Cryptography Applications

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Virtual Private Networks

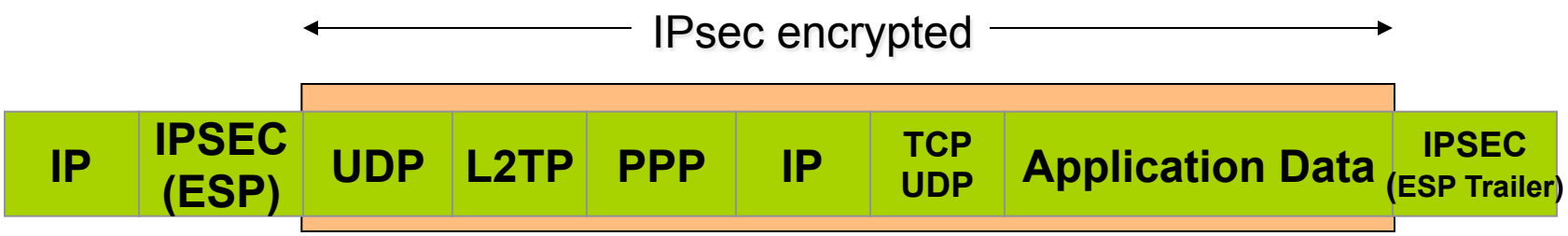
Any VPN is not automatically secure. You need to add security functionality to create secure VPNs. That means using firewalls for access control and probably IPsec or SSL/TLS for confidentiality and data origin authentication.

Layer 2 Tunneling Protocol

- Designed in IETF PPP Extensions working group
  - Combination of Cisco L2F & PPTP features
  - L2TP RFC 2661, Aug 1999
  - Uses UDP port 1701 for control and data packets
  - Uses PPP for packet encapsulation – carries most protocols (also non-IP protocols)
- Security Functionality
  - Control session authentication, keepalives
  - EAP for a broader authentication mechanisms
  - IPsec ESP for confidentiality and integrity
  - IKE for key management

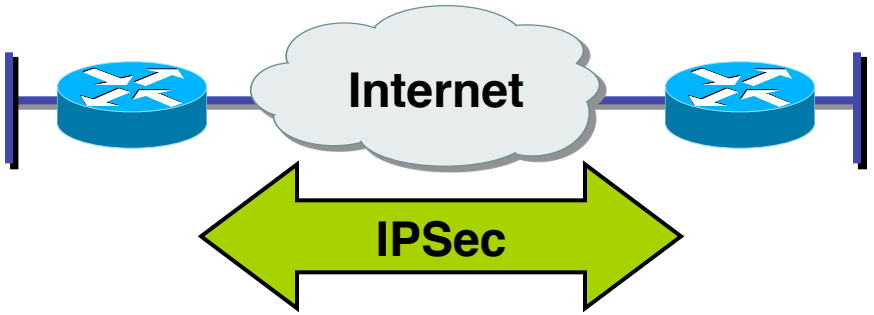
L2TP and IPsec

Multiple Encapsulations
…..careful of packet size!!



Ping with large MTU size….help discover fragmentation issues!!

What Is IPSec?

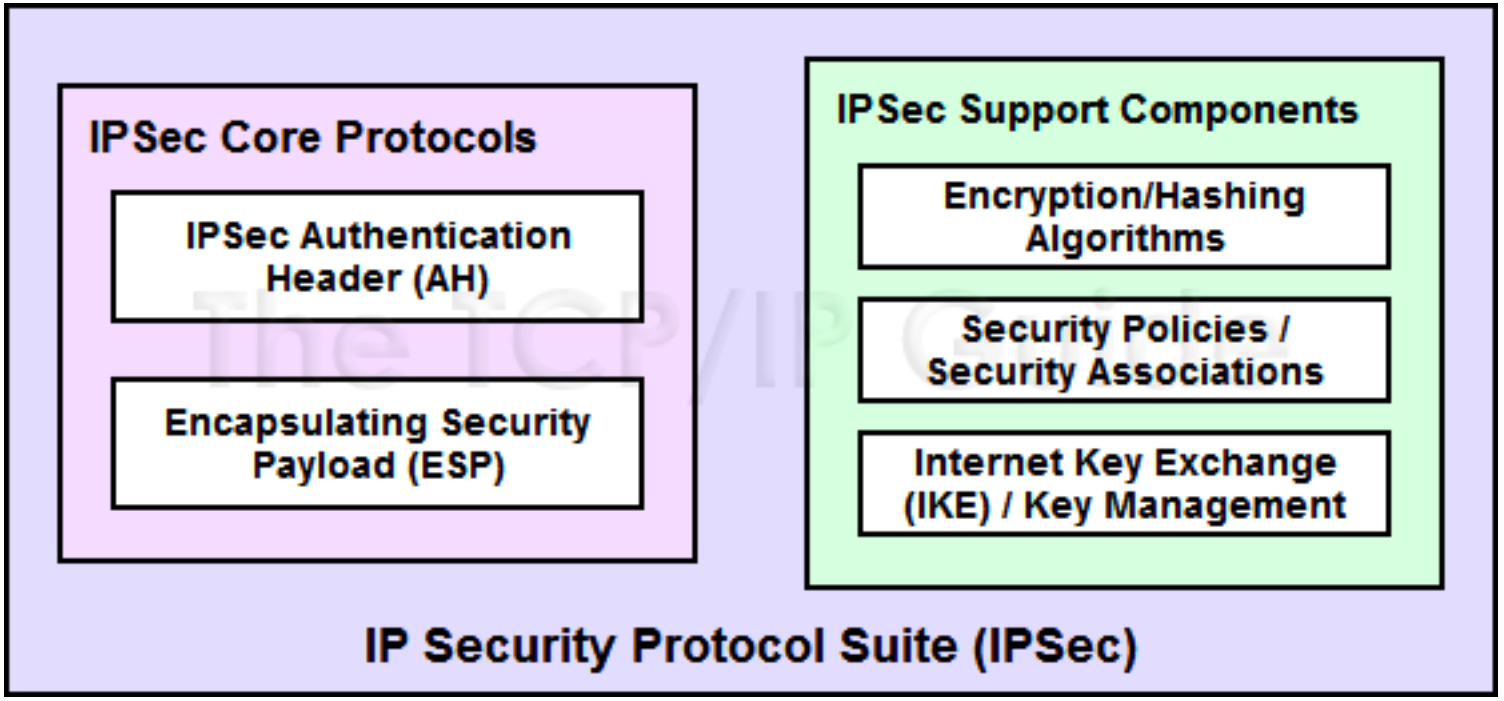


- IETF standard that enables encrypted communication between peers:
  - Consists of open standards for securing private communications
  - Network layer encryption ensuring data confidentiality, integrity, and authentication
  - Scales from small to very large networks

What Does IPsec Provide ?

- Confidentiality….many algorithms to choose from
- Data integrity and source authentication
  - Data “signed” by sender and “signature” verified by the recipient
  - Modification of data can be detected by signature “verification”
  - Because “signature” based on a shared secret, it gives source authentication
- Anti-replay protection
  - Optional : the sender must provide it but the recipient may ignore
- Key Management
  - IKE – session negotiation and establishment
  - Sessions are rekeyed or deleted automatically
  - Secret keys are securely established and authenticated
  - Remote peer is authenticated through varying options

IPsec Components



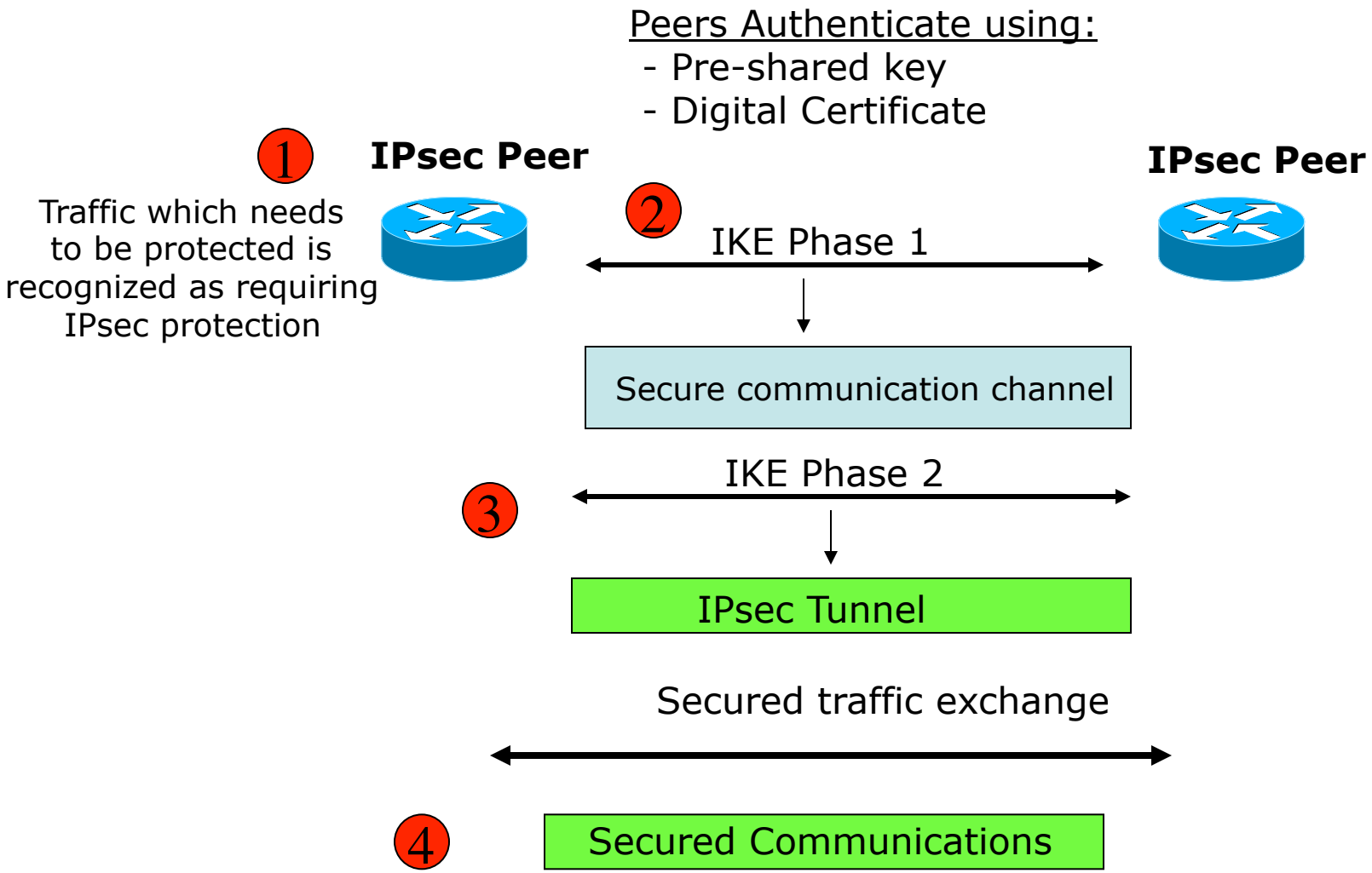
IPsec Components

- AH (Authentication Header)
  - Authentication is applied to the entire packet, with the mutable fields in the IP header zeroed out
  - If both ESP and AH are applied to a packet, AH follows ESP
  - Standard requires HMAC-MD5-96 and HMAC-SHA1-96….older implementations also support keyed MD5
- ESP (Encapsulating Security Payload)
  - Must encrypt and/or authenticate in each packet
  - Encryption occurs before authentication
  - Authentication is applied to data in the IPsec header as well as the data contained as payload
  - Standard requires DES 56-bit CBC and Triple DES. Can also use RC5, IDEA, Blowfish, CAST, RC4, NULL
- IKE (Internet Key Exchange)
  - Automated SA (Security Association) creation and key management

IPsec Components

- Encryption/Hashing Algorithms:
  - AH and ESP are generic and do not specify the exact mechanism used for encryption.
  - Two common ones used with IPSec are Message Digest 5 (MD5) and Secure Hash Algorithm 1 (SHA-1).
  - These are also called hashing algorithms because they work by computing a formula called a hash based on input data and a key.
- Security Policies and Associations, and Management Methods:
  - Some means is required to keep track of the security relationships between devices.
  - This is done in IPSec using constructs called security policies and security associations, and by providing ways to exchange security association information.
- Key Exchange Framework and Mechanism:
  - Need to be able to share keys for unlocking the encryption.
  - Internet Key Exchange (IKE) provides these capabilities

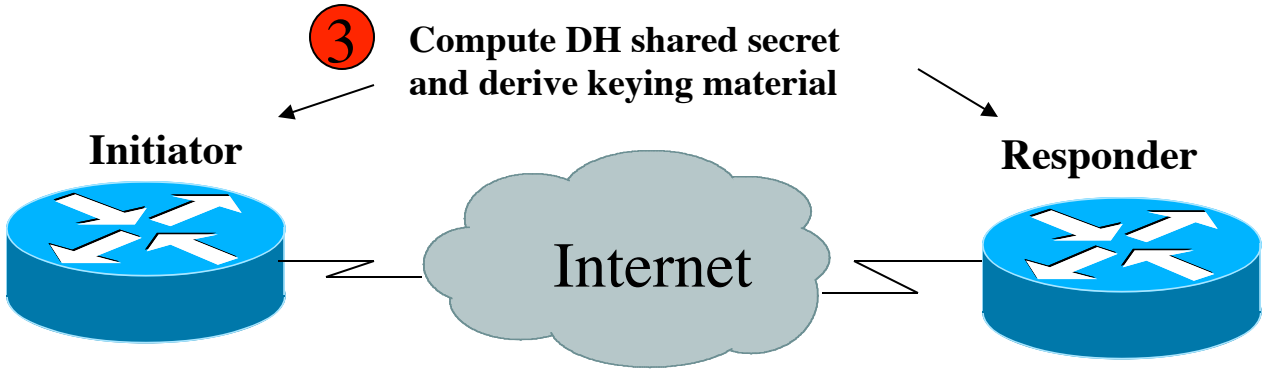
IPsec with IKE



IPsec IKE Phase 1 Uses DH Exchange

- First public key algorithm (1976)
- Diffie Hellman is a key establishment algorithm
  - Two parties in a DF exchange can generate a shared secret
  - There can even be N-party DF changes where N peers can all establish the same secret key
- Diffie Hellman can be done over an insecure channel
- IKE authenticates a Diffie-Hellman exchange
  - Pre-shared secret
  - Nonce (RSA signature)
  - Digital signature

IKE Phase 1 Main Mode



1 **Negotiate IKE Policy**

IKE Message 1 (SA proposal) →

← IKE Message 2 (accepted SA)

2 **Authenticated DH Exchange**

IKE Message 3 (DH public value, nonce) →

← IKE Message 4 (DH public value, nonce)

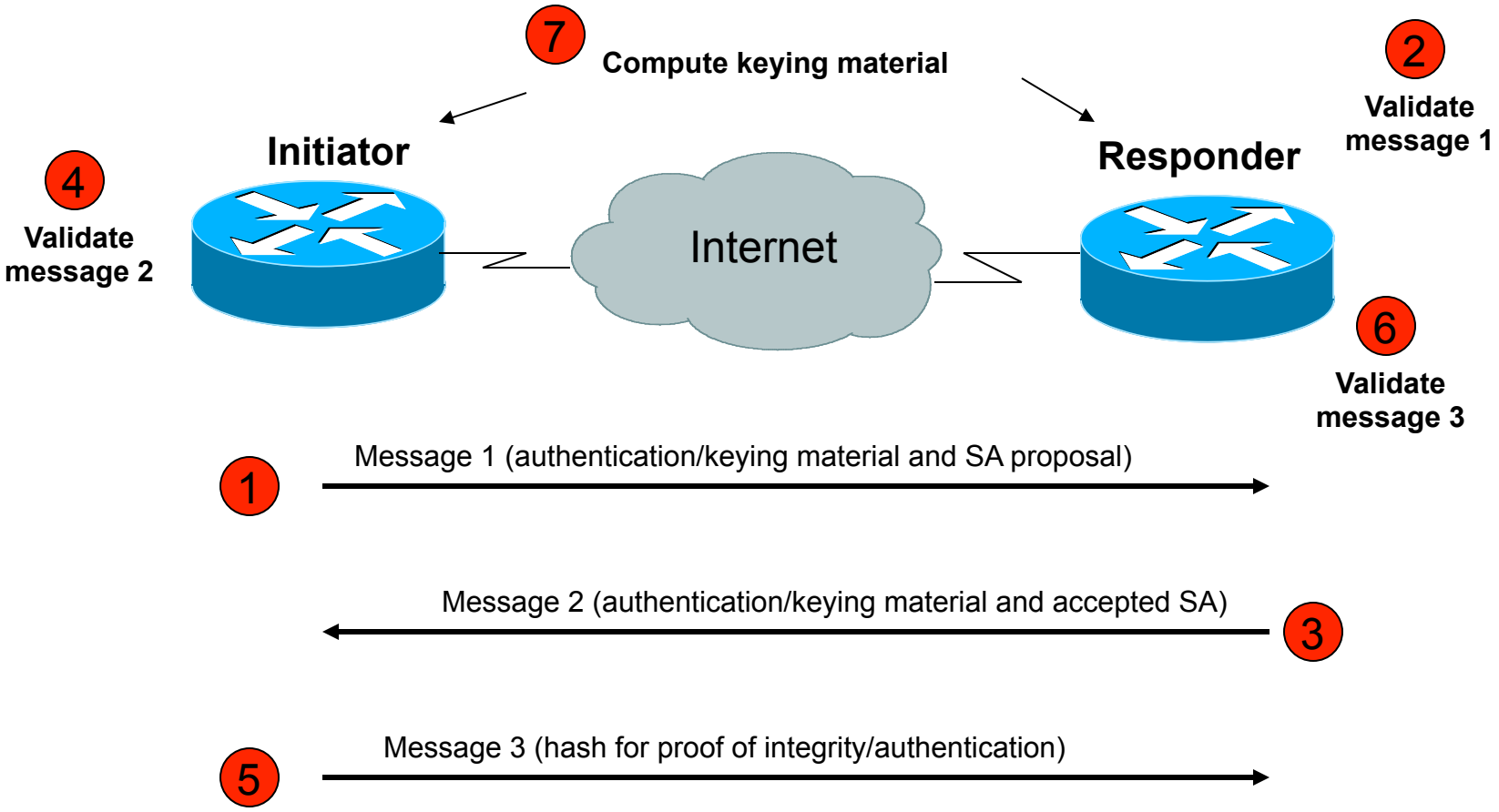
4 **Protect IKE Peer Identity**

IKE Message 5 (Authentication material, ID) →

← IKE Message 6 (Authentication material, ID)

(Encrypted)

IKE Phase 2 Quick Mode



IKE v2: Replacement for Current IKE Specification

- Feature Preservation
  - Most features and characteristics of baseline IKE v1 protocol are being preserved in v2
- Compilation of Features and Extensions
  - Quite a few features that were added on top of the baseline IKE protocol functionality in v1 are being reconciled into the mainline v2 framework
- Some New Features

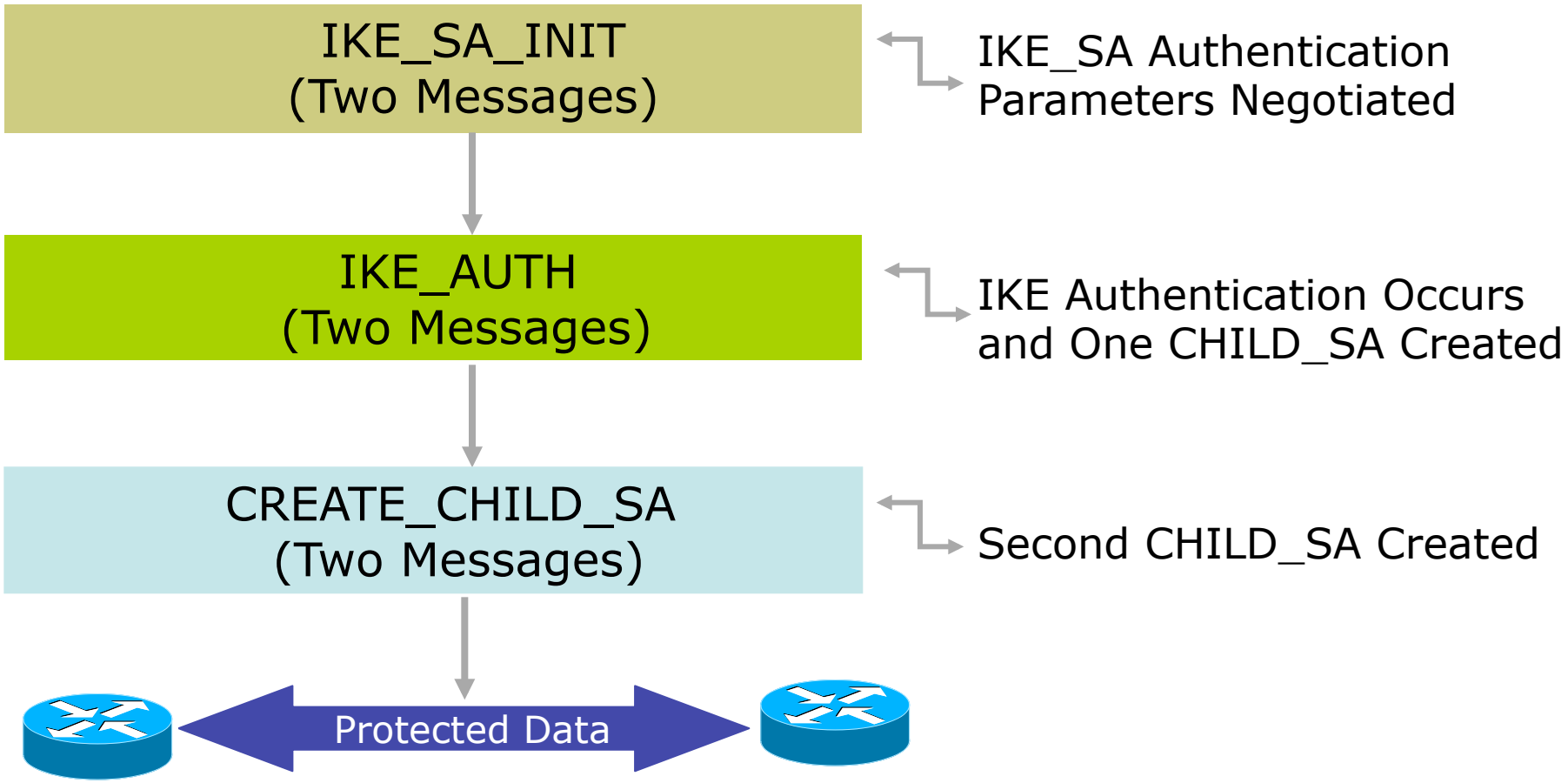
IKE v2: What Is Not Changing

- Features in v1 that have been debated but are ultimately being preserved in v2
  - Most payloads reused
  - Use of nonces to ensure uniqueness of keys
- v1 extensions and enhancements being merged into mainline v2 specification
  - Use of a ‘configuration payload’ similar to MODECFG for address assignment
  - ‘X-auth’ type functionality retained through EAP
  - Use of NAT Discovery and NAT Traversal techniques

IKE v2: What Is Changing

- Significant Changes Being to the Baseline Functionality of IKE
  - EAP adopted as the method to provide legacy authentication integration with IKE
  - Public signature keys and pre-shared keys, the only methods of IKE authentication
  - Use of ‘stateless cookie’ to avoid certain types of DOS attacks on IKE
  - Continuous phase of negotiation

How Does IKE v2 Work?



Relevant Standard(s)

- IETF specific
  - rfc2409: IKEv1
  - rfc4301: IPsec Architecture (updated)
  - rfc4303: IPsec ESP (updated)
  - rfc4306: IKEv2
  - rfc4718: IKEv2 Clarifications
  - rfc4945: IPsec PKI Profile
- IPv6 and IPsec
  - rfc4294: IPv6 Node Requirements
  - Rfc4552: Authentication/Confidentiality for OSPFv3
  - rfc4877: Mobile IPv6 Using IPsec (updated)
  - rfc4891: Using IPsec to secure IPv6-in-IPv4 Tunnels

Considerations For Using IPsec

- Security Services
  - Data origin authentication
  - Data integrity
  - Replay protection
  - Confidentiality
- Size of network
- How trusted are end hosts – can apriori communication policies be created?
- Vendor support
- What other mechanisms can accomplish similar attack risk mitigation

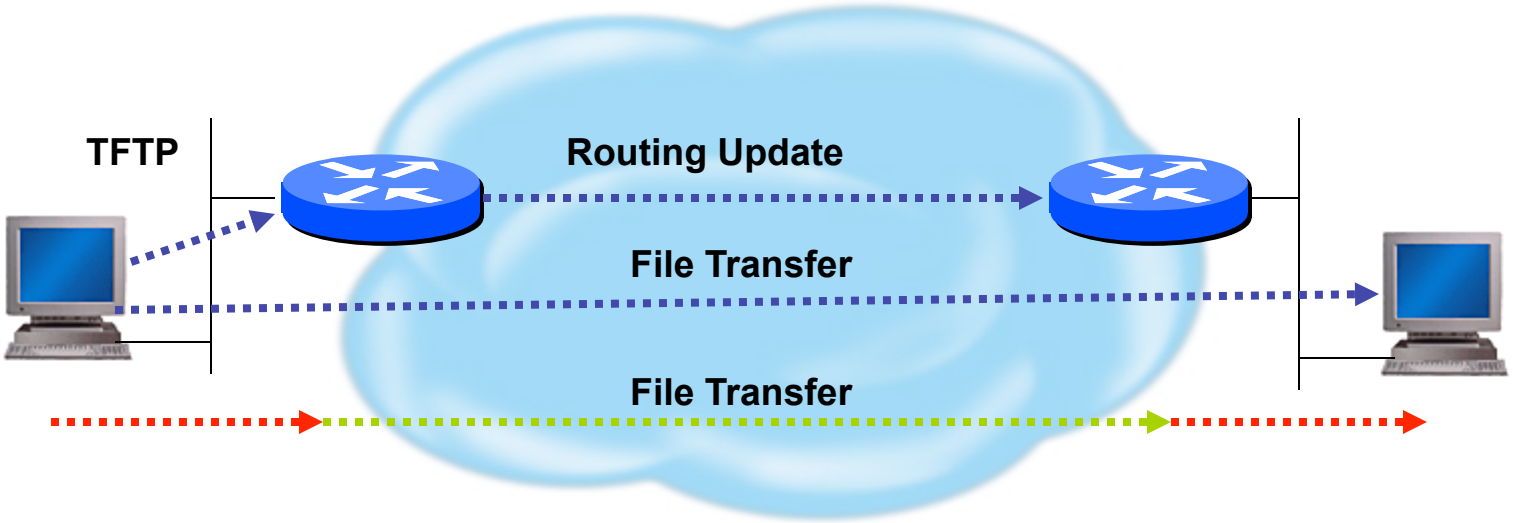
Non-Vendor Specific Deployment Issues

- Historical Perception
  - Configuration nightmare
  - Not interoperable
- Performance Perception
  - Need empirical data
  - Where is the real performance hit?
- Standards Need Cohesion

Vendor Specific Deployment Issues

- Lack of interoperable defaults
  - A default does NOT mandate a specific security policy
  - Defaults can be modified by end users
- Configuration complexity
  - Too many knobs
  - Vendor-specific terminology
- Good News: IPv6 support in most current implementations

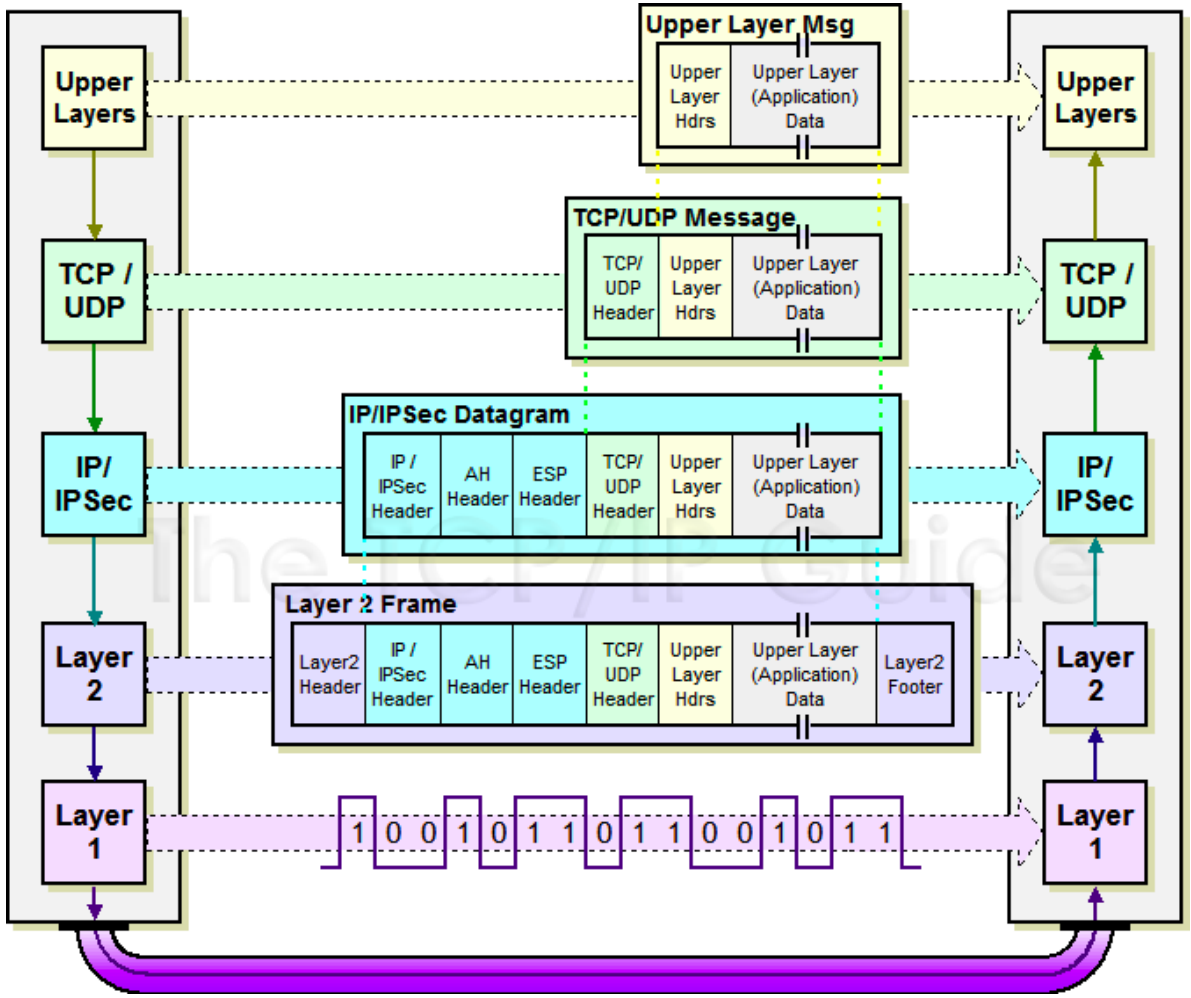
Transport vs Tunnel Mode



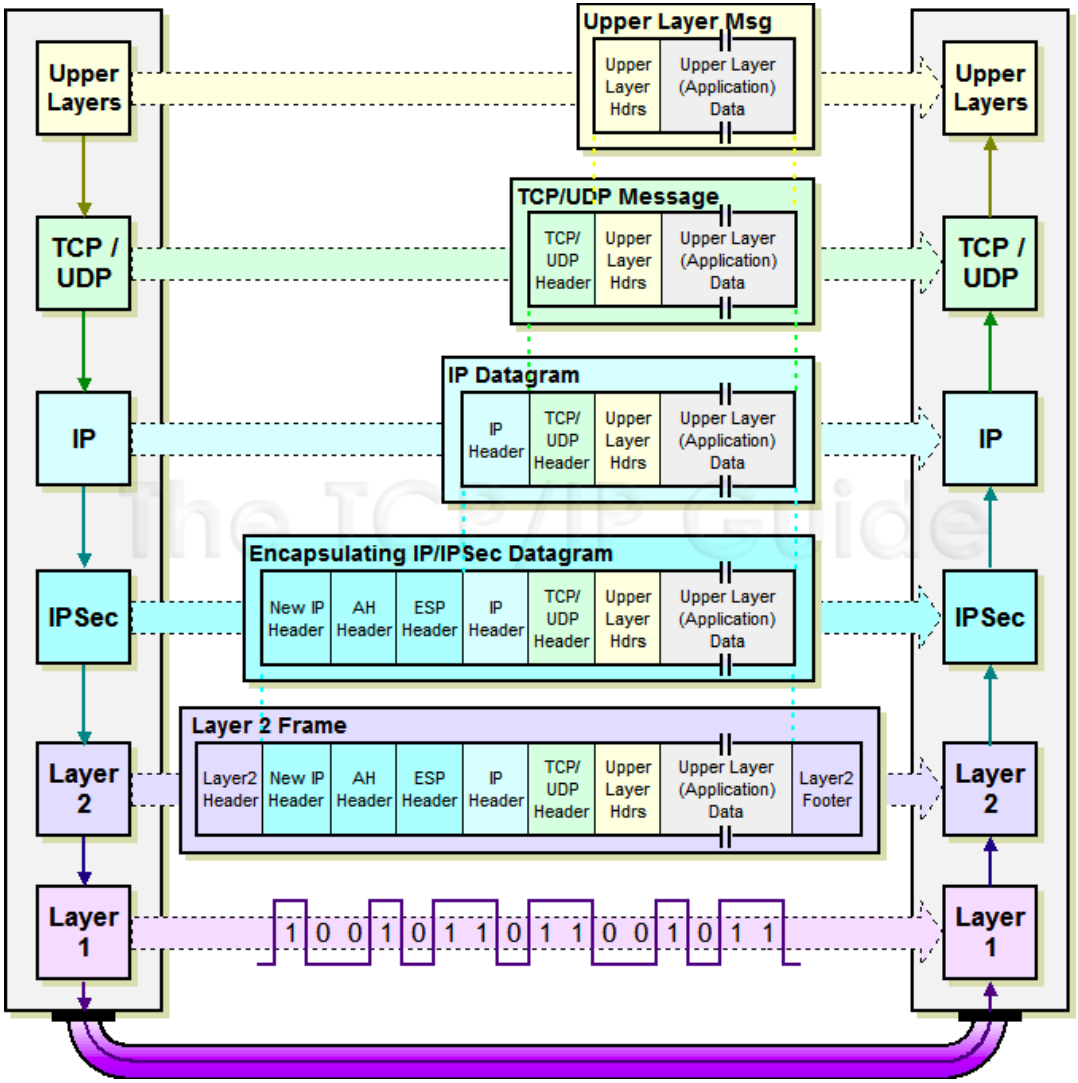
Transport Mode: End systems are the initiator and recipient of protected traffic

Tunnel Mode: Gateways act on behalf of hosts to protect traffic

Transport Mode



Tunnel Mode


Upper Layers
TCP / UDP
IP
IPSec
Layer 2
Layer 1
Upper Layer Msg
Upper Layer Hdrs
Upper Layer (Application) Data
TCP/UDP Message
TCP/ UDP Header
IP Datagram
IP Header
Encapsulating IP/IPSec Datagram
New IP Header
AH Header
ESP Header
Layer 2 Frame
Layer2 Header
Layer2 Footer
1 0 0 1 0 1 1 0 1 1 0 0 1 0 1 1

IPsec Concerns

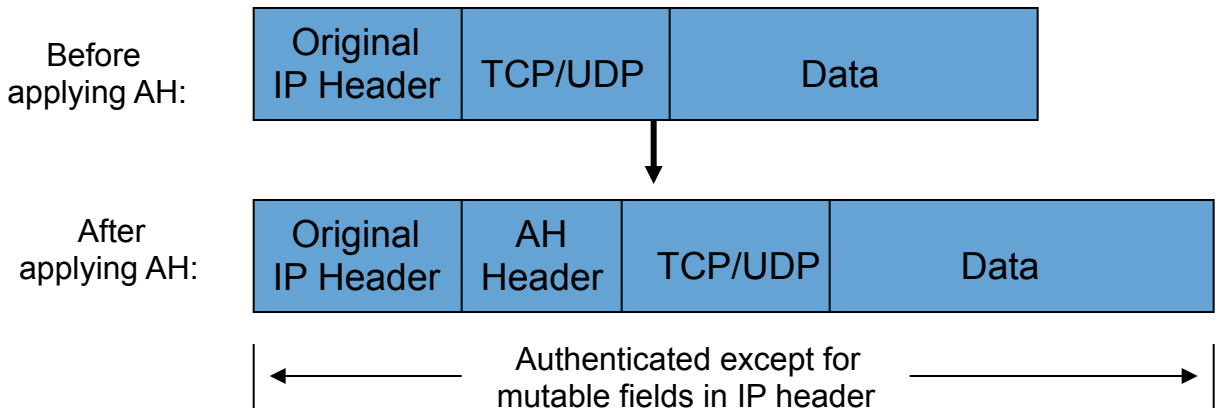
- Are enough people aware that IKEv2 is not backwards compatible with IKEv1?
  - IKEv1 is used in most IPsec implementations
  - Will IKEv2 implementations first try IKEv2 and then revert to IKEv1?
- Is IPsec implemented for IPv6?
  - Some implementations ship IPv6 capable devices without IPsec capability and host requirements is changed from MUST to SHOULD implement
- OSPFv3
  - All vendors ‘IF’ they implement IPsec used AH
  - Latest standard to describe how to use IPsec says MUST use ESP w/Null encryption and MAY use AH

IPsec Concerns (cont)

- What is transport mode interoperability status?
  - Will end user authentication be interoperable?
- PKI Issues
  - Which certificates do you trust?
  - How does IKEv1 and/or IKEv2 handle proposals with certificates?
  - Should common trusted roots be shipped by default?
  - Who is following and implementing pki4ipsec-ikecert-profile (rfc4945)
- Have mobility scenarios been tested?
  - Mobility standards rely heavily on IKEv2
- ESP – how determine if ESP-Null vs Encrypted

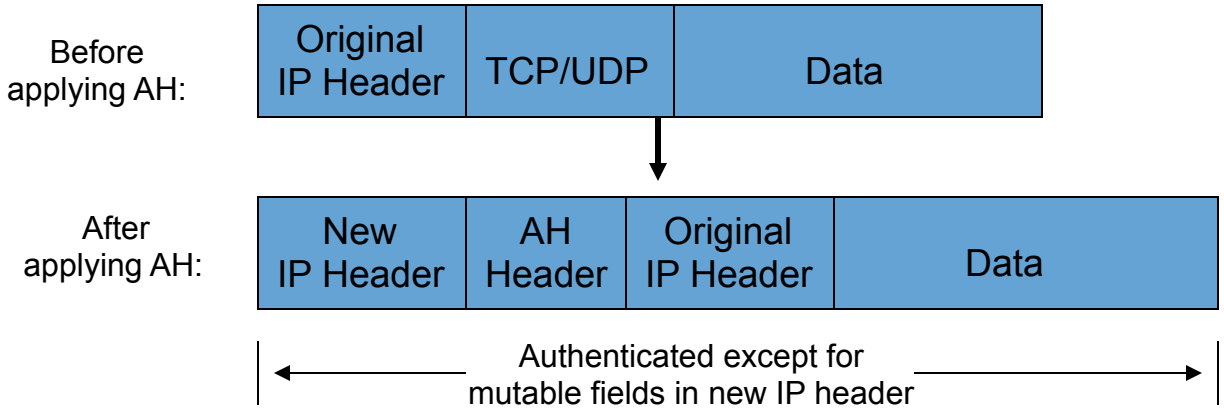
IPv4 IPsec AH

IPv4 AH Transport Mode:



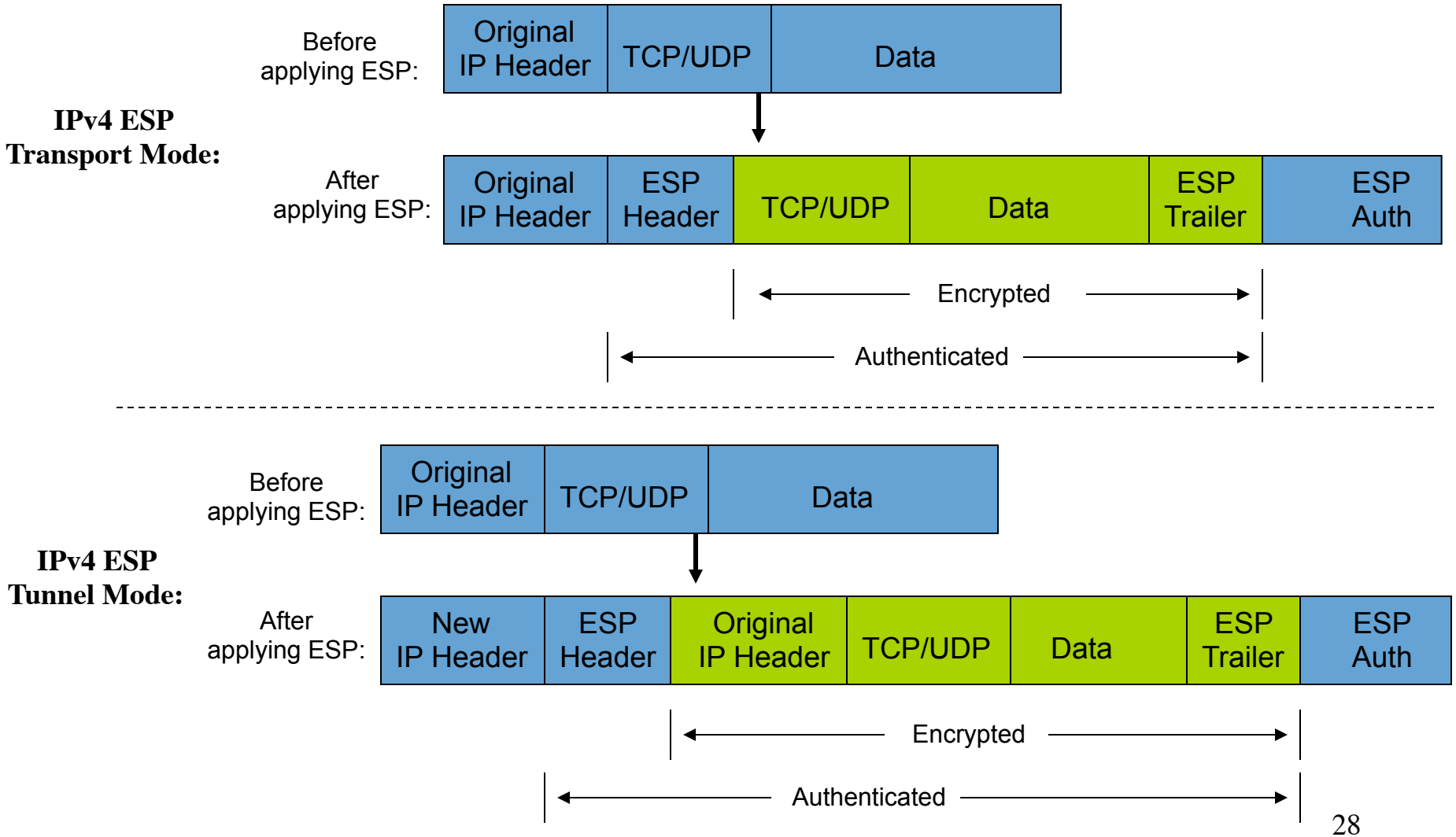
Mutable Fields:
- ToS
- TTL
- Hdr Checksum
- Offset
- Flags

IPv4 AH Tunnel Mode:

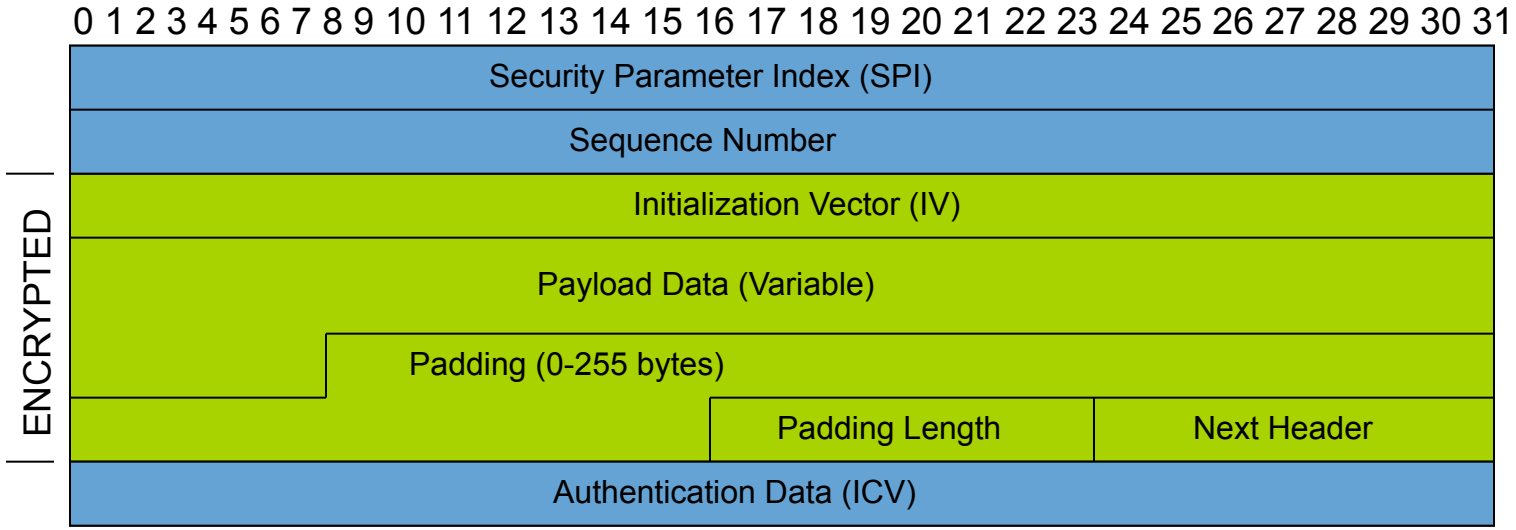


Mutable Fields:
- ToS
- TTL
- Hdr Checksum
- Offset
- Flags

IPv4 IPsec ESP



ESP Header Format



SPI:	Arbitrary 32-bit number that specifies SA to the receiving device
Seq #:	Start at 1 and must never repeat; receiver may choose to ignore
IV:	Used to initialize CBC mode of an encryption algorithm
Payload Data:	Encrypted IP header, TCP or UDP header and data
Padding:	Used for encryption algorithms which operate in CBC mode
Padding Length:	Number of bytes added to the data stream (may be 0)
Next Header:	The type of protocol from the original header which appears in the encrypted part of the packet
Auth Data:	ICV is a digital signature over the packet and it varies in length depending on the algorithm used (SHA-1, MD5)

Default Issues

Vendor A

IKE Phase 1
- SHA1
- RSA-SIG
- Group 1
- Lifetime 86400 Sec
- Main Mode

IKE Phase 2
- PFS
- Group 1

Vendor B

IKE Phase 1
- MD5
- Pre-Share Key
- Group 5
- Lifetime 86400 Sec
- Main Mode

IKE Phase 2
- PFS
- Group 5

Vendor C

IKE Phase 1
- SHA1
- Pre-Share Key
- Group 2
- Lifetime 86400 Sec
- Aggressive Mode

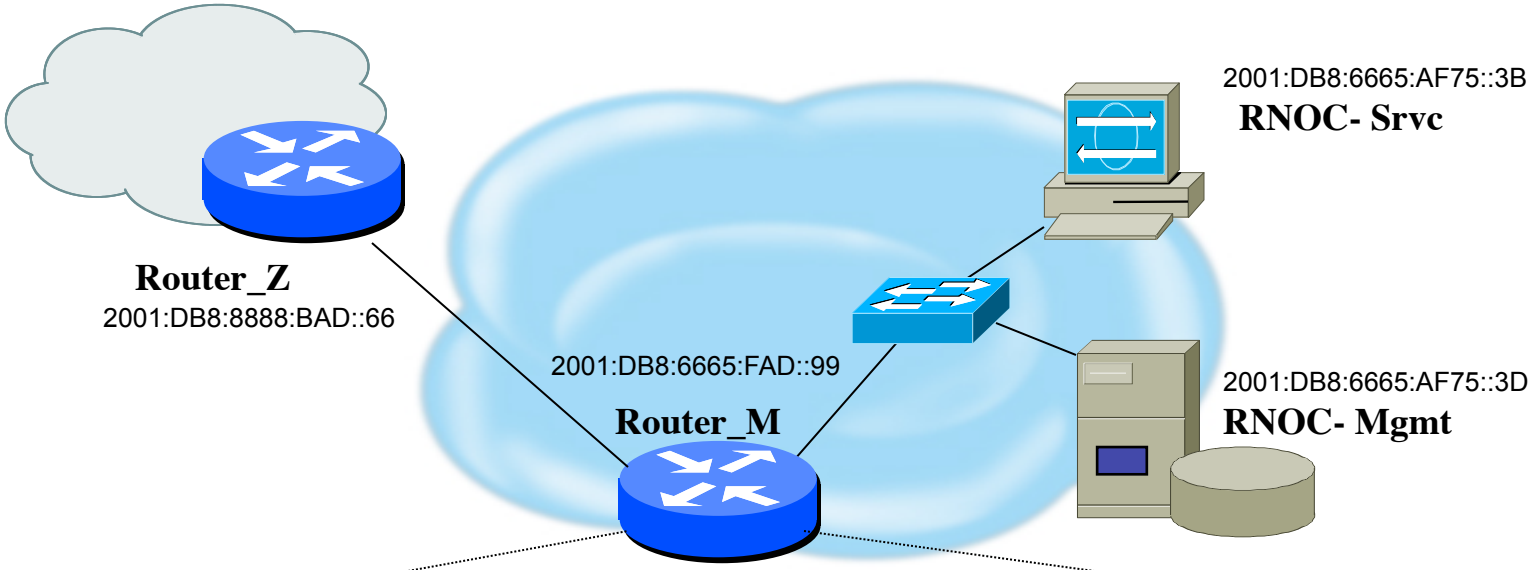
IKE Phase 2
- PFS
- Group 2

Terminology Issues

IKE Phase 1	DH Key Length	IKE Phase 2
IKE Phase 1 SA	DH Group	IKE Phase 2 SA
IKE SA	Modp #	IPsec SA
ISAKMP SA	Group #	Quick Mode
Main Mode		

Configuration complexity increased with vendor specific configuration terms

Potentially Easy Configuration



Syslog server 2001:DB8:6665:AF75::3D authenticate esp-null sha1 pre-share ‘secret4syslog’

TFTP server 2001:DB8:6665:AF75::3D authenticate esp-null aes128 pre-share ‘secret4tftp’

BGP peer 2001:DB8:8888:BAD::66 authenticate esp-null aes128 pre-share ‘secret4AS#XXX’

Interoperable Defaults For SAs

- Security Association groups elements of a conversation together
  - ESP encryption algorithm and key(s)
  - Cryptographic synchronization
  - SA lifetime
  - SA source address
  - Mode (transport or tunnel)

How Do We Communicate Securely ?

Do we want integrity protection of data ?
Do we want to keep data confidential ?
Which algorithms do we use ?
What are the key lengths ?
When do we want to create new keys ?
Are we providing security end-to-end ?

Pretty Good IPsec Policy

- IKE Phase 1 (aka ISAKMP SA or IKE SA or Main Mode)
  - 3DES (AES-192 if both ends support it)
  - Lifetime (8 hours = 480 min = 28800 sec)
  - SHA-2 (256 bit keys)
  - DH Group 14 (aka MODP# 14)
- IKE Phase 2 (aka IPsec SA or Quick Mode)
  - 3DES (AES-192 if both ends support it)
  - Lifetime (1 hour = 60 min = 3600 sec)
  - SHA-2 (256 bit keys)
  - PFS 2
  - DH Group 14 (aka MODP# 14)

Help With Configuring IPsec

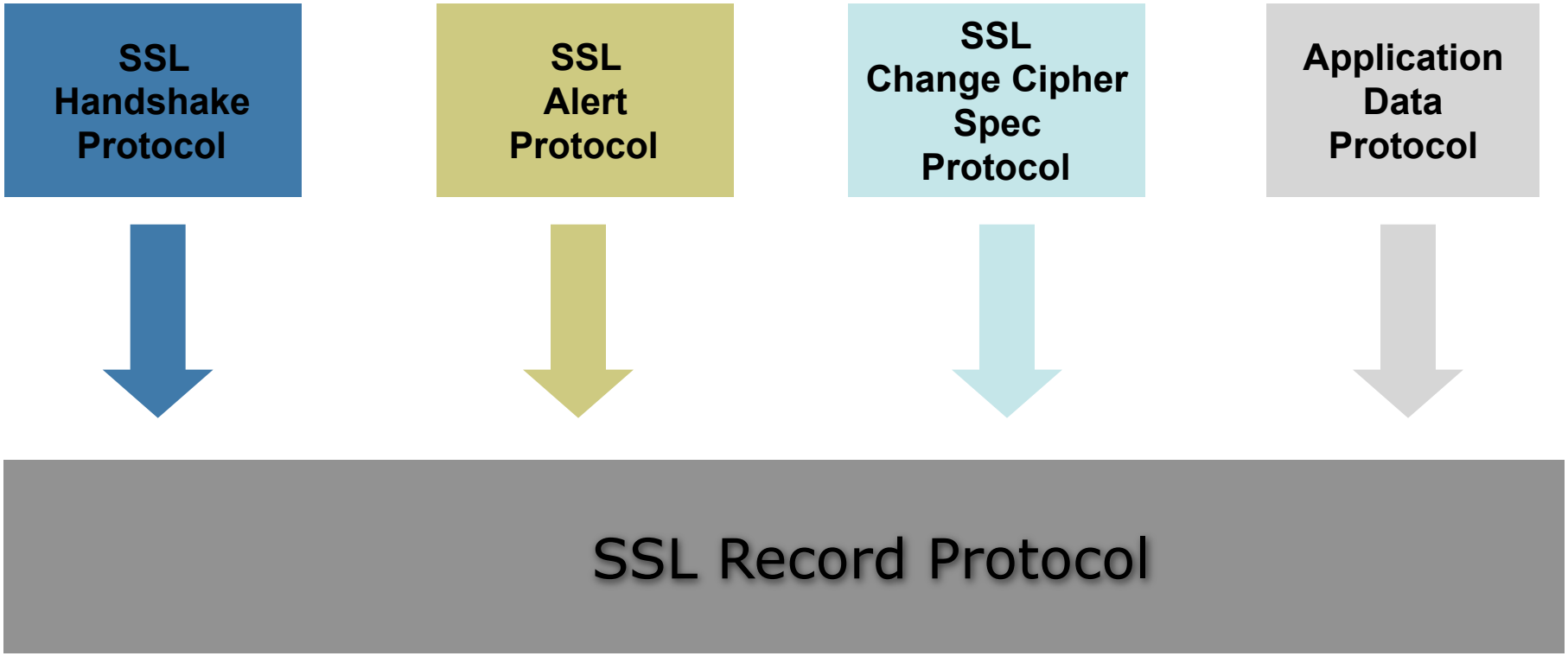
- http://www.vpnc.org/InteropProfiles/
- Documents for Cisco IPsec configuration:
  - http://www.cisco.com/en/US/tech/tk583/tk372/technologies_configuration_example09186a0080093f73.shtml
  - http://www.cisco.com/en/US/tech/tk583/tk372/technologies_configuration_example09186a0080093f86.shtml
- Document for Juniper IPsec configuration:
  - http://kb.juniper.net/InfoCenter/index?page=content&id=KB10128

SSL/TLS

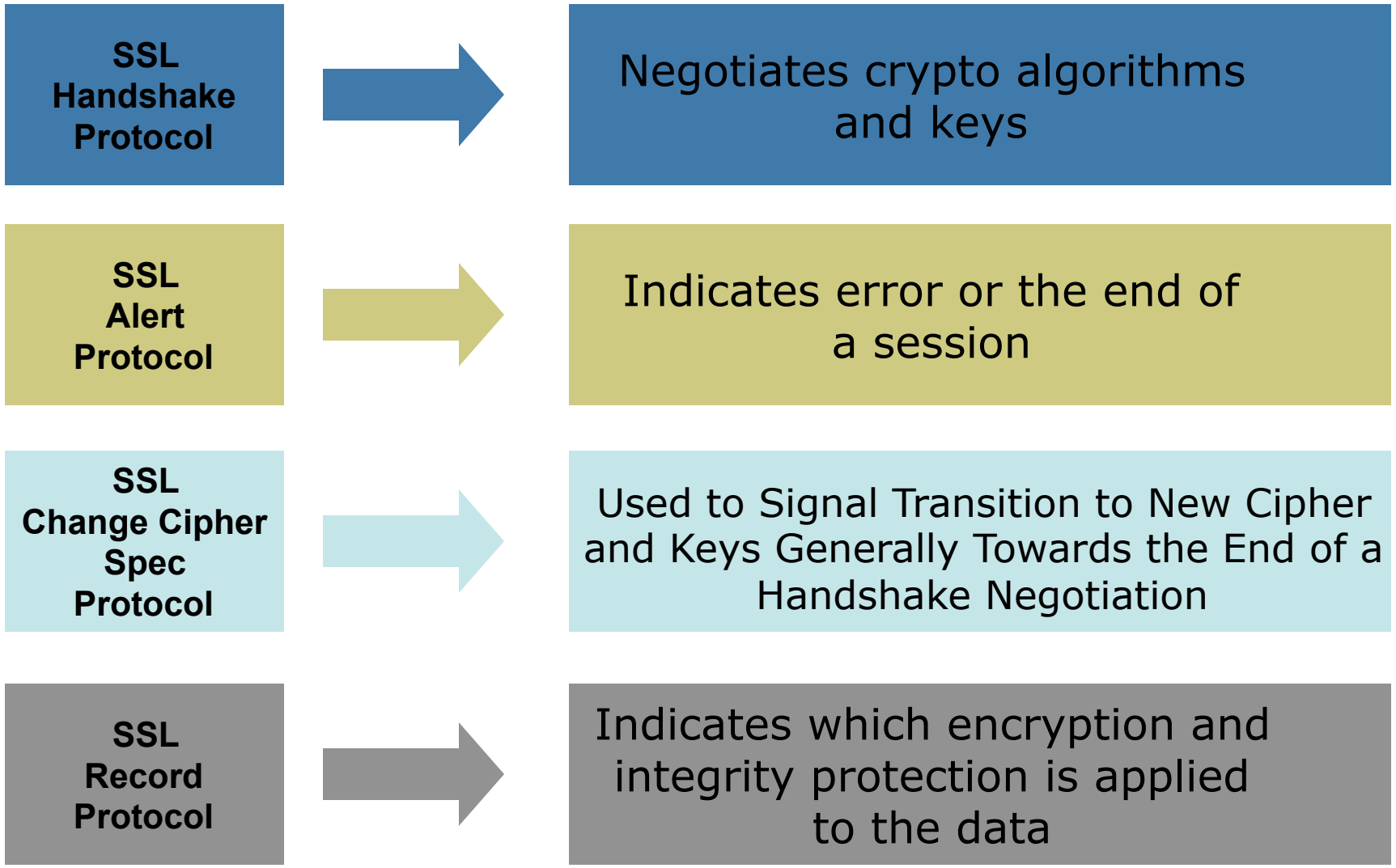
- SSL and TLS
  - SSL v3.0 specified in an I-D in 1996 (draft-freier-ssl-version3-02.txt)
  - TLS v1.0 specified in RFC 2246 in 1999
  - TLS v1.0 = *SSL v3.1* ≈ SSL v3.0
- Goals of protocol
  - Secure communication between applications
  - Data encryption
  - Server authentication
  - Message integrity
  - Client authentication (optional)

SSL Protocol Building Blocks

SSL is a Combination of a Primary Record Protocol with Four 'Client' Protocols



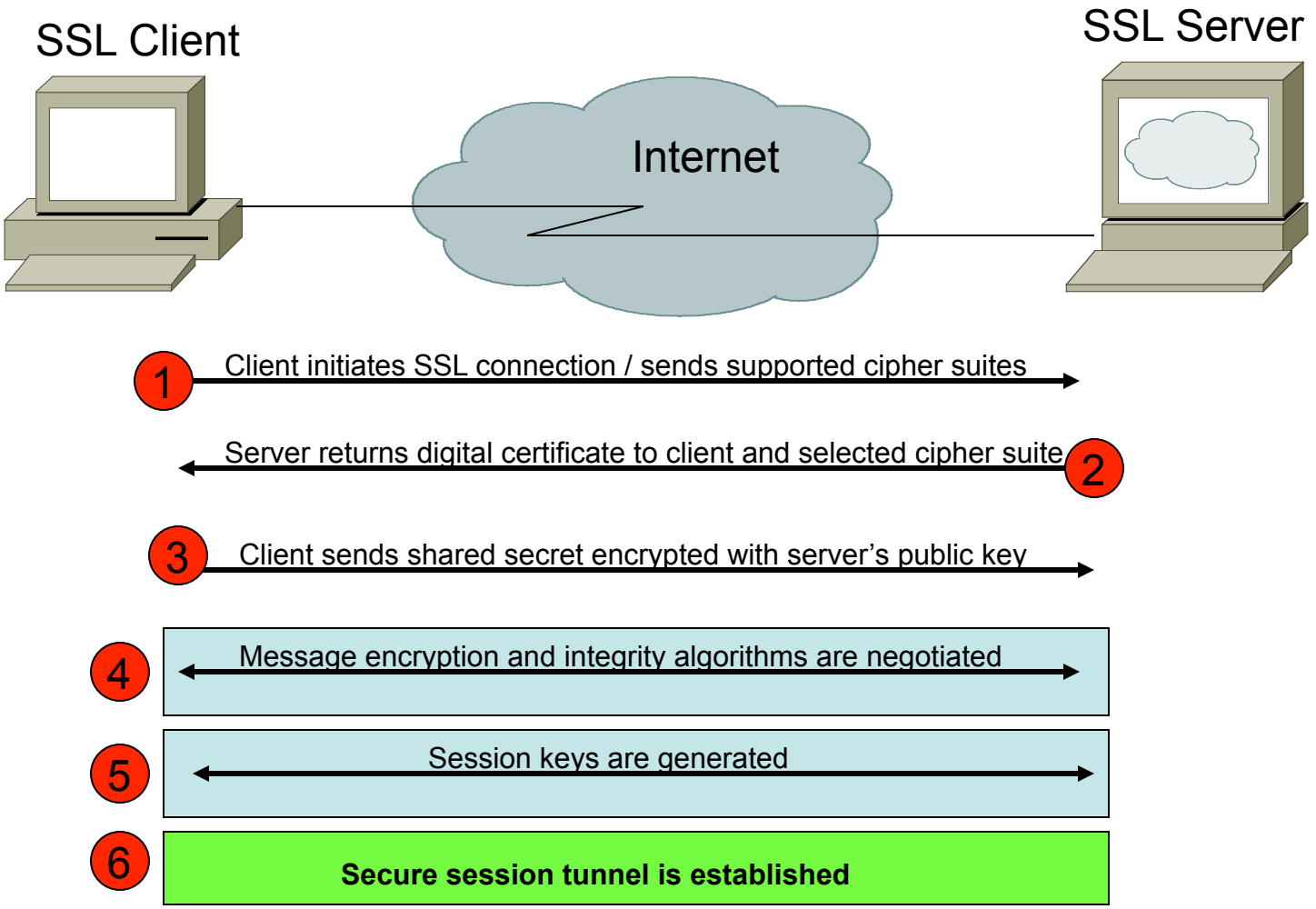
SSL Protocol Building Block Functions



SSL/TLS Properties

- Connection is private
  - Encryption is used after an initial handshake to define a secret key.
  - Symmetric cryptography used for data encryption
- Peer's identity can be authenticated
  - Asymmetric cryptography is used (RSA or DSS)
- Connection is reliable
  - Message transport includes a message integrity check using a keyed MAC.
  - Secure hash functions (such as SHA and MD5) are used for MAC computations.

The SSL Handshake Process



SSL Client Authentication

- Client authentication (certificate based) is optional and not often used
- Many application protocols incorporate their own client authentication mechanism such as username/password or S/Key
- These authentication mechanisms are more secure when run over SSL

SSL/TLS IANA Assigned Port #s

Protocol	Defined Port Number	SSL/TLS Port Number
HTTP	80	443
NNTP	119	563
POP	110	995
FTP-Data	20	989
FTP-Control	21	990
Telnet	23	992

Encrypted Communications

- Use encrypted communications whenever you need to keep information confidential
- Verify via network sniffer (e.g. wireshark) that your communication is indeed encrypted
- An important aspect is credential management (creating, distributing, storing, revoking, renewing)
- Understand if/when credentials are lost that you may not be able to recover the data
- Have a plan in place in case you forget your password that protects your private keys