depend on the encapsulated request. This allows the Responder to process the response before delivering the next request. See Additional Information for more details.

The request message format is described in `DELIVER_ENCAPSULATED_RESPONSE` Request Message Format Table.

DELIVER_ENCAPSULATED_RESPONSE Request Message Format

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0xEB = DELIVER_ENCAPSULATED_RESPONSE` Request
2	Param1	1	Request ID. The Requester shall use the same Request ID as provided by the Responder.
3	Param2	1	Reserved.
4+	Encapsulated Response	Variable	SPDM Response Message. The value of this field shall represent a valid SPDM response message. The length of this field is dependent on the SPDM Response message. The field shall start with the `RequestResponseCode` field. Both `ENCAPSULATED_REQUEST` and `ENCAPSULATED_RESPONSE_ACK` shall be invalid responses and the Responder shall respond with `ErrorCode=InvalidResponseCode` if these responses are encapsulated.

The response message format is described in `ENCAPSULATED_RESPONSE_ACK` Response Format Table.

ENCAPSULATED_RESPONSE_ACK Response Format

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0x6B = ENCAPSULATED_RESPONSE_ACK`
2	Param1	1	Request ID. This field should be unique to help the Responder match response to request. This field shall be non-zero to indicate the presence of the next request in this message.
3	Param2	1	Reserved.
4+	Encapsulated Request	Variable	SPDM Request Message. The value of this field shall represent a valid SPDM request message. The length of this field is dependent on the SPDM Request message. The field shall start with the `RequestResponseCode` field. Both `GET_ENCAPSULATED_REQUEST` and `DELIVER_ENCAPSULATED_RESPONSE` shall be invalid requests and the Requester shall respond with `ErrorCode=UnexpectedRequest` if these requests are encapsulated.

7.21.1 Additional Information

Using a unique request ID is highly recommended to avoid confusion between a retry and a new request of the `DELIVER_ENCAPSULATED_RESPONSE` request. For example, if the Responder sent the `ENCAPSULATED_RESPONSE_ACK` and that failed in transmission over the wire, the Requester could send a retry. The responder may think the `DELIVER_ENCAPSULATED_RESPONSE` was a new request especially if the request encapsulated an `ERROR` message for the original request when in fact it was a retry of the original message.

In general, if a Responder has a new request, the response timing for `ENCAPSULATED_RESP_ACK` shall be subject to the same timing constraints as the original request. For example, if the encapsulated request was `CHALLENGE_AUTH`, the Responder, too, shall adhere to `CT` timing rules when it has a subsequent request. The Responder may return `ErrorCode=ResponseNotReady`.

7.22 END_SESSION Request and END_SESSION_ACK Response

This request shall terminate a session. Further communication between the Requester and Responder using the same session ID shall be prohibited. The Responder shall return `ErrorCode=InvalidSession` after session termination. See Session Termination Handling clause for details.

The END_SESSION Request Format table describes this request's format.

END_SESSION Request Message Format

Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0xEC = END_SESSION`
2	Param1	1	See End Session Request Attributes.
3	Param2	1	Reserved.

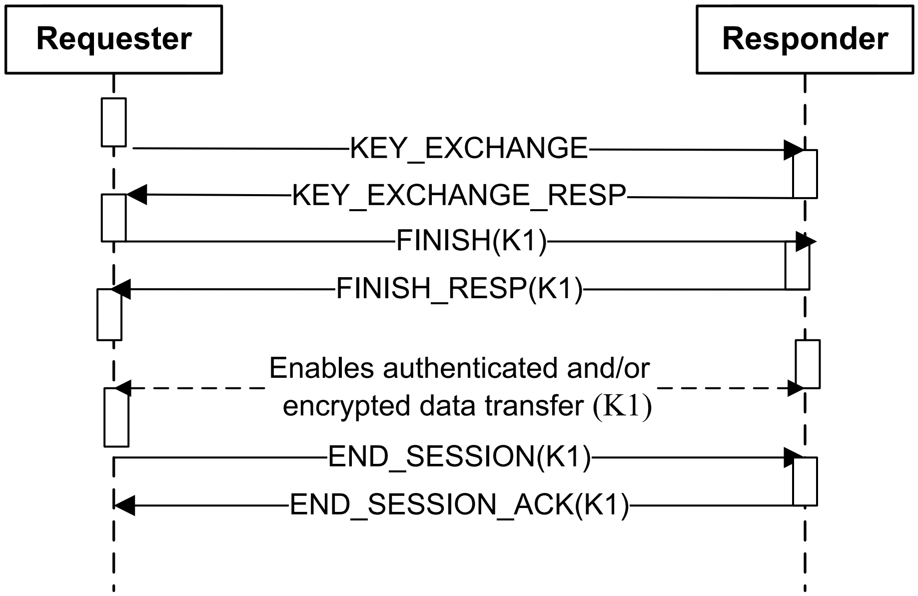
End Session Request Attributes

Bit Offset(s)	Value	Field Name	Description
0	0	Negotiated State Preservation Indicator	If the Responder supports Negotiated State caching (`CAP_CACHE==1`), the Responder shall preserve the Negotiated State.
0	1	Negotiated State Preservation Indicator	If the Responder supports Negotiated State caching, the Responder shall also clear the Negotiated State as part of session termination.
[7:1]	Reserved	Reserved	Reserved

The response message for this request is described in END_SESSION_ACK Response Format Table.

END_SESSION_ACK Response Message Format

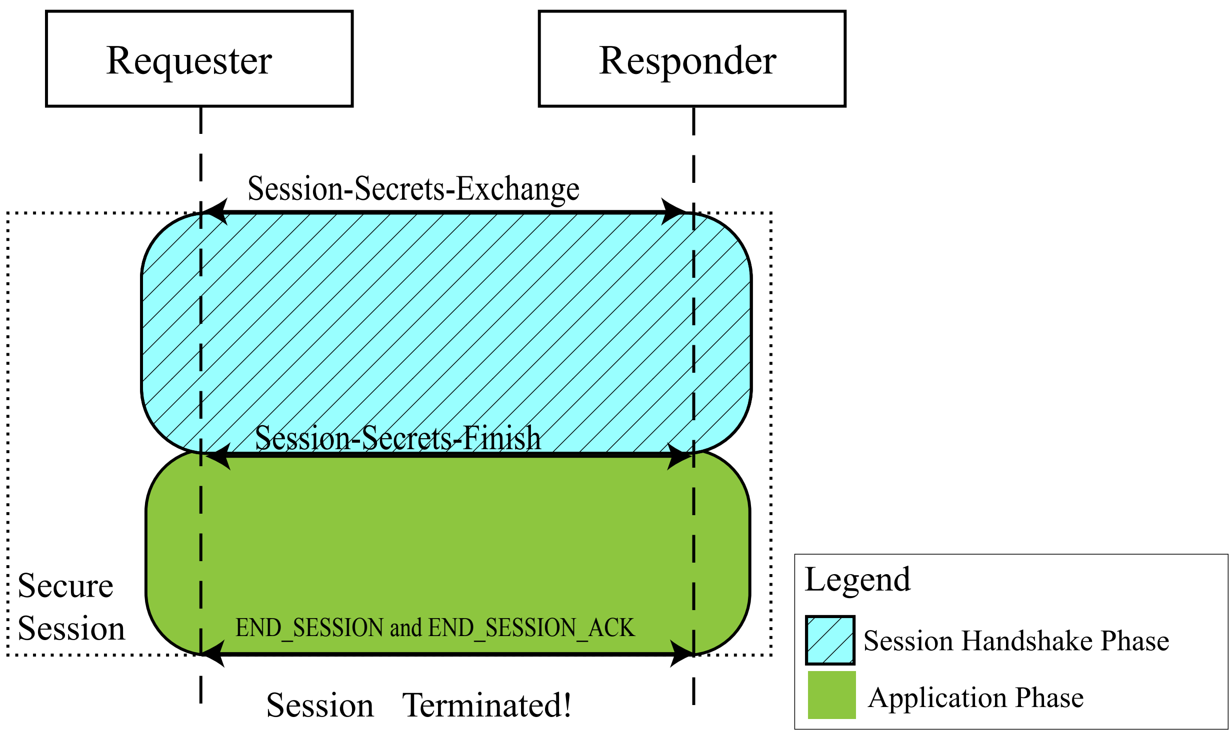
Offsets	Field	Size in bytes	Value
0	SPDMVersion	1	`V1.1 = 0x11`
1	`RequestResponseCode`	1	`0x6C = END_SESSION_ACK`
2	Param1	1	Reserved.
3	Param2	1	Reserved.


Requester
Responder
KEY_EXCHANGE
KEY_EXCHANGE_RESP
FINISH(K1)
FINISH_RESP(K1)
Enables authenticated and/or encrypted data transfer (K1)
END_SESSION(K1)
END_SESSION_ACK(K1)

8 Session

Sessions allows a Requester and Responder to have multiple channels of communication. More importantly, it allows a Requester and Responder to build a secure communication channel with cryptographic information that is bound ephemerally. Specifically, an SPDM session provides either or both of encryption or message authentication.

There are 3 phases in a session as illustrated in Session Phases: the handshake, the application and termination.



8.1 Session Handshake Phase

The session handshake phase begins with either `KEY_EXCHANGE` or `PSK_EXCHANGE`. This phase also allows for authentication of the Requester if the Responder indicated that earlier in `ALGORITHMS` response. Furthermore, this phase of the session uses the handshake secrets to secure the communication as described in the Key Schedule.

The purpose of this phase is to build trust between the Responder and Requester, first, before either side can send application data. Additionally, it also ensures the integrity of the handshake and to a certain degree, synchronicity with the derived handshake secrets.

In this phase of the session, `GET_ENCAPSULATED_REQUEST` and `DELIVER_ENCAPSULATED_RESPONES` shall be used to obtain requests from the Responder to complete the authentication of the Requester, if the Responder indicated this in `ALGORITHMS` message. The only requests allowed to be encapsulated shall be `GET_DIGEST` and `GET_CERTIFICATE`. The Requester shall provide a signature in the `FINISH` request as described in the Finish clause.

If an error occurs in this phase with `ErrorCode = DecryptError`, the session shall immediately terminate and proceed to session termination.

A successful handshake ends with either `FINISH_RSP` or `PSK_FINISH_RSP` and the application phase begins.

8.2 Application Phase

Once the handshake completes and all validation passes, the session reaches the application phase where either the Responder and Requester may send application data.

The application phase ends when either the `HEARTBEAT` requirements fail, `END_SESSION` or an `ERROR` message with `ErrorCode = DecryptError`. The next phase is the session termination phase.

8.3 Session Termination Phase

This phase is simply an internal phase; there are no explicit SPDM messages sent or received. Requesters and Responders may have other reasons to terminate a session but that is outside the scope of this specification.

When a session terminates, both Requester and Responder shall destroy or clean up all session keys such as derived session secrets, DHE secrets and encryption keys. Requester and Responder may have other internal data tied to this session that they may want to also clean up.

8.4 Maximum Simultaneous Active Session

If a Responder supports key exchanges, the maximum number of simultaneous active sessions shall be a minimum of one. If the `KEY_EXCHANGE` or `PSK_EXCHANGE` request will exceed the Responder's maximum number of simultaneous active session, the Responder shall respond with an `Errorcode = SessionLimitExceeded`.

8.5 Records and Session ID

When the session starts, the communication of secured data is done using records. A record represents a chunk or unit of data that is either or both encrypted or authenticated. This data can be either an SPDM message or application data. Usually, the record contains the session ID resulting from one of the Session-Secrets-Exchange messages to aid both the Responder and Requester in binding the record to the respective derived session secrets.

The actual format and other details of a record is outside the scope of this specification. It is generally assumed that the transport protocol will define the format and other details of the record.

9 Key Schedule

A key schedule describes how to derive the various keys such as encryption keys used by a session as well as indicate when each key is used. Key derivation makes heavy use of `HMAC` as defined by RFC2104 and `HKDF-Expand` as described in RFC5869. SPDM defines the following additional functions.

```
BinConcat(Length, Version, Label, Context)
```

where `BinConcat` shall be the concatenation of binary data, in the order shown in BinConcat Details Table:

BinConcat Details Table

Order	Data	Form	Endianness	Size
1	Length	Binary	Little	16 bits
2	Version	Text	Text	8 bytes
3	Label	Text	Text	Variable
4	Context	Binary	Little	Hash.Length

Version Details Table

SPDM Version	Version Text
SPDM 1.1	"spdm1.1 "

The `HKDF-Expand` function prototype is as follows:

```
    HKDF-Expand(secret, context, Hash.Length)
```

The `HMAC-Hash` function prototype is described as follows:

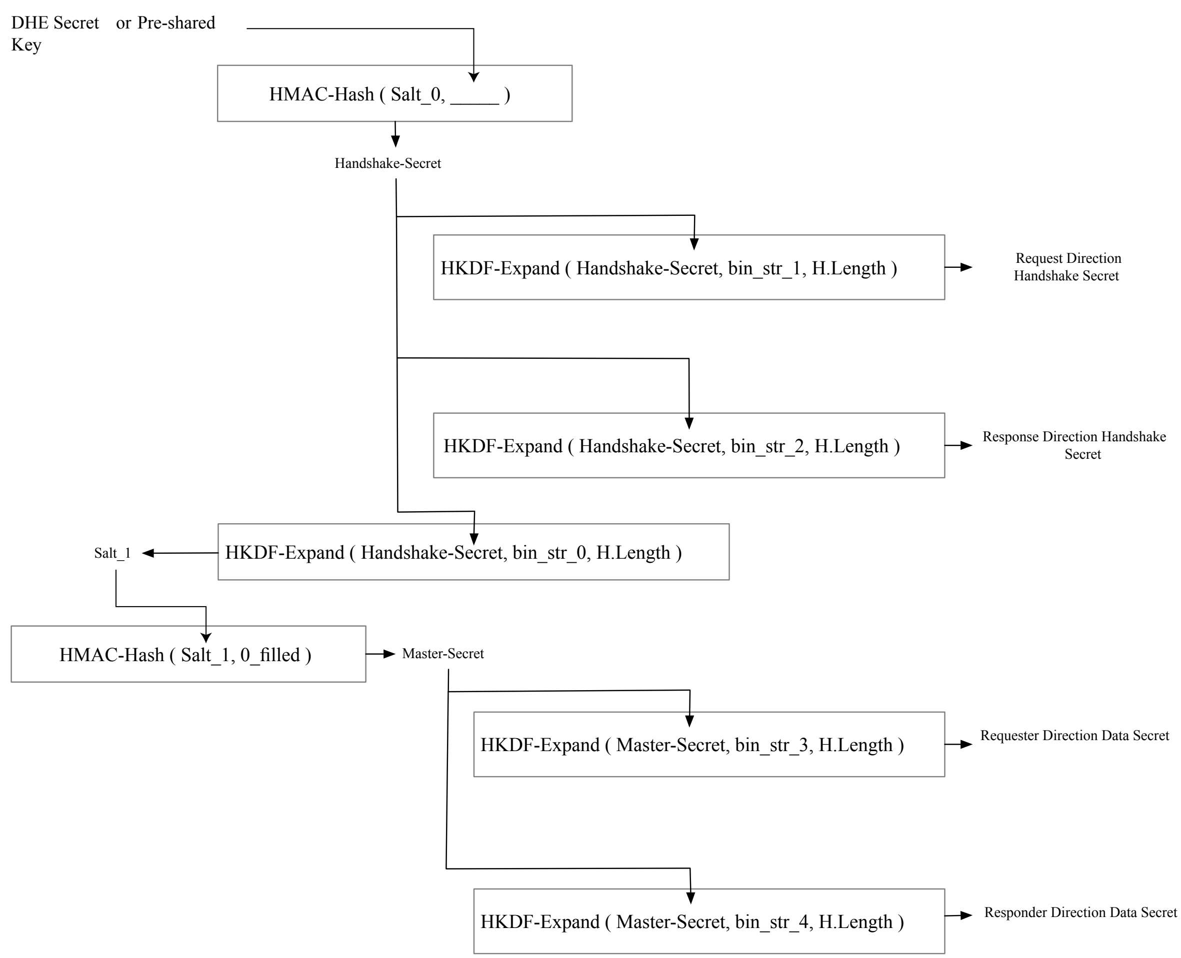
```
HMAC-Hash(salt, IKM);
```

where IKM is the Input Keying Material and HMAC-Hash uses `HMAC` as defined in RFC2104.

For `HKDF-Expand` and `HMAC-Hash`, the hash function shall be the selected hash function in `ALGORITHMS` response. Also, `Hash.Length` notation shall be the length of the hash function in `ALGORITHMS` response.

Both Responder and Requester shall use the key schedule shown in the Key Schedule Figure.

Key Schedule Figure



In the figure, arrows going out of the box are outputs of that box. Arrows going into the box are inputs into the box and point to the specific input parameter they are used in. All boxes represent a single function producing a single output and are given a name for clarity.

The Key Schedule Table accompanies the figure to complete the Key Schedule. The Responder and Requester shall also adhere to the definition of this table.

Key Schedule Table

Variable Name	Variable Definition
0_filled	A zero filled array of Hash.Length length.
bin_str0	BinConcat(Hash.Length, Version, "derived", NULL).
bin_str1	BinConcat(Hash.Length, Version, "requester traffic", TH1).
bin_str2	BinConcat(Hash.Length, Version, "responder traffic", TH1).
bin_str3	BinConcat(Hash.Length, Version, "requester app traffic", TH2)
bin_str4	BinConcat(Hash.Length, Version, "responder app traffic", TH2)
DHE Secret	This shall be the secret derived from `KEY_EXCHANGE/KEY_EXCHANGE_RSP`
Pre-shared Key	PSK

9.1 Transcript Hash in Key Derivation

There are two transcript hashes used in the Key Schedule, namely, **TH1** and **TH2**.

9.2 TH1 Definition

For `KEY_EXCHANGE`, the transcript hash for **TH1** shall be the following:

1. `[GET_VERSION].*` (if issued)
2. `[VERSION].*` (if issued)
3. `[GET_CAPABILITIES].*` (if issued)
4. `[CAPABILITIES].*` (if issued)
5. `[NEGOTIATE_ALGORITHMS].*` (if issued)
6. `[ALGORITHMS].*` (if issued)
7. The specified certificate chain in DER format (i.e. KEY_EXCHANGE Param2)
8. `[KEY_EXCHANGE].*`
9. `[KEY_EXCHANGE_RSP].*`

The PSK-based key exchange scheme derives two keys from Handshake-Secret: Requester's finished_key, and Responder's finished_key.

To calculate bin_str2 that is used in deriving the Responder's finished_key for `PSK_EXCHANGE_RSP` response, the transcript hash for **TH1** shall be the following:

1. `[GET_VERSION].*` (if issued)

2. `[VERSION].*` (if issued)
3. `[GET_CAPABILITIES].*` (if issued)
4. `[CAPABILITIES].*` (if issued)
5. `[NEGOTIATE_ALGORITHMS].*` (if issued)
6. `[ALGORITHMS].*` (if issued)
7. `[PSK_EXCHANGE].*`
8. `[PSK_EXCHANGE_RSP].SPDMVersion`
9. `[PSK_EXCHANGE_RSP].RequestResponseCode`
10. `[PSK_EXCHANGE_RSP].Param1`
11. `[PSK_EXCHANGE_RSP].Param2`
12. `[PSK_EXCHANGE_RSP].ResponderContext`

To calculate bin_str1 that is used in deriving the Requester's finished_key for `PSK_FINISH` request, the transcript hash for **TH1** shall be the following:

1. `[GET_VERSION].*` (if issued)
2. `[VERSION].*` (if issued)
3. `[GET_CAPABILITIES].*` (if issued)
4. `[CAPABILITIES].*` (if issued)
5. `[NEGOTIATE_ALGORITHMS].*` (if issued)
6. `[ALGORITHMS].*` (if issued)
7. `[PSK_EXCHANGE].*`
8. `[PSK_EXCHANGE_RSP].*`
9. `[PSK_FINISH].SPDMVersion`
10. `[PSK_FINISH].RequestResponseCode`
11. `[PSK_FINISH].Param1`
12. `[PSK_FINISH].Param2`

9.3 TH2 Definition

If the Requester and Responder used `KEY_EXCHANGE/KEY_EXCHANGE_RSP` to exchange initial keying information, then **TH2** shall be the following:

1. `[GET_CAPABILITIES].*`
2. `[CAPABILITIES].*`
3. `[NEGOTIATE_ALGORITHMS].*`
4. `[ALGORITHMS].*`
5. The specified certificate chain in DER format (i.e. KEY_EXCHANGE Param2)
6. `[KEY_EXCHANGE].*`

7. `[KEY_EXCHANGE_RSP].*`
8. The specified certificate chain in DER format (i.e. FINISH's Param2). (Valid only in Mutual Authentication)
9. `[FINISH].*` (Valid only in Mutual Authentication)
10. `[FINISH_RSP].*`

If the Requester and Responder used `PSK_EXCHANGE` to exchange initial keying information, then **TH2** shall be the following:

1. `[GET_VERSION].*` (if issued)
2. `[VERSION].*` (if issued)
3. `[GET_CAPABILITIES].*` (if issued)
4. `[CAPABILITIES].*` (if issued)
5. `[NEGOTIATE_ALGORITHMS].*` (if issued)
6. `[ALGORITHMS].*` (if issued)
7. `[PSK_EXCHANGE].*`
8. `[PSK_EXCHANGE_RSP].*`
9. `[PSK_FINISH].*`
10. `[PSK_FINISH_RSP].*`

9.4 Key Schedule Major Secrets

The key schedule produces 4 major secrets:

- Request-Direction Handshake Secret (S_0)
- Response-Direction Handshake Secret (S_1)
- Request-Direction Data Secret (S_2)
- Response-Direction Data Secret (S_3)

Each secret applies in a certain direction of transmission and only valid during a certain time frame. These four major secrets, each, will be used to derive their respective encryption key and salt to be used in the AEAD function as selected in the `ALGORITHMS` response.

9.4.1 Request-Direction Handshake Secret

This secret shall only be used during the session handshake phase and shall be applied to all requests after `KEY_EXCHANGE` up to and including `FINISH`.

9.4.2 Response-Direction Handshake Secret

This secret shall only be used during the session handshake phase and shall be applied to all responses after `KEY_EXCHANGE_RSP` up to and including `FINISH_RSP`.

9.4.3 Requester-Direction Data Secret

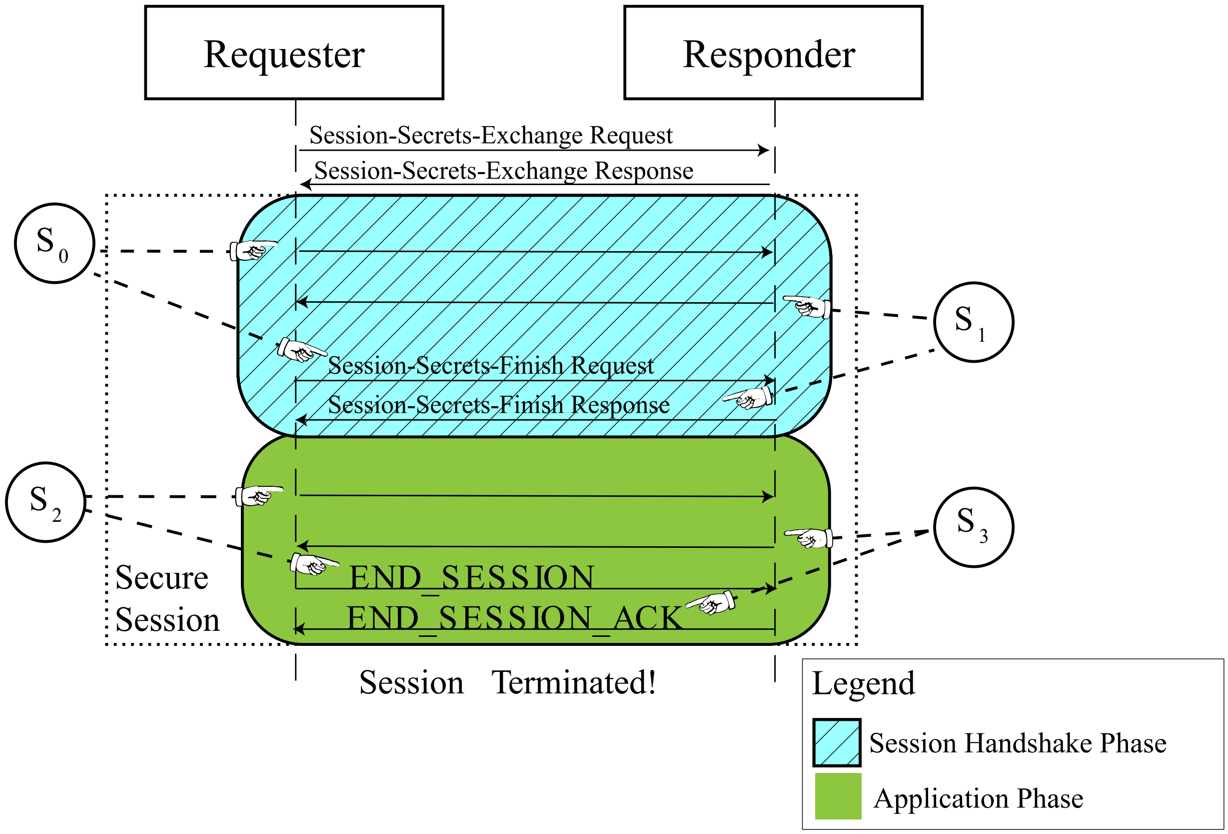
This secret shall be used for any data transmitted in the session, including but not limited to SPDM requests that are allowed to be issued post handshake. This secret shall only be applied for all data traveling from the Requester to the Responder.

9.4.4 Responder-Direction Data Secret

This secret shall be used for any data transmitted in the session, including but not limited to SPDM responses that are allowed to be issued post handshake. This secret shall only be applied for all data traveling from the Responder to the Requester.

The Secrets Usage Figure illustrates where each of the major secrets are used as described previously.

Secrets Usage Figure



9.5 Encryption Key and Salt Derivation

For each Key Schedule Major Secret, the following function shall be applied to obtain the encryption key and salt value.

```
EncryptionKey = HDKF-Expand(major-secret, bin_str_5, key_length);
Salt = HKDF-Expand(major-secret, bin_str_6, iv_length);

bin_str5 = BinConcat(key_length, Version, "key", NULL);
bin_str6 = BinConcat(iv_length, Version, "iv", NULL);
```

Both `key_length` and `iv_length` shall be the lengths associated with the selected AEAD algorithm in `ALGORITHMS` message.

9.6 Finish Key Derivation

This key shall be used to compute the verify data used in various SPDM messages. The key, `finished_key` is defined as follows:

```
finished_key = HKDF-Expand(handshake-secret, bin_str7, Hash.Length);
bin_str7 = BinConcat(Hash.Length, Version, "finished", NULL);
```

The handshake-secret shall either be Request-Direction Handshake Secret or Response-Direction Handshake secret.

9.7 Major Secret Update

The major secrets can be updated during an active session to avoid the overhead of closing down a session and recreating the session. This is achieved by issuing the `KEY_UPDATE` request.

The major secrets are rekeyed as a result of this. To compute the new secret for each new major data secret, the following algorithm shall be applied.

```
new_secret = HKDF-Expand(current_secret, bin_str8, Hash.Length);
bin_str8 = BinConcat(Hash.Length, Version, "traffic upd", NULL);
```

In computing the new secret, `current_secret` shall either be the current Requester-Direction Data Secret or Responder-Direction Data Secret. As a consequence of updating these secrets, new encryption keys and salts shall be derived from the new secrets and used immediately.

10 Application data

SPDM utilizes Authenticated Encryption with Associated Data (AEAD) cipher algorithms in much the same way that TLS 1.3 does to protect both the confidentiality and integrity of data that must remain secret, as well as the integrity of data that need to be transmitted in the clear (such as protocol headers) but must be protected from manipulation. AEAD algorithms provide both encryption and message authentication. Each algorithm specifies the details such as the size of the nonce, the position and length of the MAC and many other factors to ensure a strong cryptographic algorithm.

AEAD functions shall provide the following functions and comply with the requirements defined in RFC5116:

```
AEAD_Encrypt(encryption_key, nonce, associated_data, plaintext);
AEAD_Decrypt(encryption_key, nonce, associated_data, ciphertext);
```

where:

- `encryption_key` is the derived encryption key for the respective direction. See Key Schedule for details.
- `nonce` is the nonce. See blah for details on nonce computation.
- `associated_data` is the associated data.
- `plaintext` is the data to encrypt.
- `ciphertext` is the data to decrypt.

The function, `AEAD_Encrypt`, fully encrypts the `plaintext`, computes the MAC across both the `associated_data` and `plaintext` and produces the `ciphertext` which includes the MAC as well. The `AEAD_Decrypt` function verifies the MAC and if validation is successful, fully decrypts the `ciphertext` and produces the original `plaintext`.

10.1 Nonce Derivation

Certain AEAD ciphers have specific requirements on nonce construction, as their security properties may be compromised by the accidental reuse of a nonce value. Implementations should follow the requirements such as those provided in RFC5116 for nonce derivation.

11 ANNEX A (informative)

This specification heavily models TLS 1.3. TLS 1.3 and consequently this specification assumes the transport layer(s) provides these capabilities or attributes:

- Reliability in transmission and reception of data
- Transmission of data is either in order or the order of data can be reconstructed at reception.

While not all transports are created equal, if a transport cannot meet the above capabilities, adoption of SPDM is still possible. In these transports, this specification recommends DTLS 1.3 which at the time of this specification is still in draft form.

12 ANNEX B - Leaf certificate example

Certificate:

```
    Data:
        Version: 3 (0x2)
        Serial Number: 8 (0x8)
        Signature Algorithm: ecdsa-with-SHA256
        Issuer: C=CA, ST=NC, L=city, O=ACME, OU=ACME Devices, CN=CA
        Validity
            Not Before: Jan  1 00:00:00 1970 GMT
            Not After : Dec 31 23:59:59 9999 GMT
        Subject: C=US, ST=NC, O=ACME Widget Manufacturing, OU=ACME Widget Manufacturing Unit, CN=w0123456789
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                RSA Public-Key: (2048 bit)
                Modulus:
                    00:ba:67:47:72:78:da:28:81:d9:81:9b:db:88:03:
                    e1:10:a4:91:b8:48:ed:6b:70:3c:ec:a2:68:a9:3b:
                    5f:78:fc:ae:4a:d1:1c:63:76:54:a8:40:31:26:7f:
                    ff:3e:e0:bf:95:5c:4a:b4:6f:11:56:ca:c8:11:53:
                    23:e1:1d:a2:7a:a5:f0:22:d8:b2:fb:43:da:dd:bd:
                    52:6b:e6:a5:3f:0f:3b:60:b8:74:db:56:08:d9:ee:
                    a0:30:4a:03:21:1e:ee:60:ad:e4:00:7a:6e:6b:32:
                    1c:28:7e:9c:e8:c3:54:db:63:fd:1f:d1:46:20:9e:
                    ef:80:88:00:5f:25:db:cf:43:46:c6:1f:50:19:7f:
                    98:23:84:38:88:47:5d:51:8e:11:62:6f:0f:28:77:
                    a7:20:0e:f3:74:27:82:70:a7:96:5b:1b:bb:10:e7:
                    95:62:f5:37:4b:ba:20:4e:3c:c9:18:b2:cd:4b:58:
                    70:ab:a2:bc:f6:2f:ed:2f:48:92:be:5a:cc:5c:5e:
                    a8:ea:9d:60:e8:f8:85:7d:c0:0d:2f:6a:08:74:d1:
                    2f:e8:5e:3d:b7:35:a6:1d:d2:a6:04:99:d3:90:43:
                    66:35:e1:74:10:a8:97:3b:49:05:51:61:07:c6:08:
                    01:1c:dc:a8:5f:9e:30:97:a8:18:6c:f9:b1:2c:56:
                    e8:67
                Exponent: 65537 (0x10001)
                X509v3 extensions:
            X509v3 Basic Constraints:
                CA:FALSE
            X509v3 Key Usage:
                Digital Signature, Non Repudiation, Key Encipherment
            X509v3 Subject Alternative Name:
                otherName:1.3.6.1.4.1.412.274.1;UTF8STRING:ACME:WIDGET:0123456789
            Signature Algorithm: ecdsa-with-SHA256
            Signature Value:
                30:45:02:21:00:fc:8f:b0:ad:6f:2d:c3:2a:7e:92:6d:29:1d:
                c7:fc:0d:48:b0:c6:39:5e:c8:76:d6:40:9a:12:46:c3:39:0e:
                36:02:20:1a:ea:3a:59:ca:1e:bc:6d:6e:61:79:af:a2:05:7c:
```

```
            7d:da:41:a9:45:6d:cb:04:49:43:e6:0b:a8:8d:cd:da:e
```

12.1 Change log

Version	Date	Description
1.0.0	2019-10-16	

12.2 Bibliography

DMTF DSP4014, *DMTF Process for Working Bodies 2.6*, https://www.dmtf.org/sites/default/files/standards/documents/DSP4014_2.6.pdf