

# An Introduction to IP Security (IPSec) Encryption

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## Contents

### Introduction

#### Prerequisites

- Requirements
- Components Used
- Conventions

#### Background

#### Crypto Lingo (Vocabulary)

#### Configure ISAKMP

1. Pre-Shared Keys
2. Use a CA

#### Configure IPsec

- Create Extended ACL
- Create IPsec Transform(s)
- Create Crypto Map
- Apply Crypto Map to Interface

#### Memory and CPU Considerations

#### Output from show Commands

- IKE-Related Output
- IPsec-Related show Commands

#### Sample Configurations

- Network Diagram
- Configurations

#### Debug Information

#### Implementation Tips for IPsec

#### Help and Relevant Links

- IPsec Information
- More Sample Configurations for IPsec

#### References

#### Related Information

## Introduction

This document introduces IPsec to users in a rapid, but concise format. This document contains basic configurations of Internet Key Exchange (IKE) with pre-shared keys, IKE with a Certification Authority, and IPsec. This is not an exhaustive document. But, this document does help you to understand the tasks and the order in which they are accomplished.



**Warning:** There are severe restrictions on the export of strong cryptography. If you violate U.S.

Federal Law, then you, not Cisco, are held accountable. If you have any questions related to export control, send and E-mail to [export@cisco.com](mailto:export@cisco.com).

**Note:** Multicast and Broadcast are not supported on normal LAN to LAN tunnels or on VPN clients that terminate on any devices. Multicast can be passed only on GRE tunnels. This is supported only on routers and not on VPN 3000 Concentrators or firewalls (ASA/PIX).

# Prerequisites

## Requirements

There are no specific requirements for this document.

## Components Used

This document is not restricted to specific software and hardware versions.

## Conventions

Refer to Cisco Technical Tips Conventions for more information on document conventions.

## Background

IPsec is the next-generation network layer crypto platform for the Cisco security platforms (Cisco IOS® Software, PIX, and so forth). Originally described in RFCs 1825 through 1829, which are now obsolete, IPsec is currently discussed in a number of documents presented by the IETF IP Security Working Group . IPsec currently supports IP version 4 unicast packets. IPv6 and multicast support is to arrive at a later time.

IPsec has these strengths over current Cisco crypto offerings:

1. **Multivendor** Since the IPsec framework is standardized, customers are not locked into any specific vendor product. IPsec is found on routers, firewalls, and client desktops (Windows, Mac, and so forth).
2. **Scalability** IPsec is designed with large enterprises in mind. Therefore, it has built-in key management.

**Note:** While several Cisco platforms can use IPsec, this document is geared towards Cisco IOS software.

## Crypto Lingo (Vocabulary)

You need to know these terms in order to understand IPsec, and to read the rest of this document. When you see acronyms in other portions of this document, refer to this page for definitions.

**Advanced Encryption Standard (AES)** AES was finalized as a Federal Information Processing Standard (FIPS)—approved cryptographic algorithm to be used in order to protect electronic data transmission (FIPS PUB 197). AES is based on the Rijndael algorithm, which specifies how to use keys with a length of 128, 192, or 256 bits to encrypt blocks with a length of 128, 192, or 256 bits. All nine combinations of key length and block length are possible.

**Authentication Header (AH)** This is a security protocol that provides authentication and optional replay-detection services. AH is embedded in the data to be protected, for example, a full IP datagram. AH can be used either by itself or with Encryption Service Payload (ESP). Refer to the RFC 2402 .

**Authentication** This is one of the functions of the IPsec framework. Authentication establishes the integrity of datastream and ensures that it is not tampered with in transit. It also provides confirmation about datastream origin.

**Certification Authority (CA)** This is a third-party entity with the responsibility to issue and revoke certificates. Each device that has its own certificate and public key of the CA can authenticate every other

device within a given CA domain. This term also applies to server software that provides these services.

**Certificate** A cryptographically signed object that contains an identity and a public key associated with this identity.

**Classic crypto** This is Cisco proprietary encryption mechanism used in Cisco IOS Software Release 11.2. Classic crypto is available in Cisco IOS Software Release 11.3. But, IPsec is not retrofitted to Cisco IOS Software Release 11.2. You can also see the name classic crypto referred to as Encryption Express or Cisco Encryption Technology (CET) in the marketing literature.

**Certificate Revocation List (CRL)** This is a digitally signed message that lists all of the current but revoked certificates listed by a given CA. This is analogous to a book of stolen charge card numbers that allow stores to reject bad credit cards.

**Crypto map** This is a Cisco IOS software configuration entity that performs two primary functions. First, it selects data flows that need security processing. Second, it defines the policy for these flows and the crypto peer that traffic needs to go to.

A crypto map is applied to an interface. The concept of a crypto map was introduced in classic crypto but was expanded for IPsec.

**Data integrity** This is data integrity mechanisms, through the use of secret-key based or public-key based algorithms, that allow the recipient of a piece of protected data in order to verify that the data has not been modified in transit.

**Data confidentiality** This is the method where protected data is manipulated so that no attacker can read it. This is commonly provided by data encryption and keys that are only available to the parties involved in the communication.

**Data origin authentication** This is a security service where the receiver can verify that protected data might have originated only from the sender. This service requires a data integrity service plus a key distribution mechanism, where a secret key is shared only between the sender and receiver.

**Data Encryption Standard (DES)** The DES was published in 1977 by the National Bureau of Standards and is a secret key encryption scheme based on the Lucifer algorithm from IBM. The contrast of DES is public-key. Cisco uses DES in classic crypto (40-bit and 56-bit key lengths), IPsec crypto (56-bit key), and on the PIX Firewall (56-bit key).

**Diffie-Hellman** This is a method of the establishment of a shared key over an insecure medium. Diffie-Hellman is a component of Oakley, which is defined in this definition list.

**DSS** A digital signature algorithm designed by The US National Institute of Standards and Technology (NIST) based on public key cryptography. DSS does not do user datagram encryption. DSS is a component in classic crypto, as well as the Redcreek IPsec card, but not in IPsec implemented in Cisco IOS software.

**Encryption Service Adapter (ESA)** This is a hardware based encryption accelerator that is used in:

- Cisco 7204 and 7206 routers
- Second-generation Versatile Interface Processor2-40s (VIP2-40s) in all Cisco 7500 series routers
- VIP2-40 in the Cisco 7000 series routers that have the Cisco 7000 series Route Switch Processor (RSP7000) and Cisco 7000 series Chassis Interface (RSP7000CI) cards installed.

IPsec does not use the ESA acceleration, but it does work in a box that has an ESA card on a software-only basis.

**Encapsulating Security Payload (ESP)** A security protocol that provides data confidentiality and protection with optional authentication and replay–detection services. ESP completely encapsulates user data. ESP can be used either by itself or in conjunction with AH. Refer to RFC 2406: IP Encapsulating Security Payload (ESP) .

**Hash** This is a one way function that takes an input message of arbitrary length and produces a fixed length digest. Cisco uses both Secure Hash Algorithm (SHA) and Message Digest 5 (MD5) hashes within our implementation of the IPsec framework. See the definition for HMAC for more information.

**HMAC** This is a mechanism for message authentication that uses cryptographic hashes such as SHA and MD5. Refer to RFC 2104 for an exhaustive discussion of HMAC.

**Internet Key Exchange (IKE)** A hybrid protocol that uses part Oakley and part of another protocol suite called SKEME inside the Internet Security Association and Key Management Protocol (ISAKMP) framework. IKE is used to establish a shared security policy and authenticated keys for services, such as IPsec, that require keys. Before any IPsec traffic can be passed, each router/firewall/host must be able to verify the identity of its peer. Manually enter pre–shared keys into both hosts, by a CA service, or the forthcoming secure DNS (DNSSec) in order to do this. This is the protocol formerly known as ISAKMP/Oakley, and is defined in RFC 2409: The Internet Key Exchange (IKE) . A potential point of confusion is that the acronyms ISAKMP and IKE are both used in Cisco IOS software in order to refer to the same thing. These two items are somewhat different.

**Internet Security Association and Key Management Protocol (ISAKMP)** This is a protocol framework that defines the mechanics of the implementation of a key exchange protocol and negotiation of a security policy. ISAKMP is defined in the Internet Security Association and Key Management Protocol (ISAKMP).

**IPsec NAT Transparency** The IPsec NAT Transparency feature introduces support for IP Security (IPsec) traffic to travel through Network Address Translation (NAT) or Point Address Translation (PAT) points in the network by addressing many known incompatibilities between NAT and IPsec. NAT Traversal is a feature that is auto detected by VPN devices. There are no configuration steps for a router that runs Cisco IOS Software Release 12.2(13)T and later. If both VPN devices are NAT–T capable, NAT Traversal is auto detected and auto negotiated.

**ISAKMP/Oakley** See IKE.

**Message Digest 5 (MD5)** This is a one way hashing algorithm that produces a 128–bit hash. Both MD5 and Secure Hash Algorithm (SHA) are variations on MD4, which is designed to strengthen the security of this hashing algorithm. SHA is more secure than MD4 and MD5. Cisco uses hashes for authentication within the IPsec framework.

**Oakley** This is a key exchange protocol that defines how to acquire authenticated keying material. The basic mechanism for Oakley is the Diffie–Hellman key exchange algorithm. You can find the standard in RFC 2412: The OAKLEY Key Determination Protocol .

**Perfect Forward Secrecy (PFS)** PFS ensures that a given IPsec SA key was not derived from any other secret, like some other keys. In other words, if someone breaks a key, PFS ensures that the attacker is not able to derive any other key. If PFS is not enabled, someone can potentially break the IKE SA secret key, copy all the IPsec protected data, and then use knowledge of the IKE SA secret in order to compromise the IPsec SAs setup by this IKE SA. With PFS, breaking IKE does not give an attacker immediate access to IPsec. The attacker needs to break each IPsec SA individually. The Cisco IOS IPsec implementation uses PFS group 1 (D–H 768 bit) by default.

**Replay–detection** This is a security service where the receiver can reject old or duplicate packets in order to defeat replay attacks. Replay attacks rely on the attacker to send out older or duplicate packets to the receiver

and the receiver to think that the bogus traffic is legitimate. Replay–detection is done by the use of sequence numbers combined with authentication, and is a standard feature of IPsec.

**RSA** This is a public key cryptographic algorithm, named after its inventors, Rivest, Shamir and Adleman, with a variable key length. The main weakness of RSA is that it is significantly slow to compute compared to popular secret–key algorithms, such as DES. Cisco IKE implementation uses a Diffie–Hellman exchange in order to get the secret keys. This exchange can be authenticated with RSA, or pre–shared keys. With the Diffie–Hellman exchange, the DES key never crosses the network, not even in encrypted form, which is not the case with the RSA encrypt and sign technique. RSA is not a public domain, and must be licensed from RSA Data Security.

**Security Association (SA)** This is an instance of security policy and keying material applied to a data flow. Both IKE and IPsec use SAs, although SAs are independent of one another. IPsec SAs are unidirectional and they are unique in each security protocol. A set of SAs are needed for a protected data pipe, one per direction per protocol. For example, if you have a pipe that supports ESP between peers, one ESP SA is required for each direction. SAs are uniquely identified by destination (IPsec endpoint) address, security protocol (AH or ESP), and security parameter index (SPI).

IKE negotiates and establishes SAs on behalf of IPsec. A user can also establish IPsec SAs manually.

An IKE SA is used by IKE only. Unlike the IPsec SA, it is bi–directional.

**Secure Hash Algorithm (SHA)** This is a one way hash put forth by NIST. SHA is closely modeled after MD4 and produces a 160–bit digest. Because SHA produces a 160–bit digest, it is more resistant to brute–force attacks than 128–bit hashes (such as MD5), but it is slower.

**Split Tunneling** This is the process of allowing a remote VPN user in order to access a public network, most commonly the Internet, at the same time that the user is allowed to access resources at the remote office. This method of network access enables the user to access remote devices, such as a networked printer and servers at the same time as to access the public network (Internet). An advantage of the use of split tunneling is that it alleviates bottlenecks and conserves bandwidth as Internet traffic does not have to pass through the VPN server. A disadvantage of this method is that it essentially renders the VPN vulnerable to attack as it is accessible through the public, non–secure network.

**Transform** A transform describes a security protocol (AH or ESP) with its corresponding algorithms. For example, ESP with the DES cipher algorithm and HMAC–SHA for authentication.

**Transport Mode** This is an encapsulation mode for AH/ESP. Transport Mode encapsulates the upper layer payload, such as Transmission Control Protocol (TCP) or User Datagram Protocol (UDP), of the original IP datagram. This mode can only be used when the peers are the endpoints of the communication. The contrast of Transport Mode is Tunnel Mode.

**Tunnel Mode** This is the encapsulation of the complete IP Datagram for IPsec. Tunnel Mode is used on order to protect datagrams sourced from or destined to non–IPsec systems, such as in a Virtual Private Network (VPN) scenario.

## Configure ISAKMP

IKE exists only to establish SAs for IPsec. Before it can do this, IKE must negotiate an SA (an ISAKMP SA) relationship with the peer. Since IKE negotiates its own policy, it is possible to configure multiple policy statements with different configuration statements, then let the two hosts come to an agreement. ISAKMP negotiates:

- **An Encryption Algorithm** This is limited to 56-bit DES only.
- **A Hashing Algorithm** MD5 or SHA
- **Authentication** RSA signatures, RSA Encrypted nonces (random numbers), or pre-shared keys
- **Lifetime of the SA** In seconds

Currently, there are two methods used in order to configure ISAKMP:

1. Use pre-shared keys, which are simple to configure.
2. Use a CA, which is scalable throughout the Enterprise.

**Note:** IKE negotiation is done on UDP 500. IPsec uses IP protocols 50 and 51. Make sure these are permitted on any access lists you have between the peers.

## 1. Pre-Shared Keys

This is the quick and dirty method used in order to configure IKE. While the IKE configuration is simple and you do not use a CA, it does not scale very well.

You need to do these in order to configure IKE:

- Configure ISAKMP protection suite(s).
- Configure ISAKMP key.

### Configure ISAKMP Protection Suite(s)

This command creates the ISAKMP policy object. It is possible to have multiple policies, but there is only one in this example:

```
dt3-45a(config)#crypto isakmp policy 1
dt3-45a(config-isakmp)#
```

With the **group** command, you can declare what size modulus to use for Diffie-Hellman calculation. Group 1 is 768 bits long, and group 2 is 1024 bits long. Why would you use one over the other? Not all vendors support group 2. Also, group 2 is also significantly more CPU intensive than group one. For this reason, you do not want to use group 2 on low-end routers like the Cisco 2500 series or less. But, group 2 is more secure than group 1. Since this example uses a Cisco 4500, group 2 is used, and make sure the peer is also configured in order to use group 2. The default is group 1. If you select the default properties, the group 1 lines do not show up when you do a **write terminal** command.

```
dt3-45a(config-isakmp)#group 2
```

MD5 is our hashing algorithm in this line. While the implementation of SHA and MD5 are both mandatory, not all peers can be configured in order to negotiate one or the other. The default in Cisco IOS is SHA, which is more secure than MD5.

```
dt3-45a(config-isakmp)#hash md5
```

The lifetime of the SA, 500 seconds in this case, is shown in this command. If you do not set a lifetime, it defaults to 86400 seconds, or one day. When the lifetime timer fires, the SA is renegotiated as a security measure.

```
dt3-45a(config-isakmp)#lifetime 500
```

In this command, IKE is manually told what key to use. Therefore, the **pre-share** command is used. Two options besides the **pre-share** command are the **rsa-encr** and the **rsa-sig** commands. The **rsa-encr** command configures RSA Encrypted nonces and the **rsa-sig** command configures RSA Signature. The **rsa-encr** and the **rsa-sig** commands are addressed in the Use a CA section. For now, remember that **rsa-sig** is the default.

```
dt3-45a(config-isakmp)#authentication pre-share
```

## Configure ISAKMP key

In these commands, IKE is told what key to use. The peer, 192.168.10.38 in this case, must have the same key Slurpee-Machine in its configuration.

```
dt3-45a(config-isakmp)#exit
dt3-45a(config)#crypto isakmp key Slurpee-Machine address 192.168.10.38
```

You are now done with IKE configuration. These lines are the IKE configuration of the peer. The complete configurations for both routers are in the Sample Configurations section of this document:

```
crypto isakmp policy 1
  hash md5
  group 2
  authentication pre-share
crypto isakmp key Slurpee-Machine address 192.168.10.66
```

## 2. Use a CA

The use of a CA is a complex method used in order to configure IKE. Since it is very scalable in IPsec, you need to use IPsec instead of classic crypto. When Cisco IOS Software Release 11.3(3) is released, there are only going to be a few CA vendors that ship product. Initially, most configurations are done with the use of **pre-shared** keys. VeriSign, Entrust, Microsoft and Netscape, and probably a host of others, are working on CA products. For this example, a VeriSign CA is used.

You need to do these in order to use a CA:

- Create RSA key-pair(s) for the router.
- Request CA certificate.
- Enroll certificates for the client router.
- Configure ISAKMP protection suite(s).

### Create RSA Key-Pairs for the Router

The **crypto key gen rsa usage-keys** command can confuse you. This command creates two key-pairs for RSA:

- one key-pair for encryption
- one key-pair for digital signatures

A key-pair refers to a public key and its corresponding secret key. If you do not specify usage-keys at the end of the command, the router generates only one RSA key-pair and uses it for both encryption and digital signatures. As a warning, that this command can be used in order to create DSS keys. But DSS is a part of classic crypto, not IPsec.

```
dt3-45a(config)#crypto key gen rsa usage-keys
The name for the keys will be: dt3-45a.cisco.com
%You already have RSA keys defined for dt3-45a.cisco.com.
```

```
%Do you really want to replace them? [yes/no] yes
```

Since some RSA keys already exist on this box, it asks if you want to get rid of the keys that exist. Since the answer is yes, confirm the command. This prompt is returned:

```
Choose the size of the key modulus in the range of
 360 to 2048 for your Signature keys.
Choosing a key modulus greater than 512 may take a few minutes.

How many bits in the modulus [512]: <return>
Generating RSA keys...
[OK]

Choose the size of the key modulus in the range of
 360 to 2048 for your Encryption keys.
Choosing a key modulus greater than 512 may take a few minutes.

How many bits in the modulus [512]: <return>
Generating RSA keys...
[OK]
dt3-45a(config)#
```

The RSA key pairs with the default 512-bit modulus are now created. Exit out of config mode and enter a **show crypto key mypubkey rsa** command. You can now see your RSA public key(s). The private key portion of the key pair is never seen. Even if you do not have pre-existing keys, you see the same thing from previously.

**Note:** Remember to save your configuration once you have generated your key-pairs.

## Request a CA Certificate

You now need to configure the router in order to talk to a CA. This involves several steps. You need to eventually coordinate with your CA administrator.

In these configuration lines, a domain name is added to the router. This creates a hostname **ciscoca-ultra**, and tells the router what its IP address is, and the name servers. You need to have either hostnames defined for the CA or a DNS that works on the box. Cisco recommends that you have a DNS that works on the box.

```
dt3-45a(config)#ip host ciscoca-ultra 171.69.54.46
dt3-45a(config)#ip domain-name cisco.com
dt3-45a(config)#ip name-server 171.692.132
dt3-45a(config)#ip name-server 198.92.30.32
```

Start to configure the CA parameters. **verisign-ca** is just an arbitrary name.

```
dt3-45a(config)#crypto ca identity verisign-ca
dt3-45a(ca-identity)#
```

In this output, the Cisco enrollment protocol uses HTTP in order to talk to the CA. The **dt3-45a(ca-identity)#enrollment url http://ciscoca-ultra** command tells the router to go to the specified URL in order to interact with the CA. The **dt3-45a(ca-identity)#crypto ca authenticate verisign-ca** command instructs the router to fetch the certificate of the CA. Before you can enroll in the CA, you need to make sure you talk to the real CA. Verify the certificate of the CA with the CA administrator in order to ensure authenticity.

```
dt3-45a(ca-identity)#enrollment url http://ciscoca-ultra
dt3-45a(ca-identity)#exit
dt3-45a(ca-identity)#crypto ca authenticate verisign-ca
```



## Enroll Certificates for the Client Router

Issue the **crypto ca enroll verisign-ca** command in order to begin enrollment with the CA. There are several steps to this. First, you have to verify the identity of the CA, then the CA has to verify the identity of the router. If you ever need to revoke your certificate before it expires, if you renumber the interfaces of your router or if you believe that your certificate is compromised, you need to provide a password to the CA administrator. Enter that, as is illustrated in this output. After you enter your password, the router continues.

```
dt3-45a(config)#crypto ca enroll verisign-ca
%Start certificate enrollment ..
%Create a challenge password. You will need to verbally provide this password
to the CA Administrator in order to revoke your certificate.
For security reasons your password will not be saved in the configuration.
Please make a note of it.

Password:
Re-enter password:
```

You now see the fingerprint(s) from the CA. Verify that the fingerprint(s) are correct with the CA administrator. In addition, if you do a **show crypto ca cert** command, you see the CA certificate(s), in addition to your own certificates. The CA certificates are listed as pending at this time.

```
% The subject name for the keys will be: dt3-45a.cisco.com
% Include the router serial number in the subject name? [yes/no]: yes
% The serial number in the certificate will be: 01204044
% Include an IP address in the subject name? [yes/no]: yes
Interface: Ethernet 0
Request certificate from CA? [yes/no]: yes
```

Contact the CA administrator because this person wants to confirm the identity of the host before a certificate is issued. Once the CA issues the certificate, the status of our certificate changes from pending to available. With this, CA enrollment is complete. But, you are not done. You still need to configure ISAKMP policy object(s).

## Configure ISAKMP Protection Suite(s)

The **rsa-sig** default is used in this output. You can have multiple protection suite(s), but there is only one in this example. In the event of multiple protection suites, the policies are presented to the peer in numerical order and the peer negotiates which one to use. You need to do this if you know that all of your peers do not support certain features. The router does not attempt to negotiate things that do not make sense. For example, if you configure your policy for **rsa-sig** and you have no certificate, the router does not negotiate this.

```
dt3-45a(config)#crypto isakmp policy 1
dt3-45a(config-isakmp)#hash md5
dt3-45a(config-isakmp)#lifetime 4000
dt3-45a(config-isakmp)#exit
```

## Configure IPsec

Whether you use pre-shared keys or configure a CA, once you setup Internet Key Exchange IKE, you still have to setup IPsec. Regardless of which IKE method you use, the configuration steps for IPsec are the same.

You need to do these in order to configure IPsec:

- Create extended ACL.
- Create IPsec transform(s).
- Create crypto map.

- Apply crypto map to the interface.

## Create Extended ACL

This command is a very simple ACL that allows the routers to talk to one another, for example, a Telnet from one router to the next.

```
dt3-45a(config)#access-list 101 permit ip host 192.168.10.38
                        host 192.168.10.66
```

A more realistic ACL looks like this command. This command is an ordinary extended ACL, where 192.168.3.0 is a subnet behind the router in question, and 10.3.2.0 is a subnet somewhere behind the peer router. Remember that **permit** means encrypt and **deny** means do not encrypt.

```
dt3-45a(config)#access-list 101 permit ip 192.168.3.0 0.0.0.255
                        10.3.2.0 0.0.0.255
```

## Create IPsec Transform(s)

Create three transform sets. The first one uses ESP only, the second one uses AH combined with ESP, and the last one uses only AH. During IPsec SA negotiation, all three are offered to the peer, which chooses one. Also, for all three transform-sets, use the default **tunnel mode**. Transport mode can be used only when the crypto endpoints are also the endpoints of the communication. Transport mode can be specified by the **mode transport** command under the transform-set configuration. Tunnel mode is used primarily for the VPN scenario. Also note that **esp-rfc1829** and **ah-rfc1828** are based on the original RFCs for this technology and are obsolete transforms included for backwards compatibility. Not all vendors support these transforms, but other vendors support only these transforms.

The transform sets in these commands are not necessarily the most practical. For example, both PapaBear and BabyBear have sub-standard transform-sets. Use **esp-rfc1829** and **ah-rfc1828** together in the same transform-set.

```
dt3-45a(config)#crypto ipsec transform-set PapaBear esp-rfc1829
dt3-45a(cfg-crypto-trans)#exit
dt3-45a(config)#crypto ipsec transform-set MamaBear ah-md5-hmac esp-des
dt3-45a(cfg-crypto-trans)#exit
dt3-45a(config)#crypto ipsec transform-set BabyBear ah-rfc1828
dt3-45a(cfg-crypto-trans)#exit
dt3-45a(config)#
```

## Create Crypto Map

The **ipsec-isakmp** tag tells the router that this crypto map is an IPsec crypto map. Although there is only one peer declared in this crypto map, you can have multiple peers within a given crypto map. The **session key lifetime** can be expressed in either kilobytes (after x-amount of traffic, change the key) or seconds, as is shown in these commands. The goal of this is to make the efforts of a potential attacker more difficult. The **set transform-set** command is where you associate the transforms with the crypto map. In addition, the order in which you declare the transforms is significant. MamaBear is more preferred in this configuration, and then the rest in descending order of preference through to BabyBear. The **match address 101** command means to use access list 101 in order to determine which traffic is relevant. You can have multiple crypto maps with the same name, which is **armadillo**, in this example, and different sequence numbers, which is 10, in this example. The combination of multiple crypto maps and different sequence numbers allows you to mix and match classic crypto and IPsec. You can also modify your PFS configuration here. PFS group1 is the default in this example. You can change the PFS to group2, or turn it off all together, which you should not do.

```
dt3-45a(config)#crypto map armadillo 10 ipsec-isakmp
```

```
dt3-45a(config-crypto-map)#set peer 192.168.10.38
dt3-45a(config-crypto-map)#set session-key lifetime seconds 4000
dt3-45a(config-crypto-map)#set transform-set MamaBear PapaBear BabyBear
dt3-45a(config-crypto-map)#match address 101
```

## Apply Crypto Map to Interface

These commands apply the crypto map to the interface. You can assign only one crypto map set to an interface. If multiple crypto map entries have the same map-name but a different seq-num, they are part of the same set and are all applied to the interface. The security appliance evaluates the **crypto map** entry with the lowest seq-num first.

```
dt3-45a(config)#interface e0
dt3-45a(config-if)#crypto map armadillo
```

## Memory and CPU Considerations

Packets that are processed by IPsec are slower than packets that are processed through classic crypto. There are several reasons for this and they might cause significant performance problems:

1. IPsec introduces packet expansion, which is more likely to require fragmentation and the corresponding reassembly of IPsec datagrams.
2. Encrypted packets are probably authenticated, which means that there are two cryptographic operations that are performed for every packet.
3. The authentication algorithms are slow, although work has been done to speed up things as the Diffie-Hellman computations.

In addition, the Diffie-Hellman key exchange used in IKE is an exponentiation of very large numbers (between 768 and 1024 bytes) and can take up to four seconds on a Cisco 2500. Performance of RSA is dependent on the size of the prime number chosen for the RSA key pair.

For each router, the SA database takes up approximately 300 bytes, plus 120 bytes for every SA therein. In situations where there are two IPsec SAs, one inbound and one outbound, 540 bytes are required, in most cases. Each IKE SA entry is approximately 64 bytes each. The only time you have one IPsec SA for a dataflow is when the communication is one-way.

IPsec and IKE impacts performance when active. Diffie-Hellman key exchanges, public key authentication, and encryption/decryption consume a significant amount of resources. Although, much effort has been made in order to minimize this impact.

There is a small decrease in performance for non-encrypted packets that go through an interface that does crypto. This is because all packets have to be checked against the crypto map. There is no performance impact on packets that traverse the router that avoid an interface that does crypto. The biggest impact is on the encrypted data flows.

Use Group 1 for Diffie-Hellman key exchanges within IKE, use MD5 as your hashing algorithm, and use longer lifetimes in order to minimize the impact of the crypto subsystem on the rest of the router. In tradeoff for this performance tuning, you can get weak cryptography. Ultimately, it is up to the security policy of the customer in order to determine which features to use and which to leave alone.

## Output from show Commands

**Note:** The captures in these sections are taken from a different series of tests than those used in the previous sections of this document. Consequently, these captures can have different IP addresses and reflect slightly

different configurations. Another series of **show** commands is provided in the Debug Information section of this document.

## IKE-Related Output

Study these commands in order to check VeriSign CA enrollment. These commands show the public keys you use for RSA encryption and signatures.

```
dtl-45a#show crypto key mypubkey rsa
% Key pair was generated at: 11:31:59 PDT Apr 9 1998
Key name: dtl-45a.cisco.com
Usage: Signature Key
Key Data:
  305C300D 06092A86 4886F70D 01010105 00034B00 30480241 00C11854
39A9C75C
  4E34C987 B4D7F36C A058D697 13172767 192166E1 661483DD 0FDB907B
F9C10B7A
  CB5A034F A41DF385 23BEB6A7 C14344BE E6915A12 1C86374F 83020301 0001
% Key pair was generated at: 11:32:02 PDT Apr 9 1998
Key name: dtl-45a.cisco.com
Usage: Encryption Key
Key Data:
  305C300D 06092A86 4886F70D 01010105 00034B00 30480241 00DCF5AC
360DD5A6
  C69704CF 47B2362D 65123BD4 424B6FF6 AD10C33E 89983D08 16F1EA58
3700BCF9
  1EF17E71 5931A9FC 18D60D9A E0852DDD 3F25369C F09DFB75 05020301 0001
```

This command shows the certificates that the router recognizes. A certificate that has **pending** status has been submitted to the CA for approval.

```
dtl-45a#show crypto ca certificates
Certificate
  Subject Name
    Name: dtl-45a.cisco.com
    Serial Number: 01193485
  Status: Available
  Certificate Serial Number: 650534996414E2BE701F4EF3170EDFAD
  Key Usage: Signature

CA Certificate
  Status: Available
  Certificate Serial Number: 3051DF7169BEE31B821DFE4B3A338E5F
  Key Usage: Not Set

Certificate
  Subject Name
    Name: dtl-45a.cisco.com
    Serial Number: 01193485
  Status: Available
  Certificate Serial Number: 1e621faf3b9902bc5b49d0f99dc66d14
  Key Usage: Encryption
```

This output shows the public keys of the router and where the router learned about them.

```
dtl-45a#show crypto key pubkey-chain rsa
Codes: M - Manually configured, C - Extracted from certificate

Code Usage  IP-Address      Name
C      Signing  Cisco SystemsDevtestCISCOCA-ULTRA
C      General  172.21.30.71    dtl-7ka.cisco.com
```

This is the ISAKMP (IKE) SA table. Here you see that an SA currently exists between 172.21.30.71 and 172.21.30.70. The peer needs to have an SA entry in the same state as the output of this router.

```
dt1-7ka#show crypto isakmp sa
      dst          src          state          conn-id    slot
172.21.30.70    172.21.30.71    QM_IDLE              47         5
```

These lines show the policy objects configured. In this case, policies **1**, **2**, and **4** are used, in addition to the default. The policies are proposed to the peer in order, with **1** as the most preferred.

```
dt1-45a#show crypto isakmp policy
Protection suite of priority 1
encryption algorithm:  DES - Data Encryption Standard (56 bit
keys).
hash algorithm:        Message Digest 5
authentication method: Rivest-Shamir-Adleman Signature
Diffie-Hellman group:  #1 (768 bit)
lifetime:              180 seconds, no volume limit

Protection suite of priority 2
encryption algorithm:  DES - Data Encryption Standard (56 bit keys).
hash algorithm:        Secure Hash Standard
authentication method: Pre-Shared Key
Diffie-Hellman group:  #2 (1024 bit)
lifetime:              180 seconds, no volume limit

Protection suite of priority 4
encryption algorithm:  DES - Data Encryption Standard (56 bit keys).
hash algorithm:        Message Digest 5
authentication method: Pre-Shared Key
Diffie-Hellman group:  #2 (1024 bit)
lifetime:              180 seconds, no volume limit

Default protection suite
encryption algorithm:  DES - Data Encryption Standard (56 bit keys).
hash algorithm:        Secure Hash Standard
authentication method: Rivest-Shamir-Adleman Signature
Diffie-Hellman group:  #1 (768 bit)
lifetime:              86400 seconds, no volume limit
```

## IPsec-Related show Commands

This command shows the crypto map **ToOtherRouter**, the ACLs, and the transform proposals applied to this crypto map, the peers, and the key lifetime.

```
S3-2513-2#show crypto map
Crypto Map "ToOtherRouter" 10 ipsec-isakmp
  Peer = 192.168.1.1
  Extended IP access list 101
    access-list 101 permit ip
      source: addr = 192.168.45.0/0.0.0.255
      dest:   addr = 192.168.3.0/0.0.0.255
  Connection Id = UNSET      (0 established,      0 failed)
  Current peer: 192.168.1.1
  Session key lifetime: 4608000 kilobytes/3600 seconds
  PFS (Y/N): N
  Transform proposals={ Elvis, Bubba, BarneyDino, }
```

This configuration uses the same router as the previous output, but different commands. You see all transform proposals, which settings they negotiate, and the defaults.

```
S3-2513-2#show crypto ipsec transform-set
Transform proposal Elvis: { ah-sha-hmac }
```

```

supported settings = { Tunnel, },
default settings = { Tunnel, },
will negotiate = { Tunnel, },

{ esp-des }
supported settings = { Tunnel, },
default settings = { Tunnel, },
will negotiate = { Tunnel, },

Transform proposal Bubba: { ah-rfc1828 }
supported settings = { Tunnel, },
default settings = { Tunnel, },
will negotiate = { Tunnel, },

{ esp-des esp-md5-hmac }
supported settings = { Tunnel, },
default settings = { Tunnel, },
will negotiate = { Tunnel, },

Transform proposal BarneyDino: { ah-md5-hmac }
supported settings = { Tunnel, },
default settings = { Tunnel, },
will negotiate = { Tunnel, },

```

This command shows the current IPsec Security Associations of this router. The router has one AH SA for both incoming and outgoing.

```

S3-2513-2#show crypto ip session
Session key lifetime: 4608000 kilobytes/3600 seconds

S3-2513-2#show crypto ipsec sa

interface: Ethernet0
  Crypto map tag: ToOtherRouter, local addr. 192.168.1.2

  local ident (addr/mask/prot/port): (192.168.45.0/255.255.255.0/0/0)
  remote ident (addr/mask/prot/port): (192.168.3.0/255.255.255.0/0/0)
  current_peer: 192.168.1.1
    PERMIT, flags={origin_is_acl,}
    #pkts encaps: 0, #pkts encrypt: 0, #pkts digest 0
    #pkts decaps: 0, #pkts decrypt: 0, #pkts verify 0
    #send errors 5, #recv errors 0

  local crypto endpt.: 192.168.1.2, remote crypto endpt.: 192.168.1.1
  path mtu 1500, media mtu 1500
  current outbound spi: 25081A81

  inbound esp sas:

  inbound ah sas:
    spi: 0x1EE91DDC(518594012)
      transform: ah-md5-hmac ,
      in use settings ={Tunnel, }
      slot: 0, conn id: 16, crypto map: ToOtherRouter
      sa timing: remaining key lifetime (k/sec): (4608000/3423)
      replay detection support: Y

  outbound esp sas:

  outbound ah sas:
    spi: 0x25081A81(621288065)
      transform: ah-md5-hmac ,

```

```

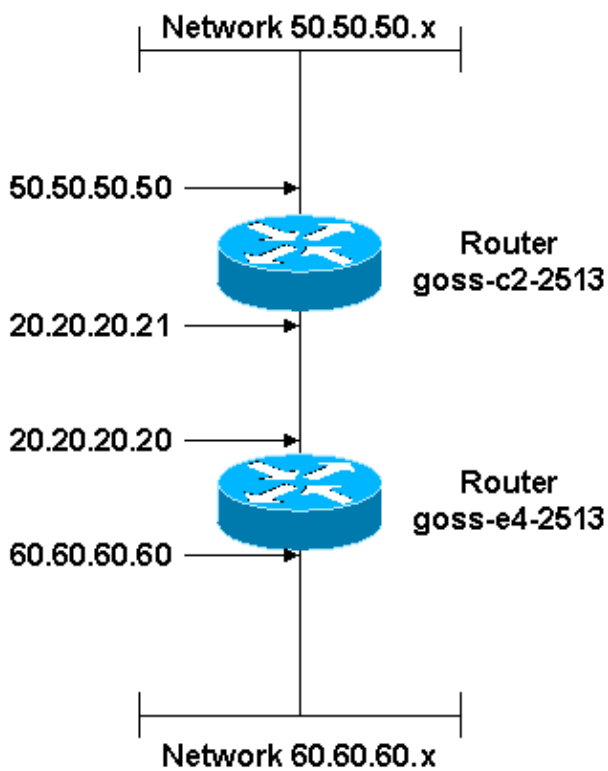
in use settings ={Tunnel, }
slot: 0, conn id: 17, crypto map: ToOtherRouter
sa timing: remaining key lifetime (k/sec): (4608000/3424)
replay detection support: Y

```

## Sample Configurations

This configuration uses **pre-shared** keys. This router configuration is used in order to create the debug output listed in the Debug Information section. This configuration allows a network called X located behind Source Router to talk to a network called Y located behind Peer Router. Consult the Cisco IOS Software documentation for your version of Cisco IOS, or use the Command Lookup Tool (registered customers only) for more information about a particular command. This tool allows the user to look up a detailed description or configuration guidelines for a particular command.

## Network Diagram



## Configurations

- Source Router
- Peer Router

Source Router
<pre> Current configuration: ! version 11.3 service timestamps debug uptime service timestamps log uptime no service password-encryption ! hostname goss-e4-2513 ! </pre>

```

enable secret 5 $1$ZuRD$YBaAh3oIv4iltIn0TMCUX1
enable password ww
!

!--- IKE configuration

crypto isakmp policy 1
  hash md5
  authentication pre-share
crypto isakmp key Slurpee-Machine address 20.20.20.21
!

!--- IPsec configuration

crypto ipsec transform-set BearPapa esp-rfc1829
crypto ipsec transform-set BearMama ah-md5-hmac esp-des
crypto ipsec transform-set BearBaby ah-rfc1828
!
crypto map armadillo 1 ipsec-isakmp
set peer 20.20.20.21
set security-association lifetime seconds 190
set transform-set BearPapa BearMama BearBaby

!--- Traffic to encrypt

match address 101
!
interface Ethernet0
  ip address 60.60.60.60 255.255.255.0
  no mop enabled
!
interface Serial0
  ip address 20.20.20.20 255.255.255.0
  no ip mroute-cache
  no fair-queue
  crypto map armadillo
!
interface Serial1
  no ip address
  shutdown
!
interface TokenRing0
  no ip address
  shutdown
!
ip classless
ip route 0.0.0.0 0.0.0.0 20.20.20.21

!--- Traffic to encrypt

access-list 101 permit ip 60.60.60.0 0.0.0.255 50.50.50.0 0.0.0.255
dialer-list 1 protocol ip permit
dialer-list 1 protocol ipx permit
!
line con 0
  exec-timeout 0 0
line aux 0
line vty 0 4
  password ww
  login
!
end

```

**Peer Router**



Current configuration:

```
!  
version 11.3  
service timestamps debug uptime  
service timestamps log uptime  
no service password-encryption  
!  
hostname goss-c2-2513  
!  
enable secret 5 $1$DBTl$Wtg2eS7Eb/Cw5l.nDhkEi/  
enable password ww  
!  
ip subnet-zero  
!  
  
!--- IKE configuration  
  
crypto isakmp policy 1  
    hash md5  
    authentication pre-share  
crypto isakmp key Slurpee-Machine address 20.20.20.20  
!  
  
!--- IPsec configuration  
  
crypto ipsec transform-set PapaBear esp-rfc1829  
crypto ipsec transform-set MamaBear ah-md5-hmac esp-des  
crypto ipsec transform-set BabyBear ah-rfc1828  
!  
!  
    crypto map armadillo 1 ipsec-isakmp  
    set peer 20.20.20.20  
    set security-association lifetime seconds 190  
    set transform-set MamaBear PapaBear BabyBear  
  
!--- Traffic to encrypt  
  
    match address 101  
!  
!  
!  
interface Ethernet0  
    ip address 50.50.50.50 255.255.255.0  
    no ip directed-broadcast  
!  
interface Serial0  
    ip address 20.20.20.21 255.255.255.0  
    no ip directed-broadcast  
    no ip mroute-cache  
    no fair-queue  
    clockrate 9600  
    crypto map armadillo  
!  
interface Serial1  
    no ip address  
    no ip directed-broadcast  
    shutdown  
!  
interface TokenRing0  
    no ip address  
    no ip directed-broadcast  
    shutdown  
!  
ip classless  
ip route 0.0.0.0 0.0.0.0 20.20.20.20
```

```

!--- Traffic to encrypt

access-list 101 permit ip 50.50.50.0 0.0.0.255 60.60.60.0 0.0.0.255
dialer-list 1 protocol ip permit
dialer-list 1 protocol ipx permit
!
!
line con 0
  exec-timeout 0 0
  transport input none
line aux 0
line aux 0
line vty 0 4
  password ww
  login
!
end

```

## Debug Information

This section has the debug output from a normal IKE/IPsec session between two routers. The configurations come from the Sample Configurations section of this document. The routers use a pre-shared key. Both routers have the **debug crypto isakmp**, **debug crypto ipsec**, and **debug crypto engine** commands enabled. This was tested with an extended ping from the Source Router ethernet interface to the Peer Router ethernet interface (60.60.60.60 to 50.50.50.50).

**Note:** The blue, italic statements in this sample debug output are notes to help you follow what happens, they are not part of the debug output.

- Source Router
- Source Router **show** Command Output After IKE/IPsec Negotiation
- Peer Router with Same Ping Sequence, as Seen from the Other Side
- Peer Router **show** Commands

Source Router
<pre> goss-e4-2513#show clock goss-e4-2513#ping Protocol [ip]: Target IP address: 50.50.50.50 Repeat count [5]: 10 Datagram size [100]: Timeout in seconds [2]: Extended commands [n]: y Source address or interface: 60.60.60.60 Type of service [0]: Set DF bit in IP header? [no]: Validate reply data? [no]: Data pattern [0xABCD]: Loose, Strict, Record, Timestamp, Verbose[none]: Sweep range of sizes [n]: Type escape sequence to abort. Sending 10, 100-byte ICMP Echos to 50.50.50.50, timeout is 2 seconds:  Apr  2 12:03:55.347: IPSEC(sa_request): ,   (key eng. msg.) src= 20.20.20.20, dest= 20.20.20.21,   src_proxy= 60.60.60.0/255.255.255.0/0/0 (type=4),   dest_proxy= 50.50.50.0/255.255.255.0/0/0 (type=4),   protocol= ESP, transform= esp-rfc1829 ,   lifedur= 190s and 4608000kb,   spi= 0x0(0), conn_id= 0, keysize= 0, flags= 0x4004 </pre>

```

Apr  2 12:03:55.355: IPSEC(sa_request): ,
    (key eng. msg.) src= 20.20.20.20, dest= 20.20.20.21,
    src_proxy= 60.60.60.0/255.255.255.0/0/0 (type=4),
    dest_proxy= 50.50.50.0/255.255.255.0/0/0 (type=4),
    protocol= AH, transform= ah-md5-hmac ,
    lifedur= 190s and 4608000kb,
    spi= 0x0(0), conn_id= 0, keysi ze= 0, flags= 0x4004
Apr  2 12:03:55.363: IPSEC(sa_request): ,
    (key eng. msg.) src= 20.20.20.20, dest= 20.20.20.21,
    src_proxy= 60.60.60.0/255.255.255.0/0/0 (type=4),
    dest_proxy= 50.50.50.0/255.255.255.0/0/0 (type=4),
    protocol= ESP, transform= esp-des ,
    lifedur= 190s and 4608000kb,
    spi= 0x0(0), conn_id= 0, keysi ze= 0, flags= 0x4004
Apr  2 12:03:55.375: IPSEC(sa_request): ,
    (key eng. msg.) src= 20.20.20.20, dest= 20.20.20.21,
    src_proxy= 60.60.60.0/255.255.255.0/0/0 (type=4),
    dest_proxy= 50.50.50.0/255.255.255.0/0/0 (type=4),
    protocol= AH, transform= ah-rfc1828 ,
    lifedur= 190s and 4608000kb,
    spi= 0x0(0), conn_id= 0, keysi ze= 0, flags= 0x4004

!--- Note that the router offers to the peer all of the
!--- available transforms.

Apr  2 12:03:55.391: ISAKMP (14): beginning Main Mode exchange
Apr  2 12:03:57.199: ISAKMP (14): processing SA payload. message ID = 0
Apr  2 12:03:57.203: ISAKMP (14): Checking ISAKMP transform 1 against
    priority 1 policy
Apr  2 12:03:57.203: ISAKMP:      encryption DES-CBC
Apr  2 12:03:57.207: ISAKMP:      hash MD5
Apr  2 12:03:57.207: ISAKMP:      default group 1
Apr  2 12:03:57.207: ISAKMP:      auth pre-share
Apr  2 12:03:57.211: ISAKMP (14): atts are acceptable. Next payload is 0
Apr  2 12:03:57.215: Crypto engine 0: generate alg param

Apr  2 12:03:58.867: CRYPTO_ENGINE: Dh phase 1 status: 0
Apr  2 12:03:58.871: ISAKMP (14): SA is doing pre-shared key authentication..
Apr  2 12:04:01.291: ISAKMP (14): processing KE payload. message ID = 0
Apr  2 12:04:01.295: Crypto engine 0: generate alg param

Apr  2 12:04:03.343: ISAKMP (14): processing NONCE payload. message ID = 0
Apr  2 12:04:03.347: Crypto engine 0: create ISAKMP SKEYID for conn id 14
Apr  2 12:04:03.363: ISAKMP (14): SKEYID state generated
Apr  2 12:04:03.367: ISAKMP (14): processing vendor id payload
Apr  2 12:04:03.371: ISAKMP (14): speaking to another IOS box!
Apr  2 12:04:03.371: generate hmac context for conn id 14
Apr  2 12:04:03.615: ISAKMP (14): processing ID payload. message ID = 0
Apr  2 12:04:03.615: ISAKMP (14): processing HASH payload. message ID = 0
Apr  2 12:04:03.619: generate hmac context for conn id 14
Apr  2 12:04:03.627: ISAKMP (14): SA has been authenticated
Apr  2 12:04:03.627: ISAKMP (14): beginning Quick Mode exchange, M-ID of 1628162439

!--- These lines represent verification that the policy
!--- attributes are fine, and the final authentication of the IKE SA.
!--- Once the IKE SA is authenticated, a valid IKE SA exists.
!--- New IKE kicks off IPsec negotiation:

Apr  2 12:04:03.635: IPSEC(key_engine): got a queue event...
Apr  2 12:04:03.635: IPSEC(spi_response): getting spi 303564824ld for SA
    .!!!from 20.20.20.21      to 20.20.20.20      for prot 3
Apr  2 12:04:03.639: IPSEC(spi_response): getting spi 423956280ld for SA

```

```

    from 20.20.20.21      to 20.20.20.20      for prot 2
Apr  2 12:04:03.643: IPSEC(spi_response): getting spi 415305621ld for SA
    from 20.20.20.21      to 20.20.20.20      for prot 3
Apr  2 12:04:03.647: IPSEC(spi_response): getting spi 218308976ld for SA
    from 20.20.20.21      to 20.20.20.20      for prot 2
Apr  2 12:04:03.891: generate hmac context for conn id 14
Apr  2 12:04:04.!!
Success rate is 50 percent (5/10), round-trip min/avg/max = 264/265/268 ms
goss-e4-2513#723: generate hmac context for conn id 14
Apr  2 12:04:04.731: ISAKMP (14): processing SA payload. message ID = 1628162439
Apr  2 12:04:04.731: ISAKMP (14): Checking IPsec proposal 1
Apr  2 12:04:04.735: ISAKMP: transform 1, ESP_DES_IV64
Apr  2 12:04:04.735: ISAKMP:   attributes in transform:
Apr  2 12:04:04.735: ISAKMP:   encaps is 1
Apr  2 12:04:04.739: ISAKMP:   SA life type in seconds
Apr  2 12:04:04.739: ISAKMP:   SA life duration (basic) of 190
Apr  2 12:04:04.739: ISAKMP:   SA life type in kilobytes
Apr  2 12:04:04.743: ISAKMP:   SA life duration (VPI) of  0x0 0x46 0x50 0x0
Apr  2 12:04:04.747: ISAKMP (14): atts are acceptable.

!--- The ISAKMP debug is listed because IKE is the
!--- entity that negotiates IPsec SAs on behalf of IPsec.

Apr  2 12:04:04.747: IPSEC(validate_proposal_request): proposal part #1,
    (key eng. msg.) dest= 20.20.20.21, src= 20.20.20.20,
    dest_proxy= 50.50.50.0/255.255.255.0/0/0 (type=4),
    src_proxy= 60.60.60.0/255.255.255.0/0/0 (type=4),
    protocol= ESP, transform= esp-rfc1829 ,
    lifedur= 0s and 0kb,
    spi= 0x0(0), conn_id= 0, keysize= 0, flags= 0x4
Apr  2 12:04:04.759: ISAKMP (14): processing NONCE payload. message ID = 1628162439
Apr  2 12:04:04.759: ISAKMP (14): processing ID payload. message ID = 1628162439
Apr  2 12:04:04.763: ISAKMP (14): processing ID payload. message ID = 1628162439
Apr  2 12:04:04.767: generate hmac context for conn id 14
Apr  2 12:04:04.799: ISAKMP (14): Creating IPsec SAs
Apr  2 12:04:04.803:   inbound SA from 20.20.20.21 to 20.20.20.20
    (proxy 50.50.50.0 to 60.60.60.0)
Apr  2 12:04:04.803:   has spi 303564824 and conn_id 15 and flags 4
Apr  2 12:04:04.807:   lifetime of 190 seconds
Apr  2 12:04:04.807:   lifetime of 4608000 kilobytes
Apr  2 12:04:04.811:   outbound SA from 20.20.20.20 to 20.20.20.21
    (proxy 60.60.60.0 to 50.50.50.0)
Apr  2 12:04:04.811:   has spi 183903875 and conn_id 16 and flags 4
Apr  2 12:04:04.815:   lifetime of 190 seconds
Apr  2 12:04:04.815:   lifetime of 4608000 kilobytes
Apr  2 12:04:04.823: IPSEC(key_engine): got a queue event...
Apr  2 12:04:04.823: IPSEC(initialize_sas): ,
    (key eng. msg.) dest= 20.20.20.20, src= 20.20.20.21,
    dest_proxy= 60.60.60.0/255.255.255.0/0/0 (type=4),
    src_proxy= 50.50.50.0/255.255.255.0/0/0 (type=4),
    protocol= ESP, transform= esp-rfc1829 ,
    lifedur= 190s and 4608000kb,
    spi= 0x12180818(303564824), conn_id= 15, keysize= 0, flags= 0x4
Apr  2 12:04:04.831: IPSEC(initialize_sas): ,
    (key eng. msg.) src= 20.20.20.20, dest= 20.20.20.21,
    src_proxy= 60.60.60.0/255.255.255.0/0/0 (type=4),
    dest_proxy= 50.50.50.0/255.255.255.0/0/0 (type=4),
    protocol= ESP, transform= esp-rfc1829 ,
    lifedur= 190s and 4608000kb,
    spi= 0xAF62683(183903875), conn_id= 16, keysize= 0, flags= 0x4
Apr  2 12:04:04.839: IPSEC(create_sa): sa created,
    (sa) sa_dest= 20.20.20.20, sa_prot= 50,
    sa_spi= 0x12180818(303564824),
    sa_trans= esp-rfc1829 , sa_conn_id= 15

```

```
Apr  2 12:04:04.843: IPSEC(create_sa): sa created,
(sa) sa_dest= 20.20.20.21, sa_prot= 50,
sa_spi= 0xAF62683(183903875),
sa_trans= esp-rfc1829 , sa_conn_id= 16
```

*!--- These lines show that IPsec SAs are created and  
!--- encrypted traffic can now pass.*

### Source Router show Command Output After IKE/IPsec Negotiation

```
goss-e4-2513#
goss-e4-2513#show crypto isakmp sa
      dst      src      state      conn-id  slot
20.20.20.21    20.20.20.20    QM_IDLE      14       0

goss-e4-2513#show crypto ipsec sa

interface: Serial0
  Crypto map tag: armadillo, local addr. 20.20.20.20

  local ident (addr/mask/prot/port): (60.60.60.0/255.255.255.0/0/0)
  remote ident (addr/mask/prot/port): (50.50.50.0/255.255.255.0/0/0)
  current_peer: 20.20.20.21
    PERMIT, flags={origin_is_acl,}
    #pkts encaps: 5, #pkts encrypt: 5, #pkts digest 0
    #pkts decaps: 5, #pkts decrypt: 5, #pkts verify 0
    #send errors 5, #recv errors 0

    local crypto endpt.: 20.20.20.20, remote crypto endpt.: 20.20.20.21
    path mtu 1500, media mtu 1500
    current outbound spi: AF62683

  inbound esp sas:
    spi: 0x12180818(303564824)
      transform: esp-rfc1829 ,
      in use settings = {Var len IV, Tunnel, }
      slot: 0, conn id: 15, crypto map: armadillo
      sa timing: remaining key lifetime (k/sec): (4607999/135)
      IV size: 8 bytes
      replay detection support: N

  inbound ah sas:

  outbound esp sas:
    spi: 0xAF62683(183903875)
      transform: esp-rfc1829 ,
      in use settings = {Var len IV, Tunnel, }
      slot: 0, conn id: 16, crypto map: armadillo
      sa timing: remaining key lifetime (k/sec): (4607999/117)
      IV size: 8 bytes
      replay detection support: N

  outbound ah sas:

goss-e4-2513#show crypto isakmp policy
Protection suite of priority 1
  encryption algorithm:  DES - Data Encryption Standard (56 bit keys).
  hash algorithm:        Message Digest 5
```

```

        authentication method: Pre-Shared Key
        Diffie-Hellman group: #1 (768 bit)
        lifetime: 86400 seconds, no volume limit
Default protection suite
        encryption algorithm: DES - Data Encryption Standard (56 bit keys).
        hash algorithm: Secure Hash Standard
        authentication method: Rivest-Shamir-Adleman Signature
        Diffie-Hellman group: #1 (768 bit)
        lifetime: 86400 seconds, no volume limit
goss-e4-2513#show crypto map
Crypto Map "armadillo" 1 ipsec-isakmp
    Peer = 20.20.20.21
    Extended IP access list 101
        access-list 101 permit ip 60.60.60.0 0.0.0.255 50.50.50.0 0.0.0.255
    Current peer: 20.20.20.21
    Security association lifetime: 4608000 kilobytes/190 seconds
    PFS (Y/N): N
    Transform sets={ BearPapa, BearMama, BearBaby, }

```

### Peer Router with Same Ping Sequence, as Seen from the Other Side

```

goss-c2-2513#show debug
Cryptographic Subsystem:
    Crypto ISAKMP debugging is on
    Crypto Engine debugging is on
    Crypto IPSEC debugging is on
goss-c2-2513#
Apr  2 12:03:55.107: ISAKMP (14): processing SA payload. message ID = 0
Apr  2 12:03:55.111: ISAKMP (14): Checking ISAKMP transform 1 against
priority 1 policy
Apr  2 12:03:55.111: ISAKMP:      encryption DES-CBC
Apr  2 12:03:55.111: ISAKMP:      hash MD5
Apr  2 12:03:55.115: ISAKMP:      default group 1
Apr  2 12:03:55.115: ISAKMP:      auth pre-share
Apr  2 12:03:55.115: ISAKMP (14): atts are acceptable. Next payload is 0

!--- IKE performs its operation, and then kicks off IPsec.

Apr  2 12:03:55.119: Crypto engine 0: generate alg param

Apr  2 12:03:56.707: CRYPTO_ENGINE: Dh phase 1 status: 0
Apr  2 12:03:56.711: ISAKMP (14): SA is doing pre-shared key authentication
Apr  2 12:03:58.667: ISAKMP (14): processing KE payload. message ID = 0
Apr  2 12:03:58.671: Crypto engine 0: generate alg param

Apr  2 12:04:00.687: ISAKMP (14): processing NONCE payload. message ID = 0
Apr  2 12:04:00.695: Crypto engine 0: create ISAKMP SKEYID for conn id 14
Apr  2 12:04:00.707: ISAKMP (14): SKEYID state generated
Apr  2 12:04:00.711: ISAKMP (14): processing vendor id payload
Apr  2 12:04:00.715: ISAKMP (14): speaking to another IOS box!
Apr  2 12:04:03.095: ISAKMP (14): processing ID payload. message ID = 0
Apr  2 12:04:03.095: ISAKMP (14): processing HASH payload. message ID = 0
Apr  2 12:04:03.099: generate hmac context for conn id 14
Apr  2 12:04:03.107: ISAKMP (14): SA has been authenticated
Apr  2 12:04:03.111: generate hmac context for conn id 14
Apr  2 12:04:03.835: generate hmac context for conn id 14
Apr  2 12:04:03.839: ISAKMP (14): processing SA payload. message ID = 1628162439
Apr  2 12:04:03.843: ISAKMP (14): Checking IPSec proposal 1
Apr  2 12:04:03.843: ISAKMP: transform 1, ESP_DES_IV64
Apr  2 12:04:03.847: ISAKMP:      attributes in transform:
Apr  2 12:04:03.847: ISAKMP:      encaps is 1
Apr  2 12:04:03.847: ISAKMP:      SA life type in seconds
Apr  2 12:04:03.851: ISAKMP:      SA life duration (basic) of 190

```

```

Apr  2 12:04:03.851: ISAKMP:      SA life type in kilobytes
Apr  2 12:04:03.855: ISAKMP:      SA life duration (VPI) of  0x0 0x46 0x50 0x0
Apr  2 12:04:03.855: ISAKMP (14): atts are acceptable.
Apr  2 12:04:03.859: IPSEC(validate_proposal_request): proposal part #1,
    (key eng. msg.) dest= 20.20.20.21, src= 20.20.20.20,
    dest_proxy= 50.50.50.0/255.255.255.0/0/0 (type=4),
    src_proxy= 60.60.60.0/255.255.255.0/0/0 (type=4),
    protocol= ESP, transform= esp-rfc1829 ,
    lifedur= 0s and 0kb,
    spi= 0x0(0), conn_id= 0, keysize= 0, flags= 0x4
Apr  2 12:04:03.867: ISAKMP (14): processing NONCE payload. message ID = 1628162439
Apr  2 12:04:03.871: ISAKMP (14): processing ID payload. message ID = 1628162439
Apr  2 12:04:03.871: ISAKMP (14): processing ID payload. message ID = 1628162439
Apr  2 12:04:03.879: IPSEC(key_engine): got a queue event...
Apr  2 12:04:03.879: IPSEC(spi_response): getting spi 183903875ld for SA
    from 20.20.20.20    to 20.20.20.21    for prot 3
Apr  2 12:04:04.131: generate hmac context for conn id 14
Apr  2 12:04:04.547: generate hmac context for conn id 14
Apr  2 12:04:04.579: ISAKMP (14): Creating IPsec SAs
Apr  2 12:04:04.579:      inbound SA from 20.20.20.20 to 20.20.20.21
    (proxy 60.60.60.0 to 50.50.50.0)
Apr  2 12:04:04.583:      has spi 183903875 and conn_id 15 and flags 4
Apr  2 12:04:04.583:      lifetime of 190 seconds
Apr  2 12:04:04.587:      lifetime of 4608000 kilobytes
Apr  2 12:04:04.587:      outbound SA from 20.20.20.21 to 20.20.20.20
    (proxy 50.50.50.0 to 60.60.60.0)
Apr  2 12:04:04.591:      has spi 303564824 and conn_id 16 and flags 4
Apr  2 12:04:04.591:      lifetime of 190 seconds
Apr  2 12:04:04.595:      lifetime of 4608000 kilobytes
Apr  2 12:04:04.599: IPSEC(key_engine): got a queue event...
Apr  2 12:04:04.599: IPSEC(initialize_sas): ,
    (key eng. msg.) dest= 20.20.20.21, src= 20.20.20.20,
    dest_proxy= 50.50.50.0/255.255.255.0/0/0 (type=4),
    src_proxy= 60.60.60.0/255.255.255.0/0/0 (type=4),
    protocol= ESP, transform= esp-rfc1829 ,
    lifedur= 190s and 4608000kb,
    spi= 0xAF62683(183903875), conn_id= 15, keysize= 0, flags= 0x4
Apr  2 12:04:04.607: IPSEC(initialize_sas): ,
    (key eng. msg.) src= 20.20.20.21, dest= 20.20.20.20,
    src_proxy= 50.50.50.0/255.255.255.0/0/0 (type=4),
    dest_proxy= 60.60.60.0/255.255.255.0/0/0 (type=4),
    protocol= ESP, transform= esp-rfc1829 ,
    lifedur= 190s and 4608000kb,
    spi= 0x12180818(303564824), conn_id= 16, keysize= 0, flags= 0x4
Apr  2 12:04:04.615: IPSEC(create_sa): sa created,
    (sa) sa_dest= 20.20.20.21, sa_prot= 50,
    sa_spi= 0xAF62683(183903875),
    sa_trans= esp-rfc1829 , sa_conn_id= 15
Apr  2 12:04:04.619: IPSEC(create_sa): sa created,
    (sa) sa_dest= 20.20.20.20, sa_prot= 50,
    sa_spi= 0x12180818(303564824),
    sa_trans= esp-rfc1829 , sa_conn_id= 16

!--- The IPsec SAs are created, and ICMP traffic can flow.

```

### Peer Router show Commands

```

!--- This illustrates a series of show command output after
!--- IKE/IPsec negotiation takes place.

```

```
goss-c2-2513#show crypto isakmp sa
```

dst	src	state	conn-id	slot
20.20.20.21	20.20.20.20	QM_IDLE	14	0

goss-c2-2513#show crypto ipsec sa

interface: Serial0

Crypto map tag: armadillo, local addr. 20.20.20.21

local ident (addr/mask/prot/port): (50.50.50.0/255.255.255.0/0/0)

remote ident (addr/mask/prot/port): (60.60.60.0/255.255.255.0/0/0)

current\_peer: 20.20.20.20

PERMIT, flags={origin\_is\_acl,}

#pkts encaps: 5, #pkts encrypt: 5, #pkts digest 0

#pkts decaps: 5, #pkts decrypt: 5, #pkts verify 0

#send errors 0, #recv errors 0

local crypto endpt.: 20.20.20.21, remote crypto endpt.: 20.20.20.20

path mtu 1500, media mtu 1500

current outbound spi: 12180818

inbound esp sas:

spi: 0xAF62683(183903875)

transform: esp-rfc1829 ,

in use settings ={Var len IV, Tunnel, }

slot: 0, conn id: 15, crypto map: armadillo

sa timing: remaining key lifetime (k/sec): (4607999/118)

IV size: 8 bytes

replay detection support: N

inbound ah sas:

outbound esp sas:

spi: 0x12180818(303564824)

transform: esp-rfc1829 ,

in use settings ={Var len IV, Tunnel, }

slot: 0, conn id: 16, crypto map: armadillo

sa timing: remaining key lifetime (k/sec): (4607999/109)

IV size: 8 bytes

replay detection support: N

outbound ah sas:

goss-c2-2513#show crypto isakmp policy

Protection suite of priority 1

encryption algorithm: DES - Data Encryption Standard (56 bit keys).

hash algorithm: Message Digest 5

authentication method: Pre-Shared Key

Diffie-Hellman group: #1 (768 bit)

lifetime: 86400 seconds, no volume limit

Default protection suite

encryption algorithm: DES - Data Encryption Standard (56 bit keys).

hash algorithm: Secure Hash Standard

authentication method: Rivest-Shamir-Adleman Signature

Diffie-Hellman group: #1 (768 bit)

lifetime: 86400 seconds, no volume limit

goss-c2-2513#show crypto map

Crypto Map "armadillo" 1 ipsec-isakmp

Peer = 20.20.20.20

Extended IP access list 101

access-list 101 permit ip 50.50.50.0 0.0.0.255 60.60.60.0 0.0.0.255

Current peer: 20.20.20.20



```
Security association lifetime: 4608000 kilobytes/190 seconds
PFS (Y/N): N
Transform sets={ MamaBear, PapaBear, BabyBear, }
```

## Implementation Tips for IPsec

These are some implementation tips for IPsec:

- Make certain that you have connectivity between the endpoints of the communication before you configure crypto.
- Make sure that either DNS works on the router, or you have entered the CA hostname, if you use a CA.
- IPsec uses IP protocols 50 and 51, and IKE traffic passes on protocol 17, port 500 (UDP 500). Make sure these are permitted appropriately.
- Be careful not to use the word any in your ACL. This causes problems. Refer to the Usage Guidelines for **access-list** in the PIX command reference for more information.
- Recommended transform combinations are:

```
esp-des and esp-sha-hmac
ah-sha-hmac and esp-des
```

- Remember that AH is just an authenticated header. The actual user datastream is not encrypted. You need ESP for datastream encryption. If you use only AH and see cleartext go across the network, do not be surprised. Also use ESP if you use AH. Note that ESP can also perform authentication . Therefore, you can use a transform combination such as **esp-des** and **esp-sha-hmac**.
- **ah-rfc1828** and **esp-rfc1829** are obsolete transforms included for backwards compatibility with older IPsec implementations. If the peer does not support newer transforms, try these instead.
- SHA is slower and more secure than MD5, whereas MD5 is faster and less secure than SHA. In some communities, the comfort level with MD5 is very low.
- When in doubt, use tunnel mode. Tunnel mode is the default and it can be used in transport mode, as well as for its VPN capabilities.
- For classic crypto users who upgrade to Cisco IOS Software Release 11.3, crypto commands storage methods in the configuration has changed in order to allow for IPsec. Consequently, if classic crypto users ever revert to Cisco IOS Software Release 11.2, these users have to re-enter their crypto configurations.
- If you do a ping test across the encrypted link when you finish your configuration, the negotiation process can take some time, about six seconds on a Cisco 4500, and about 20 seconds on a Cisco 2500, because SAs have not yet been negotiated. Even though everything is configured correctly, your ping can initially fail. The **debug crypto ipsec** and **debug crypto isakmp** commands show you what happens. Once your encrypted datastreams have finished their set up, the ping works fine.
- If you run into trouble with your negotiation(s) and make configuration changes, use the **clear crypto is** and **clear crypto sa** commands in order to flush the databases before you retry. This forces negotiation to start anew, without any legacy negotiation to get in the way. The **clear crypto is** and **clear cry sa** commands are very useful in this manner.

## Help and Relevant Links

### IPsec Information

- IPsec Support Page
- ECRA Encryption Policies and Procedures Send an E-mail to [export@cisco.com](mailto:export@cisco.com)

## More Sample Configurations for IPsec

- [Configuring and Troubleshooting Cisco's Network-Layer Encryption: IPsec and ISAKMP](#)
- [IPsec Network Security Overview](#)
- [PIX Firewall IPsec configuration documentation](#)
  - ◆ [PIX 5.1](#)
  - ◆ [PIX 5.2](#)
  - ◆ [PIX 5.3](#)
  - ◆ [PIX 6.0](#)
  - ◆ [PIX 6.1](#)
  - ◆ [PIX 6.2](#)
  - ◆ [PIX 6.3](#)

Contact the Cisco Technical Support at (800) 553-24HR, (408) 526-7209, or send an E-mail to [tac@cisco.com](mailto:tac@cisco.com) if you require further assistance with IPsec.

## References

Harkins, D. *ISAKMP/Oakley Protocol Feature Software Unit Functional Specification*. ENG-0000 Rev A. Cisco Systems.

Madson, C. *IPSec Software Unit Functional Specification ENG-17610 Rev F*. Cisco Systems.

Kaufman, C. Perlman R. and Spencer, M. *Network Security: Private Communication in a Public World*. Prentice Hall, 1995.

Schneier, B. *Applied Cryptography: Protocols, Algorithms, and Source Code in C*. Second Ed. John Wiley & Sons, Inc.

Various IETF IP Security working-drafts

## Related Information

- [IPsec Support Page](#)
- [How Virtual Private Networks Work](#)
- [Most Common L2L and Remote Access IPsec VPN Troubleshooting Solutions](#)
- [Technical Support & Documentation – Cisco Systems](#)

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