Internet Security

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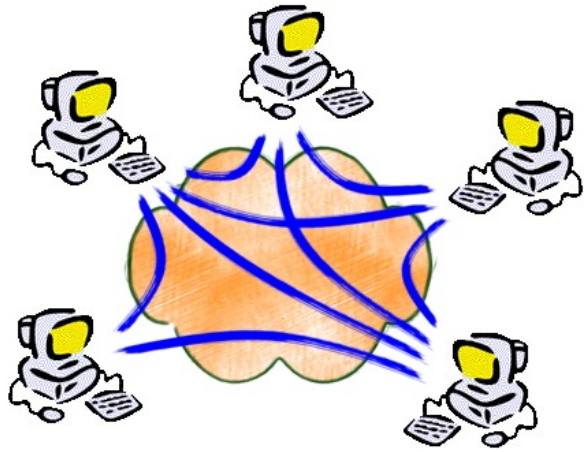
Outline

Computer networks



- Physically: a collection of “segments” that transmit bit streams.
  Examples: wire between two nodes or multi-access links like a LAN (e.g., Ethernet, token rings, packet radio networks).
- Logically: a communication medium between principals.
  Example: client communicates to server.
- A secure channel is yet another abstraction.
  Other abstractions may concern availability, privacy of communication partners, etc.

Layered communication

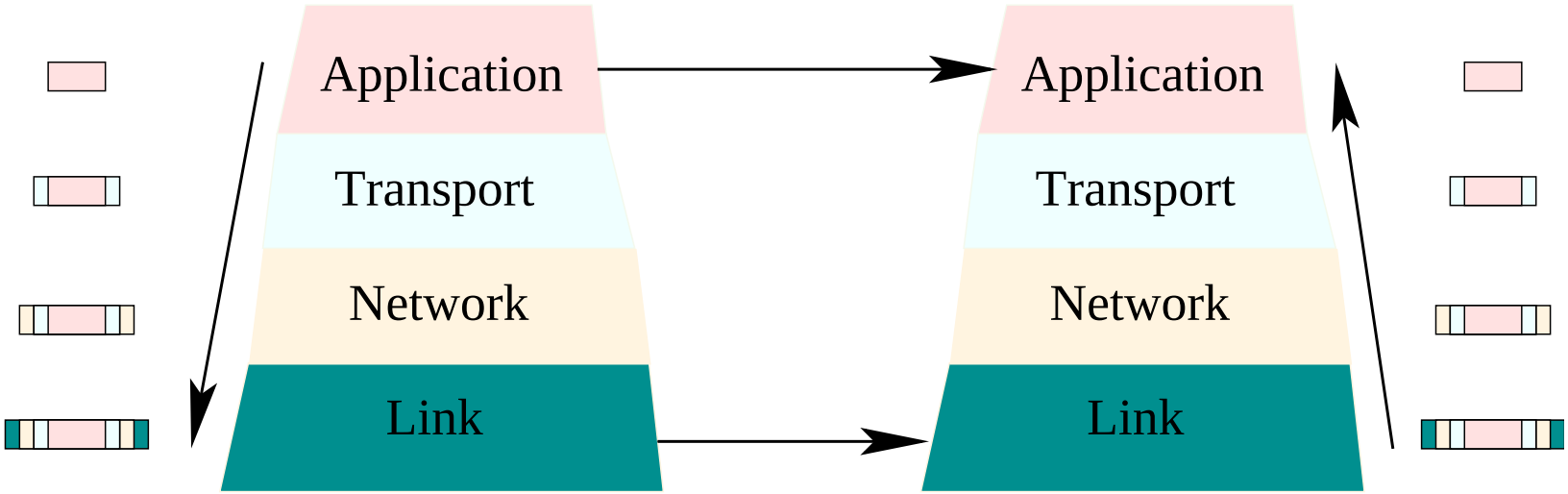
- Logical functionality built in layered way.
  - Application communication builds upon
  - reliable transport between nodes builds upon
  - unreliable transport across links and switches builds upon
  - packet transportation across single links

- TCP/IP protocol reference model

Application	Telnet, FTP, HTTP, RPC, SMTP, SET, ...
Transport/session	TCP, UDP
Network (Internet)	IP, ICMP, ...
Link (Interface)	Network interface & device drivers (IEEE 802.x, PPP, SLIP)

- Alternative model (OSI) with three additional layers: presentation, physical, and transport/session distinction.

Layered communication (II)



- *i*-th layer of one node communicates with *i*-th layer of different node, each using services provided by their lower layers.
- Headers/trailers added to (or stripped from) packets as they traverse the protocol stack.
- Layers are an abstraction. Reality is usually rather different. TCP/IP model developed by practioners in parallel to ISO/OSI.

Internet security

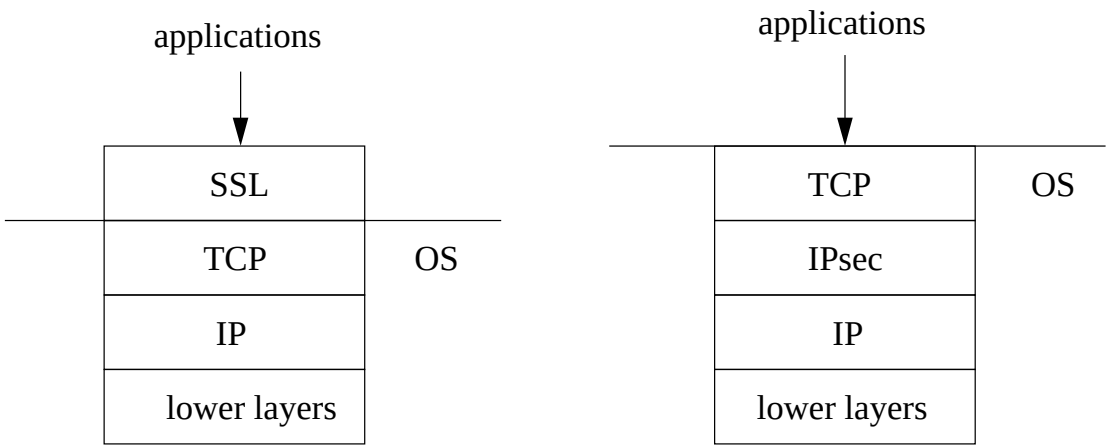
- Internet: Confederation of networks using TCP/IP protocols.
- No global domain of trust.
  - Different subnetworks may (or may not) be trustworthy.
  - 15+ hops for a packet from source to destination is common.
- Problem: how do we secure communication/applications?
- One possibility: secure applications over insecure channels.
  Example: Kerberos is typically implemented and support by different applications. Requires “kerberized” applications.
  Example: Use of PGP to encrypt/sign mail.
- Securing other layers is also possible.

What layer? – TCP/IP

- Internet Protocol (IP): deliver data across a network.
  - Packet headers specify source and destination addresses.
  - Protocol computes path and forwards packets over multiple links from source to destination.
  - Current version is IPv4 (transition to IPv6 under way).
- Transmission Control Protocol (TCP): establishes reliable communication between systems across a network.
  Reliable: either all data delivered without loss, duplication, or reordering, or the connection is terminated.
- Neither provide security: no authentication or confidentiality. Addresses can be faked. Payload can be read and modified.

What layer? (cont.)

- For most implementations of IP stacks
  - Transport layer and below implemented in operating system.
  - Above transport layer implemented in user process.
- Two representative examples:



SSL (or TLS/SSH): OS doesn't change, applications do. SSL API is a superset of "sockets" API to TCP.

IPsec: OS changes. Applications and (TCP) API unchanged.

What layer? (cont.)

Application (or end-to-end):

:-) No assumptions needed about security of protocols used, routers, etc.

:-) Security decision can be based on user-ID, data, etc.

:-(Applications must be designed “security aware”.

Between application layer and transport layer: e.g., SSL

:-) No modification to OS. Minimal changes to applications.

:-(Problems interacting with TCP. SSL may reject data that TCP accepts. SSL must then drop connection $\Rightarrow$ easy DOS.

IPsec:

:-) Transport layer security without modifying applications.

:-(Only authenticates IP addresses, no user authentication.

:-| More is possible, but it requires changing API and applications.

Outline

IP security (IPsec) – What do you get?

- Provides a secure channel for all applications.
  Encryption and/or authentication of traffic.
- Ability to do filtering, based on a policy database.
  Just as if there were a firewall between the two ends.
- Installed in:

  Operating systems: for end-to-end security;

  Security gateways: firewalls or routers.

  Latter used for implementing Virtual Private Networks (VPNs).

Applications of IPsec

- Secure branch office connectivity over the Internet
- Secure remote access over the Internet
- Establishing extranet and intranet connectivity with partners
- Echancing e-commerce security

An IPsec Scenario

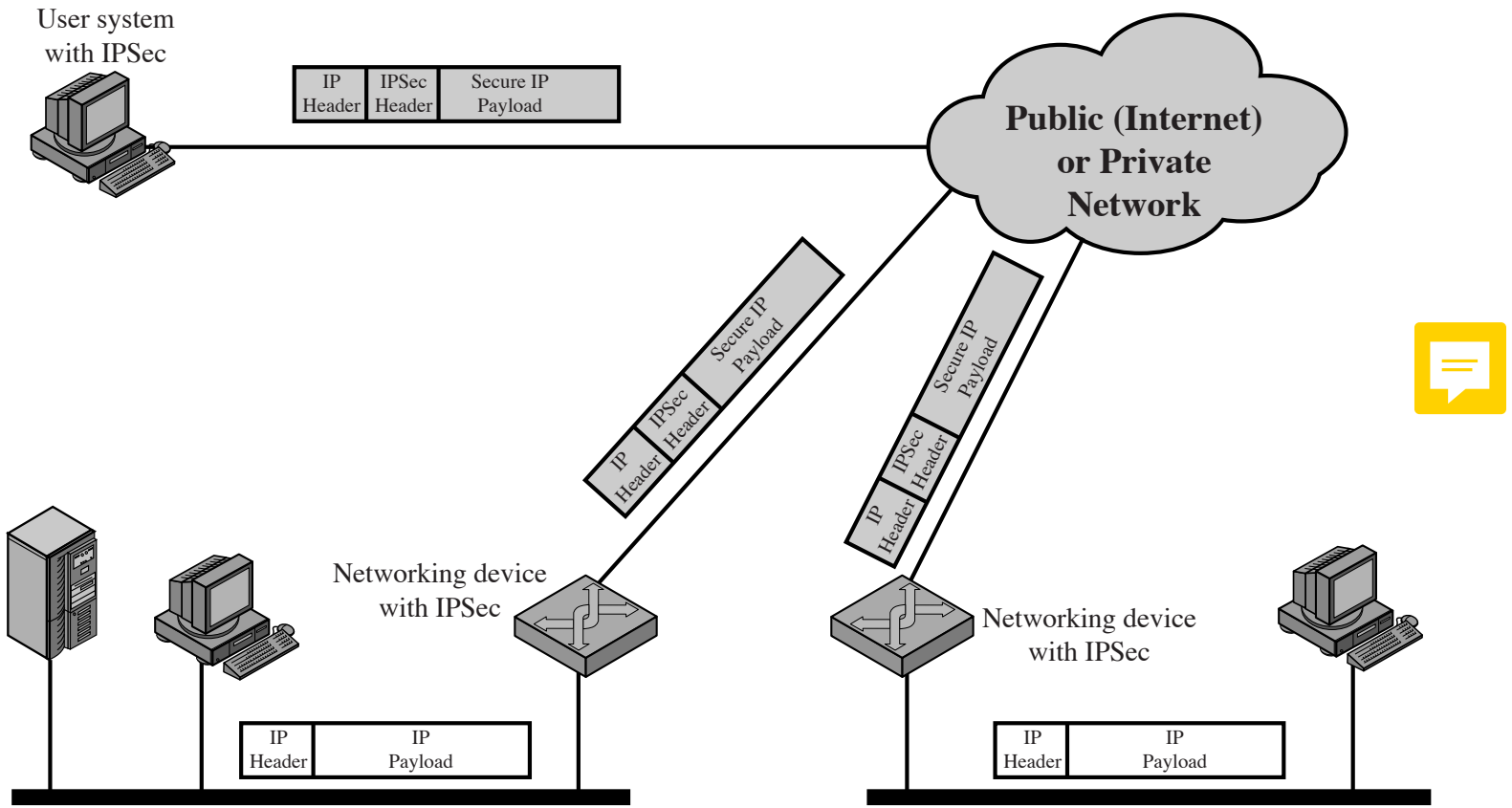


Figure 16.1 An IP Security Scenario

The IPsec standard

IPsec is an IETF Standard.

Complex specification covering protocols for a variety of purposes:

Authentication Header (AH): protects the integrity and the authenticity of IP datagrams (but not their confidentiality).

Encapsulating Security Payload (ESP): protects confidentiality and optionally also integrity.

Key Management (IKE): Internet Key Exchange Protocol.

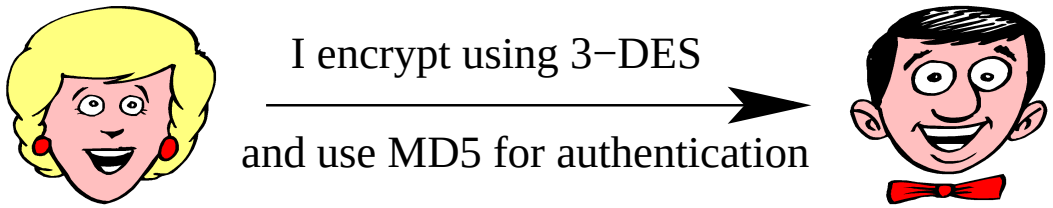
IPsec Services

Table 16.1 IPSec Services

	AH	ESP (encryption only)	ESP (encryption plus authentication)
Access control	✔	✔	✔
Connectionless integrity	✔		✔
Data origin authentication	✔		✔
Rejection of replayed packets	✔	✔	✔
Confidentiality		✔	✔
Limited traffic flow confidentiality		✔	✔

IPsec: Security Associations (SA)

- A security association is a one-way relationship between sender and receiver defining security services.



- Specifies things like: authentication algorithm (AH), encryption algorithm (ESP), keys, key lifetimes, lifetime of security association, protocol mode (tunnel or transport), ...
- Identified by fields in AH/ESP headers including the Security Parameters Index and destination address.
- SA is established using IKE, or possibly some other protocol. Implementation stores these in a security association database.

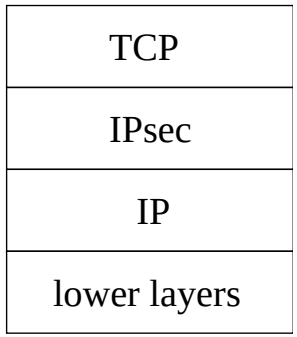
Outline

IPsec: Authentication Header (AH)

32 bits

Next header type of payload after AH	**Payload length** length of AH in 32−bit words (−‘2’)	**Reserved** for future use
Security Parameters Index (SPI) field identifying the SA for the datagram (value 0 indicates that no SA exists)		
Sequence number field counter value, used to detect replayed packets		
Authentication data variable number of 32−bit words containing the authentication data, e.g., a MAC (MD5 or SHA−1)		

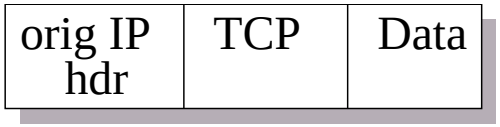
Extra header between layers 3 and 4 (IP and TCP) providing destination enough information to identify SA. AH guarantees integrity only, but also protects part of IP header.



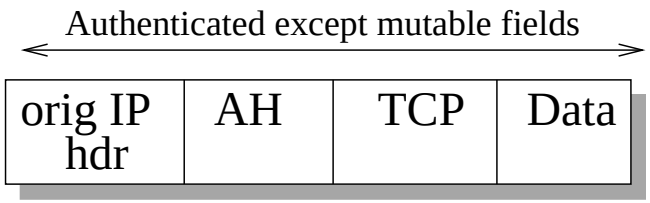
Sequence number is initialized to zero and incremented by the sender for each packet. Receiver stores incoming packets in a sliding window (default size 64) to order and sort out duplicates. (IP does not guarantee delivery or order.)

IPsec: AH modes

Original Datagram (here for TCP):

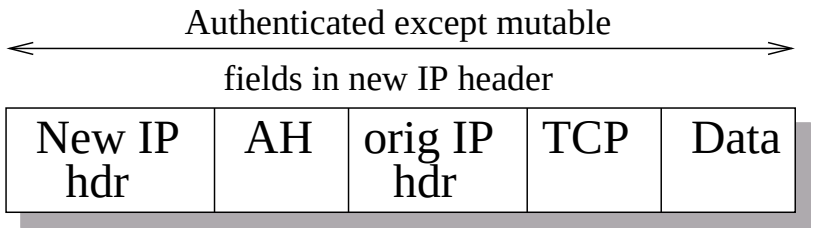


Transport mode:



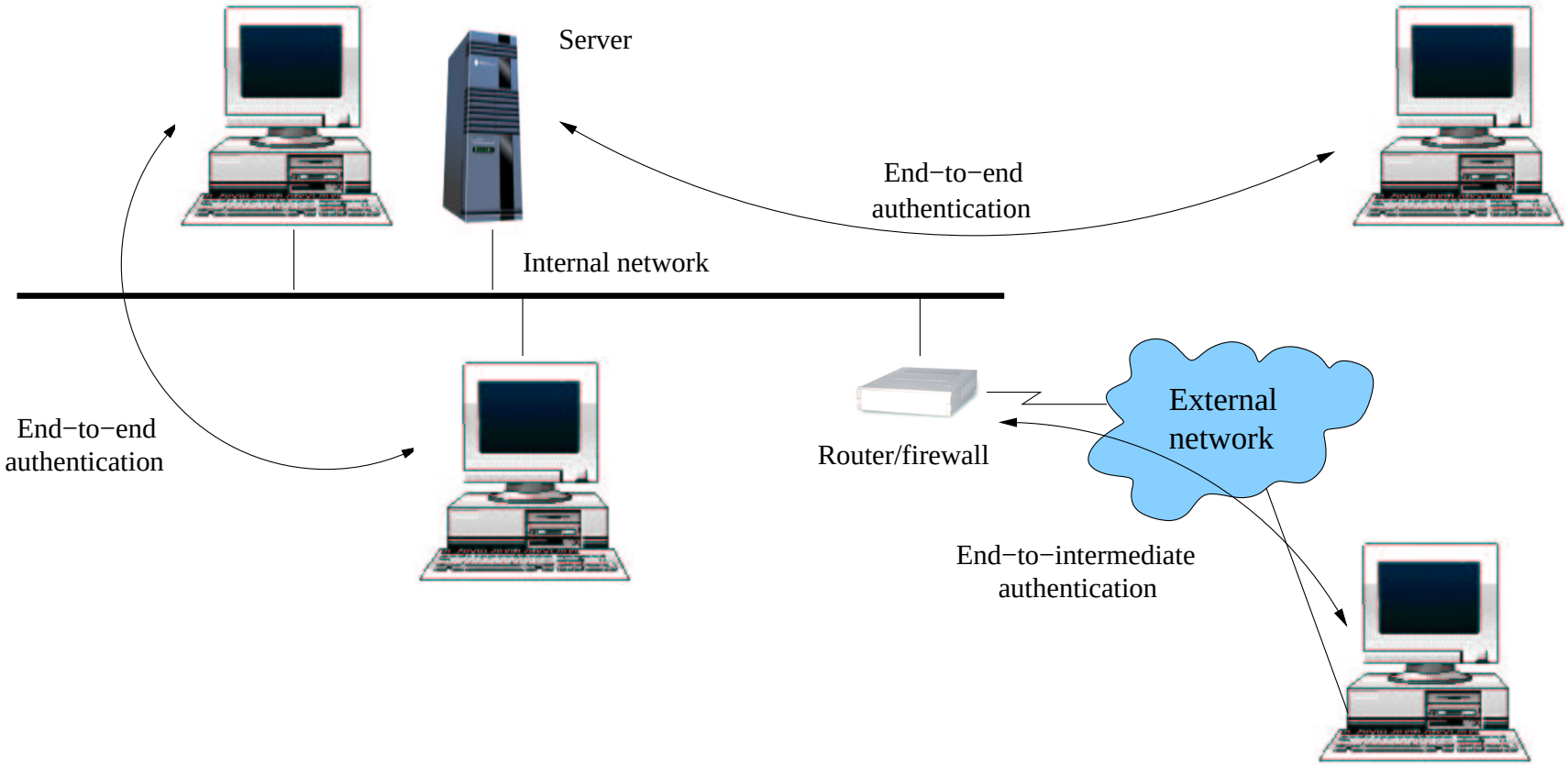
- AH inserted after IP header, before IP payload.
- MAC taken of entire packet (except for mutable fields).
- Provides end-to-end protection between IPsec-enabled systems.

Tunnel mode:



- Entire original packet authenticated; new outer IP header.
- Inner header carries ultimate source/destination address.
- New outer header also protected (except mutable fields) and may contain different IP addresses, e.g. firewalls or security gateways.

IPsec: AH application

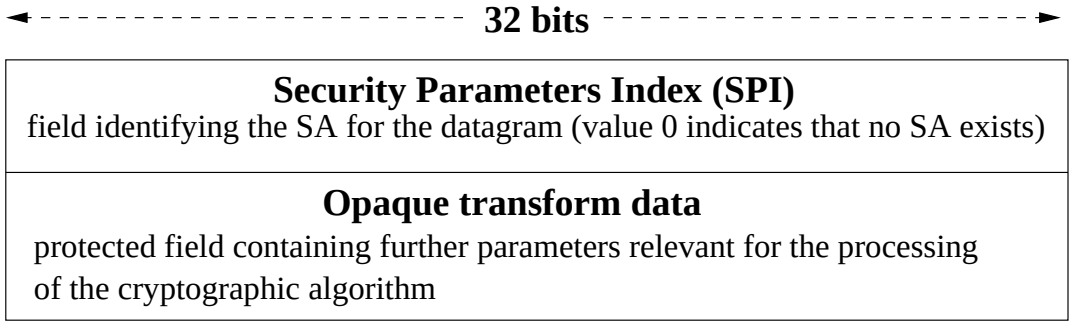


AH used to provide authenticated channels either end-to-end (typically transport mode) or in tunnel model to a security gateway.

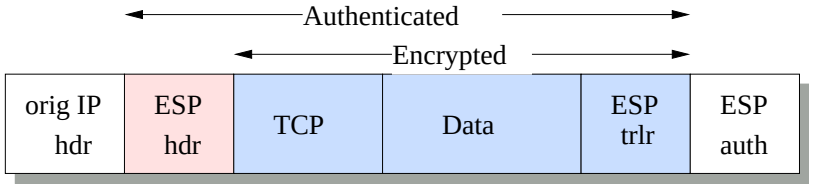
Outline

IPsec: Encapsulating Security Payload (ESP)

Header specifies encryption and optional authentication

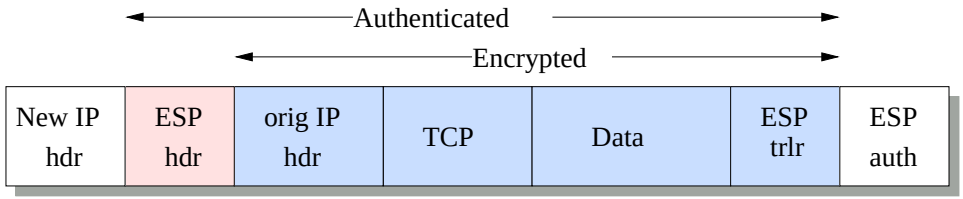


Transport mode:



encrypts only the data portion (payload) of each packet, but leaves the header untouched.

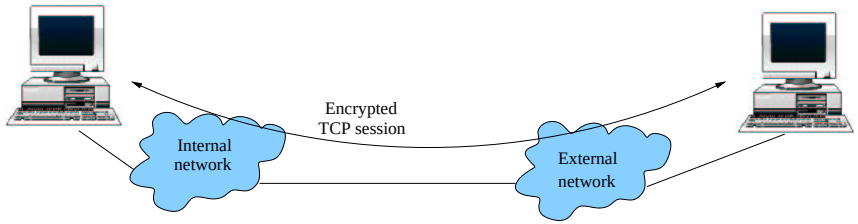
Tunnel mode:



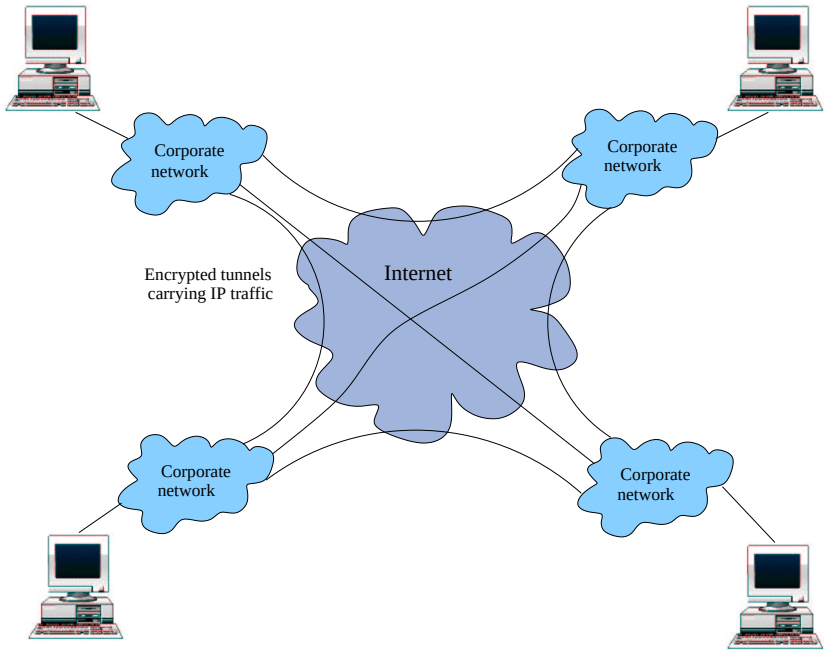
Entire IP datagram encapsulated within the ESP. Therefore both header and payload encrypted (and optionally authenticated).

IPsec: ESP Modes – applications

Transport mode provides end-to-end encryption between hosts supporting IPSec.



Tunnel mode can be used to set up a VPN.
Here hosts on different networks use Internet over tunnels between security gateways. Hosts needn't implement security capabilities.



Outline

Combining Security Associations

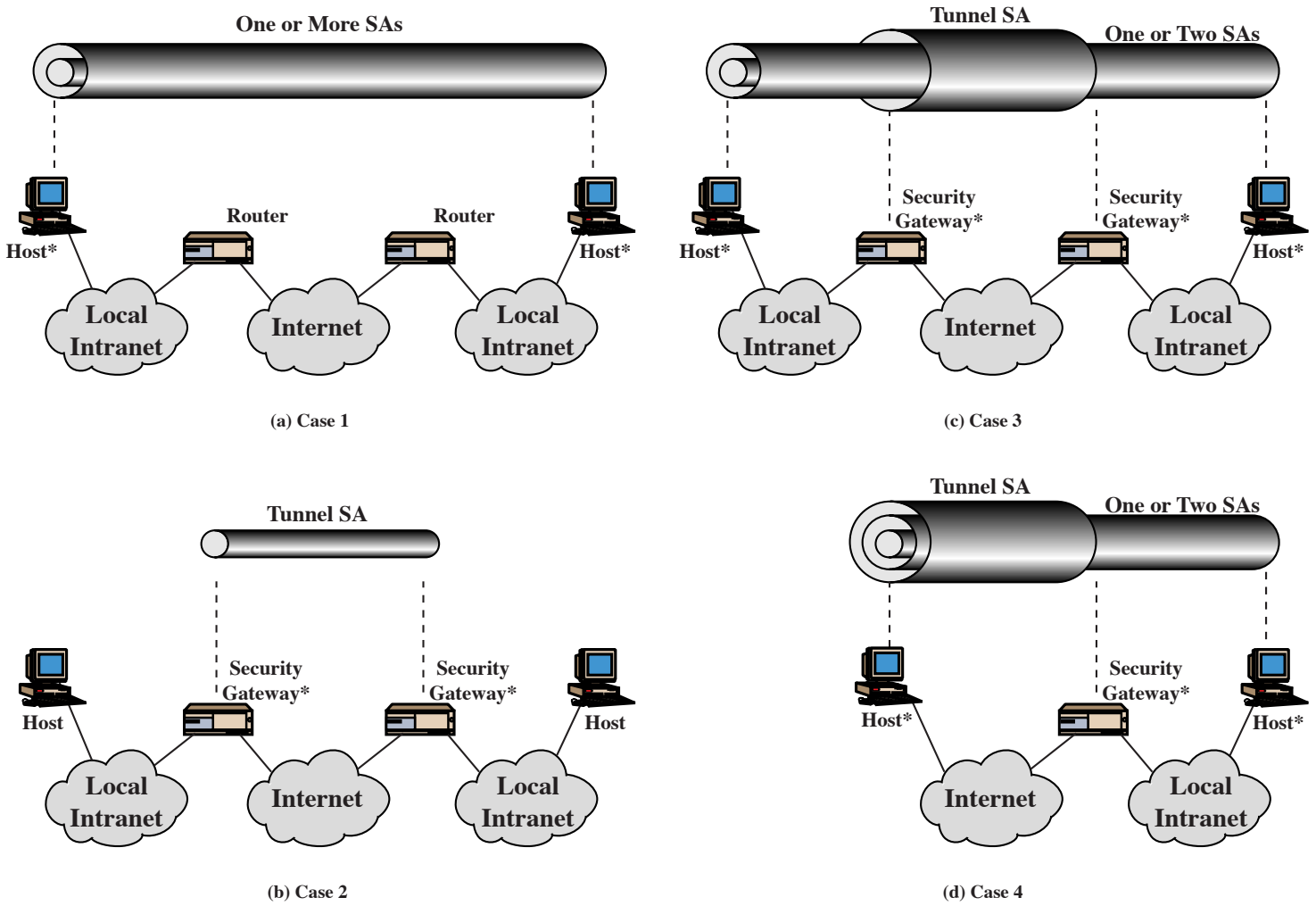


Figure 16.10 Basic Combinations of Security Associations

Outline

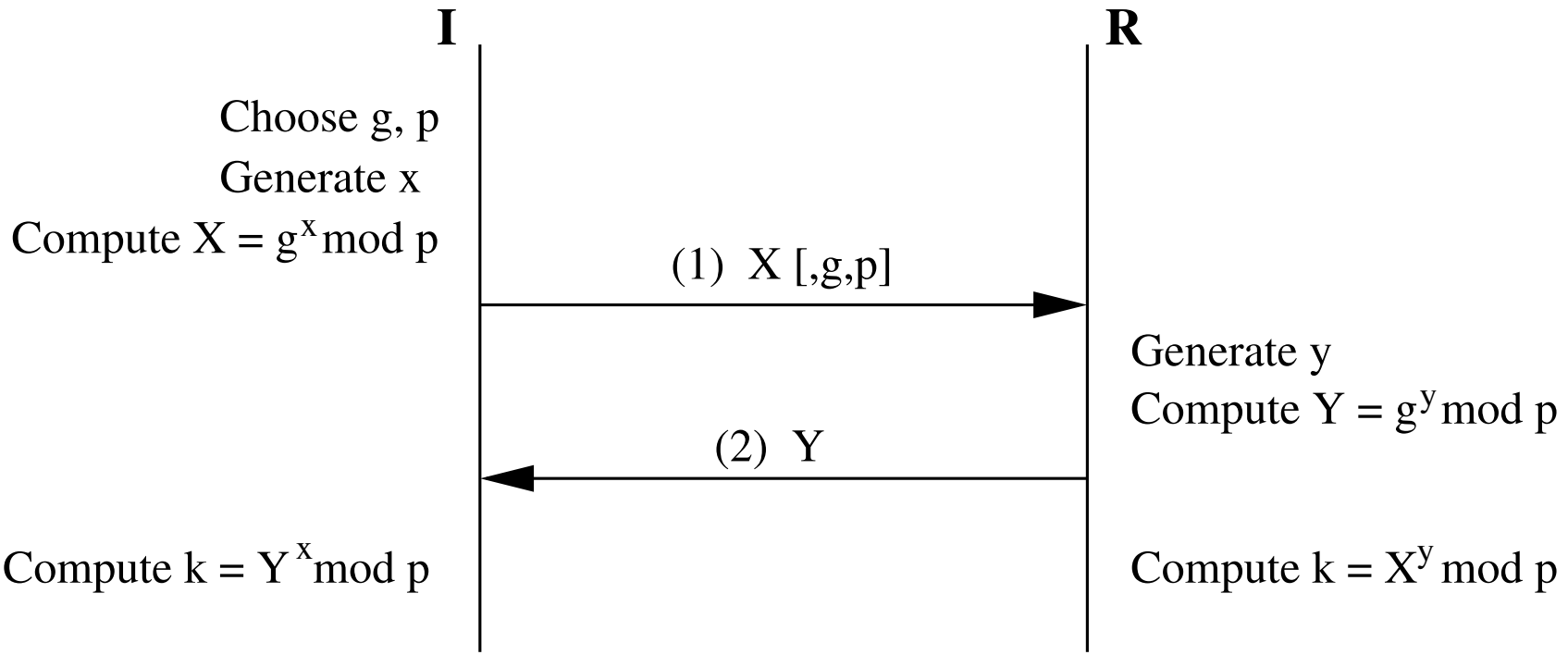
The Internet Key Exchange (IKE) protocol

- IKE establishes not just keys, but Security Associations:
  - the protocol format used (many),
  - the cryptographic and hashing algorithm used,
  - and, of course, keys...
- IKE is very flexible. E.g., supports authentication based on a variety of pre-shared secrets (master keys).
- But also very complex. Many options, alternative subprotocols, ...

IKE (cont.)

- IKE evolved from a number of different protocols, including:
  - ISAKMP (Internet Security Association and Key Management Protocol): provides a framework and a generic negotiation protocol for establishing SAs and cryptographic keys, but does not prescribe any particular authentication mechanism.
  - Oakley: a suite of key agreement protocols in which two parties generate a key jointly.
- Roughly speaking, IKE combines packet formats of ISAKMP and exchanges of OAKLEY, which are based on Diffie-Hellman.
- We start by reviewing Diffie-Hellman and considering extensions.

The Diffie-Hellman protocol

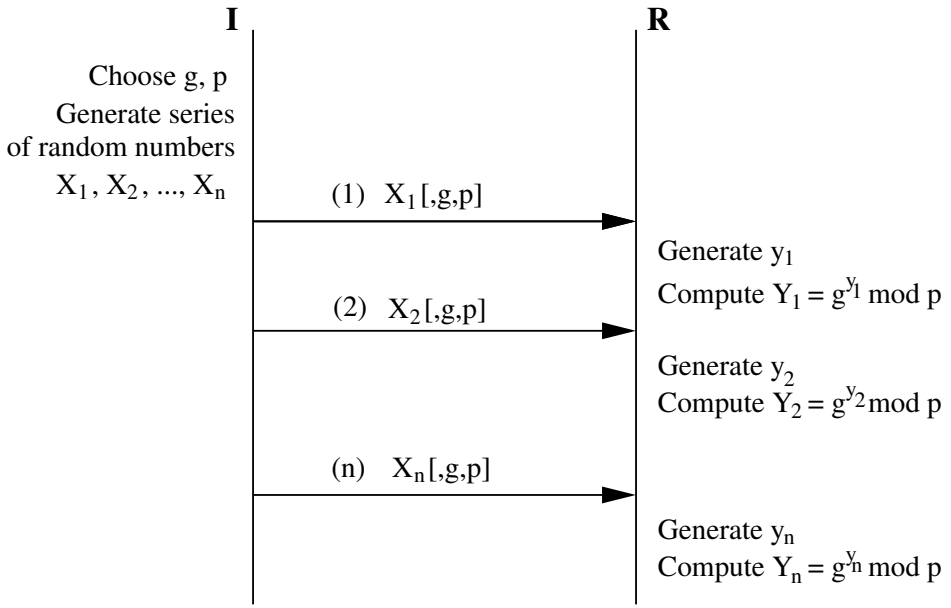


Basic Diffie-Hellman key-exchange: initiator I and responder R exchange "half-keys" to arrive at mutual session key *k*.

DOS against Diffie-Hellman

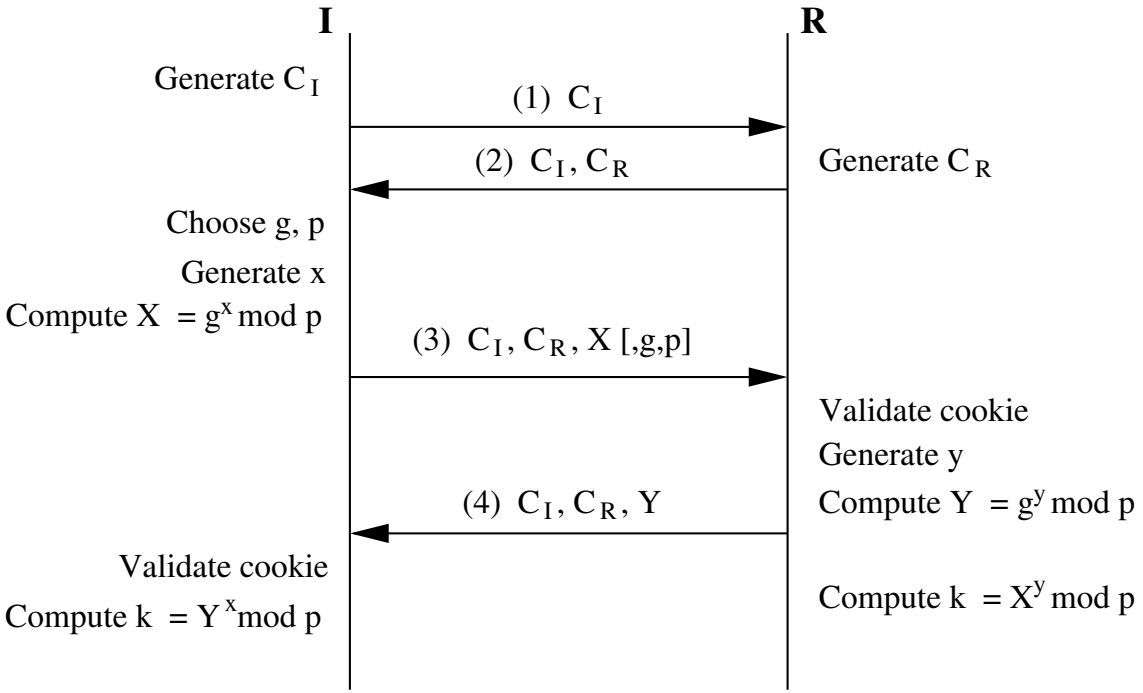
- Denial of Service (DoS) attack on R via flooding:

Attacker sends series of request packets, each with different spoofed source IP address, so that R must process each request. Expensive exponentiation and storage (of *y*s).



- Weak forms of protection available, e.g.,
  - Demand a response from a claimed address.
  - Make initiator perform some computation.

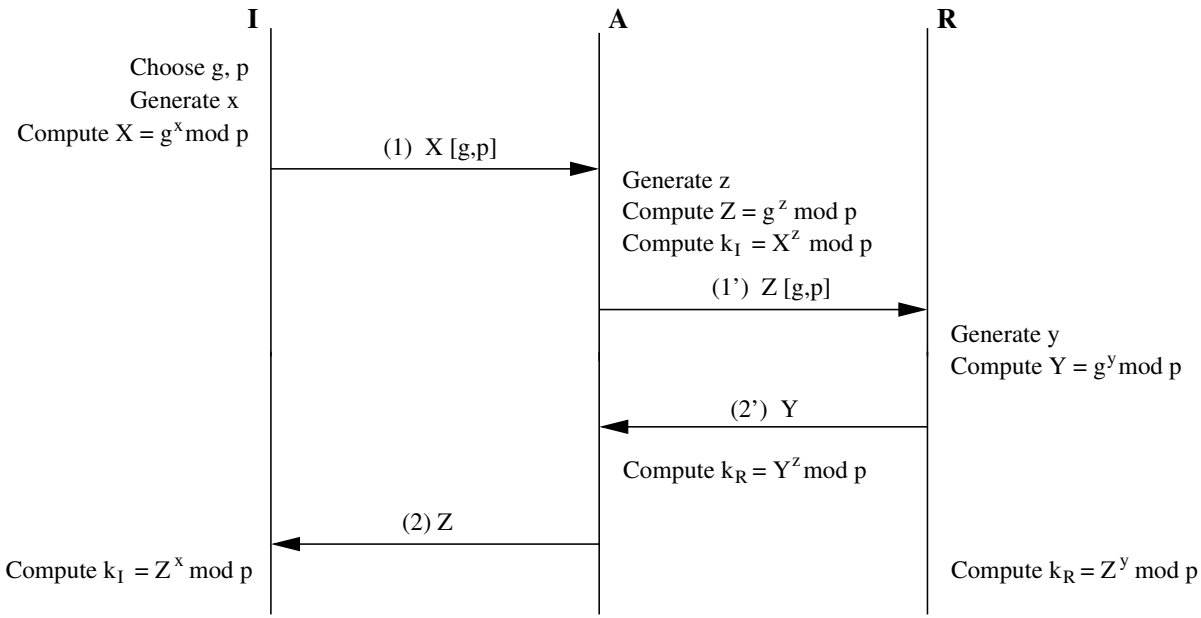
Cookies against DOS



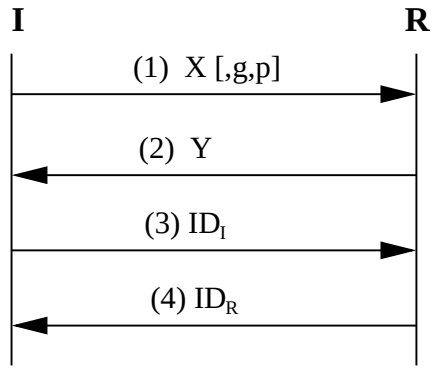
- I and R send "cookies" C_I and C_R to partner.
  Cookies are either randomly generated numbers, or even better, stateless, e.g., $C =$ hash(IP address, secret).
- Attacker must be at address and complete a cookie exchange for each address it spoofs.

Diffie Hellman – man-in-the-middle

- Unauthenticated keys $\Longrightarrow$ open to man-in-the-middle attacks



- Defend by adding two authentication steps.
  - ID_I and ID_R are digitally signed messages binding half keys to sender.
  - May also be encrypted with computed DH key.



But if you already share keys ...

- Why bother with Diffie-Hellman?
- Answer: perfect forward secrecy
  If someone records the entire conversation and later discovers Alice's and Bob's private keys, you don't want them to be able to decrypt everything.
- Example without PFS: SSL
  Alice chooses a secret, encrypts it with Bob's PK and rest of the session is protected based on that secret.
- Moreover, periodic generation of new keys and keying material complicates cryptanalysis.