实验一：私有 CA 证书签发的简单实现

专业：密码科学与技术　姓名：柳致远　　学号：2113683

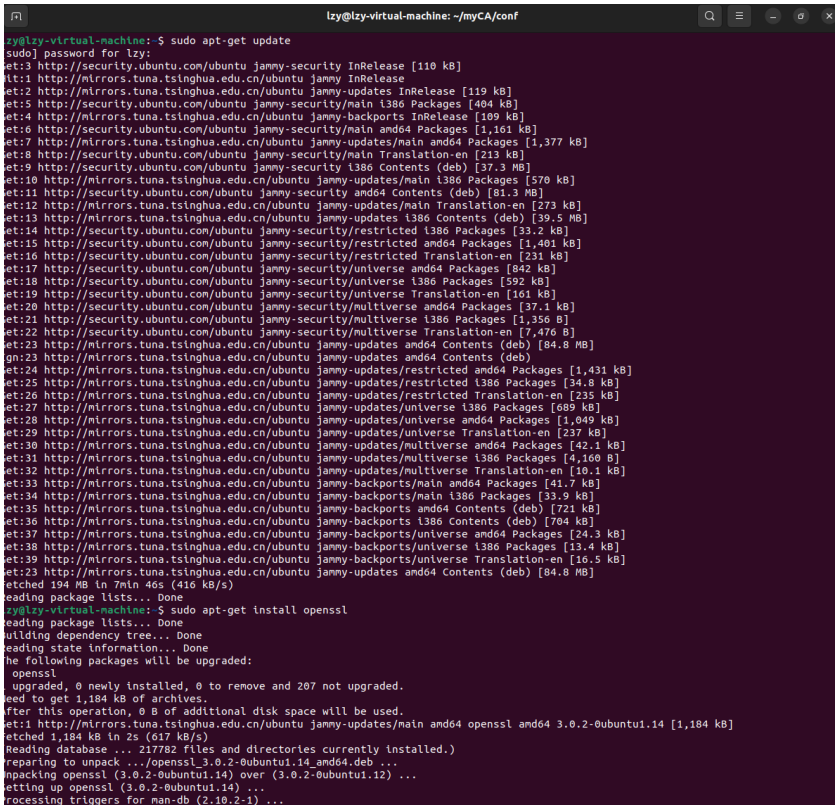
实验过程：

一、 搭建私有 CA

1、 安装 OpenSSL：

sudo apt-get update

sudo apt-get install openssl



2、 创建私有 CA 所需要的文件目录，保存 CA 的相关信息

相关指令如下：

mkdir myCA　　//创建 CA 根文件夹

cd myCA　　//进入 CA 根文件夹

mkdir newcerts private conf　　//创建三个文件夹，用来存放新发放证书、私钥和配置文件

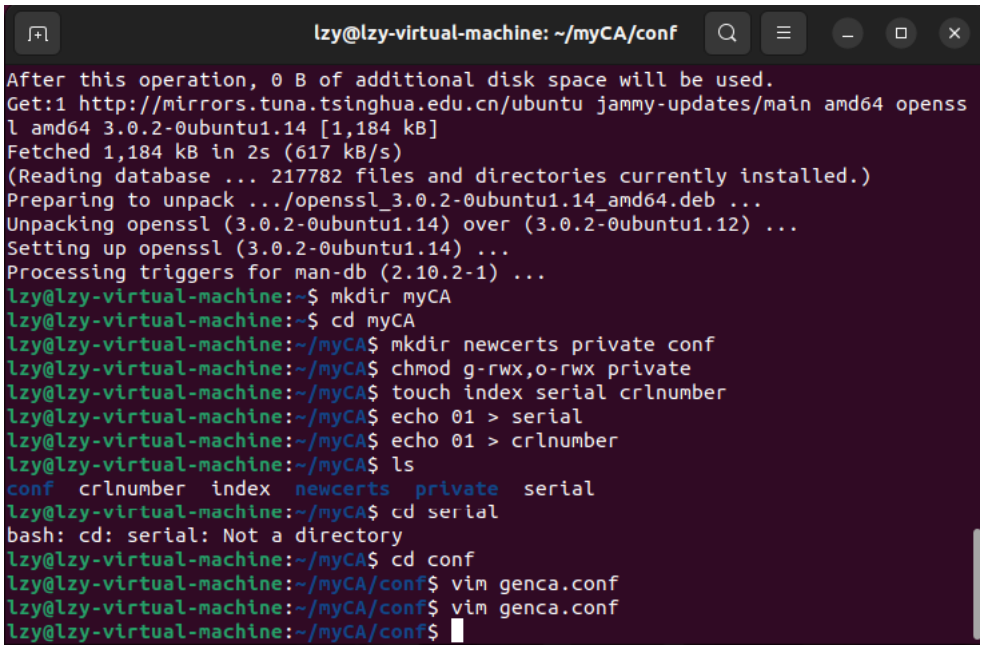
chmod g-rwx,o-rwx private　　//设置 private 文件夹的操作权限

touch index serial crlnumber　　//创建证书信息数据库、证书序号文件、crl 序号文件

echo 01 > serial　　//初始化证书的序号

echo 01 > crlnumber　　//初始化吊销证书序号

实验过程截图：



3、　创建生成 CA 自签名证书的配置文件

相关指令如下：

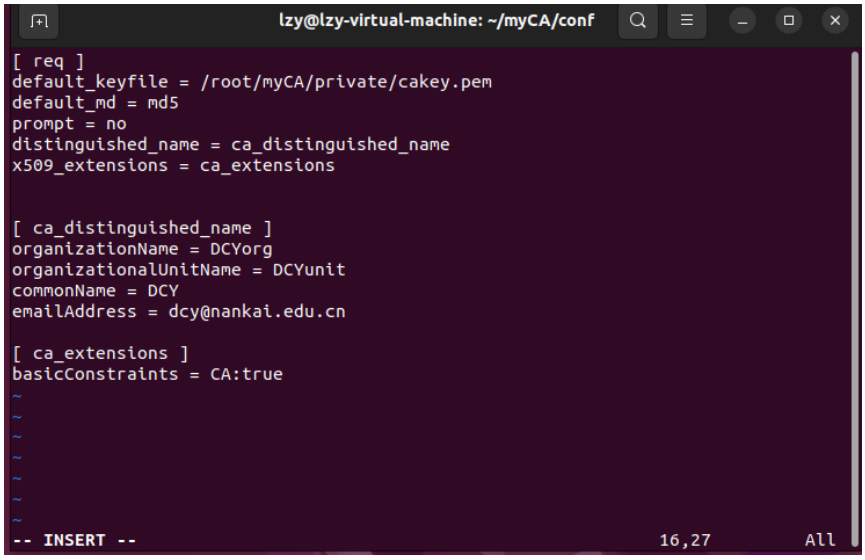
cd conf

//进入配置文件夹

vim genca.conf

//创建用来生成自签名证书的配置文件

配置文件配置如下：



4、 生成私有 CA 的私钥和自签名证书（根证书）

指令如下：

openssl req -x509 -newkey rsa:2048 -out cacert.pem -outform PEM -days 2190 -config /root/myCA/conf/genca.conf
//回到 myCA 根目录下，生成 x509 自签名证书，过程中需要输入 CA 私钥的保护密码，请牢记。
//CA 会按照 gentestca.conf 文件中配置的规则自签名生成证书

CA 自签名证书截图如下：

```
root@lzy-virtual-machine: /home/lzy/myCA
++++++++++++++++++++++++++++++++++++++++++++++++++++++
Enter PEM pass phrase:
Verifying - Enter PEM pass phrase:
-----
root@lzy-virtual-machine:/home/lzy/myCA# openssl x509 -in cacert.pem -text -noout
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            28:6a:bf:d4:0e:87:9f:0e:45:f3:3e:d5:1e:bc:61:86:59:41:fe:5f
        Signature Algorithm: md5WithRSAEncryption
        Issuer: O = DCYorg, OU = DCYunit, CN = DCY, emailAddress = dcy@nankai.edu.cn
        Validity
            Not Before: Feb 20 07:39:01 2024 GMT
            Not After : Feb 18 07:39:01 2030 GMT
        Subject: O = DCYorg, OU = DCYunit, CN = DCY, emailAddress = dcy@nankai.edu.cn
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:e8:2c:49:c0:30:3f:9c:9f:28:0b:e4:7e:69:bd:
                    8c:c2:06:dd:57:73:95:f7:4f:c9:2f:e8:61:60:d9:
                    d8:10:61:ca:1b:ad:36:e2:60:02:5f:e0:2e:0e:3c:
                    21:c2:88:99:a1:f4:1c:5d:0a:5d:9d:02:36:e4:02:
                    1f:80:bd:23:ce:d2:07:3f:7b:96:a2:7d:ef:48:2d:
                    d5:85:93:15:30:1c:ef:77:b9:2f:08:71:09:ee:f8:
                    a5:9e:ba:c5:e9:3a:40:1f:7a:c0:b9:2d:67:d4:c3:
                    92:ab:6d:ae:8a:e8:be:9d:ce:1a:e9:fe:5d:d7:e2:
                    ee:f5:3a:52:2e:a5:18:71:65:96:78:eb:e1:93:a7:
                    32:90:80:c0:a7:4d:5b:2c:b2:3d:b7:c9:99:30:53:
                    36:7f:6c:04:8f:42:b0:83:f7:52:82:b9:0c:7d:7c:
                    5e:66:45:62:92:c6:ed:4d:6f:13:5a:ed:dd:5f:d2:
                    1a:28:95:90:9b:21:ab:89:7c:ca:3c:f0:01:33:ce:
                    00:5f:23:b4:47:c5:71:57:55:3d:9b:de:c5:80:03:
                    d1:0b:0d:80:01:0a:4b:0c:57:73:15:3e:ec:31:99:
                    f4:0e:51:3f:c5:09:f3:8a:42:21:97:d9:a5:15:78:
                    09:6d:34:5d:71:d6:fd:97:e1:b3:fb:d6:cd:d8:3e:
                    4e:2d
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Basic Constraints:
                CA:TRUE
            X509v3 Subject Key Identifier:
                B6:3E:3E:76:AB:D9:17:87:BB:4E:CE:09:78:2B:90:FC:31:B1:92:9E
    Signature Algorithm: md5WithRSAEncryption
    Signature Value:
        a0:05:e3:e6:cf:e7:a6:ab:70:fe:e2:4c:14:b6:e6:eb:c6:bd:
        c8:6d:e2:db:10:a1:39:66:3d:b3:ea:41:d8:e6:c7:6b:ba:70:
        5e:60:39:9c:b9:50:f4:24:0b:e7:40:8b:6d:d7:c9:17:e5:70:
        0a:ef:b2:77:d2:36:59:05:13:11:ea:d4:31:24:d6:9d:47:4f:
        e2:63:a0:59:07:d9:c3:5c:76:4a:a2:99:52:eb:c9:6b:79:ba:
        4b:21:cf:51:6f:6d:be:91:bc:ba:4d:e5:09:57:ce:6f:fb:90:
        be:81:2e:24:55:61:3e:47:16:4b:39:48:a4:78:9e:06:09:34:
        45:48:46:67:c7:f6:3d:aa:e2:ff:6b:91:aa:0c:55:45:6a:b0:
        28:b4:a3:c3:92:28:fc:85:5c:0c:ce:44:07:22:77:e5:aa:4a:
        cb:e0:5e:98:44:30:dd:29:65:c1:0c:81:49:c8:1a:05:2a:bd:
        d1:98:03:5c:7d:30:f9:a4:d6:02:82:4b:27:1f:ea:62:ff:68:
        52:9f:6d:bd:7f:44:e7:13:77:30:46:01:db:7f:57:95:1f:2b:
        e3:9a:2a:2d:d7:01:9f:ae:09:3b:29:44:cc:4f:06:f9:34:74:
        b7:20:4c:db:8b:18:91:b3:70:91:76:1a:88:74:b7:08:30:68:
        2a:50:49:02
root@lzy-virtual-machine:/home/lzy/myCA#
```

二、 私有 CA 为服务器签发证书

1、 创建用来为其他请求签发证书的配置文件

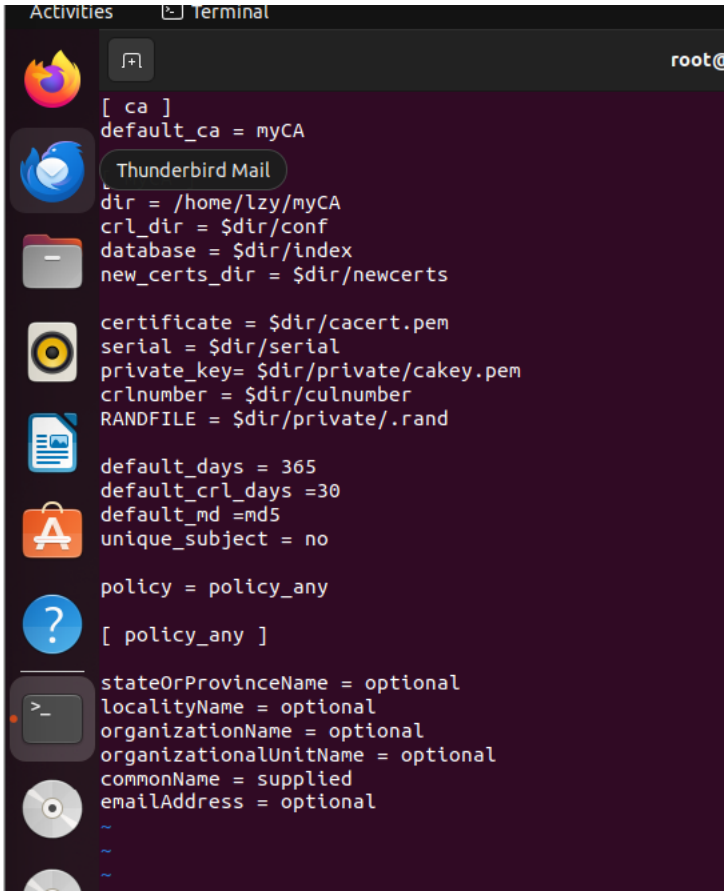
cd conf

//再次进入配置文件夹

vim ca.conf

//创建用来为其他请求签发证书的配置文件

配置文件配置如下：



2、 模拟服务器，生成私钥与证书申请的请求文件

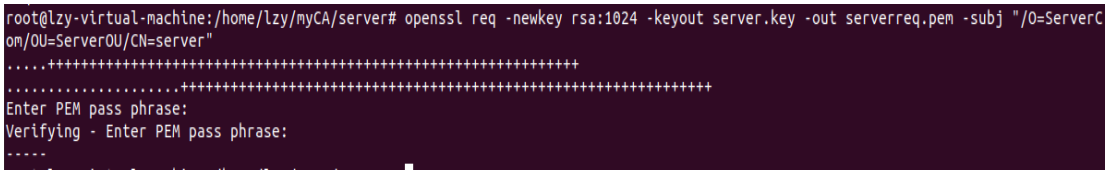
mudar server

//在任意路径下创建服务器文件夹 server

openssl req -newkey rsa:1024 -keyout server.key -out serverreq.pem -subj "/O=ServerCom/OU=ServerOU/CN=server"

//生成 server 的 1024 位私钥 server.key 和证书申请的请求文件 serverre.pem，此时需要设置服务器的私钥保护密码，请牢记

结果截图如下：



3、 CA 根据服务器的证书请求文件生成证书并将其返回给服务器

openssl ca -in serverreq.pem -out server.crt -config /root/myCA/conf/ca.conf

//向私有 CA 提交证书请求文件 serverreq.pem，CA 生成并返回证书 server.crt

//生成证书的规则是参照之前为 CA 定义的 ca.conf 配置文件执行的

实验过程截图如下：

```
root@lzy-virtual-machine:/home/lzy/myCA/server# openssl ca -in serverreq.pem -out server.crt -confi
g /home/lzy/myCA/conf/ca.conf
Using configuration from /home/lzy/myCA/conf/ca.conf
Enter pass phrase for /home/lzy/myCA/private/cakey.pem:
Check that the request matches the signature
Signature ok
The Subject's Distinguished Name is as follows
organizationName      :ASN.1 12:'ServerCom'
organizationalUnitName:ASN.1 12:'ServerOU'
commonName            :ASN.1 12:'server'
Certificate is to be certified until Feb 19 11:20:31 2025 GMT (365 days)
Sign the certificate? [y/n]:y


1 out of 1 certificate requests certified, commit? [y/n]y
Write out database with 1 new entries
Data Base Updated
```

4、 在 myCA 下的 index（证书信息数据库）中可以看到证书信息数据库的更新数据

```
V       250219112031Z           01      unknown /O=ServerCom/OU=ServerOU/CN=server
~
```

以及，在 newcerts 目录下可以看到 CA 发放给服务器的证书文件备份。

```
root@lzy-virtual-machine:/home/lzy/myCA/newcerts# ls
01.pem
```

三、 私有 CA 为客户端签发证书

1、即仿照为服务端签发证书的过程为客户端签发证书即可

首先在 myCA 目录下创建文件夹 client：

mkdir client

接着生成 client 的 1024 位私钥 client.key 和证书申请的请求文件 client.pem，此时需要设置服务器的私钥保护密码，代码修改如下：

openssl req -newkey rsa:1024 -keyout client.key -out clientreq.pem -subj "/O=ClientCom/OU=ClientOU/CN=client"

实验过程截图如下：

```
root@lzy-virtual-machine:/home/lzy/myCA/client# ls
root@lzy-virtual-machine:/home/lzy/myCA/client# openssl req -newkey rsa:1024    -keyout client.key
-out clientreq.pem -subj "/O=ClientCom/OU=ClientOU/CN=client"
.......................+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
.........................................+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++
Enter PEM pass phrase:
Verifying - Enter PEM pass phrase:
-----
```

2、同样使用之前的配置文件 ca.conf 为客户端生成并返回证书 client.crt

```
root@lzy-virtual-machine:/home/lzy/myCA/client# openssl ca -in clientreq.pem -out client.crt
-config /home/lzy/myCA/conf/ca.conf
Using configuration from /home/lzy/myCA/conf/ca.conf
Enter pass phrase for /home/lzy/myCA/private/cakey.pem:
Check that the request matches the signature
Signature ok
The Subject's Distinguished Name is as follows
organizationName      :ASN.1 12:'ClientCom'
organizationalUnitName:ASN.1 12:'ClientOU'
commonName            :ASN.1 12:'client'
Certificate is to be certified until Feb 20 12:42:49 2025 GMT (365 days)
Sign the certificate? [y/n]:y


1 out of 1 certificate requests certified, commit? [y/n]y
Write out database with 1 new entries
Data Base Updated
```

查看证书 client.crt

```
Certificate:
    Data:
        Version: 1 (0x0)
        Serial Number: 2 (0x2)
        Signature Algorithm: md5WithRSAEncryption
        Issuer: O=DCYorg, OU=DCYunit, CN=DCY/emailAddress=dcy@nankai.edu.cn
        Validity
            Not Before: Feb 21 12:42:49 2024 GMT
            Not After : Feb 20 12:42:49 2025 GMT
        Subject: O=ClientCom, OU=ClientOU, CN=client
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (1024 bit)
                Modulus:
                    00:c3:a8:76:15:93:4d:92:c9:3c:b6:13:42:b2:04:
                    e9:ae:5c:83:68:a8:ea:06:3b:6a:4d:0c:82:df:4e:
                    48:2f:76:5a:07:bd:39:a6:a9:c2:2e:80:c4:3a:4d:
                    57:aa:41:24:8f:b5:cf:80:9c:63:48:dd:69:20:63:
                    57:1b:81:0f:c9:27:8c:55:c7:c2:e0:68:ad:66:cc:
                    2f:2d:28:1a:db:09:bc:4b:20:d8:56:c5:81:86:aa:
                    c4:52:6a:f2:ce:69:fd:f0:c6:37:11:94:08:7b:d0:
                    21:d7:12:a6:88:0e:82:73:d7:18:55:1a:71:aa:08:
                    5d:75:1d:a8:31:68:cf:28:59
                Exponent: 65537 (0x10001)
    Signature Algorithm: md5WithRSAEncryption
    Signature Value:
        14:33:4a:f3:4f:77:bb:c4:bc:ab:48:6a:bf:f8:d4:9c:ba:9f:
        de:eb:b6:fc:74:92:4e:5e:ff:6c:19:20:ae:5d:c9:d7:f9:cd:
        ff:08:57:40:4b:72:ec:25:1d:5a:b4:d5:20:a1:5f:86:2e:48:
        f8:55:ca:40:f3:2b:f9:08:80:fc:c3:c0:1d:3e:35:6c:2f:5b:
        42:f6:26:56:aa:6f:d2:6a:f3:64:ba:7f:64:d5:e7:27:fc:da:
        94:13:ec:cd:c4:b0:30:c8:3a:e0:67:21:95:3f:a5:01:8e:02:
        2c:49:9d:5c:12:22:fc:40:95:23:87:c6:ea:39:5e:18:58:25:
        dc:c4:99:b3:12:70:7a:58:17:c3:6b:c3:47:c3:f9:b6:ce:9d:
        5b:cc:64:ff:4e:bb:ad:99:86:ae:72:1d:9b:de:36:bd:d3:b1:
        74:cb:de:da:3d:dd:e0:c5:70:79:eb:fb:15:2e:ea:7a:d4:b2:
        2f:c9:4e:97:8a:59:d0:7f:61:d6:a8:b0:a4:7c:71:93:5f:c6:
                                                          5,1           Top
```

在 newcerts 文件夹内保存了该证书的备份

```
root@lzy-virtual-machine:/home/lzy/myCA/newcerts# ls
01.pem  02.pem
```

并在 myCA 下的 index（证书信息数据库）中可以看到证书信息数据库的更新数据

```
V       250219112031Z           01      unknown /O=ServerCom/OU=ServerOU/CN=server
V       250220124249Z           02      unknown /O=ClientCom/OU=ClientOU/CN=client
```

四、 CA 吊销用户证书

1、 在之前的配置文件 ca.conf 的基础上生成证书吊销列表 ca.crl：

openssl ca -config /home/lzy/myCA/conf/ca.conf -gencrl -out ca.crl -crldays 30

实验结果截图如下：

```
root@lzy-virtual-machine:/home/lzy/myCA# openssl ca -config /home
/lzy/myCA/conf/ca.conf -gencrl -out ca.crl -crldays 30
Using configuration from /home/lzy/myCA/conf/ca.conf
Enter pass phrase for /home/lzy/myCA/private/cakey.pem:
root@lzy-virtual-machine:/home/lzy/myCA#
```

2、 吊销 01 证书，使用命令

openssl ca -revoke /home/lzy/myCA/newcerts/01.pem -config "/home/lzy/myCA/conf/ca.conf" 进行吊销

实验结果截图如下：

```
root@lzy-virtual-machine:/home/lzy/myCA# openssl ca -revoke /home
/lzy/myCA/newcerts/01.pem -config "/home/lzy/myCA/conf/ca.conf"
Using configuration from /home/lzy/myCA/conf/ca.conf
Enter pass phrase for /home/lzy/myCA/private/cakey.pem:
Revoking Certificate 01.
Data Base Updated
root@lzy-virtual-machine:/home/lzy/myCA#
```

3 、使用命令 openssl ca -gencrl -out /home/lzy/myCA/ca.crl -config

/home/lzy/myCA/conf/ca.conf -crldays 30 更新证书吊销列表

实验过程截图如下

```
root@lzy-virtual-machine:/home/lzy/myCA# openssl ca -gencrl -out
/home/lzy/myCA/ca.crl -config /home/lzy/myCA/conf/ca.conf -crlday
s 30
Using configuration from /home/lzy/myCA/conf/ca.conf
Enter pass phrase for /home/lzy/myCA/private/cakey.pem:
root@lzy-virtual-machine:/home/lzy/myCA#
```

使用命令 openssl crl -in ca.crl -noout -text 可以查看 crl 文件

```
root@lzy-virtual-machine:/home/lzy/myCA#  openssl crl -in ca.crl -noout -text
Certificate Revocation List (CRL):
        Version 2 (0x1)
        Signature Algorithm: md5WithRSAEncryption
        Issuer: O = DCYorg, OU = DCYunit, CN = DCY, emailAddress = dcy@nankai.edu.cn
        Last Update: Mar  3 20:01:01 2024 GMT
        Next Update: Apr  2 20:01:01 2024 GMT
        CRL extensions:
            X509v3 CRL Number:
                4
Revoked Certificates:
    Serial Number: 01
        Revocation Date: Mar  3 19:58:18 2024 GMT
    Signature Algorithm: md5WithRSAEncryption
    Signature Value:
        14:41:67:13:09:15:47:b8:f8:53:3c:9d:a3:fc:b7:67:62:8b:
        b0:0c:d5:6d:e5:24:0a:21:2a:e9:ea:b7:9e:66:b2:9e:42:3b:
        7e:d6:7c:4c:af:6c:fd:1c:9d:49:0f:15:60:52:d8:b5:d1:de:
        2b:0d:02:cb:18:ab:09:75:c9:de:9d:bc:9f:3e:d7:c4:53:df:
        c1:09:fe:fc:3c:02:83:bd:fd:94:12:8b:6e:7c:b5:4e:d7:02:
        b1:ef:84:aa:f4:61:21:c9:9d:23:be:f8:e8:73:90:56:9c:f2:
        fa:f4:79:3b:7e:1d:04:fe:61:41:1d:44:f8:4a:1c:15:a1:6a:
        1d:66:64:b0:c0:2e:81:72:3d:e8:22:a8:8b:00:6f:2f:47:f0:
        47:67:61:a6:ac:14:9c:b8:4e:0c:c9:00:6f:0c:22:5e:e3:4b:
        d8:0d:2d:90:1d:e0:98:aa:a5:15:8d:75:79:e5:56:7e:3a:30:
        6d:5c:40:e0:77:2a:c0:90:62:e9:49:03:f1:46:b6:28:68:0b:
        50:42:c6:01:cd:ca:a7:f3:5f:61:98:d4:05:39:a5:d6:1f:48:
        b9:ea:3d:72:a8:83:36:5e:9a:b9:73:51:5a:bd:a9:3b:cd:35:
        db:38:2c:be:88:31:6c:e3:f2:20:69:d7:5d:ba:9f:55:90:e7:
        7c:37:d0:dd
root@lzy-virtual-machine:/home/lzy/myCA#
```