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X.509 Authentication in Spring Security

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Spring Security (https://www.baeldung.com/category/spring/spring-security/)

Authentication (https://www.baeldung.com/tag/authentication/)

1. Overview

In this article, we'll focus on the main use cases for X.509 certificate authentication – verifying the identity of a communication peer when using the HTTPS (HTTP over SSL) protocol.

Simply put – while a secure connection is established, the client verifies the server according to its certificate (issued by a trusted certificate authority).

But beyond that, X.509 in Spring Security can be used to verify the identity of a client by the server while connecting. This is called *"mutual authentication"*, and we'll look at how that's done here as well.

Finally, we'll touch on when it makes sense to use this kind of authentication.

To demonstrate server verification, we'll create a simple web application and install a custom certificate authority in a browser.

Moreover, for *mutual authentication*, we'll create a client certificate and modify our server to allow only verified clients.

It's highly recommended to follow the tutorial step by step and create the certificates, as well as the keystore and the truststore, yourself, according to the instructions presented in the following sections. However, all the ready to use files can be found in our GitHub repository (https://github.com/eugenp/tutorials/tree/master/spring-security-modules/spring-security-x509/store).

2. Self Signed Root CA

To be able to sign our server-side and client-side certificates, we need to create our own self-signed root CA certificate first. This way we'll act as our own certificate authority.

For this purpose we'll use openssl (https://wiki.openssl.org/index.php/Binaries) library, so we need to have it installed prior to following the next step.

Let's now create the CA certificate:

```
openssl req -x509 -sha256 -days 3650 -newkey rsa:4096 -keyout
rootCA.key -out rootCA.crt
```

When we execute the above command, we need to provide the password for our private key. For the purpose of this tutorial, we use *changeit* as a passphrase.

Additionally, we need to enter information that forms a so-called distinguished name. Here, we only provide the CN (Common Name) – Baeldung.com – and leave other parts empty.

```
$ openssl req -x509 -sha256 -days 3650 -newkey rsa:4096 -keyout rootCA.key -out rootCA.crt
Generating a RSA private key
.....................................................................................
.....................................+++
.....................................................................................
++
writing new private key to 'rootCA.key'
Enter PEM pass phrase:
Verifying - Enter PEM pass phrase:
-----
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Country Name (2 letter code) [AU]:.
State or Province Name (full name) [Some-State]:.
Locality Name (eg, city) []:.
Organization Name (eg, company) [Internet Widgits Pty Ltd]:.
Organizational Unit Name (eg, section) []:.
Common Name (e.g. server FQDN or YOUR name) []:Baeldung.com
Email Address []:.
```

(/wp-content/uploads/2016/08/rootCA.jpg)

3. Keystore

> Optional Requirement: To use cryptographically strong keys together with encryption and decryption features we'll need the "*Java Cryptography Extension (JCE) Unlimited Strength Jurisdiction Policy Files*" installed in our JVM.
>
> These can be downloaded for example from Oracle (http://www.oracle.com/technetwork/java/javase/downloads/jce8-download-2133166.html) (follow the installation instructions included in the download). Some Linux distributions also provide an installable package through their package managers.

A keystore is a repository that our Spring Boot application will use to hold our server's private key and certificate. In other words, our application will use the keystore to serve the certificate to the clients during the SSL handshake.

In this tutorial, we use the Java Key-Store (JKS) format and a keytool (https://docs.oracle.com/javase/8/docs/technotes/tools/unix/keytool.html) command-line tool.

3.1. Server-side Certificate

To implement the server-side X.509 authentication in our Spring Boot application, we first need to create a server-side certificate.

Let's start with creating a so-called certificate signing request (CSR):

```
openssl req -new -newkey rsa:4096 -keyout localhost.key -out
localhost.csr
```

Similarly, as for the CA certificate, we have to provide the password for the private key. Additionally, let's use *localhost* as a common name (CN).

Before we proceed, we need to create a configuration file – *localhost.ext*. It'll store some additional parameters needed during signing the certificate.

```
authorityKeyIdentifier=keyid,issuer
basicConstraints=CA:FALSE
subjectAltName = @alt_names
[alt_names]
DNS.1 = localhost
```

A ready to use file is also available here (https://github.com/eugenp/tutorials/blob/master/spring-security-modules/spring-security-x509/store/localhost.ext).

Now, it's time to sign the request with our *rootCA.crt* certificate and its private key:

```
openssl x509 -req -CA rootCA.crt -CAkey rootCA.key -in localhost.csr
-out localhost.crt -days 365 -CAcreateserial -extfile localhost.ext
```

Note that we have to provide the same password we used when we created our CA certificate.

At this stage, we finally have a ready to use *localhost.crt* certificate signed by our own certificate authority.

To print our certificate's details in a human-readable form we can use the following command:

```
openssl x509 -in localhost.crt -text
```

3.2. Import to the Keystore

In this section, we'll see how to import the signed certificate and the corresponding private key to the *keystore.jks* file.

We'll use the PKCS 12 archive (https://en.wikipedia.org/wiki/PKCS_12), to package our server's private key together with the signed certificate. Then we'll import it to the newly created *keystore.jks*.

We can use the following command to create a *.p12* file:

```
openssl pkcs12 -export -out localhost.p12 -name "localhost" -inkey
localhost.key -in localhost.crt
```

So we now have the *localhost.key* and the *localhost.crt* bundled in the single *localhost.p12* file.

Let's now use keytool to create a *keystore.jks* repository and import the *localhost.p12* file with a single command:

```
keytool -importkeystore -srckeystore localhost.p12 -srcstoretype
PKCS12 -destkeystore keystore.jks -deststoretype JKS
```

At this stage, we have everything in place for the server authentication part. Let's proceed with our Spring Boot application configuration.

4. Example Application

Our SSL secured server project consists of a *@SpringBootApplication* (/spring-boot-application-configuration) annotated application class (which is a kind of *@Configuration (/bootstraping-a-web-application-with-spring-and-java-based-configuration)*), an *application.properties* configuration file and a very simple MVC-style front-end.

All, the application has to do, is to present an HTML page with a *"Hello [User]!"* message. This way we can inspect the server certificate in a browser to make sure, that the connection is verified and secured.

4.1. Maven Dependencies

First, we create a new Maven project with three Spring Boot Starter bundles included:

```
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-security</artifactId>
</dependency>
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-web</artifactId>
</dependency>
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-thymeleaf</artifactId>
</dependency>
```

For reference: we can find the bundles on Maven Central (security (https://search.maven.org/classic/#search%7Cgav%7C1%7Cg%3A%22org.springframework.boot%22%20AND%20a%3A%22spring-boot-starter-security%22), web (https://search.maven.org/classic/#search%7Cgav%7C1%7Cg%3A%22org.springframework.boot%22%20AND%20a%3A%22spring-boot-starter-web%22), thymeleaf (https://search.maven.org/classic/#search%7Cgav%7C1%7Cg%3A%22org.springframework.boot%22%20AND%20a%3A%22spring-boot-starter-thymeleaf%22)).

4.2. Spring Boot Application

As the next step, we create the main application class and the user-controller:

```
@SpringBootApplication
public class X509AuthenticationServer {
    public static void main(String[] args) {
        SpringApplication.run(X509AuthenticationServer.class, args);
    }
}

@Controller
public class UserController {
    @RequestMapping(value = "/user")
    public String user(Model model, Principal principal) {

        UserDetails currentUser
          = (UserDetails) ((Authentication)
principal).getPrincipal();
        model.addAttribute("username", currentUser.getUsername());
        return "user";
    }
}
```

Now, we tell the application where to find our *keystore.jks* and how to access it. We set SSL to an "enabled" status and change the standard listening port to indicate a secured connection.

Additionally, we configure some *user-details* for accessing our server via Basic Authentication:

```
server.ssl.key-store=../store/keystore.jks
server.ssl.key-store-password=${PASSWORD}
server.ssl.key-alias=localhost
server.ssl.key-password=${PASSWORD}
server.ssl.enabled=true
server.port=8443
spring.security.user.name=Admin
spring.security.user.password=admin
```

This will be the HTML template, located at the *resources/templates* folder:

```
<!DOCTYPE html>
<html xmlns:th="http://www.thymeleaf.org">
<head>
    <title>X.509 Authentication Demo</title>
</head>
<body>
    <h2>Hello <span th:text="${username}"/>!</h2>
</body>
</html>
```

4.3. Root CA Installation

Before we finish this section and look at the site, we need to install our generated root certificate authority as a trusted certificate in a browser.

An exemplary installation of our certificate authority for *Mozilla Firefox* would look like follows:

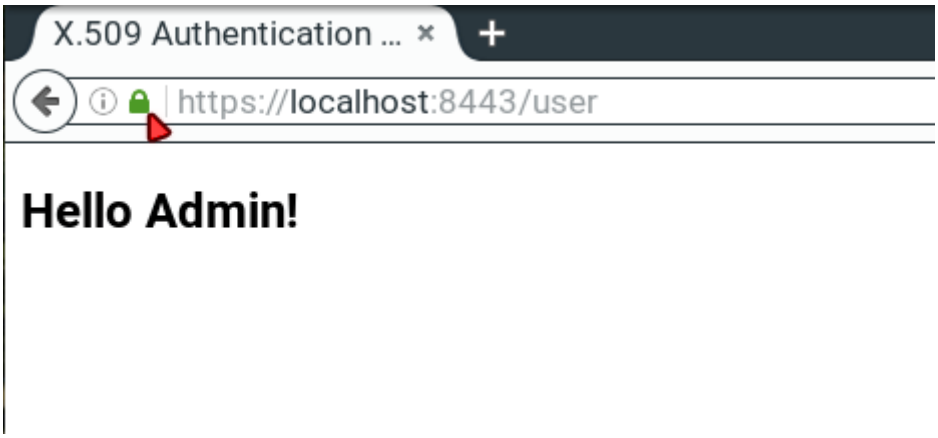
1. Type *about:preferences* in the address bar
2. Open *Advanced -> Certificates -> View Certificates -> Authorities*
3. Click on *Import*
4. Locate the *Baeldung tutorials* folder and its subfolder *spring-security-x509/keystore*
5. Select the *rootCA.crt* file and click *OK*
6. Choose "*Trust this CA to identify websites*" and click *OK*

Note: If you don't want to add our *certificate authority* to the list of *trusted authorities*, you'll later have the option to make an *exception* and show the website tough, even when it is mentioned as insecure. But then you'll see a 'yellow exclamation mark' symbol in the address bar, indicating the insecure connection!

Afterward, we will navigate to the *spring-security-x509-basic-auth* module and run:

```
mvn spring-boot:run
```

Finally, we hit *https://localhost:8443/user (https://localhost:8443/user)*, enter our user credentials from the *application.properties* and should see a *"Hello Admin!"* message. Now we're able to inspect the connection status by clicking the "green lock" symbol in the address bar, and it should be a secured connection.



(/wp-content/uploads/2016/08/Screenshot_20160822_205015.png)

5. Mutual Authentication

In the previous section, we presented how to implement the most common SSL authentication schema – server-side authentication. This means, only a server authenticated itself to clients.

In this section, we'll describe how to add the other part of the authentication – client-side authentication. This way, only clients with valid certificates signed by the authority that our server trusts, can access our secured website.

But before we continue, let's see what are the pros and cons of using the mutual SSL authentication.

Pros:

- The private key of an X.509 client certificate is stronger than any user-defined password. But it has to be kept secret!
- With a certificate, the identity of a client is well-known and easy to verify.
- No more forgotten passwords!

Cons:

- We need to create a certificate for each new client.

- The client's certificate has to be installed in a client application. In fact: X.509 client authentication is device-dependent, which makes it impossible to use this kind of authentication in public areas, for example in an internet-café.
- There must be a mechanism to revoke compromised client certificates.
- We must maintain the clients' certificates. This can easily become costly.

5.1. Truststore

A trustsore in some way is the opposite of a keystore. It holds the certificates of the external entities that we trust.

In our case, it's enough to keep the root CA certificate in the truststore.

Let's see how to create a *truststore.jks* file and import the *rootCA.crt* using keytool:

```
keytool -import -trustcacerts -noprompt -alias ca -ext
san=dns:localhost,ip:127.0.0.1 -file rootCA.crt -keystore
truststore.jks
```

Note, we need to provide the password for the newly created *trusstore.jks*. Here, we again used the *changeit* passphrase.

That's it, we've imported our own CA certificate, and the truststore is ready to be used.

5.2. Spring Security Configuration

To continue, we are modifying our *X509AuthenticationServer* to extend from *WebSecurityConfigurerAdapter* (/spring-security-authentication-provider) and override one of the provided configure methods. Here we configure the x.509 mechanism to parse the *Common Name (CN)* field of a certificate for extracting usernames.

With this extracted usernames, Spring Security is looking up in a provided *UserDetailsService* for matching users. So we also implement this service interface containing one demo user.

> Tip: In production environments, this *UserDetailsService* can load its users for example from a JDBC Datasource (/spring-jdbc-jdbctemplate).

You have to notice that we annotate our class with *@EnableWebSecurity* and *@EnableGlobalMethodSecurity* with enabled pre-/post-authorization.

With the latter we can annotate our resources with *@PreAuthorize* and *@PostAuthorize* for fine-grained access control:

```
@SpringBootApplication
@EnableWebSecurity
@EnableGlobalMethodSecurity(prePostEnabled = true)
public class X509AuthenticationServer extends
WebSecurityConfigurerAdapter {
    ...

    @Override
    protected void configure(HttpSecurity http) throws Exception {
        http.authorizeRequests().anyRequest().authenticated()
          .and()
          .x509()
            .subjectPrincipalRegex("CN=(.*?)(?:,|$)")
            .userDetailsService(userDetailsService());
    }

    @Bean
    public UserDetailsService userDetailsService() {
        return new UserDetailsService() {
            @Override
            public UserDetails loadUserByUsername(String username) {
                if (username.equals("Bob")) {
                    return new User(username, "",
                      AuthorityUtils

.commaSeparatedStringToAuthorityList("ROLE_USER"));
                }
                throw new UsernameNotFoundException("User not
found!");
            }
        };
    }
}
```

As said previously, we are now able to use *Expression-Based Access Control* in our controller. More specifically, our authorization annotations are respected because of the *@EnableGlobalMethodSecurity* annotation in our *@Configuration*:

```
@Controller
public class UserController {
    @PreAuthorize("hasAuthority('ROLE_USER')")
    @RequestMapping(value = "/user")
    public String user(Model model, Principal principal) {
        ...
    }
}
```

An overview of all possible authorization options can be found in the *official documentation (https://docs.spring.io/spring-security/site/docs/current/reference/html/authorization.html#method-security-expressions)*.

As a final modification step, we have to tell the application where our *truststore* is located and that *SSL client authentication* is necessary (*server.ssl.client-auth=need*).

So we put the following into our *application.properties*:

```
server.ssl.trust-store=store/truststore.jks
server.ssl.trust-store-password=${PASSWORD}
server.ssl.client-auth=need
```

Now, if we run the application and point our browser to *https://localhost:8443/user (https://localhost:8443/user)*, we become informed that the peer cannot be verified and it denies to open our website.

5.3. Client-side Certificate

Now it's time to create the client-side certificate. The steps we need to take, are pretty much the same as for the server-side certificate we already created.

First, we have to create a certificate signing request:

```
openssl req -new -newkey rsa:4096 -nodes -keyout clientBob.key -out
clientBob.csr
```

We'll have to provide information that will be incorporated into the certificate. For this exercise, let's only enter the common name (CN) – Bob. It's important as we use this entry during the authorization and only Bob is recognized by our sample application.

Next, we need to sign the request with our CA:

```
openssl x509 -req -CA rootCA.crt -CAkey rootCA.key -in clientBob.csr
-out clientBob.crt -days 365 -CAcreateserial
```

The last step we need to take is to package the signed certificate and the private key into the PKCS file:

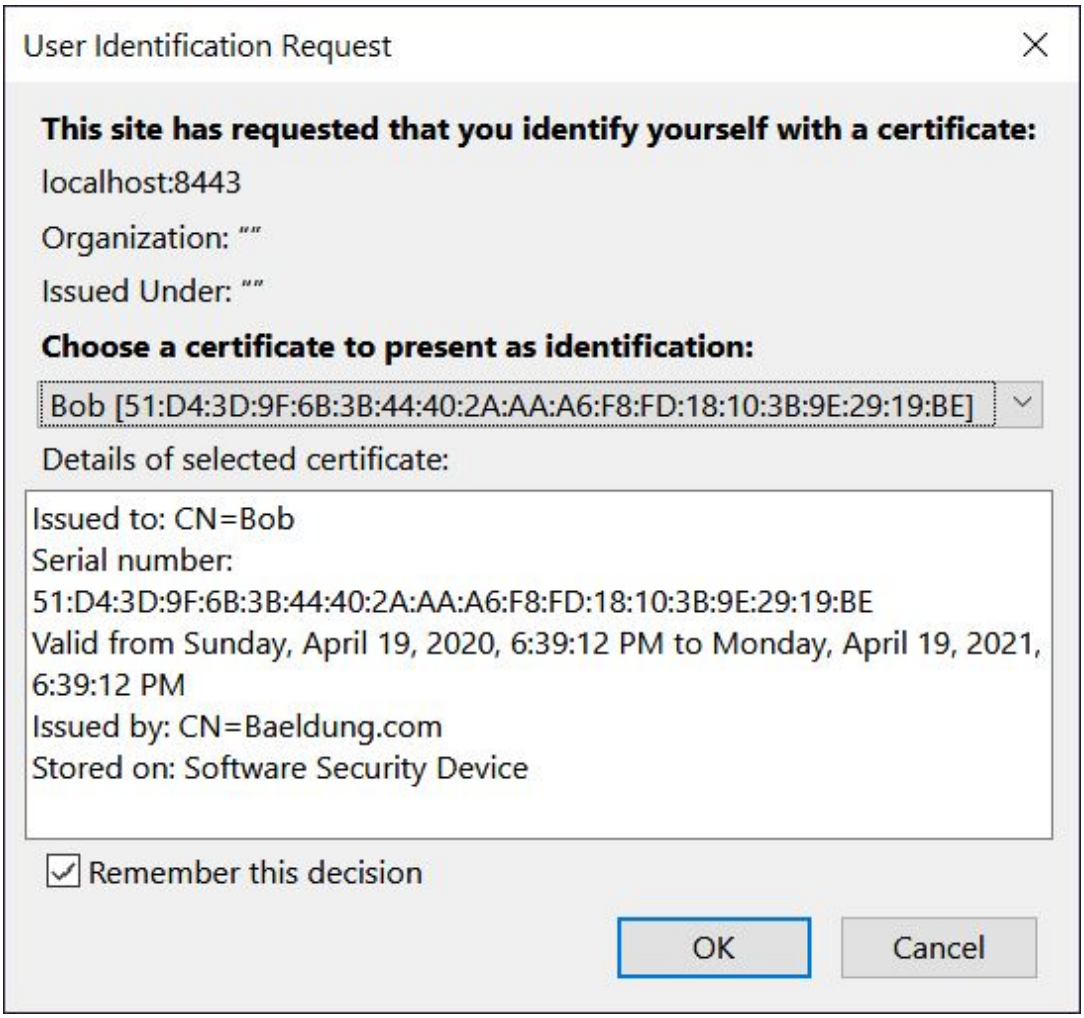
```
openssl pkcs12 -export -out clientBob.p12 -name "clientBob" -inkey
clientBob.key -in clientBob.crt
```

Finally, we're ready to install the client certificate in the browser.

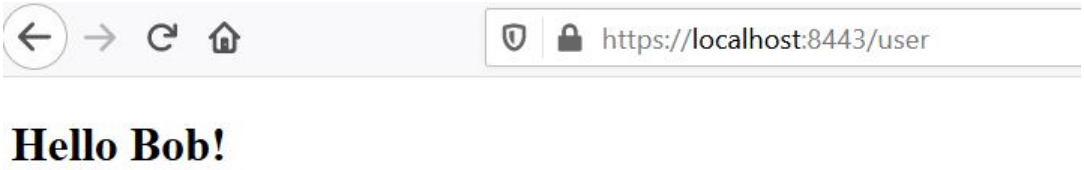
Again, we'll use Firefox:

1. Type *about:preferences* in the address bar
2. Open *Advanced -> View Certificates -> Your Certificates*
3. Click on *Import*
4. Locate the *Baeldung tutorials* folder and its subfolder *spring-security-x509/store*
5. Select the *clientBob.p12* file and click *OK*
6. Input the password for your certificate and click *OK*

Now, when we refresh our website, we'll be prompted to select the client certificate we'd like to use:



(/wp-content/uploads/2016/08/clientCert.jpg)
If we see a welcome message like *"Hello Bob!"*, that means everything works as expected!



(/wp-content/uploads/2016/08/bob.jpg)

6. Mutual Authentication With XML

Adding X.509 client authentication to an *http* security configuration in *XML* (/spring-security-digest-authentication) is also possible:

```
<http>
    ...
    <x509 subject-principal-regex="CN=(.*?)(?:,|$)"
      user-service-ref="userService"/>

    <authentication-manager>
        <authentication-provider>
            <user-service id="userService">
                <user name="Bob" password=""
authorities="ROLE_USER"/>
            </user-service>
        </authentication-provider>
    </authentication-manager>
    ...
</http>
```

To configure an underlying Tomcat, we have to put our *keystore* and our *truststore* into its *conf* folder and edit the *server.xml*:

```
<Connector port="8443" protocol="HTTP/1.1" SSLEnabled="true"
scheme="https" secure="true"
    clientAuth="true" sslProtocol="TLS"
    keystoreFile="${catalina.home}/conf/keystore.jks"
    keystoreType="JKS" keystorePass="changeit"
    truststoreFile="${catalina.home}/conf/truststore.jks"
    truststoreType="JKS" truststorePass="changeit"
/>
```

> Tip: With *clientAuth* set to *"want"*, *SSL* is still enabled, even if the client doesn't provide a valid certificate. But in this case, we have to use a second authentication mechanism, for example, a login-form, to access the secured resources.

7. Conclusion

In summary, we've learned how to create a self-signed CA certificate and how to use it to sign other certificates.

Additionally, we've created both, server-side and client-side certificates. Then we've presented how to import them into a keystore and a truststore accordingly.

Furthermore, you now should be able to package a certificate together with its private key into the PKCS12 format.

We've also discussed when it makes sense to use Spring Security X.509 client authentication, so it is up to you, to decide, whether to implement it into your web application, or not.

And to wrap up, find the source code to this article on Github (https://github.com/eugenp/tutorials/tree/master/spring-security-modules/spring-security-x509).

0

Eugen Paraschiv (https://www.baeldung.com/) 3 years ago

Reply to Rudy Bonefas

Hey Rudy – I haven't ever looked into that aspect of Zuul – so I'm not sure – you'll have to have a look at their docs.

Cheers,

Eugen.

0

daniel pr 3 years ago

hi, how can i authenticate with smarth card certificate?

0

Eugen Paraschiv (https://www.baeldung.com/) 3 years ago

Reply to daniel pr

I've never done that myself, so I'm not sure if it's something that the framework supports.

Cheers,

Eugen.

0

Karol 3 years ago

Hi, I want to implement security with matching CN from cert, but only for specific url (let say /security/*) and other request should be accessible with non certyficate checking over http. Is it possible?

Regards

0

Eugen Paraschiv (https://www.baeldung.com/) 3 years ago

Reply to Karol

Sure Karol – you can define multiple HTTP elements in your security configuration and set these up separately.

0

Logan 3 years ago

Hi, I have a question about Mutual Authentication. Is it secure enough? Let's suppose, that someone will get user cert (which is signed by CA) and generate his own cert. Will server accept that certyficate? Would be more secure to authorize user using their cert serial or fingerptint?

0

Eugen Paraschiv (https://www.baeldung.com/) 3 years ago

Reply to Logan

Hey Logan,
"Secure enough" is entirely dependent on what you're trying to do, but X.509 is certainly secure.
Now, let's clear up a couple of terms. Keep in mind that the public key is – well – public. It's the private key that the client uses that shouldn't be compromised. And that re-positions your questions about the server accepting the certificate – so it's worth exploring that mechanism a bit first.
And finally, I'm not sure what you mean by "fingerprint" (there are several ways to read that).
Hope that points you in the right direction. Cheers,
Eugen.

+ 1 −

Charrad Nabil 3 years ago

Hi, Do you know how I can recover CN, DN, expiration date, CA … of certificate?

+ 0 −

Eugen Paraschiv (https://www.baeldung.com/) 3 years ago

Reply to Charrad Nabil

I haven't ever tried to do that programmatically. I imagine, once you have the actual certificate, you can inspect it and retrieve from it wherever you need. But again, I haven't tried it.
Cheers,
Eugen.

+ 0 −

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