NC STATE UNIVERSITY Computer Science

CSC 774 -- Network Security

Topic 5: Internet Key Management

Outline

- Key Management
  - Security Principles
  - Center-based Key Management
  - Certificate-based Key Management
- Internet Key Management
  - Manual Exchange
  - SKIP
  - Oakley
  - ISAKMP

Key Management

- Why do we need key management
  - AH and ESP require encryption and authentication keys
- Process to negotiate and establish IPSec SA's between two entities

Security Principles

- Basic security principle for session keys
  - Compromise of a session key
    - Doesn't permit reuse of the compromised session key.
    - Doesn't compromise future session keys and long-term keys.

Security Principles (Cont'd)

- Perfect forward secrecy (PFS)
  - Compromise of current keys (session key or long-term key) doesn't compromise past session keys.
  - Concern for encryption keys but not for authentication keys.
  - Not really "perfect" in the same sense as perfect secrecy for one-time pad.

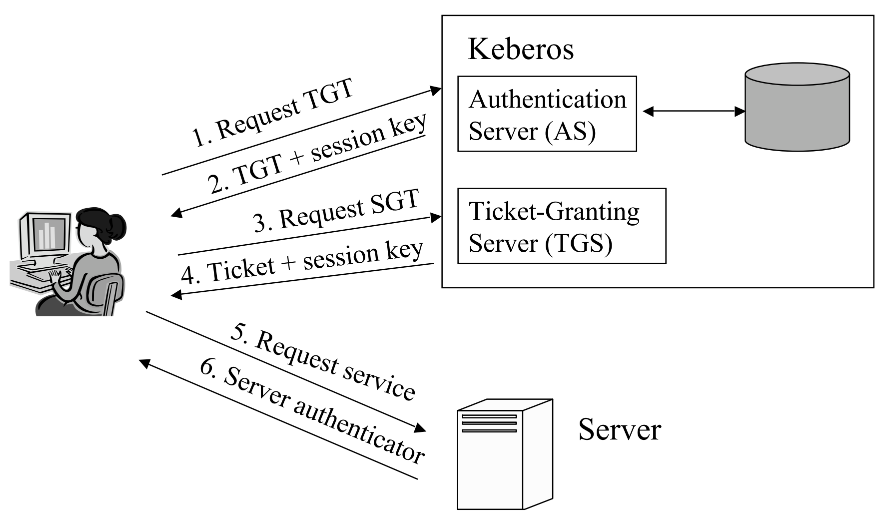
Center-Based Key Management

- Key Distribution Center (KDC)
  - Communication parties depend on KDC to establish a pair-wise key.
  - The KDC generates the cryptographic key
  - Pull based
    - Alice communicates with the KDC before she communicates with Bob
  - Push based
    - Alice communicates with Bob, and it's Bob's responsibility to contact the KDC to get the pair-wise key.

Center-Based Key Management (Cont'd)

- Key Translation Center (KTC)
  - Similar to KDC
  - Difference
    - One of the participants generates the cryptographic; KTC only translates and forwards it to the other participant.

An Example of KDC: Kerberos



Certificate-Based Key Distribution

- Public key certificate
  - Bind an identity and a public key together
  - Verify the authenticity of a party's public key
- Key transfer
  - Transfer a locally generated pair-wise key to a remote entity
- Key exchange (agreement)
  - Both communication parties generate a key cooperatively.
  - Example: Diffie-Hellman key exchange

Internet Key Management

- Two major competing proposals
  - Simple Key Management for Internet Protocols (SKIP)
  - ISAKMP/OAKLEY
    - Photuris
      - Ephemeral D-H + authentication + Cookie
      - The first to use cookie to thwart DOS attacks
    - SKEME
    - Oakley
    - ISAKMP
    - ISAKMP/OAKLEY → IKE

Manual Key Management

- Mandatory
- Useful when IPSec developers are debugging
- Keys exchanged offline (phone, email, etc.)
- Set up SPI and negotiate parameters

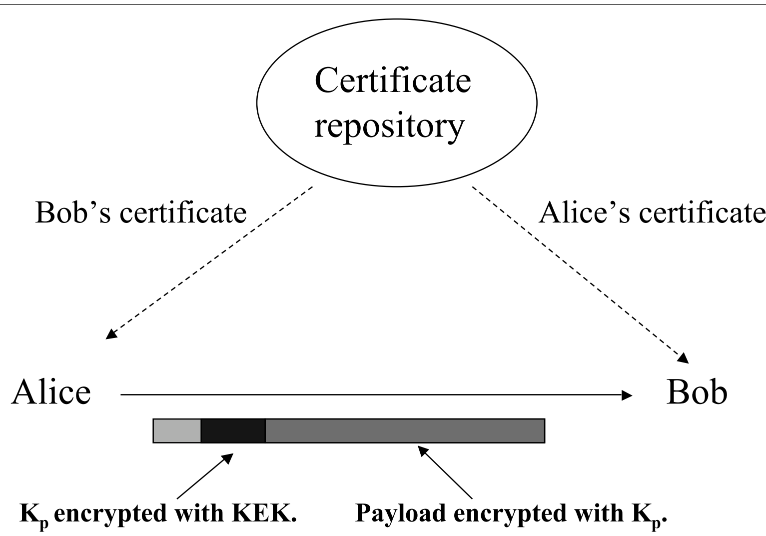
Automatic Key Management

- Key Distribution and Management combined
  - SKIP
- Key establishment protocol
  - Oakley
    - focus on key exchange
- Key management
  - Internet Security Association & Key Management Protocol (ISAKMP)
    - Focus on SA and key management
    - Clearly separated from key exchange.

SKIP

- Idea
  - IP is connectionless in nature
  - Using security association forces a pseudo session layer underneath IP
  - Proposal: use session-less key establishment and management
    - Pre-distributed and authenticated D-H public key
    - Packet-specific encryption keys are included in the IP packets

SKIP (Cont'd)



SKIP (Cont'd)

- KEK should be changed periodically
  - Minimize the exposure of KEK
  - Prevent the reuse of compromised packet keys
- SKIP's approach
  - KEK = h (K_{AB}, n), where h is a one-way hash function, K_{AB} is the the long term key between A and B, and n is a counter.

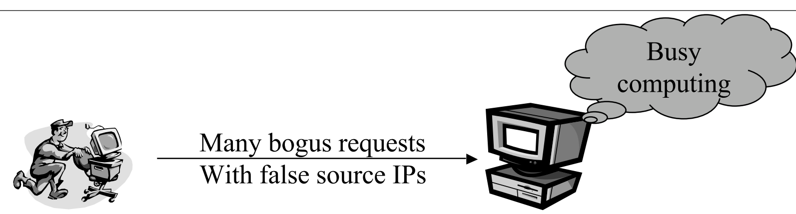
SKIP (Cont'd)

- Limitations
  - No Perfect Forward Secrecy
    - Can be modified to provide PFS, but it will lose the sessionless property.
  - No concept of SA; difficult to work with the current IPSec architecture
- Not the standard, but remains as an alternative.

Oakley

- Oakley is a refinement of the basic Diffie-Hellman key exchange protocol.
- Why need refinement?
  - Resource clogging attack
  - Replay attack
  - Man-in-the-middle attack
  - Choice of D-H groups

Resource Clogging Attack



- Stopping requests is difficult
  - We need to provide services.
- Ignoring requests is dangerous
  - Denial of service attacks

Resource Clogging Attack (Cont'd)

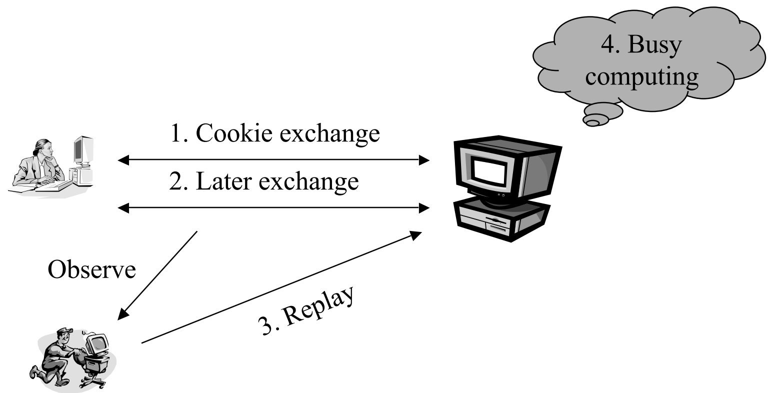
- Counter measure
  - If we cannot stop bogus requests, at least we should know from where the requests are sent.
  - Cookie
    - Each side sends a pseudo-random number, the cookie, in the initial message, which the other side acknowledges.
    - The acknowledgement must be repeated in the following messages.
    - Do not begin D-H calculation until getting acknowledgement for the other side.
    - Cookies are used to thwart resource clogging attack
      - Thwart, not prevent.

Requirements for cookie generation

- The cookie must depend on the specific parties.
  - Prevent an attacker from reusing cookies.
- Impossible to forge
  - Use secret values
- Efficient
- Cookies are also used for key naming
  - Each key is uniquely identified by the initiator's cookie and the responder's cookie.

Replay Attack

- Counter measure
  - Use nonce



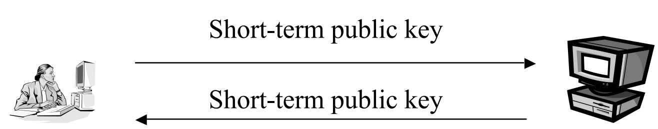
Man-in-the-middle-attack

- Counter measure
  - Authentication
  - Depend on other mechanisms.
    - Pre-shared key.
    - Public key certificates.

Oakley Groups

- 0 no group (placeholder or non-DH)
- 1 MODP, 768-bit modulus
- 2 MODP, 1024-bit modulus
- 3 MODP, 1536-bit modulus
- 4 EC2N over $GF(2^{155})$
- 5 EC2N over $GF(2^{185})$

Ephemeral Diffie-Hellman



- Session key is computed on the basis of short-term DH public-private keys.
- Exchange of these short-term public keys requires authentication and integrity.
  - Digital signatures.
  - Keyed message digests.
- The only protocol known to support Perfect Forward Secrecy.

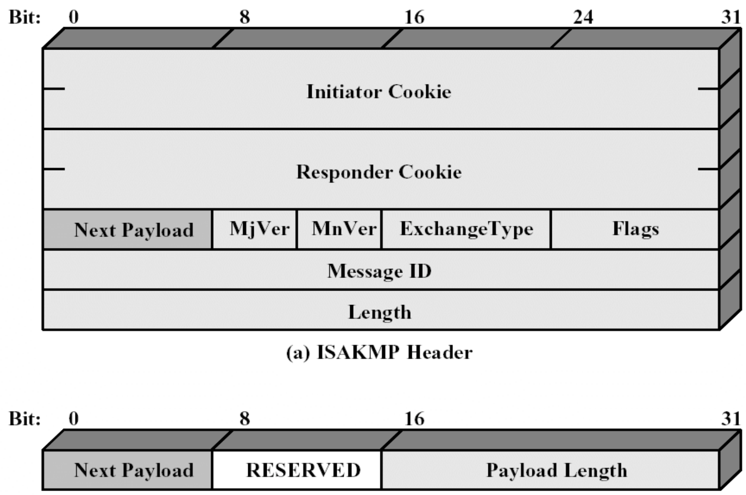
ISAKMP

- Oakley
  - Key exchange protocol
  - Developed to use with ISAKMP
- ISAKMP
  - Security association and key management protocol
  - Defines procedures and packet formats to establish, negotiate, modify, and delete security associations.
  - Defines payloads for security association, key exchange, etc.

ISAKMP Message

- Fixed format header
  - 64 bit initiator and responder cookies
  - Exchange type (8 bits)
  - Next payload type (8 bits)
  - Flags: encryption, commit, authentication, etc.
  - 32 bit message ID
    - Resolve multiple phase 2 SAs being negotiated simultaneously
  - Variable number of payloads
    - Each has a generic header with
      - Payload boundaries
      - Next payload type (possible none)

ISAKMP Formats



(a) ISAKMP Header

(b) Generic Payload Header

ISAKMP Phases

- Phase 1
  - Establish ISAKMP SA to protect further ISAKMP exchanges
  - Or use pre-established ISAKMP SA
  - ISAKMP SA identified by initiator cookie and responder cookie
- Phase 2
  - Negotiate security services in SA for target security protocol or application.

ISAKMP

- Disadvantage
  - Additional overhead due to 2 phases
- Advantages
  - Same ISAKMP SA can be used to negotiate phase 2 for multiple protocols
  - ISAKMP SA can be used to facilitate maintenance of SAs.
  - ISAKMP SA can simplify phase 2.

ISAKMP Domain Of Interpretation (DOI)

- DOI defines
  - Payload format
  - Exchange types
  - Naming conventions for security policies, cryptographic algorithms
- DOI for IPSEC has been defined.

ISAKMP Exchange Types

- 0 none
- 1 base
- 2 identity protection
- 3 authentication only
- 4 aggressive
- 5 informational
- 6-31 reserved
- 32-239 DOI specific use
- 240-255 private use

ISAKMP Exchange Types

- Base exchange
  - reveals identities
- Identity protection exchange
  - Protects identities at cost of extra messages.
- Authentication only exchange
  - No key exchange
- Aggressive exchange
  - Reduce number of message, but reveals identity
- Informational exchange
  - One-way transmission of information.

ISAKKMP Payload Types

• 0	none	
• 1	SA	security association
• 2	P	proposal
• 3	T	transform
• 4	KE	key exchange
• 5	ID	identification
• 6	CERT	certificate
• 7	CR	certificate request

ISAKKMP Payload Types

• 8	H	hash
• 9	SIG	signature
• 10	NONCE	nonce
• 11	N	notification
• 12	D	delete
• 13	VID	vender ID
• 14-127		reserved
• 128-255		private use

ISAKMP Payload Types

Type	Parameters	Description
Security Association (SA)	Domain of Interpretation, Situation	Used to negotiate security attributes and indicate the DOI and Situation under which negotiation is taking place.
Proposal (P)	Proposal #, Protocol-ID, SPI Size, # of Transforms, SPI	Used during SA negotiation; indicates protocol to be used and number of transforms.
Transform (T)	Transform #, Transform-ID, SA Attributes	Used during SA negotiation; indicates transform and related SA attributes.
Key Exchange (KE)	Key Exchange Data	Supports a variety of key exchange techniques.
Identification (ID)	ID Type, ID Data	Used to exchange identification information.
Certificate (CERT)	Cert Encoding, Certificate Data	Used to transport certificates and other certificate-related information.
Certificate Request (CR)	# Cert Types, Certificate Types, # Cert Auths, Certificate Authorities	Used to request certificates; indicates the types of certificates requested and the acceptable certificate authorities.
Hash (HASH)	Hash Data	Contains data generated by a hash function.
Signature (SIG)	Signature Data	Contains data generated by a digital signature function.
Nonce (NONCE)	Nonce Data	Contains a nonce.
Notification (N)	DOI, Protocol-ID, SPI Size, Notify Message Type, SPI, Notification Data	Used to transmit notification data, such as an error condition.
Delete (D)	DOI, Protocol-ID, SPI Size, # of SPIs, SPI (one or more)	Indicates an SA that is no longer valid.

ISAKMP Exchanges

Exchange	Note
(a) Base Exchange	
(1) **I → R:** SA; NONCE	Begin ISAKMP-SA negotiation
(2) **R → I:** SA; NONCE	Basic SA agreed upon
(3) **I → R:** KE; ID_I; AUTH	Key generated; Initiator identity verified by responder
(4) **R → I:** KE; ID_R; AUTH	Responder identity verified by initiator; Key generated; SA established
(b) Identity Protection Exchange	
(1) **I → R:** SA	Begin ISAKMP-SA negotiation
(2) **R → I:** SA	Basic SA agreed upon
(3) **I → R:** KE; NONCE	Key generated
(4) **R → I:** KE; NONCE	Key generated
(5)* **I → R:** ID_I; AUTH	Initiator identity verified by responder
(6)* **R → I:** ID_R; AUTH	Responder identity verified by initiator; SA established
(c) Authentication Only Exchange	
(1) **I → R:** SA; NONCE	Begin ISAKMP-SA negotiation
(2) **R → I:** SA; NONCE; ID_R; AUTH	Basic SA agreed upon; Responder identity verified by initiator
(3) **I → R:** ID_I; AUTH	Initiator identity verified by responder; SA established
(d) Aggressive Exchange	
(1) **I → R:** SA; KE; NONCE; ID_I	Begin ISAKMP-SA negotiation and key exchange
(2) **R → I:** SA; KE; NONCE; ID_R; AUTH	Initiator identity verified by responder; Key generated; Basic SA agreed upon
(3)* **I → R:** AUTH	Responder identity verified by initiator; SA established
(e) Informational Exchange	
(1)* **I → R:** N/D	Error or status notification, or deletion

Notation:
I = initiator
R = responder
* = signifies payload encryption after the ISAKMP header