CS 253: Web Security

Transport Layer Security

The problem with HTTP

- HTTP is not "secure"
  - Why?

HTTP request-response

Client

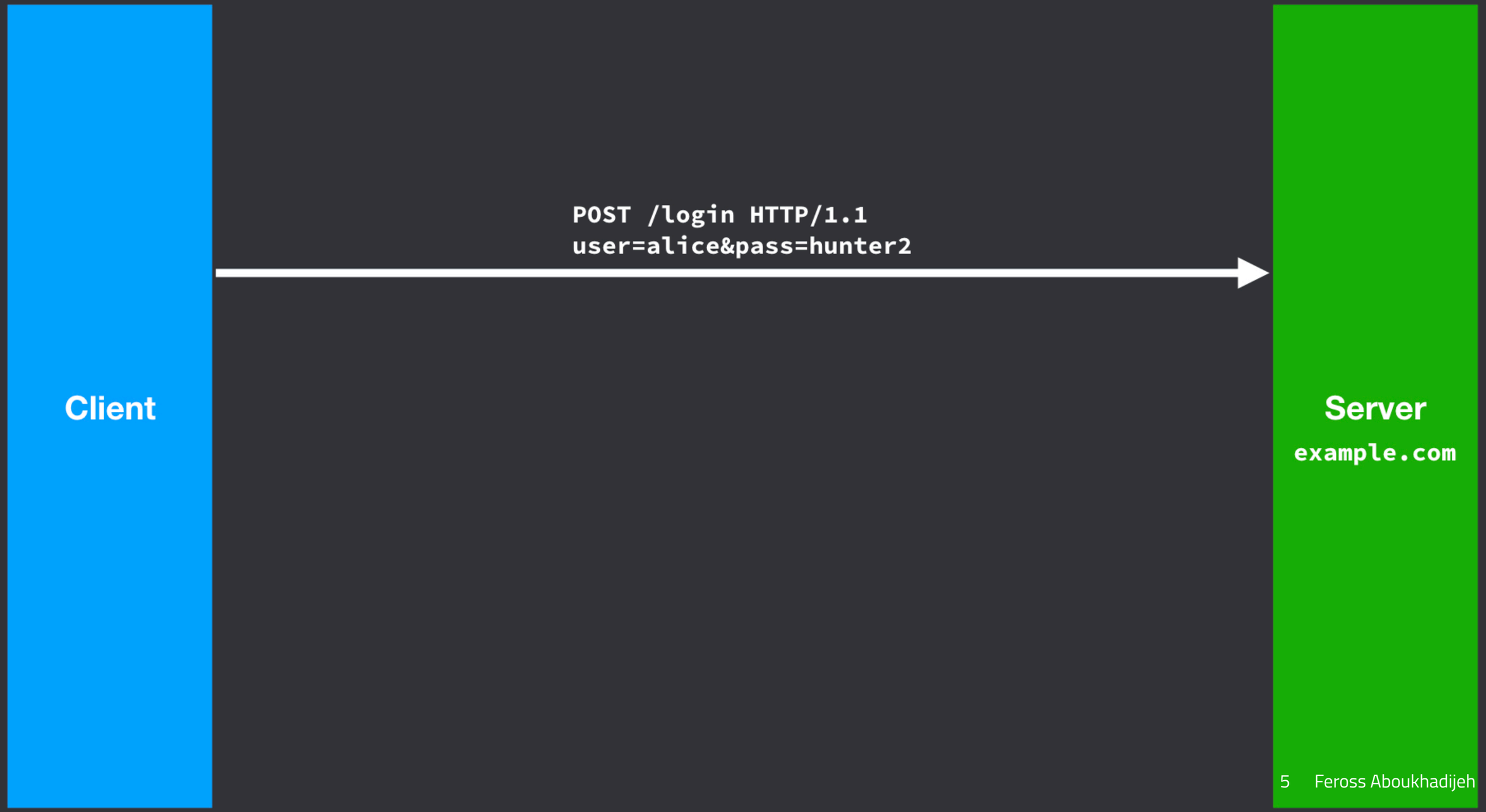
Server

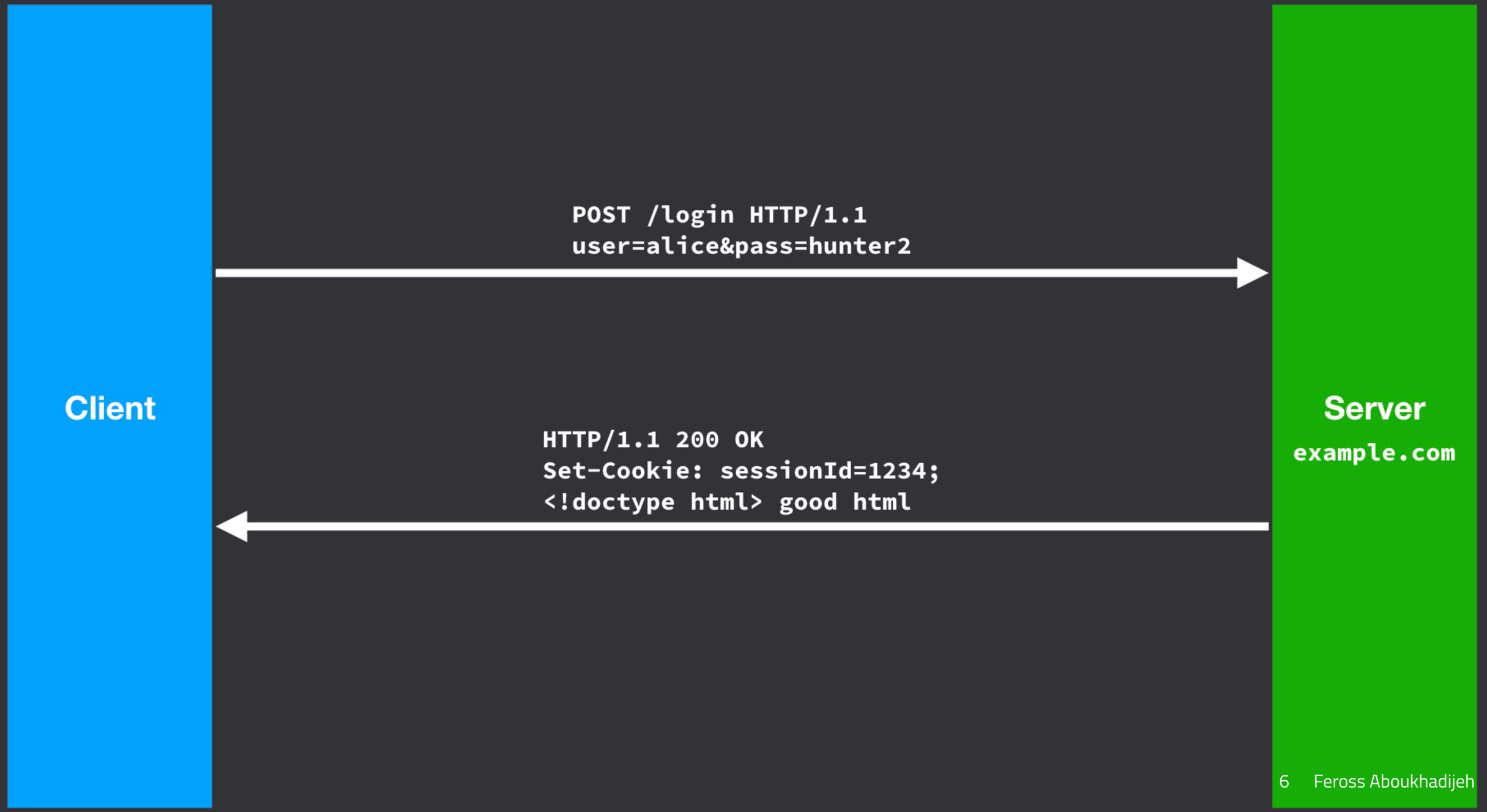
example.com

Client

Server

`example.com`


Client
POST /login HTTP/1.1
user=alice&pass=hunter2
Server
example.com


Client
POST /login HTTP/1.1
user=alice&pass=hunter2
HTTP/1.1 200 OK
Set-Cookie: sessionId=1234;
<!doctype html> good html
Server
example.com

Passive attacker

Client

Passive Attacker

Server

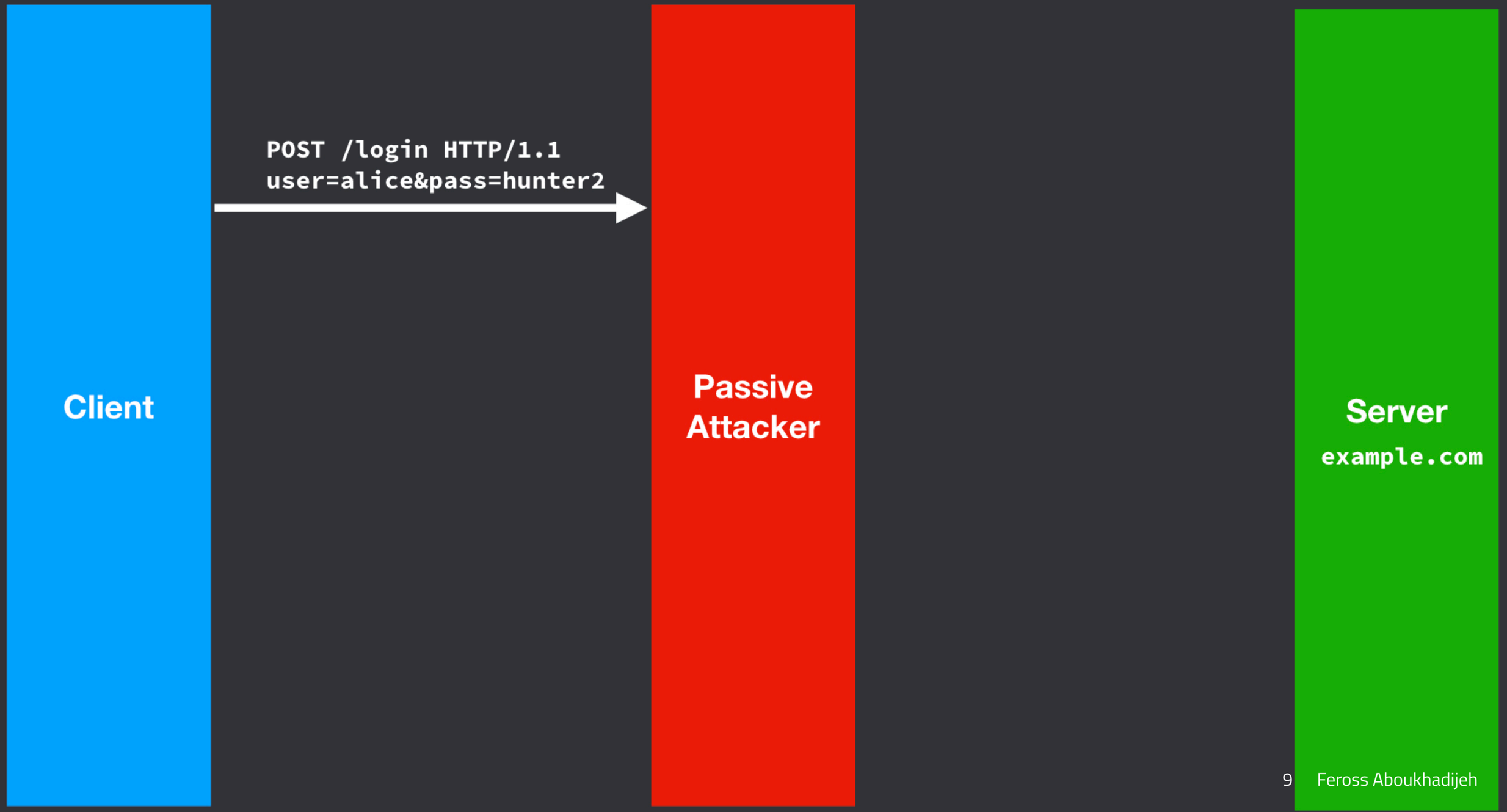
example.com

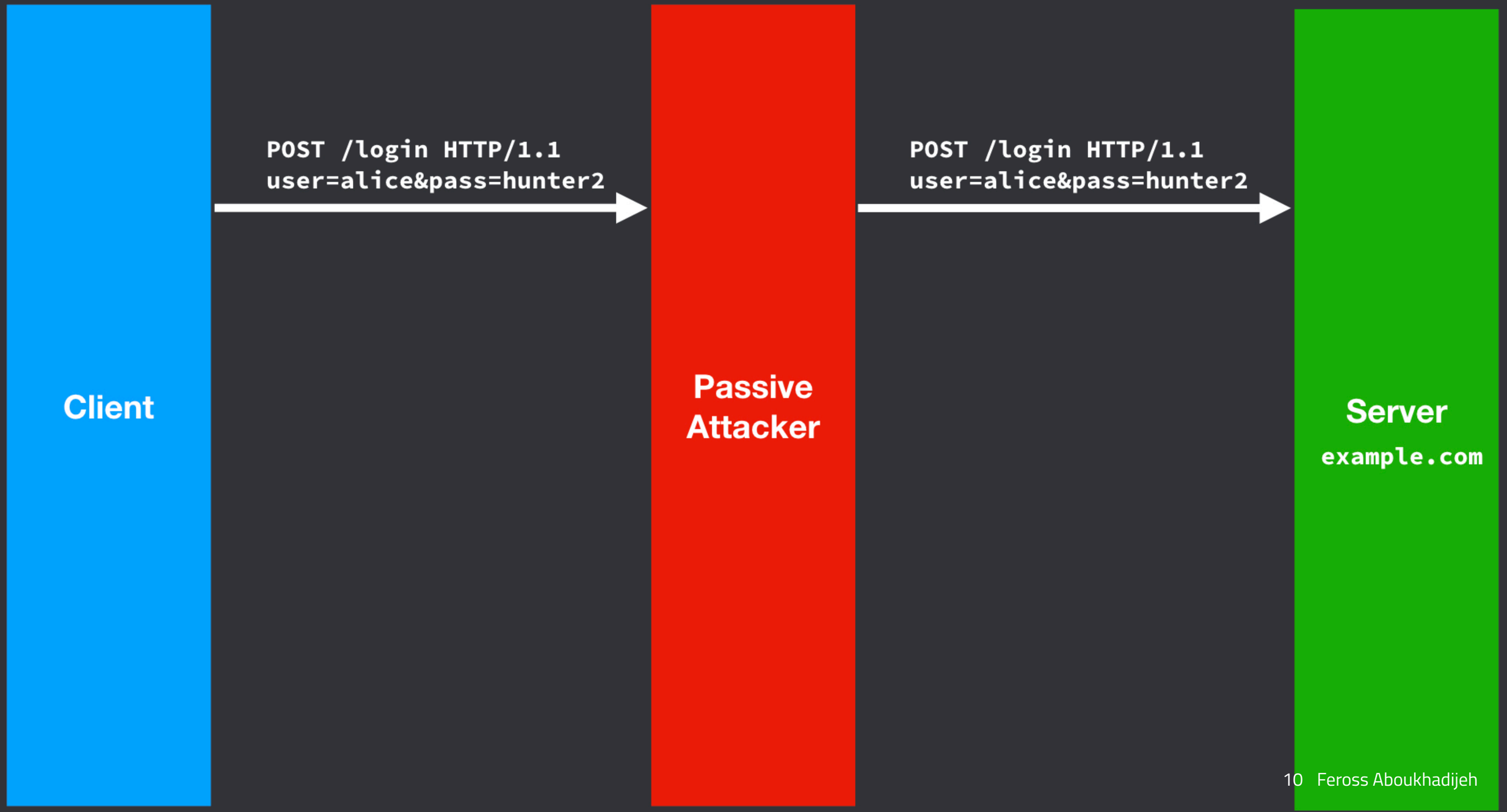
Client

Passive Attacker

Server

`example.com`


Client
POST /login HTTP/1.1
user=alice&pass=hunter2
Passive Attacker
Server
example.com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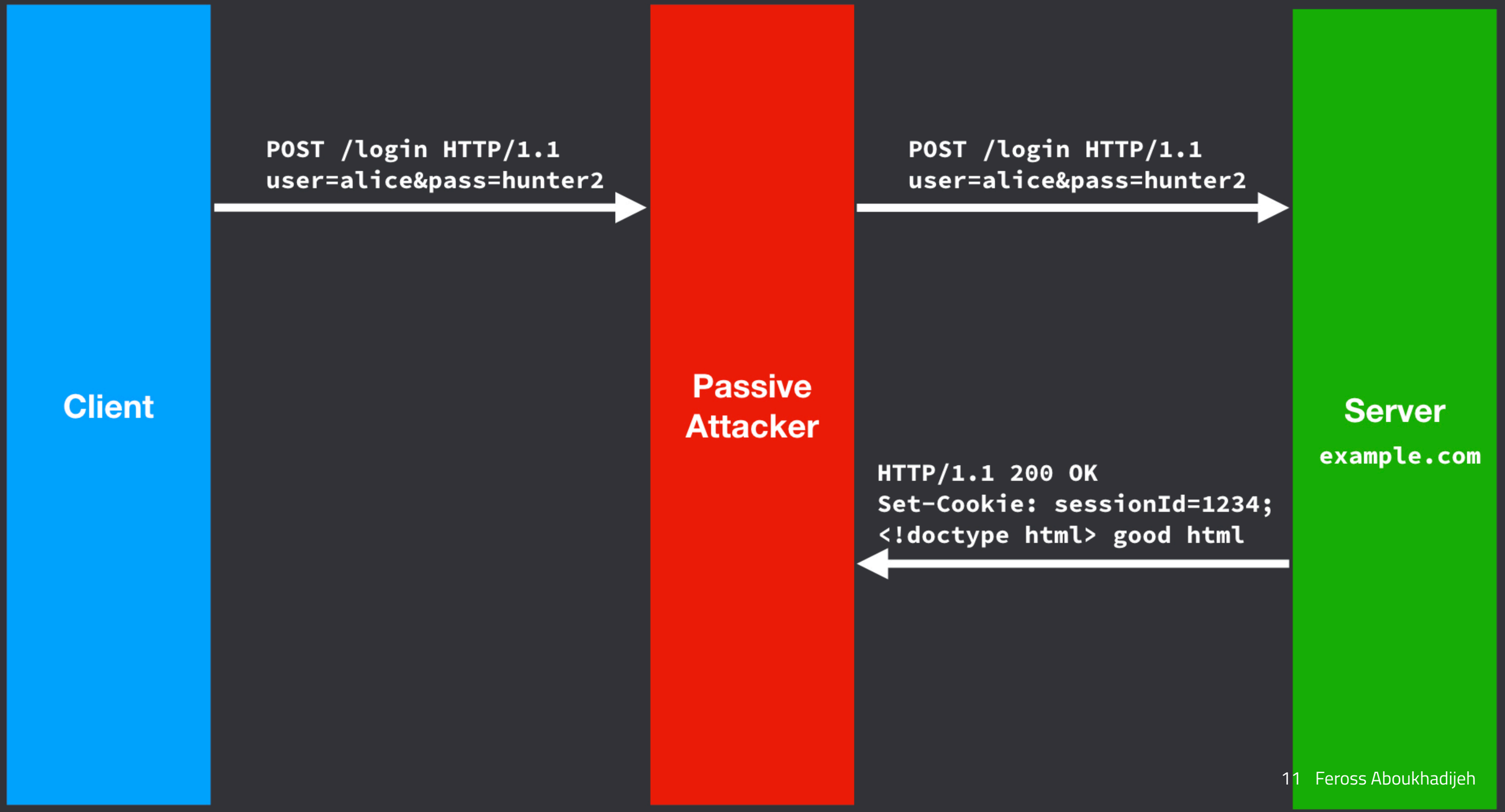
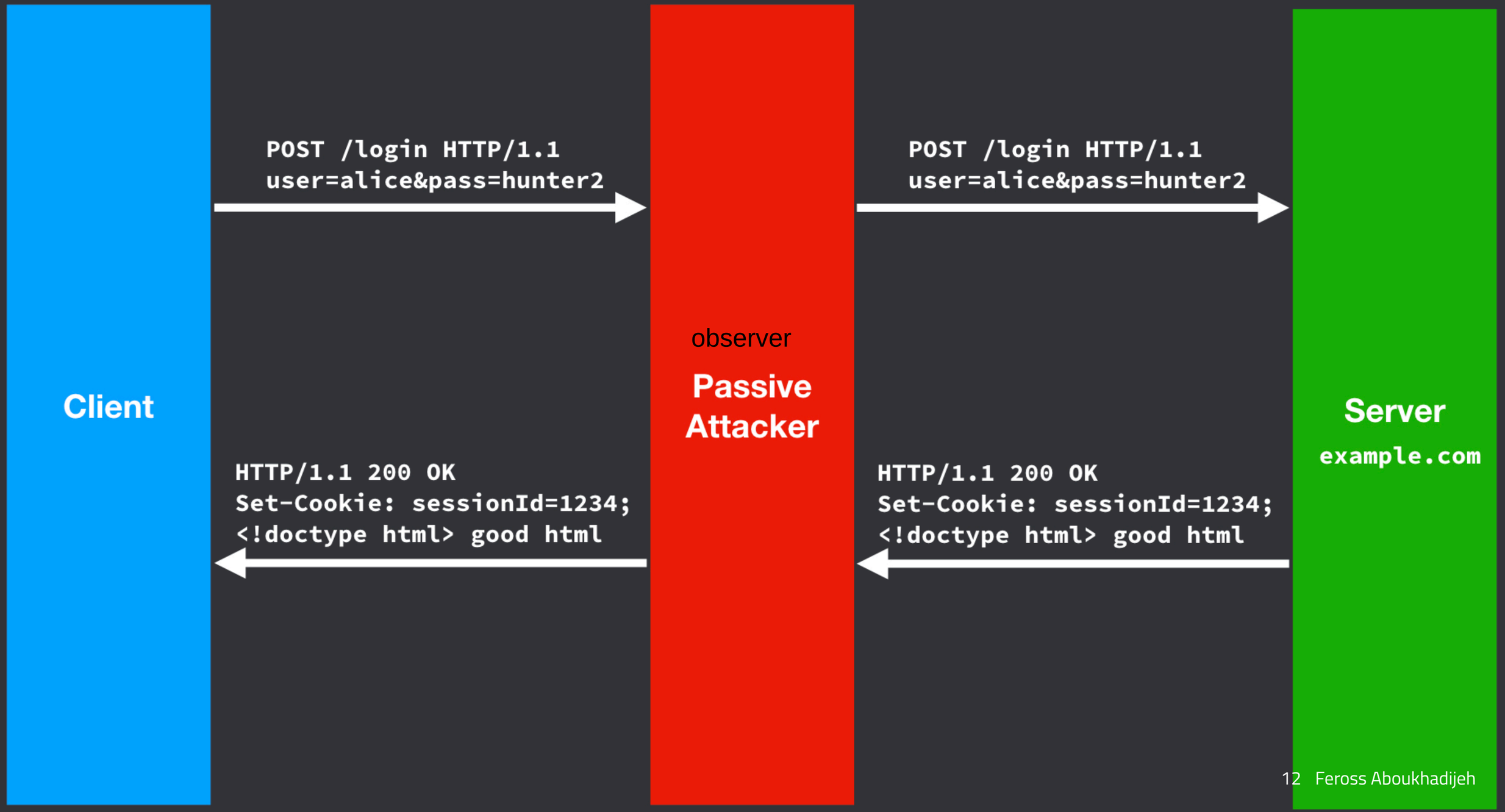
user=alice&pass=hunter2
Passive Attacker
POST /login HTTP/1.1
user=alice&pass=hunter2
Server
example.com


Client
POST /login HTTP/1.1
user=alice&pass=hunter2
Passive Attacker
POST /login HTTP/1.1
user=alice&pass=hunter2
Server
example.com
HTTP/1.1 200 OK
Set-Cookie: sessionId=1234;
<!doctype html> good html


Client
POST /login HTTP/1.1
user=alice&pass=hunter2
observer
Passive
Attacker
POST /login HTTP/1.1
user=alice&pass=hunter2
Server
example.com
HTTP/1.1 200 OK
Set-Cookie: sessionId=1234;
<!doctype html> good html
HTTP/1.1 200 OK
Set-Cookie: sessionId=1234;
<!doctype html> good html

Active attacker

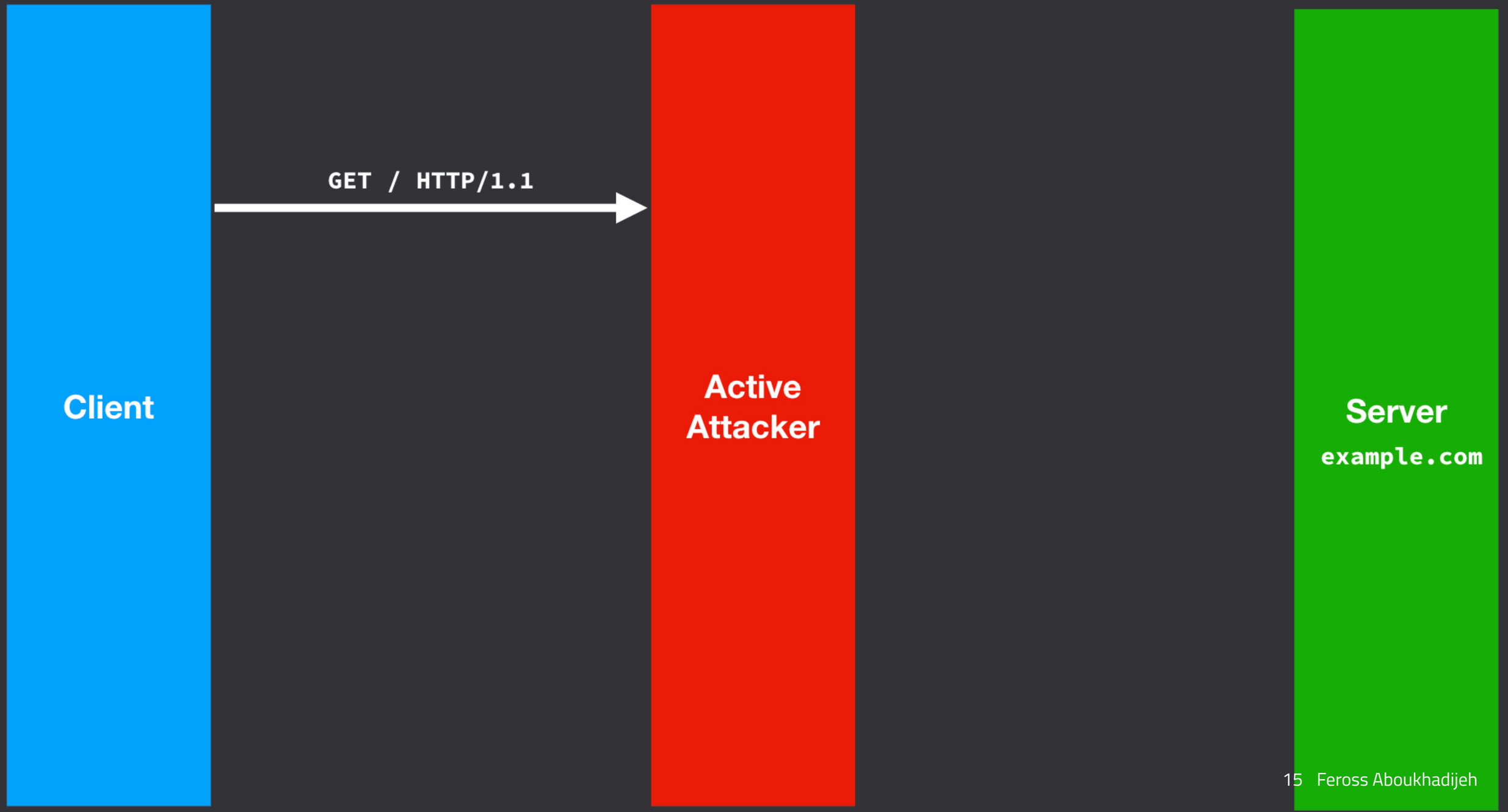
Client

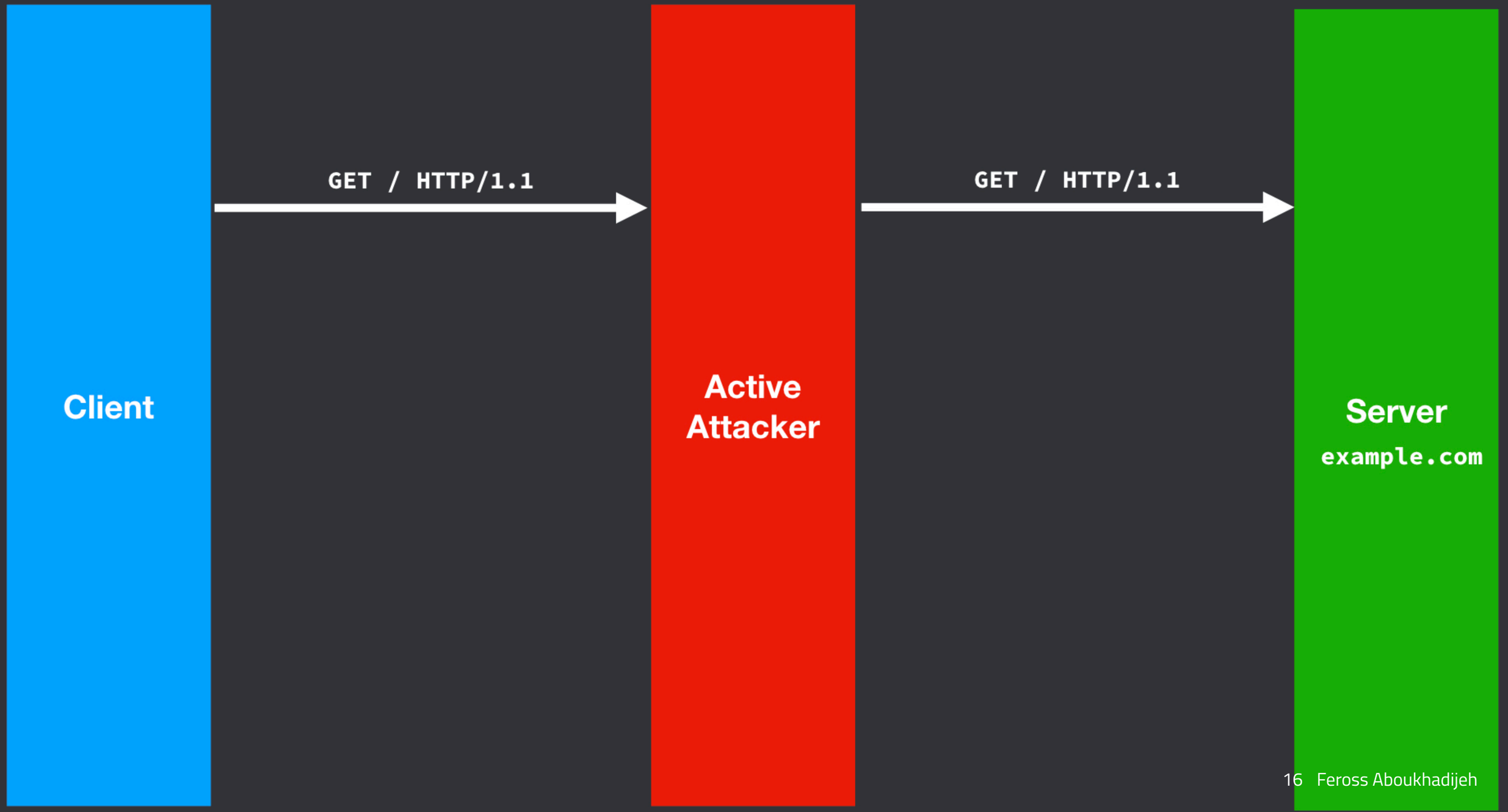
Active Attacker

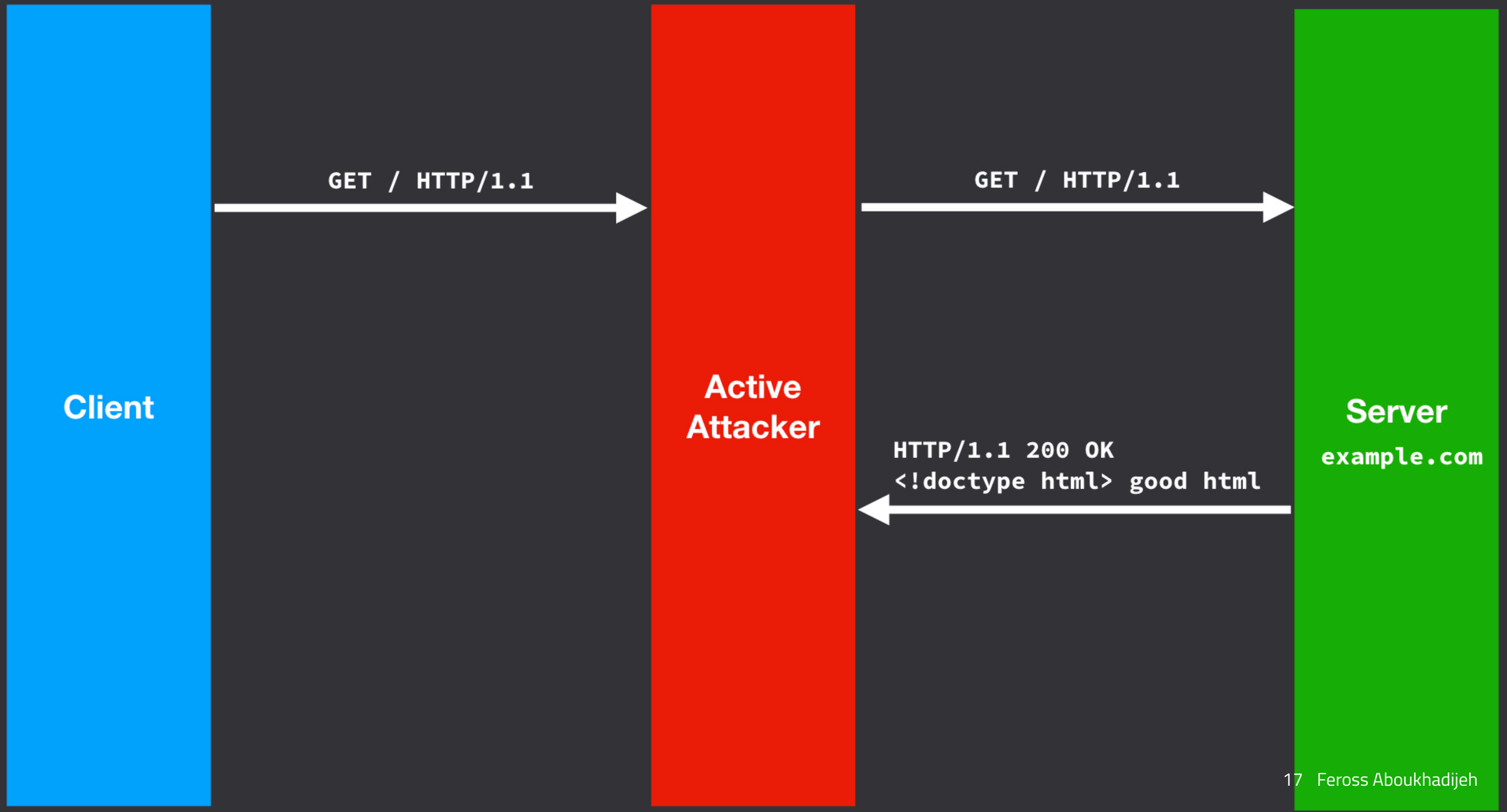
Server

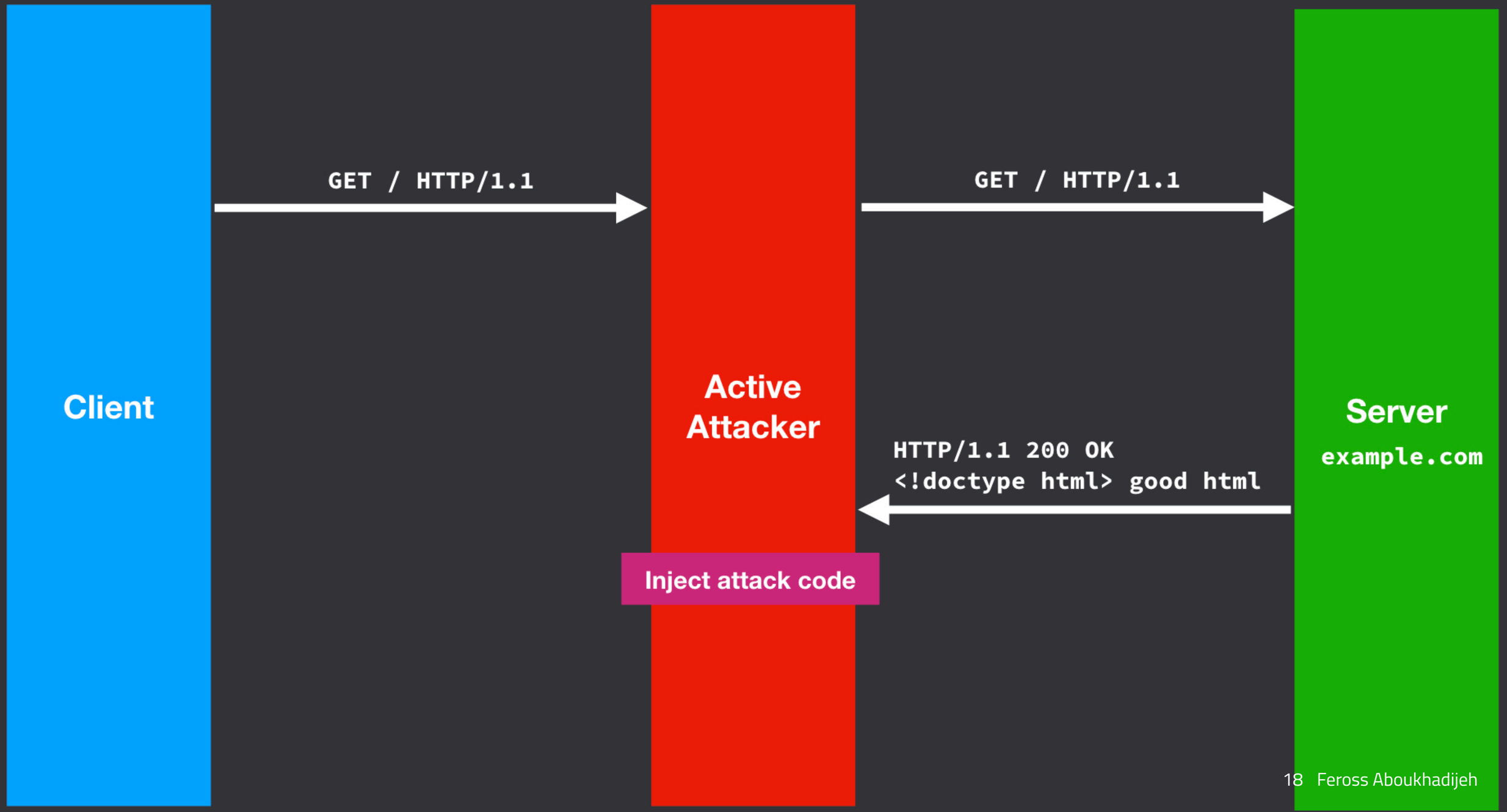
example.com

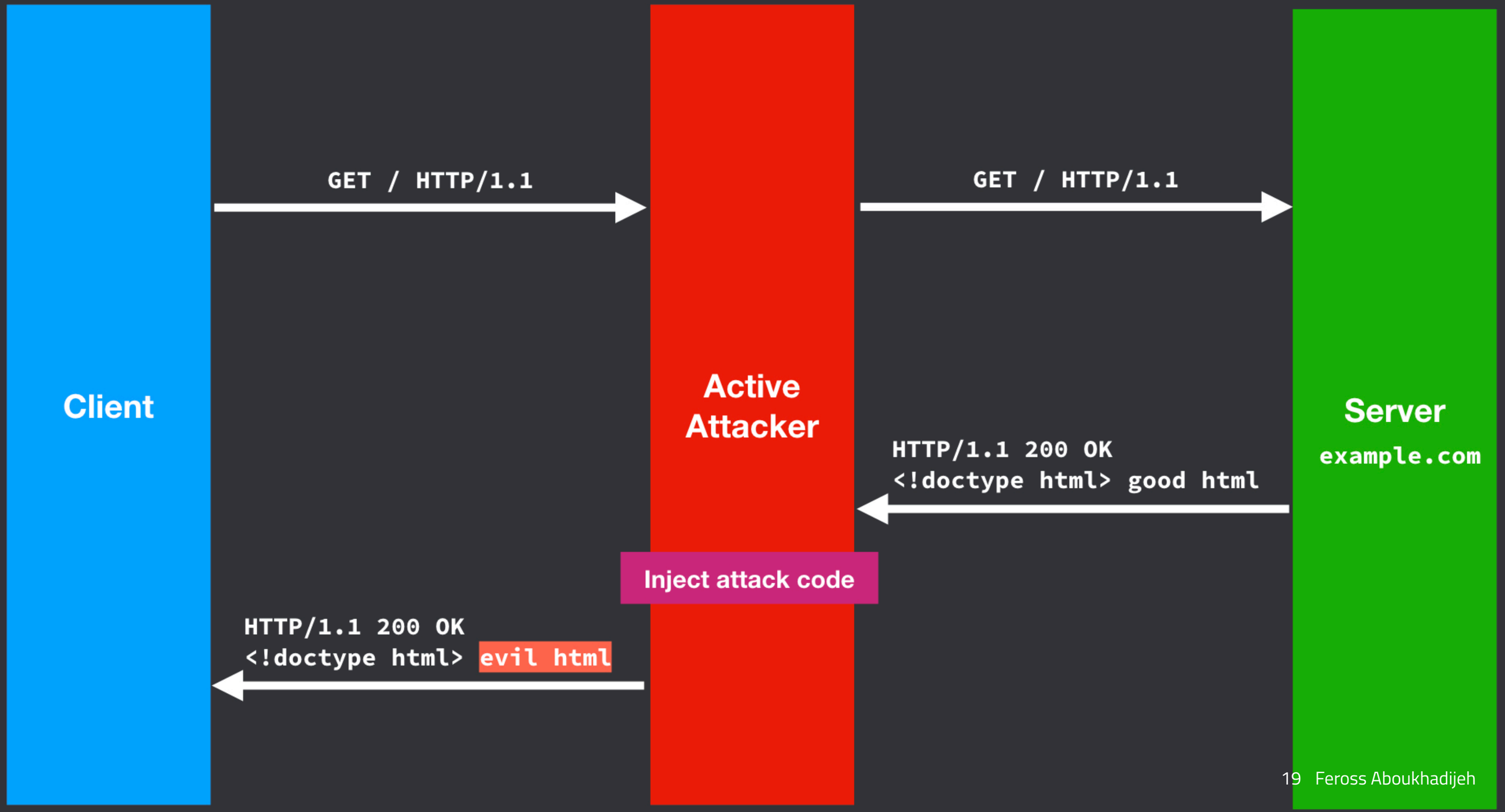

Client
Active Attacker
Server
example.com


Client
GET / HTTP/1.1
Active Attacker
Server
example.com


Client
GET / HTTP/1.1
Active Attacker
GET / HTTP/1.1
Server
example.com


Client
GET / HTTP/1.1
Active Attacker
GET / HTTP/1.1
Server
example.com
HTTP/1.1 200 OK
<!doctype html> good html


Client
GET / HTTP/1.1
Active Attacker
GET / HTTP/1.1
Server
example.com
HTTP/1.1 200 OK
<!doctype html> good html
Inject attack code


Client
GET / HTTP/1.1
Active Attacker
GET / HTTP/1.1
Server
example.com
HTTP/1.1 200 OK
<!doctype html> good html
Inject attack code
HTTP/1.1 200 OK
<!doctype html> evil html

What is the threat model?

- **Network attackers** control network infrastructure like routers or DNS servers
- Network attackers may eavesdrop, inject, block, or modify packets
- Potential network attackers occur anywhere there is an untrusted router or ISP
  - Wireless networks at cafes or hotels
  - Border gateways between countries

Goal: Secure communication

- Secure communication requires three properties
  - **Privacy:** No eavesdropping
  - **Integrity:** No tampering
  - **Authentication:** No impersonation

Goal: Secure communication

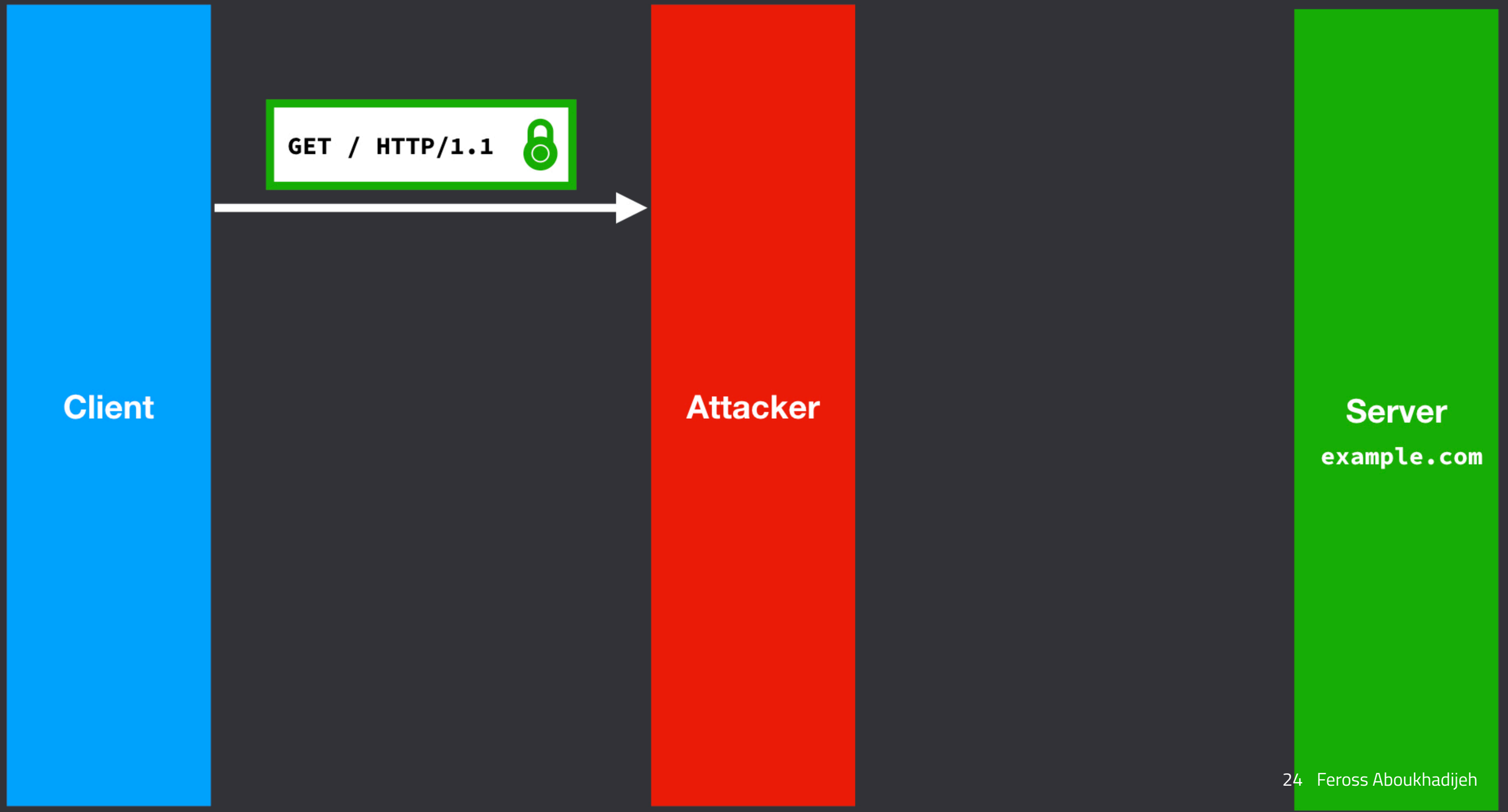
Client

Attacker

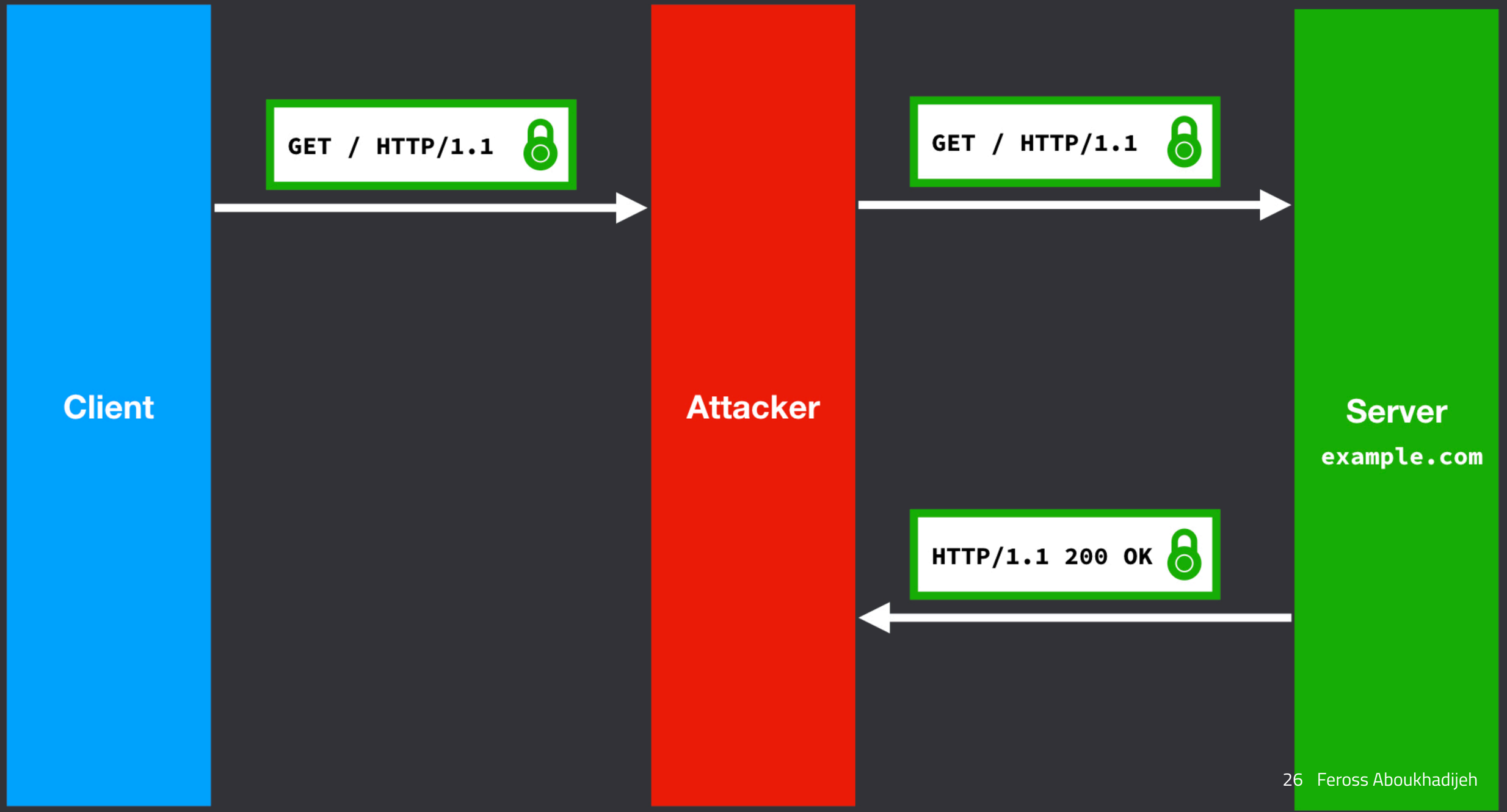
Server

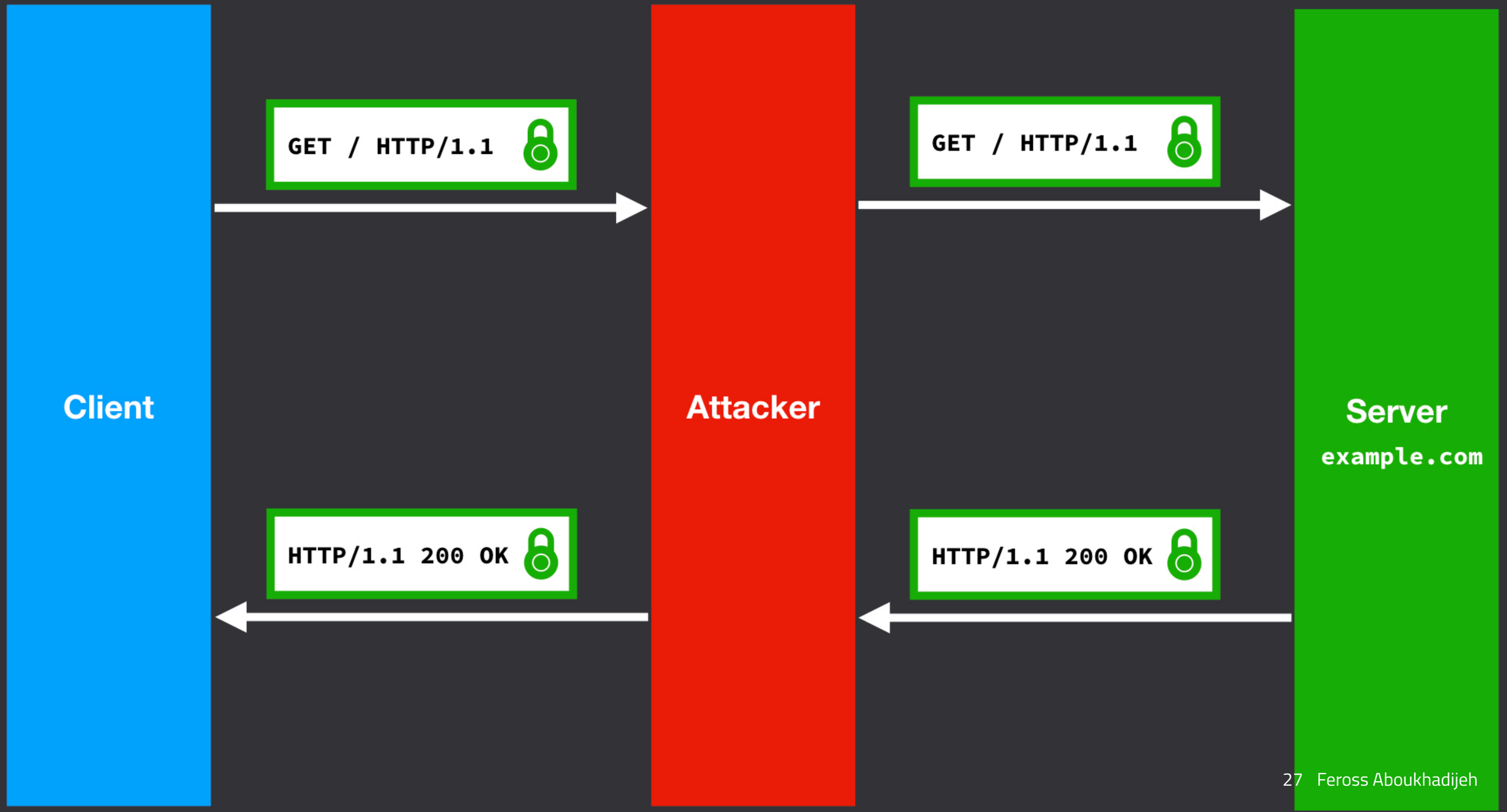
example.com

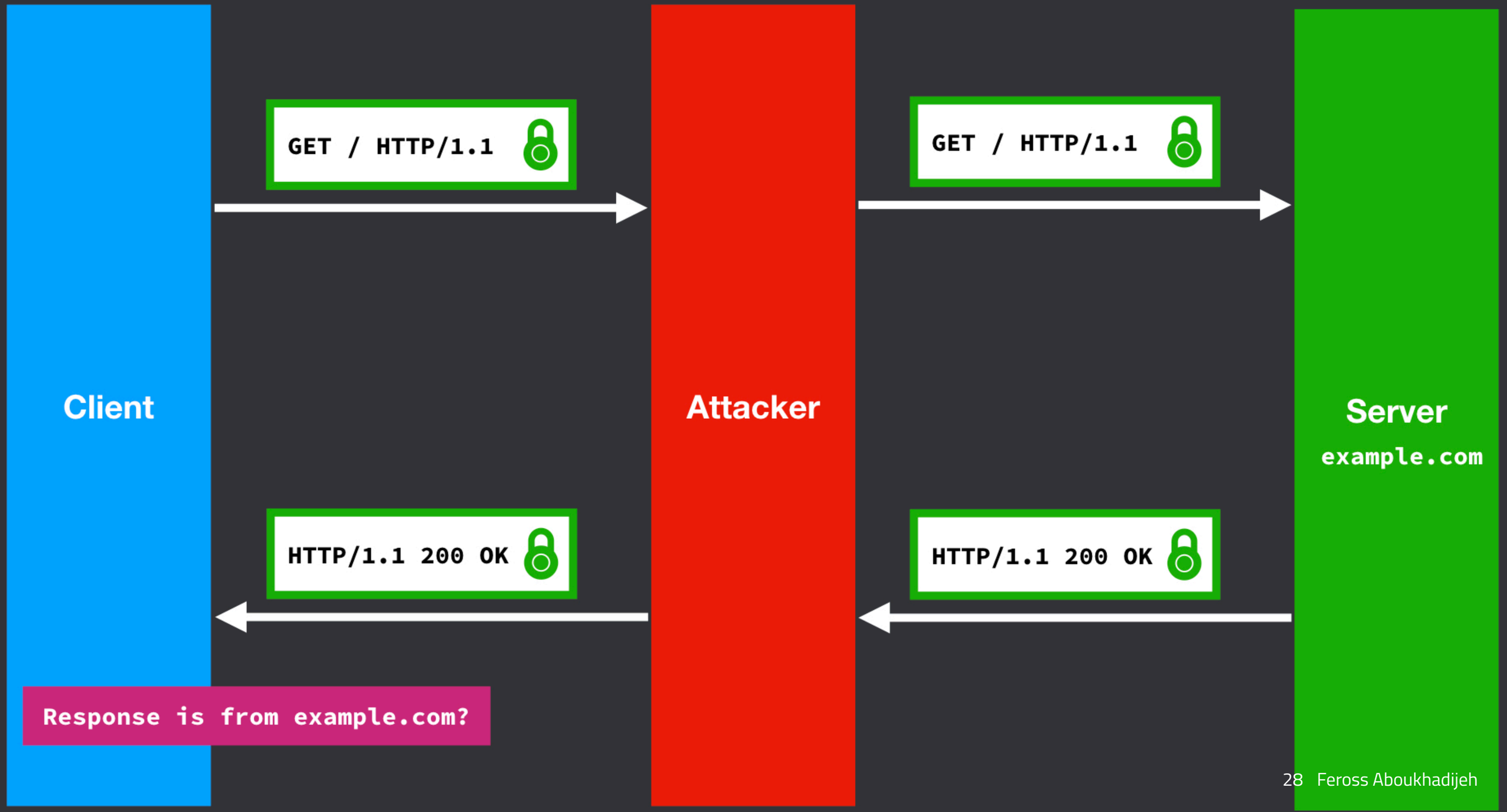

Client
Attacker
Server
example.com

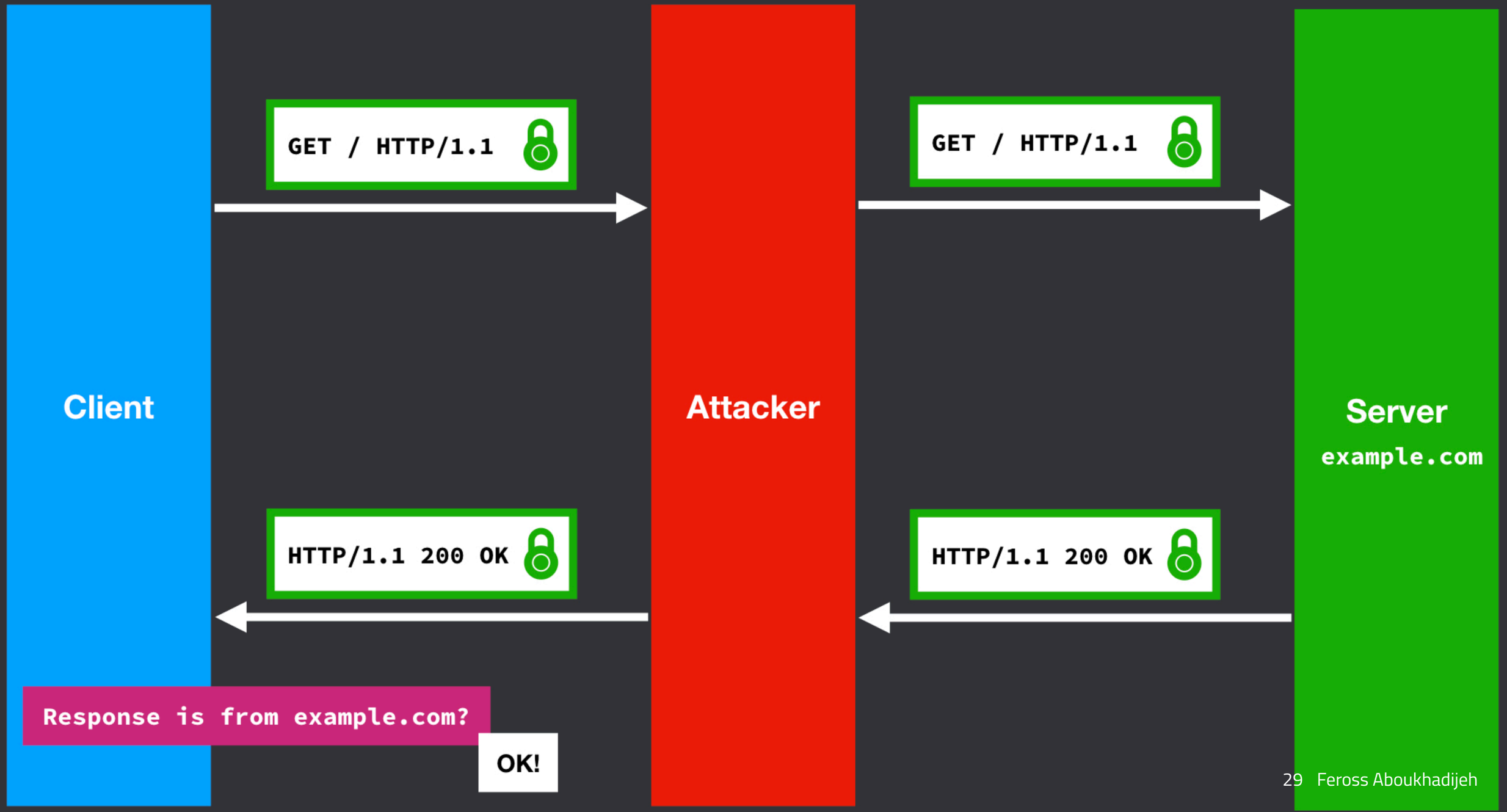

Client
GET / HTTP/1.1
Attacker
Server
example.com


Client
GET / HTTP/1.1
Attacker
GET / HTTP/1.1
Server
example.com


Client
GET / HTTP/1.1
Attacker
GET / HTTP/1.1
Server
example.com
HTTP/1.1 200 OK


Client
GET / HTTP/1.1
Attacker
GET / HTTP/1.1
Server
example.com
HTTP/1.1 200 OK
HTTP/1.1 200 OK


Client
GET / HTTP/1.1
Attacker
GET / HTTP/1.1
Server
example.com
HTTP/1.1 200 OK
HTTP/1.1 200 OK
Response is from example.com?


Client
GET / HTTP/1.1
Attacker
GET / HTTP/1.1
Server
example.com
HTTP/1.1 200 OK
HTTP/1.1 200 OK
Response is from example.com?
OK!

Transport Layer Security (TLS)

- **Hypertext Transfer Protocol Secure (HTTPS)** keeps browsing safe by securely connecting the browser with the website server
- HTTPS relies on **Transport Layer Security (TLS)** encryption to secure connections
- TLS is used with web traffic, email, instant messaging, voice over IP (VoIP), and many other protocols
  - When TLS is used with HTTP, we call it HTTPS

Anonymous Diffie-Hellman key exchange

Client

Server

example.com

Client

Server

example.com

Group G = {1, g, g^2, g^3, …, g^{q-1}}

Client

Server

example.com

Group $G = \{1, g, g^2, g^3, \ldots, g^{q-1}\}$

$a \leftarrow \{1, \ldots, q\}$

Client

Server

example.com

Group $G = \{1, g, g^2, g^3, \ldots, g^{q-1}\}$

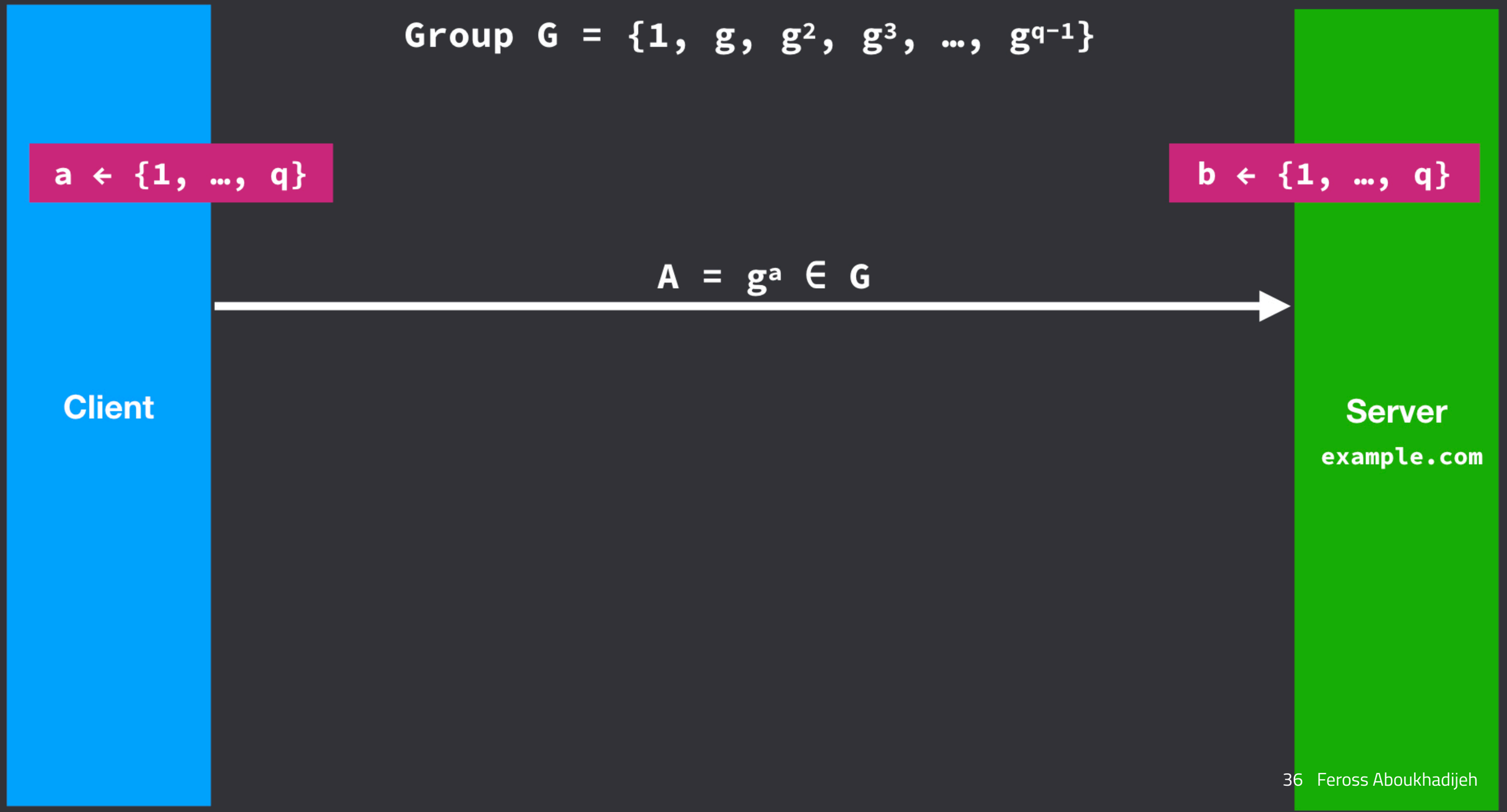
$a \leftarrow \{1, \ldots, q\}$

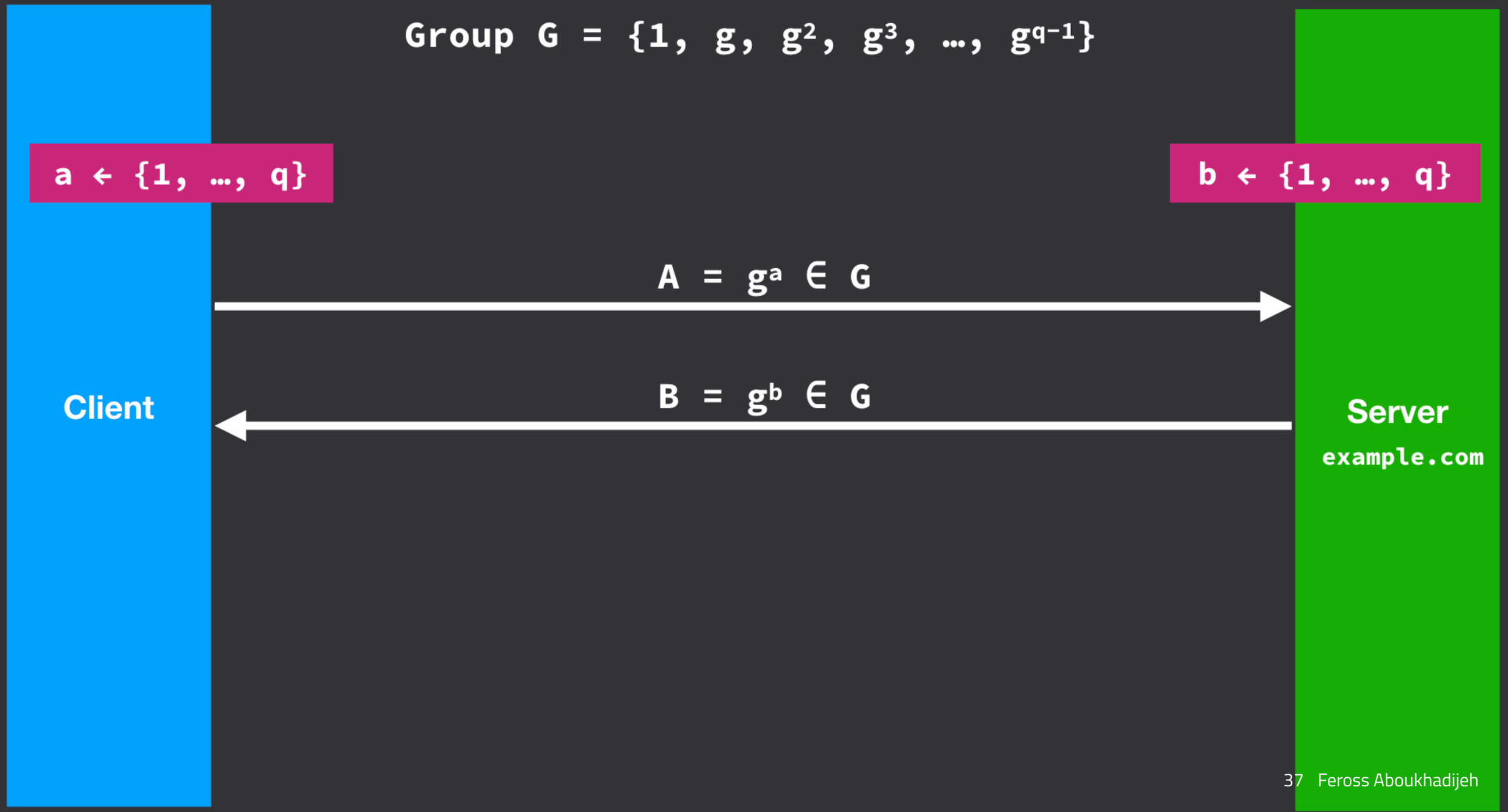
Client

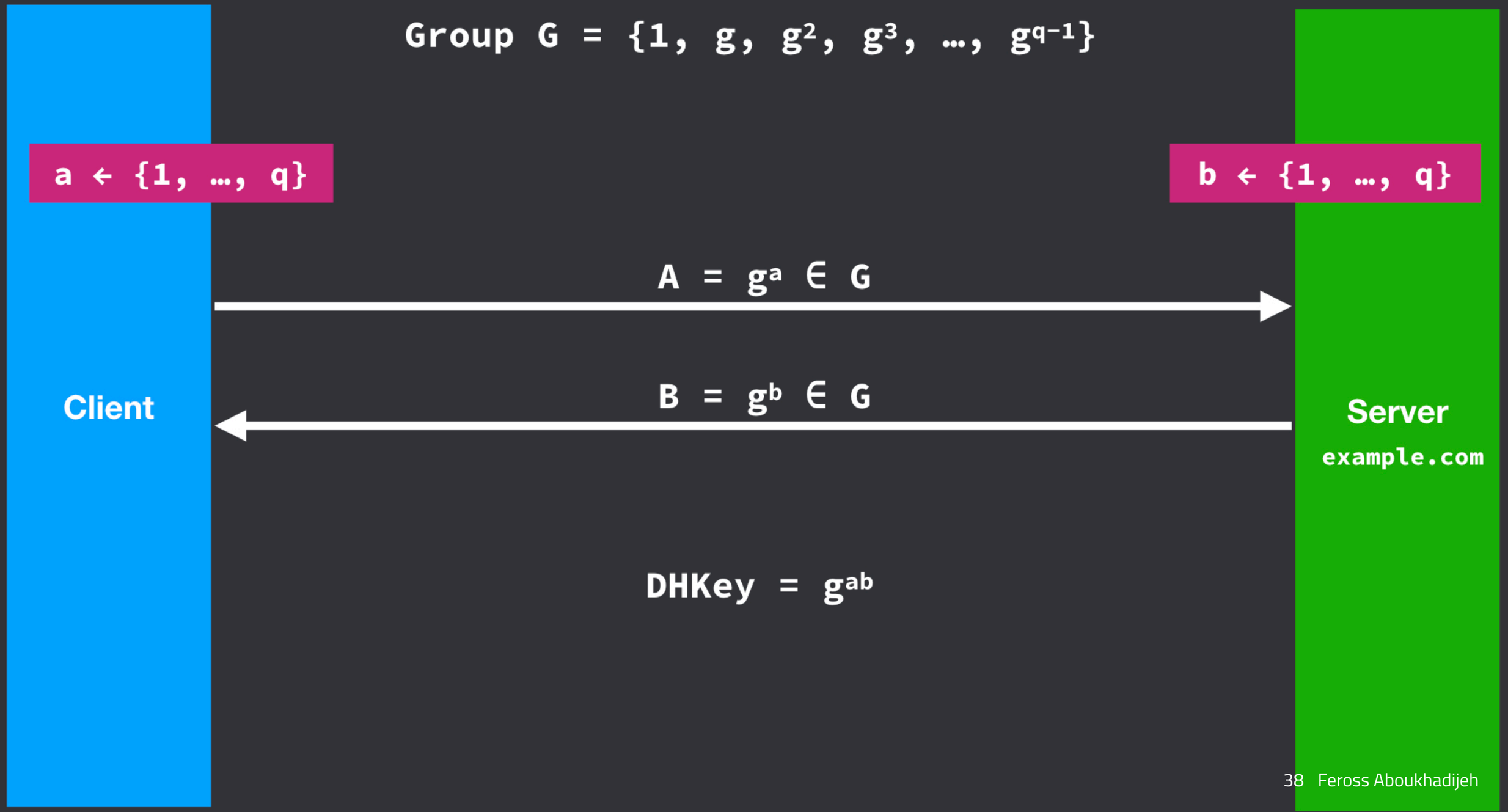
$b \leftarrow \{1, \ldots, q\}$

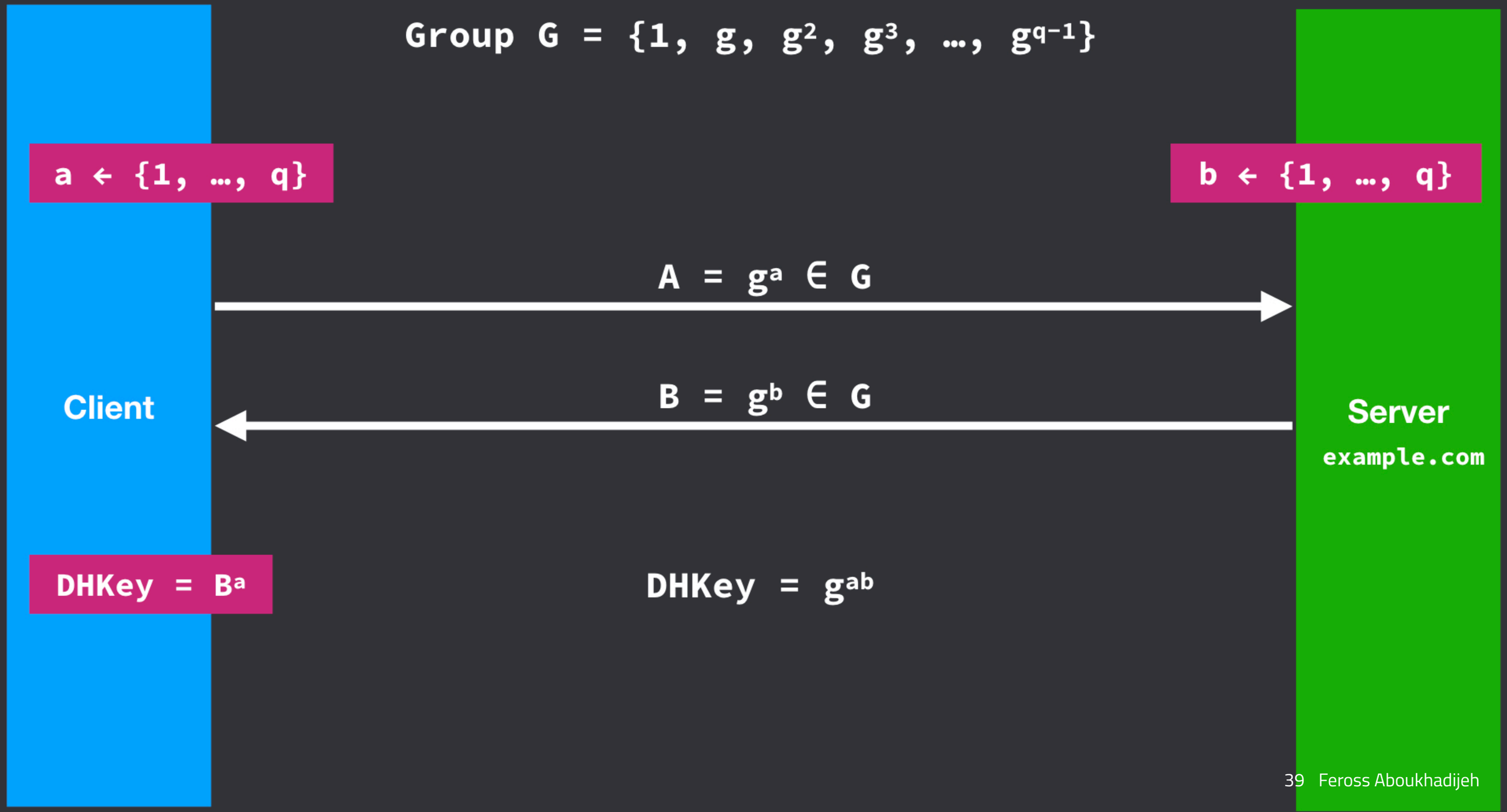
Server

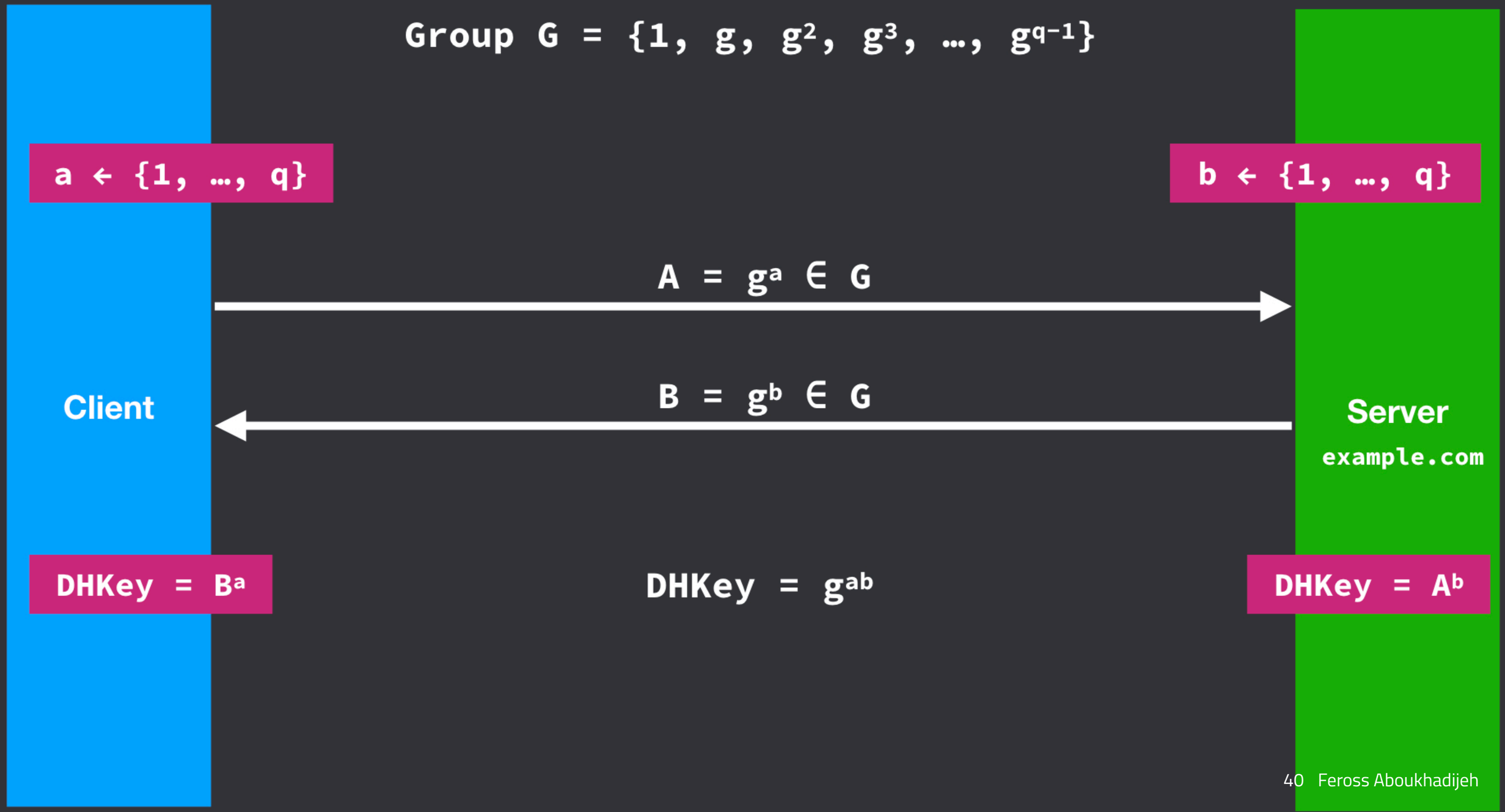
example.com

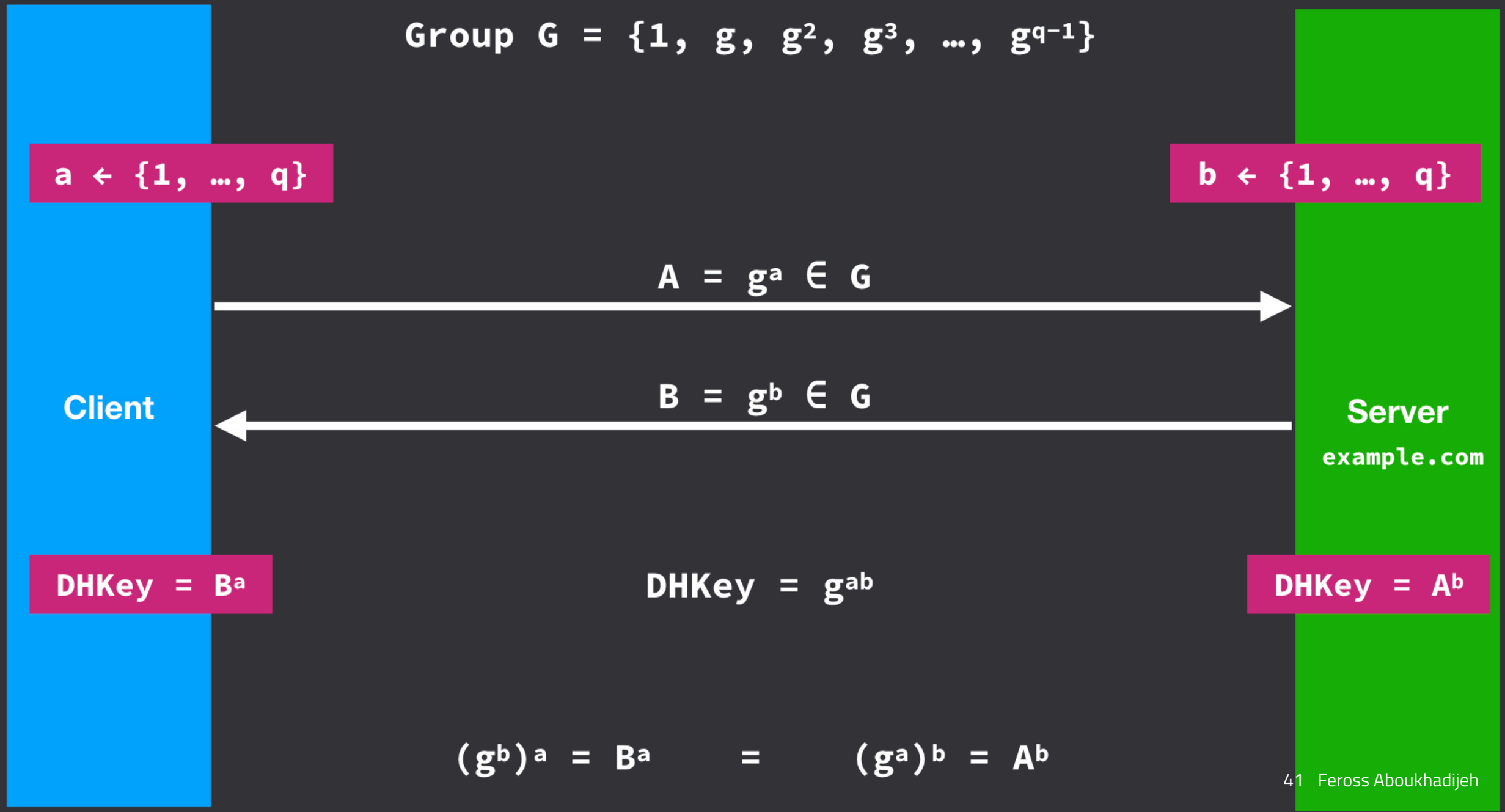

Group G = {1, g, g^2, g^3, …, g^(q-1)}
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
Client
Server
example.com


Group G = {1, g, g^2, g^3, …, g^(q-1)}
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
B = g^b ∈ G
Client
Server
example.com


Group G = {1, g, g^2, g^3, …, g^(q-1)}
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
B = g^b ∈ G
Client
Server
example.com
DHKey = g^ab


Group G = {1, g, g^2, g^3, …, g^(q-1)}
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
B = g^b ∈ G
Client
Server
example.com
DHKey = B^a
DHKey = g^ab


Group G = {1, g, g^2, g^3, …, g^(q-1)}
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
B = g^b ∈ G
Client
Server
example.com
DHKey = B^a
DHKey = g^ab
DHKey = A^b


Group G = {1, g, g^2, g^3, …, g^(q-1)}
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
B = g^b ∈ G
Client
Server
example.com
DHKey = B^a
DHKey = g^ab
DHKey = A^b
(g^b)^a = B^a = (g^a)^b = A^b

Anonymous key exchange

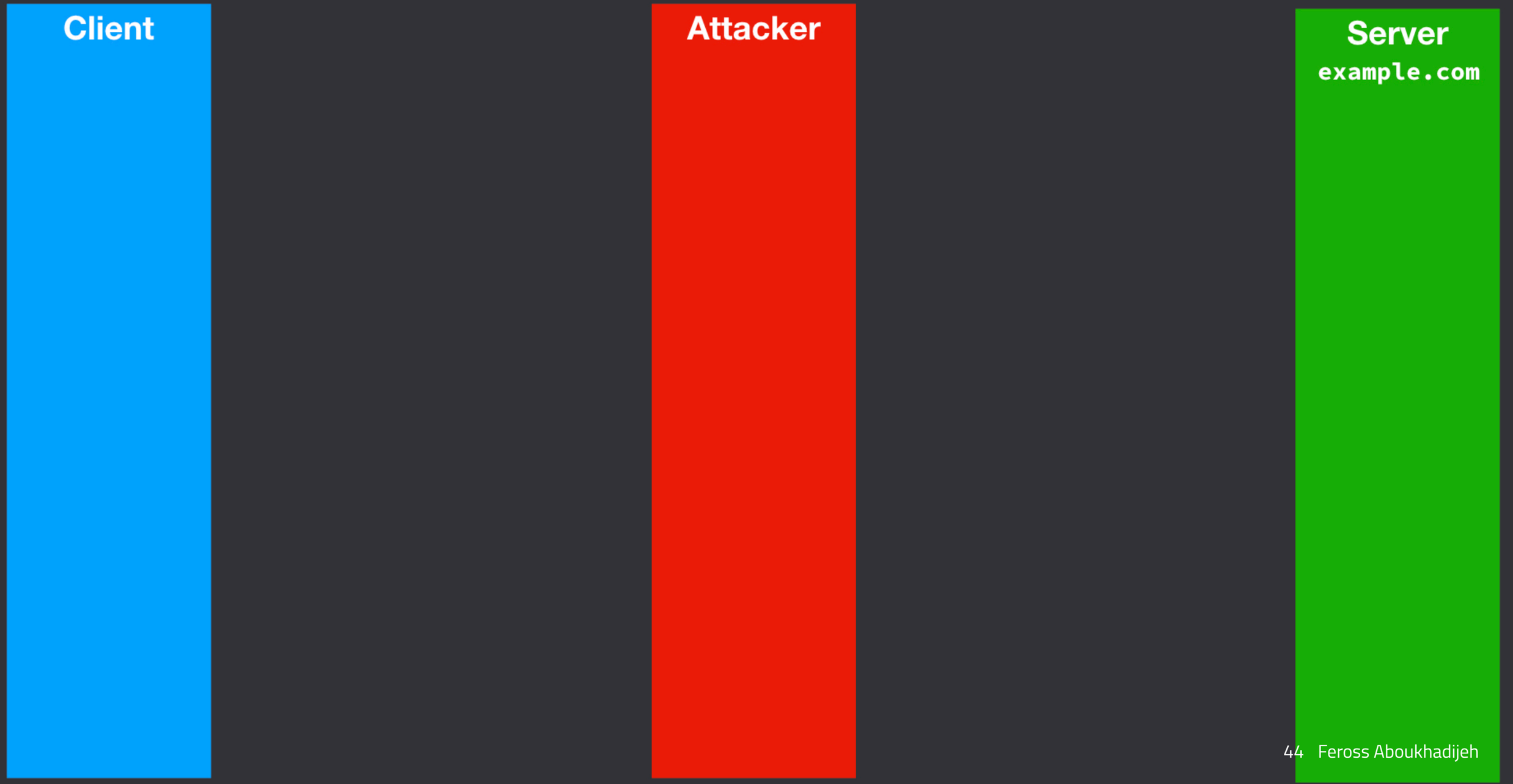
- **Problem:** Client doesn't know with which server it performed key exchange
  - It's possible that the client securely derived a key with the **network attacker** instead of the **intended server**!
- While the communication is *technically* **private** (secure against eavesdropping), it lacks **authentication**
  - **Key idea:** Without authentication, you can't actually have privacy

Group G = {1, g, g^2, g^3, …, g^{q-1}}

Man-in-the-middle attack on Anonymous Diffie-Helman key exchange

Server
example.com

Group $G = \{1, g, g^2, g^3, \ldots, g^{q-1}\}$



Group G = {1, g, g^2, g^3, …, g^{q-1}}

Client

a ← {1, …, q}

Attacker

Server

example.com

Group G = {1, g, g^2, g^3, …, g^{q-1}}

Client

$a \leftarrow \{1, \ldots, q\}$

Attacker

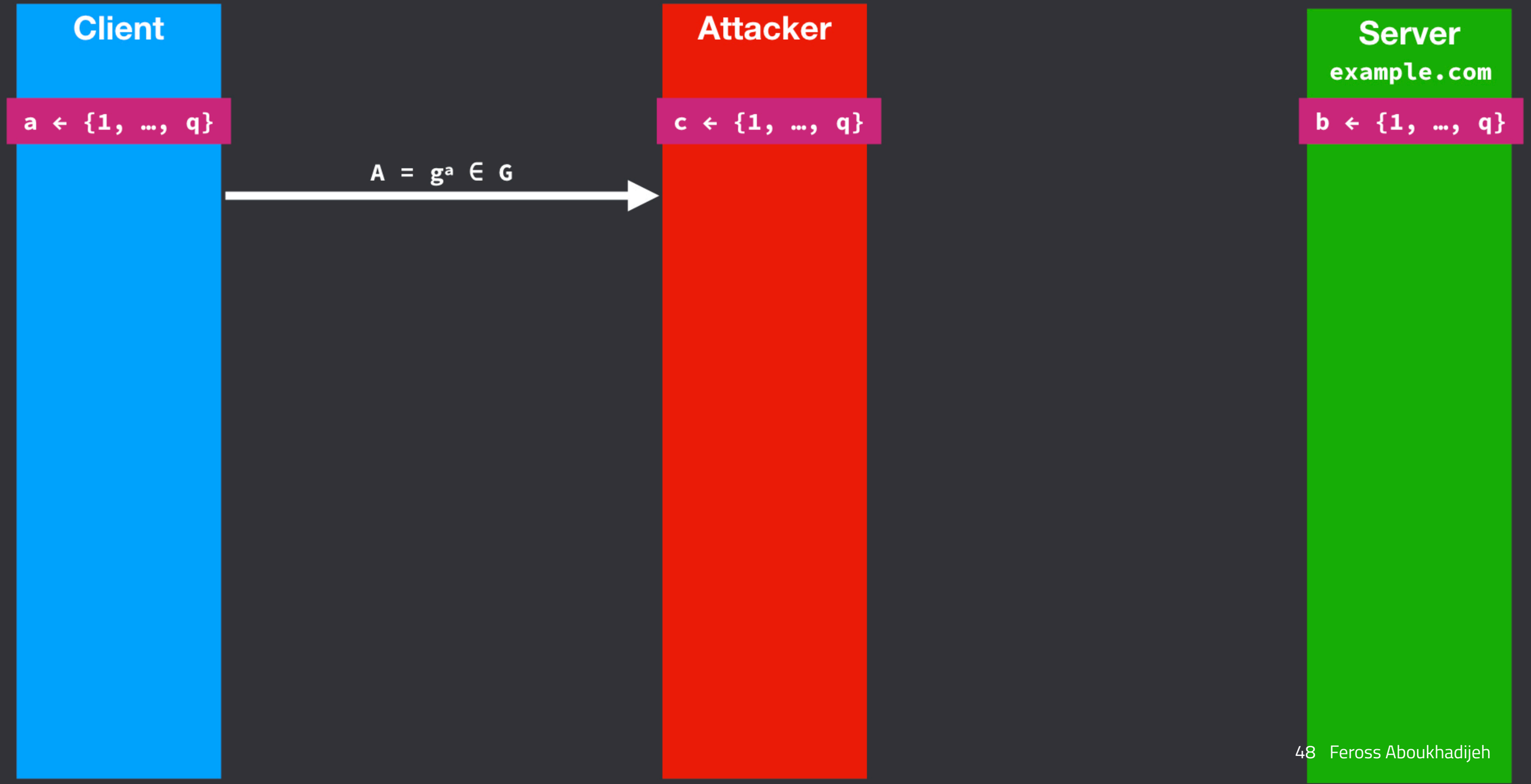
$c \leftarrow \{1, \ldots, q\}$

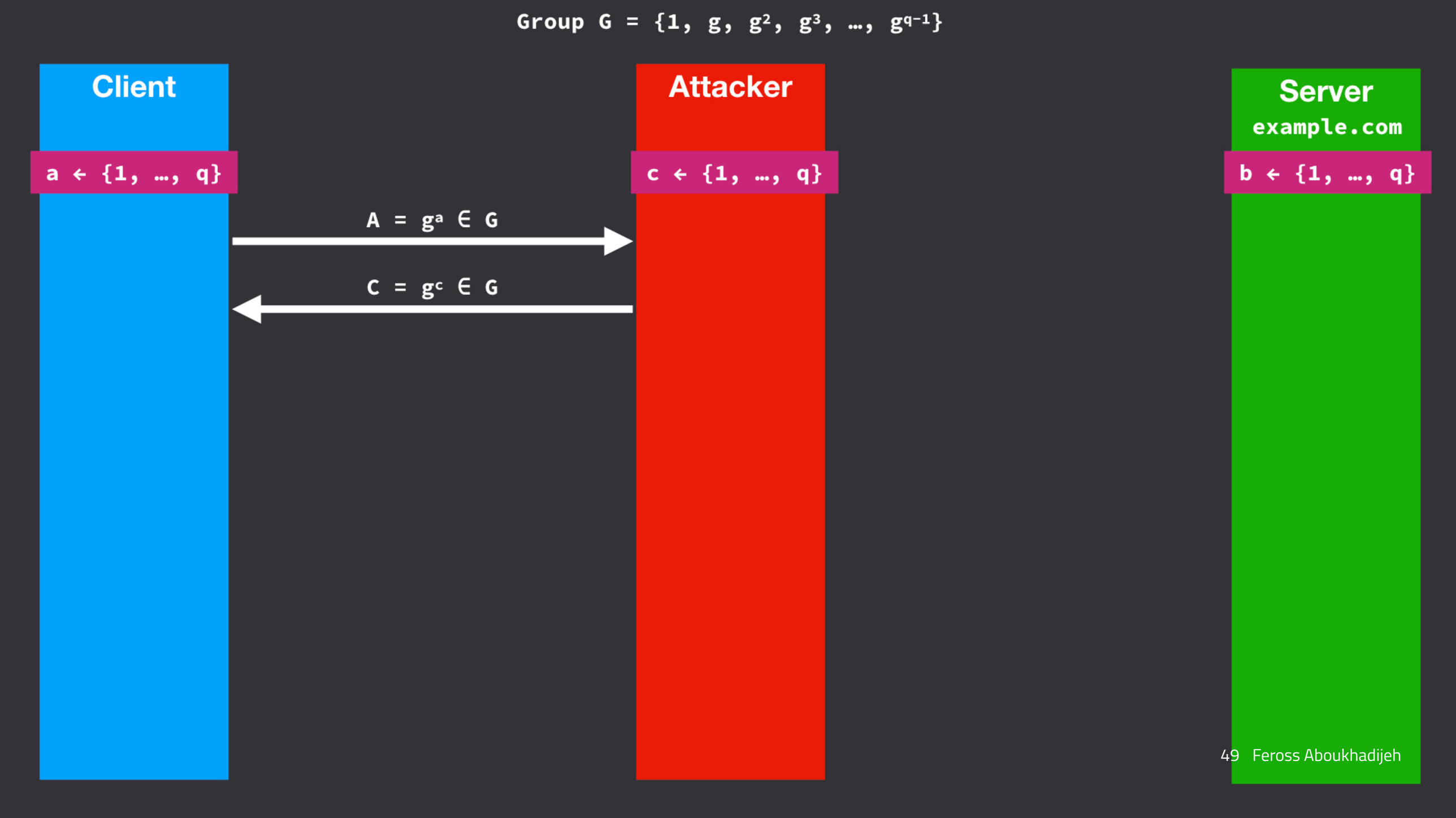
Server

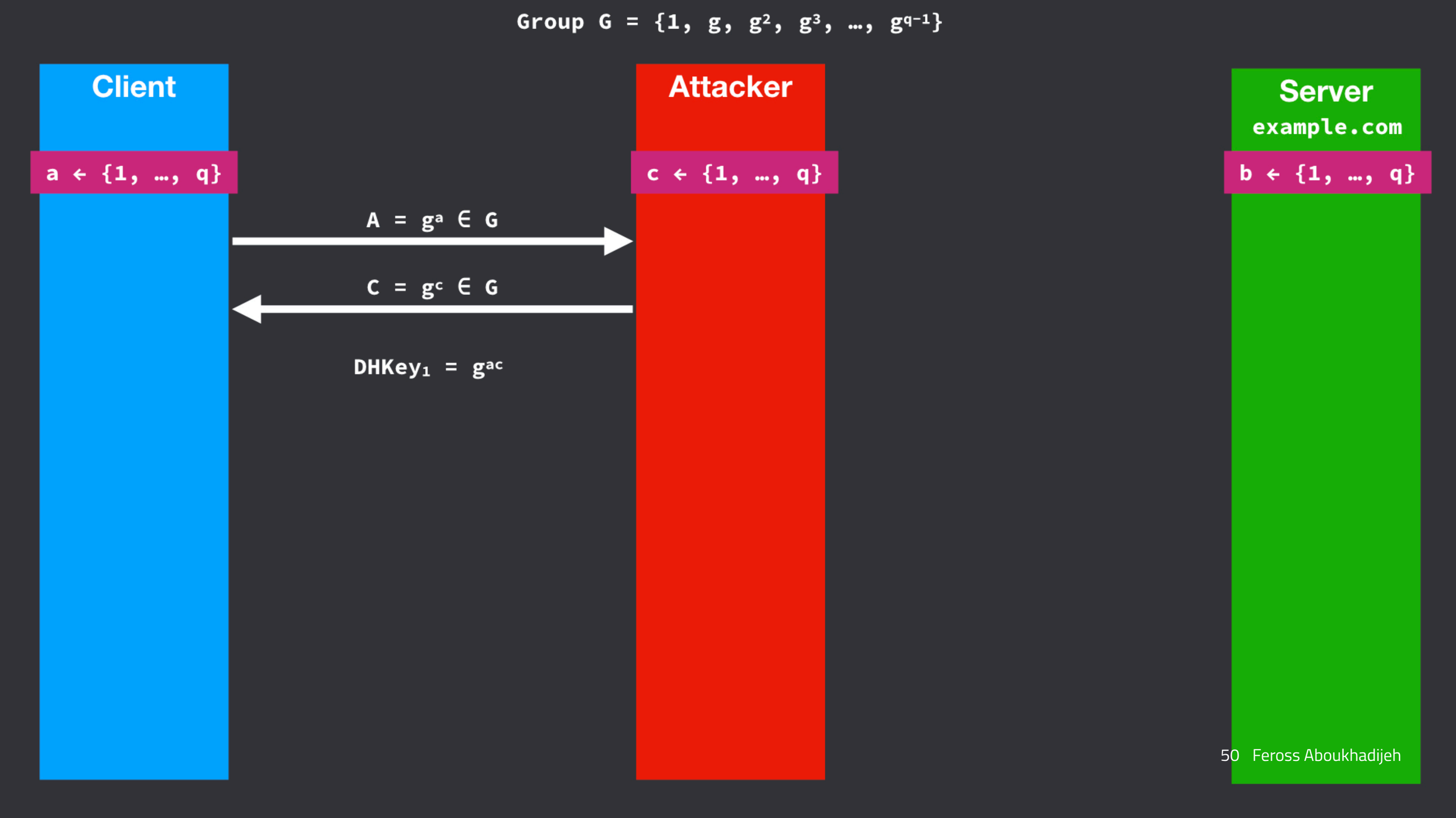
example.com

Group $G = \{1, g, g^2, g^3, \ldots, g^{q-1}\}$

Group $G = \{1, g, g^2, g^3, \ldots, g^{q-1}\}$




Group G = {1, g, g^2, g^3, …, g^(q-1)}
Client
a ← {1, …, q}
Attacker
c ← {1, …, q}
Server
example.com
b ← {1, …, q}
A = g^a ∈ G
C = g^c ∈ G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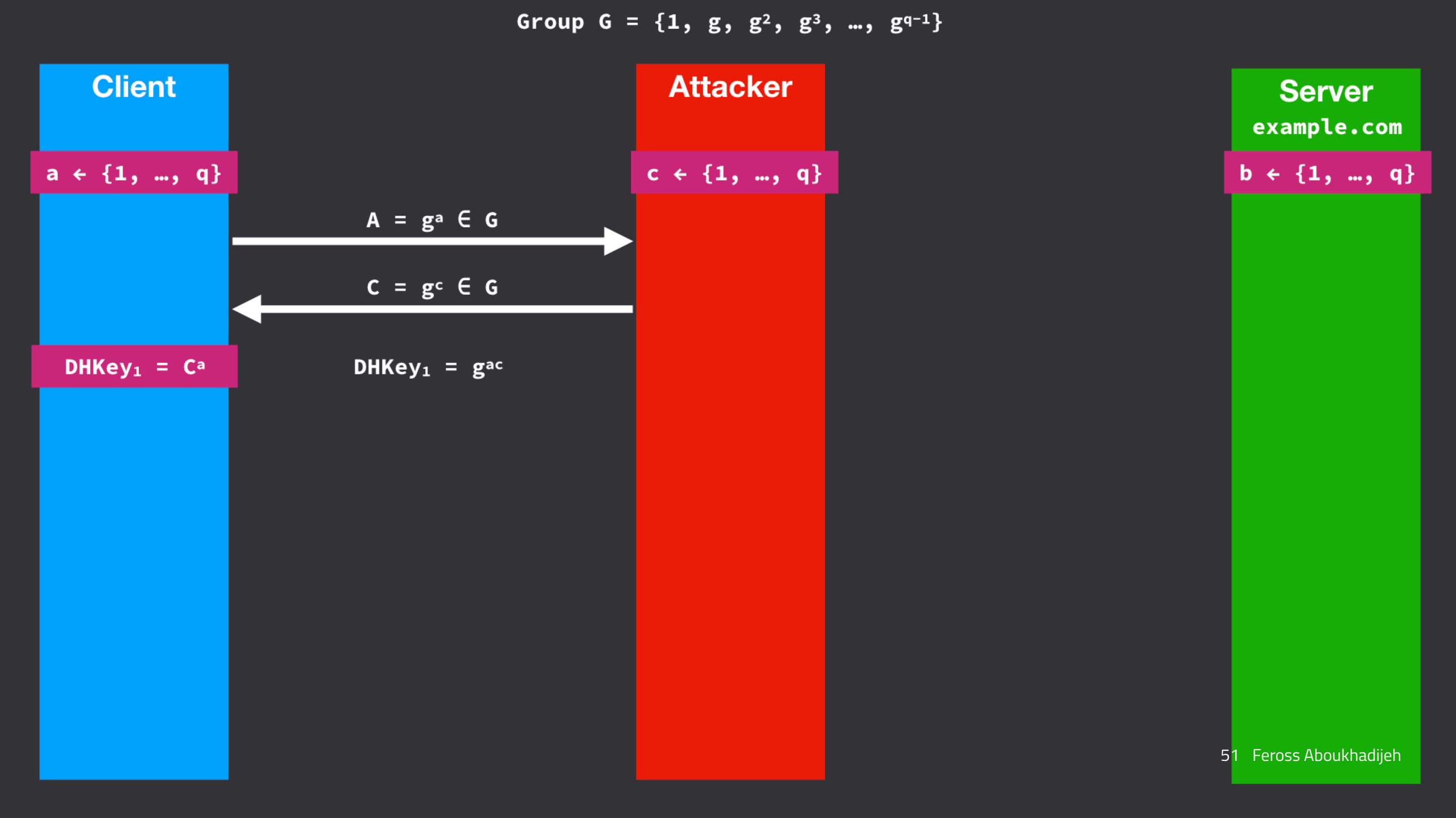
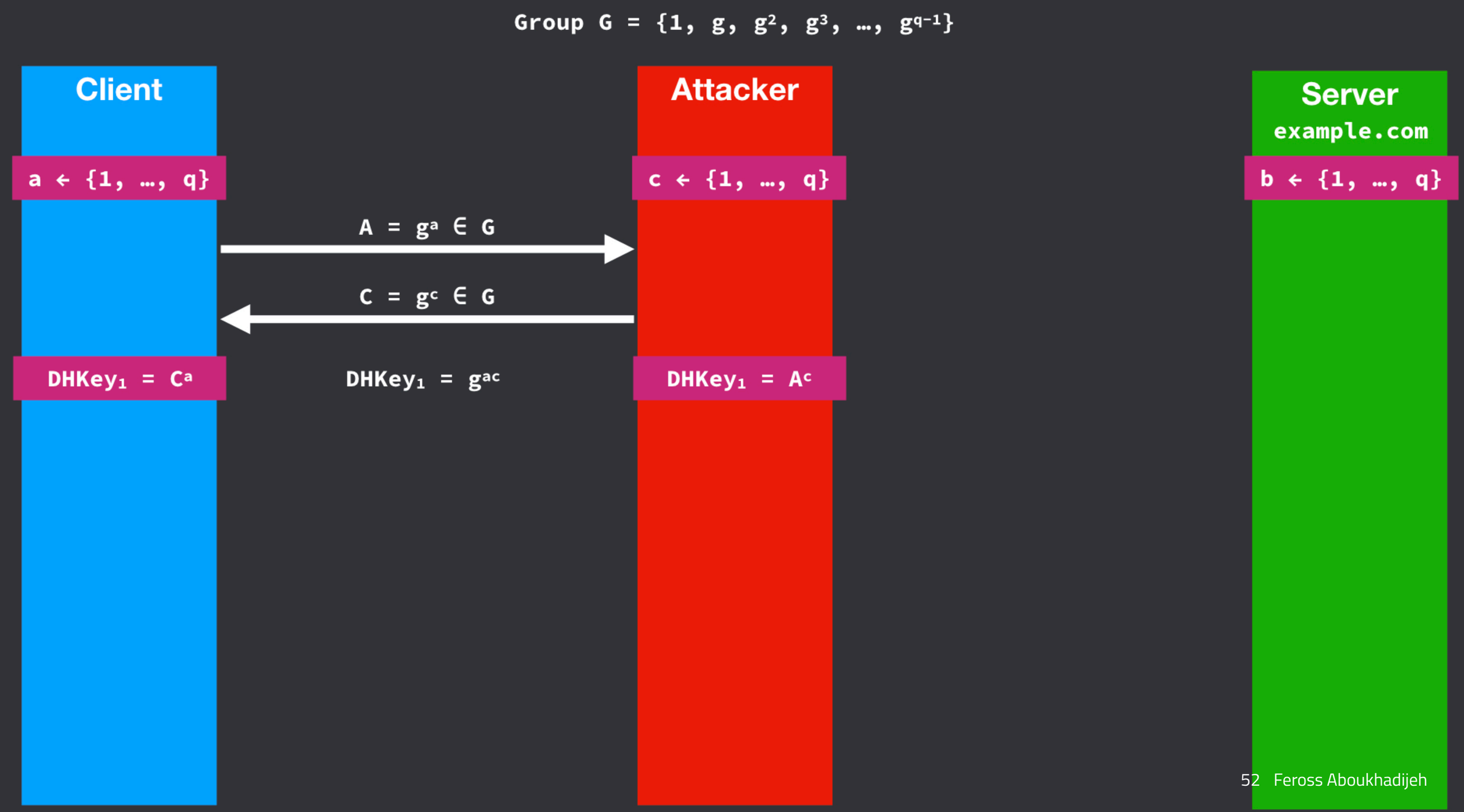
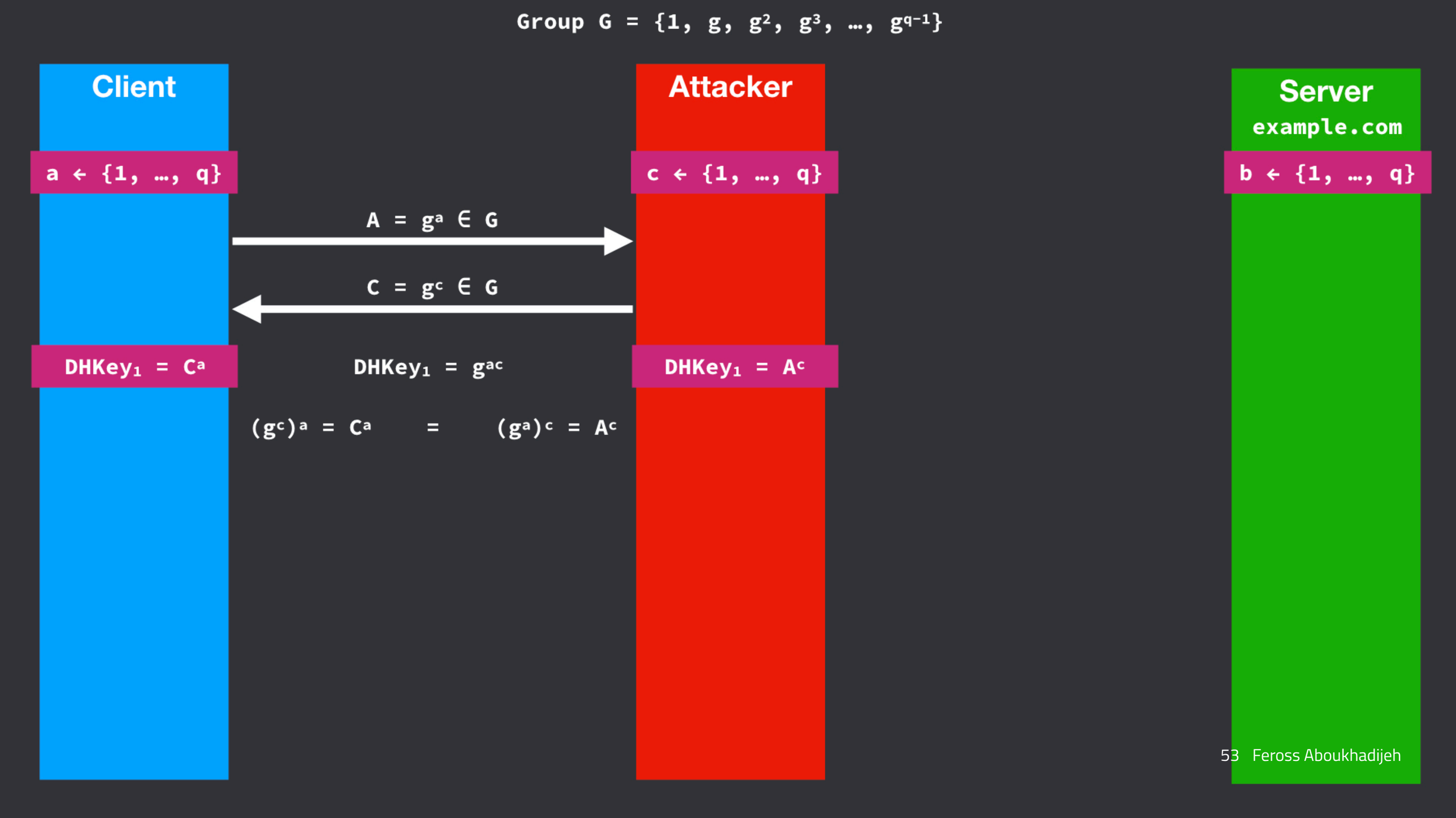
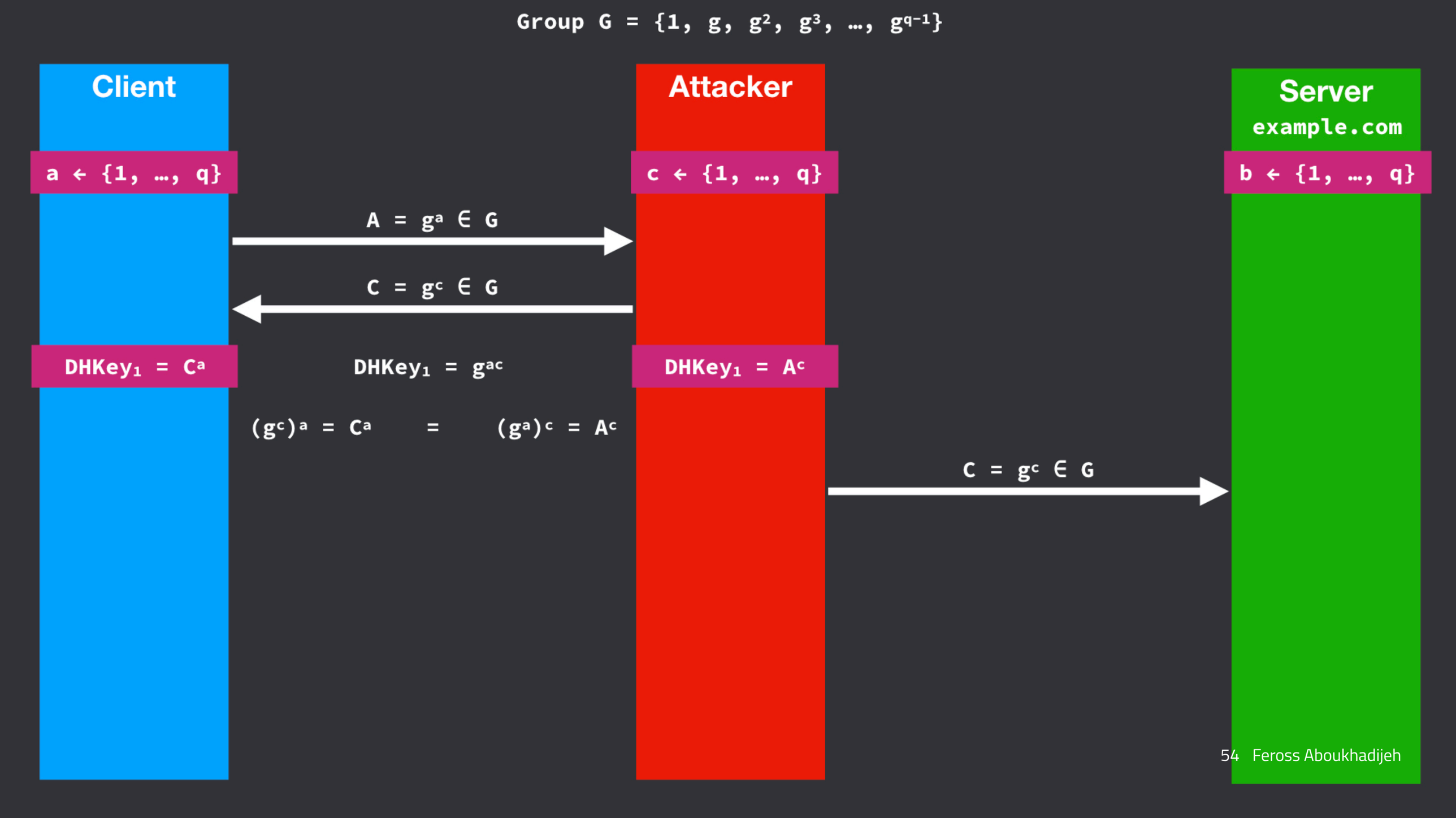
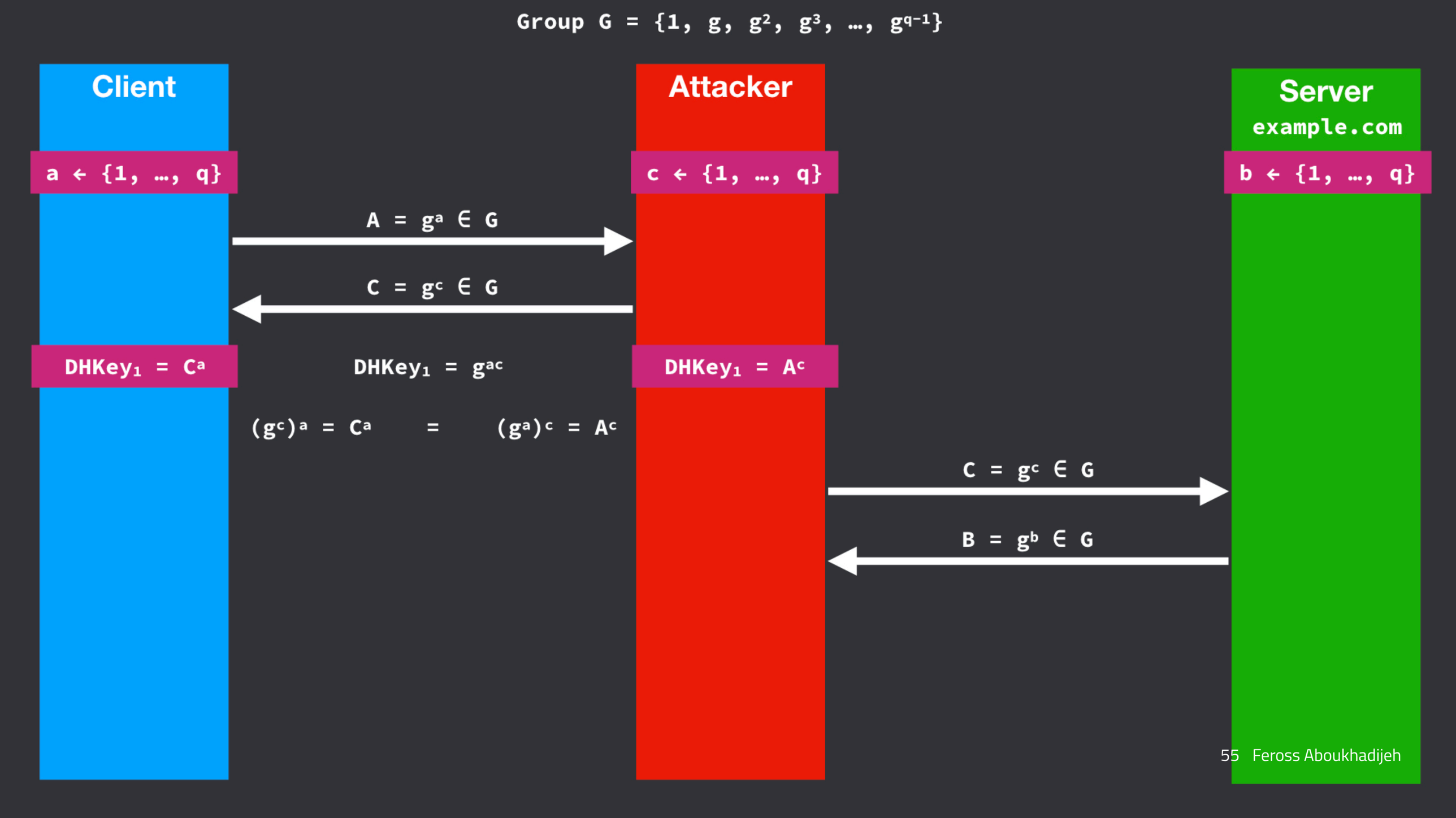
Attacker
c ← {1, …, q}
Server
example.com
b ← {1, …, q}
A = g^a ∈ G
C = g^c ∈ G
DHKey_1 = g^ac


Group G = {1, g, g², g³, …, g^(q-1)}
Client
a ← {1, …, q}
Attacker
c ← {1, …, q}
Server
example.com
b ← {1, …, q}
A = g^a ∈ G
C = g^c ∈ G
DHKey1 = C^a
DHKey1 = g^ac


Group G = {1, g, g², g³, …, g^(q−1)}
Client
Attacker
Server
example.com
a ← {1, …, q}
c ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
C = g^c ∈ G
DHKey1 = C^a
DHKey1 = g^ac
DHKey1 = A^c


Group G = {1, g, g², g³, …, g^(q-1)}
Client
Attacker
Server
example.com
a ← {1, …, q}
c ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
C = g^c ∈ G
DHKey1 = C^a
DHKey1 = g^ac
DHKey1 = A^c
(g^c)^a = C^a = (g^a)^c = A^c


Group G = {1, g, g², g³, …, g^(q−1)}
Client
Attacker
Server
example.com
a ← {1, …, q}
c ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
C = g^c ∈ G
DHKey1 = C^a
DHKey1 = g^ac
DHKey1 = A^c
(g^c)^a = C^a = (g^a)^c = A^c
C = g^c ∈ G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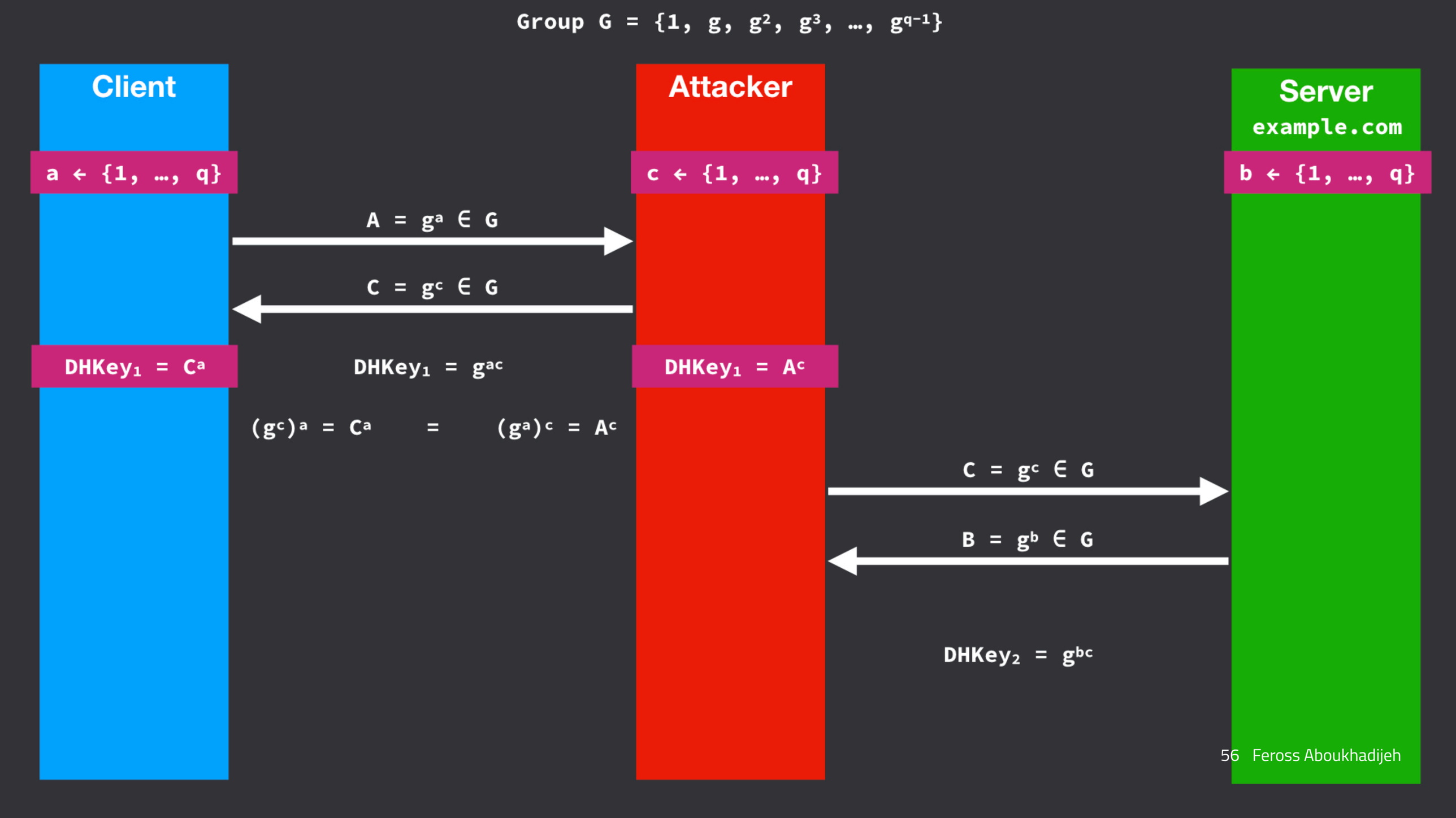
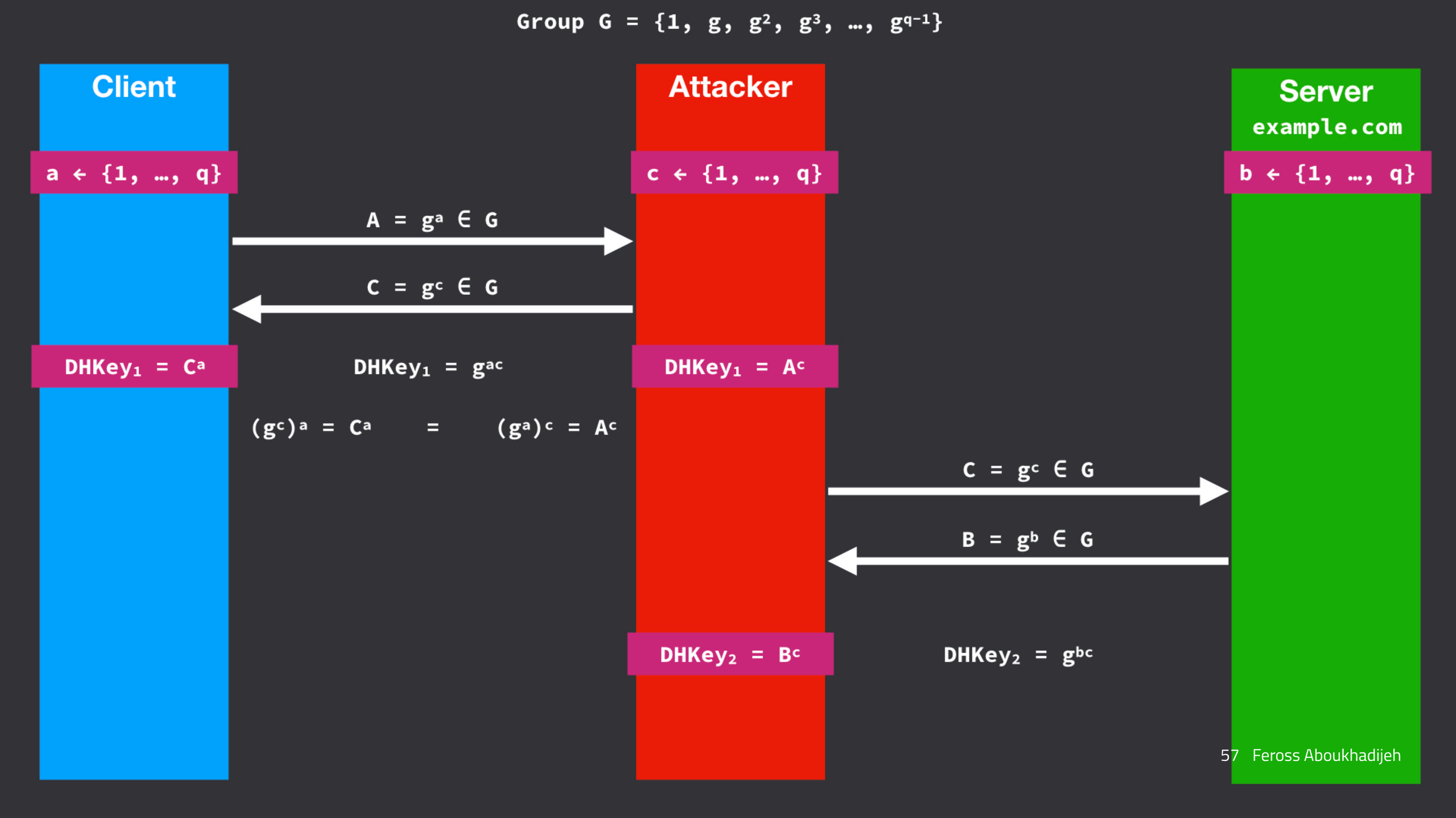
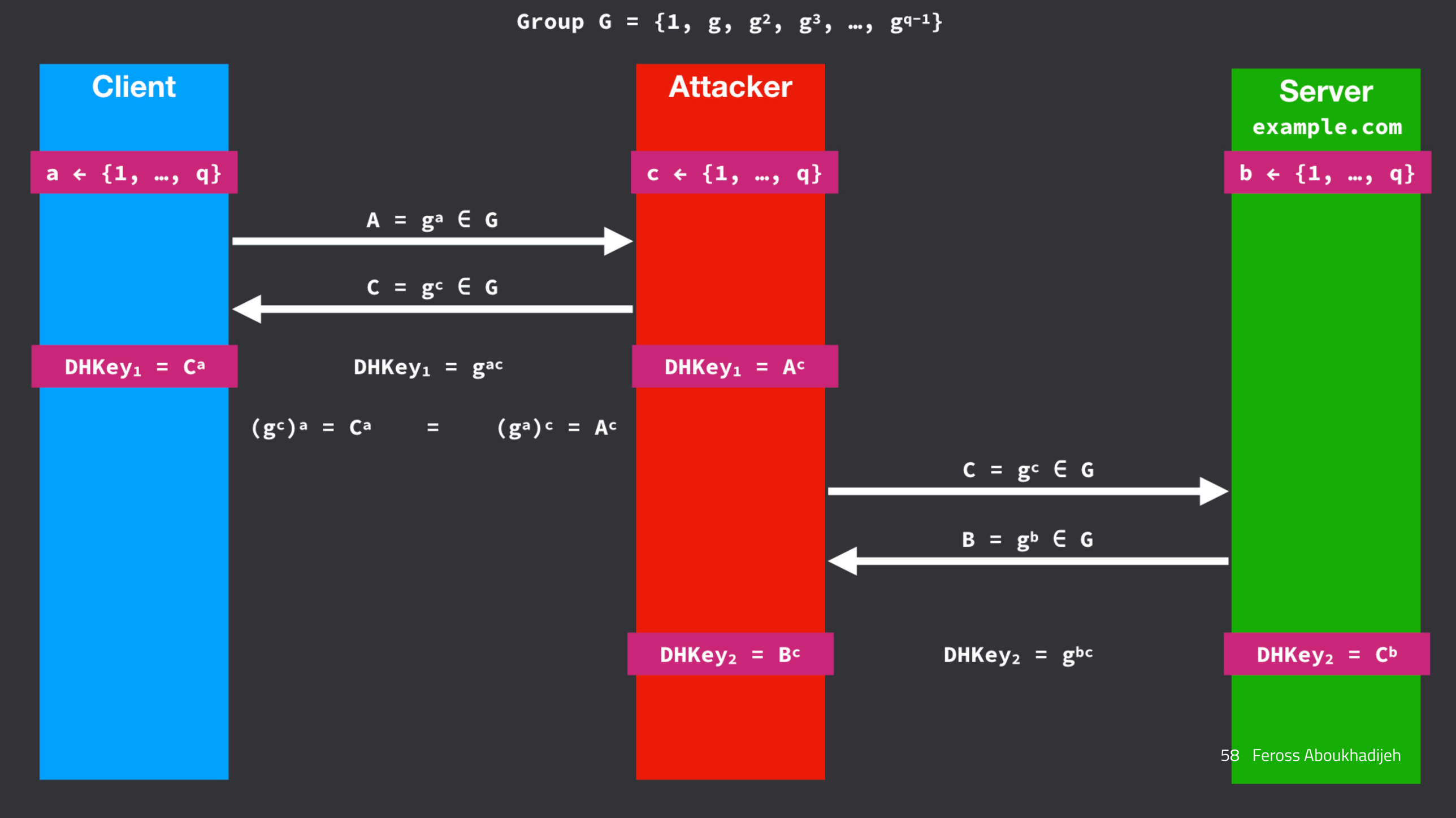
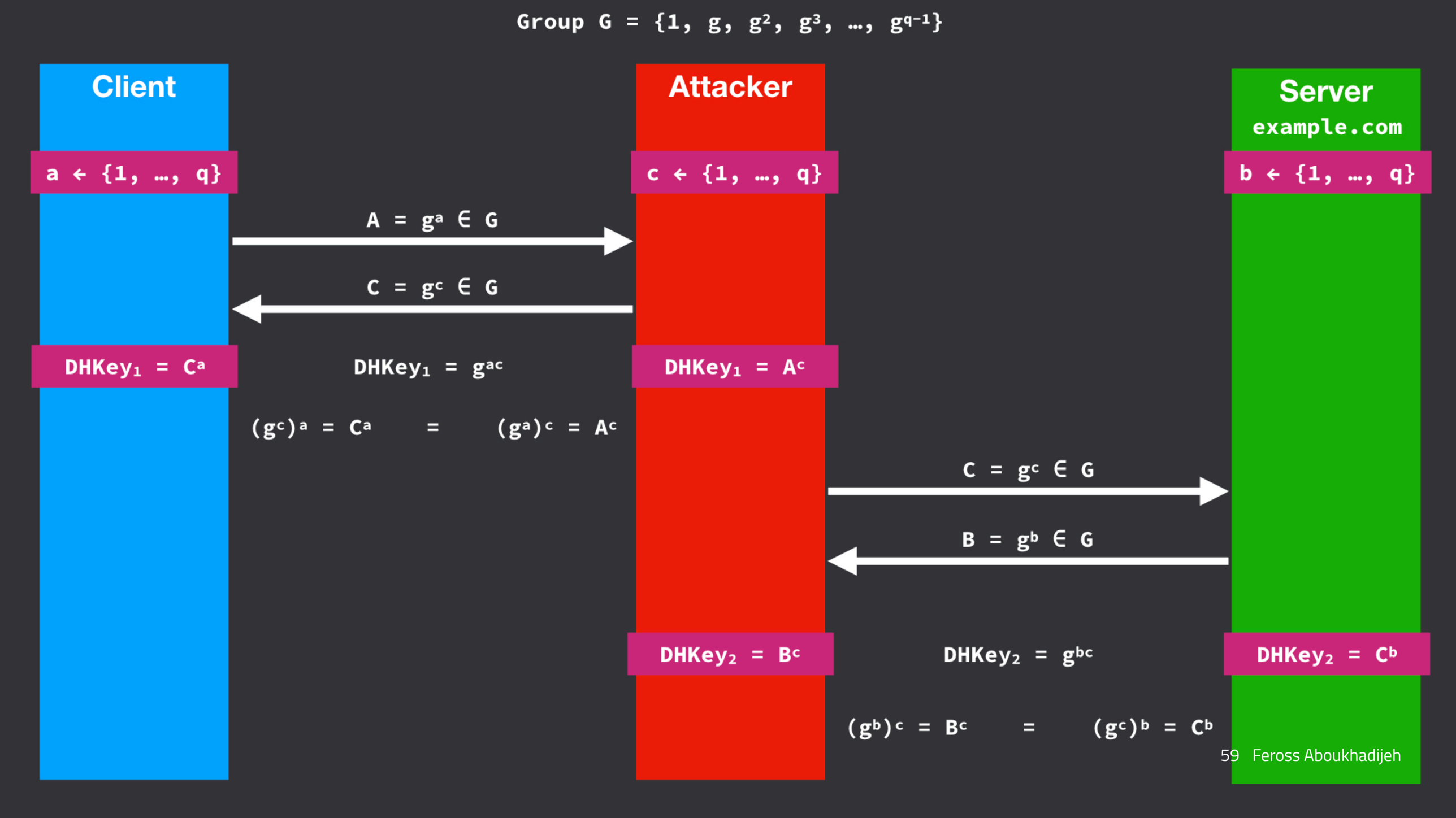
Client
Attacker
Server
example.com
a ← {1, …, q}
c ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
C = g^c ∈ G
DHKey1 = C^a
DHKey1 = g^ac
DHKey1 = A^c
(g^c)^a = C^a = (g^a)^c = A^c
C = g^c ∈ G
B = g^b ∈ G


Group G = {1, g, g², g³, …, g^(q−1)}
Client
Attacker
Server
example.com
a ← {1, …, q}
c ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
C = g^c ∈ G
DHKey1 = C^a
DHKey1 = g^ac
DHKey1 = A^c
(g^c)^a = C^a = (g^a)^c = A^c
C = g^c ∈ G
B = g^b ∈ G
DHKey2 = g^bc


Group G = {1, g, g², g³, …, g^(q−1)}
Client
Attacker
Server
example.com
a ← {1, …, q}
c ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
C = g^c ∈ G
DHKey1 = C^a
DHKey1 = g^ac
DHKey1 = A^c
(g^c)^a = C^a = (g^a)^c = A^c
C = g^c ∈ G
B = g^b ∈ G
DHKey2 = B^c
DHKey2 = g^bc


Group G = {1, g, g², g³, …, g^(q−1)}
Client
Attacker
Server
example.com
a ← {1, …, q}
c ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
C = g^c ∈ G
DHKey1 = C^a
DHKey1 = g^ac
DHKey1 = A^c
(g^c)^a = C^a = (g^a)^c = A^c
C = g^c ∈ G
B = g^b ∈ G
DHKey2 = B^c
DHKey2 = g^bc
DHKey2 = C^b


Group G = {1, g, g², g³, …, g^(q−1)}
Client
Attacker
Server
example.com
a ← {1, …, q}
c ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
C = g^c ∈ G
DHKey1 = C^a
DHKey1 = g^ac
DHKey1 = A^c
(g^c)^a = C^a = (g^a)^c = A^c
C = g^c ∈ G
B = g^b ∈ G
DHKey2 = B^c
DHKey2 = g^bc
DHKey2 = C^b
(g^b)^c = B^c = (g^c)^b = C^b

How do we get authentication?

- **Goal:** If the client could authenticate the server it is performing key exchange with, then it could securely derive a shared key with that (and only that) server
- **Solution:** Use **public-key cryptography** for authentication
  - Remember **signing** from lecture 3 on cookies?
  - Let's review

Review: Signature schemes

- Triple of algorithms **`(G, S, V)`**
  - **`G`**() → (**`pk`**, **`sk`**) - generator returns public key and secret key
  - **`S`**(**`sk`**, **`x`**) → **`t`** - signing returns a tag **`t`** for input **`x`**
  - **`V`**(**`pk`**, **`x`**, **`t`**) → **`accept|reject`** - checks validity of tag **`t`** for given input **`x`**
- Algorithm properties
  - **Correctness property: `V`**(**`pk`**, **`x`**, **`S`**(**`sk`**, **`x`**)) = **`accept`** should always be true
  - **Security property: `V`**(**`pk`**, **`x`**, **`t`**) = **`accept`** should almost never be true when **`x`** and **`t`** are chosen by the attacker

Authenticated Diffie-Helman key exchange

Client

Server
example.com

Client

Server

`example.com`

Client

Group $G = \{1, g, g^2, g^3, \ldots, g^{q-1}\}$

Server

example.com

Client

pk

Group G = {1, g, g^2, g^3, …, g^{q-1}}

Server

example.com

Client

pk

Group G = {1, g, g^2, g^3, …, g^{q-1}}

Server

example.com

sk

Client

pk

$a \leftarrow \{1, \ldots, q\}$

Group $G = \{1, g, g^2, g^3, \ldots, g^{q-1}\}$

Server

example.com

sk

Client

pk

a ← {1, …, q}

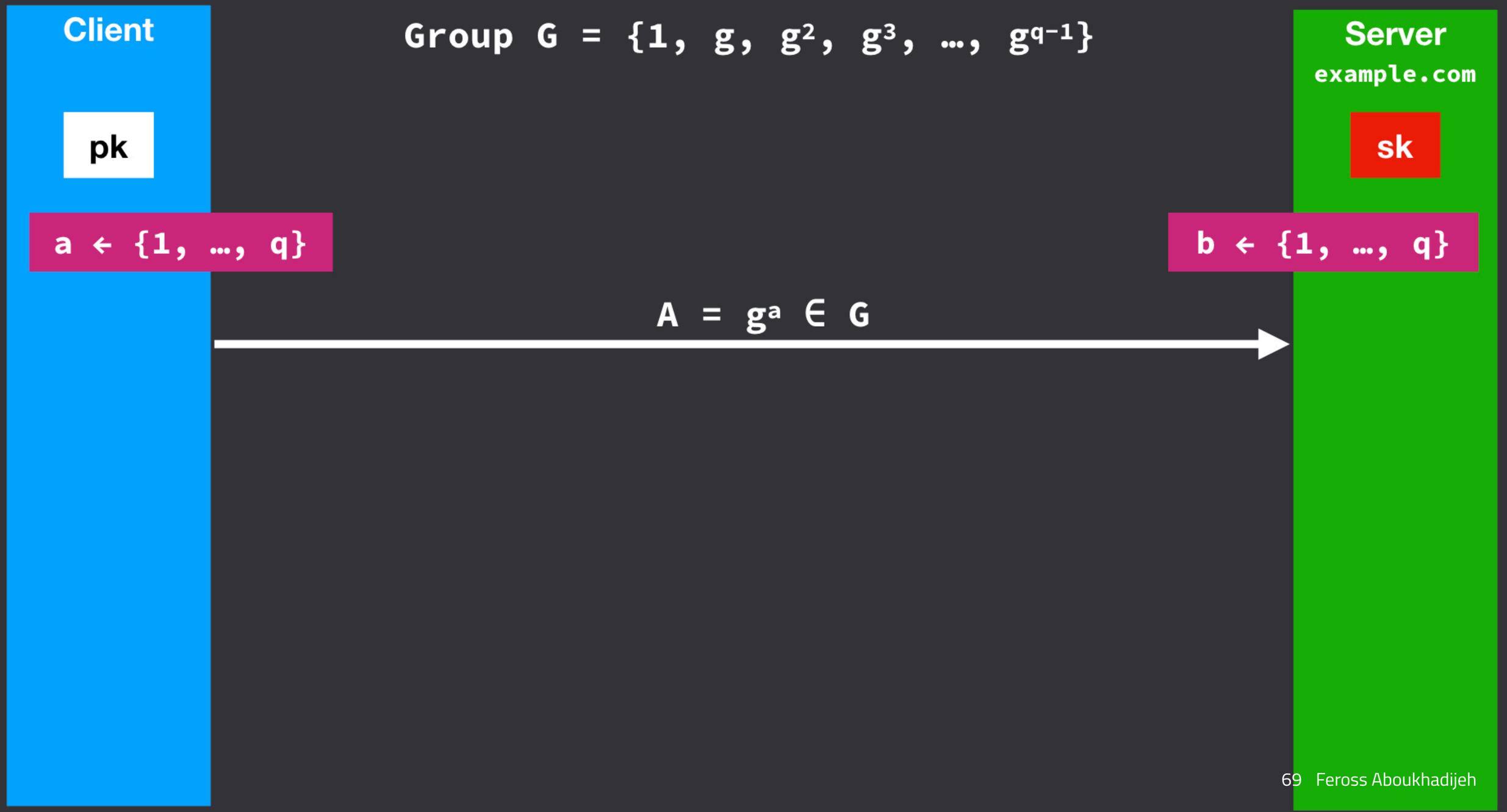
Group G = {1, g, g^2, g^3, …, g^{q-1}}

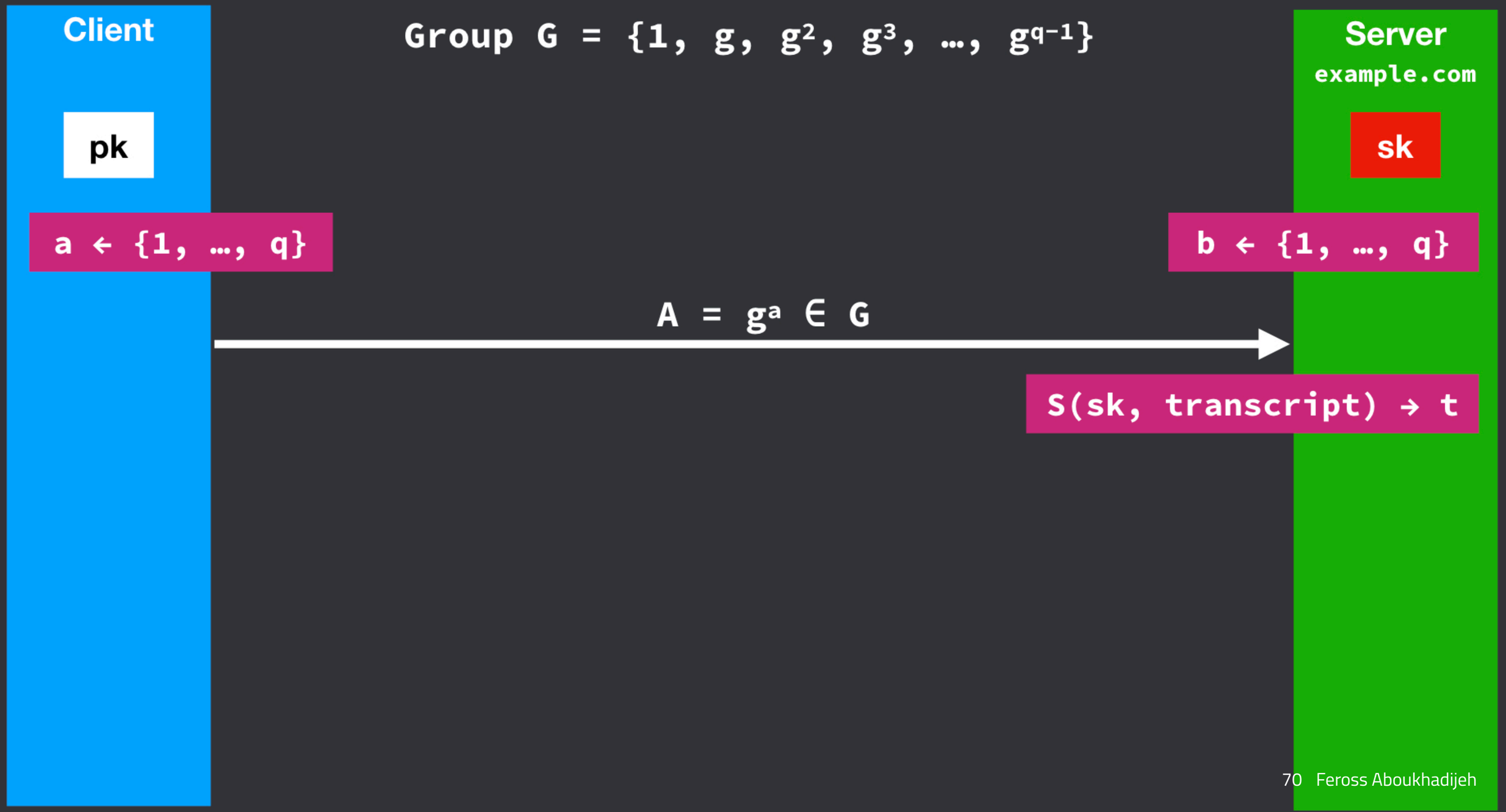
Server

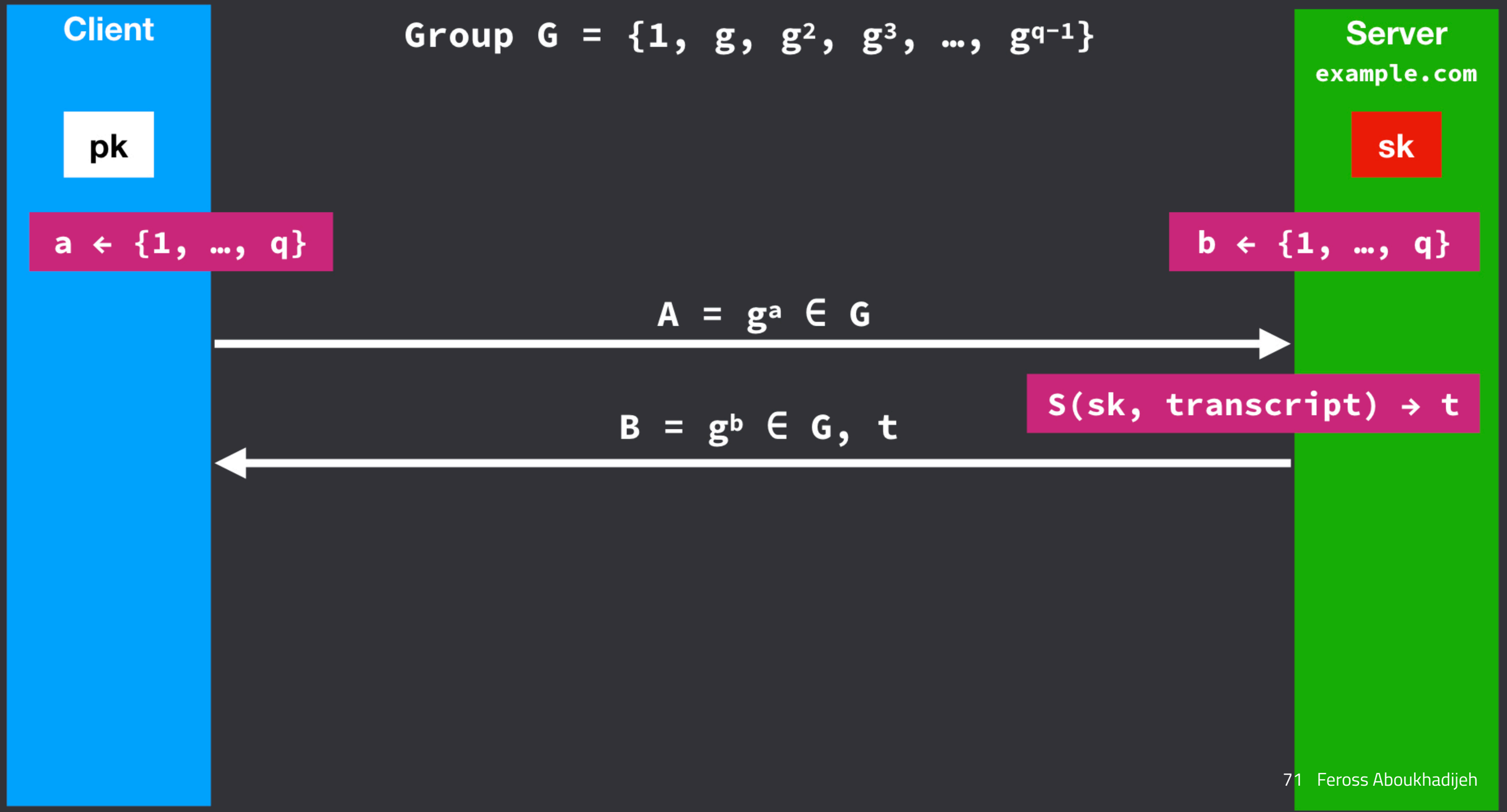
example.com

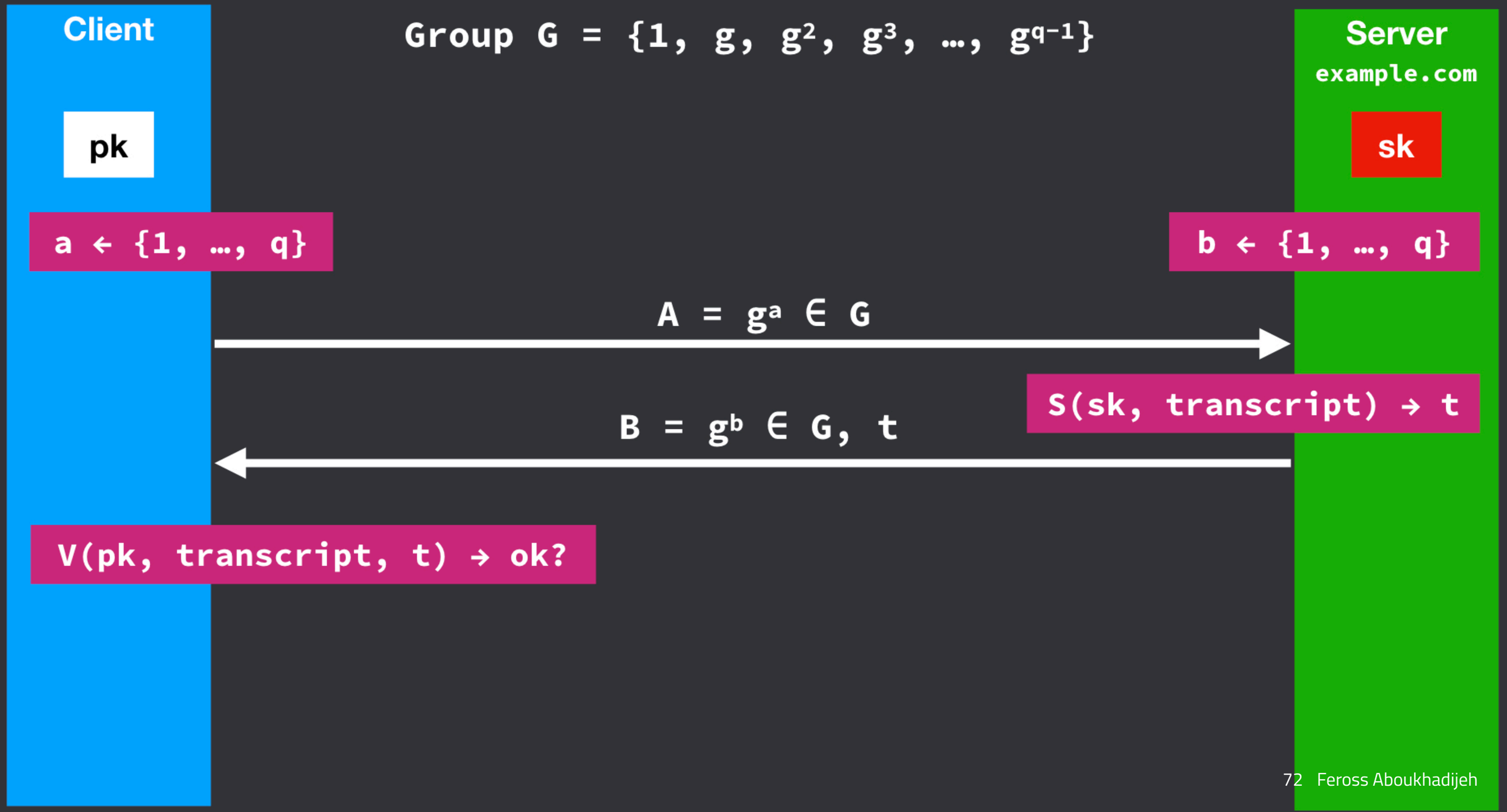
sk

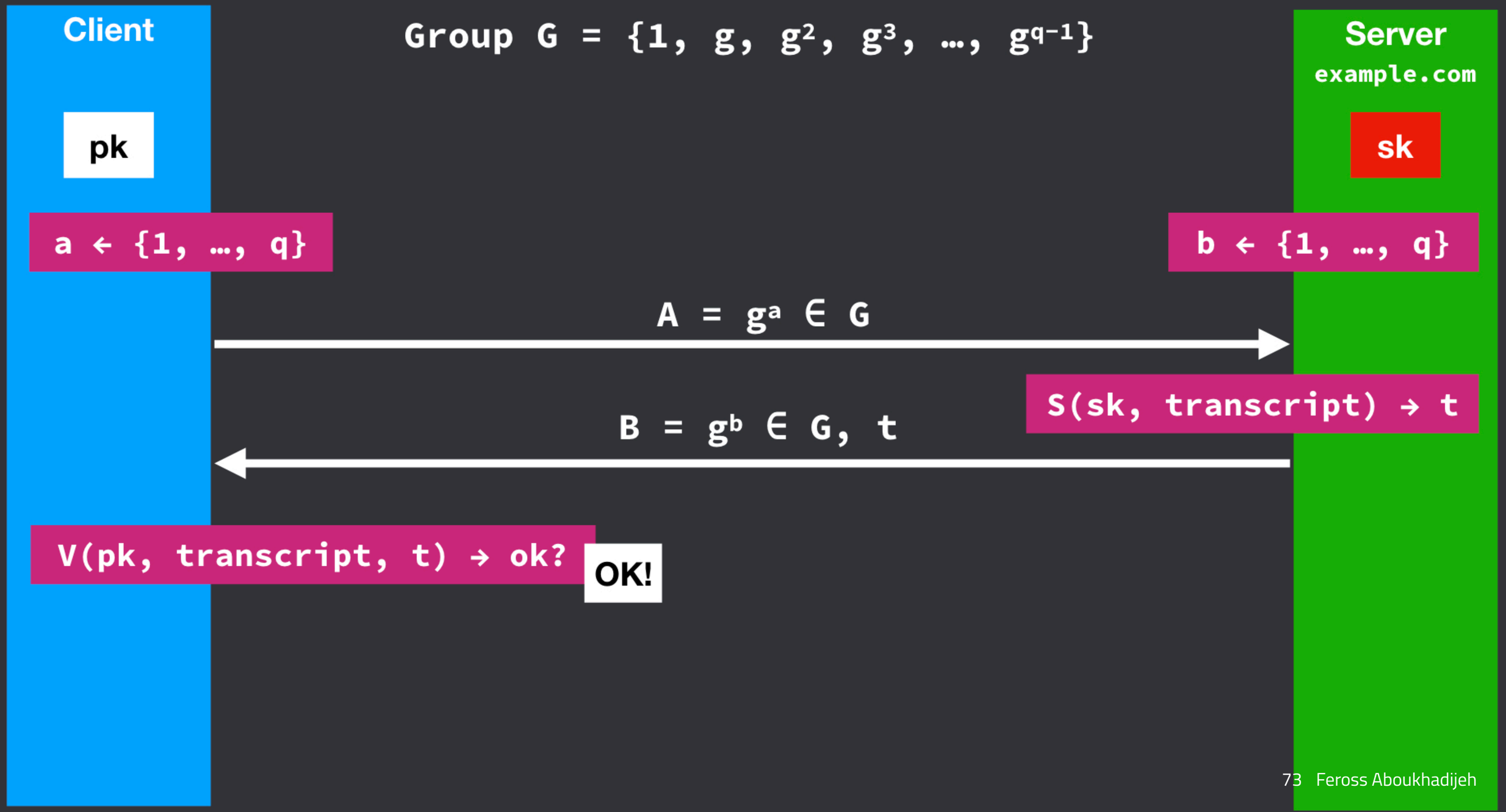
b ← {1, …, q}

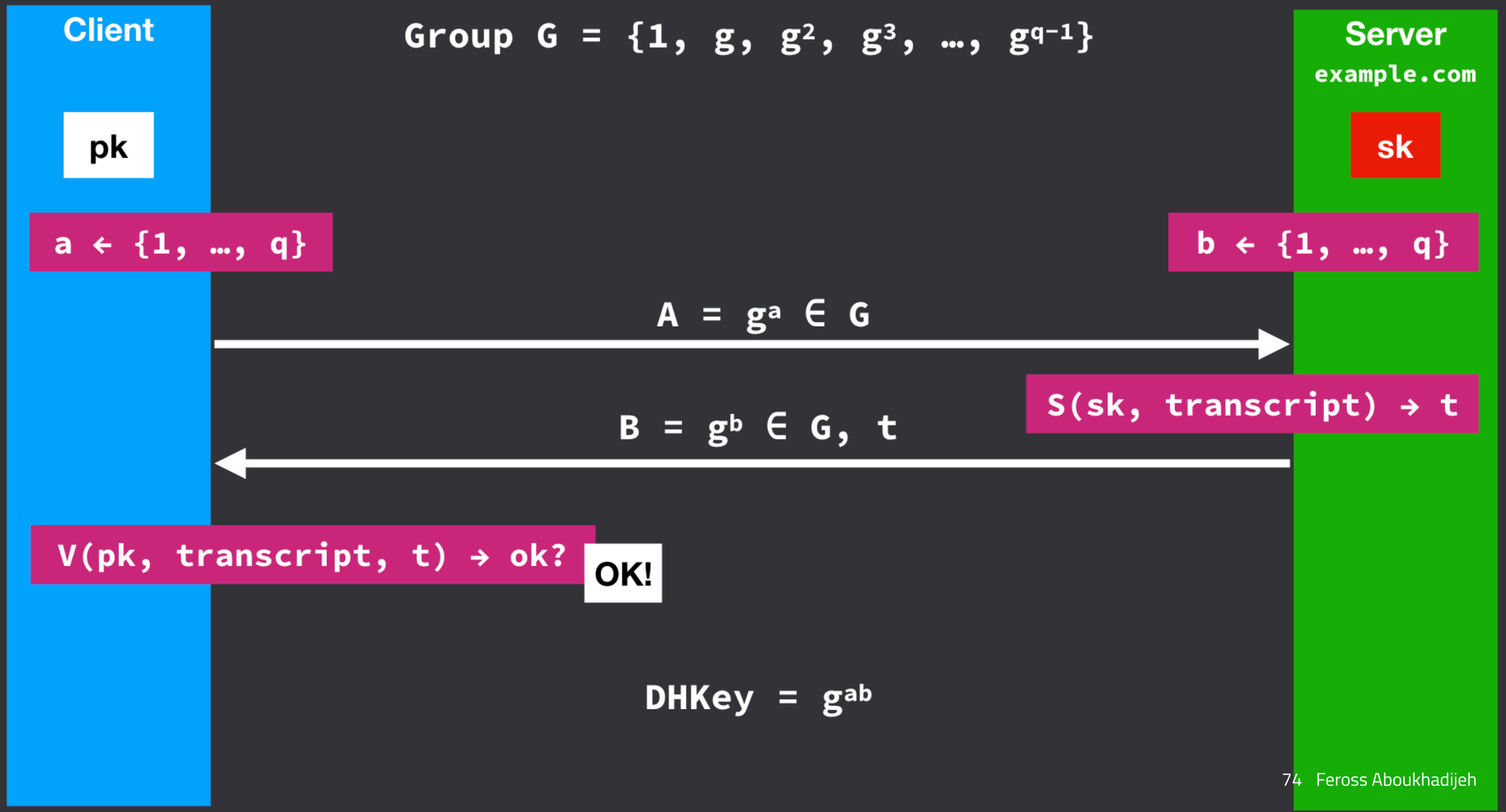

Client
pk
a ← {1, …, q}
Group G = {1, g, g², g³, …, g^(q−1)}
A = g^a ∈ G
Server
example.com
sk
b ← {1, …, q}

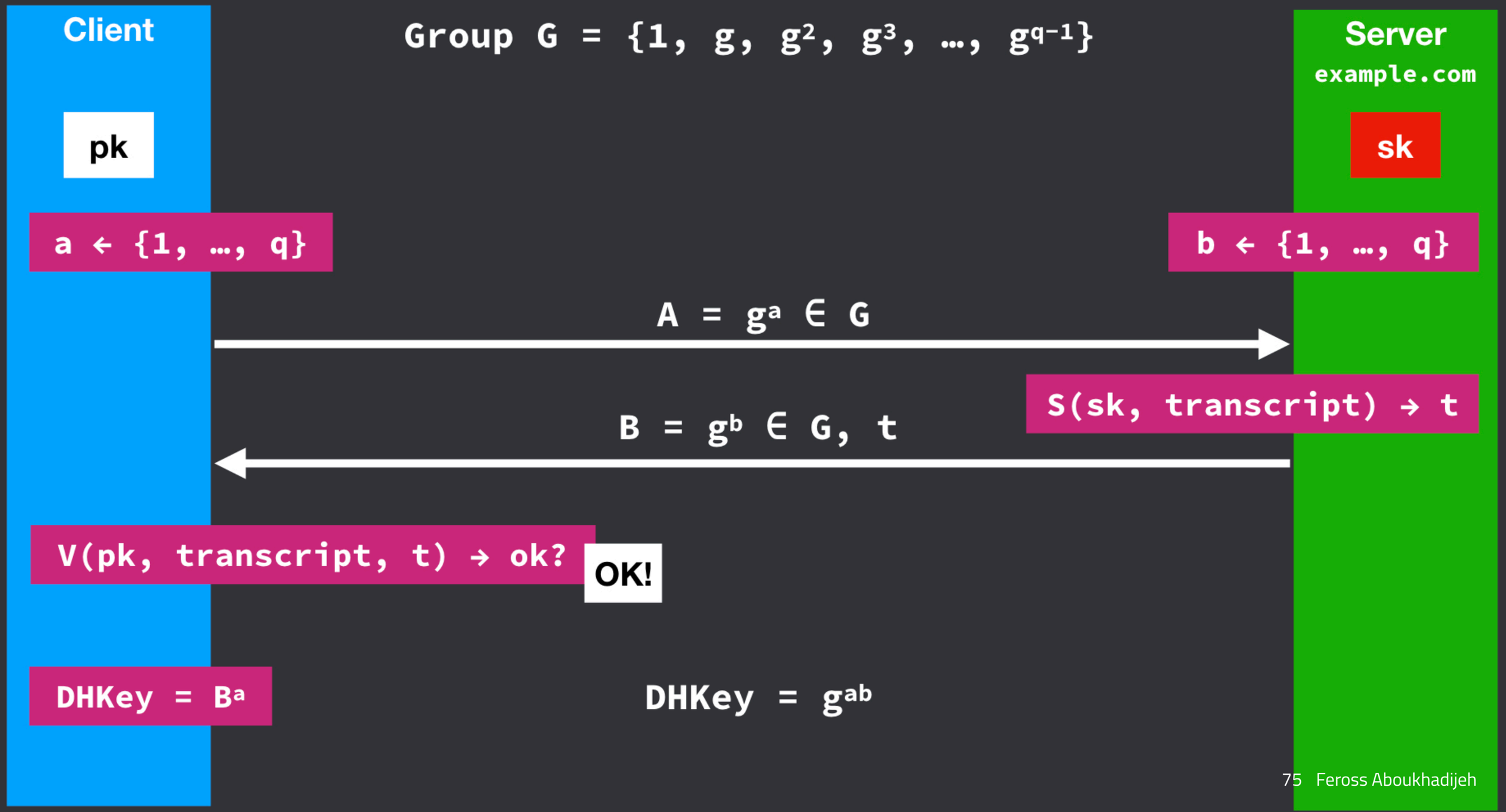

Client
pk
a ← {1, …, q}
Group G = {1, g, g², g³, …, g^(q−1)}
A = g^a ∈ G
Server
example.com
sk
b ← {1, …, q}
S(sk, transcript) → t

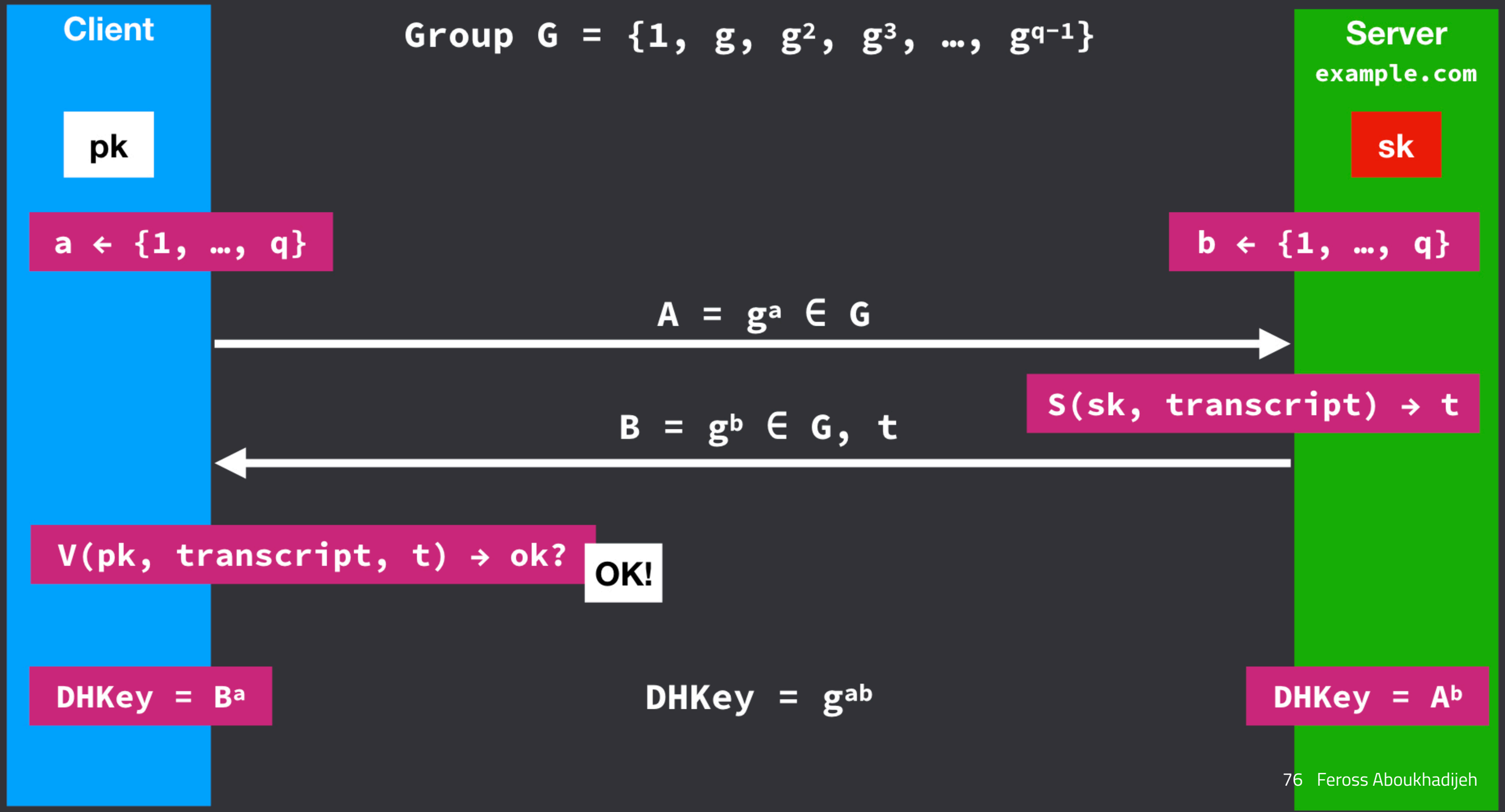

Client
pk
a ← {1, …, q}
Group G = {1, g, g^2, g^3, …, g^(q-1)}
Server
example.com
sk
b ← {1, …, q}
A = g^a ∈ G
S(sk, transcript) → t
B = g^b ∈ G, t

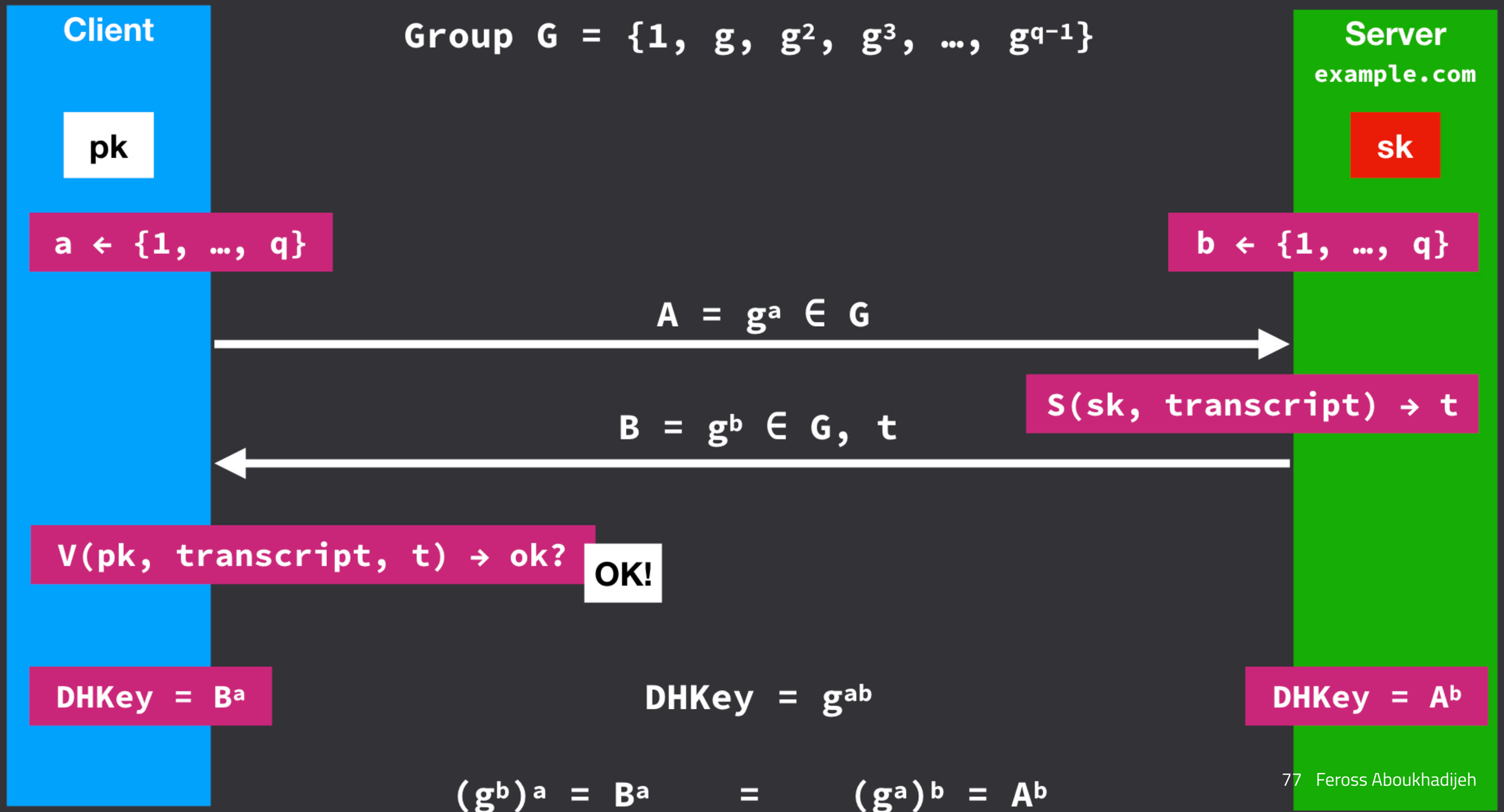

Client
pk
Group G = {1, g, g^2, g^3, …, g^(q-1)}
Server
example.com
sk
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
S(sk, transcript) → t
B = g^b ∈ G, t
V(pk, transcript, t) → ok?


Client
pk
Group G = {1, g, g^2, g^3, …, g^(q-1)}
Server
example.com
sk
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
S(sk, transcript) → t
B = g^b ∈ G, t
V(pk, transcript, t) → ok?
OK!


Client
Group G = {1, g, g^2, g^3, …, g^(q-1)}
Server
example.com
pk
sk
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
S(sk, transcript) → t
B = g^b ∈ G, t
V(pk, transcript, t) → ok?
OK!
DHKey = g^ab

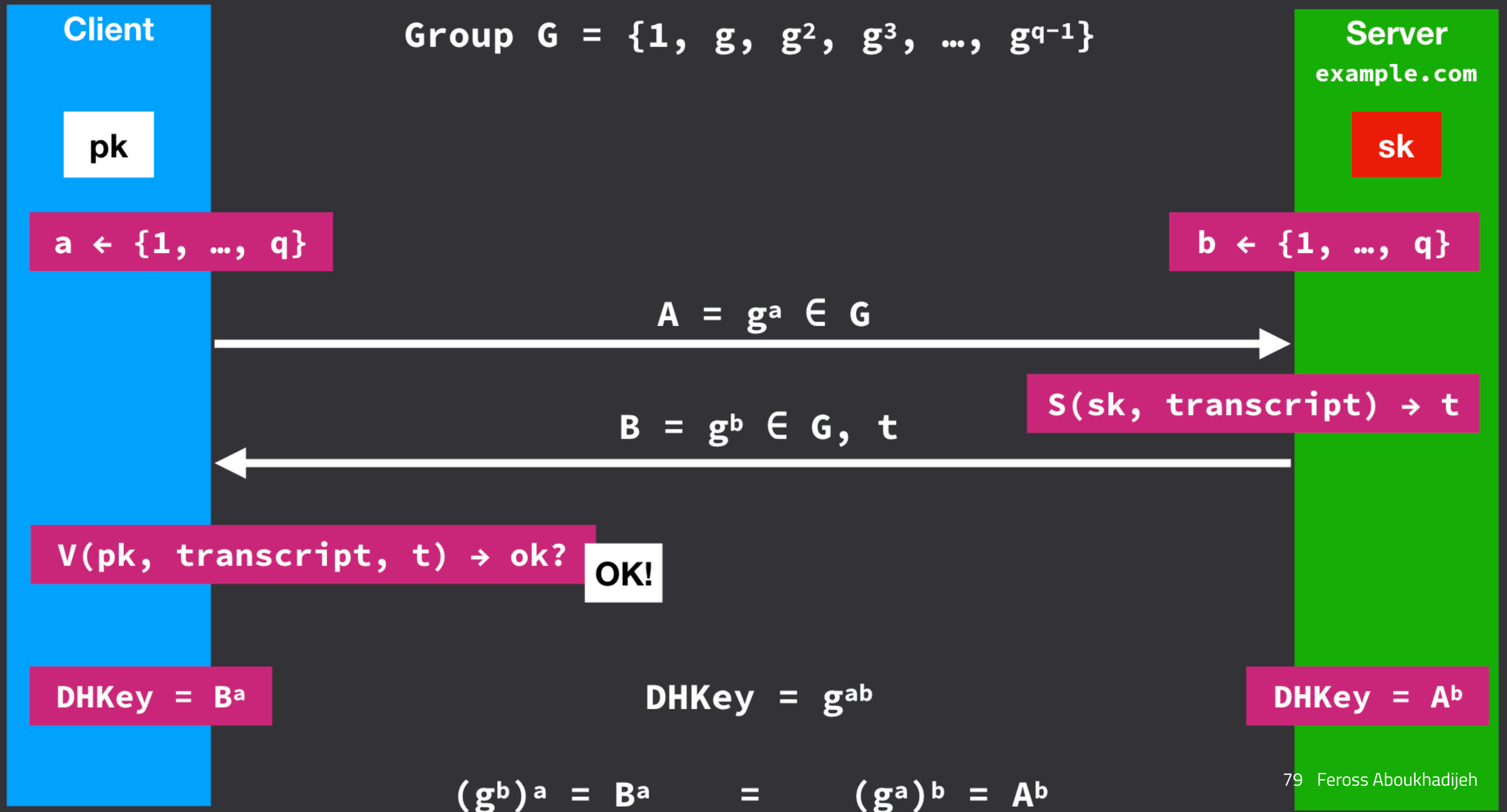

Client
Group G = {1, g, g^2, g^3, …, g^(q-1)}
Server
example.com
pk
sk
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
S(sk, transcript) → t
B = g^b ∈ G, t
V(pk, transcript, t) → ok?
OK!
DHKey = B^a
DHKey = g^ab


Client
Group G = {1, g, g^2, g^3, …, g^(q-1)}
Server
example.com
pk
sk
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
S(sk, transcript) → t
B = g^b ∈ G, t
V(pk, transcript, t) → ok?
OK!
DHKey = B^a
DHKey = g^ab
DHKey = A^b


Client
Server
example.com
Group G = {1, g, g², g³, …, g^(q−1)}
pk
sk
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
S(sk, transcript) → t
B = g^b ∈ G, t
V(pk, transcript, t) → ok?
OK!
DHKey = B^a
DHKey = g^ab
DHKey = A^b
(g^b)^a = B^a = (g^a)^b = A^b

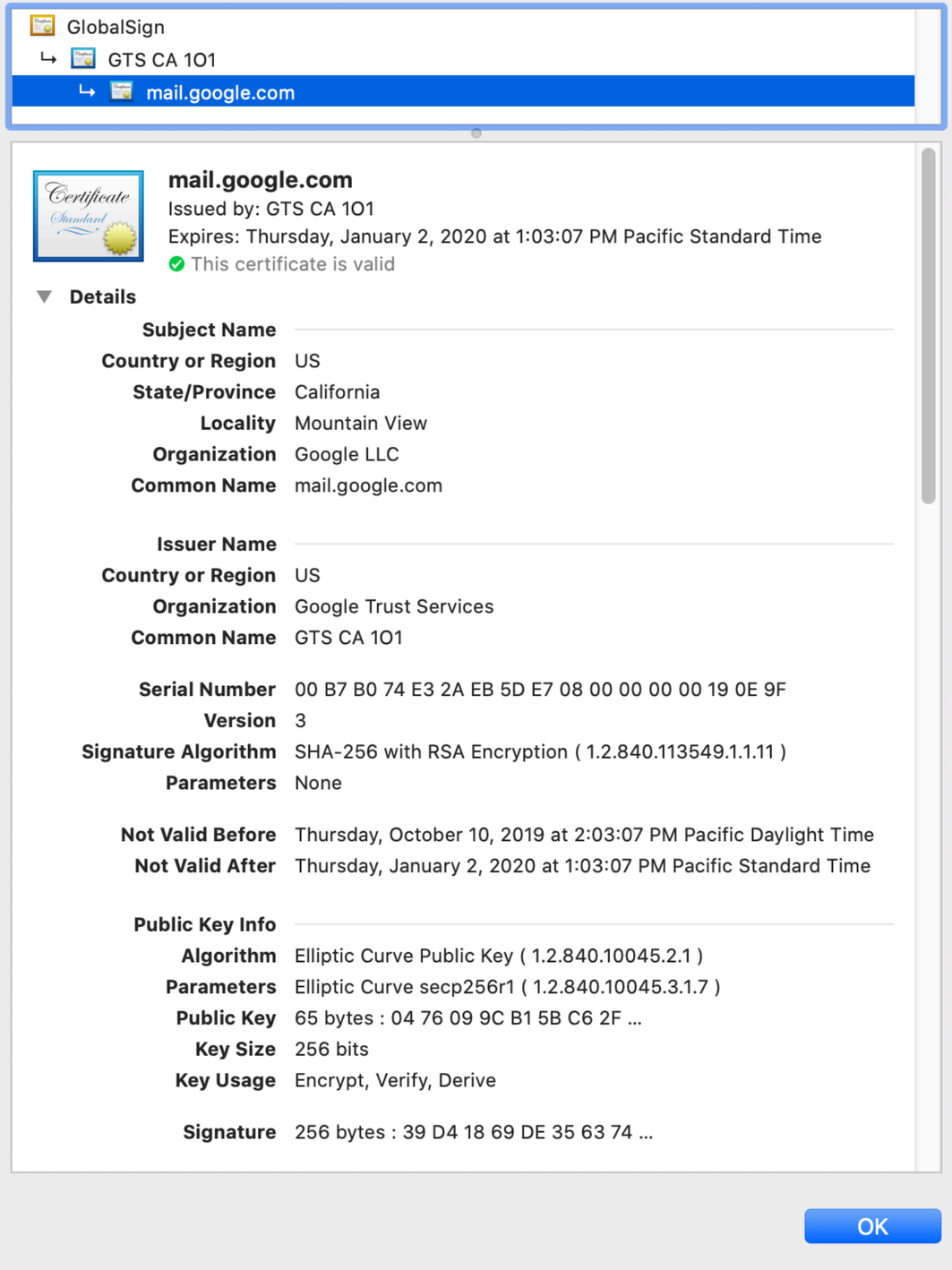
How does the client get the server's public key?

- Idea: Build in every website's public key into the browser
  - Would be a huge list, constantly changing, cannot connect to server if list is out-of-date
- Idea: Server can send the public key to the client during the key exchange
  - Back to the same problem as anonymous key exchange!
  - What's to stop an active network attacker from send their own public key in the exchange?


Client
Server
example.com
Group G = {1, g, g², g³, …, g^(q−1)}
pk
sk
a ← {1, …, q}
b ← {1, …, q}
A = g^a ∈ G
S(sk, transcript) → t
B = g^b ∈ G, t
V(pk, transcript, t) → ok?
OK!
DHKey = B^a
DHKey = g^ab
DHKey = A^b
(g^b)^a = B^a = (g^a)^b = A^b

Certificate authorities (CAs)

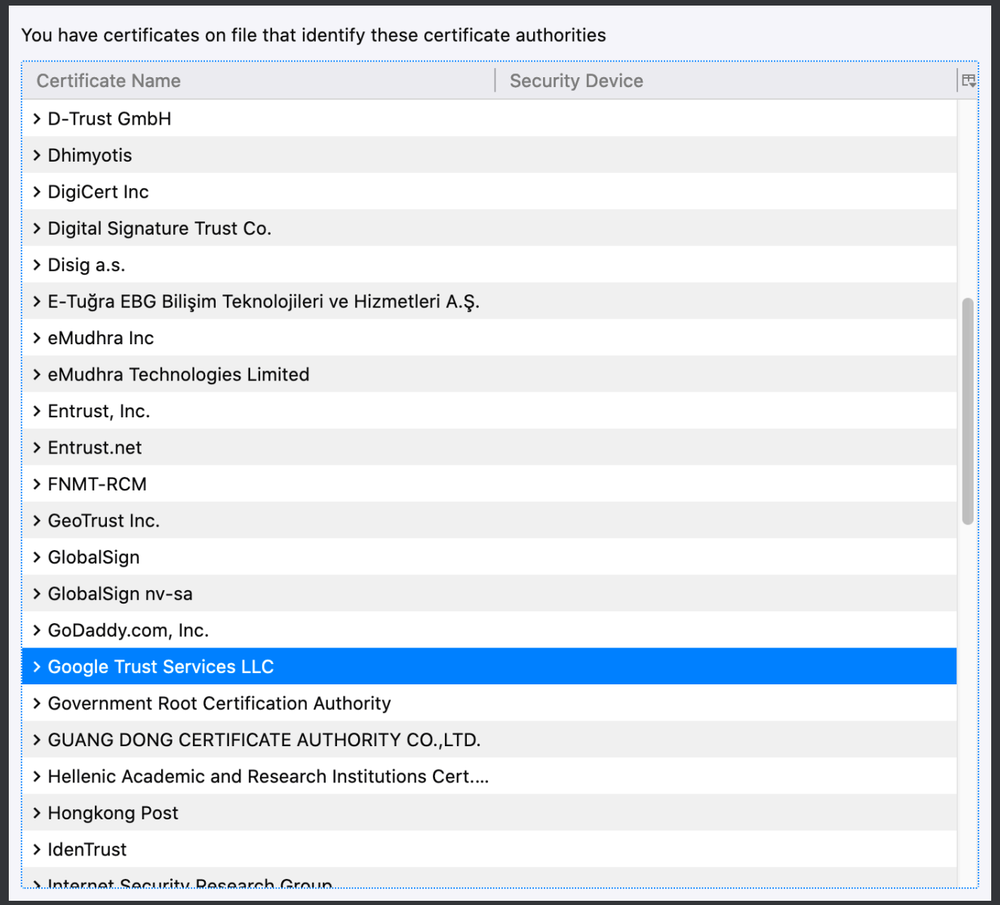
- A **certificate authority (CA)** is an entity that issues digital certificates
- A **certificate** certifies that a **named subject** is the owner of a specific **public key**
  - "I, CERTIFICATE_AUTHORITY, certify that SUBJECT_NAME is the owner of public key PUBLIC_KEY"


GlobalSign
GTS CA 1O1
mail.google.com
mail.google.com
Issued by: GTS CA 1O1
Expires: Thursday, January 2, 2020 at 1:03:07 PM Pacific Standard Time
This certificate is valid
Details
Subject Name
Country or Region US
State/Province California
Locality Mountain View
Organization Google LLC
Common Name mail.google.com
Issuer Name
Country or Region US
Organization Google Trust Services
Common Name GTS CA 1O1
Serial Number 00 B7 B0 74 E3 2A EB 5D E7 08 00 00 00 00 19 0E 9F
Version 3
Signature Algorithm SHA-256 with RSA Encryption (1.2.840.113549.1.1.11)
Parameters None
Not Valid Before Thursday, October 10, 2019 at 2:03:07 PM Pacific Daylight Time
Not Valid After Thursday, January 2, 2020 at 1:03:07 PM Pacific Standard Time
Public Key Info
Algorithm Elliptic Curve Public Key (1.2.840.10045.2.1)
Parameters Elliptic Curve secp256r1 (1.2.840.10045.3.1.7)
Public Key 65 bytes : 04 76 09 9C B1 5B C6 2F ...
Key Size 256 bits
Key Usage Encrypt, Verify, Derive
Signature 256 bytes : 39 D4 18 69 DE 35 63 74 ...
OK

Common name rules

- Subject's **`CommonName`** can be:
  - an explicit name, e.g. **cs.stanford.edu**
  - a wildcard cert, e.g. ***.stanford.edu** or **cs*.stanford.edu**
- Matching rules
  - The * must occur in the leftmost subdomain component
  - The * does not match **.** characters
  - Example: ***.a.com** matches **x.a.com** but not **y.x.a.com**

Who does your browser trust?



Certificate exchange

Client

Server

Certificate Authority

Client

Server
example.com

Certificate Authority

Client

pk_{CA}

Server

`example.com`

Certificate Authority

Client

pk_{CA}

Server

example.com

Certificate Authority

sk_{CA}

Client

pk_{CA}

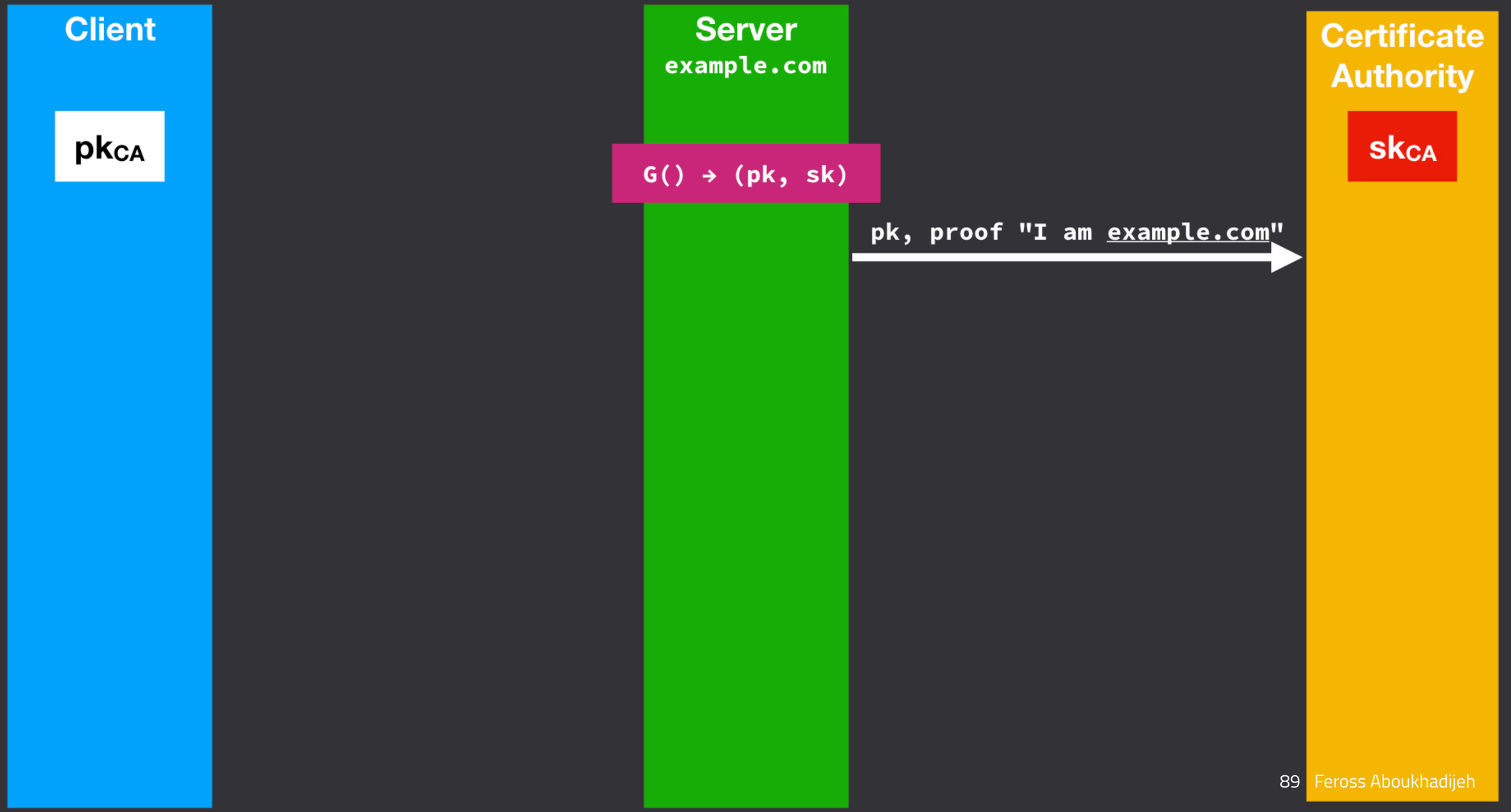
Server

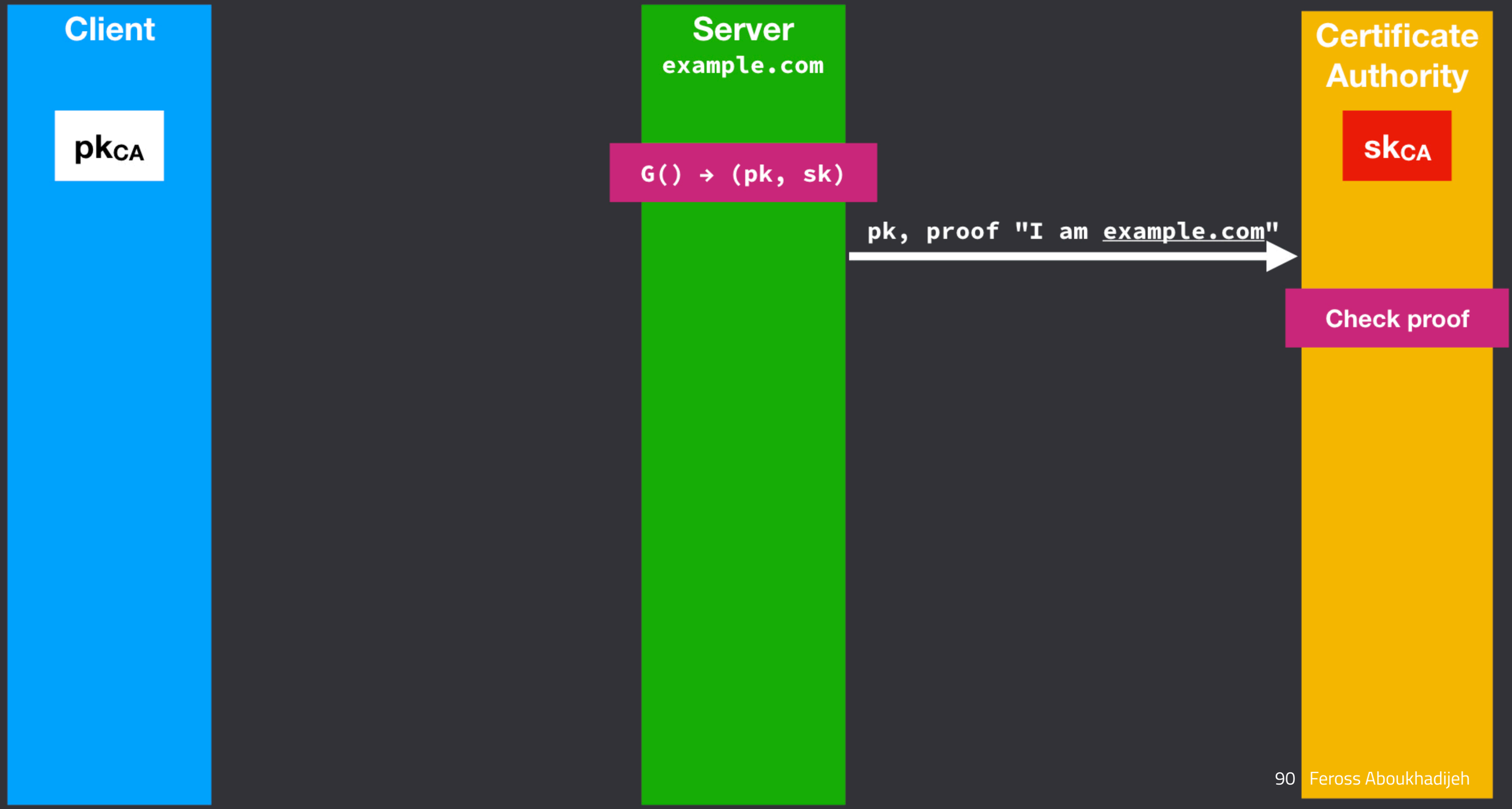
example.com

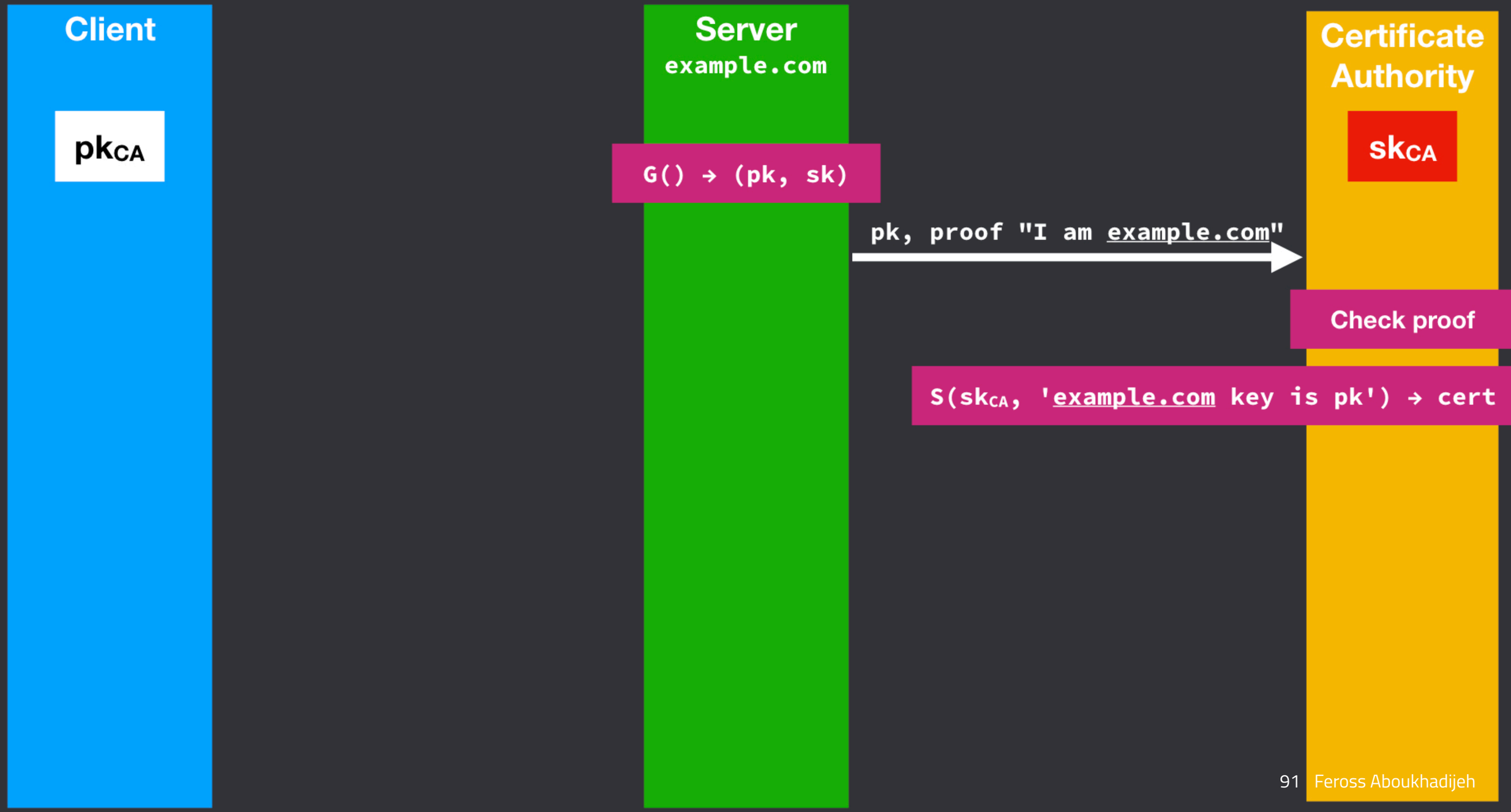
`G() → (pk, sk)`

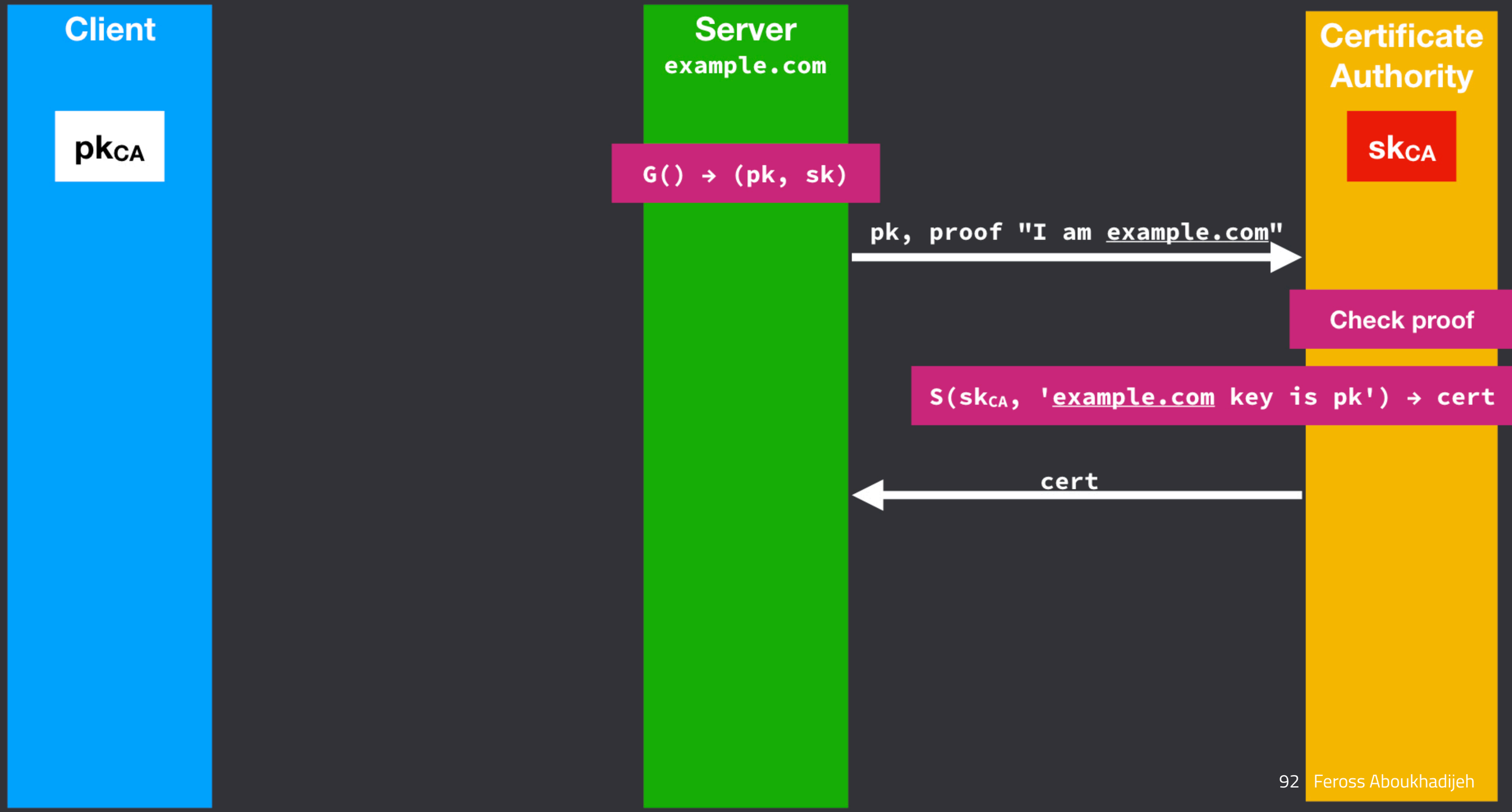
Certificate Authority

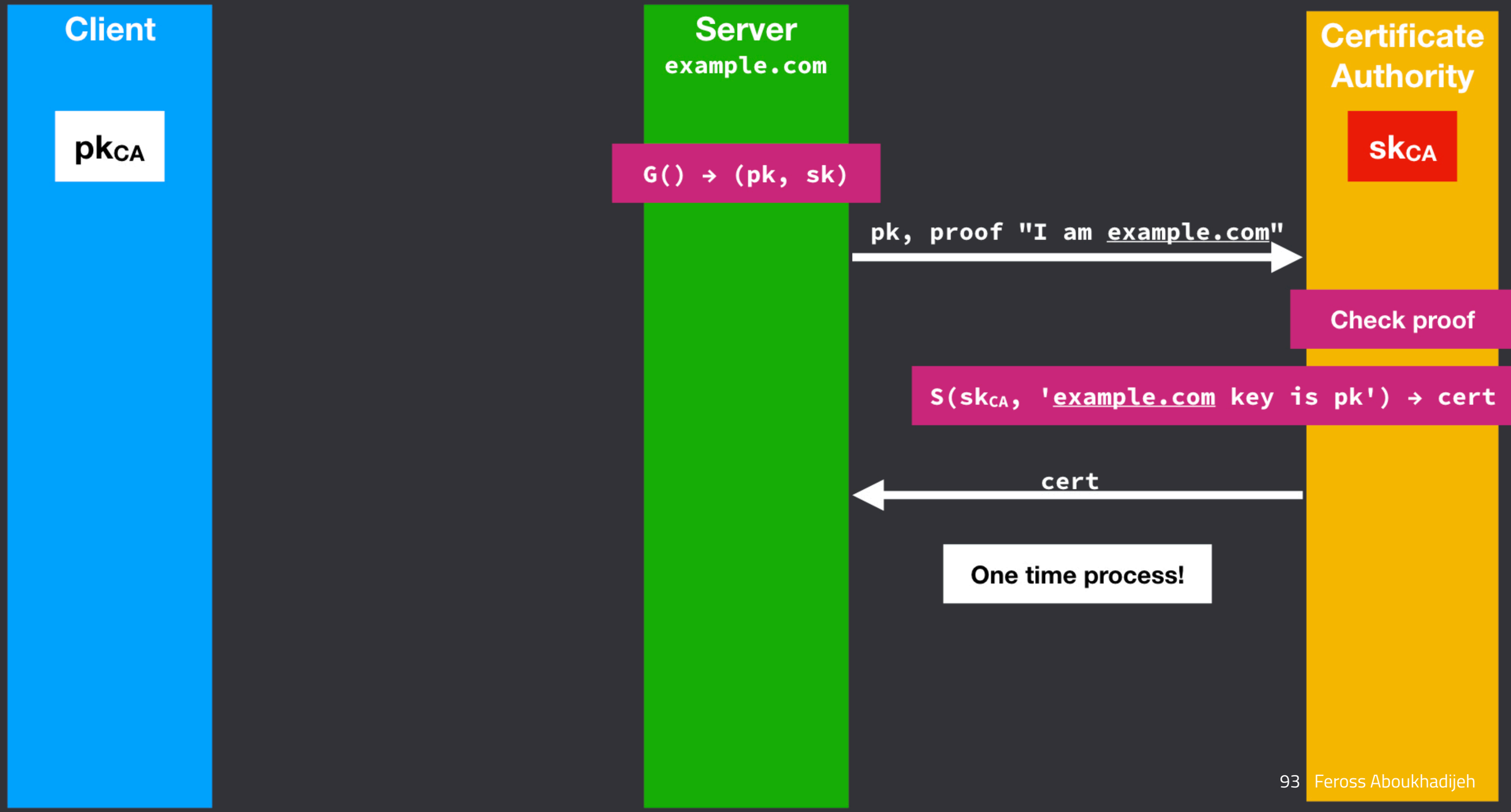
sk_{CA}

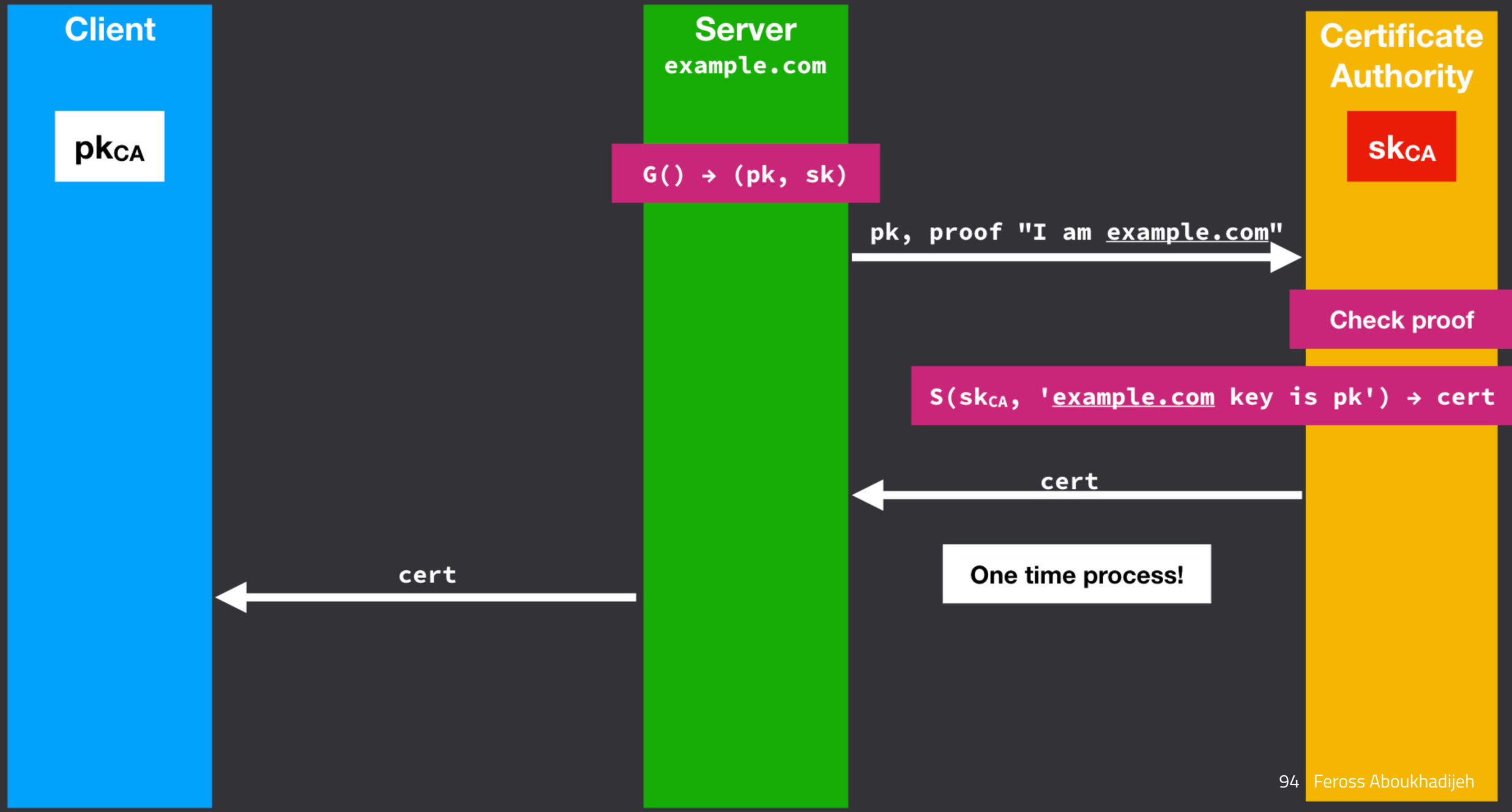

Client
pk_{CA}
Server
example.com
G() → (pk, sk)
pk, proof "I am example.com"
Certificate Authority
sk_{CA}

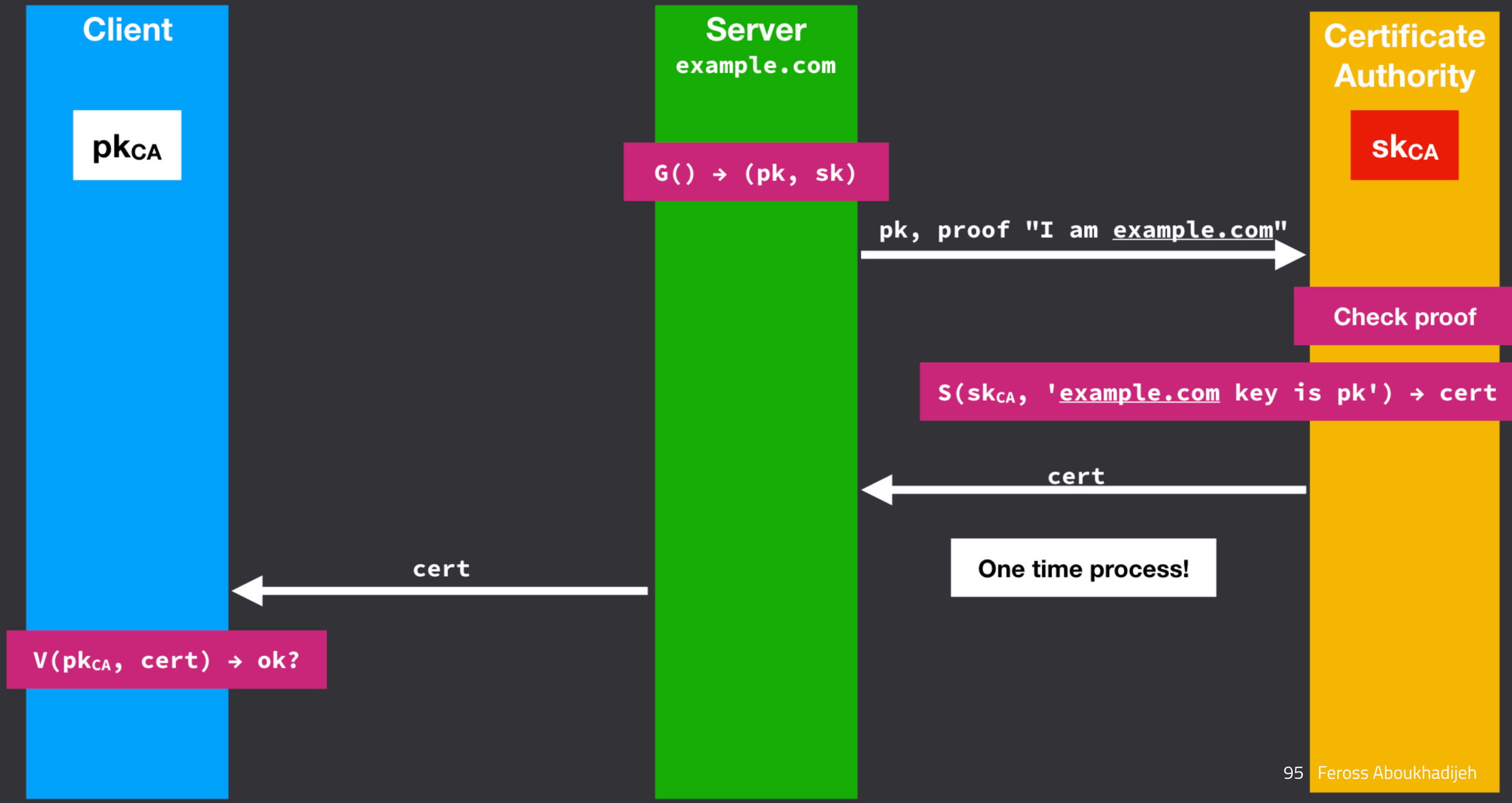

Client
pk_{CA}
Server
example.com
G() → (pk, sk)
pk, proof "I am example.com"
Certificate Authority
sk_{CA}
Check proof

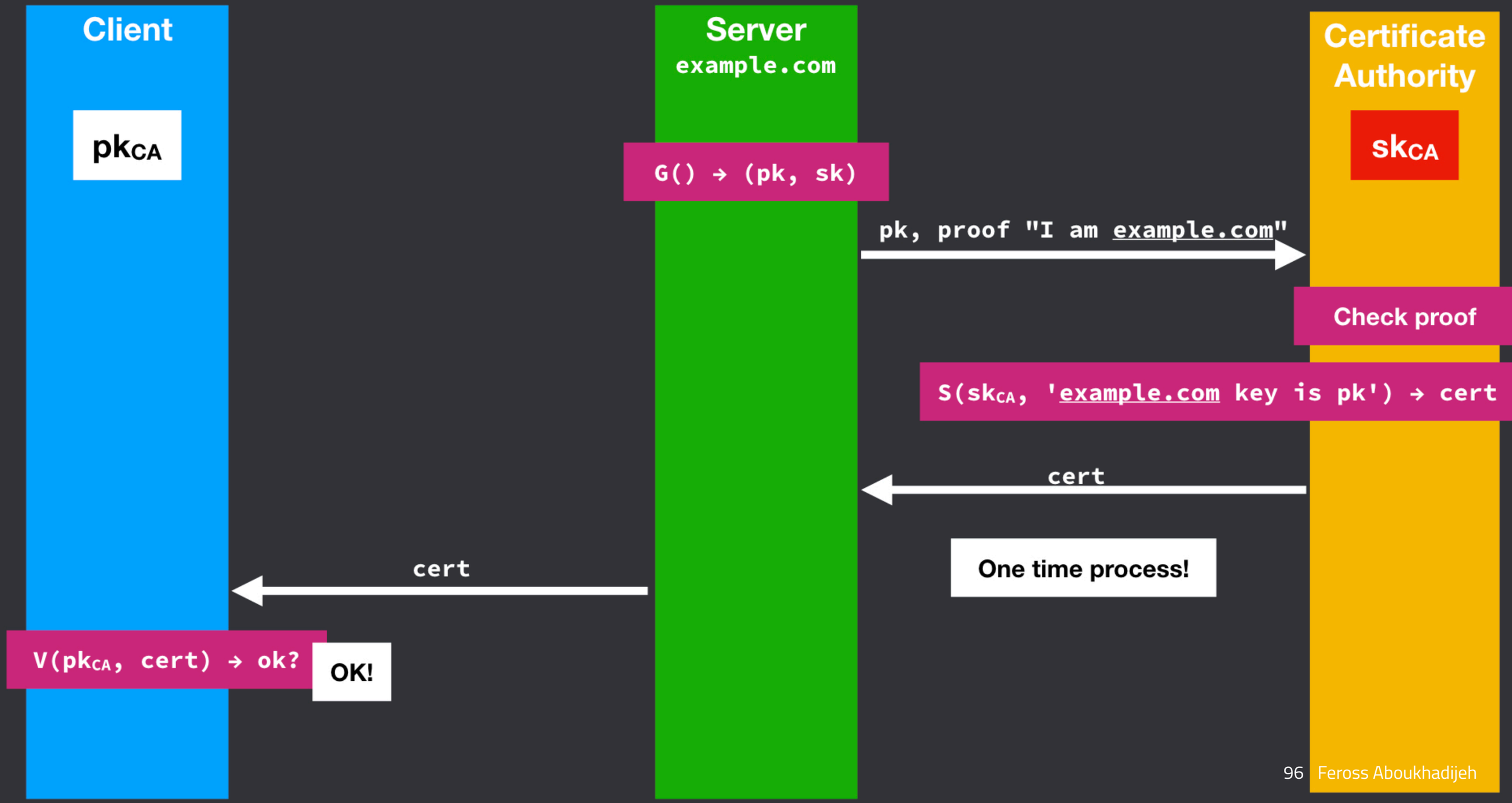

Client
pk_{CA}
Server
example.com
G() → (pk, sk)
pk, proof "I am example.com"
Certificate Authority
sk_{CA}
Check proof
S(sk_{CA}, 'example.com key is pk') → cert

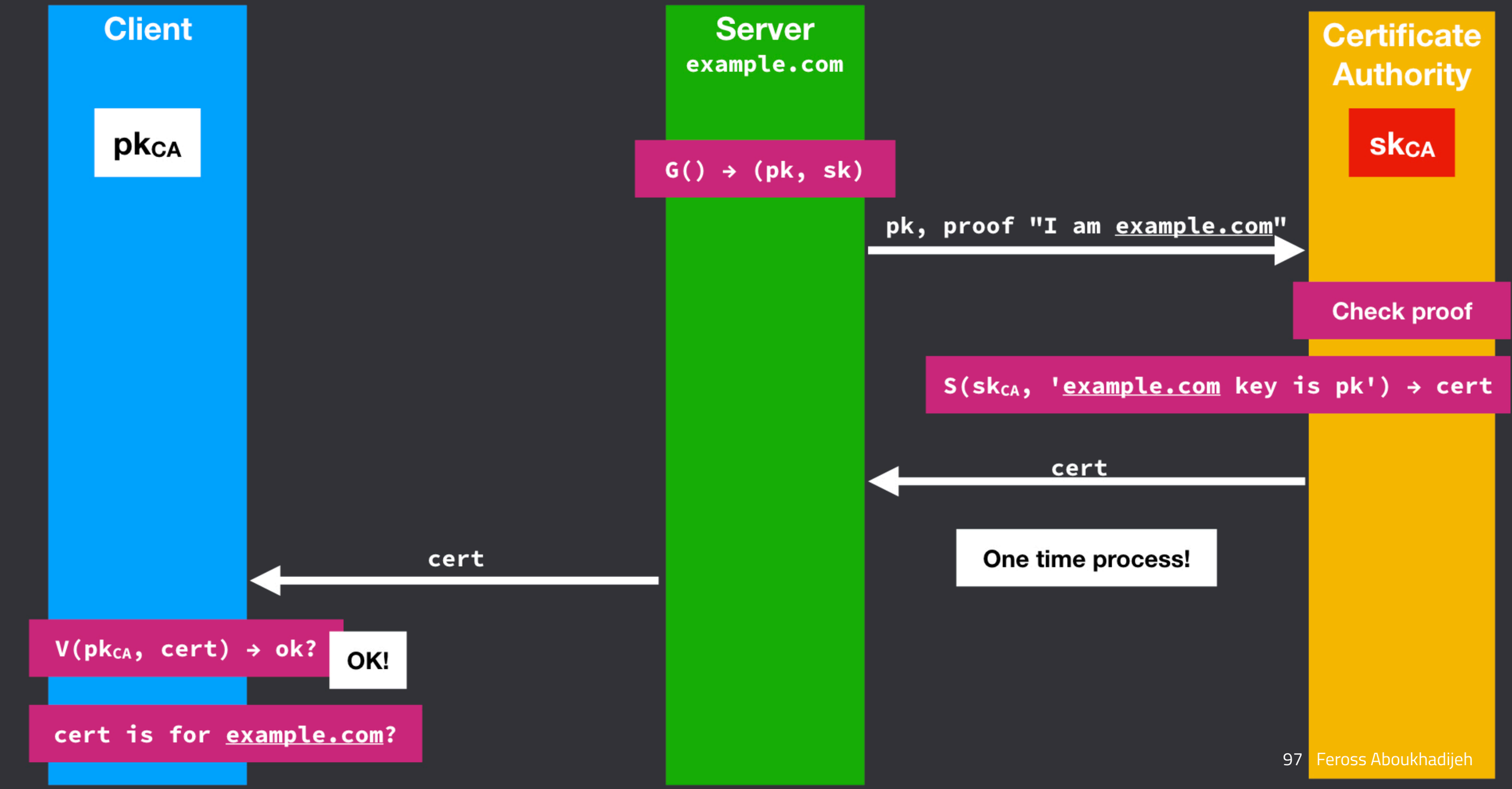

Client
pk_{CA}
Server
example.com
G() → (pk, sk)
Certificate Authority
sk_{CA}
pk, proof "I am example.com"
Check proof
S(sk_{CA}, 'example.com key is pk') → cert
cert

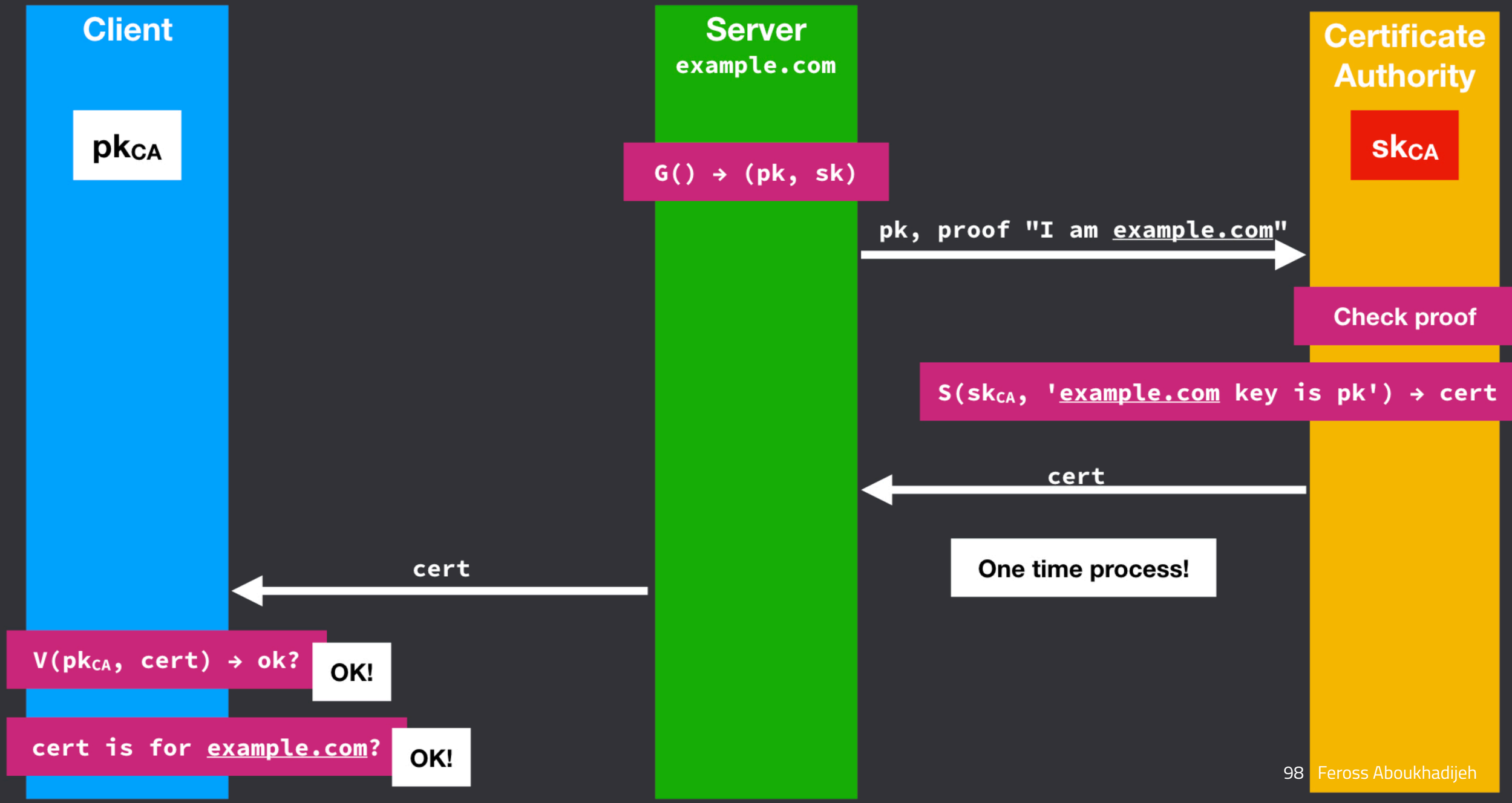

Client
pk_{CA}
Server
example.com
G() → (pk, sk)
Certificate Authority
sk_{CA}
pk, proof "I am example.com"
Check proof
$S(sk_{CA}$, 'example.com key is pk') → cert
cert
One time process!

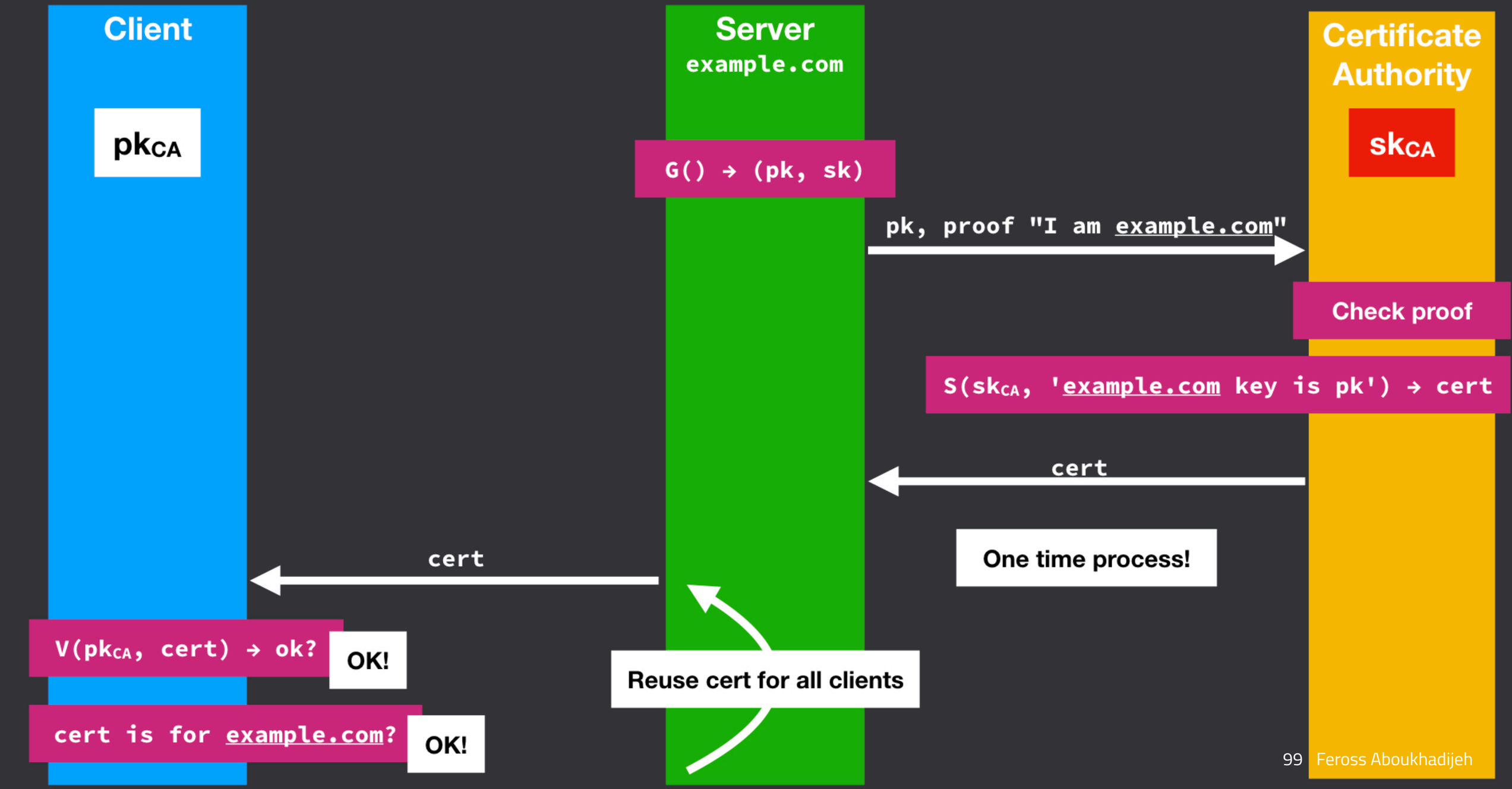

Client
pk_{CA}
Server
example.com
G() → (pk, sk)
Certificate Authority
sk_{CA}
pk, proof "I am example.com"
Check proof
S(sk_{CA}, 'example.com key is pk') → cert
cert
One time process!
cert


Client
pk_{CA}
Server
example.com
G() → (pk, sk)
Certificate Authority
sk_{CA}
pk, proof "I am example.com"
Check proof
$S(sk_{CA}$, 'example.com key is pk') → cert
cert
One time process!
cert
$V(pk_{CA}$, cert) → ok?


Client
pk_{CA}
Server
example.com
G() → (pk, sk)
Certificate Authority
sk_{CA}
pk, proof "I am example.com"
Check proof
$S(sk_{CA}$, 'example.com key is pk') → cert
cert
One time process!
cert
$V(pk_{CA}$, cert) → ok?
OK!


Client
pk_{CA}
Server
example.com
G() → (pk, sk)
Certificate Authority
sk_{CA}
pk, proof "I am example.com"
Check proof
S(sk_{CA}, 'example.com key is pk') → cert
cert
One time process!
cert
V(pk_{CA}, cert) → ok?
OK!
cert is for example.com?

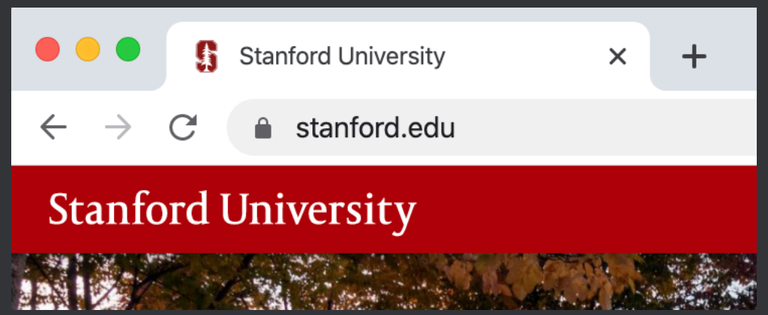

Client
pk_{CA}
Server
example.com
G() → (pk, sk)
Certificate Authority
sk_{CA}
pk, proof "I am example.com"
Check proof
$S(sk_{CA}$, 'example.com key is pk') → cert
cert
One time process!
cert
$V(pk_{CA}$, cert) → ok?
OK!
cert is for example.com?
OK!


Client
pk_{CA}
Server
example.com
G() → (pk, sk)
Certificate Authority
sk_{CA}
pk, proof "I am example.com"
Check proof
S(sk_{CA}, 'example.com key is pk') → cert
cert
One time process!
cert
V(pk_{CA}, cert) → ok?
OK!
Reuse cert for all clients
cert is for example.com?
OK!

TLS 1.3

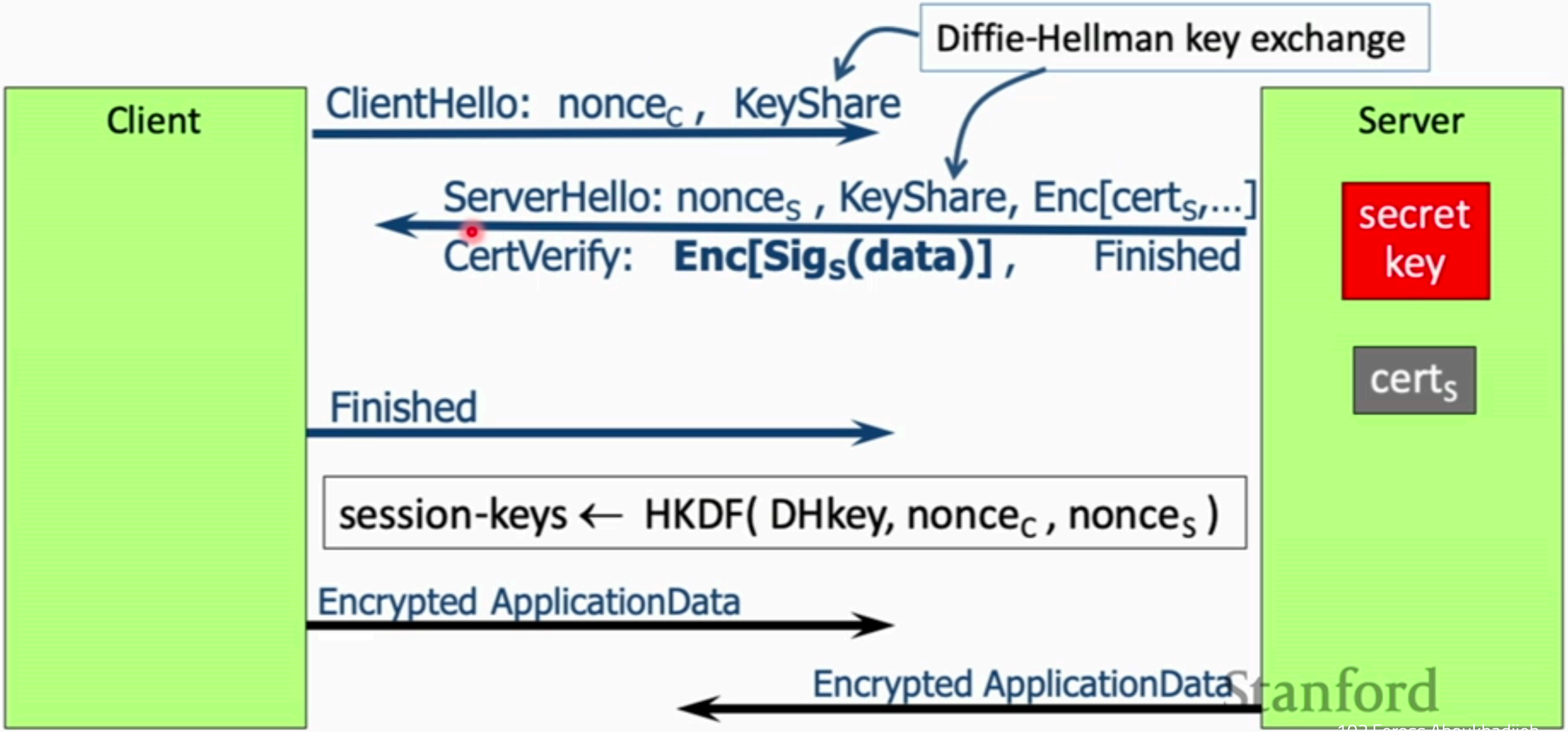
- TLS 1.3 is the latest version of TLS which replaces TLS 1.2, which replaced TLS 1.1, 1.0, SSL 3.0, 2.0, 1.0.
- **Goal:** "provide privacy and reliability between two communicating applications"
- Two phase protocol
  - **Handshake protocol:** Establish a shared secret key using public-key cryptography
  - **Record protocol:** Transmit data using the negotiated key

HTTPS requirements for lock icon



- All elements on the page must be fetched using HTTPS
- For all elements
  - HTTPS certificate must be issued by a CA trusted by browser
  - HTTPS certificate must not be expired
  - HTTPS certificate **`CommonName`** or **`SubjectAlternativeName`** must match the URL

TLS 1.3 session setup (simplified)



Most common: server authentication only

TLS 1.3 properties

- **Nonces:** Prevent replay of an old session
- **Forward secrecy:** server compromise does not expose old sessions
- **Some identity protection:** certificates are sent encrypted
- **One-sided authentication:** Client authenticates the server using the server's certificate
  - TLS has support for mutual authentication ("client certificates") but it is rarely used

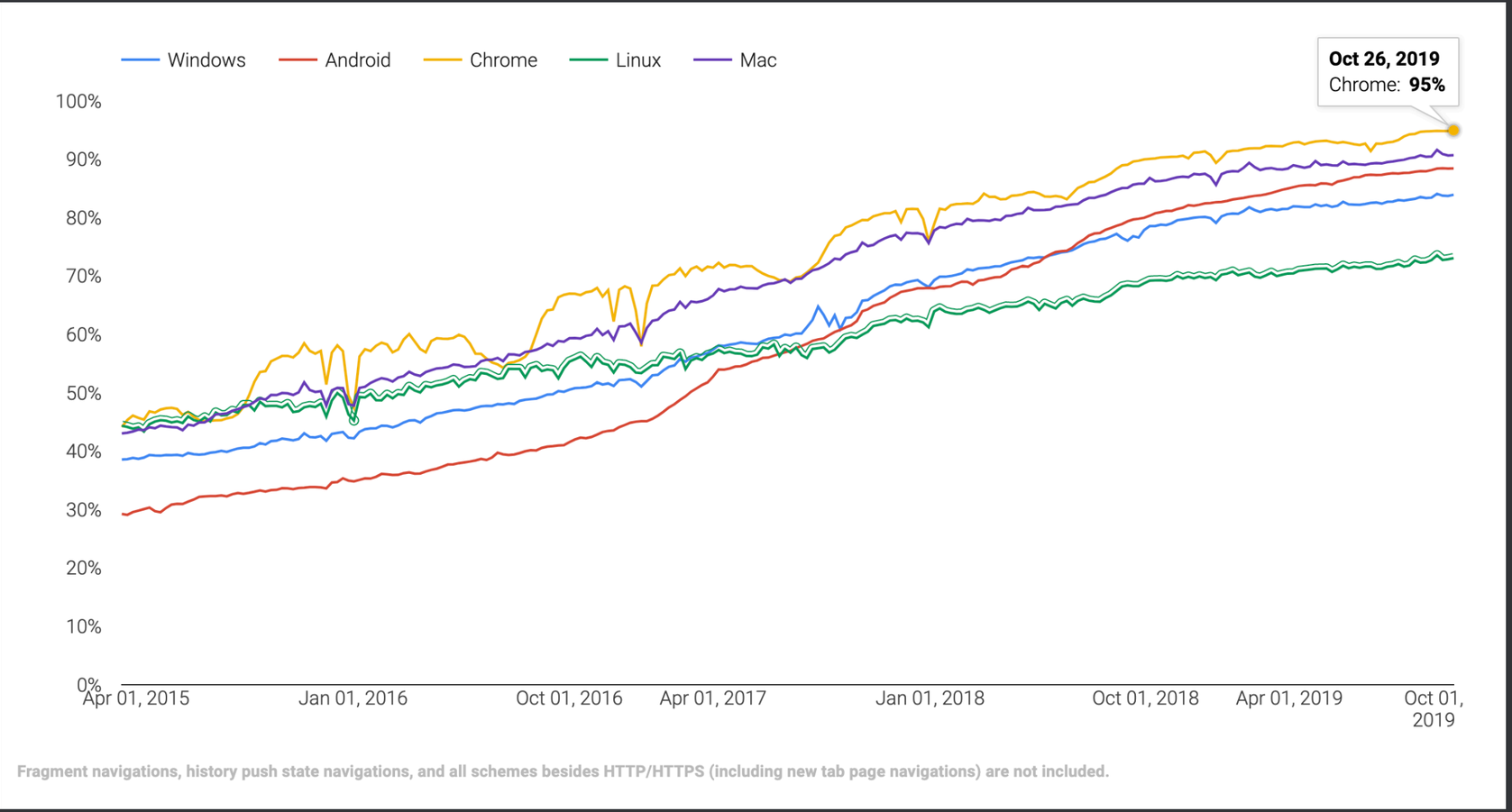
HTTPS adoption

- Survey of **top 100** non-Google sites on the internet, which account for 25% of website traffic worldwide
- Sites that **work** on HTTPS
  - ? / 100
- Sites that **default** to HTTPS
  - ? / 100

HTTPS adoption

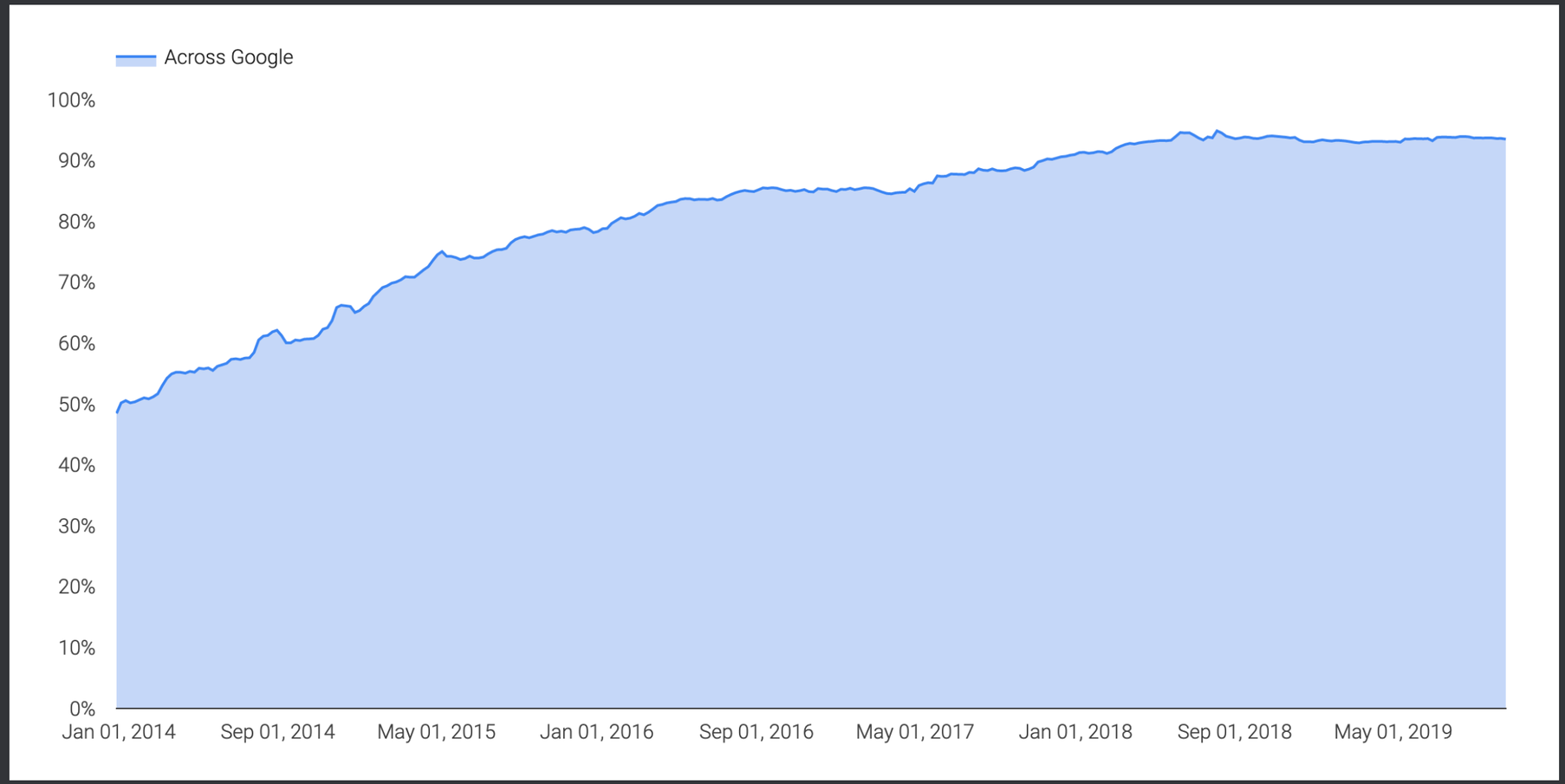
- Survey of **top 100** non-Google sites on the internet, which account for 25% of website traffic worldwide
- Sites that **work** on HTTPS
  - 96 / 100
- Sites that **default** to HTTPS
  - 90 / 100

% pages loaded over HTTPS in Chrome by platform



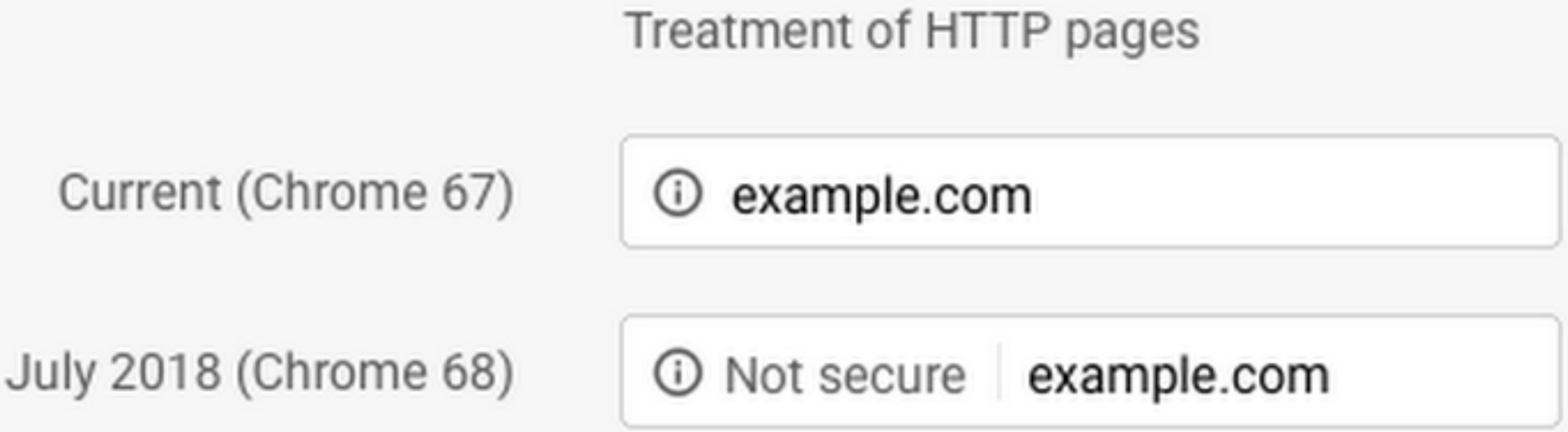
Fragment navigations, history push state navigations, and all schemes besides HTTP/HTTPS (including new tab page navigations) are not included.

% Google pages loaded over HTTPS



Why not 100%?

- Old excuses (not true anymore)
  - Crypto is slow
  - Ad networks do not support HTTPS
- "**Mobile devices account for the vast majority of unencrypted end user traffic** that originates from a given set of surveyed Google services. Some older devices cannot support modern encryption, standards, or protocols. Unfortunately, **these devices may no longer support software updates** and, as a result, may never support encryption"


Treatment of HTTP pages
Current (Chrome 67)
example.com
July 2018 (Chrome 68)
Not secure
example.com

TLS certificate chains

- How many CAs are there?
  - Top-level CAs = ~60
  - Intermediate CAs = ~1200
- If any single CA is compromised, security of all websites on the internet could be compromised – yikes!

NEWS

Hackers spied on 300,000 Iranians using fake Google certificate

Investigation reveals month-long, massive Gmail snooping campaign

By Gregg Keizer

Senior Reporter, Computerworld | SEP 6, 2011 5:43 AM PST

About 300,000 Iranians had their Gmail accounts compromised and their messages read by hackers, according to a forensics firm that has investigated the theft of hundreds of digital certificates from a Dutch company.

Although the report did not identify the hacker, or hackers, who may have spied on the Iranian users, security researchers have pointed to Iran's government, which has been linked to other attempts to intercept the communications of activists and protesters.

oss Aboukhadijeh

TECHNOLOGY

Trustico revokes 23,000 SSL certificates due to compromise

The Register®
Biting the hand that feeds IT

Security

New hack on Comodo reseller exposes private data

And then there were four

By Dan Goodin 24 May 2011 at 19:58 5 SHARE ▼

Yet another official reseller of SSL certificate authority Comodo has suffered a security breach that allowed attackers to gain unauthorized access to data.

Brazil-based ComodoBR is at least the fourth Comodo partner to be compromised this year. In March, the servers of a separate registration authority were hacked by attackers who used their access to forge counterfeit certificates signed with Comodo's root signing key. Comodo admitted that two more of its resellers were hit in similar attacks, although no keys were issued.

Comodo has so far declined to name the resellers.

The SQL-injection attack on ComodoBR exploited vulnerabilities in the company's web applications that allowed the hackers to pass database commands to the website's backend server. The attackers posted two data files that appeared to show information related to certificate signing requests, in addition to email addresses, user IDs, and password

Comodo reseller hack

- The attackers registered fraudulent certificates for **gmail.com**, **google.com**, **login.yahoo.com**, **login.skype.com**, **addons.mozilla.com**, and **login.live.com**
- Quote from Comodo president and CEO
  - "So as a summary: its an SQL attack (fairly common) on a company in Brazil who sells some of our products.” he wrote in an email. “Nothing to report really."

mozilla

Mozilla Security Blog

MAR
12
2018

Distrust of Symantec TLS Certificates

Kathleen Wilson

Kathleen Wilson

A Certification Authority (CA) is an organization that browser vendors (like Mozilla) trust to issue certificates to websites. Last year, Mozilla published and discussed a set of issues with one of the oldest and largest CAs run by Symantec. The discussion resulted in the adoption of a consensus proposal to gradually remove trust in all Symantec TLS/SSL certificates from Firefox. The proposal includes a number of phases designed to minimize the impact of the change to Firefox users:

- January 2018 (Firefox 58): Notices in the Browser Console warn about Symantec certificates issued before 2016-06-01, to encourage site owners to replace their TLS certificates.
- May 2018 (Firefox 60): Websites will show an untrusted connection error if they use a TLS certificate issued before 2016-06-01 that chains up to a Symantec root certificate.
- October 2018 (Firefox 63): Distrust of Symantec root certificates for website server TLS authentication.

Kathleen Wilson

More from Kathleen Wilson »

Categories

HTTPS attack: TLS Strip

- This attack is commonly known as "ssl strip"
- Most servers which support HTTPS implement an HTTP to HTTPS redirect
- When user omits protocol, the browser assumes **http://** protocol
- What if the attacker intercepts the first unencrypted HTTP request?
  - Then they can man-in-the-middle all the traffic to rewrite the HTML to keep the user on the HTTP version of the site

Redirect HTTP to HTTPS

Client

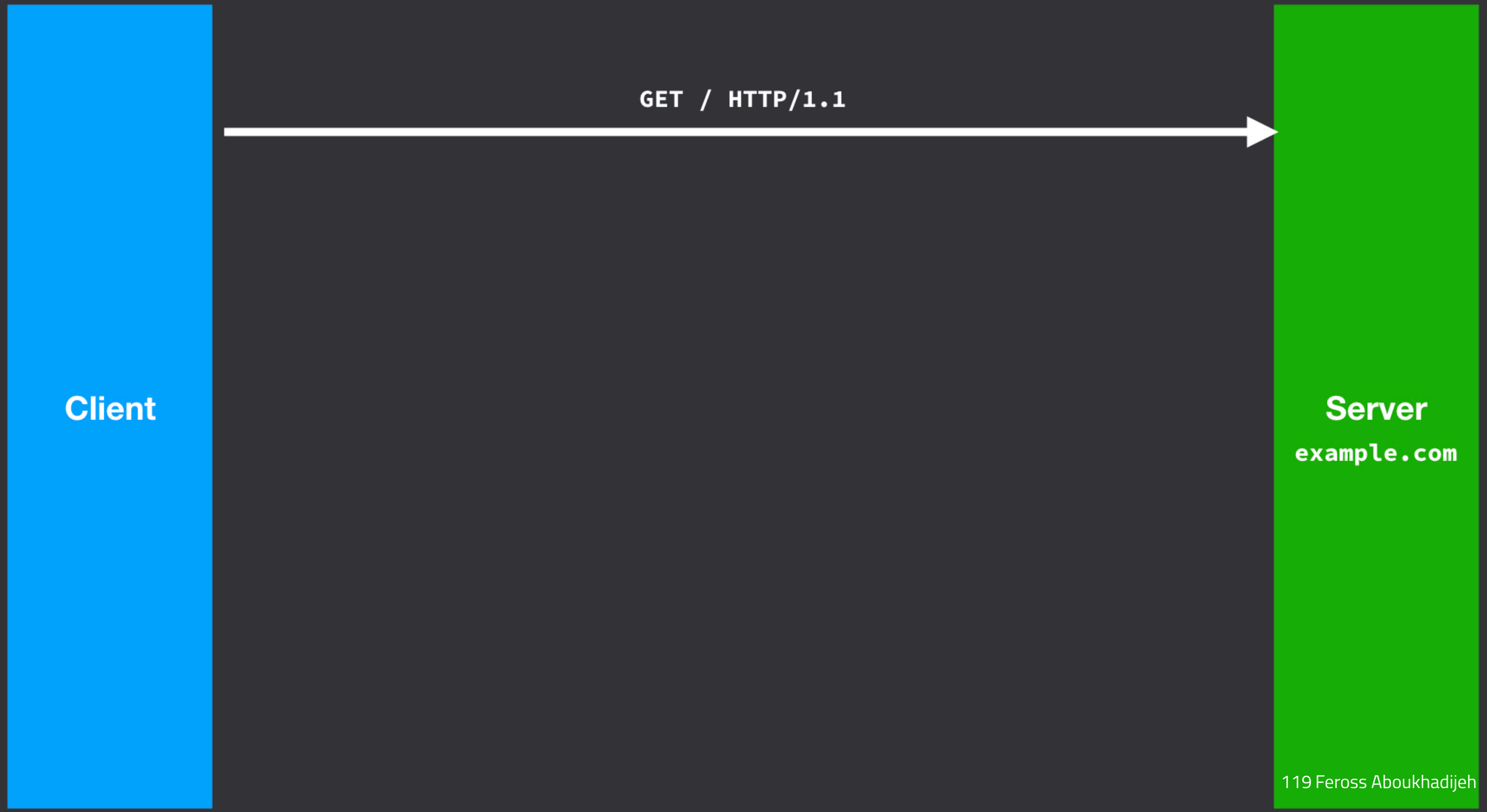
Server

example.com

Client

Server

`example.com`


GET / HTTP/1.1
Client
Server
example.com


GET / HTTP/1.1
HTTP/1.1 301 Moved Permanently
Location: https://example.com
<!doctype html> Page has moved!
Client
Server
example.com
120 Feross Aboukhadijeh


GET / HTTP/1.1
HTTP/1.1 301 Moved Permanently
Location: https://example.com
<!doctype html> Page has moved!
Client
GET / HTTP/1.1
Server
example.com
121 Feross Aboukhadijeh


GET / HTTP/1.1
HTTP/1.1 301 Moved Permanently
Location: https://example.com
<!doctype html> Page has moved!
Client
Server
example.com
GET / HTTP/1.1
HTTP/1.1 200 OK
<!doctype html> good html
122 Feross Aboukhadijeh

TLS Strip attack

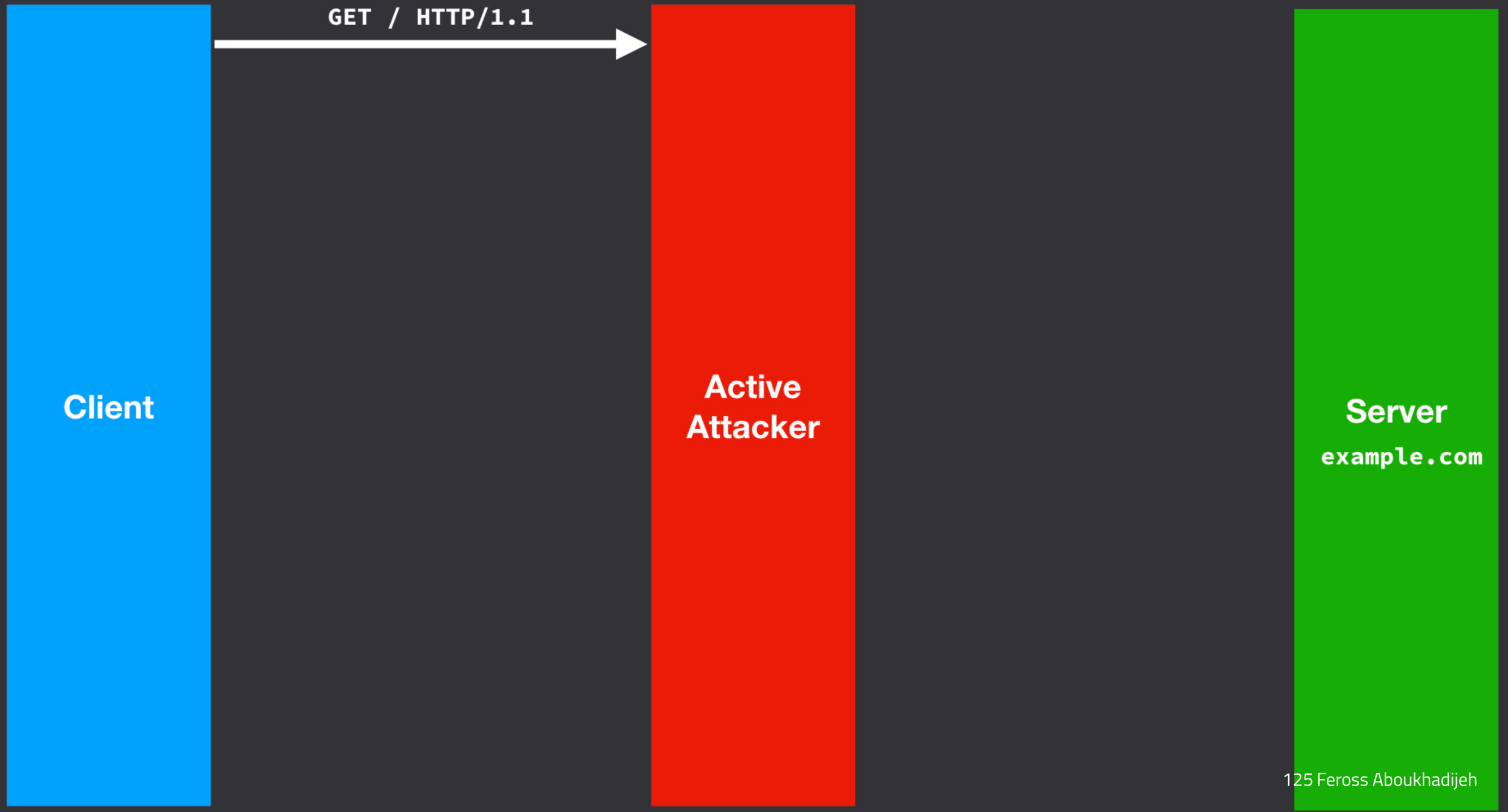
Client

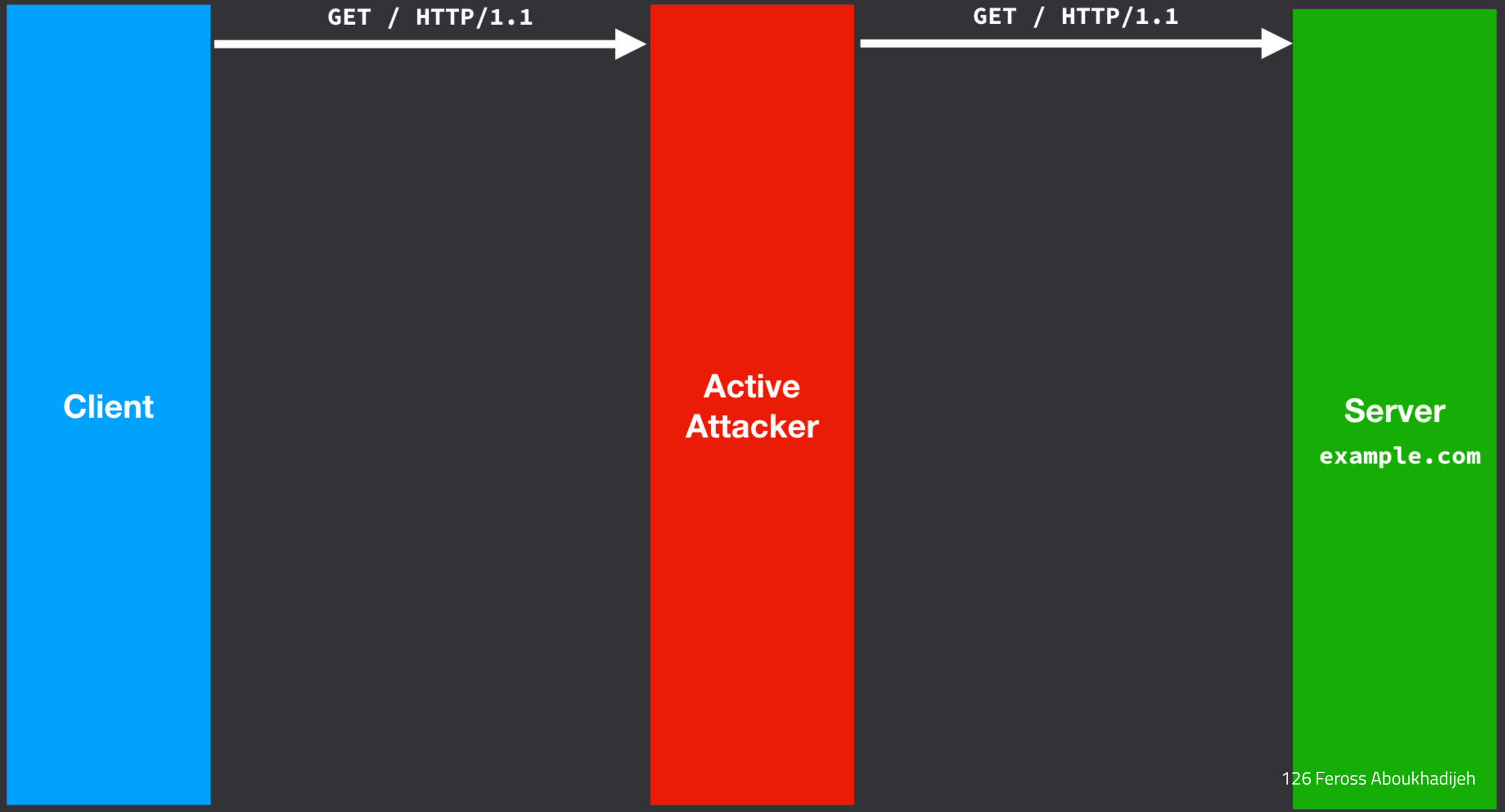
Active Attacker

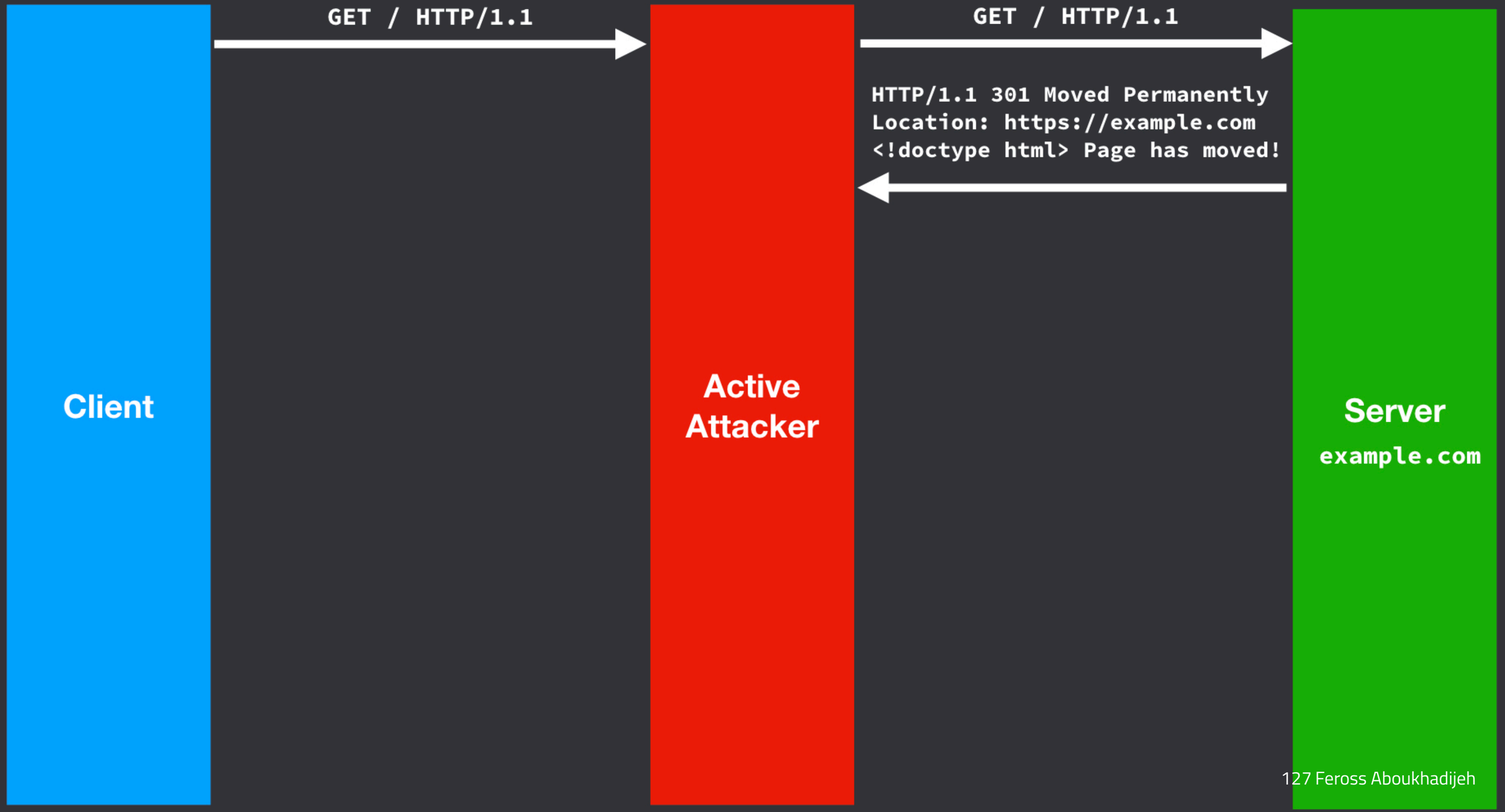
Server

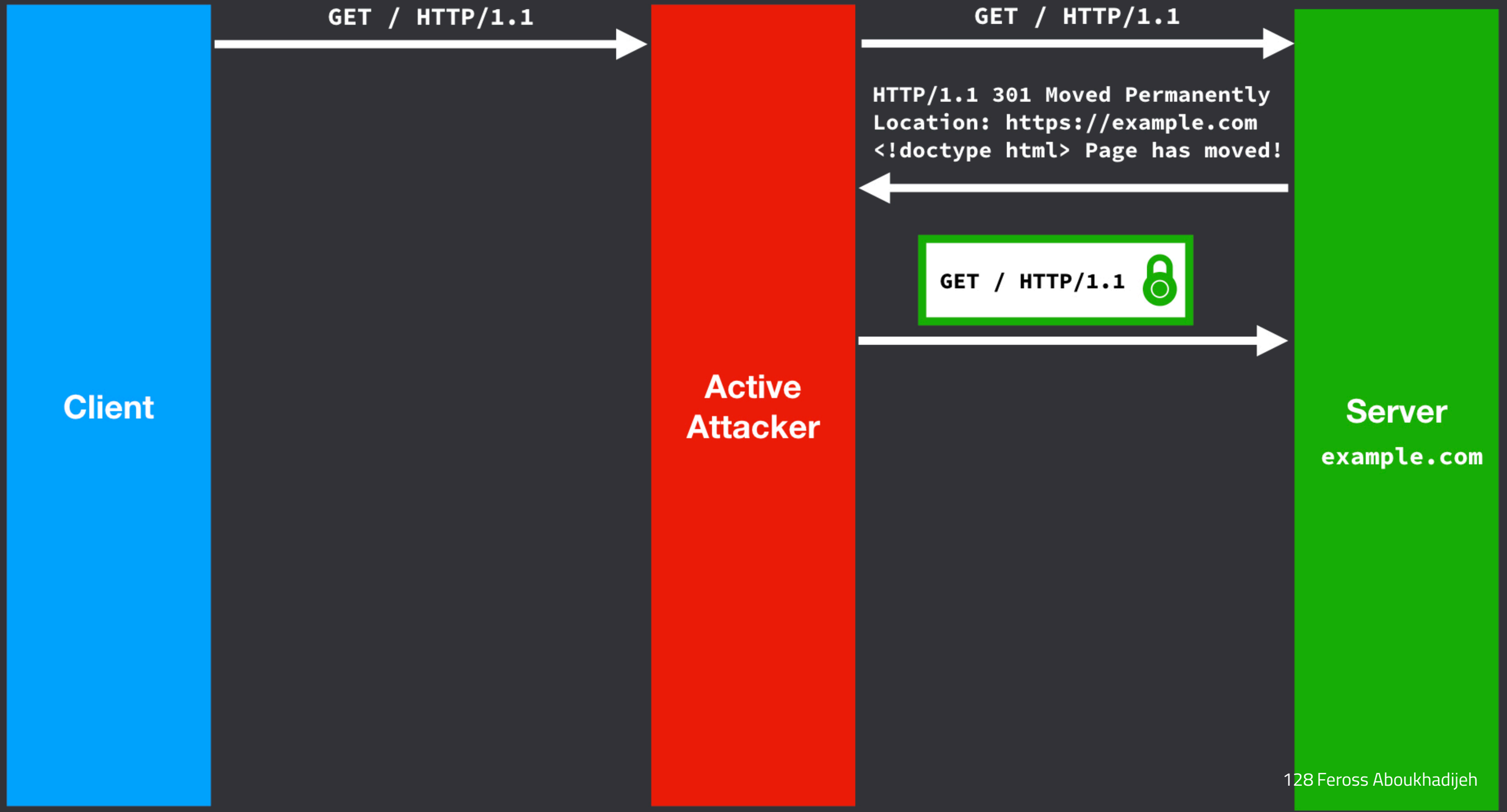
example.com

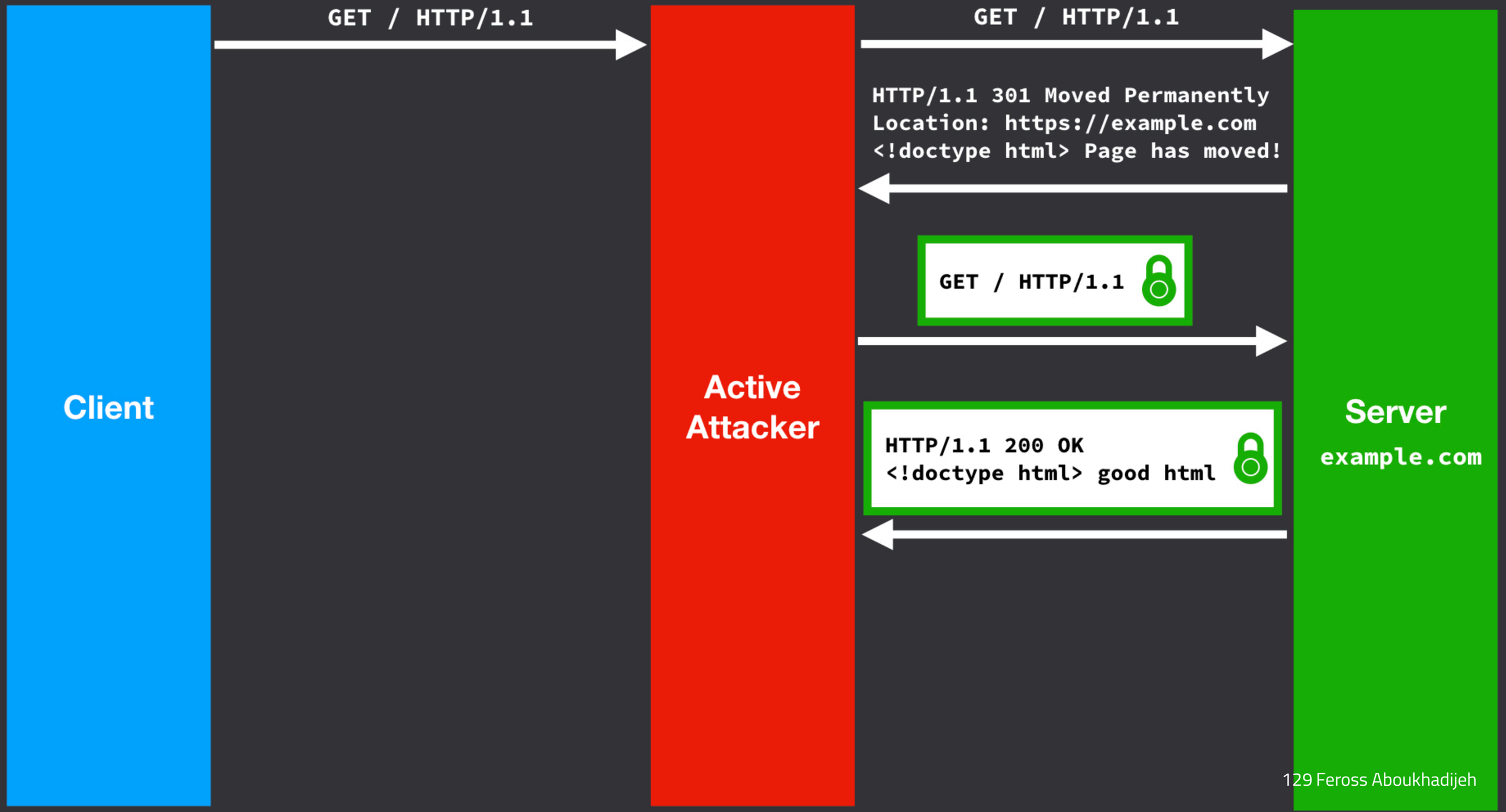

Client
Active Attacker
Server
example.com

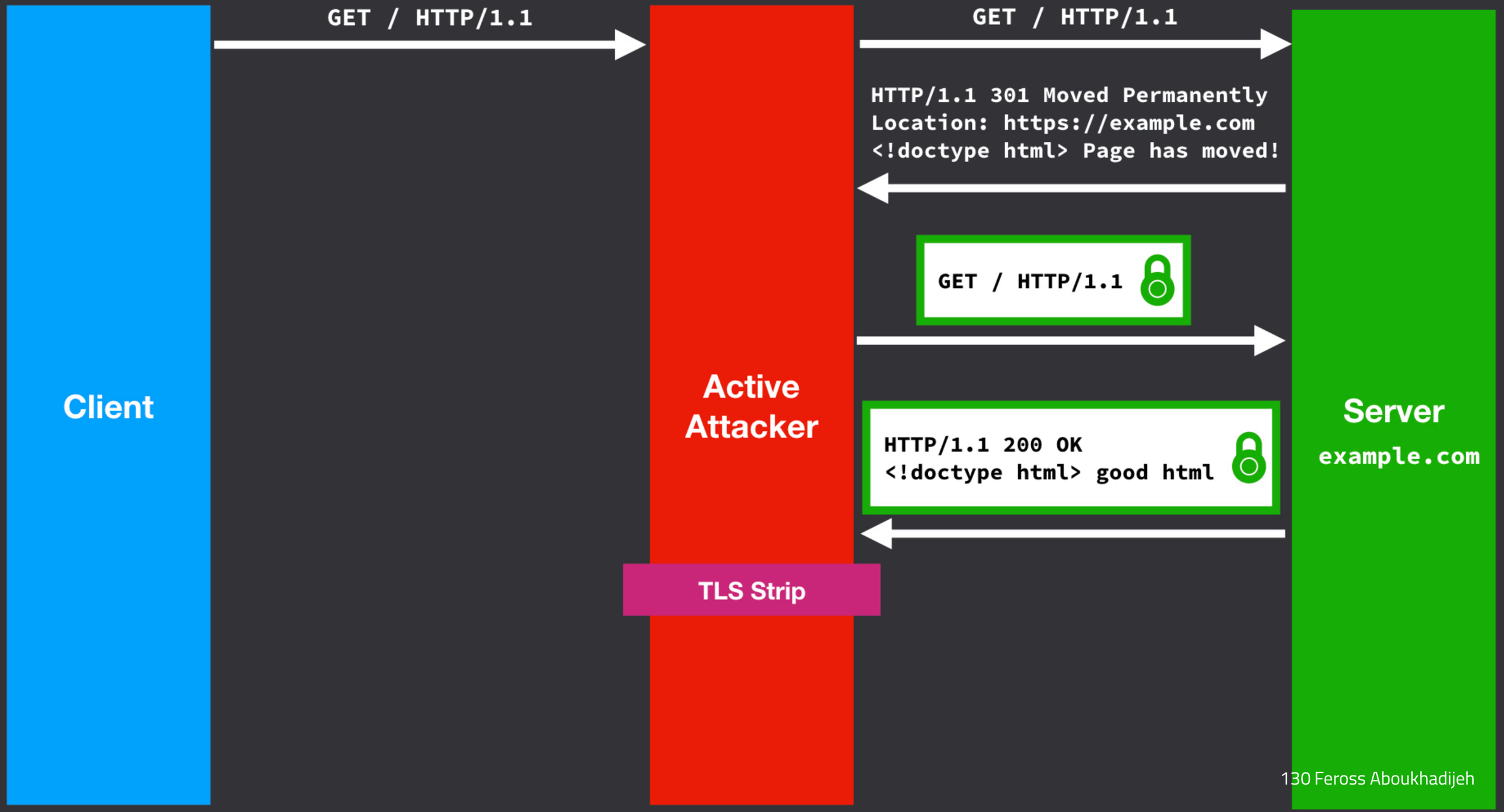

GET / HTTP/1.1
Client
Active Attacker
Server
example.com

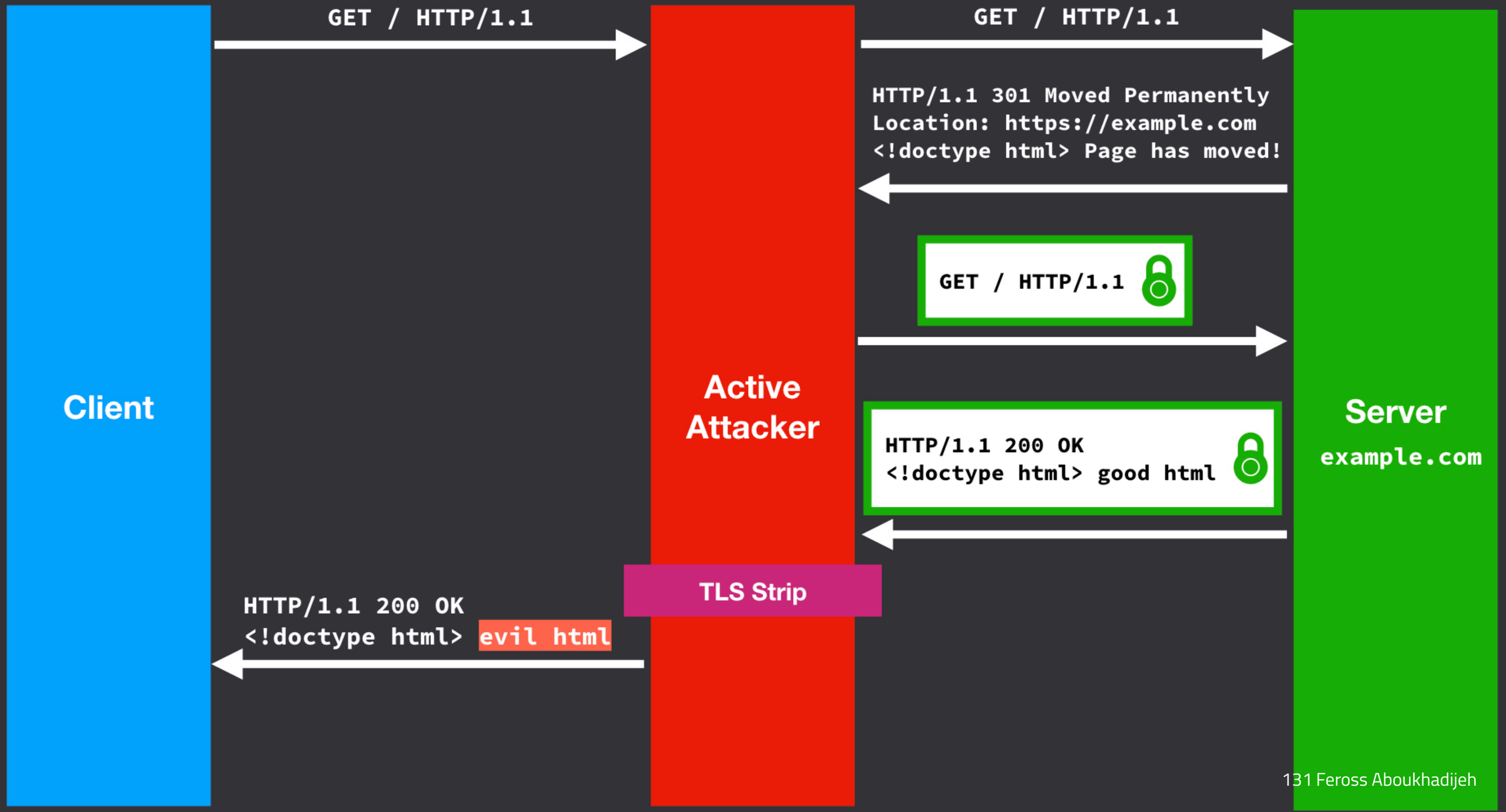

GET / HTTP/1.1
GET / HTTP/1.1
Client
Active Attacker
Server
example.com

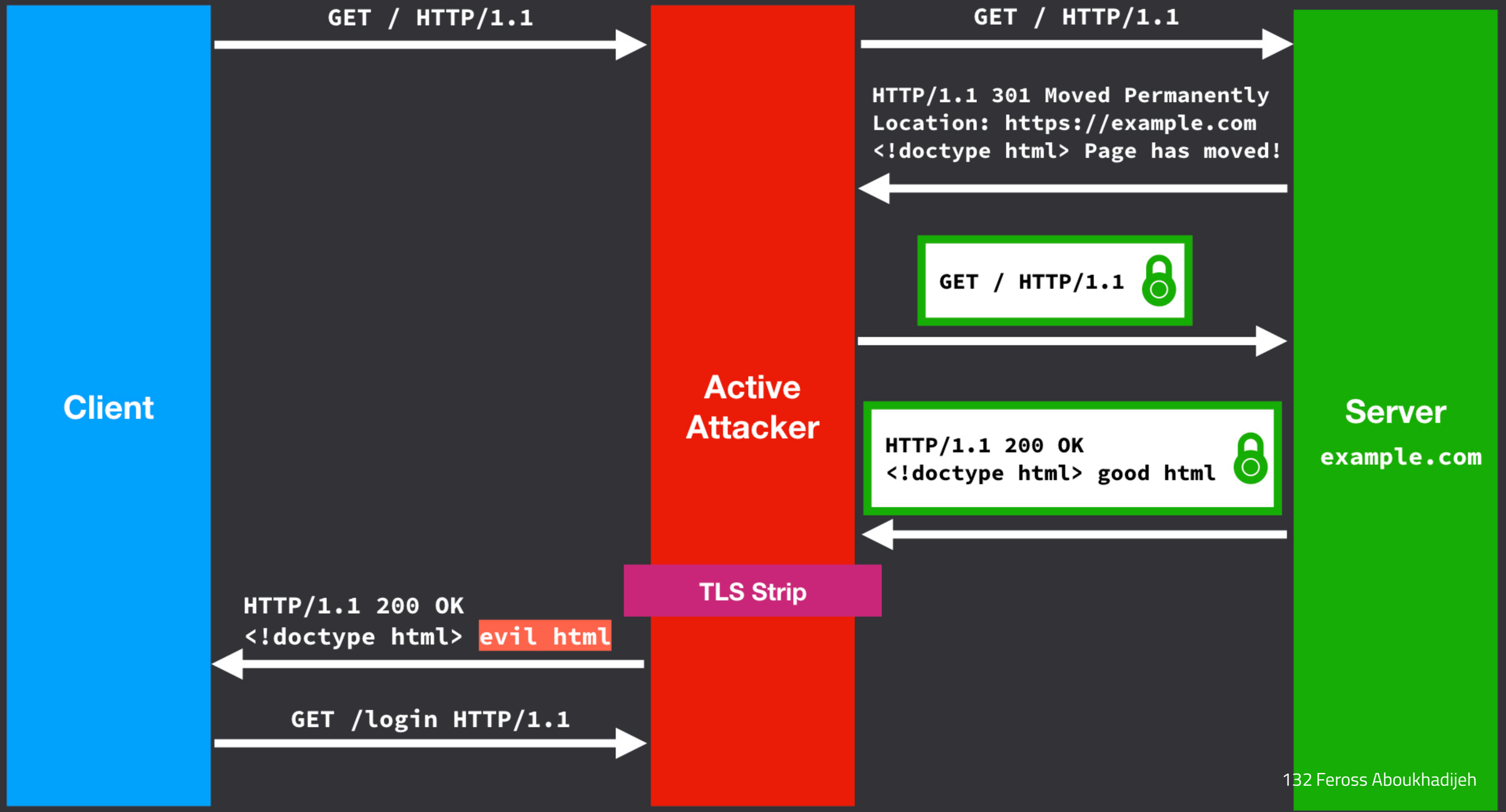

Client
GET / HTTP/1.1
Active Attacker
GET / HTTP/1.1
HTTP/1.1 301 Moved Permanently
Location: https://example.com
<!doctype html> Page has moved!
Server
example.com

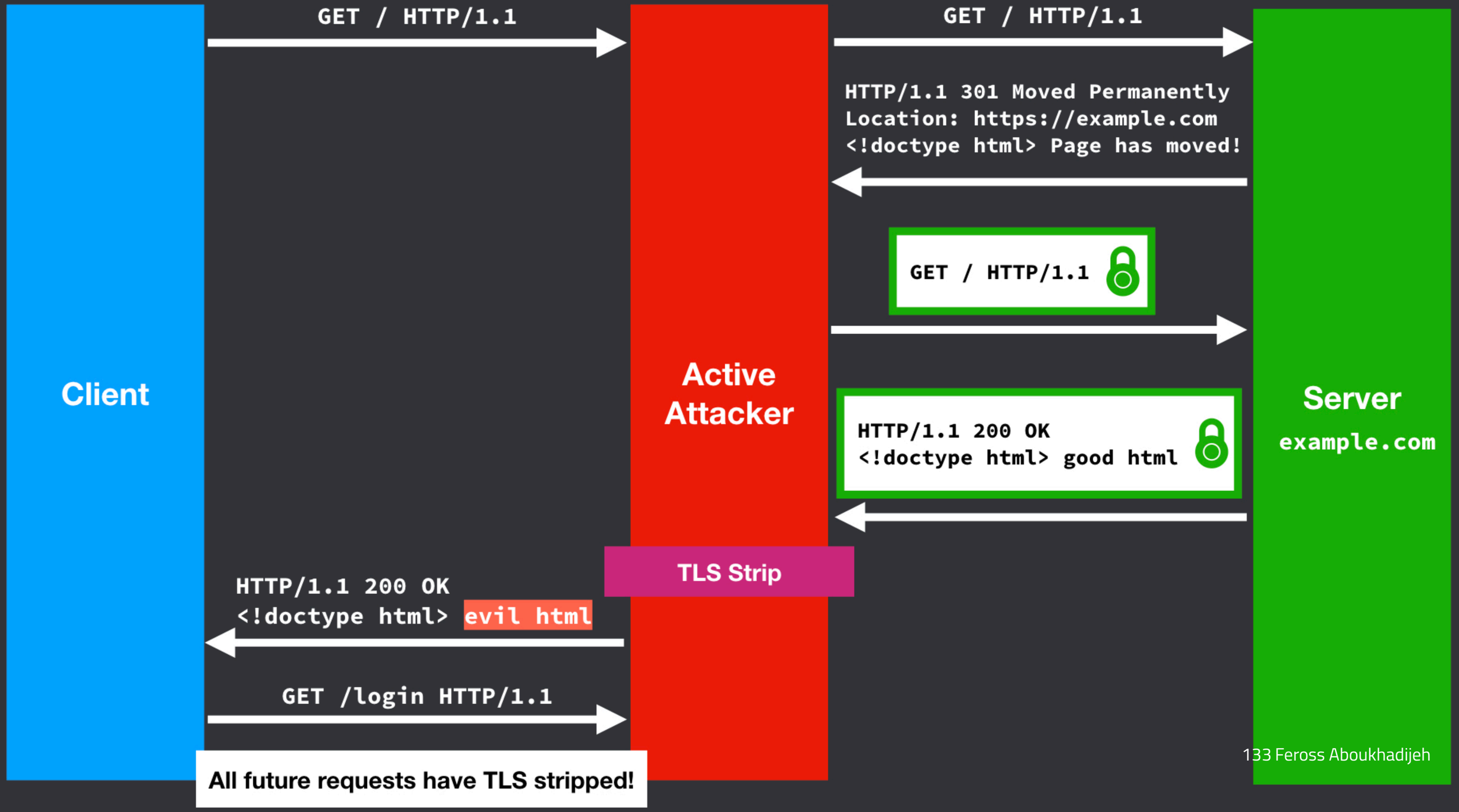

Client
GET / HTTP/1.1
Active Attacker
GET / HTTP/1.1
HTTP/1.1 301 Moved Permanently
Location: https://example.com
<!doctype html> Page has moved!
GET / HTTP/1.1
Server
example.com


Client
GET / HTTP/1.1
Active Attacker
GET / HTTP/1.1
HTTP/1.1 301 Moved Permanently
Location: https://example.com
<!doctype html> Page has moved!
GET / HTTP/1.1
HTTP/1.1 200 OK
<!doctype html> good html
Server
example.com


Client
GET / HTTP/1.1
Active Attacker
GET / HTTP/1.1
HTTP/1.1 301 Moved Permanently
Location: https://example.com
<!doctype html> Page has moved!
GET / HTTP/1.1
HTTP/1.1 200 OK
<!doctype html> good html
TLS Strip
Server
example.com


Client
GET / HTTP/1.1
Active Attacker
GET / HTTP/1.1
Server
example.com
HTTP/1.1 301 Moved Permanently
Location: https://example.com
<!doctype html> Page has moved!
GET / HTTP/1.1
HTTP/1.1 200 OK
<!doctype html> good html
TLS Strip
HTTP/1.1 200 OK
<!doctype html> evil html


Client
GET / HTTP/1.1
Active Attacker
GET / HTTP/1.1
Server
example.com
HTTP/1.1 301 Moved Permanently
Location: https://example.com
<!doctype html> Page has moved!
GET / HTTP/1.1
HTTP/1.1 200 OK
<!doctype html> good html
TLS Strip
HTTP/1.1 200 OK
<!doctype html> evil html
GET /login HTTP/1.1


Client
GET / HTTP/1.1
Active Attacker
GET / HTTP/1.1
Server
example.com
HTTP/1.1 301 Moved Permanently
Location: https://example.com
<!doctype html> Page has moved!
GET / HTTP/1.1
HTTP/1.1 200 OK
<!doctype html> good html
TLS Strip
HTTP/1.1 200 OK
<!doctype html> evil html
GET /login HTTP/1.1
All future requests have TLS stripped!

HTTP strict transport security (HSTS)

- To defend against the TLS Strip attack, the server tells the browser "no matter what protocol the user specifies, always use HTTPS"
- **`Strict-Transport-Security: max-age=31536000`**
  - Use HTTP header to force browser to use HTTPS for one year!
- **Downside:** "Trust on first use model" means that first visit to a site is still not secure against man-in-the-middle!
- Should clearing history also clear the HSTS list? Privacy vs. security

HSTS Preload list

- Browsers offer to hardcode sites which want to always be HTTPS only
- **`Strict-Transport-Security: max-age=63072000; includeSubDomains; preload`**
  - Must send **`includeSubDomains`** and **`preload`** options
- Difficult/impossible to remove a domain once hardocded into the browser itself
- Certain TLDs added the whole TLD to the preload list (e.g. **`.dev`**)

Lots more, but no time today!

- Public Key Pinning (HPKP)
- Certificate Transparency
- DNS Certification Authority Authorization (DNS CAA)

END

Credits:

Dan Boneh

https://transparencyreport.google.com/https/overview