CS120: Computer Networks

Lecture 28. Network Security 2

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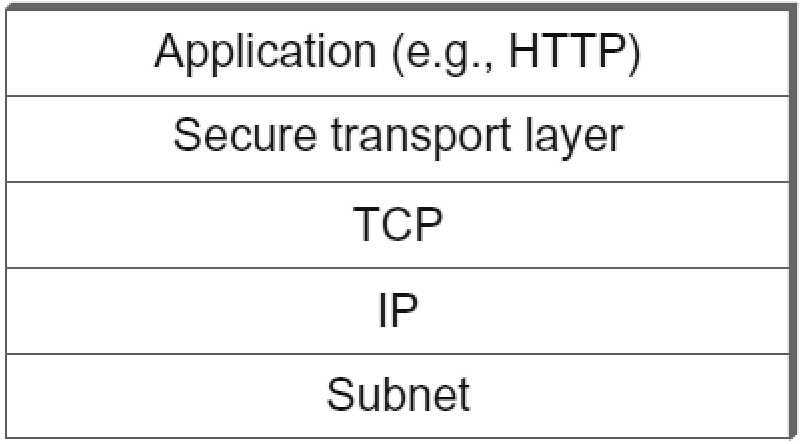
Example Systems

- TLS/SSL
- SSH
- Wi-Fi Security

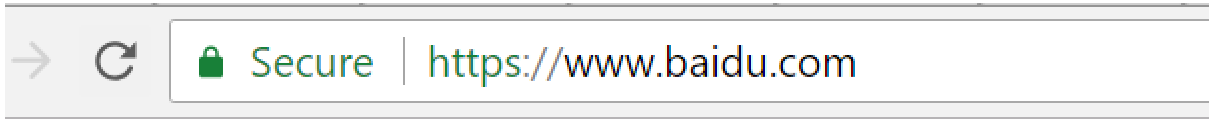
SSL: A Secure Transportation Layer Protocol

- SSL: Secure Sockets Layer
  - Deprecated [2015]
- TLS: Transport Layer Security
  - TLS 1.3: RFC 8846 [2018]
- Security for applications that use TCP
  - HTTPS (HTTP over SSL)
  - Some VPN
- Be able to handle threats:
  - Eavesdropping
    - Confidentiality
  - Manipulation
    - Integrity
  - Impersonation
    - Authentication



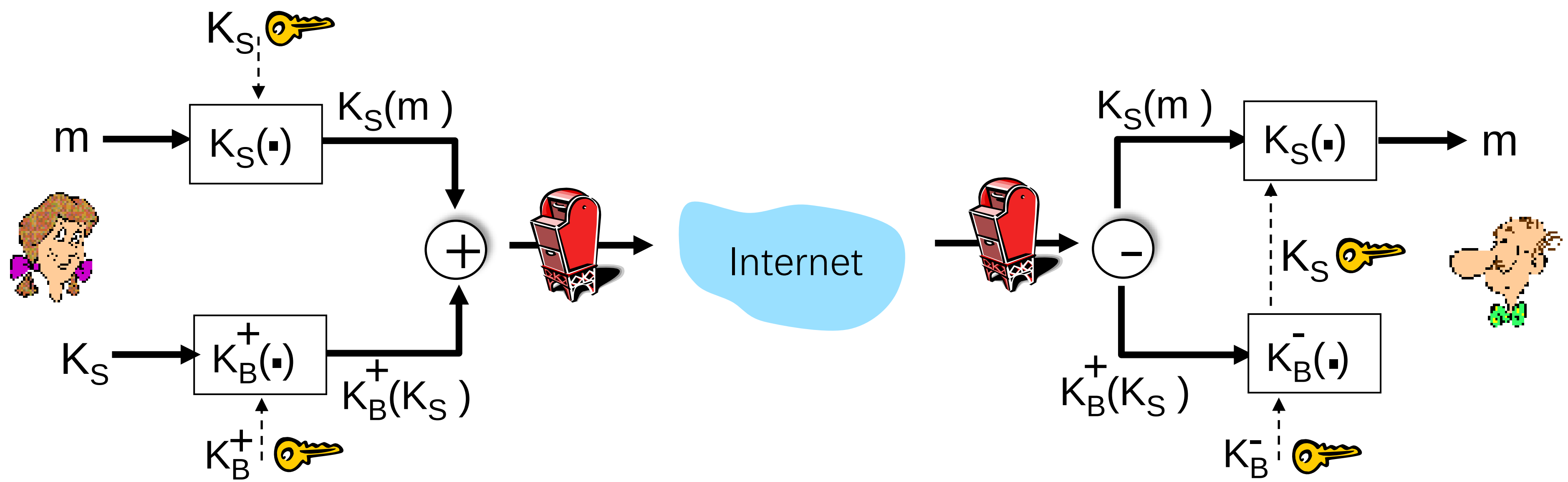
HTTPS

- Suppose a browser (client) wants to connect to a server who has a certificate from a trusted CA



Secure Message: Confidentiality

Alice wants to send *confidential* Message, m, to Bob.



Alice:

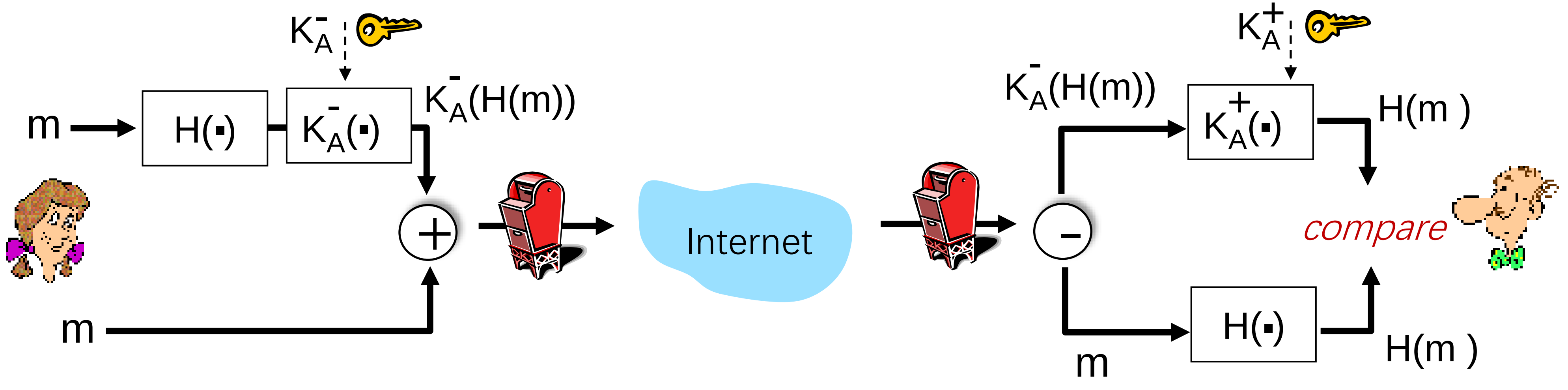
- generates random *symmetric* private key, K_S
- encrypts message with K_S (for efficiency)
- also encrypts K_S with Bob's public key
- sends both $K_S(m)$ and $K^+_B(K_S)$ to Bob

Bob:

- uses his private key to decrypt and recover K_S
- uses K_S to decrypt $K_S(m)$ to recover m

Secure Message: Integrity + Authentication

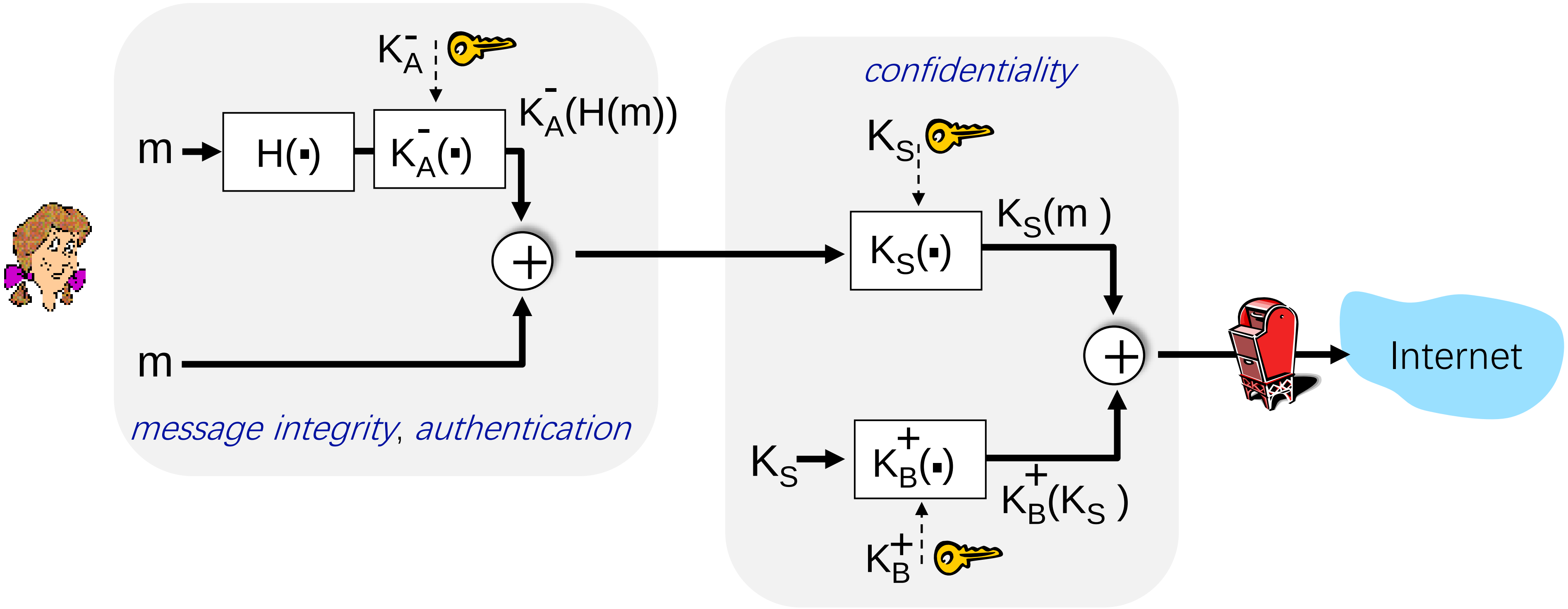
Alice wants to send m to Bob, with *message integrity*, *authentication*



- Alice digitally signs hash of her message with her private key, providing integrity and authentication
- Alice sends both message (unencrypted) and digital signature to Bob

Secure Message: ALL

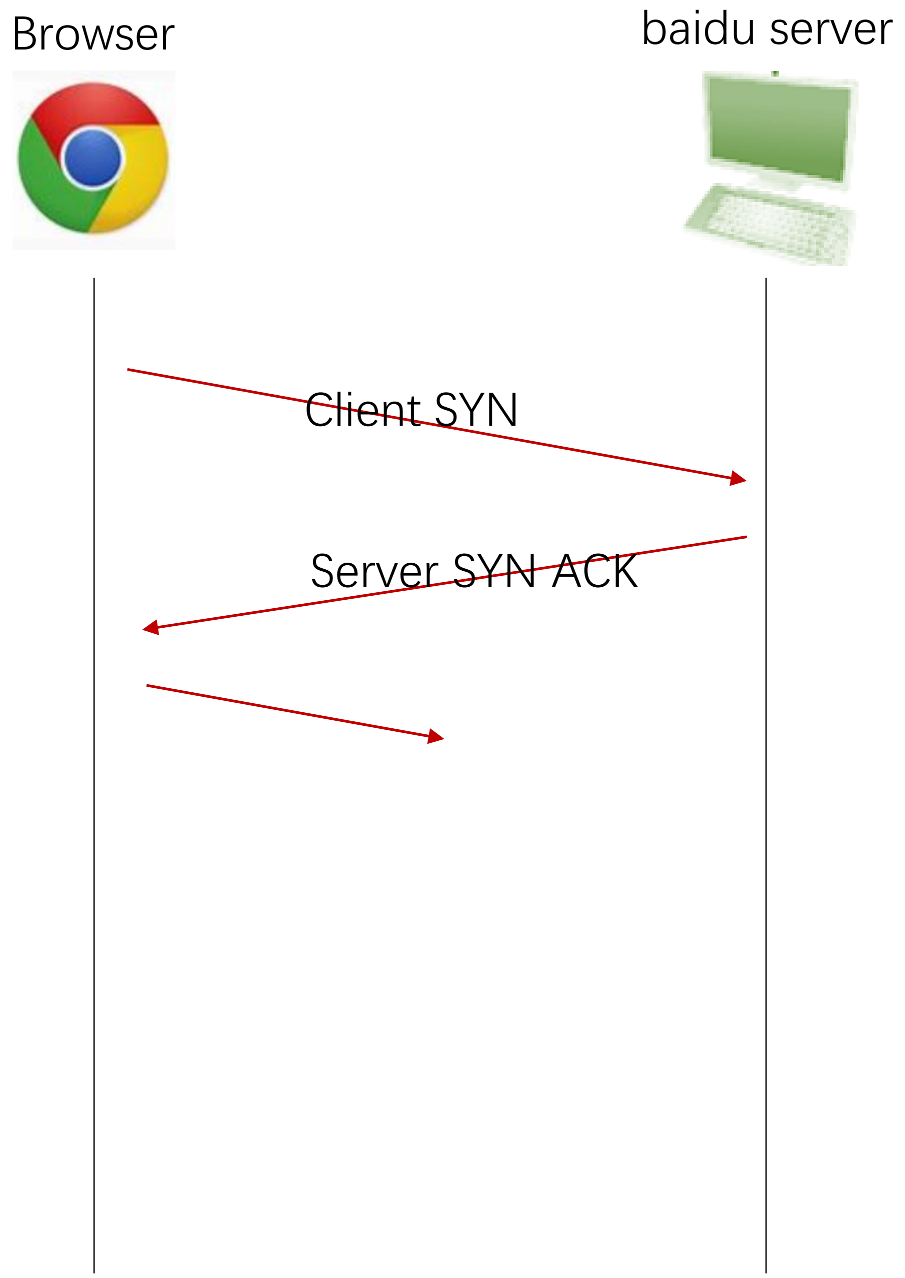
Alice sends m to Bob, with *confidentiality, message integrity, authentication*



Alice uses three keys: her private key, Bob's public key, new symmetric key

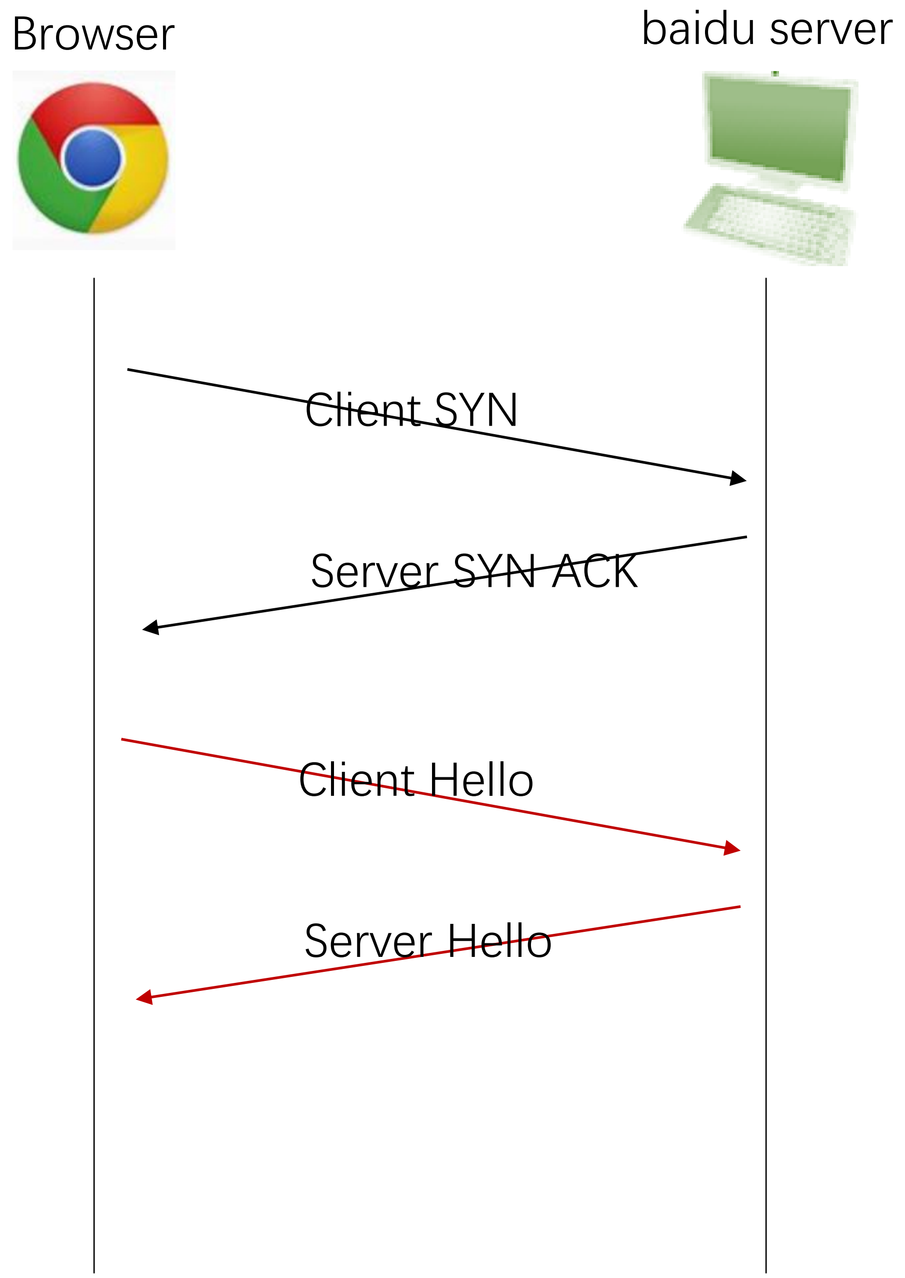
HTTPS via RSA

- Browser obtains the IP of the domain name www.baidu.com
- Browser connects to Baidu's HTTPS server (port 443) via TCP



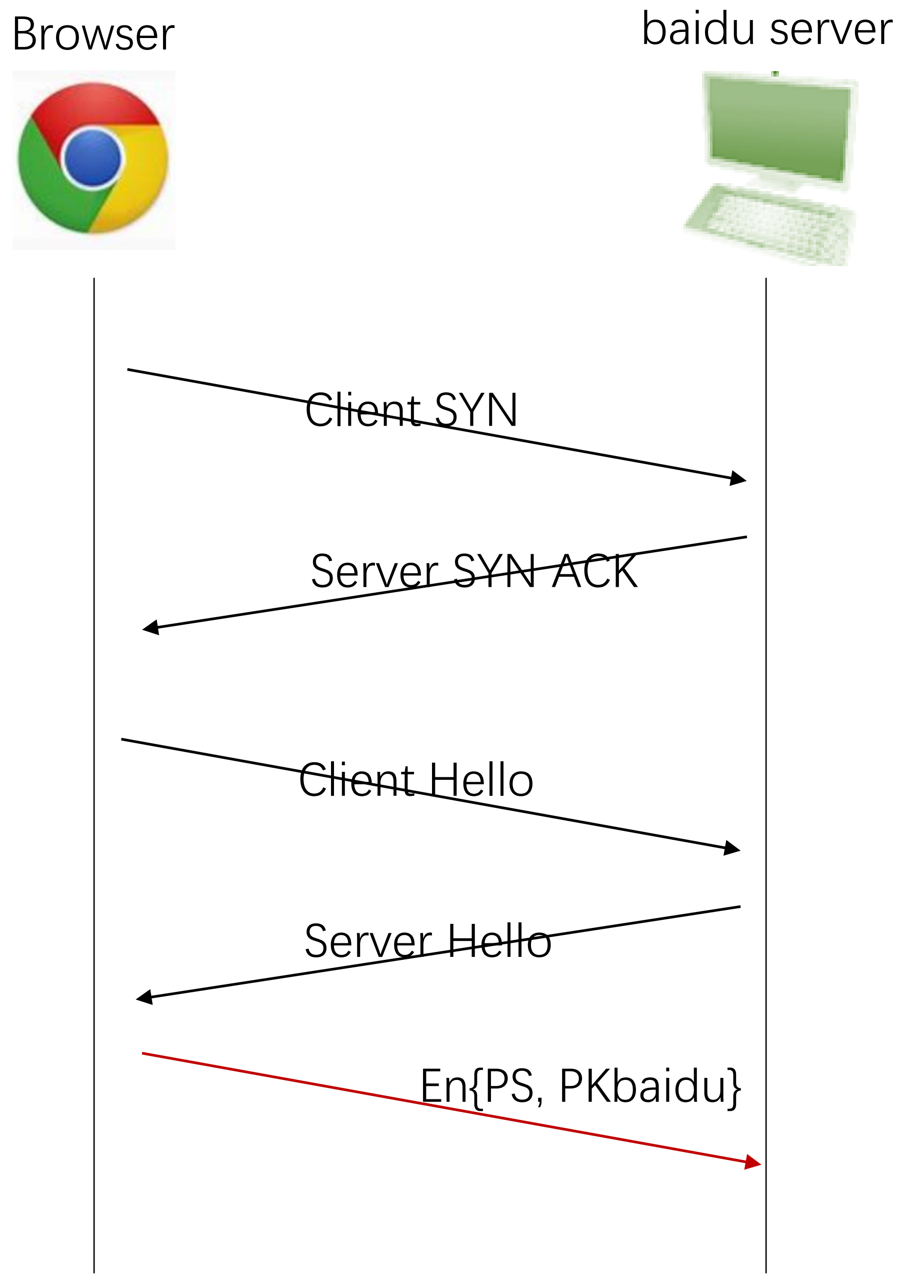
HTTPS via RSA

- Client Hello contains
  - 256-bit random number R_B
  - list of crypto algorithms it supports
- Server Hello contains
  - 256-bit random number R_S
  - Selects algorithms to use for this session
  - Server's certificate
- Browser validates server's cert
  - According to CAs



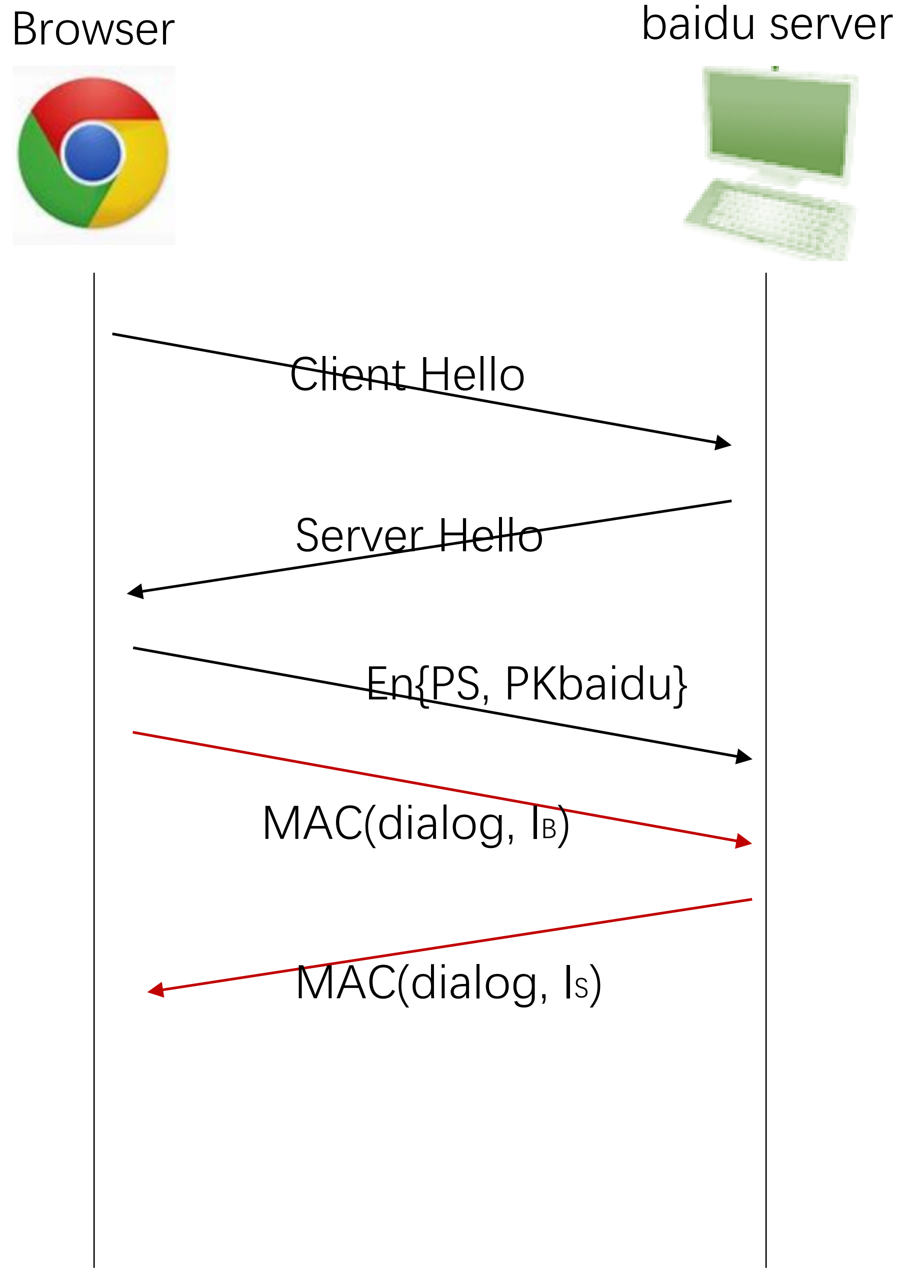
HTTPS via RSA

- Browser constructs "Premaster Secret" **PS**.
  - Uses R_B, R_S
- Browser sends **PS** encrypted using Baidu's public RSA key: PKbaidu
- Using **PS**, R_B, and R_S, browser & server derive symmetric cipher keys (C_B, C_S) & MAC integrity keys (I_B, I_S)
  - One pair to use in each direction
  - Considered bad to use same key for more than one cryptographic function
    - i.e., I and C should be different

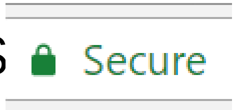


HTTPS via RSA

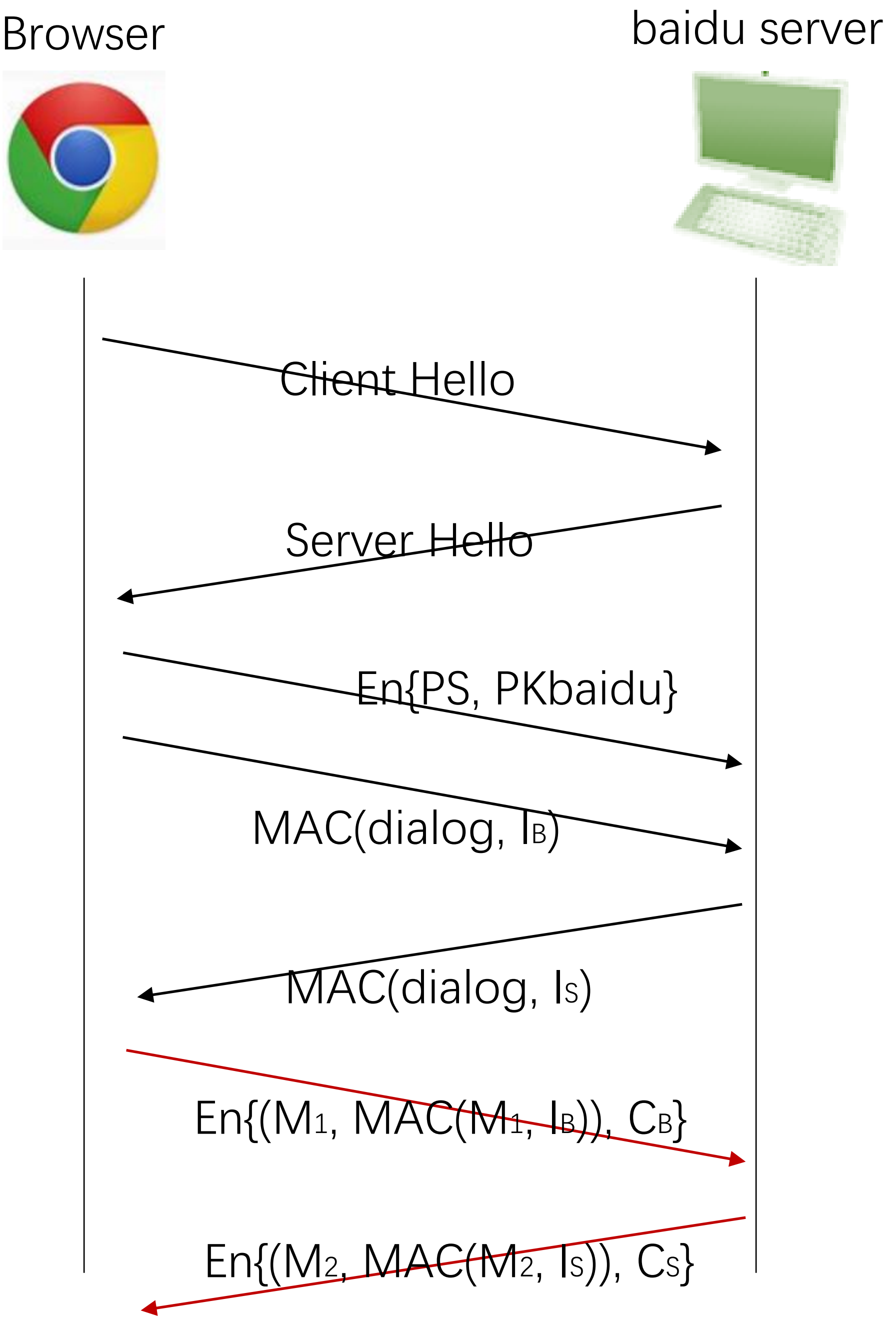
- Browser & server exchange MACs computed over entire dialog so far
  - Verify that (C_B, C_S) (I_B, I_S) are calculated correctly
- If the MAC is verified correctly, Browser displays 



HTTPS via RSA

- Browser & server exchange MACs computed over entire dialog so far
- If good MAC, Browser displays 

- All subsequent communication encrypted with symmetric cipher (AES, 3DES, etc.)

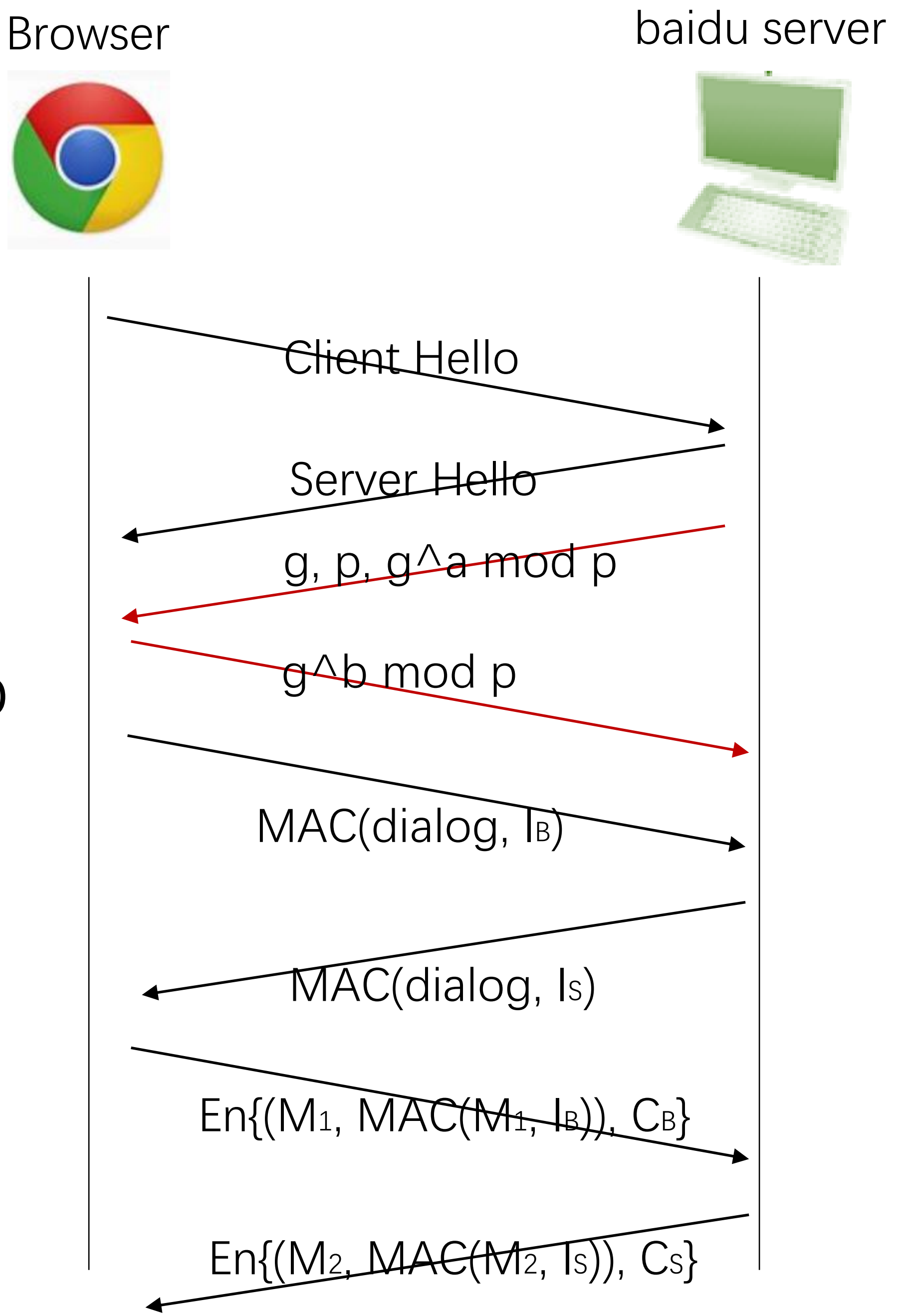


HTTPS via Diffie-Hellman Key Exchange

- Forward Secrecy
  - Assumptions:
    - The attacker can log all the traffic.
    - Assume PKbaidu is known to the attacker (some day in the future the private key of the server might be compromised)
    - Since in RSA, **PS** is encrypted by Pkbaidu. R_B and R_S are not encrypted
  - Attacker can calculate session keys (C_B, C_S) (I_B, I_S) and decode the logged conversations
- Solution
  - Diffie-Hellman Key exchange
    - Secure the conversations even with the above assumptions.

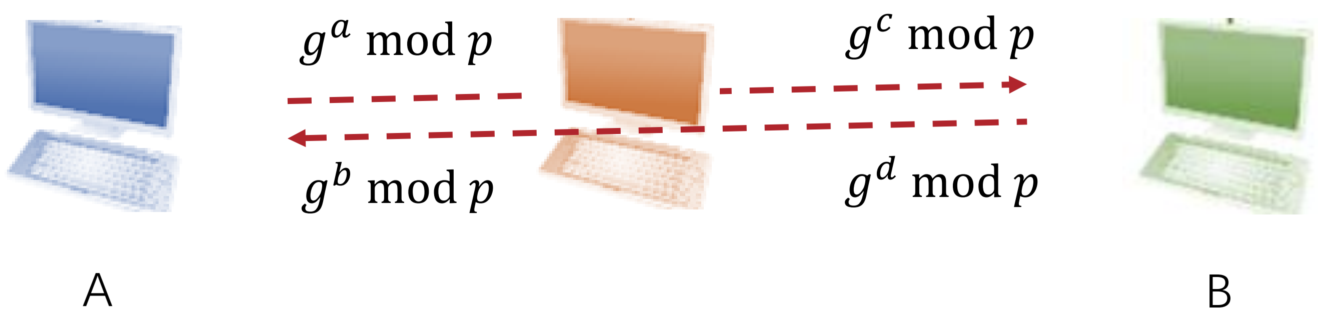
HTTPS via DH

- Server generates a random number **a**, sends public parameters (g, and p) and g^a mod p
- Browser generates a random number b, computes **PS** = g^ab mod p, sends g^b mod p to server
- Server computes **PS** = g^ab mod p



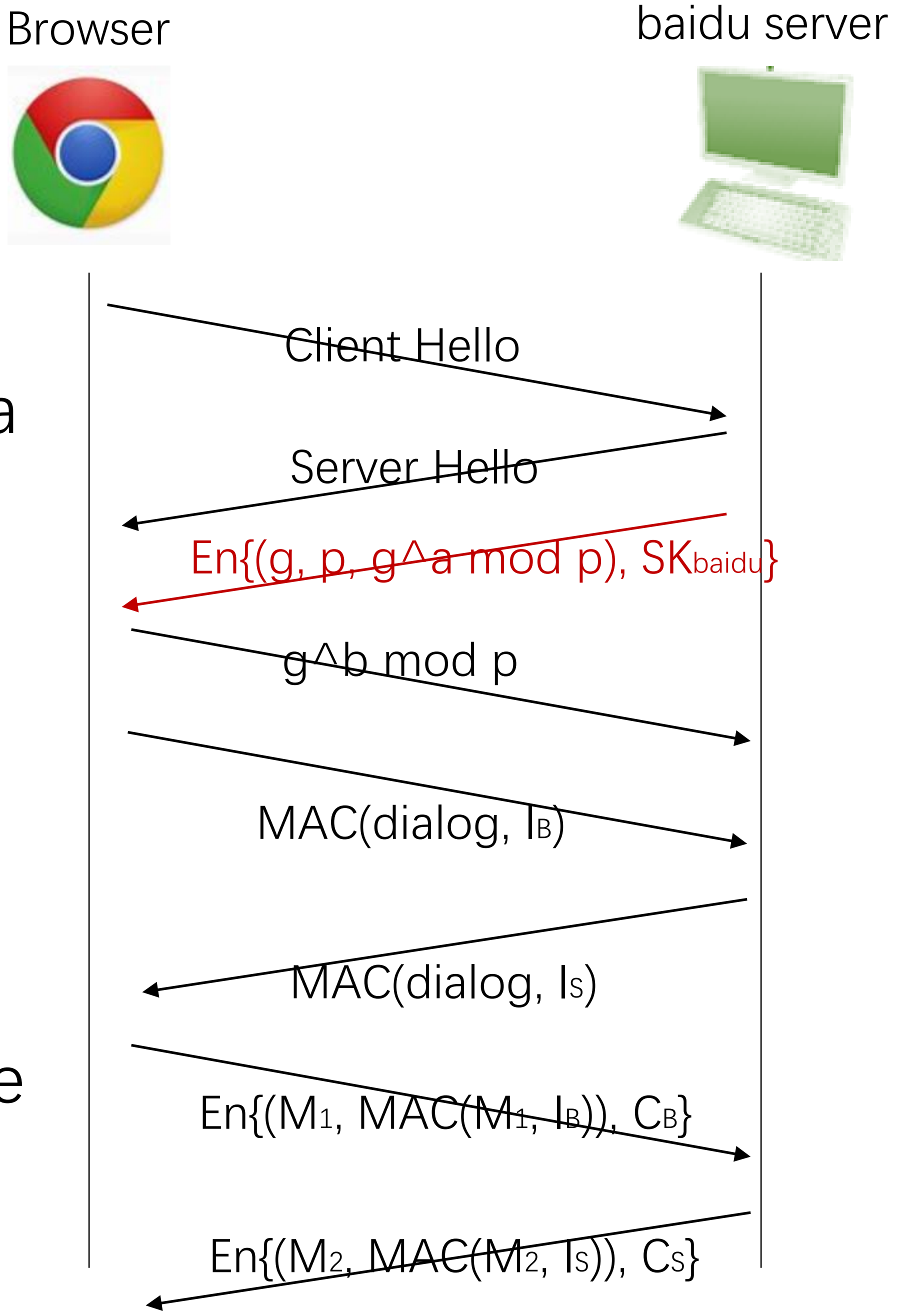
Diffie-Hellman Key Exchange

- Man in the middle attack
  - A cannot authenticate he is talking with B
- Diffie-Hellman Key Exchange is not secure without authentication



HTTPS via DH

- Server generates a random number **a**, sends public parameters (g, and p) and g^a mod p
  - Sign the content with servers' private key **SKbaidu**
- Browser generates a random number **b**, computes **PS** = g^ab mod p, sends g^b mod p to server
- Server computes **PS** = g^ab mod p
- Attacker is not able to calculate **PS**, because **a** and **b** have not been transmitted!



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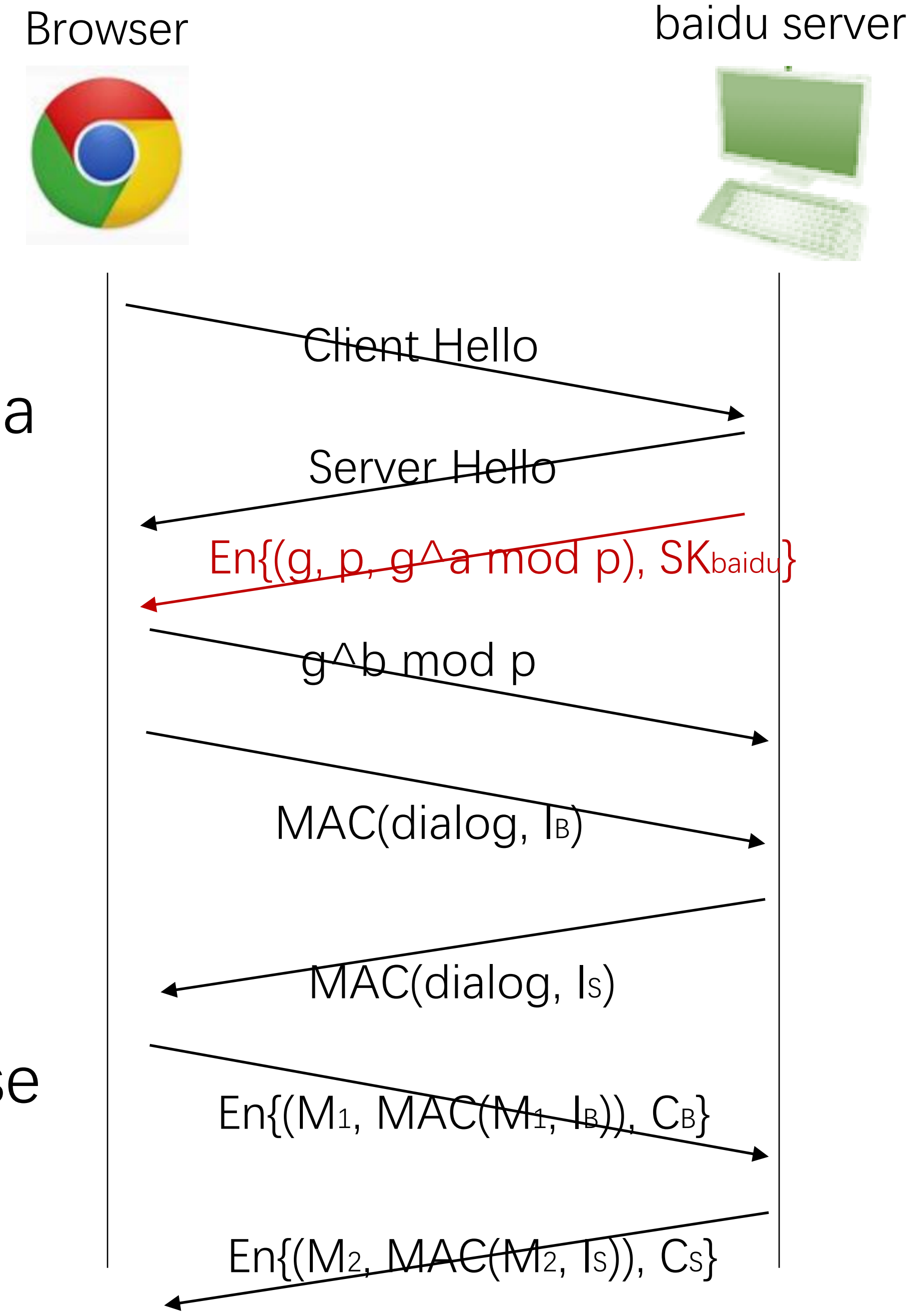
RSA and Diffie-Hellman Key Exchange are combined to improve security



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