IP Security
- PartIII

Professor Yeali S. Sun
Information Management Department
National Taiwan University

Key Management

Key Management

- Goal
  - To determine and distribute secret keys for such as IPsec Encryption and Authentication.
  - Need mechanisms for communicating peers to agree on algorithms, key sizes, and other minutiae (small details).
- Typical scenario
  - Four keys: Transmit and receive pairs of keys for both AH and ESP between two communicating applications.

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Two types of key management

- Manual
  - System administrator manually configures each system with its own keys and the keys of the other party
  - For small, static environments
- Automated
  - An automated system provides on-demand creation of keys for SAs
  - For large, dynamic environments

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The Internet Key Exchange (IKE)

RFC2409

D. Harkins and D. Carrel November 1998

Standards Track

Preface

- ISAKMP – framework
- Oakley – key exchange protocol
- SKEME – key exchange protocol

ISAKMP

- Internet Security Association and Key Management Protocol
- A framework for peer <u>authentication</u> and <u>key exchange</u>
- Define a set of message types to
  - enable the use of a variety of key exchange algorithm; and
  - allow negotiation of security attributes

  between communicating parties.
- The default automated key management protocol.

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Oakley

- A key exchange protocol
- Enabling two users to exchange a key ***securely.***
- Based on Diffie-Hellman algorithm with added security.
- Mandated for use with the initial version of ISAKMP

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SKEME (**S**ecure **K**ey **E**xchange **ME**chanism protocol)

- A versatile key exchange technique which provides anonymity, repudiability, and quick key refreshment.

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Internet Key Exchange (IKE)

- IKE is a protocol using *part of* Oakley and *part of* SKEME in conjunction with ISAKMP.
- The goal is to **obtain authenticated keying material** for use with ISAKMP, and for other security associations such as AH and ESP for the IETF IPsec DOI.

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Oakley

Diffie-Hellman Key Determination Protocol (1/6)

- It allows two parties to agree on a *shared* value *without* requiring encryption.
- Users A and B
- In priori agreement on two global parameters: q and α
  - q: a large prime number
  - α: a primitive root of q
- Primitive root
  - If α is the primitive root of a very large prime number *q*, then the following numbers are distinct

    $$\alpha \bmod q, \alpha^2 \bmod q, \ldots, \alpha^{q-1} \bmod q$$

  - For any integer *b*, one can find a *unique* exponent *i* such that

    $$b = \alpha^i \bmod q \quad \text{where } 0 <= i <= (q-1)$$

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Diffie-Hellman Key Determination Protocol (2/6)

- Procedure
  - User A selects a random integer X_A as its private key and sends User B its public key Y_A $(= \alpha^{XA})$
  - User B selects a random integer X_B as its private key and sends User A its public key Y_B $(= \alpha^{XB})$
  - Compute the secret session key.

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Diffie-Hellman Key Determination Protocol (3/6)

Global Public Element

q - prime number

α - $\alpha < q$ and α is a primitive root of q

User A Key Generation

Select private X_A $X_A < q$

Calculate public Y_A $Y_A = \alpha^{XA}$

User B Key Generation

Select private X_B $X_B < q$

Calculate public Y_B $Y_B = \alpha^{XB}$

Exchange Public Keys Y_A and Y_B

Generation of secret key by A

$K = (Y_B)^{XA} \bmod q$

Generation of secret key by B

$K = (Y_A)^{XB} \bmod q$

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Diffie-Hellman Key Determination Protocol: Algorithm (4/6)

- $K = (Y_B)^{X_A} \bmod q$
  $= (\alpha^{X_B} \bmod q)^{X_A} \bmod q$
  $= (\alpha^{X_B})^{X_A} \bmod q$
  $= \alpha^{X_B X_A} \bmod q$
  $= (\alpha^{X_A})^{X_B} \bmod q$
  $= (\alpha^{X_A} \bmod q)^{X_B} \bmod q$
  $= (Y_A)^{X_B} \bmod q$

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Diffie-Hellman Key Determination Protocol: Advantages (5/6)

- Secret keys are created only when needed.
- No need to store secret keys for a long period of time.
- No need to transfer secret keys over the Internet
- Authentication (secret keys are generated using the secret key of the public key's true owner)

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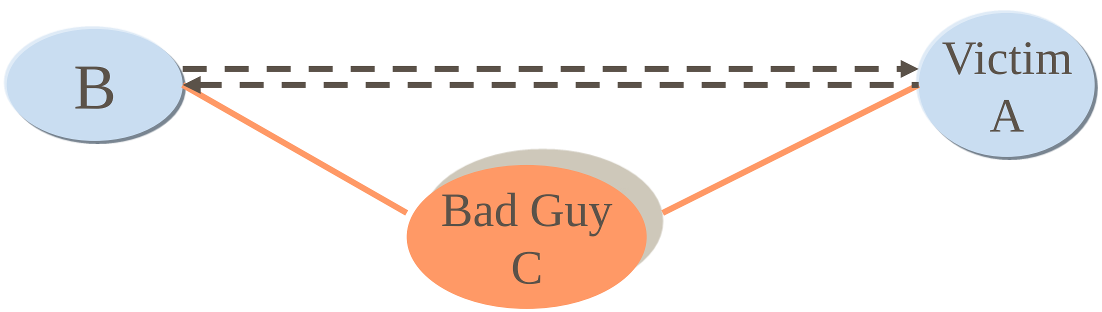
Diffie-Hellman Key Determination Protocol: Weakness (6/6)

- It does **NOT** provide information about the ***identities*** of the parties.
- Subject to a man-in-the-middle attack



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Oakley: features (1/9)

- Add *authentication* to the Diffie-Hellman exchange
  - to prevent man-in-the-middle attacks.
- Cookies
  - anti-clogging tokens to prevent denial of service (clogging) attack
  - to protect computing resources from attack without spending excessive CPU resources to determine its authenticity.

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Oakley: features (2/9)

- Support the use of different *groups* for the Diffie-Hellman key exchange.
  - Allow two parties to negotiate global parameters of the Diffie-Hellman key exchange (i.e., q and α) and the identity of the algorithm.
  - Three distinct group representations are defined
    - modular exponentiation groups (α=2, 768-bit modulus, 1024-bit modulus, etc.)
    - elliptic curve groups over 2^{155}
    - elliptic curve groups over 2^{185}

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Oakley: features (3/9)

    - For each representation, many distinct realizations are possible, depending on parameter selection.
- Nonces
    - To ensure against reply attacks

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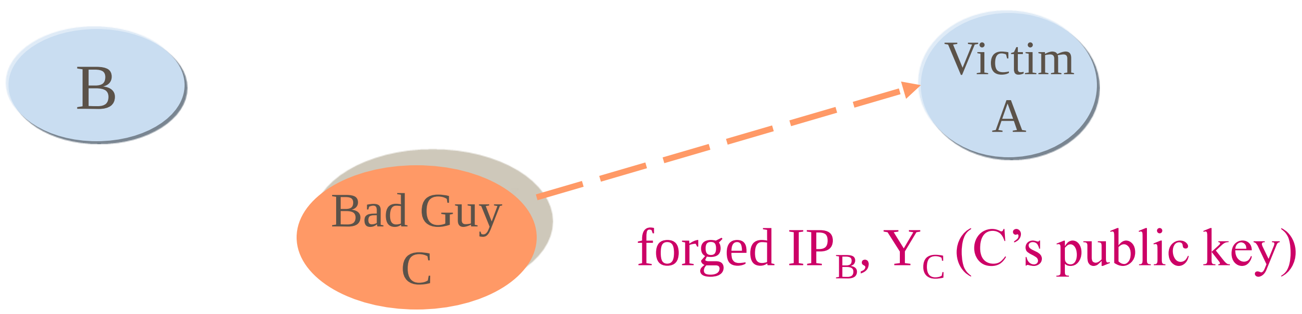
Oakley: Clogging (Denial of Service) Attack (4/9)

- Bad guy C **forges** the source address of a legitimate User B and sends a public key to the victim A.
- The victim A computes secret key. (no authentication)
- Repeated messages of this type can **clog** the victim's system.



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Oakley: cookies for anti-clogging tokens (5/9)

The concept of cookie

- Cookies provide a weak form of source address identification for the two communicating parties.
- They do cookie exchange before to perform the computationally expensive part of the protocol (large integer exponentiations).

- Each party sends a *pseudorandom number* – cookie – in the initial message which the other side acknowledges.
- This acknowledgment is repeated in the *first* message of the Diffie-Hellman key exchange.
- If the source address is forged, the opponent gets no answer.

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Oakley: Cookies Requirements (6/9)

- The cookie *must* depend on the specific parties (a weak form of authentication).
- The issuing entity will use local secret info in the generation and subsequent verification of a cookie.
- Fast cookie generation and verification to prevent attacks sabotaging processor resources.
  - e.g., use a fast hash (e.g., MD5) over the IP src/dst addr., the UDP src/dst ports and a locally generated secret value.
- Cookies are 64-bit pseudo-random numbers.
  - The generation method must ensure with high probability that the numbers used for each IP remote address are unique over some time period, such as one hour.

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Oakley: Cookie Requirements (7/9)

- Protection
  - To <u>prevent</u> attacks that obtain a cookie using an real IP address and UDP port to swamp the victim with requests from randomly chosen IP addresses or ports.
  - It is impossible for anyone other than the issuing party to generate cookies that will be accepted by the entity.
- Note that absolute protection against denial of service is *impossible*, but this anti-clogging token provides a technique for making it easier to handle.

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Oakley: Authentication Methods (8/9)

Three are specified

- Digital signatures
  - Generate *a mutual hash* over some parameters, e.g., user IDs and nonces.
  - Each party *encrypts the hash with its private key*.
  - The receiving party authenticates the sender using *sender's public key decryption*.
- Public-key encryption
  - A sending party encrypts information such as IDs and nonces with its private key.
  - The receiving party authenticates the sender using its public key decryption.
- Symmetric-key encryption
  - A key is derived from some out-of-band mechanism to authenticate both by symmetric encryption of exchange parameters.

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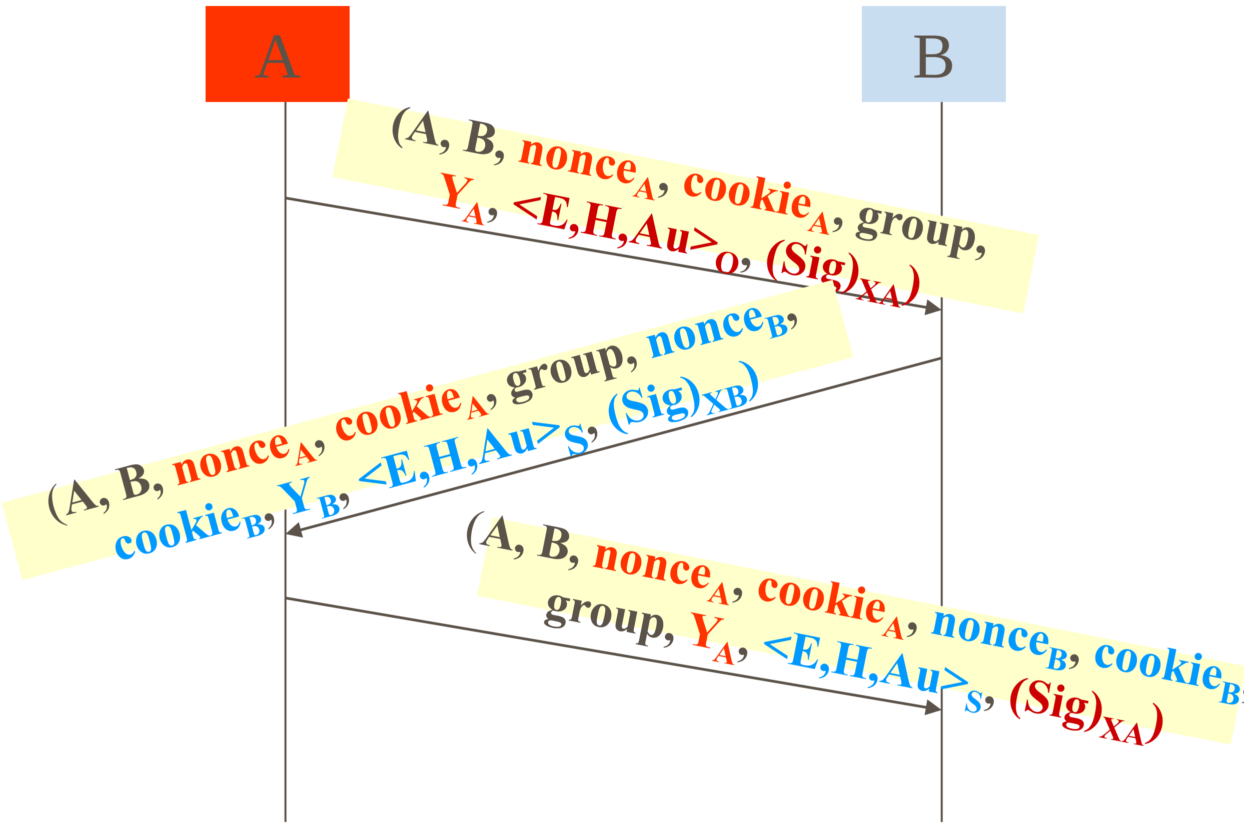
Oakley: Aggressive Key Exchange (9/9)



- group: name of D-H grp for this exchange
- E: encryption
- H: Hashing
- Au: authentication
- Sig: IDs, nonces, group, Y's, EHAS

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Internet Security Association and Key Management Protocol (ISAKMP)

RFC 2408

November 1998

Standards Track

ISAKMP: Goals

- Defines procedures and packet formats to establish, negotiate, modify and delete Security Associations (SA).
- At the establishment phase, payloads are defined to exchange key generation and authentication data.

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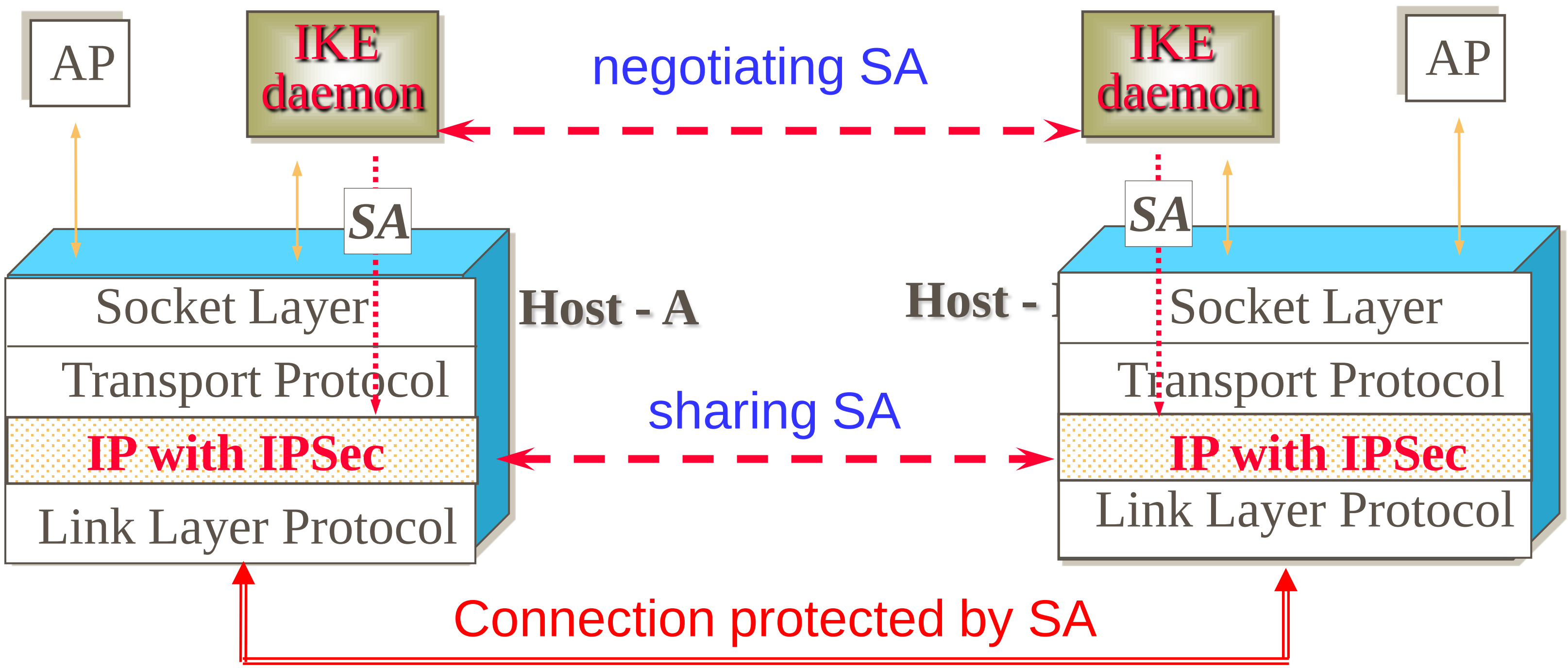

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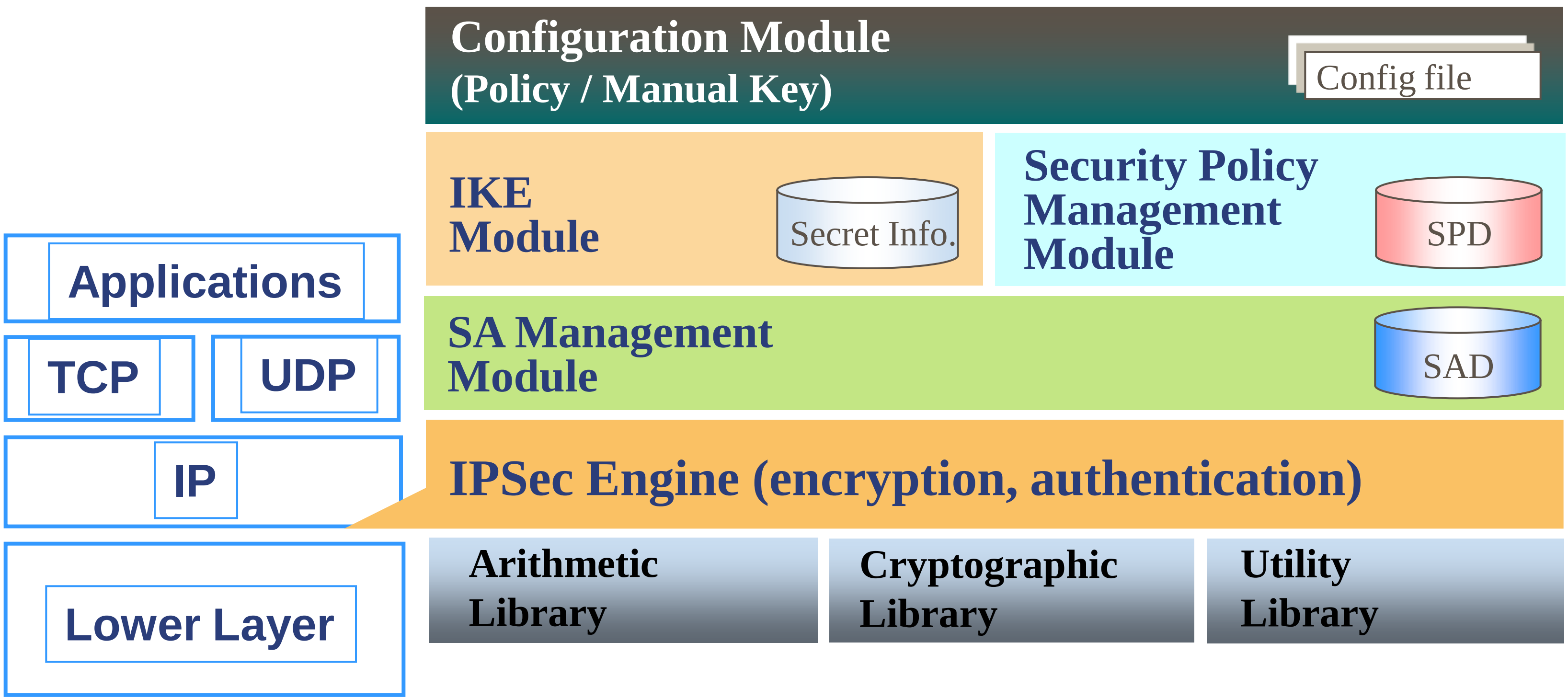
IPsec Architecture



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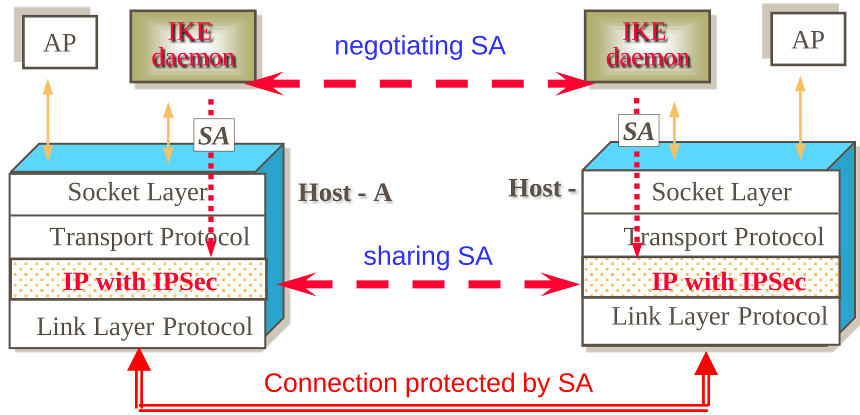
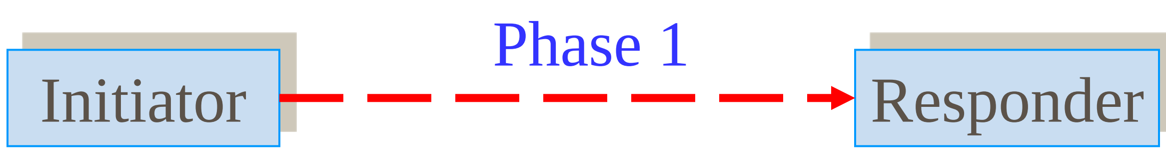
ISAKMP: Two Phases of negotiation



- The *establishment* of a secure communication channel between two parties consists of two phases:
  - Phase 1. Establish an ISAKMP SA.
  - Phase 2. Establish actual IPsec SA.
- Initiator and Responder



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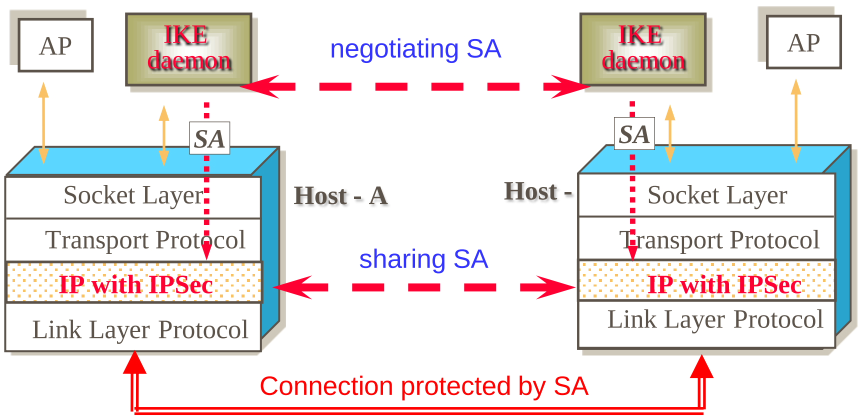
ISAKMP: Two Phases of negotiation



Phase I: Goals

- *Negotiate* ISAKMP SA *parameters*
- Establish a *shared secret* for Phase II.
- *Authenticate identities of* servers/hosts.

Phase II: Goals

- Establish IPsec SA
- Authenticate identities of users or application processes.

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ISAKMP: Header (1/6)

- An ISAKMP message consists of an ISAKMP header followed by one or more payloads.
- Initiator cookie (8 octets)
- Responder cookie (8 octets)
- Two cookie fields are used to identify an SA

Initiator Cookie				
Responder Cookie				
Next Payload	Major Version	Minor Version	Exchange Type	Flags
Message ID				
Length				

ISAKMP: Header

(2/6)

Initiator Cookie				
Responder Cookie				
Next Payload	Major Version	Minor Version	Exchange Type	Flags
Message ID				
Length				

- Next payload (1 octet)
  - Indicates the type of the first payload in the message (value 0 means the last).
- Major Version (4 bits)
  - Indicates the major version of the ISAKMP protocol in use.
- Minor version (4 bits)
  - Indicates the minor version
- Exchange type (1 octet)
  - Indicates the message and payload ordering in the ISAKMP exchanges.
- Flags (1 octet)
  - Indicates specific options set for the ISAKMP exchange.

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ISAKMP: Next Payload Types (3/6)

- None (0)
- Security Association (SA) (1)
- Proposal (P) (2)
- Transform (T) (3)
- Key Exchange (KE) (4)
- Identification (ID) (5)
- Certificate (CERT) (6)
- Certificate Request (CR) (7)
- Hash (HASH) (8)
- Signature (SIG) (9)
- Nonce (NONCE) (10)
- Notification (N) (11)
- Delete (D) (12)
- Vendor ID (VID) (13)

- RESERVED (14-127)
- Private USE (128-255)

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ISAKMP: Exchange Types (4/6)

- None (0)
- Base (1)
- Identity Protection (2)
- Authentication Only (3)
- Aggressive (4)
- Informational (5)
- ISAKMP Future Use (6-31)
- DOI Specific Use (32-239)
- Private Use (240-255)

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ISAKMP: Header

(5/6)

Initiator Cookie				
Responder Cookie				
Next Payload	Major Version	Minor Version	Exchange Type	Flags
Message ID				
Length				

- Flags (8 bits)
  - Encryption bit (0 - the least significant bit)
    - 1: all payloads following the header are encrypted
    - 0: payload is not encrypted.
  - Commit bit (1)
    - signal key exchange synchronization.
    - to ensure the encrypted material is not received prior to completion of the SA establishment.
    - can be set at anytime by either party.
    - The value must be reset after the Phase 1 negotiation.
  - Authentication Only bit (2)
    - allow the transmission of information with integrity check but no encryption. (e.g., “emergency mode”).
  - The remaining bits are set to 0 prior to transmission.

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ISAKMP Header: (6/6)

Initiator Cookie				
Responder Cookie				
Next Payload	Major Version	Minor Version	Exchange Type	Flags
Message ID				
Length				

- Message ID (4 octets)
  - Unique message identifier
  - During phase I, the value is set to 0.
  - The value is randomly generated by the initiator for phase II negotiation.
- Length (4 octets)
  - The length of total message (header + payloads) in octets.

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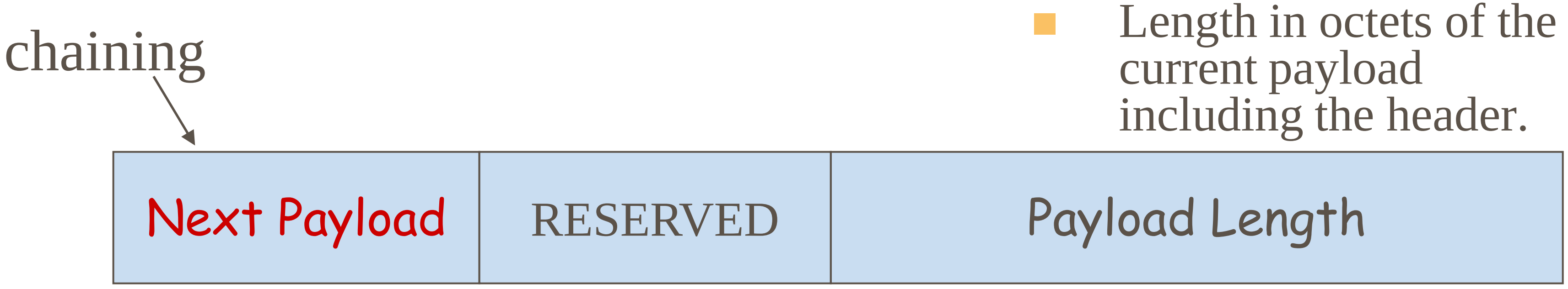
ISAKMP payload: generic payload header (1/2)

- Each ISAKMP payload has a generic payload header plus a number of data attributes.

- Next Payload (1 octet)
  - Identifier for the payload type of the next payload in the message.
  - If the last, the field is set to 0.
- RSERVED (1 octet)
  - Unused; set to 0.
- Payload length (2 octets)
  - Length in octets of the current payload including the header.



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ISAKMP payload: data attribute fields (2/2)

A F	Attribute Type	AF=0 Attribute Length AF=1 Attribute Value
AF=0 Attribute Value AF=1 Not Transmitted		

- Data attribute fields contain information about the attributes for each domain in a DOI document, e.g., IPSEC DOI (IPDOI).
- Attribute Format (AF) (1 bit)
  - 0: Type/Length/Value
  - 1: Type/Value

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ISAKMP Exchange Types

- Basic exchange
- Identity Protection Exchange
- Authentication Only Exchange
- Aggressive Exchange
- Informational Exchange

Type #1 - Base Exchange (1/4)

- Goal
  - Allow the Key Exchange and Authentication related info to be transmitted in one message.

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Type #1 - Base Exchange (2/4)

Initiator		Responder	
(1) HDR; SA; NONCE	=>		//begin ISAKMP capability exchange
(2)	<=	(2) HDR; SA; NONCE	//basic SA agreed
(3) HDR; KE; IDii; AUTH	=>		// key generated by responder //initiator identity verified by responder

(4)	<=	HDR; KE; IDir; AUTH	// responder identity verified by initiator
			//key generated by initiator
			//SA established

Type #1 - Base Exchange (3/4)

Step (1)

- The SA, Proposal, and Transform payloads are included in the SA payload.
- NONCE
  - a random info used to guarantee liveness and protect against replay attacks.
  - NONCEs provided by both parties are used by the authentication mechanism as a shared proof of participation in the exchange.

Step (2)

- Local security policy dictates the action of the responder if no proposed protection suite is accepted,
  - e.g., the transmission of a Notify payload as part of an Informational Exchange.

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Type #1 - Base Exchange (4/4)

- Notes
  - This can reduce the number of round trips at the expense of **not** providing identity protection.
  - Identities are exchanged before a common shared secret has been established and, therefore, encryption of the identities is not possible.

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Type #2 - Identity Protection Exchange (1/2)

- Goal
  - Separate the Key Exchange info from the Identity and Authentication related info
  - Protect identity exchange under the protection of a previously established common shared secret.
- At the expense of two additional messages.

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Type #2 - Identity Protection Exchange (2/2)

Initiator		Responder	
(1) HDR; SA	=>		//begin ISAKMP capability exchange
(2)	<=	(2) HDR; SA	//basic SA agreed
(3) HDR; KE; NONCE	=>		// key generated by initiator and responder
(4)	<=	HDR; KE; NONCE	
(5) HDR*; IDii; AUTH	=>		//initiator identity verified by responder
(6)	<=	HDR*; IDir; AUTH	// responder identity verified by initiator
			//SA established

(5) &(6)

- The initiator and responder exchange identification info and the results of the agreed upon authentication function.
- This info is transmitted under the protection of the common shared secret.

Type #3 - Authentication Only Exchange (1/2)

- The goal is to allow only Authentication related info to be transmitted.
- Perform only authentication without the computational expense of computing keys.
- Therefore, none of the transmitted info will be encrypted.

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Type #3 - Authentication Only Exchange (2/2)

Initiator		Responder	
(1) HDR; SA; NONCE	=>		//begin ISAKMP // capability exchange
(2)	<=	(2) HDR; SA; NONCE IDir; AUTH	//basic SA agreed // responder identity verified by initiator
(3) HDR; IDii; AUTH	=>		//initiator identity verified by responder //SA established

Type #4 - Aggressive Exchange (1/2)

- The goal is to allow SA, KE and AUTH related payloads to be transmitted in one message.
- To reduce the number of round trips at the expense of **not** providing identity protection.
- The SA is created in one single exchange.

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Type #4 - Aggressive Exchange (2/2)

Initiator		Responder	
(1) HDR; SA; KE; NONCE; IDii	=>		//begin ISAKMP & key // exchange
(2)	<=	(2) HDR; SA; KE; NONCE; IDir; AUTH	//initiator identity verified by responder
(3) HDR*; AUTH	=>		// responder identity verified by initiator //SA established

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Type #5 - Informational Exchange

- The goal is to allow one-way transmittal of info that can be used for security association management.

Initiator		Responder
(1) HDR*; N/D // Notify or Delete Payload	=>	// error notification or deletion

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