IPSEC: AH and ESP

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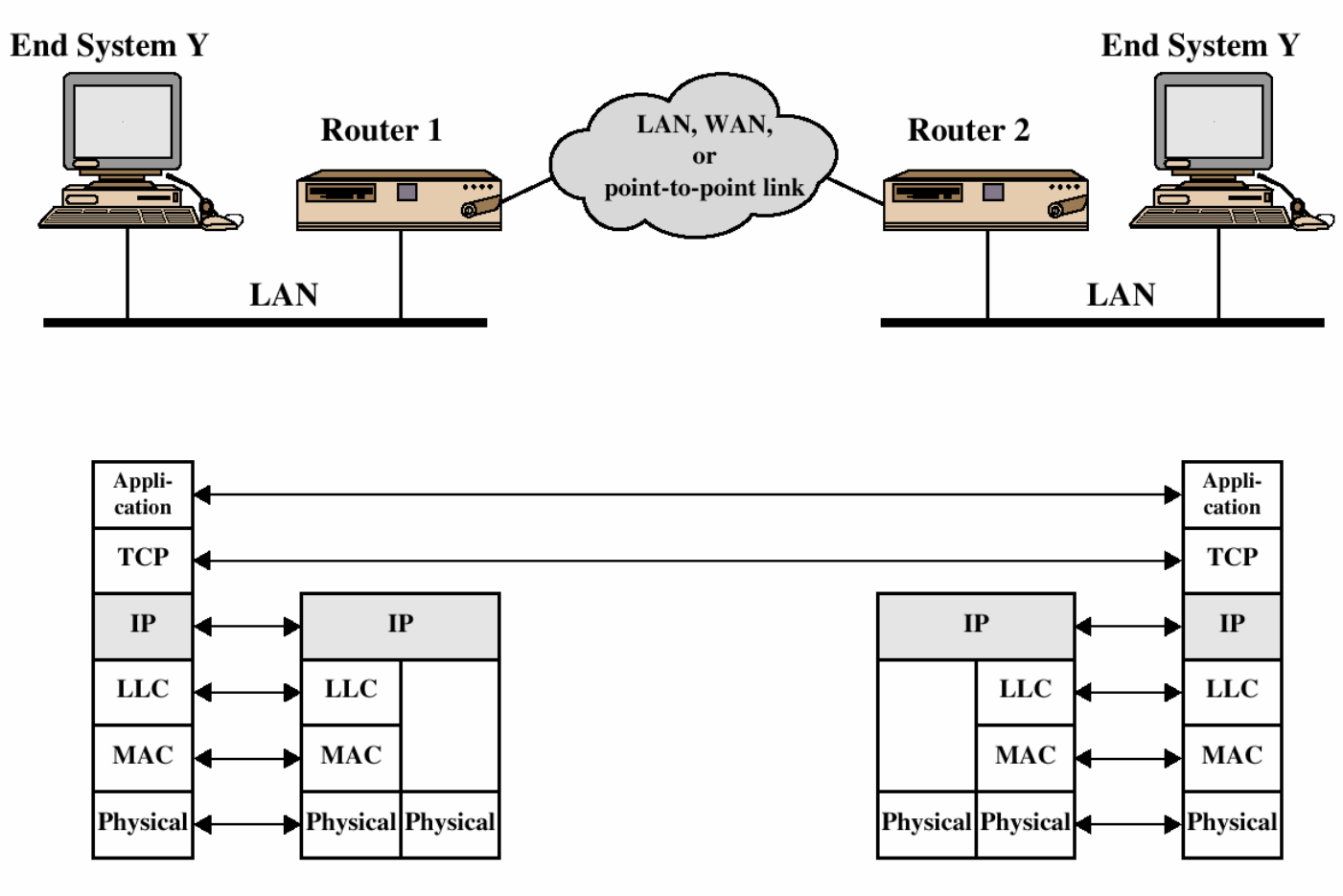
Based on material by Vitaly Shmatikov, Univ. of Texas, and by the previous course teachers

Reading

- Kaufman, chapter 16-17

TCP/IP Example

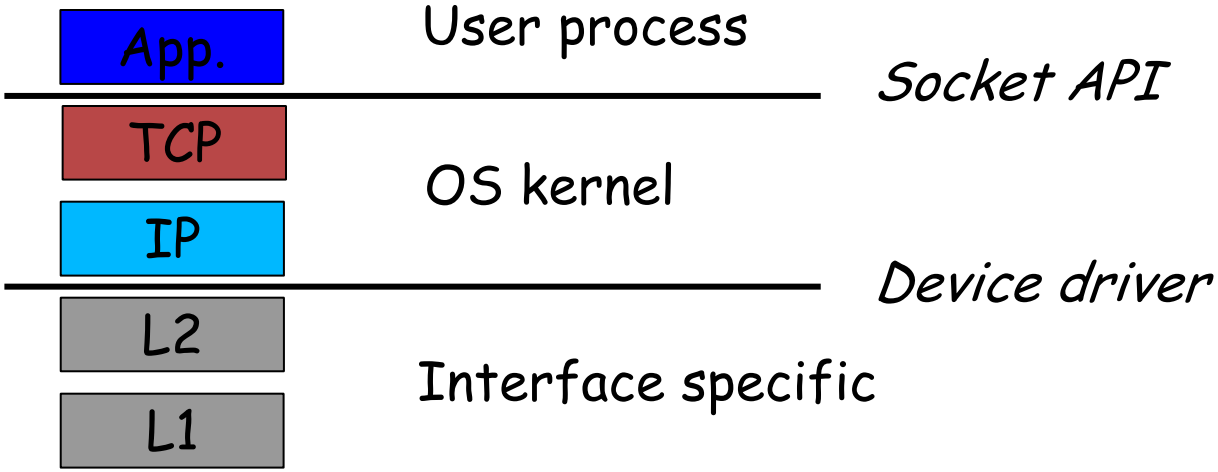


IP Security Issues

- Eavesdropping
- Modification of packets in transit
- Identity spoofing (forged source IP addresses)
- Denial of service

- Many solutions are application-specific
  - TLS for Web, S/MIME for email, SSH for remote login
- IPsec aims to provide a framework of open standards for secure communications over IP
  - Protect every protocol running on top of IPv4 and IPv6

Operating system layers

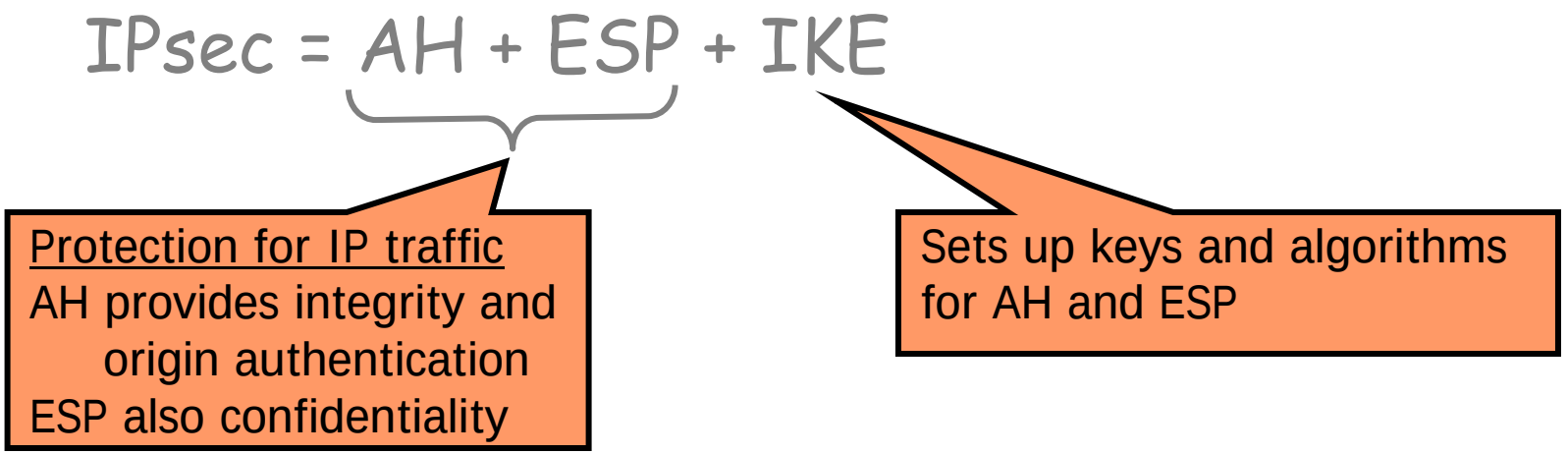


- SSL (Secure Socket Layer) changes the API to TCP/IP
  - Applications change, but OS doesn't
- IPSec implemented in OS
  - Applications and API remain unchanged (at least in theory)
- To make full use of IPSec, API and apps have to change!
  - and accordingly also the applications

Overview of IPsec

- Authenticated Keying
  - Internet Key Exchange (IKE)
    - Next lecture
- Data Encapsulation
  - ESP: IP Encapsulating Security Payload (RFC 4303)
  - AH: IP Authentication Header (RFC 4302)
- Security Architecture (RFC 4301)
  - Tunnel/transport Mode
  - Databases (Security Association, Policy, Peer Authorization)

IPsec: Network Layer Security



- AH and ESP rely on an existing security association
  - Idea: parties must share a set of secret keys and agree on each other's IP addresses and crypto algorithms
- Internet Key Exchange (IKE)
  - Goal: establish security association for AH and ESP
  - If IKE is broken, AH and ESP provide no protection!

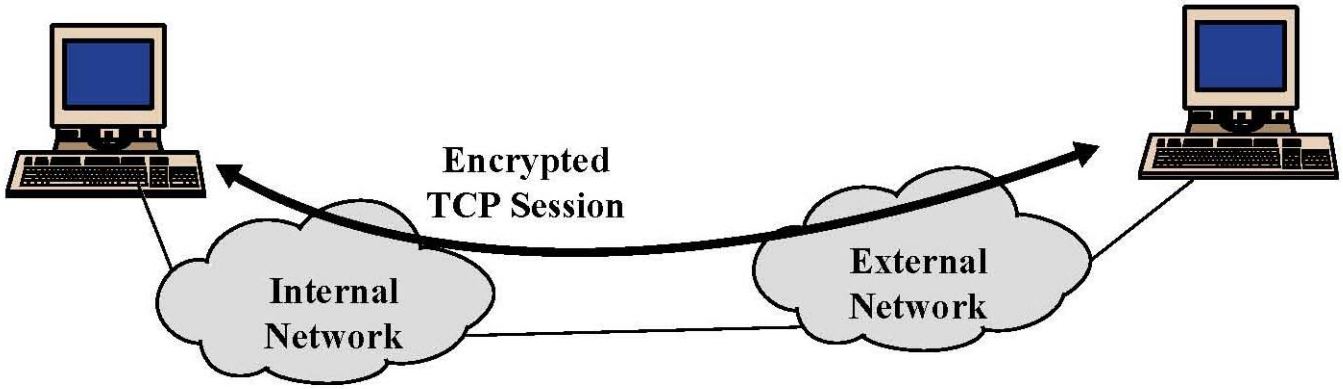
IPsec Security Services

- Authentication and integrity for packet sources
  - Ensures connectionless integrity (for a single packet) and partial sequence integrity (prevent packet replay)
- Confidentiality (encapsulation) for packet contents
- Authentication and encapsulation can be used separately or together
- Either provided in one of two modes
  - Transport mode
  - Tunnel mode

IPsec Modes

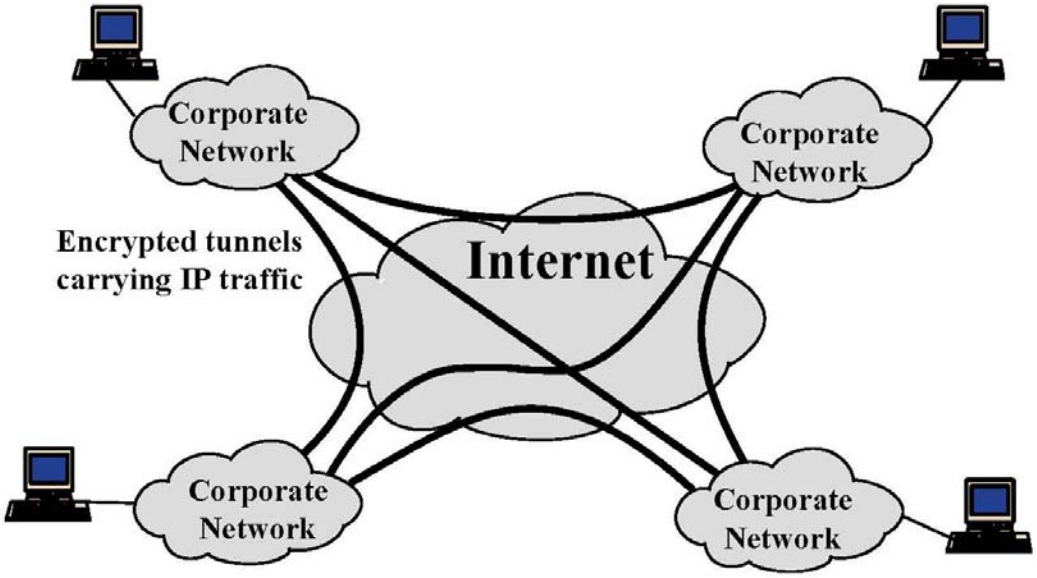
- Transport mode
  - Used to deliver services from host to host or from host to gateway
  - Usually within the same network, but can also be end-to-end across networks
- Tunnel mode
  - Used to deliver services from gateway to gateway or from host to gateway
  - Usually gateways owned by the same organization
    - With an insecure network in the middle

IPsec in Transport Mode



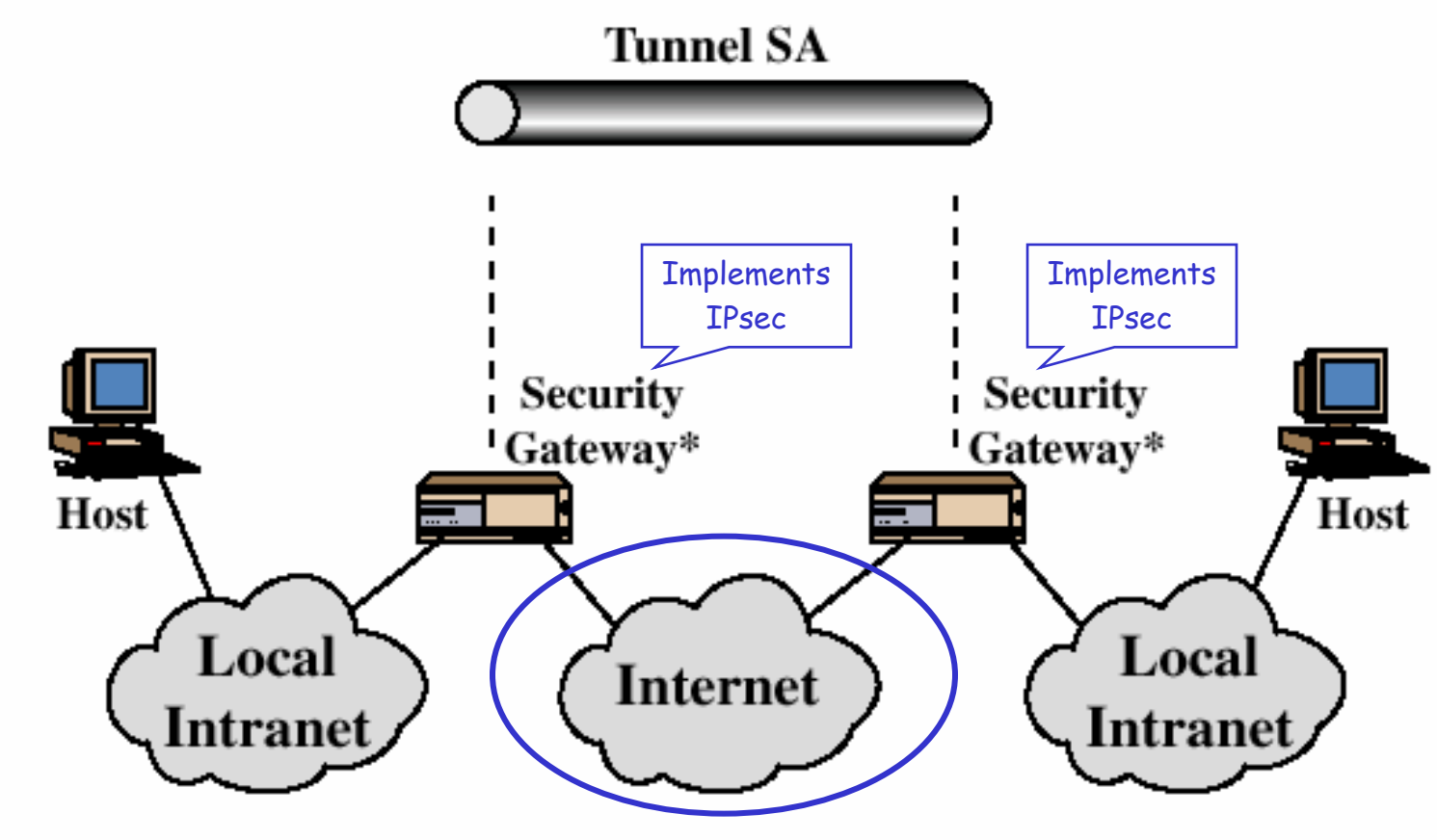
- End-to-end security between two hosts
  - Typically, client to gateway (e.g., PC to remote host)
- Requires IPsec support at each host

IPsec in Tunnel Mode



- Gateway-to-gateway security
  - Internal traffic behind gateways not protected
  - Typical application: virtual private network (VPN)
- Only requires IPsec support at gateways

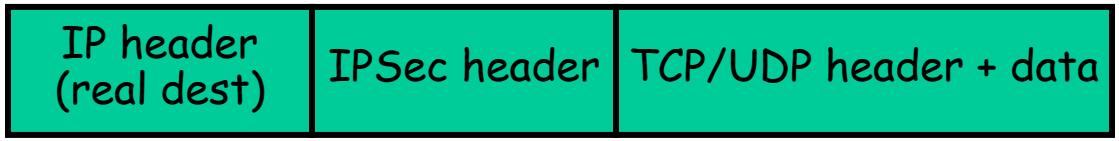
Tunnel Mode Illustration



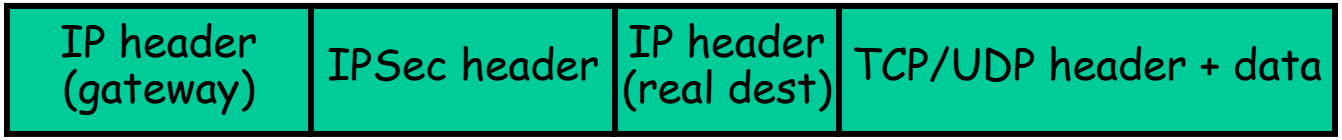
IPsec protects communication on the insecure part of the network

Transport Mode vs Tunnel Mode

- Transport mode secures packet payload and leaves IP header unchanged



- Tunnel mode encapsulates both IP header and payload into IPsec packets



Security Association (SA)

- One-way sender-recipient relationship
  - Manually configured or negotiated through IKE
- SA determines how packets are processed
  - Cryptographic algorithms, keys, AH/ESP, lifetimes, sequence numbers, mode (transport or tunnel) – read Kaufman!
- SA is uniquely identified by {SPI, dst IP addr, flag}
  - SPI: Security Parameter Index
    - Chosen be destination (unless traffic is multicast…)
  - Flag: ESP or AH
  - Each IPsec implementation keeps a database of SAs
  - SPI is sent with packet, tells recipient which SA to use

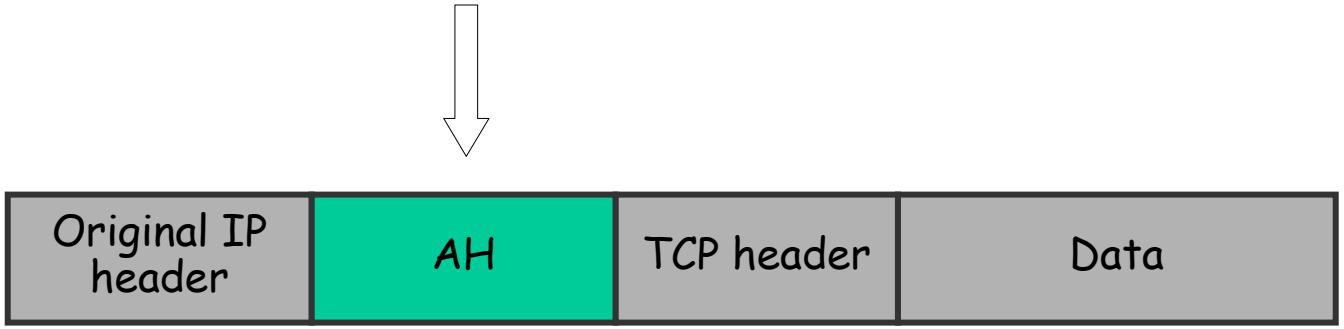
Sending and Receiving IPsec Packets

- When Alice is sending to Bob:
  - Consult "security policy database" (SPD) to check if packet should protected with IPsec or not ("selector" fields)
  - SPD provides pointer to the associated SA entry in the security association database (SAD)
  - SA provides SPI, algorithm, key, sequence number, etc.
  - Include the SPI in the message
- When Bob receives a message:
  - Lookup the SA based on the *destination* address and SPI (In a multicast message the address is not Bob's own)
  - Find algorithm, key, sequence number, etc.
  - After decrypting message, verify that packet matches "selector" in the policy database (SPD)

Encapsulation Formats

- AH
  - Authentication Header
  - Only provides integrity
- ESP
  - Encapsulating Security Payload
  - Provides integrity and/or privacy

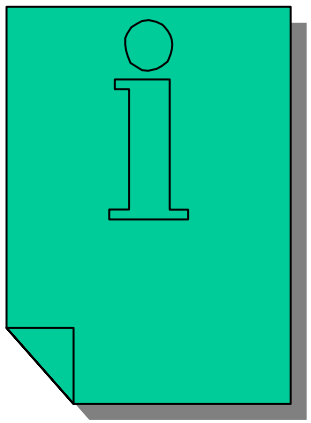
AH in transport mode



AH: Authentication Header

- RFC 4302
- Sender authentication
- Integrity for packet contents and IP header
- Sender and receiver must share a secret key
  - This key is used in HMAC computation
  - The key is set up by IKE key establishment protocol and recorded in the Security Association (SA)

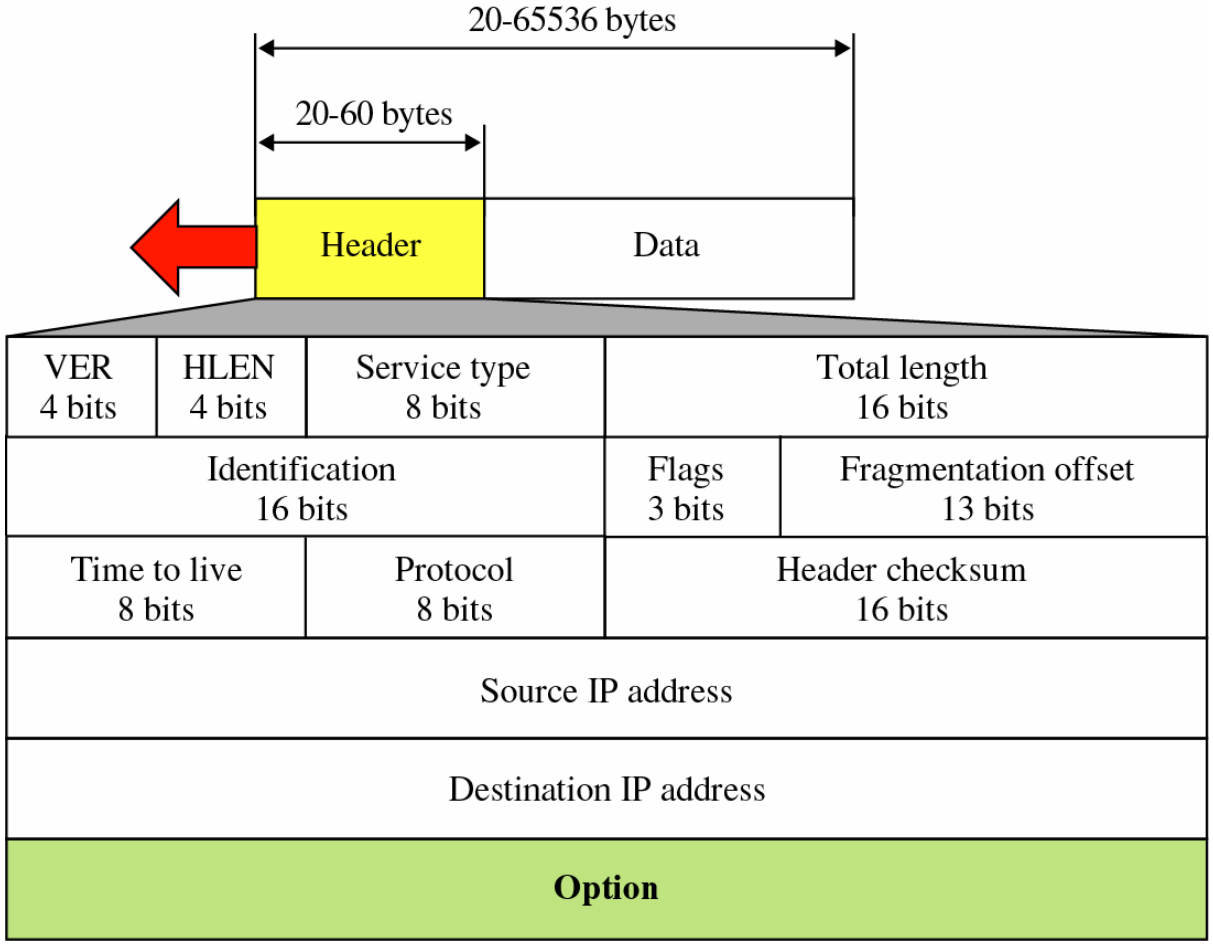
AHv2, RFC 4302



Let authentication header implement IP integrity by holding a hash of a shared secret and the content of an IP packet

AH and IP Header

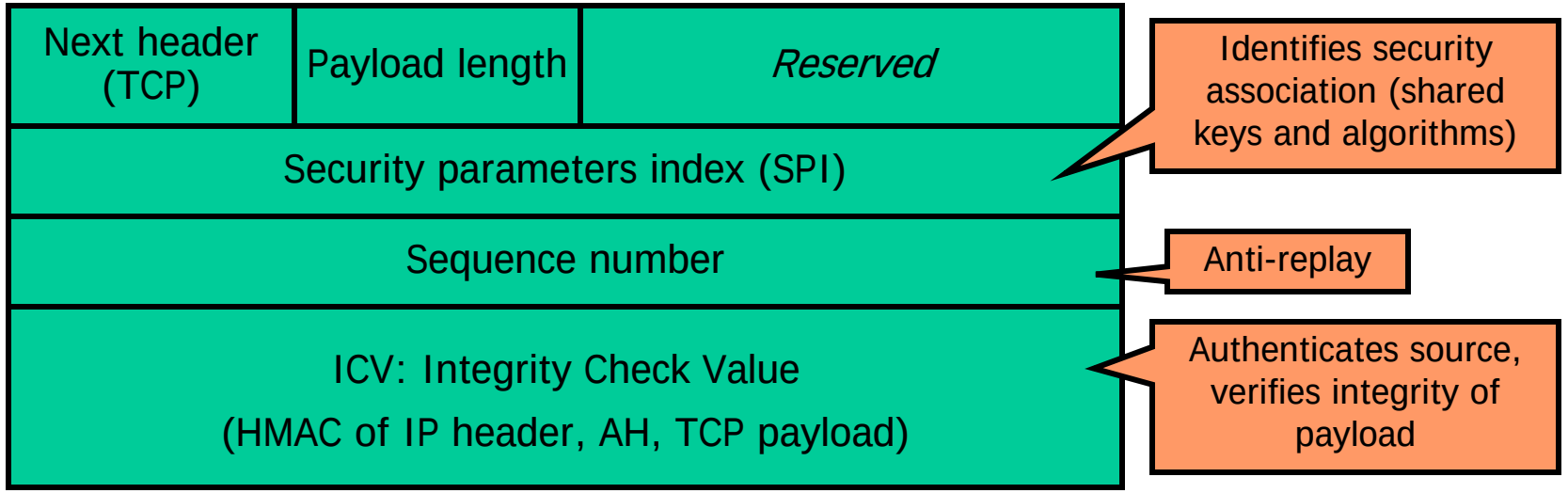
- Mutable fields
  - may change
    - Service type
    - Fragm. offset
    - TTL
    - Header checksum
- Predictable fields
  - may change in a predictable way
    - Dst address (source routing)
- Immutable fields
  - will not change
    - the rest....



Mutable fields can't be included in the AH's end-to-end integrity check

Authentication Header Format

- Provides integrity and origin authentication
- Authenticates portions of the IP header
- Anti-replay service (to counter denial of service)
- No confidentiality

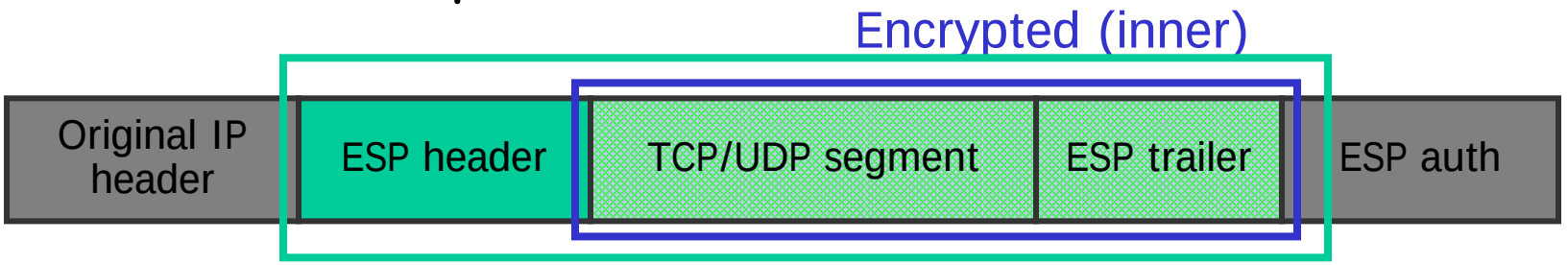


ESP: Encapsulating Security Payload

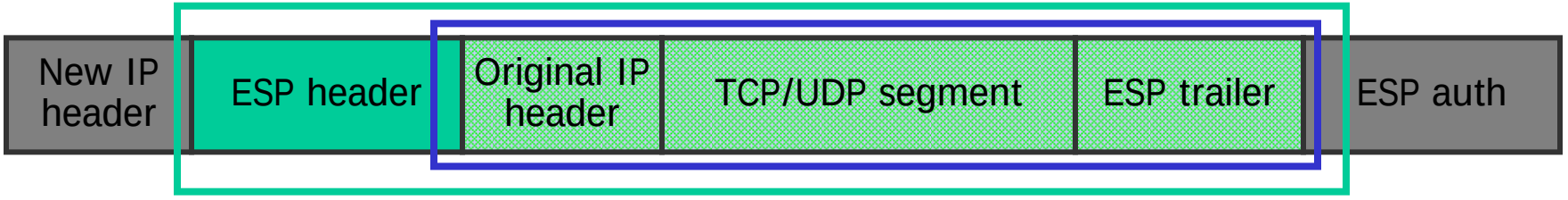
- RFC 4303
- Adds new header and trailer fields to packet
- Transport mode
  - Confidentiality of packet between two hosts
  - Complete hole through firewalls
  - Used sparingly
- Tunnel mode
  - Confidentiality of packet between two gateways or a host and a gateway
  - Implements VPN tunnels

ESP Security Guarantees

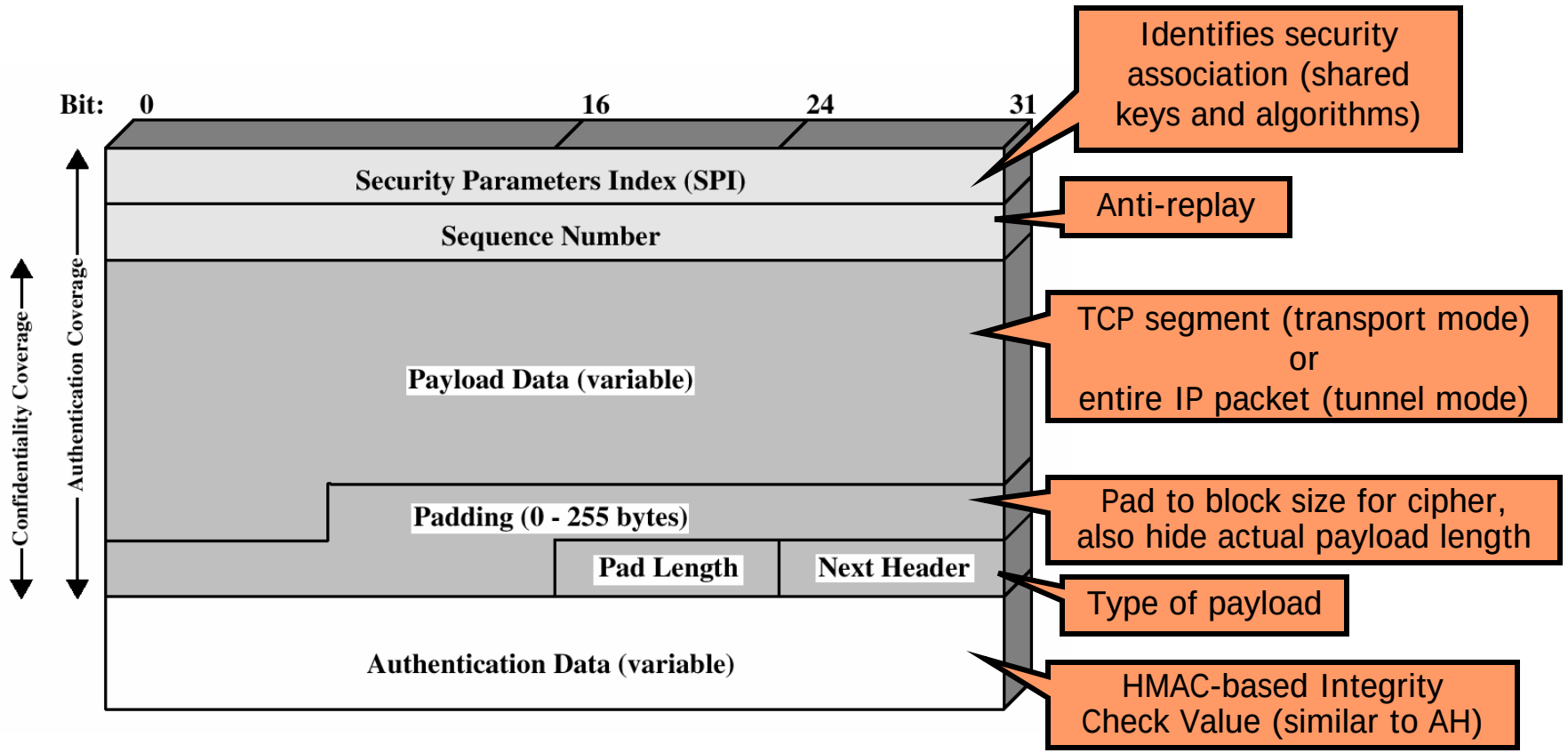
- Confidentiality and integrity for packet payload
  - Symmetric cipher negotiated as part of security assoc
- Optionally provides authentication (similar to AH)
- Can work in transport…



- …or tunnel mode



ESP Packet


Bit:
0
16
24
31
Security Parameters Index (SPI)
Sequence Number
Payload Data (variable)
Padding (0 - 255 bytes)
Pad Length
Next Header
Authentication Data (variable)
Confidentiality Coverage
Authentication Coverage
Identifies security association (shared keys and algorithms)
Anti-replay
TCP segment (transport mode) or entire IP packet (tunnel mode)
Pad to block size for cipher, also hide actual payload length
Type of payload
HMAC-based Integrity Check Value (similar to AH)

Virtual Private Networks (VPN)

- ESP is often used to implement a VPN
  - Packets go from internal network to a gateway with TCP/IP headers for address in another network
  - Entire packet hidden by encryption
    - Including original headers so destination addresses are hidden
  - Receiving gateway decrypts packet and forwards original IP packet to receiving address in the network that it protects
- This is known as a VPN tunnel
  - Secure communication between parts of the same organization over public Internet

Use Cases Summary

- Host-Host
  - Transport mode
  - (Or tunnel mode)
- Gateway-Gateway
  - Tunnel mode
- Host-Gateway
  - Tunnel mode