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CSE543 Computer and Network Security

Module: Network Security

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Communication Security

- Want to establish a secure channel to remote hosts over an untrusted network
  - Users - when logging in to a remote host
  - Applications - when communicating across network
  - Hosts - when logically part of the same isolated network
- The communication service must …
  - Authenticate the end-points (each other)
  - Negotiate what security is necessary (and how achieved)
  - Establish a secure channel (e.g., key distribution/agreement)
  - Process the traffic between the end points
- Also known as *communications security*.

Users' Communications Security

- Login to a host over an untrusted network
  - Using unauthenticated login - telnet, rsh - up to this point
- Problems
  - How does user authenticate host?
  - How does host authenticate user?

SSH (Secure Shell)

- Secure communication protocol…
  - Between user's client and remote machine (server)
  - Used to implement remote login
  - Runs on any transport layer (TCP/IP)
- Setup
  - Authentication agent on client
    - To produce and process messages on behalf of the user
  - SSH Server
    - To handle user logins to that host
    - Forward X and TCP communications
- Remote machine use approximates local machine

SSH Protocol

- How to authenticate server-user and user-server?
  - Users lack public keys
  - But, servers may hold login passwords of users

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SSH Protocol

- (1) Client opens connection to server
- (2) Server responds with its host key and server key
  - Public keys identifying server and enabling communication
- (3) Client generates random number and encrypts with host and server keys
- (4) Server extracts random number (key) and can use
  - Server is authenticated
- (5) Server authenticates user
  - Password and RSA authentication
- (6) Preparatory phase
  - To setup TCP/IP, X11 forwarding, etc.
- (7) Interactive session phase

SSH Protocol

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- **Answer**:

SSH Protocol

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- **Answer**: Server public keys (host and server) and user passwords

- How are we sure that these are the legitimate public keys for the server?

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SSH Protocol

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- How to establish a secure channel?
  - Between the client and server
  - For remote processing of commands
- **Answer**: Client chooses key
- How does client know what kind of key to pick?

SSHv2 Protocol

- A number of improvements were made to the SSHv2 protocol (see Section 5)
  - Stronger use of crypto - better algorithms
  - Performance - 1.5 round trips on average
  - Prevent eavesdropping - encrypt all SSH traffic
  - Prevent IP spoofing - always validates server identity
  - Prevent hijacking - integrity checking using HMAC
- Not backwards compatible with SSHv1

Application Comm Security

- Applications may want to construct secure communication channels transparently to users
  - How can they do that?

Application (Web) Security: SSL

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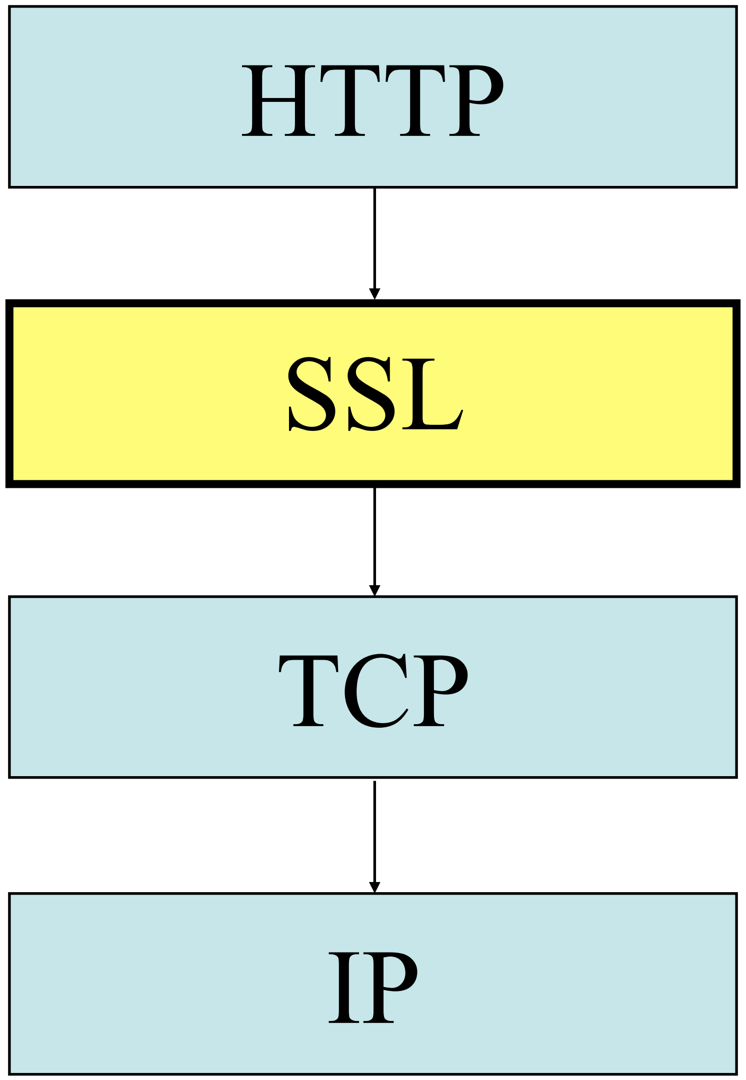
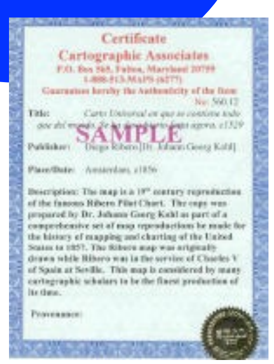
- Secure socket Layer (SSL/TLS)
- Used to authenticate servers
  - Uses certificates, "root" CAs
- **Can** authenticate clients
- Inclusive security protocol
- Security at the socket layer
  - Transport Layer Security (TLS)
  - Provides
    - authentication
    - confidentiality
    - integrity



SSL Handshake

Client



(1) Client Hello (algorithms,…) →

← (2) Server Hello (alg. selection,…)

← (3) Server Certificate

(4) ClientKeyRequest →

← (5) ChangeCipherSuite

(6) ChangeCipherSuite →

← (7) Finished

(8) Finished →

Server

Simplified Protocol Detail

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Participants: Alice/A (client) and Bob/B (server)
Crypto Elements : Random R, Certificate C, k_i^+ Public Key (of i)
Crypto Functions : Hash function $H(x)$, Encryption $E(k, d)$, Decryption $D(k, d)$, Keyed MAC $HMAC(k, d)$

1.	Alice → Bob	R_A
2.	Bob → Alice	R_B, C_B
	Alice	pick pre-master secret S
	Alice	calculate master secret $K = H(S, R_A, R_B)$
3.	Alice → Bob	$E(k_B^+, S), HMAC(K,' CLNT' + [\#1, \#2])$
	Bob	recover pre-master secret $S = D(k_B^-, E(k_B^+, S))$
	Bob	calculate master secret $K = H(S, R_A, R_B)$
4.	Bob → Alice	$HMAC(K,' SRVR' + [\#1, \#2])$

Note: Alice and Bob : IV Keys, Encryption Keys, and Integrity Keys 6 keys,where each key $k_i = g_i(K, R_A, R_B)$, and g_i is key generator function.

SSL Tradeoffs

- Pros
  - Server authentication*
  - GUI clues for users
  - Built into every browser
  - Easy to configure on the server
  - Protocol has been analyzed like crazy
- Cons
  - Users don’t check certificates
  - Too easy to obtain certificates
  - Too many roots in the browsers
  - Some settings are terrible

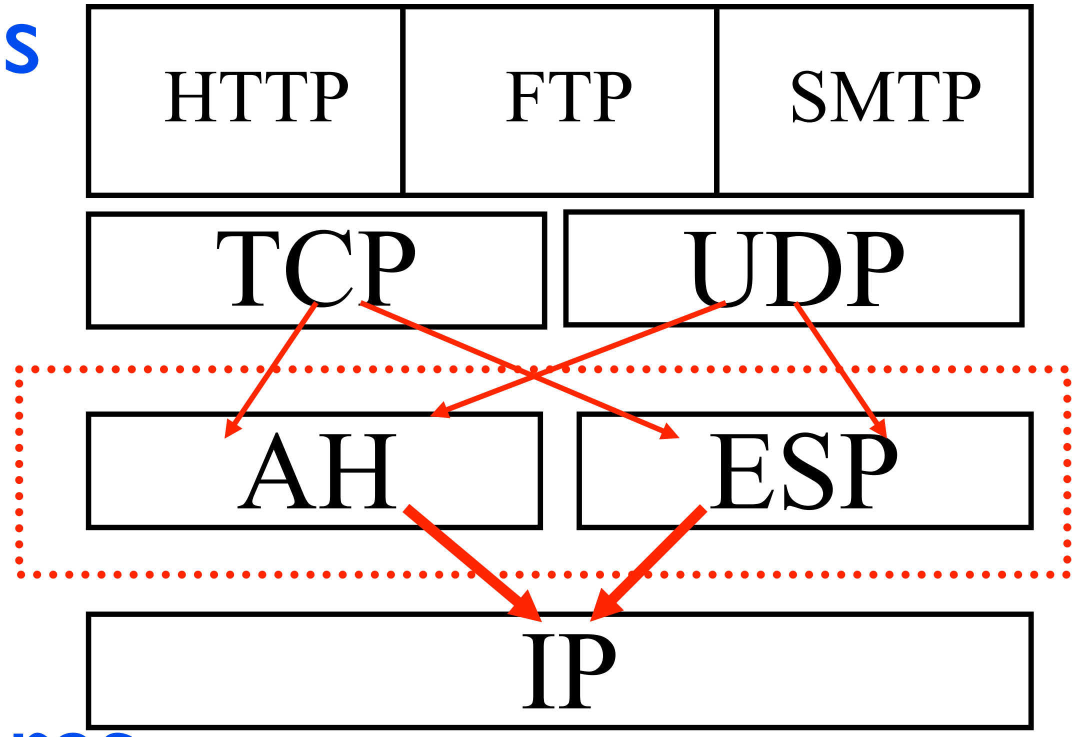
IPsec (not IPSec!)

- Host-level protection service
  - IP-layer security (below TCP/UDP)
  - De-facto standard for host level security
  - Developed by the IETF (over many years)
  - Available in most operating systems/devices
    - E.g., XP, Vista, OS X, Linux, BSD*, …
  - Implements a wide range of protocols and cryptographic algorithms

- *Selectively* provides ….
  - Confidentiality, integrity, authenticity, replay protection, DOS protection

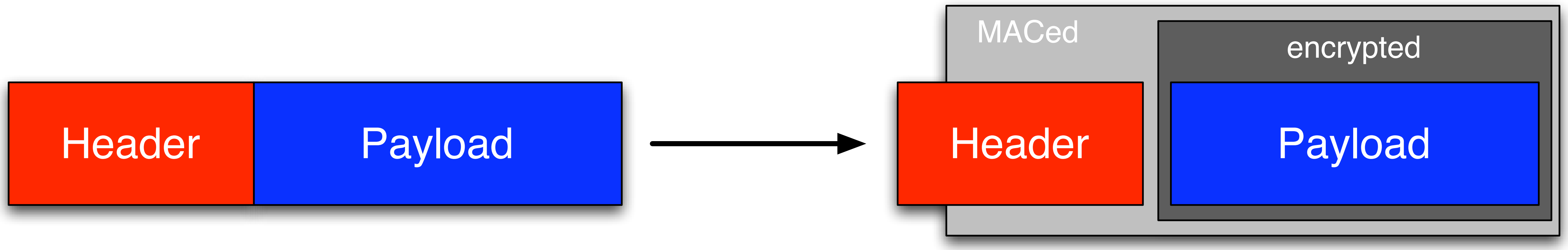
IPsec and the IP protocol stack

- IPsec puts the two main protocols in between IP and the other protocols
  - AH - authentication header
  - ESP - encapsulating security payload
- Other functions provided by external protocols and architectures

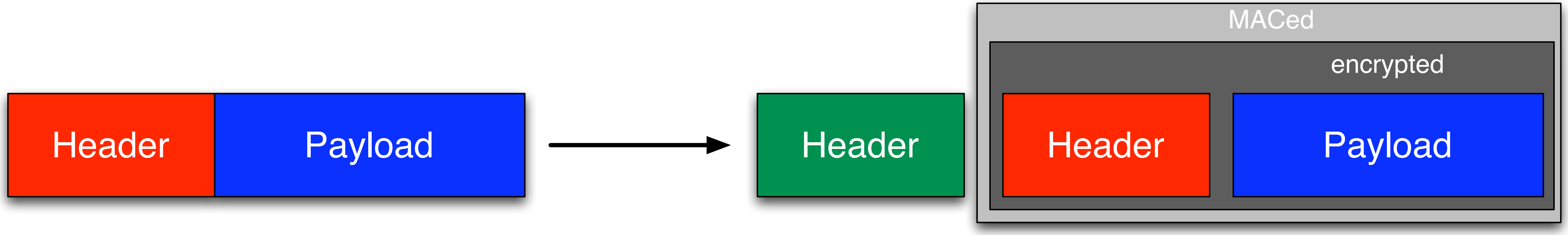


Modes of operation

- Transport : the payload is encrypted and the non-mutable fields are integrity verified (via MAC)

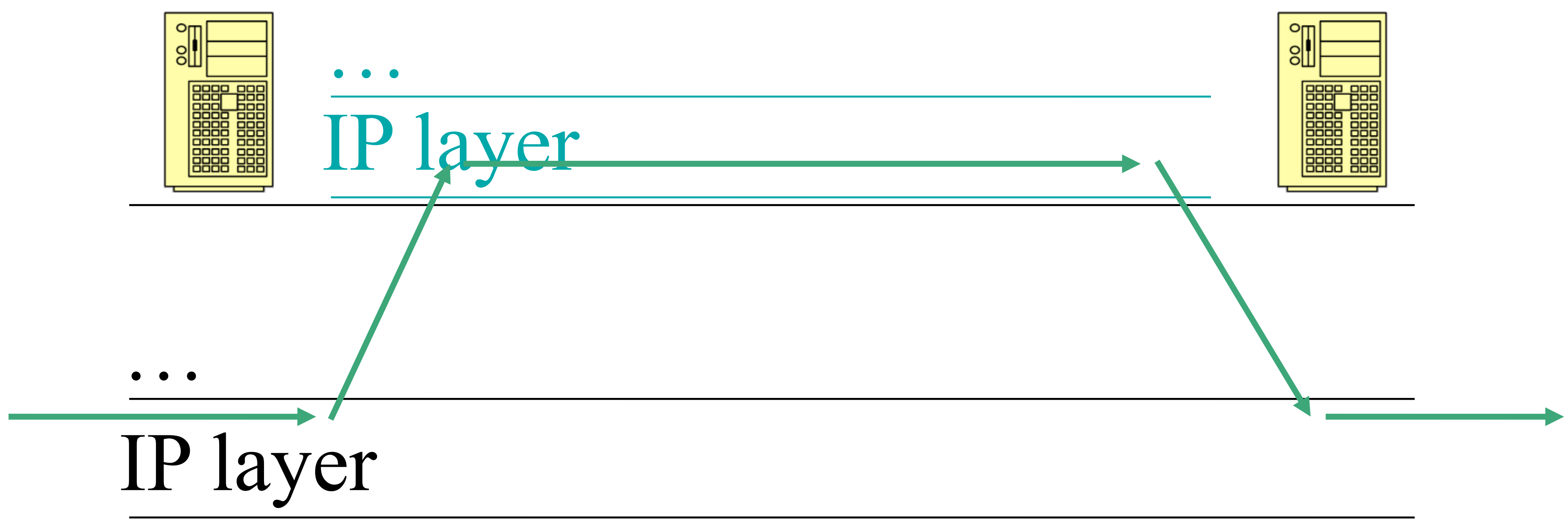


- Tunnel : each packet is completely encapsulated (encrypted) in an outer IP packet
  - Hides not only data, but some routing information



Tunneling

- "IP over IP"
  - Network-level packets are encapsulated
  - Allows traffic to evade firewalls

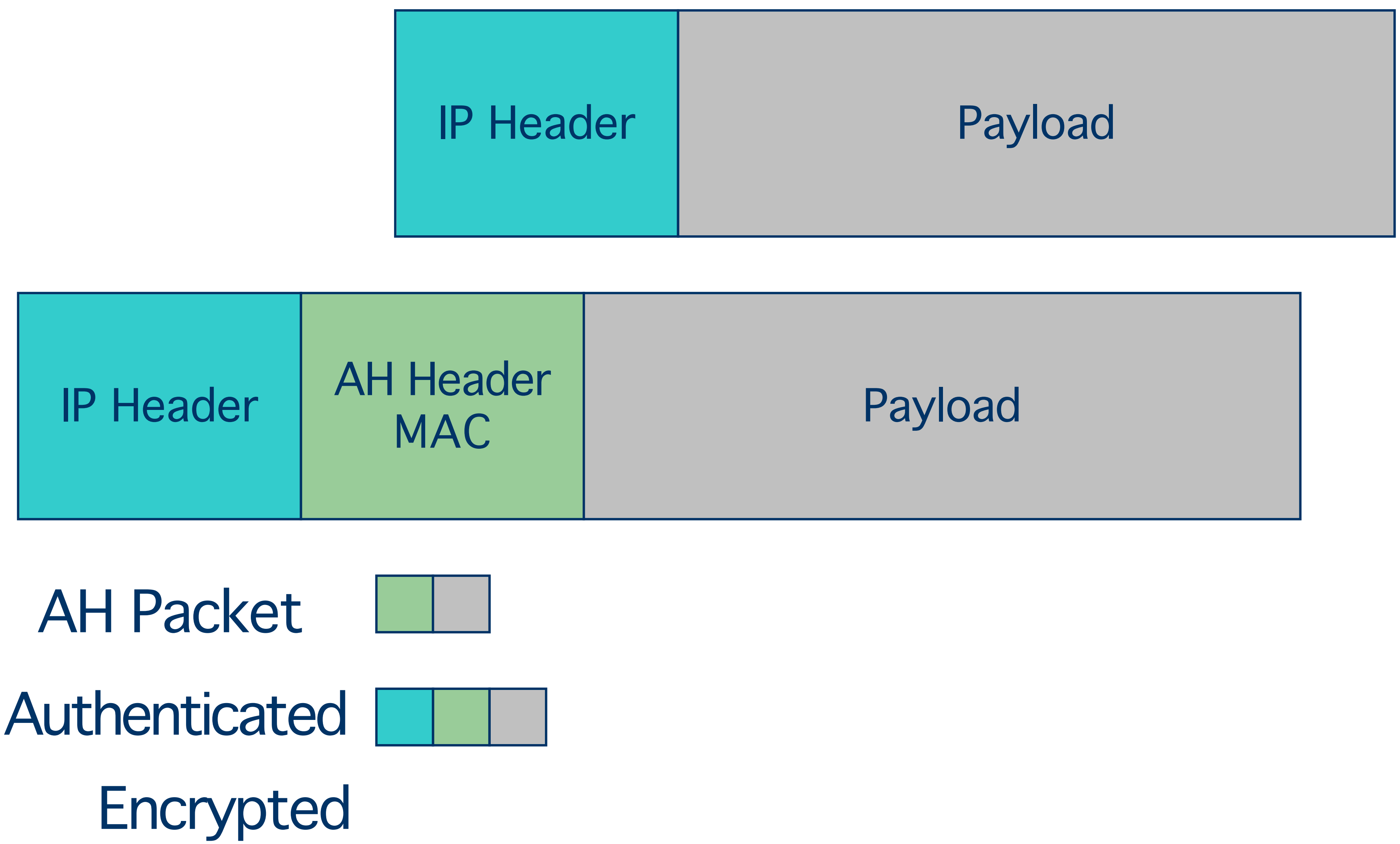


Authentication Header (AH)

- Authenticity and integrity
  - via HMAC
  - over IP headers and data
- Advantage: the authenticity of data and IP header information is protected
  - it gets a little complicated with *mutable* fields, which are supposed to be altered by network as packet traverses the network
  - some fields are *immutable*, and are protected
- Confidentiality of data is *not* preserved
- Replay protection via AH sequence numbers
  - note that this replicates some features of TCP (good?)

Authentication Header (AH)

- Modifications to the packet format



Encapsulating Security Payload (ESP)

- Confidentiality, authenticity and integrity
  - via encryption and HMAC
  - over IP *payload* (data)
- Advantage: the security manipulations are done solely on user data
  - TCP packet is fully secured
  - simplifies processing
- Use "null" encryption to get authenticity/integrity only
- Note that the TCP ports are hidden when encrypted
  - good: better security, less is known about traffic
  - bad: impossible for FW to filter/traffic based on port
- Cost: can require many more resources than AH

Encapsulating Security Payload (ESP)

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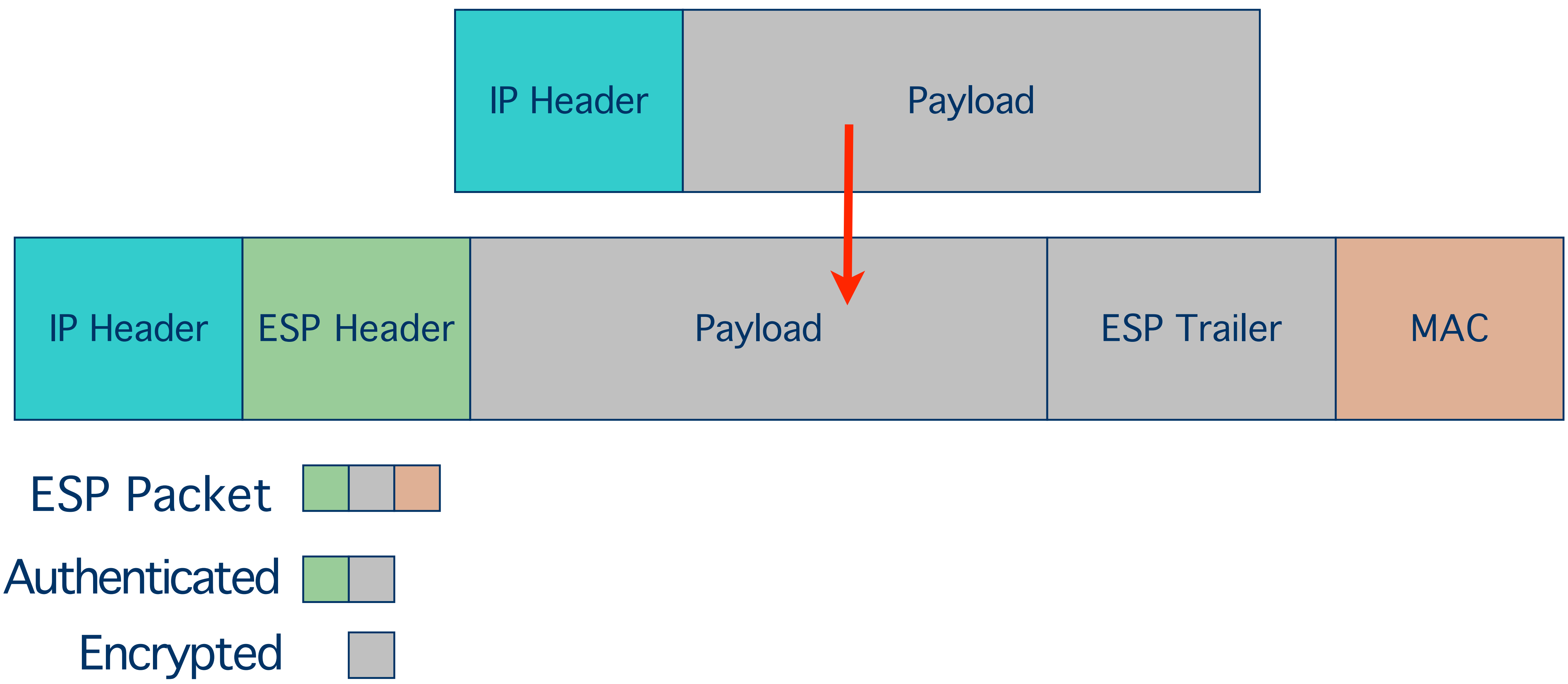


Practical Issues and Limitations

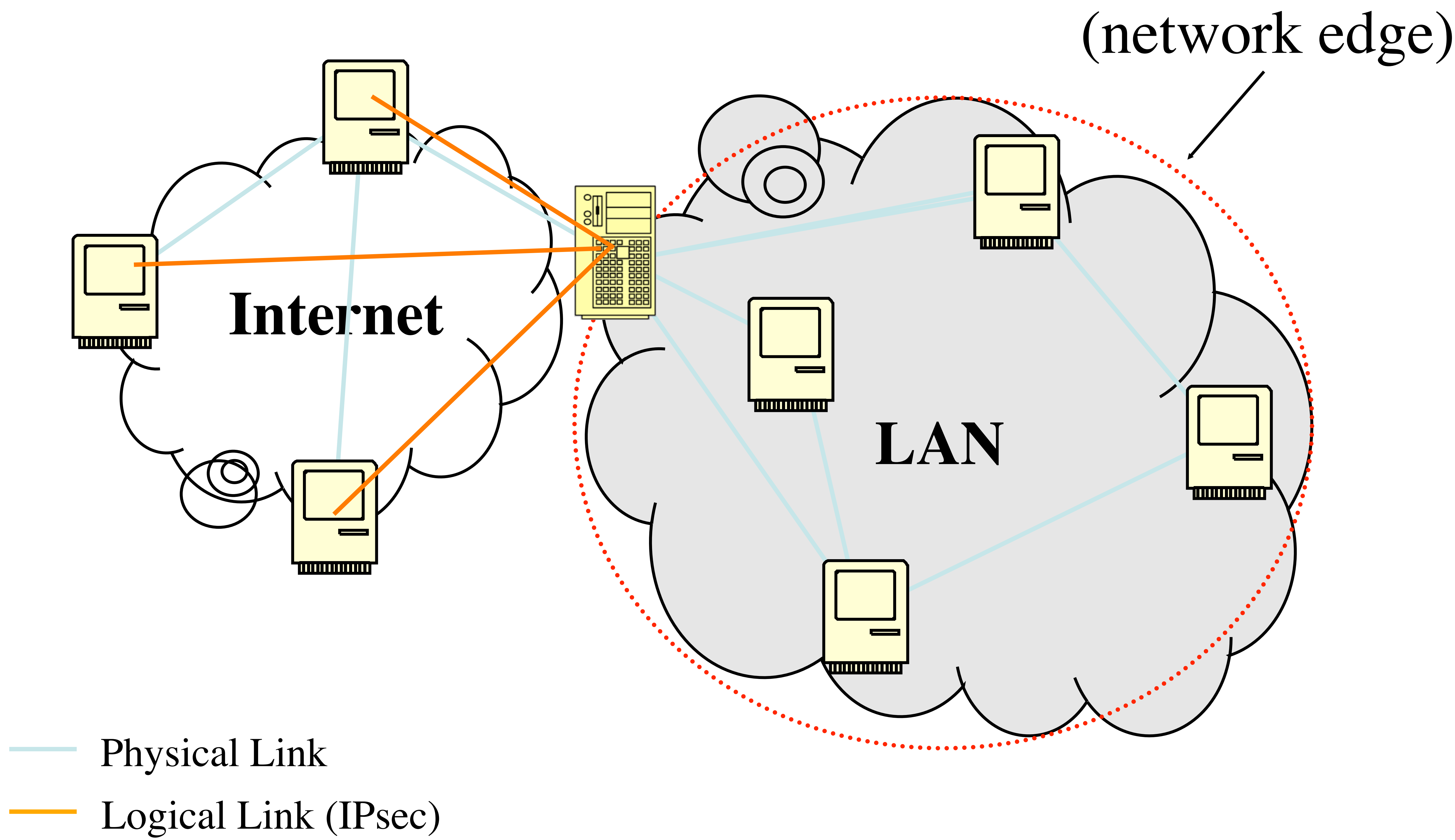
- IPsec implementations
  - Large footprint
    - resource poor devices are in trouble
    - New standards to simplify (e.g, JFK, IKE2)
  - Slow to adopt new technologies
  - Configuration is really complicated/obscure

- Issues
  - IPsec tries to be "everything for everybody at all times"
    - Massive, complicated, and unwieldy
  - Policy infrastructure has not emerged
  - Large-scale management tools are limited (e.g., CISCO)
  - Often not used securely (common pre-shared keys)

Network Isolation: VPNs

- Idea: I want to create a collection of hosts that operate in a coordinated way
  - E.g., a virtual security perimeter over physical network
  - Hosts work as if they are isolated from malicious hosts
- Solution: Virtual Private Networks
  - Create virtual network topology over physical network
  - Use communications security protocol suites to secure virtual links "tunneling"
  - Manage networks as if they are physically separate
  - Hosts can route traffic to regular networks (*split-tunneling*)

VPN Example: RW/Telecommuter



Virtual LANs (VLANs)

- VPNs built with hardware
  - Physically wire VPN via soft configuration of a switch crossbar
  - No encryption – none needed
  - “wire based isolation”
  - Many switches support VLANs
  - Allows networks to be reorganized without rewiring
- Example usage: two departments in same hallway
  - Each office is associated with department
  - Configuring the network switch gives physical isolation
  - Note: often used to ensure QoS