Overview of IPSec

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IP is not Secure!

- IP protocol was designed in late 70s to early 80s
  - Part of DARPA Internet Project
  - Very small network
    - All hosts are known!
    - So are the users!
    - Therefore, security was not an issue

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Security Issues in plain IP

- Source address spoofing
- Bogus packets
- Replayed packets
- Re-ordered packets
- Eavesdropping on data in packets
- Eavesdropping on addressing info in packets

- No origin authentication
- No data integrity
- No data confidentiality
- No meta-data confidentiality

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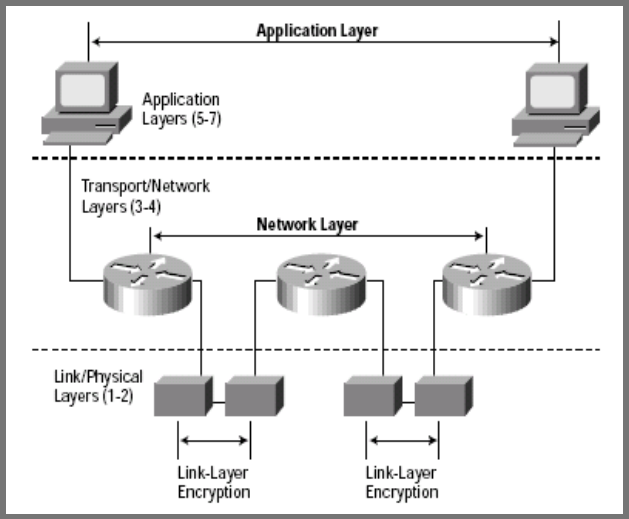
IPSec Placement

- lives at the network layer
- transparent to applications



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Quick recap of IP

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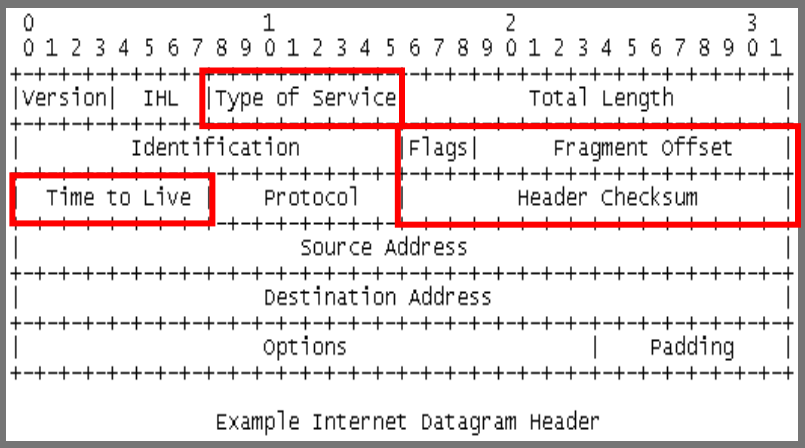
IPv4 Header Format



Mutable, Immutable

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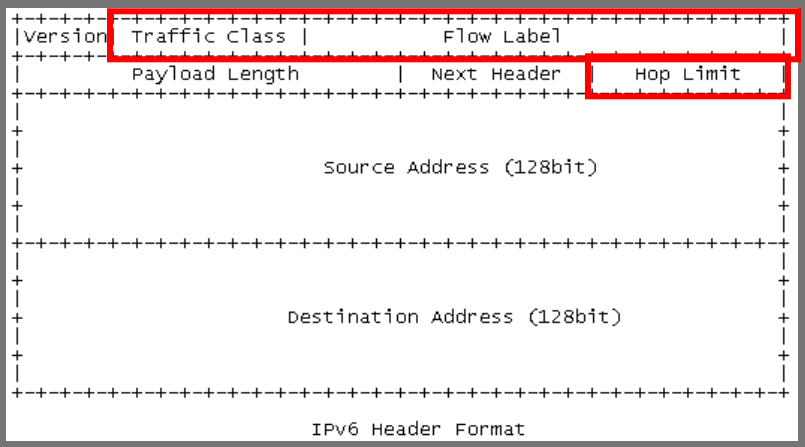
IPv6 Header Format



IPv6 Header Format

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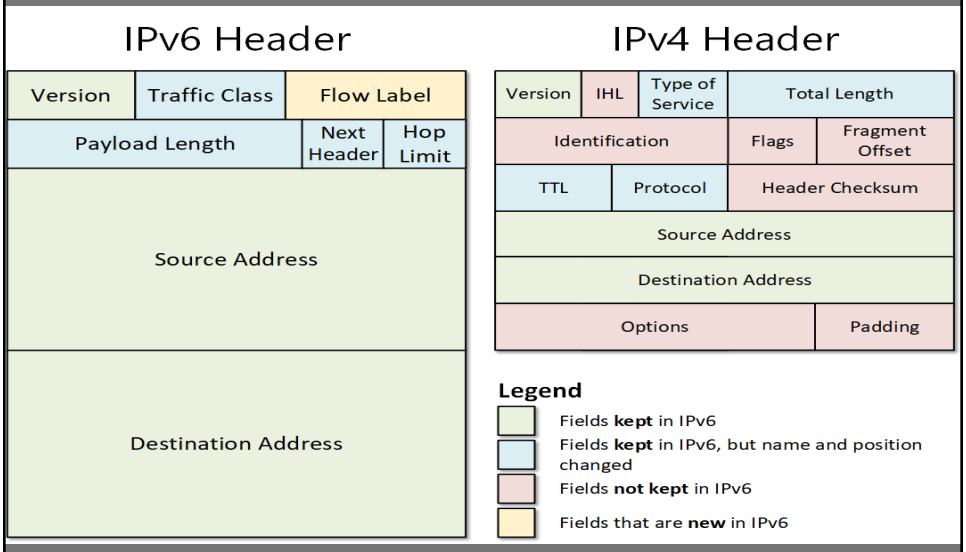
IPv4 v. IPv6



The rest of this presentation uses IPv4

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Goals of IPSec

- verify sources of IP packets
  - Origin authentication
- Detect replay and reordering of packets
  - Freshness
- Integrity of packet data
- Confidentiality of packet data
- Confidentiality of packet metadata
  - Eavesdropper can't tell who's talking to whom

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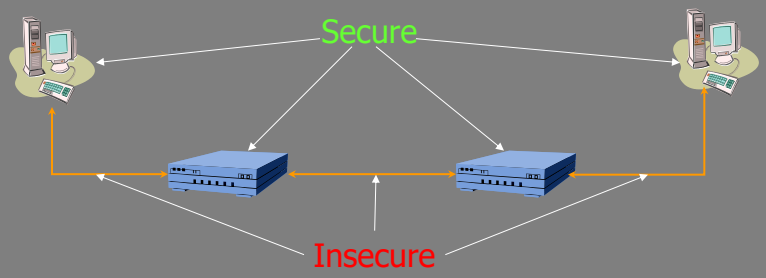
The IPSec Security Model



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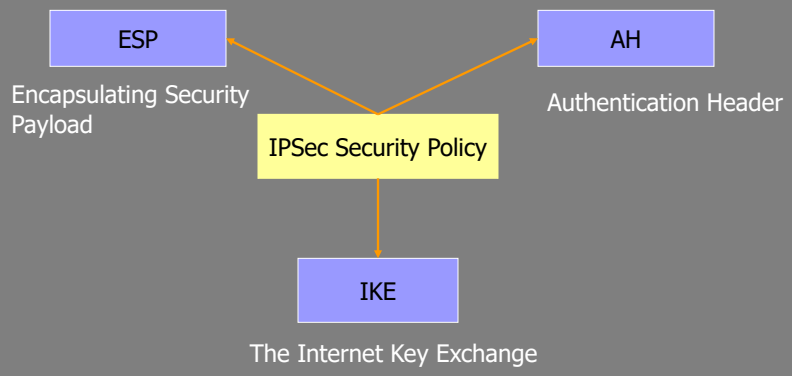
IPSec Architecture



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IPSec Architecture

- Provides security in three cases:
  1. host-to-host
  2. host-to-gateway
  3. gateway-to-gateway

  (host means IP interface)
- Uses 2 formats: AH and ESP
- Operates in two modes: Transport and Tunnel

Note: Gateway is typically a border router of stub AD

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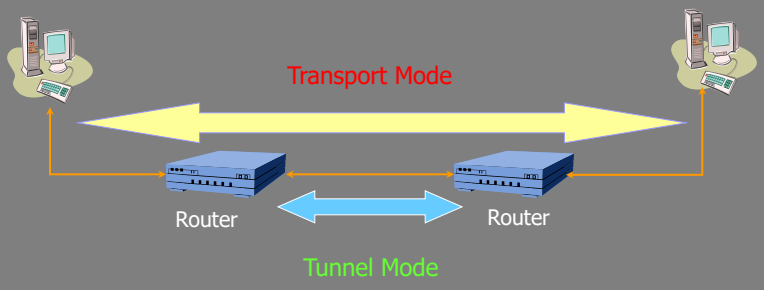
IPsec Architecture: typical use-cases: Modes



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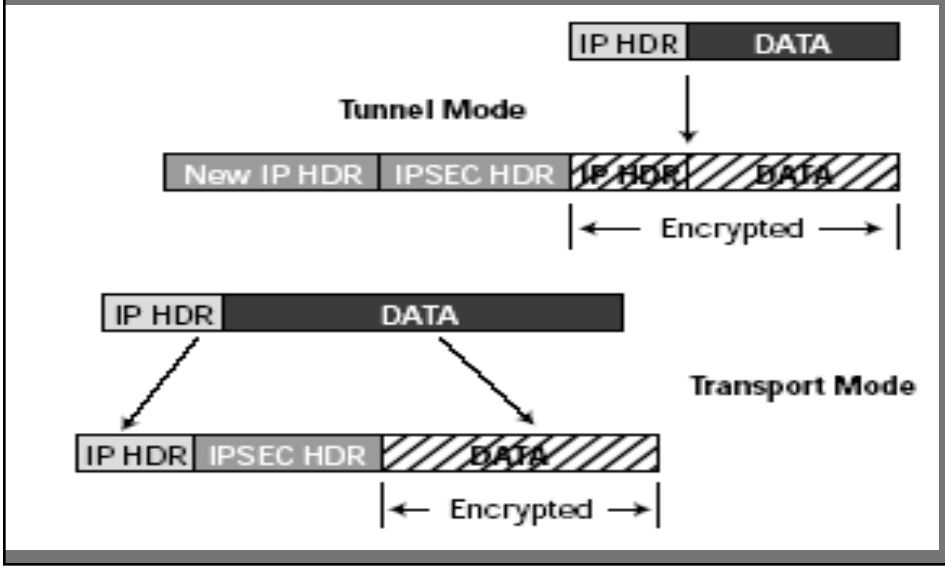
IPSec Modes



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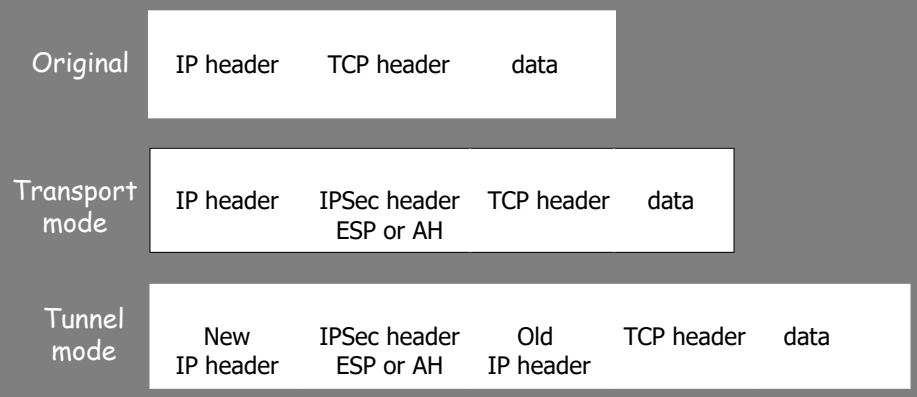
IPSec Modes



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IPSec Specs

- A set of packet formats (RFC 2401)
  - Authentication Header (AH)
    - RFC 2402
  - Encapsulating Security Payload (ESP)
    - RFC 2406
  - Internet Key Exchange (IKE)
    - RFC 2409

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Authentication Header (AH)

- Provides origin authentication
  - Protects against source address spoofing
- Provides data integrity
- Protects against replay attacks
  - Uses monotonically increasing sequence numbers
- NO data or metadata confidentiality!

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AH Details

- 32-bit monotonically increasing sequence number to detect replay attacks
- Cryptographic hash algorithms to protect data integrity
  - Symmetric cryptography
  - Various flavors of HMAC

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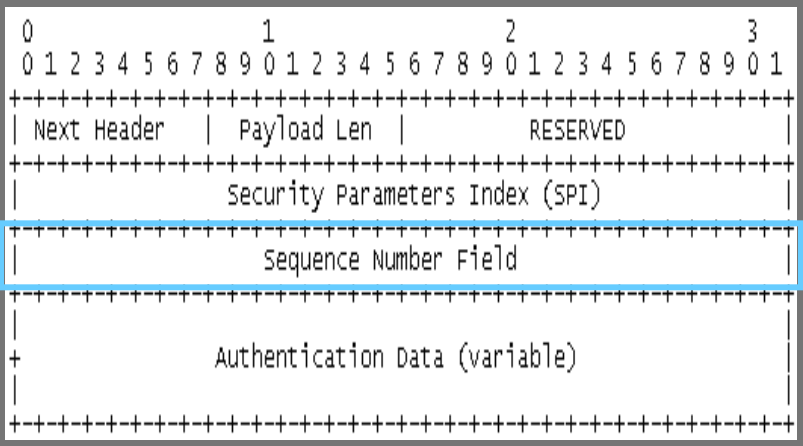
AH Format



The sender's counter is initialized to 0 when an SA is established.

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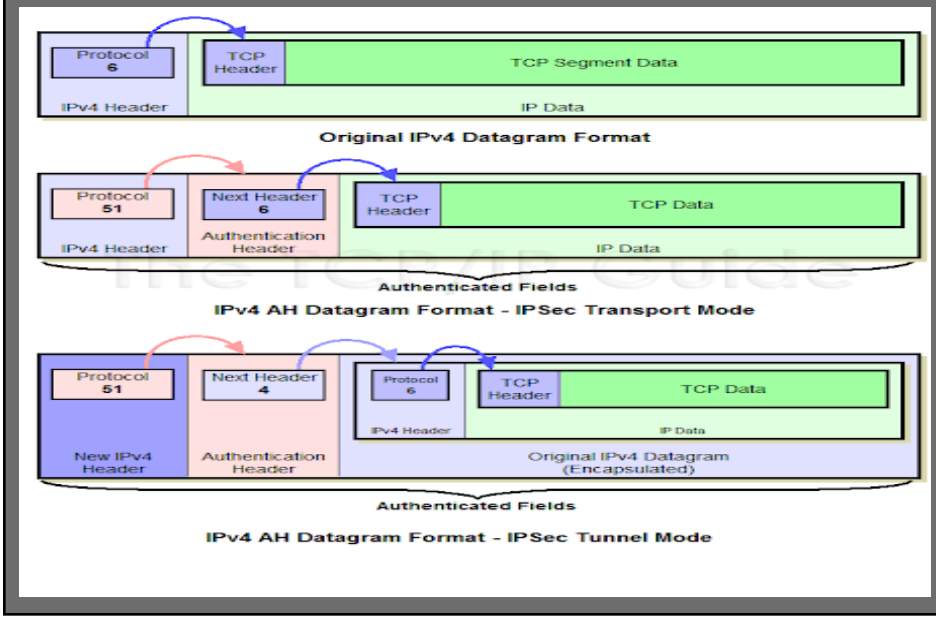
AH Packet: Transport v. Tunnel



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Encapsulating Security Payload (ESP)

- Provides all that AH offers

plus

- Data confidentiality via symmetric encryption

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ESP Details

- Same as AH:
  - Use 32-bit sequence number to counter replaying attacks
  - Use integrity check algorithms
- Only in ESP:
  - Data confidentiality:
    - Uses symmetric key encryption algorithms to encrypt packets

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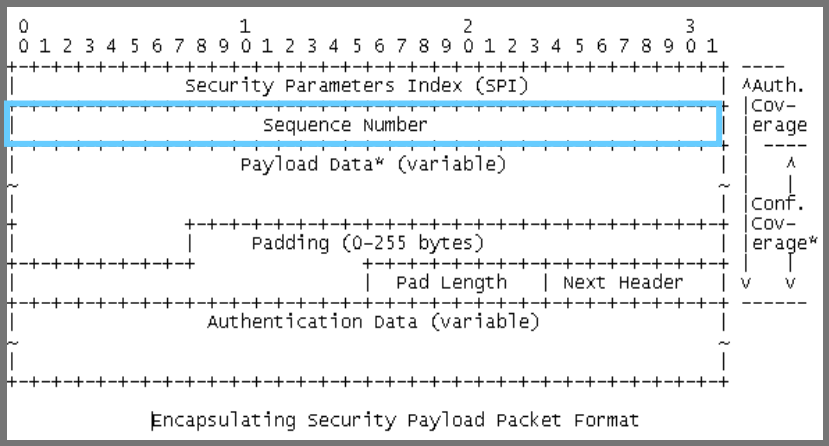
ESP Format



The sender's counter is initialized to 0 when an SA is established.

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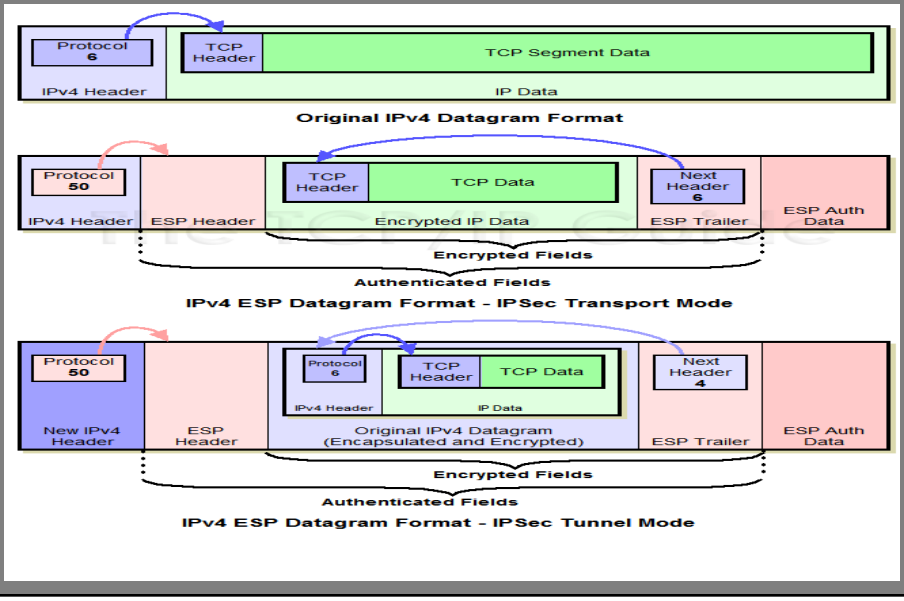
ESP Packet: Transport v. Tunnel



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Questions?

1. Why have both AH and ESP?
2. Both AH and ESP use symmetric key based algorithms
   - Why not public-key cryptography?
   - How are the keys being exchanged?
   - What algorithms should we use?
   - Similar to deciding on the ciphersuite in SSL

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Discussion

- IPSec authenticates machines/hosts, not users
- Does not stop denial of service attacks
  - In fact, makes DoS easier
- Order of operations: Encryption/Authentication

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Internet Key Exchange (IKE)

- Exchange and negotiate security policies
- Establish security sessions
  - Identified as "*Security Associations" (SA)*
- Key exchange
- Key management
- Can be used outside IPsec as well

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IPsec/IKE Acronyms

- Security Association (SA)
  - Collection of attribute associated with a connection
  - Is one-way
    - One SA for inbound traffic, another SA for outbound traffic
    - Similar to SSL/TLS (different keys used in each direction)
- Security Association Database (SAD)
  - A database of SAs

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IPsec/IKE Acronyms

- Security Parameter Index (SPI)
  - A unique index for each entry in the SADB
  - Identifies the SA associated with a packet
- Security Policy Database (SPD)
  - Store policies used to establish SAs

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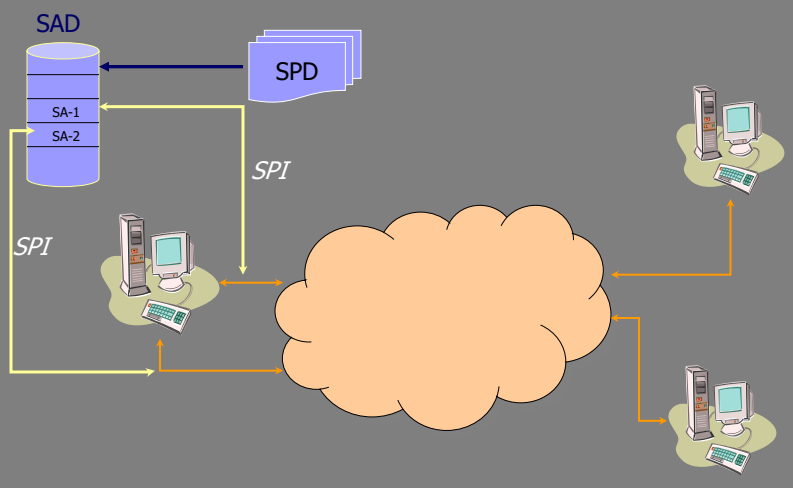
How They Fit Together



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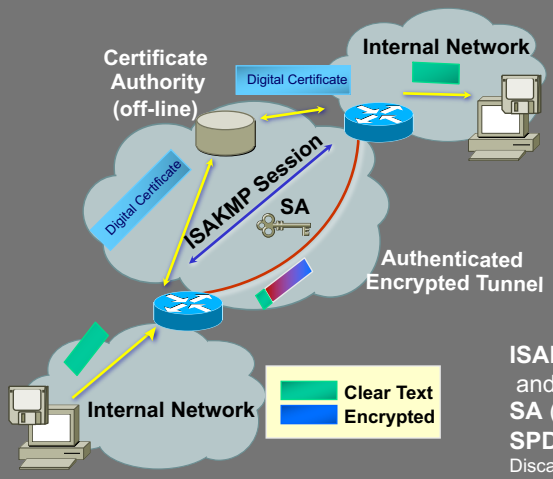
IPSec and IKE in Practice



- Sets up a keying channel
- Sets up data channels

ISAKMP (Internet Security Association and Key Management Protocol)
SA (Security Associations)
SPD (Security Policy Database)
Discard,bypass IPsec, apply IPSec (Overhead)

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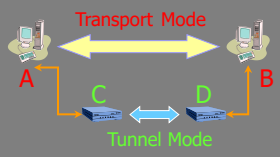
SPD and SADB Example



A's SPD

From	To	Protocol	Port	Policy
A	B	Any	Any	AH[HMAC-MD5]

A's SAD

From	To	Protocol	SPI	SA Record
A	B	AH	12	HMAC-MD5 key

C's SPD

From	To	Protocol	Port	Policy	Tunnel Dest
A_{sub}	B_{sub}	Any	Any	ESP[3DES]	D

C's SAD

From	To	Protocol	SPI	SA Record
A_{sub}	B_{sub}	ESP	14	3DES key

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How It Works

- IKE operates in two phases
  - Phase 1: negotiate and establish an auxiliary end-to-end secure channel
    - Used by subsequent phase 2 negotiations
    - Only established once between two end points!
  - Phase 2: negotiate and establish custom secure channels
    - Occurs multiple times
  - Both phases use Diffie-Hellman key exchange to establish a shared key

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IKE Phase 1

- Goal: to establish a secure channel between two end points
  - This channel provides basic security features:
    - Source authentication
    - Data integrity and data confidentiality
    - Protection against replay attacks

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IKE Phase 1

- Rationale: each application has different security requirements
- But they all need to negotiate policies and exchange keys!
- So, provide the basic security features and allow application to establish custom sessions

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Examples

- All packets sent to address mybank.com must be encrypted using 3DES with HMAC-MD5 integrity check
- All packets sent to address www.forum.com must use integrity check with HMAC-SHA1 (no encryption is required)

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Phase 1 Exchange

- Can operate in two modes:
  - Main mode
    - Six messages in three round trips
    - More options
  - Quick mode
    - Four messages in two round trips
    - Less options

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Phase 1 (Main Mode)

Initiator

Responder

[Header, SA_1]

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Phase 1 (Main Mode)

Establish vocabulary for further communication

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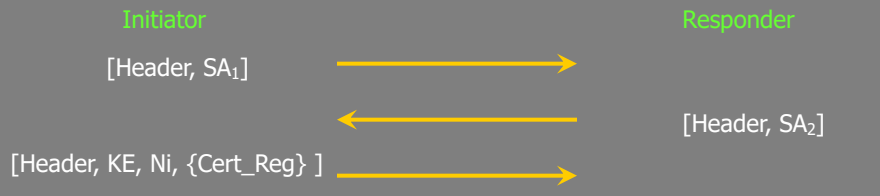
Phase 1 (Main Mode)



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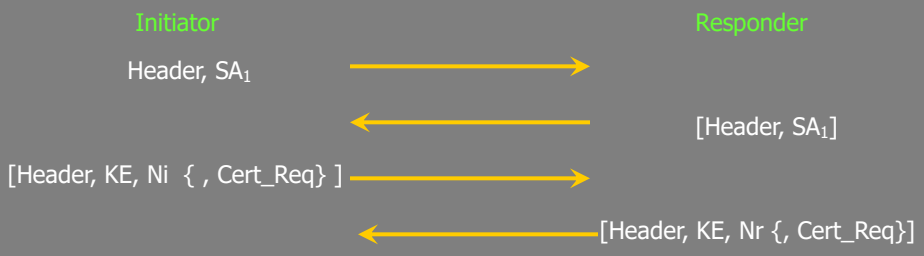
Phase 1 (Main Mode)



Establish secret key using Diffie-Hellman key exchange
Use nonces to prevent replay attacks

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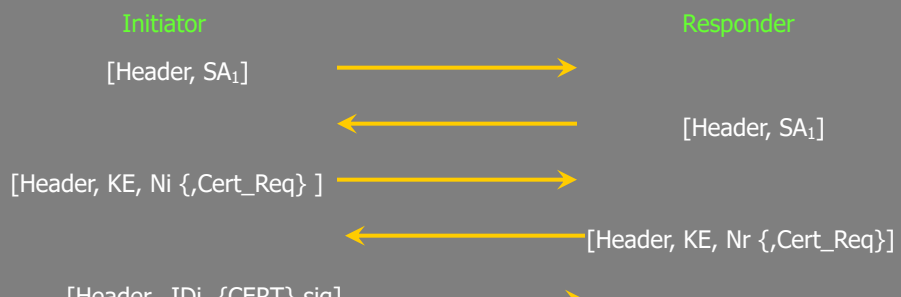
Phase 1 (Main Mode)



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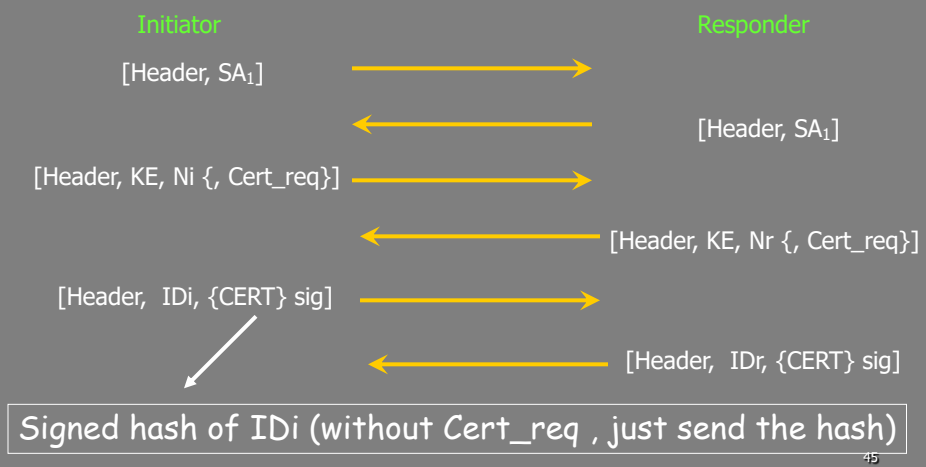
Phase 1 (Main Mode)



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Phase 1 (Aggressive Mode)

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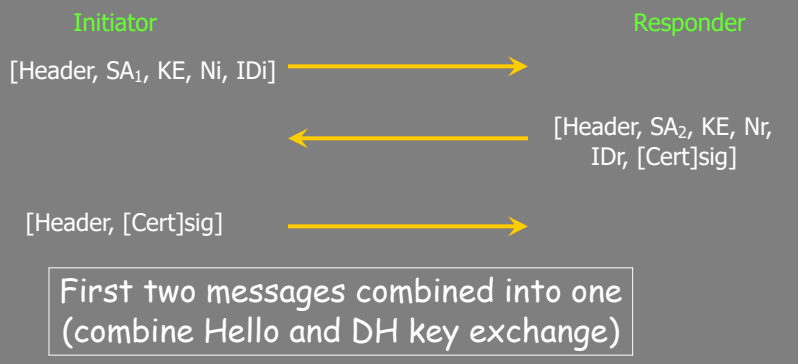
Phase 1 (Aggressive Mode)



First two messages combined into one (combine Hello and DH key exchange)

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IPSec (Phase 1)

- Four different way to authenticate (either mode)
  - Digital signature
  - Two forms of authentication with public key encryption
  - Pre-shared key
- NOTE: IKE does use public-key based cryptography for encryption

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IPSec (Phase 2)

- **Goal:** to establish custom secure channels between two end points
  - End points are identified by <IP, port>:
    - e.g. <www.mybank.com, 8000>
  - Or by packet:
    - e.g. All packets going to 128.124.100.0/24
  - Use the secure channel established in Phase 1 for communication

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IPSec (Phase 2)

- **Only one mode:** Quick Mode
- Multiple quick mode exchanges can be multiplexed
- Generate SAs for two end points
- Can use secure channel established in phase 1

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IP Payload Compression

- Used for compression
- Can be specified as part of the IPSec policy
- Will not cover!

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Outline

- Why IPsec?
- IPsec Architecture
- Internet Key Exchange (IKE)
- IPSec Policy
- Discussion

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IPsec Policy

- Phase 1 policies are defined in terms of *protection suites*
- Each protection suite
  - Must contain the following:
    - Encryption algorithm
    - Hash algorithm
    - Authentication method
    - Diffie-Hellman Group
  - May optionally contain the following:
    - Lifetime
    - …

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IPSec Policy

- Phase 2 policies are defined in terms of *proposals*
- Each proposal:
  - May contain one or more of the following
    - AH sub-proposals
    - ESP sub-proposals
    - IPComp sub-proposals
    - Along with necessary attributes such as
      - Key length, life time, etc

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IPSec Policy Example

- In English:
  - All traffic to 128.104.120.0/24 must be:
    - Use pre-hashed key authentication
    - DH group is MODP with 1024-bit modulus
    - Hash algorithm is HMAC-SHA (128 bit key)
    - Encryption using 3DES
- In IPSec:
  - [Auth=Pre-Hash;
    DH=MODP(1024-bit);
    HASH=HMAC-SHA;
    ENC=3DES]

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IPsec Policy Example

- In English:
  - All traffic to 128.104.120.0/24 must use one of the following:
    - AH with HMAC-SHA or,
    - ESP with 3DES as encryption algorithm and (HMAC-MD5 or HMAC-SHA as hashing algorithm)
- In IPsec:
  - [AH: HMAC-SHA] or,
  - [ESP: (3DES and HMAC-MD5) or
    (3DES and HMAC-SHA)]

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Virtual Private Networks (VPNs)

- Virtual
  - It is not a physically distinct network
- Private
  - Tunnels are encrypted to provide confidentiality
- CS dept might have a VPN
  - I can be on this VPN while traveling

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Alice is Traveling

- Alice works for the mergers and acquisitions (M&A) department of takeover.com
- She is at Hicktown taking over a meat-packing plant
- She wants to access the M&A server at her company (confidentially of course)

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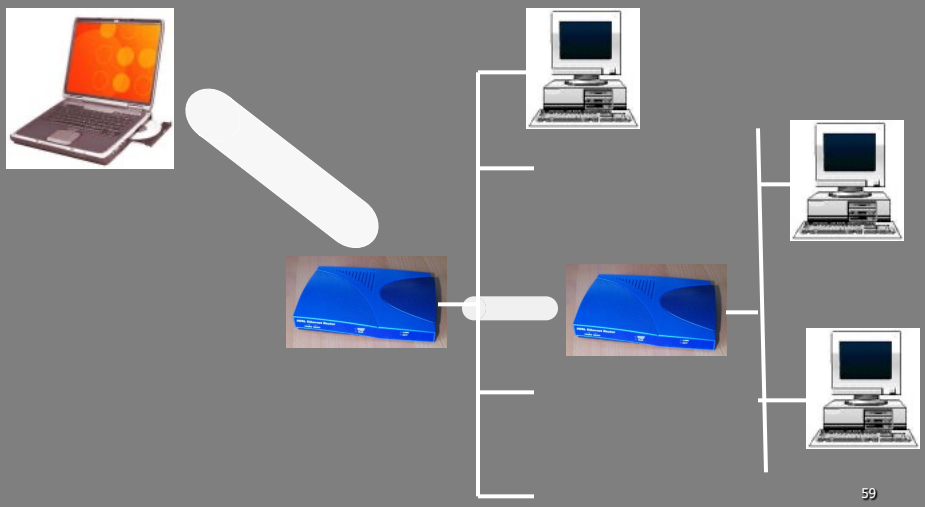
Alice is Traveling



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Outline

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- IPsec Policy
- Discussion

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Discussion

- IPSec is not the only solution!
  - Security features can be added on top of IP!
    - e.g. Kerberos, SSL
- Confused?
  - IP, IPSec protocols are very complex!
    - Two modes, three sub protocols
  - Complexity is the biggest enemy of security

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Discussion

- Has it been used?
  - Yes—primarily used by some VPN vendors
    - But not all routers support it
  - No—it is not really an end-to-end solution
    - Authentication is too coarse (host based)
    - Default encryption algorithm too weak (DES)
    - Too complex for applications to use

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Resources

- IP, IPsec and related RFCs:
  - http://www.ietf.org/html.charters/ipsec-charter.html
  - IPsec: RFC 2401, IKE: RFC 2409
  - www.freeswan.org
- Google search