

# DIFFIE-HELLMAN KEY EXCHANGE VIA REST

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ABSTRACT. Discussion on Diffie-Hellman Key Exchange and its implementation via REST.

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## 1. INTRODUCTION

Diffie-Hellman (DH) protocol is a method of asymmetric exchange of the cryptographic keys for a group of two or more participants, developed in 1976 by cryptographers Ralph Merkle, Whitfield Diffie and Martin Hellman. In contrast to symmetric key exchange, the Diffie-Hellman protocol eliminates the direct transfer of the shared secret between the participants, each participant computes a shared secret with his own private-public key pair. The Diffie-Hellman protocol is based on a one-way function of the form

$$A = G^a \bmod P \quad (1.1)$$

where  $A$  is the user's public key,  $a$  is the user's private key,  $P = 2Q + 1$  is modulus, such that 2048 bits safe-prime because  $Q$  is also prime,  $G$  is generator such that  $G$  is primitive root modulo  $P$ . We say that  $G$  is primitive root modulo  $P$  if for each  $1 \leq a \leq P - 1$  the  $A = G^a \bmod P$  is unique and belong to the set  $\{1, 2, \dots, P - 1\}$ . The period of such cyclic group  $\mathbb{Z}_P$  is  $P - 1$  then.

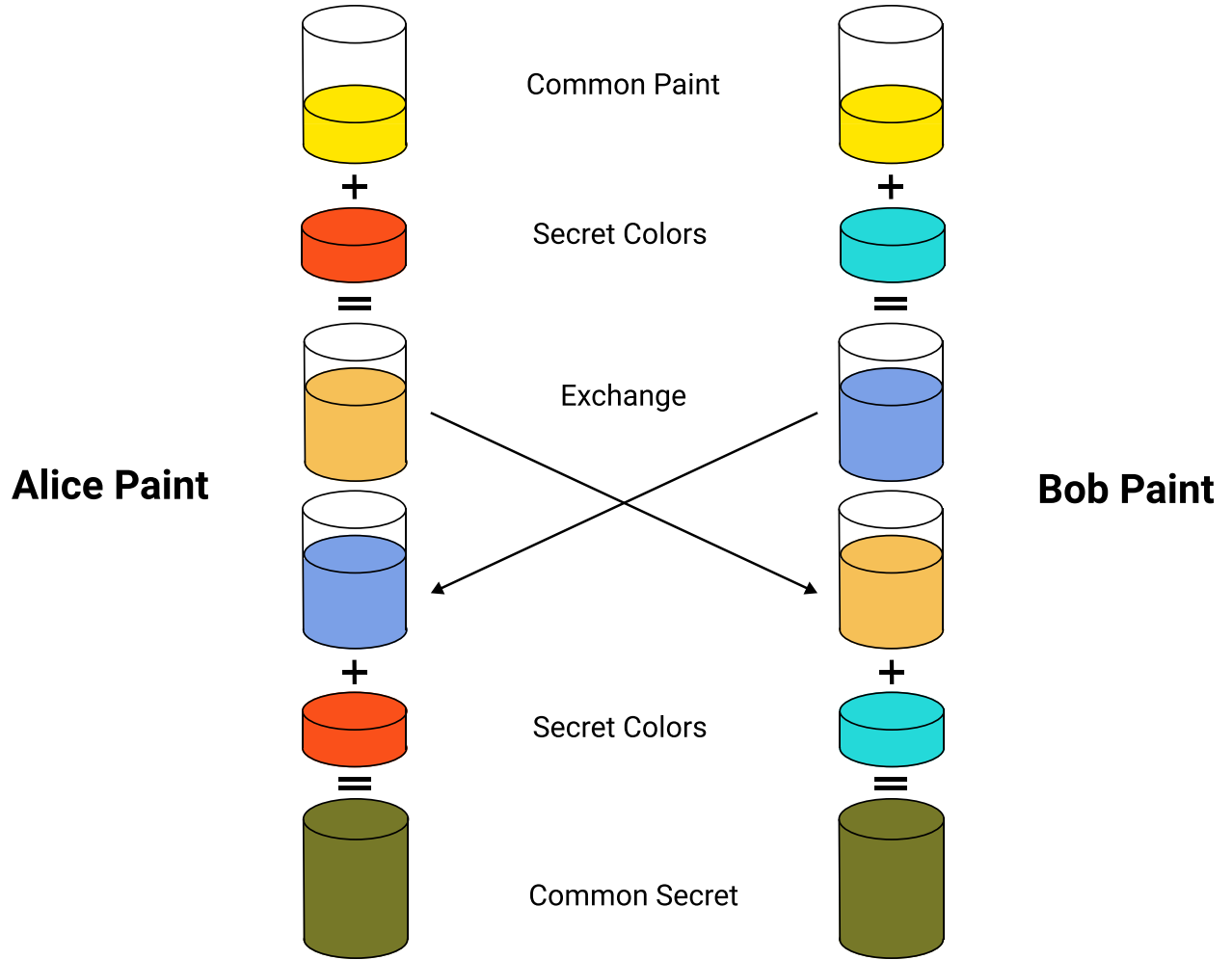
Thus, the safety of the Diffie-Hellman protocol is based on the discrete logarithm problem, which is unsolvable in polynomial time if the constants  $G$  and  $P$  are chosen correctly. Graphically, the flow of the Diffie-Hellman protocol can be expressed through the analogy with mixing paints, as below picture shows

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**Figure 1.** Diffie–Hellman key exchange concept diagram.

In contrast to the Diffie–Hellman based on discrete logarithm problem, there is an Elliptic Curve Diffie–Hellman key exchange, which based on the elliptic curve discrete logarithm problem. Although, the idea is quite same, the difference only in that Elliptic Curve Diffie–Hellman ensures the same safety as discrete logarithm Diffie–Hellman with lower value of the prime modulus  $P$ . For instance, 521 bit modulus used in Elliptic Curve Diffie–Hellman is equally safe as 2048 bit modulus in discrete logarithm Diffie–Hellman. To summarize, the flow of Diffie–Hellman key exchange is as follows. Given 2048 bits public prime modulus  $P$  and generator  $G$  such that  $G$  is primitive root modulo  $P$  then

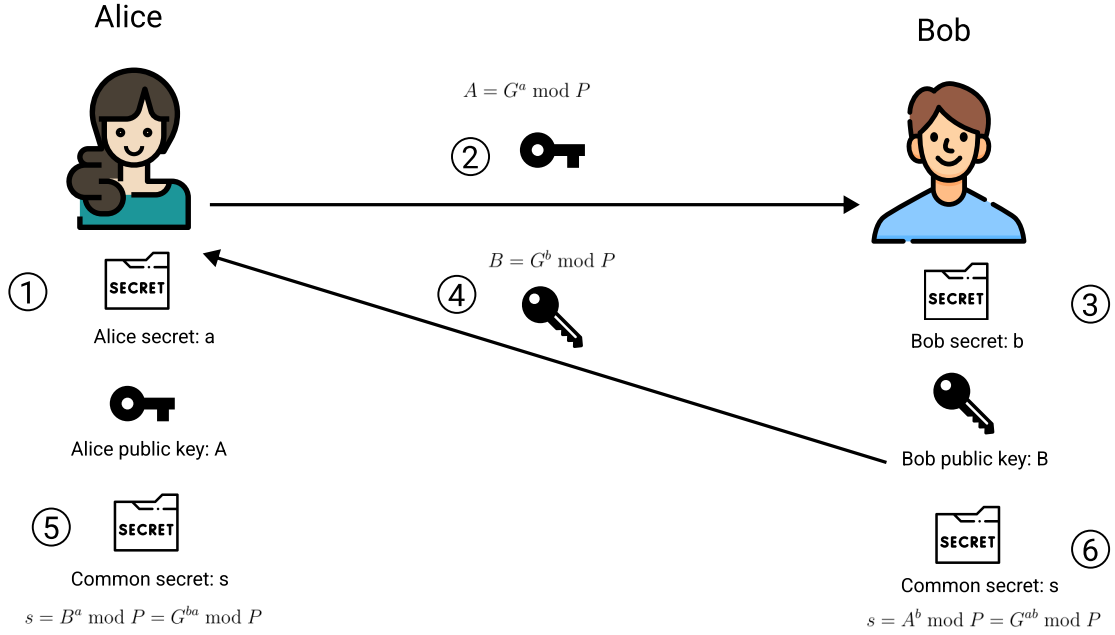
- (1) Alice chooses her secret  $a$ .
- (2) Alice sends to Bob her public key  $A = G^a \bmod P$ .
- (3) Bob chooses his secret  $b$ .
- (4) Bob sends to Alice his public key  $B = G^b \bmod P$ .
- (5) Alice computes common secret  $s = B^a \bmod P$ .

(6) Bob computes common secret  $s = A^b \bmod P$ .

(7) Alice and Bob have arrived to the same value

$$s = A^b \bmod P = G^{ab} \bmod P \quad (1.2)$$

$$s = B^a \bmod P = G^{ba} \bmod P \quad (1.3)$$



**Figure 2.** Diffie–Hellman key exchange concept diagram.

## 2. DIFFIE–HELLMAN KEY EXCHANGE IMPLEMENTATION VIA REST

Although, the idea of Diffie–Hellman key exchange looks quite simple, some remarks on the concrete implementation should be added. Firstly, it is necessary to implement the mechanism of key exchange request between two or more parties. As it discussed above, each user has his own private-public keys pair, so in order to perform request between parties, it should be implemented dedicate REST [OCJ<sup>+</sup>15] web-service endpoint, for instance the POST: `api/key-exchange-requests` which takes the request body of the form

```
{
  "requestedUserId": "3fa85f64-5717-4562-b3fc-2c963f66afa6",
  "publicKey": "RUNLMSAAAAC2lkqYcTGhutQPxcjvoqUELKoy0"
}
```

So, request sender generates on the client side a key pair, keeps private on in the file system and shares the public in request to receiver. Therefore, the second party has received the key exchange request. In order to display all the key exchange requests awaiting the

confirmation of decline decisions, it is worth to implement another REST endpoint such that GET: `api/key-exchange-requests`, so that requested party will have the list of requests to proceed. This endpoint may return the data structure like follows

```
{
  "keyExchangeRequests": [
    {
      "requestId": "81d314c1-913f-4686-827e-ef2a65ccc370",
      "senderId": "3fa85f64-5717-4562-b3fc-2c963f66afa6",
      "senderPublicKey": "RUNLMSAAAAC2lkqYcTGhutQPxcjvoqUELKoy0"
    }
  ],
  "message": "SUCCESS",
  "success": true
}
```

Finally, requested party should be able to confirm or decline the key exchange request, the DELETE: `api/key-exchange-requests` endpoint should be implemented then. The server is able to fetch the request thanks to the body endpoint takes

```
{
  "requestId": "3fa85f64-5717-4562-b3fc-2c963f66afa6",
  "confirmed": true,
  "publicKey": "string"
}
```

Therefore, an identifier of awaiting request is passed to the server among with boolean value indicating the confirmation. Under the roof of this operation are also generation of private-public keys pair for the requested party and generation of common secret stored in client's file system. As result, the initial request sender receives a public key as confirmation from requested party. Requested side may get all his public keys via the REST web-service using the resource GET: `api/public-keys`

```
{
  "publicKeys": [
    {
      "partnerId": "ae9e10a4-0c7e-4911-8450-4139d4a114a7",
      "partnerPublicKey": "RUNLMSAAAAAbc49wfaZ+QF9J2cu1S66bkp0"
    }
  ],
  "message": "SUCCESS",
  "success": true
}
```

```
}

```

Now requested participant is able to derive the common secret. In order to provide an example, a simple command line interface is implemented. We have used an Elliptic Curve Diffie—Hellman implementation `ECDiffieHellmanCng Class` from the namespace `System.Security.Cryptography` of the .NET base class library. The P-256 curve is used.

More precisely, the following CLI commands are implemented

- `MangoAPI.DiffieHellmanConsole login SENDER_EMAIL SENDER_PASSWORD`
- `MangoAPI.DiffieHellmanConsole key-exchange RECEIVER_ID`
- `MangoAPI.DiffieHellmanConsole key-exchange-requests`
- `MangoAPI.DiffieHellmanConsole confirm-key-exchange REQUEST_ID`
- `MangoAPI.DiffieHellmanConsole print-public-keys`
- `MangoAPI.DiffieHellmanConsole create-common-secret RECEIVER_ID`

Commands are self-explanatory, therefore we skip the detailed documentation on them. An example of console output straightforward

```
PS C:\Users\pkolosov> MangoAPI.DiffieHellmanConsole login $env:SENDER_EMAIL $env:SENDER_PASSWORD
Attempting to login ...
Writing tokens to file ...
Login operation success.

PS C:\Users\pkolosov> MangoAPI.DiffieHellmanConsole key-exchange $env:RECEIVER_ID
Key exchange request with an ID 5810fb94-e3ce-4d2a-a033-95366a7c2b30 created successfully.
Writing private key to file...
Writing public key to file ...
Key exchange request sent successfully.

PS C:\Users\pkolosov> MangoAPI.DiffieHellmanConsole login $env:RECEIVER_EMAIL $env:RECEIVER_PASSWORD
Attempting to login ...
Writing tokens to file ...
Login operation success.

PS C:\Users\pkolosov> MangoAPI.DiffieHellmanConsole key-exchange-requests
RequestId: 5810fb94-e3ce-4d2a-a033-95366a7c2b30
SenderId: fd3c67c5-c6ff-4a5d-a166-98ece1b7752b
Sender Public Key: RUNLMSAAADBFEUGJcwSeMlwDi4Jf4s6IAbCvP5w0TiYB/G/iKB3IhbSgSNeG0PUje2NBdjp534psQbKf6Gup7JfM5zwxivY

PS C:\Users\pkolosov> MangoAPI.DiffieHellmanConsole confirm-key-exchange 5810fb94-e3ce-4d2a-a033-95366a7c2b30
Writing private key to file...
Writing public key to file ...
Writing common secret to file...
Key exchange request confirmed successfully.

PS C:\Users\pkolosov> MangoAPI.DiffieHellmanConsole print-public-keys
PartnerId: fd3c67c5-c6ff-4a5d-a166-98ece1b7752b
Public Key: RUNLMSAAADBFEUGJcwSeMlwDi4Jf4s6IAbCvP5w0TiYB/G/iKB3IhbSgSNeG0PUje2NBdjp534psQbKf6Gup7JfM5zwxivY

PS C:\Users\pkolosov> MangoAPI.DiffieHellmanConsole login $env:SENDER_EMAIL $env:SENDER_PASSWORD
Attempting to login ...
Writing tokens to file ...
Login operation success.

PS C:\Users\pkolosov> MangoAPI.DiffieHellmanConsole create-common-secret $env:RECEIVER_ID
Writing common secret to file...
Common secret generated successfully.
```

**Figure 3.** Diffie—Hellman key exchange console output.

In order to repeat the outputs on the screenshot the user may reference to the resources

- API: <https://back.mangomessenger.com/swagger>
- Source: <https://github.com/MangoInstantMessenger/MangoMessengerAPI>

Finally, both test accounts reached the same base 64 common secret.



**Figure 4.** Common secrets.

## REFERENCES

- [OCJ<sup>+</sup>15] Shyue Ping Ong, Shreyas Cholia, Anubhav Jain, Miriam Brafman, Dan Gunter, Gerbrand Ceder, and Kristin A Persson. The materials application programming interface (api): A simple, flexible and efficient api for materials data based on representational state transfer (rest) principles. *Computational Materials Science*, 97:209–215, 2015.

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