Transport-layer security (TLS)

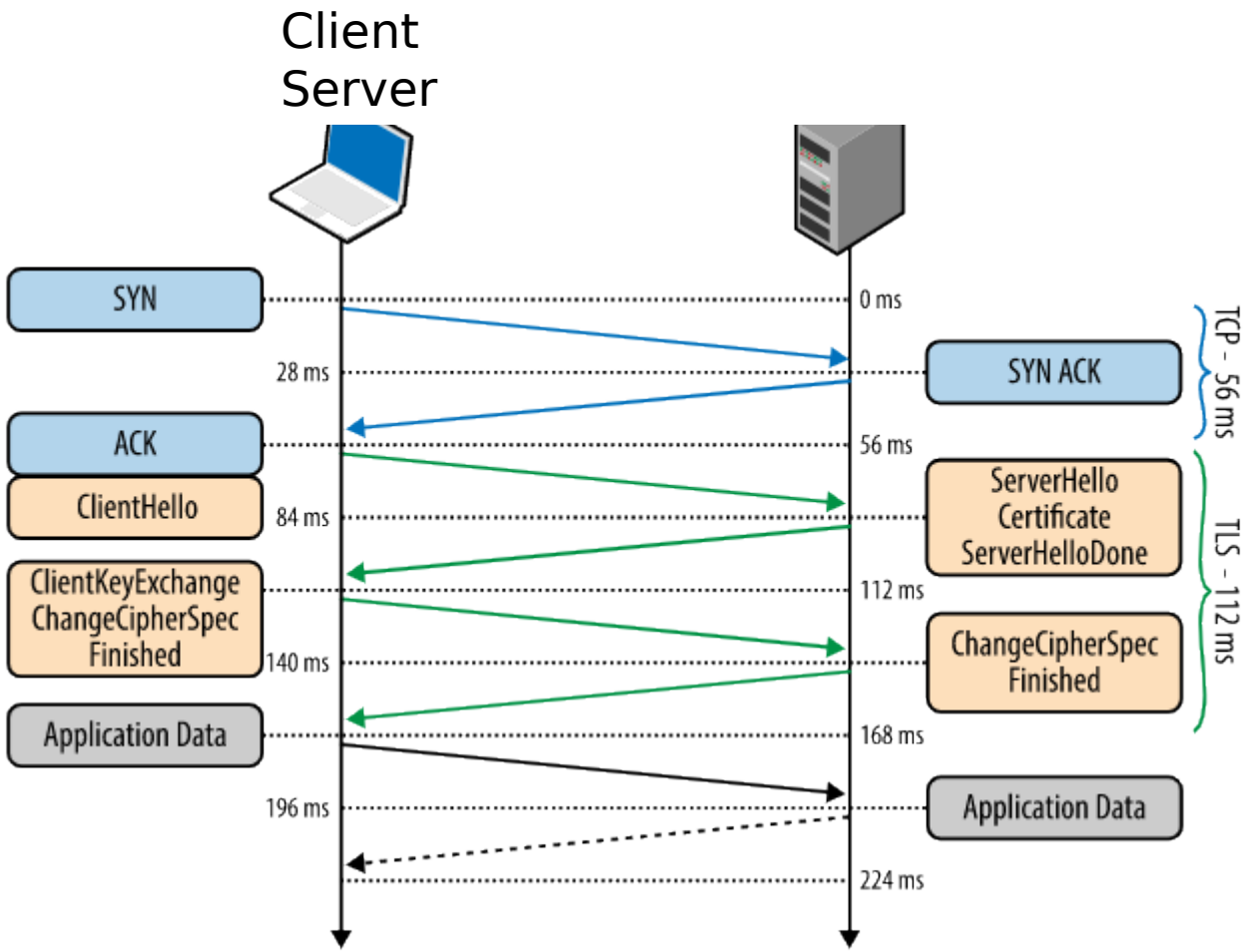
- widely deployed security protocol above the transport layer
  - supported by almost all browsers, web servers: https (port 443)
- provides:
  - confidentiality: via *symmetric encryption*
  - integrity: via *cryptographic hashing*
  - authentication: via *public key cryptography*
- history:
  - early research, implementation: secure network programming, secure sockets
  - secure socket layer (SSL) deprecated [2015]
  - TLS 1.3: RFC 8846 [2018]

Transport-layer security: what's needed?

- let's *build* a toy TLS protocol, *t-tls,* to see what's needed!

  - handshake: Alice, Bob use their certificates, private keys to authenticate each other, exchange or create shared secret
  - key derivation: Alice, Bob use shared secret to derive set of keys
  - data transfer: stream data transfer: data as a series of records
    - not just one-time transactions
  - connection closure: special messages to securely close connection

TLS: initial handshake



TLS handshake phase:

- Client establishes TCP connection with Server
- Server sends certificate
- Client verifies certificate
- Client sends Server a master secret key (MS), used to generate all other keys for TLS session
- potential issues:
  - 3 RTT before client can start receiving data (including TCP handshake)

TlS: cryptographic keys

- considered bad to use same key for more than one cryptographic function
  - different keys for message authentication code (MAC) and encryption
- four keys:
  - K_c : encryption key for data sent from client to server
  - M_c : MAC key for data sent from client to server
  - K_s : encryption key for data sent from server to client
  - M_s : MAC key for data sent from server to client
- keys derived from key derivation function (KDF)
  - takes master secret and (possibly) some additional random data to create new keys

TLS: encrypting data

- recall: TCP provides data *byte stream* abstraction
- Q: can we encrypt data in-stream as written into TCP socket?
  - *A:* where would MAC go? If at end, no message integrity until all data received and connection closed!
  - *solution:* break stream in series of "records"
    - each client-to-server record carries a MAC, created using M_c
    - receiver can act on each record as it arrives
- tls record encrypted using symmetric key, $K_{c,}$ passed to TCP:

TLS : encrypting data (more)

- possible attacks on data stream?
  - *re-ordering:* man-in middle intercepts TCP segments and reorders (manipulating sequence #s in unencrypted TCP header)
  - *replay*

- solutions:
  - use TLS sequence numbers (data, TLS-seq-# incorporated into MAC)
  - use nonce

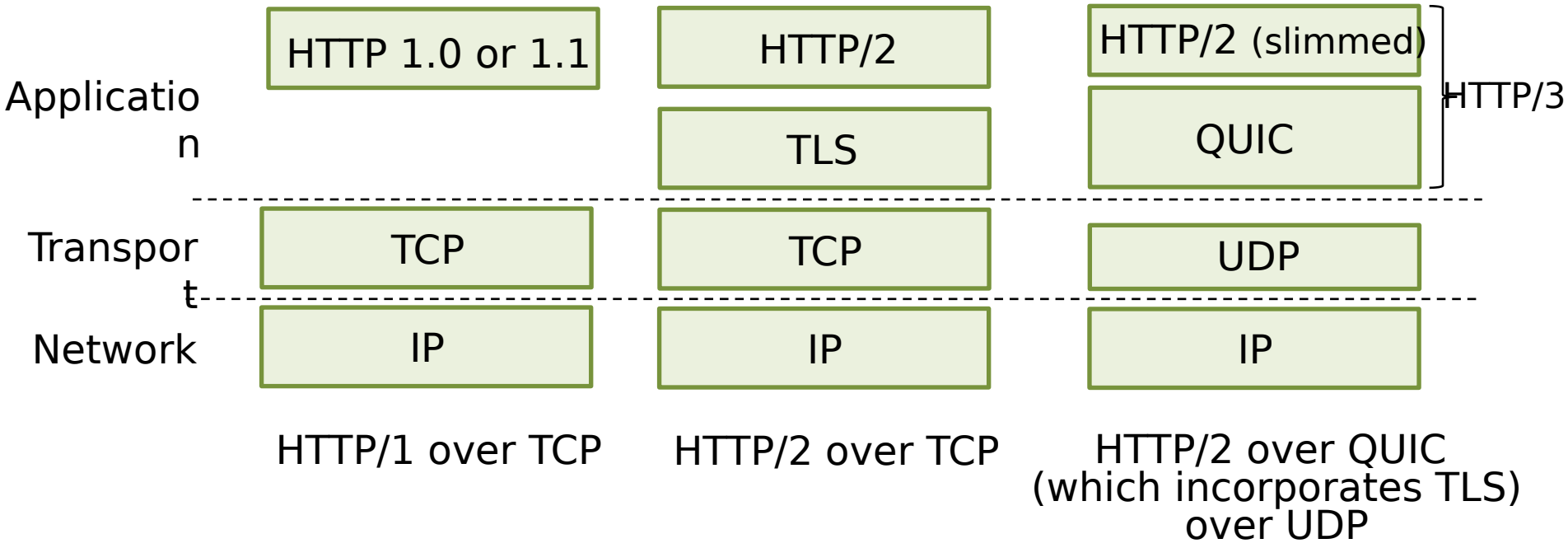
TLS : connection close

- truncation attack:
  - attacker forges TCP connection close segment
  - one or both sides thinks there is less data than there actually is
- solution: record types, with one type for closure
  - type 0 for data; type 1 for close
- MAC now computed using data, type, sequence #

K_C(*length* | *type* | *data* | *MAC*)

Transport-layer security (TLS)

- TLS provides an API that *any* application can use
- an HTTP view of TLS:



Exercizes

- Look a messages with “curl -v” and with Wireshark
- Try also with open ssl
  - openssl s_client -crlf -connect www.google.com:443 –servername www.google.com
  - Then:

HEAD / HTTP/1.0

Host: www.google.com