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The Group Domain of Interpretation
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Abstract

This document describes an updated version of the Group Domain of Interpretation (GDOI) protocol specified in RFC 3547. The GDOI provides group key management to support secure group communications according to the architecture specified in RFC 4046. The GDOI manages group security associations, which are used by IPsec and potentially other data security protocols.

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1. Introduction

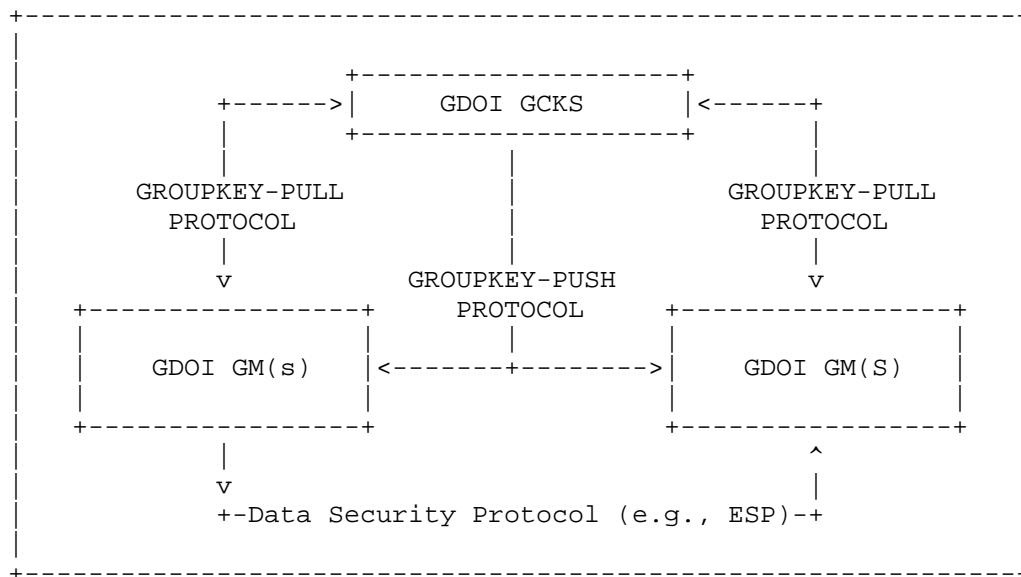
Secure group and multicast applications require a method by which each group member shares common security policy and keying material. This document describes the Group Domain of Interpretation (GDOI), which is an ISAKMP [RFC2408] Domain of Interpretation (DOI), a group key management system. The GDOI distributes security associations (SAs) for IPsec AH [RFC4302] and ESP [RFC4303] protocols and potentially other data security protocols used in group applications. The GDOI uses the group key management model defined in [RFC4046], and described more generally by the The Multicast Group Security Architecture [RFC3740].

In this group key management model, the GDOI protocol participants are a "group controller/key server" (GCKS) and a group member (GM). A group member contacts ("registers with") a GCKS to join the group. During the registration mutual authentication and authorization are achieved, after which the GCKS distributes current group policy and keying material to the group member over an authenticated and encrypted session. The GCKS may also initiate contact ("rekeys") group members to provide updates to group policy.

ISAKMP defines two "phases" of negotiation (p.16 of [RFC2408]). A Phase 1 security association provides mutual authentication and authorization, and a security association that is used by the protocol participants to execute a phase 2 exchange. This document incorporates (i.e., uses but does not re-define) the Phase 1 security association definition from the Internet DOI [RFC2407], [RFC2409]. Phase 1 security association types other than ISAKMP are possible, and are noted in Appendix A. Requirements of those phase 1 security associations are specified in Section 2. The GDOI includes two new phase 2 ISAKMP exchanges (protocols), as well as necessary new payload definitions to the ISAKMP standard (p. 14 of [RFC2408]). These two new protocols are:

1. The GROUPKEY-PULL registration protocol exchange. This exchange uses "pull" behavior since the member initiates the retrieval of these SAs from a GCKS. It is protected by an ISAKMP phase 1 protocol, as described above. At the culmination of a GROUPKEY-PULL exchange, an authorized group member has received and installed a set of SAs that represent group policy, and it is ready to participate in secure group communications.
2. The GROUPKEY-PUSH rekey protocol exchange. The rekey protocol is a datagram initiated ("pushed") by the GCKS, usually delivered to group members using a IP multicast address. The rekey protocol is an ISAKMP protocol, where cryptographic policy and keying material ("Re-key SA") is included in the group policy

distributed by the GCKS in the GROUPKEY-PULL exchange. At the culmination of a GROUPKEY-PUSH exchange the key server has sent group policy to all authorized group members, allowing receiving group members to participate in secure group communications. If a group management method is included in group policy (as described in Section 1.5.1), at the conclusion of the GROUPKEY-PUSH exchange some members of the group may have been de-authorized and no longer able to participate in the secure group communications.



Although the GROUPKEY-PUSH protocol specified by this document can be used to refresh the Re-key SA protecting the GROUPKEY-PUSH protocol, the most common use of GROUPKEY-PUSH is to establish keying material and policy for a data security protocol.

In summary, GDOI is a group security association management protocol: All GDOI messages are used to create, maintain, or delete security associations for a group. As described above, these security associations protect one or more data security protocol SAs, a Re-key SA, and/or other data shared by group members for multicast and groups security applications.

1.1. Requirements notation

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

1.2. Terminology

The following key terms are used throughout this document.

Data-Security SA. The security policy distributed by a GDOI GCKS describing traffic that is expected to be protected by group members. This document described the distribution of IPsec AH and ESP Data-Security SAs.

GCKS. A Group Controller/Key Server [RFC3740] that defines group policy and distributes keys for that policy.

Group Member. An authorized member of a secure group, sending and/or receiving IP packets related to the group.

GROUPKEY-PULL. A protocol used by a GDOI Group Member to request group policy and keying material.

GROUPKEY-PUSH. A protocol used by a GDOI GCKS to distribute updates of group policy and keying material to authorized group members.

Key Encrypting Key (KEK). The symmetric cipher key used to protect the GROUPKEY-PUSH message.

Logical Key Hierarchy (LKH). A group management method defined in Section 5.4 of [RFC2627].

Re-key SA. The security policy protecting a GROUPKEY-PUSH protocol.

Traffic Encryption Key (TEK). The symmetric cipher key used to protect a data security protocol (e.g., IPsec ESP).

1.3. GDOI Applications

GDOI can be used to distribute keys for several secure multicast applications, where different applications have different key management requirements. This section outlines two example ways that GDOI can be used. Other examples can be found in Section 10 of [HD03].

A simple application is secure delivery of periodic multicast content over an organization's IP network, perhaps a multicast video broadcast. Assuming the content delivery timeframe is bounded and the group membership is not expected to change over time, there is no need for group policy to include a GROUPKEY-PUSH exchange, and there's no need for the GCKS to distribute a Re-key SA. Thus, the GDOI GCKS may only need to distribute a single set of Data-Security SAs to protect the time-bounded broadcast.

In contrast, a persistent IP multicast application (e.g., stock-ticker delivery service) may have many group members, where the group membership changes over time. A periodic change of Data-security SAs may be desirable, and the potential for change in group membership requires the use of a group management method enabling de-authorization of group members. The GDOI GCKS will distribute the current set of Data-Security SAs and a Re-key SA to registering group members. It will then deliver regularly-scheduled GROUPKEY-PUSH protocol delivering the new SAs for the group. Additionally, the group membership on the GCKS may be frequently adjusted, which will result in GROUPKEY-PUSH exchange delivering a new Rekey SAs protected by a group management method. Each GROUPKEY-PUSH may include Data-security SAs and/or a Rekey SA.

In each example the relevant policy is defined on the GCKS and relayed to group members using the GROUPKEY-PULL and/or GROUPKEY-PUSH protocols. Specific policy choices configured by the GCKS administrator depends on each application.

1.4. Extending GDOI

Not all secure multicast or multimedia applications can use IPsec ESP or AH. Many Real Time Transport Protocol applications, for example, require security above the IP layer to preserve RTP header compression efficiencies and transport-independence [RFC3550]. Alternatively, GDOI can distribute message authentication code (MAC) policy and keys for legacy applications that have defined their own security associations [I-D.weis-gdoi-mac-tek].

In order to add a new data security protocol, a new RFC MUST specify the data-security SA parameters conveyed by GDOI for that security protocol; these parameters are listed in Section 5.5.2 of this document.

Data security protocol SAs MUST protect group traffic. GDOI provides no restriction on whether that group traffic is transmitted as unicast or multicast packets.

1.5. Forward and Backward Access Control

Through GROUPKEY-PUSH, the GDOI supports group management methods such as LKH (section 5.4 of [RFC2627]) that have the property of denying access to a new group key by a member removed from the group (forward access control) and to an old group key by a member added to the group (backward access control). An unrelated notion to PFS, "forward access control" and "backward access control" have been called "perfect forward security" and "perfect backward security" in the literature [RFC2627].

Group management algorithms providing forward and backward access control other than LKH have been proposed in the literature, including OFT [OFT] and Subset Difference [NNL]. These algorithms could be used with GDOI, but are not specified as a part of this document.

1.5.1. Forward Access Control Requirements

When group membership is altered using a group management algorithm new Data-security SAs are usually also needed. New SAs ensure that members who were denied access can no longer participate in the group.

If forward access control is a desired property of the group, new Data-security SAs MUST NOT be included in a GROUPKEY-PUSH message which changes group membership. This is required because the new Data-security SAs are not protected with the new KEK. Instead, two sequential GROUPKEY-PUSH messages must be sent by the GCKS; the first changing the KEK, and the second (protected with the new KEK) distributing the new Data-security SAs.

Note that in the above sequence, although the new KEK can effectively deny access to the group to some group members they will be able to view the new KEK policy. If forward access control policy for the group includes keeping the KEK policy secret as well as the KEK itself secret, then two GROUPKEY-PUSH messages changing the KEK must occur before the new Data-security SAs are transmitted.

If other methods of using LKH or other group management algorithms are added to GDOI, those methods MAY remove the above restrictions requiring multiple GROUPKEY-PUSH messages, providing those methods specify how forward access control policy is maintained within a single GROUPKEY-PUSH message.

2. GDOI Phase 1 protocol

The GDOI GROUPKEY-PULL exchange is a "phase 2" protocol which MUST be protected by a "phase 1" protocol. The "phase 1" protocol can be any protocol which provides for the following protections:

- o Peer Authentication
- o Confidentiality
- o Message Integrity

The following sections describe one such "phase 1" protocol. Other protocols which may be potential "phase 1" protocols are described in Appendix A. However, the use of the protocols listed there are not considered part of this document.

2.1. ISAKMP Phase 1 protocol

This document defines how the ISAKMP phase 1 exchanges as defined in [RFC2409] can be used as a "phase 1" protocol for GDOI. The following sections define characteristics of the ISAKMP phase 1 protocols that are unique for these exchanges when used for GDOI.

Section 7.1 describes how the ISAKMP Phase 1 protocols meet the requirements of a GDOI "phase 1" protocol.

2.1.1. DOI value

The Phase 1 SA payload has a DOI value. That value MUST be the GDOI DOI value as defined later in this document.

2.1.2. UDP port

IANA has assigned port 848 for the use of GDOI, which allows for an implementation to use separate ISAKMP implementations to service GDOI and IKEv1 [RFC2409]. A GCKS SHOULD listen on this port for GROUPKEY-PULL exchanges, and the GCKS MAY use this port to distribute GROUPKEY-PUSH messages. An ISAKMP phase 1 exchange implementation supporting NAT Traversal [RFC3947] may move to port 4500 to process the GROUPKEY-PULL exchange.

3. GROUPKEY-PULL Exchange

The goal of the GROUPKEY-PULL exchange is to establish a Re-key and/or Data-security SAs at the member for a particular group. A Phase 1 SA protects the GROUPKEY-PULL; there MAY be multiple GROUPKEY-PULL exchanges for a given Phase 1 SA. The GROUPKEY-PULL exchange downloads the data security keys (TEKs) and/or group key encrypting key (KEK) or KEK array under the protection of the Phase 1 SA.

3.1. Authorization

The Phase 1 identity SHOULD be used by a GCKS to authorize the Phase 2 (GROUPKEY-PULL) request for a group key. A group member MUST ensure that the Phase 1 identity of the GCKS is an authorized GCKS. When no authorization is performed, it is possible for a rogue GDOI participant to perpetrate a man-in-the-middle attack between a group member and a GCKS [MP04].

3.2. Messages

The GROUPKEY-PULL is a Phase 2 exchange. Phase 1 computes SKEYID_a which is the "key" in the keyed hash used in the GROUPKEY-PULL HASH payloads. When using the Phase 1 defined in this document, SKEYID_a is derived according to [RFC2409]. As with the IKEv1 HASH payload generation (Section 5.5 of [RFC2409], each GROUPKEY-PULL message hashes a uniquely defined set of values. Nonces permute the HASH and provide some protection against replay attacks. Replay protection is important to protect the GCKS from attacks that a key management server will attract.

The GROUPKEY-PULL uses nonces to guarantee "liveness", or against replay of a recent GROUPKEY-PULL message. The replay attack is only useful in the context of the current Phase 1. If a GROUPKEY-PULL message is replayed based on a previous Phase 1, the HASH calculation will fail due to a wrong SKEYID_a. The message will fail processing before the nonce is ever evaluated. In order for either peer to get the benefit of the replay protection, it must postpone as much processing as possible until it receives the message in the protocol that proves the peer is live. For example, the Responder MUST NOT adjust its internal state (e.g., keeping a record of the Initiator) until it receives a message with Nr included properly in the HASH payload.

Nonces require an additional message in the protocol exchange to ensure that the GCKS does not add a group member until it proves liveness. The GROUPKEY-PULL member-initiator expects to find its nonce, Ni, in the HASH of a returned message. And the GROUPKEY-PULL

GCKS responder expects to see its nonce, Nr, in the HASH of a returned message before providing group-keying material as in the following exchange.

Initiator (Member)		Responder (GCKS)
-----		-----
HDR*, HASH(1), Ni, ID	-->	
	<--	HDR*, HASH(2), Nr, SA
HDR*, HASH(3)	-->	
	<--	HDR*, HASH(4), [SEQ,] KD

Hashes are computed as follows:

```

HASH(1) = prf(SKEYID_a, M-ID | Ni | ID)
HASH(2) = prf(SKEYID_a, M-ID | Ni_b | Nr | SA)
HASH(3) = prf(SKEYID_a, M-ID | Ni_b | Nr_b
HASH(4) = prf(SKEYID_a, M-ID | Ni_b | Nr_b [ | SEQ | ] KD)

```

* Protected by the Phase 1 SA, encryption occurs after HDR

HDR is an ISAKMP header payload that uses the Phase 1 cookies and a message identifier (M-ID) as in IKEv1. Note that nonces are included in the first two messages, with the GCKS returning only the SA policy payload before liveness is proven. The HASH payloads [RFC2409] prove that the peer has the Phase 1 secret (SKEYID_a) and the nonce for the exchange identified by message id, M-ID. Once liveness is established, the last message completes the real processing of downloading the KD payload.

In addition to the Nonce and HASH payloads, the member-initiator identifies the group it wishes to join through the ISAKMP ID payload. The GCKS responder informs the member of the current value of the sequence number in the SEQ payload; the sequence number provides anti-replay state associated with a KEK. The SEQ payload has no other use, and is omitted from the GROUPKEY_PULL exchange when a KEK attribute is not included in the SA payload.

When a SEQ payload is included in the GROUPKEY-PULL exchange, it includes the most recently used sequence number for the group. At the conclusion of a GROUPKEY-PULL exchange, the initiating group member MUST NOT accept any rekey message with both the KEK attribute SPI value and a sequence number less than or equal to the one received during the GROUPKEY-PULL. When the first group member initiates a GROUPKEY-PULL exchange, the GCKS provides a Sequence Number of zero, since no GROUPKEY-PUSH messages have yet been sent. Note the sequence number increments only with GROUPKEY-PUSH messages.

The GROUPKEY-PULL exchange distributes the current sequence number to the group member.

The sequence number resets to a value of one with the usage of a new KEK attribute. Thus the first packet sent for a given Rekey SA will have a Sequence Number of 1. The sequence number increments with each successive rekey.

The GCKS responder informs the member of the cryptographic policies of the group in the SA payload, which describes the DOI, KEK and/or TEK keying material, and authentication transforms. The SPIs are also determined by the GCKS and downloaded in the SA payload chain (see Section 5.2). The SA KEK attribute contains the ISAKMP cookie pair for the Re-key SA, which is not negotiated but downloaded. The SA TEK attribute contains a SPI as defined in Section 5.5 of this document. The second message downloads this SA payload. If a Re-key SA is defined in the SA payload, then KD will contain the KEK; if one or more Data-security SAs are defined in the SA payload, KD will contain the TEKs. This is useful if there is an initial set of TEKs for the particular group and can obviate the need for future TEK GROUPKEY-PUSH messages (described in section 4).

3.2.1. ISAKMP Header Initialization

Cookies are used in the ISAKMP header to identify a particular GDOI session. The GDOI GROUPKEY-PULL exchange uses cookies according to ISAKMP [RFC2408].

Next Payload identifies an ISAKMP or GDOI payload (see Section 5.0).

Major Version is 1 and Minor Version is 0 according to ISAKMP (Section 3.1 of [RFC2408]).

The Exchange Type has value 32 for the GDOI GROUPKEY-PULL exchange.

Flags, Message ID, and Length are according to ISAKMP (Section 3.1 of [RFC2408]).

3.3. Initiator Operations

Before a group member (GDOI initiator) contacts the GCKS, it must determine the group identifier and acceptable Phase 1 policy via an out-of-band method. Phase 1 is initiated using the GDOI DOI in the SA payload. Once Phase 1 is complete, the initiator state machine moves to the GDOI protocol.

To construct the first GDOI message the initiator chooses Ni and creates a nonce payload, builds an identity payload including the

group identifier, and generates HASH(1).

Upon receipt of the second GDOI message, the initiator validates HASH(2), extracts the nonce Nr, and interprets the SA payload. The SA payload contains policy describing the security protocol and cryptographic protocols used by the group. This policy describes the Re-key SA (if present), Data-security SAs, and other group policy. If the policy in the SA payload is acceptable to the initiator, it continues the protocol.

The initiator constructs the third GDOI message by creating HASH(3).

Upon receipt of the fourth GDOI message, the initiator validates HASH(4).

If SEQ payload is present, the sequence number in the SEQ payload must be checked against any previously received sequence number for this group. If it is less than the previously received number, it should be considered stale and ignored. This could happen if two GROUPKEY-PULL messages happened in parallel, and the sequence number changed between the times the results of two GROUPKEY-PULL messages were returned from the GCKS.

The initiator interprets the KD key packets, where each key packet includes the keying material for SAs distributed in the SA payload. Keying material is matched by comparing the SPIs in the key packets to SPIs previously sent in the SA payloads. Once TEK keys and policy are matched, the initiator provides them to the data security subsystem, and it is ready to send or receive packets matching the TEK policy. If this group has a KEK, the KEK policy and keys are marked as ready for use, and the initiator knows to expect the sequence number reset to 1 with the next Rekey SA, which will be encrypted with the new KEK attribute. The initiator is now ready to receive GROUPKEY-PUSH messages.

If the KD payload included an LKH array of keys, the initiator takes the last key in the array as the group KEK. The array is then stored without further processing.

3.4. Receiver Operations

The GCKS (responder) passively listens for incoming requests from group members. The Phase 1 authenticates the group member and sets up the secure session with them.

Upon receipt of the first GDOI message the GCKS validates HASH(1), extracts the Ni and group identifier in the ID payload. It verifies that its database contains the group information for the group

identifier.

The GCKS constructs the second GDOI message, including a nonce N_r , and the policy for the group in an SA payload, followed by SA GAP, SA KEK, and/or SA TEK payloads according to the GCKS policy. (See Section 5.2.1 for details on how the GCKS chooses which payloads to send.)

Upon receipt of the third GDOI message the GCKS validates $HASH(3)$.

The GCKS constructs the fourth GDOI message, including the SEQ payload (if the GCKS sends rekey messages), and the KD payload containing keys corresponding to policy previously sent in the SA TEK and SA KEK payloads. If a group management algorithm is defined as part of group policy, the GCKS will first insert the group member into the group management structure (e.g., a leaf in the LKH tree), and then create an LKH array of keys and include it in the KD payload. The first key in the array is associated with the group member leaf node, followed by each LKH node above it in the tree, culminating with the root node (which is also the KEK).

4. GROUPKEY-PUSH Message

GDOI sends control information securely using group communications. Typically this will be using IP multicast distribution of a GROUPKEY-PUSH message but it can also be "pushed" using unicast delivery if IP multicast is not possible. The GROUPKEY-PUSH message replaces a Re-key SA KEK or KEK array, and/or creates a new Data-security SA.

Member	GCKS or Delegate
-----	-----
<---- HDR*, SEQ, [D,] SA, KD, SIG	

* Protected by the Re-key SA KEK; encryption occurs after HDR

HDR is defined below. The SEQ payload is defined in the Payloads section. One or more D (Delete) payloads (further described in Section 5.9) optionally specify the deletion of existing group policy. The SA defines the policy (e.g., protection suite) and attributes (e.g., SPI) for a replacement Re-key SA and/or Data-security SAs. KD is the key download payload as described in the Payloads section.

The SIG payload includes a signature of a hash of the entire GROUPKEY-PUSH message (excepting the SIG payload bytes) before it has been encrypted. The HASH is taken over the string 'rekey', the GROUPKEY-PUSH HDR, followed by all payloads preceding the SIG payload. The prefixed string ensures that the signature of the Rekey datagram cannot be used for any other purpose in the GDOI protocol. After the SIG payload is created using the signature of the above hash, with the receiver verifying the signature using a public key retrieved in policy received by a GROUPKEY-PULL exchange, or distributed in an earlier GROUPKEY-PUSH message. The current KEK encryption key (previously distributed in a GROUPKEY-PULL exchange or GROUPKEY-PUSH message) encrypts all the payloads following the GROUPKEY-PUSH HDR. Note: The rationale for this order of operations is given in Section 7.3.5.

If the SA defines the use of a single KEK or an LKH KEK array, KD MUST contain a corresponding KEK or KEK array for a new Re-key SA, which has a new cookie pair. When the KD payload carries a new SA KEK attribute (section 5.3), a Re-key SA is replaced with a new SA having the same group identifier (ID specified in message 1 of section 3.2) and incrementing the same sequence counter, which is initialized in message 4 of section 3.2. Note the first packet for the given Rekey SA encrypted with the new KEK attribute will have a Sequence number of 1. If the SA defines an SA TEK payload, this informs the member that a new Data-security SA has been created, with keying material carried in KD (Section 5.6).

If the SA defines a large LKH KEK array (e.g., during group initialization and batched rekeying), parts of the array MAY be sent in different unique GROUPKEY-PUSH datagrams. However, each of the GROUPKEY-PUSH datagrams MUST be a fully formed GROUPKEY-PUSH datagram. This results in each datagram containing a sequence number and the policy in the SA payload, which corresponds to the KEK array portion sent in the KD payload.

4.1. Use of signature keys

A signing key should not be used in more than one context (e.g., used for host authentication and also for message authentication). Thus, the GCKS SHOULD NOT use the same key to sign the SIG payload in the GROUPKEY-PUSH message as was used for authentication in the GROUPKEY-PULL exchange.

4.2. ISAKMP Header Initialization

Unlike ISAKMP or IKEv1, the cookie pair is completely determined by the GCKS. The cookie pair in the GDOI ISAKMP header identifies the Re- key SA to differentiate the secure groups managed by a GCKS. Thus, GDOI uses the cookie fields as an SPI.

Next Payload identifies an ISAKMP or GDOI payload (see Section 5.0).

Major Version is 1 and Minor Version is 0 according to ISAKMP (Section 3.1 of [RFC2408]).

The Exchange Type has value 33 for the GDOI GROUPKEY-PUSH message.

Flags MUST have the Encryption bit set according to [RFC2008, Section 3.1]. All other bits MUST be set to zero.

Message ID MUST be set to zero.

Length is according to ISAKMP (Section 3.1 of [RFC2408]).

4.3. GCKS Operations

GCKS or its delegate may initiate a Rekey message for one of several reasons, e.g., the group membership has changed or keys are due to expire.

To begin the rekey datagram the GCKS builds an ISAKMP HDR with the correct cookie pair, and a SEQ payload that includes a sequence number which is one greater than the previous rekey datagram. If the message is using the new KEK attribute for the first time, the SEQ is reset to 1 in this message.

An SA payload is then added. This is identical in structure and meaning to a SA payload sent in a GROUPKEY-PULL exchange. If there are changes to the KEK (including due to group members being excluded, in the case of LKH), an SA_KEK attribute is added to the SA. If there are one or more new TEKs then SA_TEK attributes are added to describe that policy.

A KD payload is then added. This is identical in structure and meaning to a KD payload sent in a GROUPKEY-PULL exchange. If an SA_KEK attribute was included in the SA payload then corresponding KEK keys (or a KEK update array) is included. A KEK update array is created by first determining which group members have been excluded, and then generating new keys as necessary and distribute LKH update arrays sufficient to provide the new KEK to remaining group members (see Section 5.4.1 of [RFC2627] for details). TEK keys are also sent for each SA_TEK attribute included in the SA payload.

In the penultimate step, the initiator hashes the string "rekey" followed by the key management message already formed. The hash is signed, placed in a SIG payload and added to the datagram.

Lastly, the payloads following the HDR are encrypted using the current KEK encryption key. The datagram can now be sent.

4.4. Group Member Operations

A group member receiving the GROUPKEY-PUSH datagram matches the cookie pair in the ISAKMP HDR to an existing SA. The message is decrypted, and the form of the datagram is validated. This weeds out obvious ill-formed messages (which may be sent as part of a Denial of Service attack on the group).

The sequence number in the SEQ payload is validated to ensure that it is greater than the previously received sequence number, and that it fits within a window of acceptable values. The SIG payload is then validated. If the signature fails, the message is discarded.

The SA and KD payloads are processed which results in a new GDOI Rekey SA (if the SA payload included an SA_KEK attribute) and/or new IPsec SAs being added to the system. If the KD payload includes an LKH update array, the group member compares the LKH ID in each key update packet to the LKH IDs that it holds. If it finds a match, it decrypts the key using the key prior to it in the key array and stores the new key in the LKH key array that it holds. The final decryption yields the new group KEK.

5. Payloads and Defined Values

This document specifies use of several ISAKMP payloads, which are defined in accordance with RFC 2408. The following payloads are extended or further specified.

Next Payload Type	Value
-----	-----
Security Association (SA)	1
Identification (ID)	5
Nonce (N)	10

Several payload formats specific to the group security exchanges are required.

Next Payload Type	Value
-----	-----
SA KEK Payload (SAK)	15
SA TEK Payload (SAT)	16
Key Download (KD)	17
Sequence Number (SEQ)	18
SA Group Associated Policy (GAP)	TBD-1

5.1. Identification Payload

The Identification Payload is defined in RFC 2408. For the GDOI, it is used to identify a group identity that will later be associated with Security Associations for the group. A group identity may map to a specific IP multicast group, or may specify a more general identifier, such as one that represents a set of related multicast streams.

When used with the GDOI, the DOI Specific ID Data field MUST be set to 0.

When used with the GDOI, the ID_KEY_ID ID Type MUST be supported by a conforming implementation, and MUST specify a four (4)-octet group identifier as its value. Implementations MAY also support other ID Types.

5.2. Security Association Payload

The Security Association payload is defined in RFC 2408. For the GDOI, it is used by the GCKS to assert security attributes for both Re-key and Data-security SAs.

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
! Next Payload !   RESERVED   !           Payload Length           !
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
!                                     DOI                             !
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
!                                     Situation                         !
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
! SA Attribute Next Payload   !           RESERVED2                 !
+-----+-----+-----+-----+-----+-----+-----+-----+-----+

```

The Security Association Payload fields are defined as follows:

- o Next Payload (1 octet) -- Identifies the next payload for the GROUPKEY-PULL or the GROUPKEY-PUSH message as defined above. The next payload MUST NOT be a SAK Payload or SAT Payload type, but the next non-Security Association type payload.
- o RESERVED (1 octet) -- Must be zero.
- o Payload Length (2 octets) -- Is the octet length of the current payload including the generic header and all TEK and KEK payloads.
- o DOI (4 octets) -- Is the GDOI, which is value 2.
- o Situation (4 octets) -- Must be zero.
- o SA Attribute Next Payload (1 octet) -- Must be either a SAK Payload or a SAT Payload. See section 5.2.1 for a description of which circumstances are required for each payload type to be present.
- o RESERVED (2 octets) -- Must be zero.

5.2.1. Payloads following the SA payload

Payloads that define specific security association attributes for the KEK and/or TEKs used by the group MUST follow the SA payload. How many of each payload is dependent upon the group policy. There may be zero or one SAK Payloads, zero or more GAP Payloads, and zero or more SAT Payloads, where either one SAK or SAT payload MUST be present. When present, the order of the SA Attributes payloads must be: KEK, GAP, and TEKs.

This latitude allows various group policies to be accommodated. For example if the group policy does not require the use of a Re-key SA, the GCKS would not need to send an SA KEK attribute to the group member since all SA updates would be performed using the Registration

SA. Alternatively, group policy might use a Re-key SA but choose to download a KEK to the group member only as part of the Registration SA. Therefore, the KEK policy (in the SA KEK attribute) would not be necessary as part of the Re-key SA message SA payload.

Specifying multiple SATs allows multiple sessions to be part of the same group and multiple streams to be associated with a session (e.g., video, audio, and text) but each with individual security association policy.

A GAP payload allows for the distribution of group-wise policy, such as instructions as to when to activate and de-activate SAs.

5.3. SA KEK payload

The SA KEK (SAK) payload contains security attributes for the KEK method for a group and parameters specific to the GROUPKEY-PULL operation. The source and destination identities describe the identities used for the GROUPKEY-PULL datagram.

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
! Next Payload !   RESERVED   !           Payload Length           !
+-----+-----+-----+-----+-----+-----+-----+-----+
!   Protocol   ! SRC ID Type !           SRC ID Port           !
+-----+-----+-----+-----+-----+-----+-----+-----+
!SRC ID Data Len!           SRC Identification Data           ~
+-----+-----+-----+-----+-----+-----+-----+-----+
! DST ID Type  !           DST ID Port           !DST ID Data Len!
+-----+-----+-----+-----+-----+-----+-----+-----+
!                                     DST Identification Data           ~
+-----+-----+-----+-----+-----+-----+-----+-----+
!                                     SPI                                     !
+-----+-----+-----+-----+-----+-----+-----+-----+
!                                     RESERVED2                           !
+-----+-----+-----+-----+-----+-----+-----+-----+
~                                     KEK Attributes                           ~
+-----+-----+-----+-----+-----+-----+-----+-----+

```

The SAK Payload fields are defined as follows:

o Next Payload (1 octet) -- Identifies the next payload for the GROUPKEY-PULL or the GROUPKEY-PUSH message. The only valid next payload types for this message are a GAP Payload, SAT Payload or zero

to indicate that no SA Attribute payloads follow.

- o RESERVED (1 octet) -- Must be zero.

- o Payload Length (2 octets) -- Length of this payload, including the KEK attributes.

- o Protocol (1 octet) -- Value describing an IP protocol ID (e.g., UDP/TCP) for the rekey datagram.

- o SRC ID Type (1 octet) -- Value describing the identity information found in the SRC Identification Data field. Defined values are specified by the IPsec Identification Type section in the IANA isakmpd-registry [ISAKMP-REG].

- o SRC ID Port (2 octets) -- Value specifying a port associated with the source Id. A value of zero means that the SRC ID Port field should be ignored.

- o SRC ID Data Len (1 octet) -- Value specifying the length of the SRC Identification Data field.

- o SRC Identification Data (variable length) -- Value, as indicated by the SRC ID Type.

- o DST ID Type (1 octet) -- Value describing the identity information found in the DST Identification Data field. Defined values are specified by the IPsec Identification Type section in the IANA isakmpd-registry [ISAKMP-REG].

- o DST ID Prot (1 octet) -- Value describing an IP protocol ID (e.g., UDP/TCP).

- o DST ID Port (2 octets) -- Value specifying a port associated with the source Id.

- o DST ID Data Len (1 octet) -- Value specifying the length of the DST Identification Data field.

- o DST Identification Data (variable length) -- Value, as indicated by the DST ID Type.

- o SPI (16 octets) -- Security Parameter Index for the KEK. The SPI must be the ISAKMP Header cookie pair where the first 8 octets become the "Initiator Cookie" field of the GROUPKEY-PUSH message ISAKMP HDR, and the second 8 octets become the "Responder Cookie" in the same HDR. As described above, these cookies are assigned by the GCKS.

- o RESERVED2 (4 octets) -- Must be zero.
- o KEK Attributes -- Contains KEK policy attributes associated with the group. The following sections describe the possible attributes. Any or all attributes may be optional, depending on the group policy.

5.3.1. KEK Attributes

The following attributes may be present in a SAK Payload. The attributes must follow the format defined in ISAKMP (Section 3.3 of [RFC2408]). In the table, attributes that are defined as TV are marked as Basic (B); attributes that are defined as TLV are marked as Variable (V).

ID Class	Value	Type
-----	-----	----
RESERVED	0	
KEK_MANAGEMENT_ALGORITHM	1	B
KEK_ALGORITHM	2	B
KEK_KEY_LENGTH	3	B
KEK_KEY_LIFETIME	4	V
SIG_HASH_ALGORITHM	5	B
SIG_ALGORITHM	6	B
SIG_KEY_LENGTH	7	B

The KEK_MANAGEMENT_ALGORITHM attribute may only be included in a GROUPKEY-PULL message.

5.3.2. KEK_MANAGEMENT_ALGORITHM

The KEK_MANAGEMENT_ALGORITHM class specifies the group KEK management algorithm used to provide forward or backward access control (i.e., used to exclude group members). Defined values are specified in the following table.

KEK Management Type	Value
-----	-----
RESERVED	0
LKH	1
RESERVED	2-127
Private Use	128-255

5.3.2.1. LKH

This type indicates the group management method described in Section 5.4 of [RFC2627]. A general discussion of LKH operations can also be found in Section 6.3 of Multicast and Group Security [HD03]

5.3.3. KEK_ALGORITHM

The KEK_ALGORITHM class specifies the encryption algorithm using with the KEK. Defined values are specified in the following table. An GDOI implementation MUST abort if it encounters an attribute or capability that it does not understand.

Algorithm Type	Value
-----	-----
RESERVED	0
KEK_ALG_DES	1
KEK_ALG_3DES	2
KEK_ALG_AES	3
RESERVED	4-127
Private Use	128-255

If a KEK_MANAGEMENT_ALGORITHM is defined which defines multiple keys (e.g., LKH), and if the management algorithm does not specify the algorithm for those keys, then the algorithm defined by the KEK_ALGORITHM attribute MUST be used for all keys which are included as part of the management.

5.3.3.1. KEK_ALG_DES

This type specifies DES using the Cipher Block Chaining (CBC) mode as described in [FIPS81].

5.3.3.2. KEK_ALG_3DES

This type specifies 3DES using three independent keys as described in "Keying Option 1" in [FIPS46-3].

5.3.3.3. KEK_ALG_AES

This type specifies AES as described in [FIPS197]. The mode of operation for AES is Cipher Block Chaining (CBC) as recommended in [SP.800-38A].

5.3.4. KEK_KEY_LENGTH

The KEK_KEY_LENGTH class specifies the KEK Algorithm key length (in bits). The Group Controller/Key Server (GCKS) adds the KEK_KEY_LEN attribute to the SA payload when distributing KEK policy to group members. The group member verifies whether or not it has the capability of using a cipher key of that size. If the cipher definition includes a fixed key length (e.g., KEK_ALG_3DES), the group member can make its decision solely using the KEK_ALGORITHM attribute and does not need the KEK_KEY_LEN attribute. Sending the KEK_KEY_LEN attribute in the SA payload is OPTIONAL if the KEK cipher has a fixed key length. Also, note that the KEK_KEY_LEN includes only the actual length of the cipher key (the IV length is not included in this attribute).

5.3.5. KEK_KEY_LIFETIME

The KEK_KEY_LIFETIME class specifies the maximum time for which the KEK is valid. The GCKS may refresh the KEK at any time before the end of the valid period. The value is a four (4) octet number defining a valid time period in seconds.

5.3.6. SIG_HASH_ALGORITHM

SIG_HASH_ALGORITHM specifies the SIG payload hash algorithm. The following table defines the algorithms for SIG_HASH_ALGORITHM.

Algorithm Type	Value
-----	-----
RESERVED	0
SIG_HASH_MD5	1
SIG_HASH_SHA1	2
SIG_HASH_SHA256	TBD-2
SIG_HASH_SHA384	TBD-3
SIG_HASH_SHA512	TBD-4
RESERVED	6-127
Private Use	128-255

The SHA hash algorithms are defined in the Secure Hash Standard[FIPS.180-2.2002].

If the SIG_ALGORITHM is SIG_ALG_ECDSA-256, SIG_ALG_ECDSA-384, or SIG_ALG_ECDSA-521 the hash algorithm is implicit in the definition, and SIG_HASH_ALGORITHM is not required to be present in a SAK Payload.

5.3.7. SIG_ALGORITHM

The SIG_ALGORITHM class specifies the SIG payload signature algorithm. Defined values are specified in the following table.

Algorithm Type	Value
-----	-----
RESERVED	0
SIG_ALG_RSA	1
SIG_ALG_DSS	2
SIG_ALG_ECDSS	3
SIG_ALG_RSA_PSS	TBD-6
SIG_ALG_ECDSA-256	TBD-7
SIG_ALG_ECDSA-384	TBD-8
SIG_ALG_ECDSA-521	TBD-9
RESERVED	8-127
Private Use	128-255

5.3.7.1. SIG_ALG_RSA

This algorithm specifies the RSA digital signature algorithm using the EMSA-PKCS1-v1_5 encoding method, as described in [RFC3447].

5.3.7.2. SIG_ALG_DSS

This algorithm specifies the DSS digital signature algorithm as described in Section 4 of [FIPS186-3].

5.3.7.3. SIG_ALG_ECDSS

This algorithm specifies the Elliptic Curve digital signature algorithm as described in Section 5 of [FIPS186-3]. This definition is deprecated in favor of the SIG_ALG_ECDSA family of algorithms.

5.3.7.4. SIG_ALG_RSA_PSS

This algorithm specifies the RSA digital signature algorithm using the EMSA-PSS encoding method, as described in [RFC3447].

5.3.7.5. SIG_ALG_ECDSA-256

This algorithm specifies the 256-bit Random ECP Group, as described in [RFC5903]. The format of the signature in the SIG payload MUST be as specified in [RFC4754].

5.3.7.6. SIG_ALG_ECDSA-384

This algorithm specifies the 384-bit Random ECP Group, as described in [RFC5903]. The format of the signature in the SIG payload MUST be as specified in [RFC4754].

5.3.7.7. SIG_ALG_ECDSA-521

This algorithm specifies the 521-bit Random ECP Group, as described in [RFC5903]. The format of the signature in the SIG payload MUST be as specified in [RFC4754].

5.3.8. SIG_KEY_LENGTH

The SIG_KEY_LENGTH class specifies the length of the SIG payload key in bits.

5.4. Group Associated Policy

RFC 3547 provides for the distribution of policy in the GROUPKEY-PULL exchange in an SA payload. Policy can define GROUPKEY-PUSH policy (SA KEK) or traffic encryption policy (SA TEK) such as IPsec policy. There is a need to distribute group policy that fits into neither category. Some of this policy is generic to the group, and some is sender-specific policy for a particular group member.

GDOI distributes this associated group policy in a new payload called the SA Group Associated Policy (SA GAP). The SA GAP payload follows any SA KEK payload, and is placed before any SA TEK payloads. In the case that group policy does not include an SA KEK, the SA Attribute Next Payload field in the SA payload MAY indicate the SA GAP payload.

The SA GAP payload is defined as follows:

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
! Next Payload !  RESERVED  !           Payload Length           !
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
!                                     Group Associated Policy Attributes ~
+-----+-----+-----+-----+-----+-----+-----+-----+-----+

```

The SA GAP payload fields are defined as follows:

- o Next Payload (1 octet) -- Identifies the next payload present in the GROUPKEY-PULL or the GROUPKEY-PUSH message. The only valid next payload type for this message is an SA TEK or zero to indicate there are no more security association attributes.

- o RESERVED (1 octet) -- Must be zero.
- o Payload Length (2 octets) -- Length of this payload, including the SA GAP header and Attributes.
- o Group Associated Policy Attributes (variable) -- Contains attributes following the format defined in Section 3.3 of RFC 2408.

Several group associated policy attributes are defined in this memo. An GDOI implementation MUST abort if it encounters an attribute or capability that it does not understand.

5.4.1. ACTIVATION_TIME_DELAY

This attribute allows a GCKS to set the Activation Time Delay for SAs generated from TEKs. The value is in seconds.

5.4.2. DEACTIVATION_TIME_DELAY

This attribute allows a GCKS to set the Deactivation Time Delay for SAs generated from TEKs. The value is in seconds. The values of Activation Time Delay and Deactivation Time Delay are independent. However, the Deactivation Time Delay value should be larger, which allows new SAs to be activated before older SAs are deactivated. Such a policy ensures that protected group traffic will always flow without interruption.

5.4.3. SENDER_ID

Several new AES counter-based modes of operation have been specified for ESP [RFC3686],[RFC4106],[RFC4309],[RFC4543] and AH [RFC4543]. These AES counter-based modes require that no two senders in the group ever send a packet with the same IV. This requirement is met using the method described in [I-D.ietf-msec-ipsec-group-counter-modes], which requires each sender to be allocated a unique Sender ID (SID). The SENDER_ID attribute is used to distribute an SID to a group member during the GROUPKEY-PULL message. Other algorithms with the same need may be defined in the future; the sender MUST use the IV construction method described above with those algorithms as well.

The SENDER_ID attribute value contains the following fields.

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
!   SID Length   !                               SID Value           ~
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

- o SID Length (1 octet) -- A natural number defining the number of bits to be used in the SID field of the counter mode transform nonce. The length of the SID is chosen by the GCKS administrator based on the counter-based mode specification and the number of expected group members. In accordance with [I-D.ietf-msec-ipsec-group-counter-modes] an implementation MUST support values of 8, 12, and 16.
- o SID Value (variable) -- The Sender ID value allocated to the group member.

5.4.3.1. GCKS Semantics

The GCKS maintains a SID counter (SIDC). It is incremented each time a SENDER_ID attribute is distributed to a group member. The first group member to register is given the SID of 1.

Any group member registering will be given a new SID value, which allows group members to act as a group sender when an older SID value becomes unusable (as described in the next section).

A GCKS MAY allocate multiple SID values in one SA GAP payload. Allocating several SID values at the same time to a group member expected to send at a high rate would obviate the need for the group member to re-register as frequently.

If a GCKS allocates all SID values, it can no longer respond to GDOI registrations and must re-initialize the entire group. This is done by including Delete Payload for all ESP and AH SAs in a GDOI rekey message, resetting the SIDC to zero, and creating new ESP and AH SAs that match the group policy. When group members re-register, the SIDs are allocated again beginning with the value 1 as described above. Each re-registering group member will be given a new SID and the new group policy.

The SENDER_ID attribute MUST NOT be sent as part of a GROUPKEY-PUSH message, because distributing the same sender-specific policy to more than one group member may reduce the security of the group.

5.4.3.2. Group Member Semantics

The SENDER_ID attribute value distributed to the group member MUST be used by that group member as the Sender Identifier (SID) field portion of the IV. The SID is used for all counter mode SAs distributed by the GCKS to be used for communications sent as a part of this group.

When the Sender-Specific IV (SSIV) field for any IPsec SA is exhausted, the group member MUST no longer act as a sender using its active SID. The group member SHOULD re-register, during which time the GCKS will issue a new SID to the group member. The new SID replaces the existing SID used by this group member, and also resets the SSIV value to its starting value. A group member MAY re-register prior to the actual exhaustion of the SSIV field to avoid dropping data packets due to the exhaustion of available SSIV values combined with a particular SID value.

A group member MUST NOT process a SENDER_ID attribute present in a GROUPKEY-PUSH message.

5.5. SA TEK Payload

The SA TEK (SAT) payload contains security attributes for a single TEK associated with a group.

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
! Next Payload !   RESERVED   !           Payload Length           !
+-----+-----+-----+-----+-----+-----+-----+-----+
! Protocol-ID   !           TEK Protocol-Specific Payload           ~
+-----+-----+-----+-----+-----+-----+-----+-----+
~                                                                 ~
+-----+-----+-----+-----+-----+-----+-----+-----+

```

The SAT Payload fields are defined as follows:

- o Next Payload (1 octet) -- Identifies the next payload for the GROUPKEY-PULL or the GROUPKEY-PUSH message. The only valid next payload types for this message are another SAT Payload or zero to indicate there are no more security association attributes.
- o RESERVED (1 octet) -- Must be zero.
- o Payload Length (2 octets) -- Length of this payload, including the TEK Protocol-Specific Payload.

o Protocol-ID (1 octet) -- Value specifying the Security Protocol.
The following table defines values for the Security Protocol

Protocol ID	Value
-----	-----
RESERVED	0
GDOI_PROTO_IPSEC_ESP	1
GDOI_PROTO_IPSEC_AH	TBD-5
RESERVED	3-127
Private Use	128-255

o TEK Protocol-Specific Payload (variable) -- Payload which describes the attributes specific for the Protocol-ID.

5.5.1. GDOI_PROTO_IPSEC_ESP/GDOI_PROTO_IPSEC_AH

The TEK Protocol-Specific payload for ESP and AH is as follows:

```

0                               1                               2                               3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
!  Protocol  ! SRC ID Type  ! SRC ID Port  !
+-----+-----+-----+-----+-----+-----+-----+-----+
!SRC ID Data Len! SRC Identification Data ~
+-----+-----+-----+-----+-----+-----+-----+-----+
! DST ID Type  ! DST ID Port  !DST ID Data Len!
+-----+-----+-----+-----+-----+-----+-----+-----+
! DST Identification Data ~
+-----+-----+-----+-----+-----+-----+-----+-----+
! Transform ID ! SPI ~
+-----+-----+-----+-----+-----+-----+-----+-----+
! SPI ! RFC 2407 SA Attributes ~
+-----+-----+-----+-----+-----+-----+-----+-----+

```

The SAT Payload fields are defined as follows:

o Protocol (1 octet) -- Value describing an IP protocol ID (e.g., UDP/TCP). A value of zero means that the Protocol field should be ignored.

o SRC ID Type (1 octet) -- Value describing the identity information found in the SRC Identification Data field. Defined values are specified by the IPsec Identification Type section in the IANA isakmpd-registry [ISAKMP-REG].

o SRC ID Port (2 octets) -- Value specifying a port associated with

the source Id. A value of zero means that the SRC ID Port field should be ignored.

- o SRC ID Data Len (1 octet) -- Value specifying the length of the SRC Identification Data field.

- o SRC Identification Data (variable length) -- Value, as indicated by the SRC ID Type. Set to three bytes of zero for multiple-source multicast groups that use a common TEK for all senders.

- o DST ID Type (1 octet) -- Value describing the identity information found in the DST Identification Data field. Defined values are specified by the IPsec Identification Type section in the IANA isakmpd-registry [ISAKMP-REG].

- o DST ID Prot (1 octet) -- Value describing an IP protocol ID (e.g., UDP/TCP). A value of zero means that the DST Id Prot field should be ignored.

- o DST ID Port (2 octets) -- Value specifying a port associated with the source Id. A value of zero means that the DST ID Port field should be ignored.

- o DST ID Data Len (1 octet) -- Value specifying the length of the DST Identification Data field.

- o DST Identification Data (variable length) -- Value, as indicated by the DST ID Type.

- o Transform ID (1 octet) -- Value specifying which ESP or AH transform is to be used. The list of valid values is defined in the IPsec ESP or IPsec AH Transform Identifiers section of the IANA isakmpd-registry [ISAKMP-REG].

- o SPI (4 octets) -- Security Parameter Index for ESP.

- o RFC 2407 Attributes -- ESP and AH Attributes from RFC 2407 Section 4.5. The GDOI supports all IPsec DOI SA Attributes for GDOI_PROTO_IPSEC_ESP and GDOI_PROTO_IPSEC_AH excluding the Group Description (section 4.5 of [RFC2407], which MUST NOT be sent by a GDOI implementation and is ignored by a GDOI implementation if received. The following attributes MUST be supported by an implementation supporting ESP and AH: SA Life Type, SA Life Duration, Encapsulation Mode. An implementation supporting ESP must also support the Authentication Algorithm attribute if the ESP transform includes authentication/ The Authentication Algorithm attribute of the IPsec DOI is group authentication in GDOI.

5.5.1.1.1. Harmonization with RFC 5374

The Multicast Extensions to the Security Architecture for the Internet Protocol (RFC 5374) introduces new requirements for a group key management system distributing IPsec policy. The following sections describe new GDOI requirements that result from harmonizing with that document.

5.5.1.1.1.1. Group Security Policy Database Attributes

RFC 5374 describes new attributes as part of the Group Security Policy Database (GSPD). These attributes describe policy that a group key management system must convey to a group member in order to support those extensions. The GDOI SA TEK payload distributes IPsec policy using IPsec security association attributes defined in [ISAKMP-REG]. This section defines how GDOI can convey the new attributes as IPsec Security Association Attributes.

5.5.1.1.1.2. Address Preservation

Applications use the extensions in RFC 5374 to copy the IP addresses into the outer IP header when encapsulating an IP packet as an IPsec tunnel mode packet. This allows an IP multicast packet to continue to be routed as a IP multiast packet. In order for the GDOI group member to appropriately set up the GSPD, the GCKS must provide that policy to the group member.

Depending on group policy, several address preservation methods are possible: no address preservation ("None"), preservation of the original source address ("Source-Only"), preservation of the original destination address ("Destination-Only"), or both addresses ("Source-And-Destination"). This memo adds the "Address Preservation" security association attribute. If this attribute is not included in a GDOI SA TEK payload provided by a GCKS, then Source-And-Destination address preservation has been defined for the SA TEK.

5.5.1.1.1.3. SA Direction

Depending on group policy, an IPsec SA created from an SA TEK payload may be required in one or both directions. SA TEK policy used by multiple senders is required to be installed in both the sending and receiving direction ("Symmetric"), whereas SA TEK for a single sender should only be installed in the receiving direction by receivers ("Receiver-Only") and in the sending direction by the sender ("Sender-Only"). This memo adds the "SA Direction" security association attribute. If the attribute is not included in a GDOI SA TEK payload, then the IPsec SA is treated as a Symmetric IPsec SA.

5.5.1.1.4. Re-key rollover

Section 4.2.1 of RFC 5374 specifies a key rollover method that requires two values be given it from the group key management protocol. The Activation Time Delay (ATD) attribute allows the GCKS to specify how long after the start of a re-key event that a group member is to activate new TEKs. The Deactivation Time Delay (DTD) attribute allows the GCKS to specify how long after the start of a re-key event that a group member is to deactivate existing TEKs.

This memo adds new attributes by which a GCKS can relay these values to group members as part of the Group Associated Policy described in Section 5.

5.5.2. Other Security Protocols

Besides ESP and AH, GDOI should serve to establish SAs for secure groups needed by other Security Protocols that operate at the transport, application, and internetwork layers. These other Security Protocols, however, are in the process of being developed or do not yet exist.

The following information needs to be provided for a Security Protocol to the GDOI.

- o The Protocol-ID for the particular Security Protocol
- o The SPI Size
- o The method of SPI generation
- o The transforms, attributes and keys needed by the Security Protocol

All Security Protocols must provide the information in the bulleted list above to guide the GDOI specification for that protocol. Definitions for the support of those Security Protocols in GDOI will be specified in separate documents.

A Security Protocol MAY protect traffic at any level of the network stack. However, in all cases applications of the Security Protocol MUST protect traffic which MAY be shared by more than two entities.

5.6. Key Download Payload

The Key Download Payload contains group keys for the group specified in the SA Payload. These key download payloads can have several security attributes applied to them based upon the security policy of

the group as defined by the associated SA Payload.

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
! Next Payload !   RESERVED   !           Payload Length           !
+-----+-----+-----+-----+-----+-----+-----+-----+
! Number of Key Packets           !           RESERVED2           !
+-----+-----+-----+-----+-----+-----+-----+-----+
~                               ~
                               Key Packets
+-----+-----+-----+-----+-----+-----+-----+-----+

```

The Key Download Payload fields are defined as follows:

- o Next Payload (1 octet) -- Identifier for the payload type of the next payload in the message. If the current payload is the last in the message, then this field will be zero.

- o RESERVED (1 octet) -- Unused, set to zero.

- o Payload Length (2 octets) -- Length in octets of the current payload, including the generic payload header.

- o Number of Key Packets (2 octets) -- Contains the total number of both TEK and Rekey arrays being passed in this data block.

- o Key Packets Several types of key packets are defined. Each Key Packet has the following format.

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
!   KD Type   !   RESERVED   !           KD Length           !
+-----+-----+-----+-----+-----+-----+-----+-----+
!   SPI Size   !           SPI (variable)           ~
+-----+-----+-----+-----+-----+-----+-----+-----+
~                               ~
                               Key Packet Attributes
+-----+-----+-----+-----+-----+-----+-----+-----+

```

- o Key Download (KD) Type (1 octet) -- Identifier for the Key Data field of this Key Packet.

Key Download Type	Value
-----	-----
RESERVED	0
TEK	1
KEK	2
LKH	3
RESERVED	4-127
Private Use	128-255

"KEK" is a single key whereas LKH is an array of key-encrypting keys.

o RESERVED (1 octet) -- Unused, set to zero.

o Key Download Length (2 octets) -- Length in octets of the Key Packet data, including the Key Packet header.

o SPI Size (1 octet) -- Value specifying the length in octets of the SPI as defined by the Protocol-Id.

o SPI (variable length) -- Security Parameter Index which matches a SPI previously sent in an SAK or SAT Payload.

o Key Packet Attributes (variable length) -- Contains Key information. The format of this field is specific to the value of the KD Type field. The following sections describe the format of each KD Type.

5.6.1. TEK Download Type

The following attributes may be present in a TEK Download Type. Exactly one attribute matching each type sent in the SAT payload MUST be present. The attributes must follow the format defined in ISAKMP (Section 3.3 of [RFC2408]). In the table, attributes defined as TV are marked as Basic (B); attributes defined as TLV are marked as Variable (V).

TEK Class	Value	Type
-----	-----	-----
RESERVED	0	
TEK_ALGORITHM_KEY	1	V
TEK_INTEGRITY_KEY	2	V
TEK_SOURCE_AUTH_KEY	3	V

If no TEK key packets are included in a Registration KD payload, the group member can expect to receive the TEK as part of a Re-key SA.

At least one TEK must be included in each Re-key KD payload.

Multiple TEKs may be included if multiple streams associated with the

SA are to be rekeyed.

When an algorithm specification specifies the format of the keying material, the value transported in the KD payload for that key is passed according to that specification. The keying material may contain information besides a key. For example, The Use of Galois/Counter Mode (GCM) in IPsec Encapsulating Security Payload (ESP) [RFC4106] defines a salt value as part of KEYMAT.

5.6.1.1. TEK_ALGORITHM_KEY

The TEK_ALGORITHM_KEY class declares that the encryption key for this SPI is contained as the Key Packet Attribute. The encryption algorithm that will use this key was specified in the SAT payload.

In the case that the algorithm requires multiple keys (e.g., 3DES), all keys will be included in one attribute.

DES keys will consist of 64 bits (the 56 key bits with parity bit). Triple DES keys will be specified as a single 192 bit attribute (including parity bits) in the order that the keys are to be used for encryption (e.g., DES_KEY1, DES_KEY2, DES_KEY3).

5.6.1.2. TEK_INTEGRITY_KEY

The TEK_INTEGRITY_KEY class declares that the integrity key for this SPI is contained as the Key Packet Attribute. The integrity algorithm that will use this key was specified in the SAT payload. Thus, GDOI assumes that both the symmetric encryption and integrity keys are pushed to the member. HMAC-SHA1 keys will consist of 160 bits[RFC2404], HMAC-MD5 keys will consist of 128 bits[RFC2403]. HMAC-SHA2 and AES-GMAC keys will have a key length equal to the output length of the hash functions [RFC4868][RFC4543].

5.6.1.3. TEK_SOURCE_AUTH_KEY

The TEK_SOURCE_AUTH_KEY class declares that the source authentication key for this SPI is contained in the Key Packet Attribute. The source authentication algorithm that will use this key was specified in the SAT payload.

5.6.2. KEK Download Type

The following attributes may be present in a KEK Download Type. Exactly one attribute matching each type sent in the SAK payload MUST be present. The attributes must follow the format defined in ISAKMP (Section 3.3 of [RFC2408]). In the table, attributes defined as TV are marked as Basic (B); attributes defined as TLV are marked as

Variable (V).

KEK Class	Value	Type
-----	-----	----
RESERVED	0	
KEK_ALGORITHM_KEY	1	V
SIG_ALGORITHM_KEY	2	V

If the KEK key packet is included, there MUST be only one present in the KD payload.

5.6.2.1. KEK_ALGORITHM_KEY

The KEK_ALGORITHM_KEY class declares the encryption key for this SPI is contained in the Key Packet Attribute. The encryption algorithm that will use this key was specified in the SAK payload.

If the mode of operation for the algorithm requires an Initialization Vector (IV), an explicit IV MUST be included in the KEK_ALGORITHM_KEY before the actual key.

5.6.2.2. SIG_ALGORITHM_KEY

The SIG_ALGORITHM_KEY class declares that the public key for this SPI is contained in the Key Packet Attribute, which may be useful when no public key infrastructure is available. The signature algorithm that will use this key was specified in the SAK payload.

5.6.3. LKH Download Type

The LKH key packet is comprised of attributes representing different nodes in the LKH key tree.

The following attributes are used to pass an LKH KEK array in the KD payload. The attributes must follow the format defined in ISAKMP (Section 3.3 of [RFC2408]). In the table, attributes defined as TV are marked as Basic (B); attributes defined as TLV are marked as Variable (V).

KEK Class	Value	Type
-----	----	----
RESERVED	0	
LKH_DOWNLOAD_ARRAY	1	V
LKH_UPDATE_ARRAY	2	V
SIG_ALGORITHM_KEY	3	V
RESERVED	4-127	
Private Use	128-255	

If an LKH key packet is included in the KD payload, there must be only one present.

5.6.3.1. LKH_DOWNLOAD_ARRAY

This attribute is used to download a set of keys to a group member. It MUST NOT be included in a GROUPKEY-PUSH message KD payload if the GROUPKEY-PUSH is sent to more than the group member. If an LKH_DOWNLOAD_ARRAY attribute is included in a KD payload, there must be only one present.

This attribute consists of a header block, followed by one or more LKH keys.

```

      0               1               2               3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
!  LKH Version  !               # of LKH Keys               !  RESERVED  !
+-----+-----+-----+-----+-----+-----+-----+-----+
!                                     LKH Keys                                     !
~                                                                 ~
+-----+-----+-----+-----+-----+-----+-----+-----+

```

The KEK_LKH attribute fields are defined as follows:

- o LKH version (1 octet) -- Version of the LKH data format. Must be one.
- o Number of LKH Keys (2 octets) -- This value is the number of distinct LKH keys in this sequence.
- o RESERVED (1 octet) -- Unused, set to zero. Each LKH Key is defined as follows:

```

      0               1               2               3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
!-----+-----+-----+-----+-----+-----+-----+-----+
!               LKH ID               !   Key Type   !   RESERVED   !
+-----+-----+-----+-----+-----+-----+-----+-----+
~-----+-----+-----+-----+-----+-----+-----+-----+
~               Key Creation Date               !
+-----+-----+-----+-----+-----+-----+-----+-----+
~-----+-----+-----+-----+-----+-----+-----+-----+
~               Key expiration Date               !
+-----+-----+-----+-----+-----+-----+-----+-----+
~-----+-----+-----+-----+-----+-----+-----+-----+
~               Key Handle               !
+-----+-----+-----+-----+-----+-----+-----+-----+
!-----+-----+-----+-----+-----+-----+-----+-----+
!               Key Data               !
+-----+-----+-----+-----+-----+-----+-----+-----+

```

o LKH ID (2 octets) -- Identity of the LKH node. A GCKS is free to choose the ID in an implementation-specific manner (e.g., the position of this key in a binary tree structure used by LKH).

o Key Type (1 octet) -- Encryption algorithm for which this key data is to be used. This value is specified in Section 5.3.3.

o RESERVED (1 octet) -- Unused, set to zero.

o Key Creation Date (4 octets) -- Time value of when this key data was originally generated. A time value of zero indicates that there is no time before which this key is not valid.

o Key Expiration Date (4 octets) -- Time value of when this key is no longer valid for use. A time value of zero indicates that this key does not have an expiration time.

o Key Handle (4 octets) -- Value assigned by the GCKS to uniquely identify a key within an LKH ID. Each new key distributed by the GCKS for this node will have a key handle identity distinct from previous or successive key handles specified for this node.

o Key Data (variable length) -- Key data, which is dependent on the Key Type algorithm for its format. If the mode of operation for the algorithm requires an Initialization Vector (IV), an explicit IV MUST be included in the Key Data field prepended to the actual key.

The Key Creation Date and Key expiration Dates MAY be zero. This is necessary in the case where time synchronization within the group is not possible.

The first LKH Key structure in an LKH_DOWNLOAD_ARRAY attribute contains the Leaf identifier and key for the group member. The rest

of the LKH Key structures contain keys along the path of the key tree in order from the leaf, culminating in the group KEK.

5.6.3.2. LKH_UPDATE_ARRAY

This attribute is used to update the keys for a group. It is most likely to be included in a GROUPKEY-PUSH message KD payload to rekey the entire group. This attribute consists of a header block, followed by one or more LKH keys, as defined in the previous section.

There may be any number of UPDATE_ARRAY attributes included in a KD payload.

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
!  LKH Version  !           # of LKH Keys           !  RESERVED  !
+-----+-----+-----+-----+-----+-----+-----+-----+
!               LKH ID               !           RESERVED2           !
+-----+-----+-----+-----+-----+-----+-----+-----+
!                               Key Handle                               !
+-----+-----+-----+-----+-----+-----+-----+-----+
!                               LKH Keys                               !
~                               ~
+-----+-----+-----+-----+-----+-----+-----+-----+

```

o LKH version (1 octet) -- Version of the LKH data format. Must be one.

o Number of LKH Keys (2 octets) -- Number of distinct LKH keys in this sequence.

o RESERVED (1 octet) -- Unused, set to zero.

o LKH ID (2 octets) -- Node identifier associated with the key used to encrypt the first LKH Key.

o RESERVED2 (2 octets) -- Unused, set to zero.

o Key Handle (4 octets) -- Value assigned by the GCKS to uniquely identify the key within the LKH ID used to encrypt the first LKH Key.

The LKH Keys are as defined in the previous section. The LKH Key structures contain keys along the path of the key tree in order from the LKH ID found in the LKH_UPDATE_ARRAY header, culminating in the group KEK. The Key Data field of each LKH Key is encrypted with the LKH key preceding it in the LKH_UPDATE_ARRAY attribute. The first

LKH Key is encrypted under the key defined by the LKH ID and Key Handle found in the LKH_UPDATE_ARRAY header.

5.6.3.3. SIG_ALGORITHM_KEY

The SIG_ALGORITHM_KEY class declares that the public key for this SPI is contained in the Key Packet Attribute, which may be useful when no public key infrastructure is available. The signature algorithm that will use this key was specified in the SAK payload.

5.7. Sequence Number Payload

The Sequence Number Payload (SEQ) provides an anti-replay protection for GROUPKEY-PUSH messages. Its use is similar to the Sequence Number field defined in the IPsec ESP protocol [RFC4303].

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
! Next Payload !  RESERVED  !           Payload Length           !
+-----+-----+-----+-----+-----+-----+-----+-----+
!                                     Sequence Number                                     !
+-----+-----+-----+-----+-----+-----+-----+-----+

```

The Sequence Number Payload fields are defined as follows:

- o Next Payload (1 octet) -- Identifier for the payload type of the next payload in the message. If the current payload is the last in the message, then this field will be zero.
- o RESERVED (1 octet) -- Unused, set to zero.
- o Payload Length (2 octets) -- Length in octets of the current payload, including the generic payload header.
- o Sequence Number (4 octets) -- This field contains a monotonically increasing counter value for the group. It is initialized to zero by the GCKS, and incremented in each subsequently-transmitted message. Thus the first packet sent for a given Rekey SA will have a Sequence Number of 1. The GDOI implementation keeps a sequence counter as an attribute for the Rekey SA and increments the counter upon receipt of a GROUPKEY-PUSH message. The current value of the sequence number must be transmitted to group members as a part of the Registration SA payload. A group member must keep a sliding receive window. The window must be treated as in the ESP protocol [RFC4303] Section 3.4.3.

5.8. Nonce

The data portion of the Nonce payload (i.e., `Ni_b` and `Nr_b` included in the HASHs) MUST be a value between 8 and 128 bytes.

5.9. Delete

There are times the GCKS may want to signal to receivers to delete SAs, for example at the end of a broadcast. Deletion of keys may be accomplished by sending an ISAKMP Delete payload (Section 3.15 of [RFC2408]) as part of a GDOI GROUPKEY-PUSH message.

One or more Delete payloads MAY be placed following the SEQ payload in a GROUPKEY-PUSH message. If a GCKS has no further SAs to send to group members, the SA and KD payloads MUST be omitted from the message.

The following fields of the Delete Payload are further defined as follows:

- o The Domain of Interpretation field contains the GDOI DOI.
- o The Protocol-Id field contains TEK protocol id values defined in Section 5.5 of this document. To delete a KEK SA, the value of zero MUST be used as the protocol id. Note that only one protocol id value can be defined in a Delete payload. If a TEK SA and a KEK SA must be deleted, they must be sent in different Delete payloads.

There may be circumstances where the GCKS may want to start over with a clean slate. If the administrator is no longer confident in the integrity of the group, the GCKS can signal deletion of all policy of a particular TEK protocol by sending a TEK with a SPI value equal to zero in the delete payload. For example, if the GCKS wishes to remove all the KEKs and all the TEKs in the group, the GCKS SHOULD send a delete payload with a spi of zero and a protocol_id of a TEK protocol_id value, followed by another delete payload with a spi of zero and protocol_id of zero, indicating that the KEK SA should be deleted.

6. Algorithm Selection

For GDOI implementations to interoperate, they must support one or more security algorithms in common. This section specifies the security algorithm implementation requirements for standards-conformant GDOI implementations. In all cases the choices are intended to maintain at least 112 bits of security [SP.800-131].

Algorithms not referenced in this section MAY be used.

6.1. KEK

These tables list the algorithm selections for values related to the KEK.

Requirement	KEK Management Algorithm
-----	-----
SHOULD	LKH
Requirement	KEK Algorithm (notes)
-----	-----
MUST	KEK_ALG_AES with 128-bit keys
SHOULD NOT	KEK_ALG_DES (1)
Requirement	KEK Signature Hash Algorithm (notes)
-----	-----
MUST	SIG_HASH_SHA256
SHOULD	SIG_HASH_SHA1 (2)
SHOULD NOT	SIG_HASH_MD5 (3)
Requirement	KEK Signature Algorithm (notes)
-----	-----
MUST	SIG_ALG_RSA with 2048-bit keys

Notes:

- (1) DES, with its small key size and corresponding security strength is of questionable security for general use
- (2) The use of SIG_HASH_SHA1 as a signature hash algorithm used with GROUPKEY-PUSH messages remains safe at the time of this writing, and is a widely deployed signature hash algorithm.
- (3) Although a real weakness with second preimage resistance with MD5 has not been found at the time of this writing, the security strength of MD5 has been shown to be rapidly declining over time and it's use should be understood and carefully weighed.

6.2. TEK

The following table lists the requirements for Security Protocol support for an implementation.

Requirement	KEK Management Algorithm
-----	-----
MUST	GDOI_PROTO_IPSEC_ESP

7. Security Considerations

GDOI is a security association (SA) management protocol for groups of senders and receivers. Unlike a data security protocol, SA management includes a key establishment protocol to securely establish keys at communication endpoints. This protocol performs entity authentication of the GDOI member or Group Controller/Key Server (GCKS), it provides confidentiality of key management messages, and it provides source authentication of those messages. This protocol also uses best-known practices for defense against man-in-middle, connection hijacking, replay, reflection, and denial-of-service (DOS) attacks on unsecured networks [STS], [RFC2522], [SKEME]. GDOI assumes the network is not secure and may be under the complete control of an attacker.

GDOI assumes that the host computer is secure even though the network is insecure. GDOI ultimately establishes keys among members of a group, which MUST be trusted to use those keys in an authorized manner according to group policy. The security of GDOI, therefore, is as good as the degree to which group members can be trusted to protect authenticators, encryption keys, decryption keys, and message authentication keys.

There are three phases of GDOI as described in this document: an ISAKMP Phase 1 protocol, a new exchange called GROUPKEY-PULL which is protected by the ISAKMP Phase 1 protocol, and a new message called GROUPKEY-PUSH. Each phase is considered separately below.

7.1. ISAKMP Phase 1

As described in this document, GDOI uses the Phase 1 exchanges defined in [RFC2409] to protect the GROUPKEY-PULL exchange. Therefore all security properties and considerations of those exchanges (as noted in [RFC2409]) are relevant for GDOI.

GDOI may inherit the problems of its ancestor protocols [FS00], such as identity exposure, absence of unidirectional authentication, or stateful cookies [PK01]. GDOI could benefit, however, from improvements to its ancestor protocols just as it benefits from years of experience and work embodied in those protocols. To reap the benefits of future IKE improvements, however, GDOI would need to be revised in a future standards-track RFC, which is beyond the scope of this specification.

7.1.1. Authentication

Authentication is provided via the mechanisms defined in [RFC2409], namely Pre-Shared Keys or Public Key encryption.

7.1.2. Confidentiality

Confidentiality is achieved in Phase 1 through a Diffie-Hellman exchange that provides keying material, and through negotiation of encryption transforms.

The Phase 1 protocol will be protecting encryption and integrity keys sent in the GROUPKEY-PULL protocol. The strength of the encryption used for Phase 1 SHOULD exceed that of the keys sent in the GROUPKEY-PULL protocol.

7.1.3. Man-in-the-Middle Attack Protection

A successful man-in-the-middle or connection-hijacking attack foils entity authentication of one or more of the communicating entities during key establishment. GDOI relies on Phase 1 authentication to defeat man-in-the-middle attacks.

7.1.4. Replay/Reflection Attack Protection

In a replay/reflection attack, an attacker captures messages between GDOI entities and subsequently forwards them to a GDOI entity. Replay and reflection attacks seek to gain information from a subsequent GDOI message response or seek to disrupt the operation of a GDOI member or GCKS entity. GDOI relies on the Phase 1 nonce mechanism in combination with a hash-based message authentication code to protect against the replay or reflection of previous key management messages.

7.1.5. Denial of Service Protection

A denial of service attacker sends messages to a GDOI entity to cause that entity to perform unneeded message authentication operations. GDOI uses the Phase 1 cookie mechanism to identify spurious messages prior to cryptographic hash processing. This is a "weak" form of denial of service protection in that the GDOI entity must check for good cookies, which can be successfully imitated by a sophisticated attacker. The Phase 1 cookie mechanism is stateful, and commits memory resources for cookies, but stateless cookies are a better defense against denial of service attacks.

7.2. GROUPKEY-PULL Exchange

The GROUPKEY-PULL exchange allows a group member to request SAs and keys from a GCKS. It runs as a "phase 2" protocol under protection of the Phase 1 security association.

7.2.1. Authentication

Peer authentication is not required in the GROUPKEY-PULL protocol. It is running in the context of the Phase 1 protocol, which has previously authenticated the identity of the peer.

Message authentication is provided by HASH payloads in each message, where the HASH is defined to be over SKEYID_a (derived in the Phase 1 exchange), the ISAKMP Message-ID, and all payloads in the message. Because only the two endpoints of the exchange know the SKEYID_a value, this provides confidence that the peer sent the message.

7.2.2. Confidentiality

Confidentiality is provided by the Phase 1 security association, after the manner described in [RFC2409].

7.2.3. Man-in-the-Middle Attack Protection

Message authentication (described above) includes a secret known only to the group member and GCKS when constructing a HASH payload. This prevents man-in-the-middle and connection-hijacking attacks because an attacker would not be able to change the message undetected.

7.2.4. Replay/Reflection Attack Protection

Nonces provide freshness of the GROUPKEY-PULL exchange. The group member and GCKS exchange nonce values first two messages. These nonces are included in subsequent HASH payload calculations. The Group member and GCKS MUST NOT perform any computationally expensive tasks before receiving a HASH with its own nonce included. The GCKS MUST NOT update the group management state (e.g., LKH key tree) until it receives the third message in the exchange with a valid HASH payload including its own nonce.

Implementations SHOULD keep a record of recently received GROUPKEY-PULL messages and reject messages that have already been processed. This enables an early discard of the replayed messages.

7.2.5. Denial of Service Protection

A GROUPKEY-PULL message identifies its messages using a cookie pair from the Phase 1 exchange that precedes it. The cookies provide a weak form of denial of service protection as described above, in the sense that a GROUPKEY-PULL message with invalid cookies will be discarded.

The replay protection mechanisms described above provide the basis

for denial of service protection.

7.2.6. Authorization

A GCKS implementation should maintain an authorization list of authorized group members. Group members will specifically list each authorized GCKS in its Group Peer Authorization Database (GPAD) [RFC5374].

7.3. GROUPKEY-PUSH Exchange

The GROUPKEY-PUSH exchange is a single message that allows a GCKS to send SAs and keys to group members. This is likely to be sent to all members using an IP multicast group. This provides an efficient rekey and group membership adjustment capability.

7.3.1. Authentication

The GROUPKEY-PULL exchange identifies a public key that is used for message authentication. The GROUPKEY-PUSH message is digitally signed using the corresponding private key held by the GCKS or its delegate. This digital signature provides source authentication for the message. Thus, GDOI protects the GCKS from impersonation in group environments.

7.3.2. Confidentiality

The GCKS encrypts the GROUPKEY-PUSH message with an encryption key that was established by the GROUPKEY-PULL exchange.

7.3.3. Man-in-the-Middle Attack Protection

This combination of confidentiality and message authentication services protects the GROUPKEY-PUSH message from man-in-middle and connection-hijacking attacks.

7.3.4. Replay/Reflection Attack Protection

The GROUPKEY-PUSH message includes a monotonically increasing sequence number to protect against replay and reflection attacks. A group member will recognize a replayed message by comparing the sequence number to a sliding window, in the same manner as the ESP protocol uses sequence numbers.

Implementations SHOULD keep a record of recently received GROUPKEY-PUSH messages and reject duplicate messages. This enables an early discard of the replayed messages.

7.3.5. Denial of Service Protection

A cookie pair identifies the security association for the GROUPKEY-PUSH message. The cookies thus serve as a weak form of denial-of-service protection for the GROUPKEY-PUSH message.

The digital signature used for message authentication has a much greater computational cost than a message authentication code and could amplify the effects of a denial of service attack on GDOI members who process GROUPKEY-PUSH messages. The added cost of digital signatures is justified by the need to prevent GCKS impersonation: If a shared symmetric key were used for GROUPKEY-PUSH message authentication, then GCKS source authentication would be impossible and any member would be capable of GCKS impersonation.

The potential of the digital signature amplifying a denial of service attack is mitigated by the order of operations a group member takes, where the least expensive cryptographic operation is performed first. The group member first decrypts the message using a symmetric cipher. If it is a validly formed message then the sequence number is checked against the replay window. Only if the sequence number is valid is the digital signature verified. Thus in order for a denial of service attack to be mounted, an attacker would need to know both the symmetric encryption key used for confidentiality, and a valid sequence number. Generally speaking this means only current group members can effectively deploy a denial of service attack.

7.3.6. Forward Access Control

If a group management algorithm (such as LKH) is used, forward access control may not be ensured in some cases. This can happen if some group members are denied access to the group in the same GROUPKEY-PUSH message as new policy and TEKs are delivered to the group. As discussed in Section 1.5.1, forward access control can be maintained by sending multiple GROUPKEY-PUSH messages, where the group membership changes are sent from the GCKS separate from the new policy and TEKs.

8. IANA Considerations

This memo requests IANA to make several additions to existing registries, and to add several new GDOI registries. When the new registries are added, the following terms are to be applied as described in the Guidelines for Writing an IANA Considerations Section in RFCs [RFC5226]: Standards Action, and Private Use.

8.1. Additions to current registries

The GDOI KEK Attribute named SIG_HASH_ALGORITHM [GDOI-REG] should be assigned several new Algorithm Type values from the RESERVED space to represent the SHA-256, SHA-384, and SHA-512 hash algorithms as defined in [FIPS.180-2.2002]. The new algorithm names should be SIG_HASH_SHA256, SIG_HASH_SHA384, and SIG_HASH_SHA512 respectively and have the values of TBD-2, TBD-3, and TBD-4 respectively.

The GDOI KEK Attributed named SIG_ALGORITHM [GDOI-REG] should be assigned a new Algorithm Type value from the RESERVED space to represent the RSA PSS encoding type. The new algorithm name should be SIG_ALG_RSA_PSS, and has the value of TBD-6.

A new GDOI SA TEK type Protocol-ID type [GDOI-REG] should be assigned from the RESERVED space. The new algorithm id should be called GDOI_PROTO_IPSEC_AH, refers to the IPsec AH encapsulation, and has a value of TBD-5.

A new Next Payload Type [ISAKMP-REG] should be assigned. The new type is called "SA Group Associated Policy (GAP)", and has a value of TBD-1.

8.2. New registries

A new namespace should be created in the GDOI Payloads registry [GDOI-REG] to describe SA GAP Payload Values. The following rules apply to define the attributes in SA SSA Payload Values:

Attribute Type	Value	Type
----	-----	----
RESERVED	0	
ACTIVATION_TIME_DELAY	1	B
DEACTIVATION_TIME_DELAY	2	B
SENDER_ID	3	V
Standards Action	4-127	
Private Use	128-255	

A new IPsec Security Association Attribute [ISAKMP-REG] defining the preservation of IP addresses is needed. The attribute class is

called "Address Preservation", and it is a Basic type. The following rules apply to define the values of the attribute:

Name	Value
----	-----
Reserved	0
None	1
Source-Only	2
Destination-Only	3
Source-And-Destination	4
Standards Action	5-61439
Private Use	61440-65535

A new IPsec Security Association Attribute [ISAKMP-REG] defining the SA direction is needed. The attribute class is called "SA Direction", and it is a Basic type. The following rules apply to define the values of the attribute:

Name	Value
----	-----
Reserved	0
Sender-Only	1
Receiver-Only	2
Symmetric	3
Standards Action	4-61439
Private Use	61440-65535

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Appendix A. Alternate GDOI Phase 1 protocols

This section describes a manner in which other protocols could be used as GDOI Phase 1 protocols in place of the ISAKMP Phase 1 protocol. However, they are not specified as a part of this document. A separate document MUST be written in order for another protocol to be used as a GDOI Phase 1 protocol.

Other possible phase 1 protocols are also described in [RFC4046].

Any GDOI phase 1 protocol MUST satisfy the requirements specified in Section 2 of this document.

A.1. IKEv2 Exchange

Version 2 of the IKE protocol (IKEv2) [RFC5996] has been published. That protocol simplifies IKE processing, and combines the two phases of IKE. An IKEv2 Phase 1 negotiates an IPsec SA during phase 1, which was not possible in IKE. However, IKEv2 also defines a phase 2 protocol. The phase 2 protocol is protected by the Phase 1, similar in concept to how IKE Quick Mode is protected by the IKE Phase 1 protocols in [RFC2409].

It would be possible to define GDOI as a phase 2 protocol protected by an IKEv2 initial exchange. Alternatively, it would be possible to define a new protocol re-using some of the IKEv2 initial exchange (e.g., `IKE_SA_INIT`).

A.2. KINK Protocol

The Kerberized Internet Negotiation of Keys (KINK) [RFC4430] has defined a method of encapsulating an IKEv1 Quick Mode [RFC2409] encapsulated in Kerberos `KRB_AP_REQ` and `KRB_AP_REP` payloads. KINK provides a low-latency, computationally inexpensive, easily managed, and cryptographically sound method of setting up IPsec security associations.

The KINK message format includes a GDOI field in the KINK header. The [RFC4430] document defines the DOI for the IPsec DOI.

A new DOI for KINK could be defined which would encapsulate a `GROUPKEY-PULL` exchange in the Kerberos `KRB_AP_REQ` and `KRB_AP_REP` payloads. As such, GDOI would benefit from the computational efficiencies of KINK.

Appendix B. Significant Changes from RFC 3547

The following significant changes have been made from RFC 3547.

- o The Proof of Possession (POP) payload was removed from the GROUPKEY-PULL exchange. It provided an alternate form of authorization, but its use was underspecified. Furthermore, Meadows and Pavlovic [MP04] discussed a man-in-the-middle attack on the POP authorization method, which would require changes to its semantics. No known implementation of RFC 3547 supported the POP payload, so it was removed. Removal of the POP payload obviated the need for the CERT payload in that exchange and it was removed as well.
- o The Key Exchange Payloads (KE_I, KE_R) payloads were removed from the GROUPKEY-PULL exchange. However, the specification for computing keying material for the additional encryption function in RFC 3547 is faulty. Furthermore, it has been observed that because the GDOI registration message uses strong ciphers and provides authenticated encryption, additional encryption of the keying material in a GDOI registration message provides negligible value. Therefore, the use of KE payloads is deprecated in this memo.
- o The Certificate Payload (CERT) was removed from the GROUPKEY-PUSH exchange. The use of this payload was underspecified. In all known use cases, the public key of used to verify the GROUPKEY-PUSH payload is distributed directly from the key server as part of the GROUPKEY-PULL exchange.
- o Supported cryptographic algorithms were changed to meet current guidance. Implementations are required to support AES with 128-bit keys to encrypt the rekey message, and SHA-256 for cryptographic signatures. The use of DES is deprecated.
- o New protocol support for AH.
- o New protocol definitions were added to conform to the most recent Security Architecture for the Internet Protocol [RFC4301] and the Multicast Extensions to the Security Architecture for the Internet Protocol[RFC5374]. This includes addition of the GAP payload
- o New protocol definitions were added to support Using Counter Modes with ESP and AH to Protect Group Traffic[I-D.ietf-msec-ipsec-group-counter-modes].

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