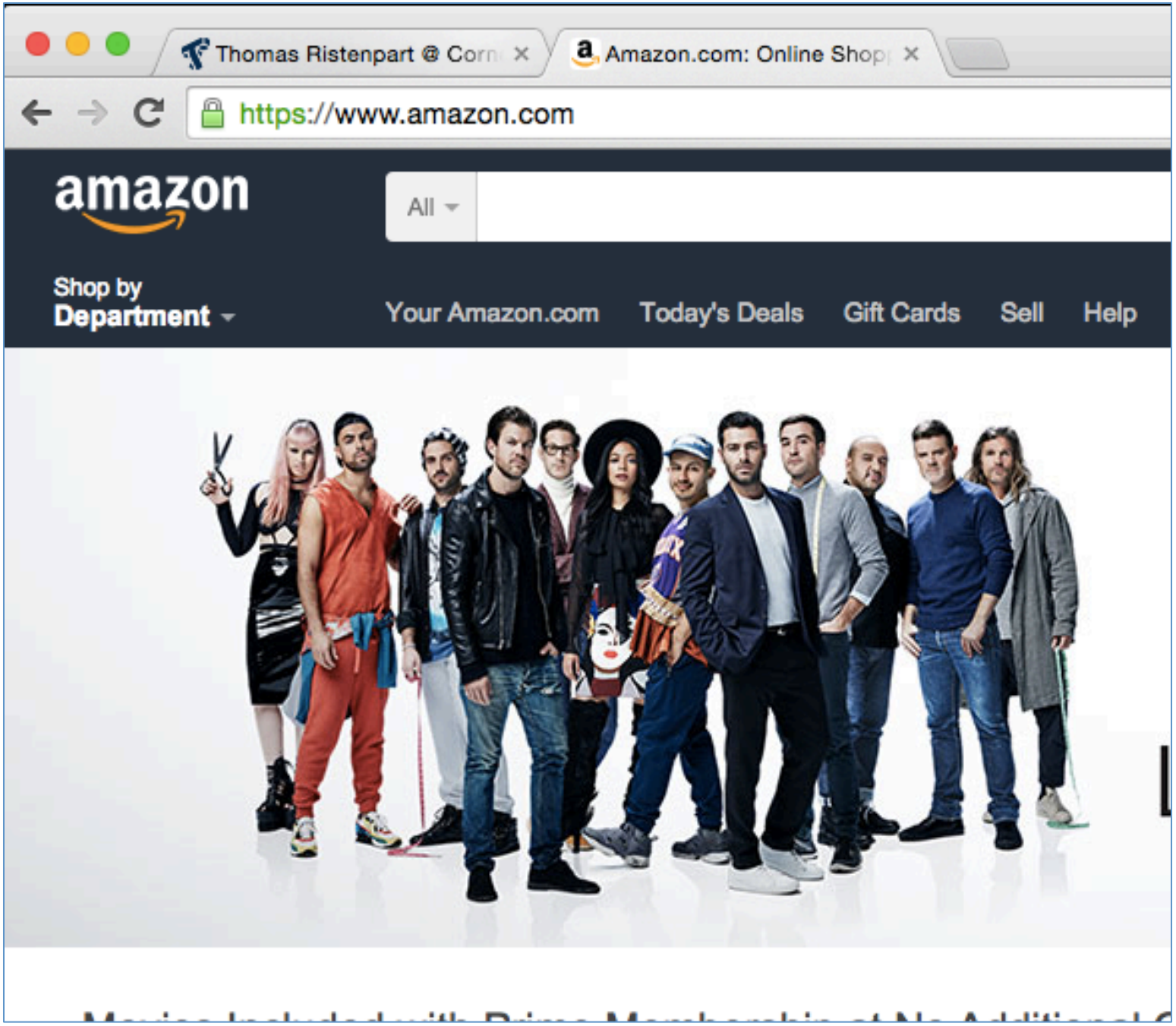
Today in Cryptography (5830)

TLS Overview
Public-key encryption
Key transport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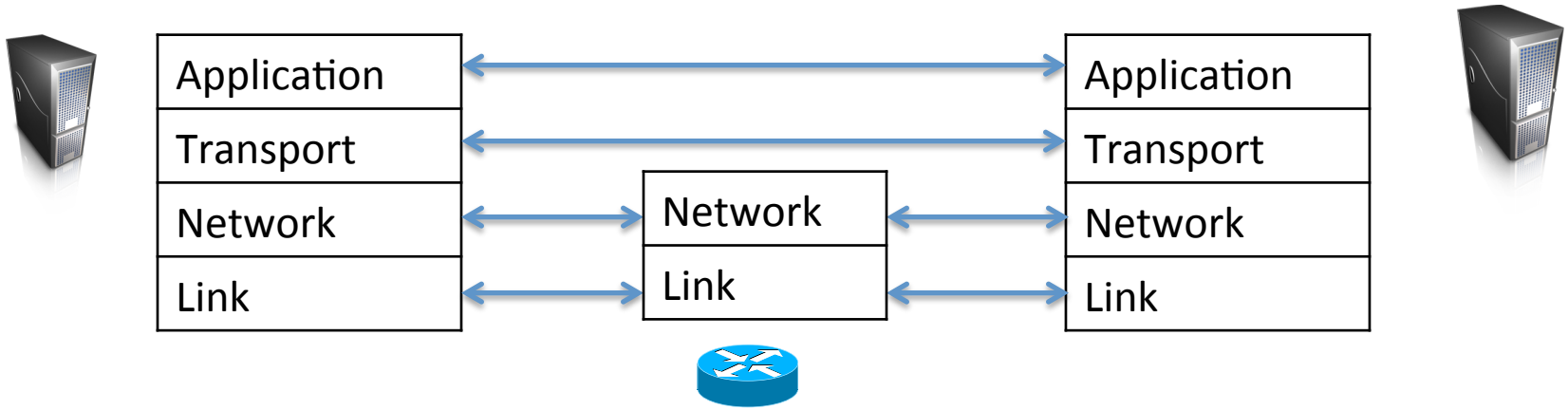
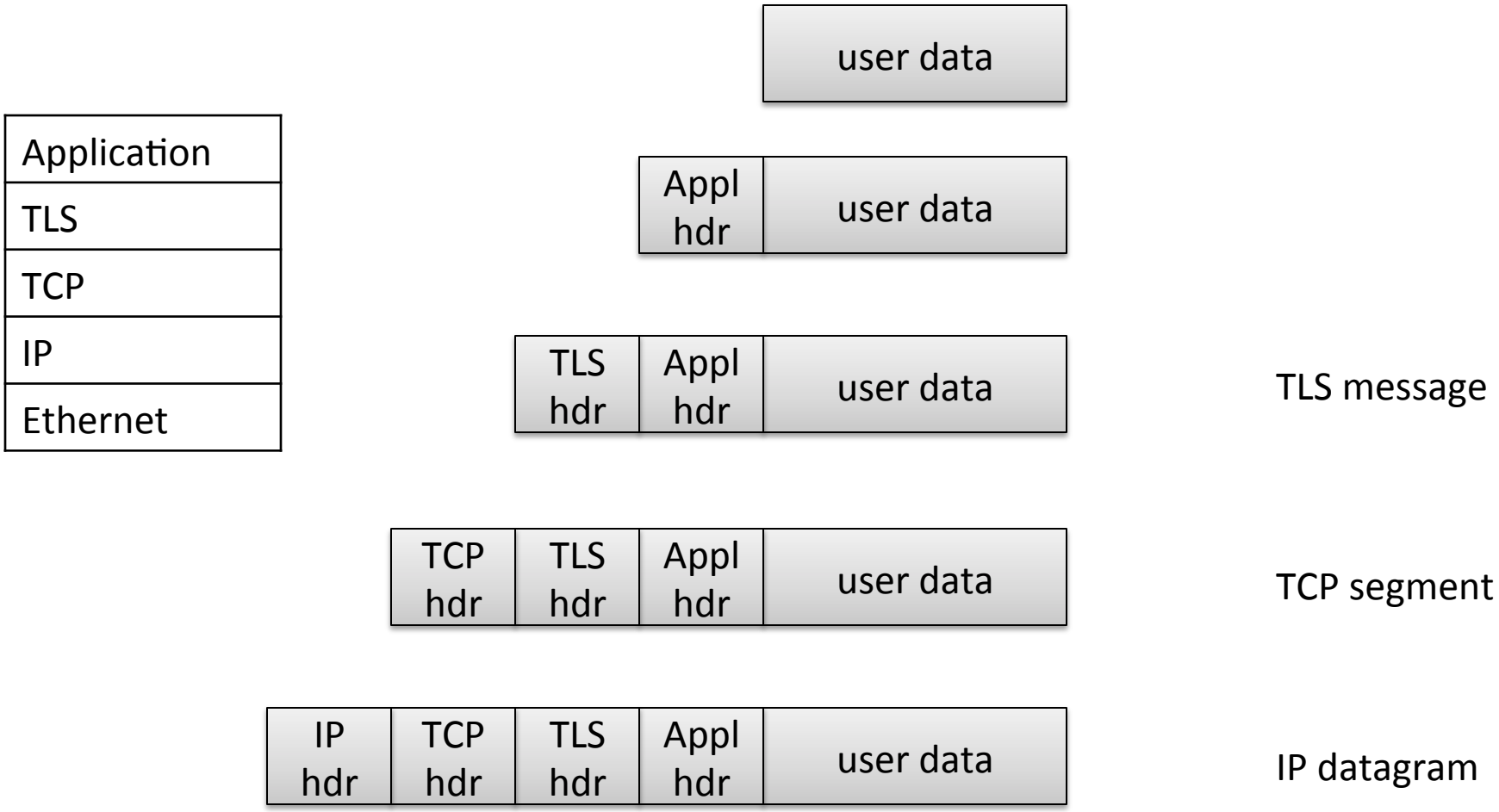
Internet protocol stack

Application	HTTP, FTP, SMTP, SSH, etc.
Transport	TCP, UDP
Network	IP, ICMP, IGMP
Link	802x (802.11, Ethernet)



TLS sits between application and TCP

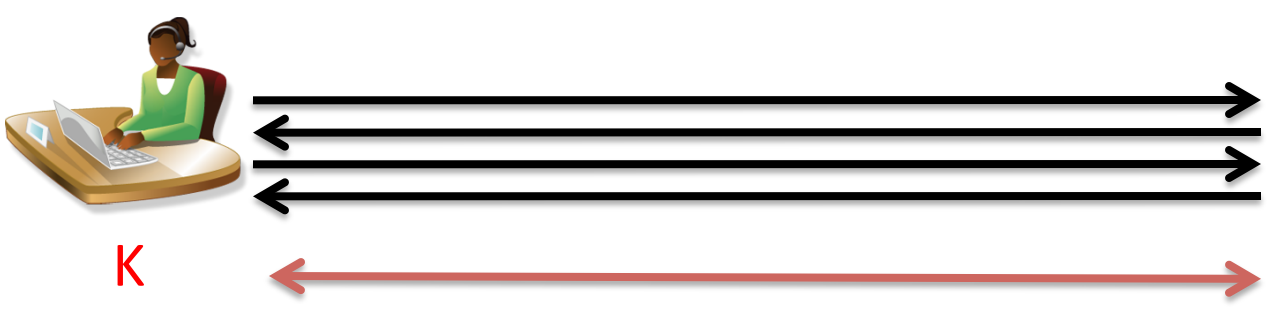


Places TLS is used

- HTTPS
  - HTTP messages but over TLS, not TCP
- Email connections
  - When getting information from your email server (not the email contents themselves)
- Virtual private networks (VPNs)
  - Tunnel other internet connections over a TLS connection

How does TLS work (high level)?

https://amazon.com



Step 1:
Key exchange protocol to share secret K

Step 2:
Send data via secure channel

The secure channel is implemented via our now familiar symmetric encryption primitives

Goals of handshake:

- Negotiate version
- Negotiate parameters (crypto to use)
- Authenticate server (Is server actually Amazon.com?)
  - Digital signatures and certificates
- Establish shared secret
  - Asymmetric encryption primitives

A short history of TLS

How many cryptographers involved?

SSL ver 2.0 designed by **Hickman** at Netscape

SSL ver 2

1994

Wagner, Goldberg break SSL ver 2

1995

Freier, Karlton, Kocher design SSL ver 3.0

SSL ver 3

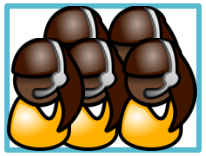
1998

Bleichenbacher breaks RSA PKCS #1 encryption, used in SSL ver 3

1999

TLS ver 1 released as IETF standard, based on SSL 3, **many cryptographers** involved

TLS ver 1.0



2001

Vaudenay, Klima et al. padding attacks

2002

Rogaway IV re-use insecurity

2003

Brumley, Boneh remote timing attacks

2006

TLS ver 1.1 released as standard

TLS ver 1.1

⋮

(more attacks and fixes)

TLS handshake for RSA transport

Client

Server

Pick random Nc

ClientHello, MaxVer, Nc, Ciphers/CompMethods →

Pick random Ns

← ServerHello, Ver, Ns, SessionID, Cipher/CompMethod

Check CERT using CA public verification key

← CERT = (pk of bank, signature over it)

Pick random PMS
C <- E(pk,PMS)

C →

PMS <- D(sk,C)

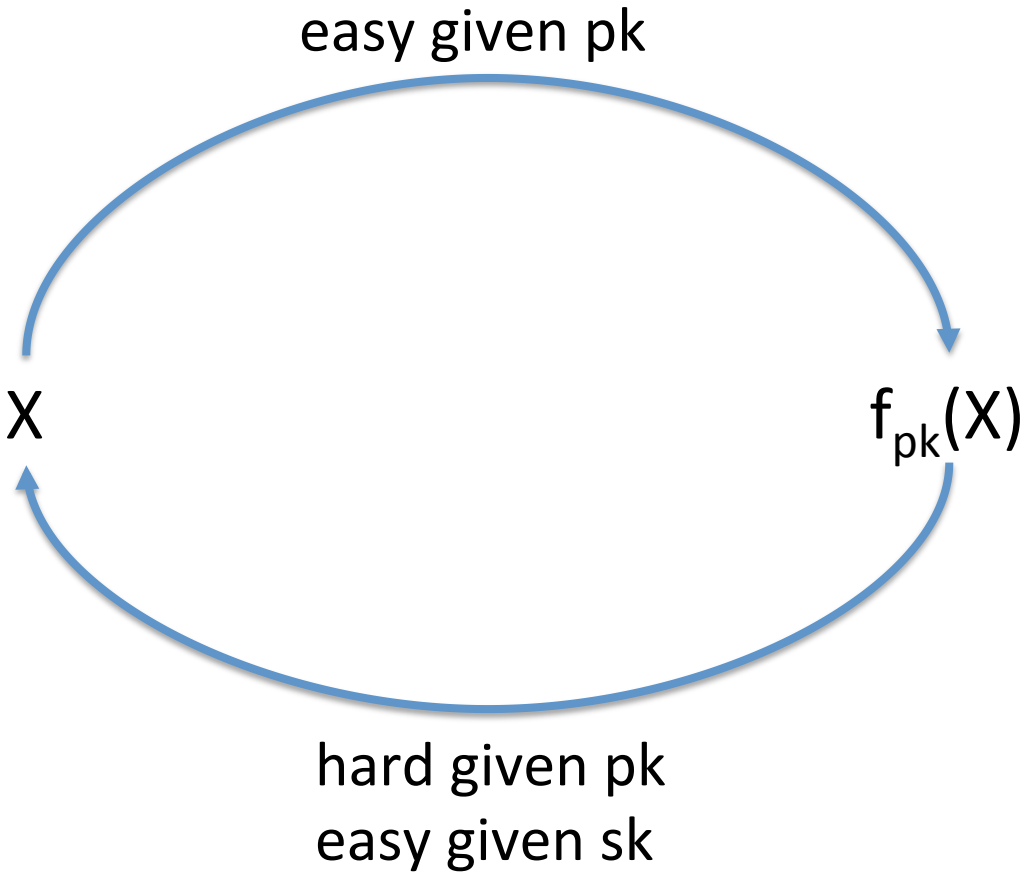
ChangeCipherSpec,
{ Finished, PRF(MS, "Client finished" || H(transcript)) } →

ChangeCipherSpec,
{ Finished, PRF(MS, "Server finished" || H(transcript')) } ←

Bracket notation means contents encrypted

MS <- PRF(PMS, "master secret" || Nc || Ns)

Trapdoor functions



TLS handshake for Diffie-Hellman Key Exchange

Client

Server

Pick random Nc

ClientHello, MaxVer, Nc, Ciphers/CompMethods

Check CERT using CA public verification key

ServerHello, Ver, Ns, SessionID, Cipher/CompMethod

Pick random Ns

Pick random x

$X = g^x$

CERT = (pk_s , signature over it)

p , g , X , σ = Sign(sk_s, p || g || X)

Y

Check σ

Pick random y

$Y = g^y$

$PMS = g^{xy}$

$PMS = g^{xy}$

ChangeCipherSpec,

{ Finished, PRF(MS, "Client finished" || H(transcript)) }

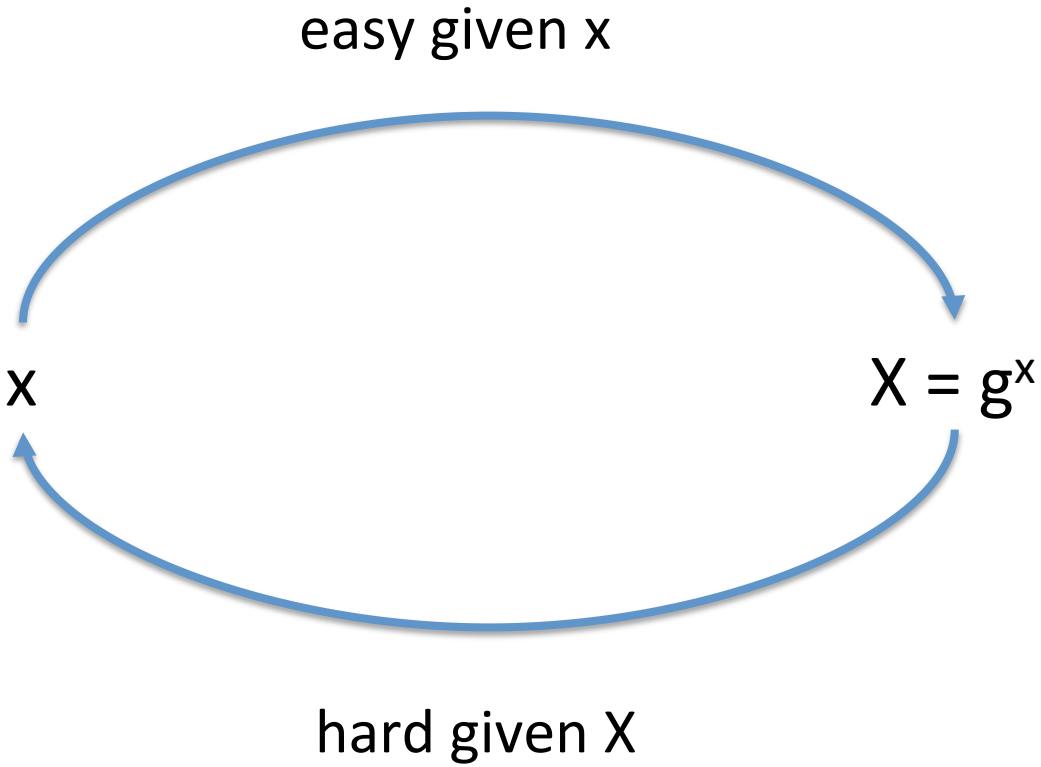
ChangeCipherSpec,

{ Finished, PRF(MS, "Server finished" || H(transcript')) }

Bracket notation means contents encrypted

MS <- PRF(PMS, "master secret" || Nc || Ns)

One-way functions



TLS Key derivation & use

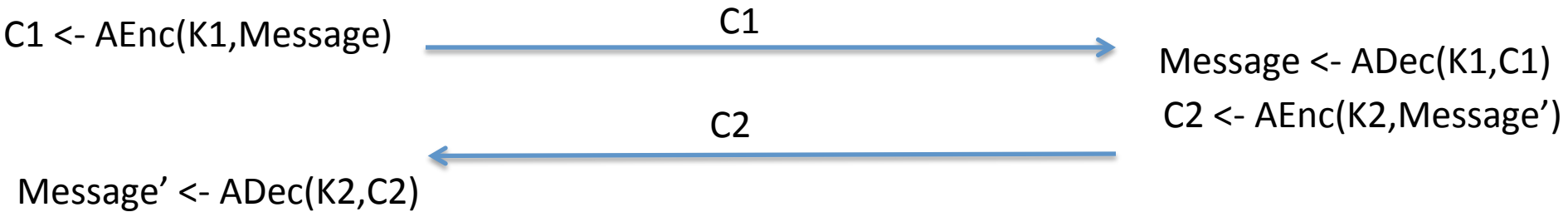
MS <- PRF(PMS, “master secret” || Nc || Ns)

K1,K2 <- PRF(MS, “key expansion” || Ns || Nc)

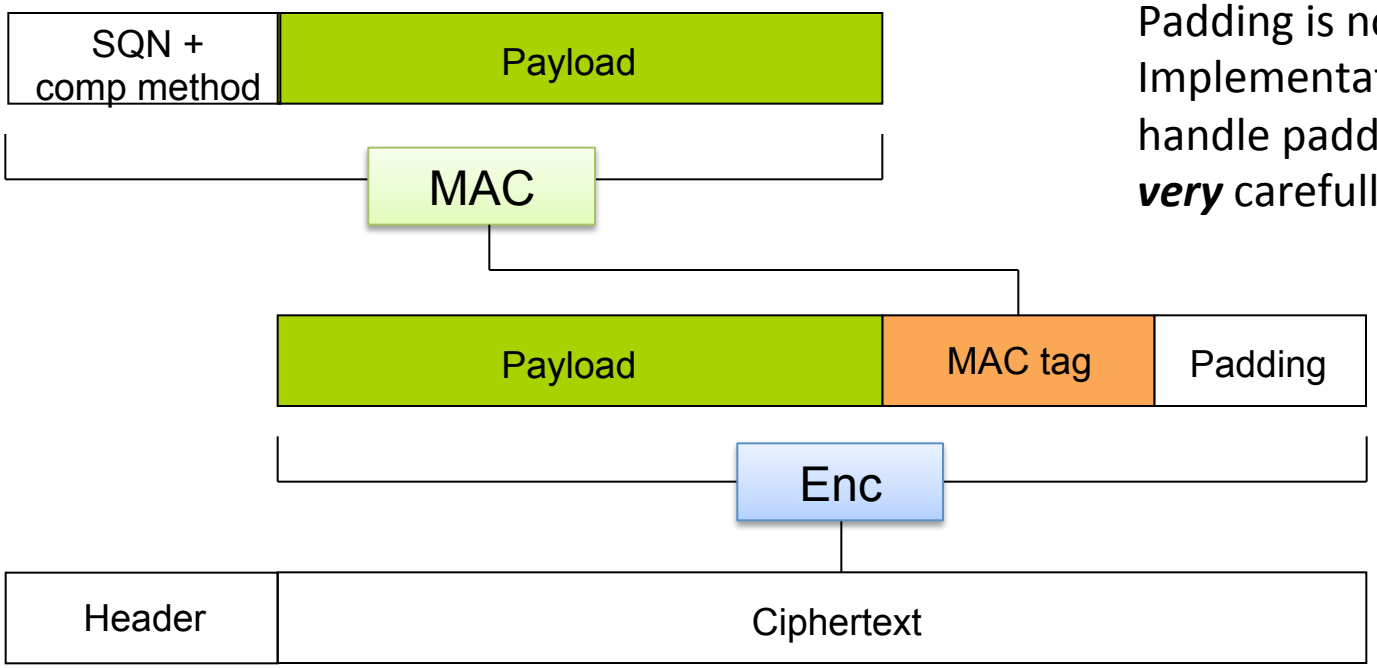
PRF(secret, message) = HMAC-HASH(secret, A(1) + seed) +
HMAC-HASH(secret, A(2) + seed) +
HMAC-HASH(secret, A(3) + seed) + ...

Where A(0) = seed and A(i) = HMAC_hash(secret, A(i-1))

This mess replaced with HKDF in 1.3



TLS 1.2 record protocol: MAC-Encode-Encrypt (MEE)



Padding is not MAC'd. Implementations must handle padding checks ***very*** carefully.

MAC	HMAC-MD5, HMAC-SHA1, HMAC-SHA256
Encrypt	CBC-AES128, CBC-AES256, CBC-3DES, RC4-128

Record layer details

- Fragmentation
  - Maximum TLS ciphertext handles 2^{14} bytes of message data
  - Split longer requested submission into multiple chunks
- Sequence numbers keep track of count of chunks sent in each direction
- Compression methods
  - Generally a bad idea to use (why?)