hyperledger-fabric-ca Documentation

Release master

hyperledger

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This build of the docs is from the “master” branch

CHAPTER 1

Fabric CA User's Guide

The Hyperledger Fabric CA is a Certificate Authority (CA) for Hyperledger Fabric.

It provides features such as:

- registration of identities, or connects to LDAP as the user registry
- issuance of Enrollment Certificates (ECerts)
- certificate renewal and revocation

Hyperledger Fabric CA consists of both a server and a client component as described later in this document.

For developers interested in contributing to Hyperledger Fabric CA, see the Fabric CA repository for more information.

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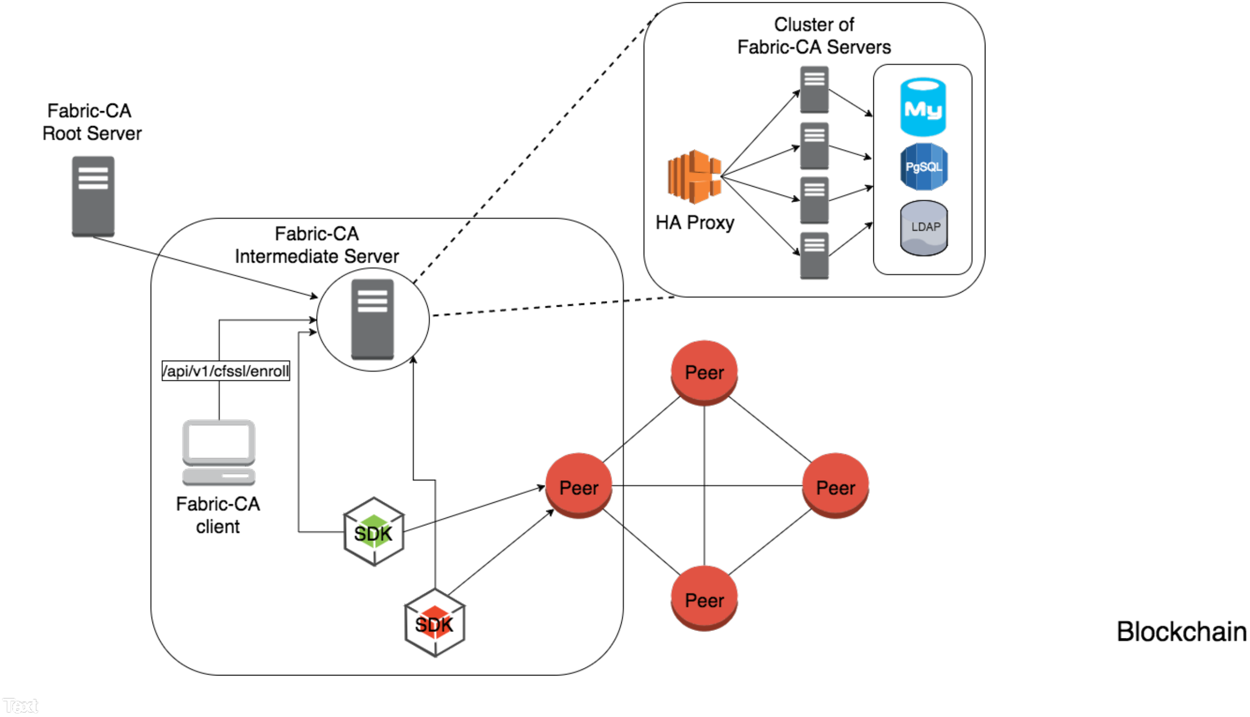
Overview

The diagram below illustrates how the Hyperledger Fabric CA server fits into the overall Hyperledger Fabric architecture.



There are two ways of interacting with a Hyperledger Fabric CA server: via the Hyperledger Fabric CA client or through one of the Fabric SDKs. All communication to the Hyperledger Fabric CA server is via REST APIs. See *fabric-ca/swagger/swagger-fabric-ca.json* for the swagger documentation for these REST APIs. You may view this documentation via the http://editor2.swagger.io online editor.

The Hyperledger Fabric CA client or SDK may connect to a server in a cluster of Hyperledger Fabric CA servers. This is illustrated in the top right section of the diagram. The client routes to an HA Proxy endpoint which load balances traffic to one of the fabric-ca-server cluster members.

All Hyperledger Fabric CA servers in a cluster share the same database for keeping track of identities and certificates. If LDAP is configured, the identity information is kept in LDAP rather than the database.

A server may contain multiple CAs. Each CA is either a root CA or an intermediate CA. Each intermediate CA has a parent CA which is either a root CA or another intermediate CA.

Getting Started

Prerequisites

- Go 1.9+ installation
- `GOPATH` environment variable is set correctly
- libtool and libtdhl-dev packages are installed

The following installs the libtool dependencies on Ubuntu:

```
sudo apt install libtool libltdl-dev
```

The following installs the libtool dependencies on MacOSX:

```
brew install libtool
```

Note: libtldl-dev is not necessary on MacOSX if you instal libtool via Homebrew

For more information on libtool, see https://www.gnu.org/software/libtool.

For more information on libltdl-dev, see https://www.gnu.org/software/libtool/manual/html_node/Using-libltdl.html.

Install

The following installs both the *fabric-ca-server* and *fabric-ca-client* binaries in $GOPATH/bin.

```
go get -u github.com/hyperledger/fabric-ca/cmd/...
```

Note: If you have already cloned the fabric-ca repository, make sure you are on the master branch before running the 'go get' command above. Otherwise, you might see the following error:

```
<gopath>/src/github.com/hyperledger/fabric-ca; git pull --ff-only
There is no tracking information for the current branch.
Please specify which branch you want to merge with.
See git-pull(1) for details.

    git pull <remote> <branch>

If you wish to set tracking information for this branch you can do so with:
    git branch --set-upstream-to=<remote>/<branch> tlsdoc

package github.com/hyperledger/fabric-ca/cmd/fabric-ca-client: exit status 1
```

Start Server Natively

The following starts the *fabric-ca-server* with default settings.

```
fabric-ca-server start -b admin:adminpw
```

The *-b* option provides the enrollment ID and secret for a bootstrap administrator; this is required if LDAP is not enabled with the "ldap.enabled" setting.

A default configuration file named *fabric-ca-server-config.yaml* is created in the local directory which can be customized.

Start Server via Docker

Docker Hub

Go to: https://hub.docker.com/r/hyperledger/fabric-ca/tags/

Find the tag that matches the architecture and version of fabric-ca that you want to pull.

Navigate to *$GOPATH/src/github.com/hyperledger/fabric-ca/docker/server* and open up docker-compose.yml in an editor.

Change the *image* line to reflect the tag you found previously. The file may look like this for an x86 architecture for version beta.

```
fabric-ca-server:
  image: hyperledger/fabric-ca:x86_64-1.0.0-beta
  container_name: fabric-ca-server
  ports:
    - "7054:7054"
  environment:
    - FABRIC_CA_HOME=/etc/hyperledger/fabric-ca-server
  volumes:
    - "./fabric-ca-server:/etc/hyperledger/fabric-ca-server"
  command: sh -c 'fabric-ca-server start -b admin:adminpw'
```

Open up a terminal in the same directory as the docker-compose.yml file and execute the following:

```
# docker-compose up -d
```

This will pull down the specified fabric-ca image in the compose file if it does not already exist, and start an instance of the fabric-ca server.

Building Your Own Docker image

You can build and start the server via docker-compose as shown below.

```
cd $GOPATH/src/github.com/hyperledger/fabric-ca
make docker
cd docker/server
docker-compose up -d
```

The hyperledger/fabric-ca docker image contains both the fabric-ca-server and the fabric-ca-client.

```
# cd $GOPATH/src/github.com/hyperledger/fabric-ca
# FABRIC_CA_DYNAMIC_LINK=true make docker
# cd docker/server
# docker-compose up -d
```

Explore the Fabric CA CLI

This section simply provides the usage messages for the Fabric CA server and client for convenience. Additional usage information is provided in following sections.

The following links shows the Server Command Line and Client Command Line.

Note: Note that command line options that are string slices (lists) can be specified either by specifying the option with comma-separated list elements or by specifying the option multiple times, each with a string value that make up the list. For example, to specify `host1` and `host2` for the `csr.hosts` option, you can either pass `--csr.hosts 'host1,host2'` or `--csr.hosts host1 --csr.hosts host2`. When using the former format, please make sure there are no space before or after any commas.

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Configuration Settings

The Fabric CA provides 3 ways to configure settings on the Fabric CA server and client. The precedence order is:

1. CLI flags
2. Environment variables
3. Configuration file

In the remainder of this document, we refer to making changes to configuration files. However, configuration file changes can be overridden through environment variables or CLI flags.

For example, if we have the following in the client configuration file:

```
tls:
  # Enable TLS (default: false)
  enabled: false

  # TLS for the client's listenting port (default: false)
  certfiles:
  client:
    certfile: cert.pem
    keyfile:
```

The following environment variable may be used to override the `cert.pem` setting in the configuration file:

```
export FABRIC_CA_CLIENT_TLS_CLIENT_CERTFILE=cert2.pem
```

If we wanted to override both the environment variable and configuration file, we can use a command line flag.

```
fabric-ca-client enroll --tls.client.certfile cert3.pem
```

The same approach applies to fabric-ca-server, except instead of using `FABIRC_CA_CLIENT` as the prefix to environment variables, `FABRIC_CA_SERVER` is used.

A word on file paths

All the properties in the Fabric CA server and client configuration file that specify file names support both relative and absolute paths. Relative paths are relative to the config directory, where the configuration file is located. For example, if the config directory is `~/config` and the tls section is as shown below, the Fabric CA server or client will look for the `root.pem` file in the `~/config` directory, `cert.pem` file in the `~/config/certs` directory and the `key.pem` file in the `/abs/path` directory

```
tls:
  enabled: true
  certfiles:
    - root.pem
  client:
    certfile: certs/cert.pem
    keyfile: /abs/path/key.pem
```

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Fabric CA Server

This section describes the Fabric CA server.

You may initialize the Fabric CA server before starting it. This provides an opportunity for you to generate a default configuration file that can be reviewed and customized before starting the server.

The Fabric CA server's home directory is determined as follows:

- if the –home command line option is set, use its value
- otherwise, if the `FABRIC_CA_SERVER_HOME` environment variable is set, use its value
- otherwise, if `FABRIC_CA_HOME` environment variable is set, use its value
- otherwise, if the `CA_CFG_PATH` environment variable is set, use its value
- otherwise, use current working directory

For the remainder of this server section, we assume that you have set the `FABRIC_CA_HOME` environment variable to `$HOME/fabric-ca/server`.

The instructions below assume that the server configuration file exists in the server's home directory.

Initializing the server

Initialize the Fabric CA server as follows:

```
fabric-ca-server init -b admin:adminpw
```

The `-b` (bootstrap identity) option is required for initialization when LDAP is disabled. At least one bootstrap identity is required to start the Fabric CA server; this identity is the server administrator.

The server configuration file contains a Certificate Signing Request (CSR) section that can be configured. The following is a sample CSR.

```
cn: fabric-ca-server
names:
   - C: US
     ST: "North Carolina"
     L:
     O: Hyperledger
     OU: Fabric
hosts:
  - host1.example.com
  - localhost
ca:
   expiry: 131400h
   pathlength: 1
```

All of the fields above pertain to the X.509 signing key and certificate which is generated by the `fabric-ca-server init`. This corresponds to the `ca.certfile` and `ca.keyfile` files in the server's configuration file. The fields are as follows:

- **cn** is the Common Name
- **O** is the organization name
- **OU** is the organizational unit
- **L** is the location or city
- **ST** is the state
- **C** is the country

If custom values for the CSR are required, you may customize the configuration file, delete the files specified by the `ca.certfile` and `ca.keyfile` configuration items, and then run the `fabric-ca-server init -b admin:adminpw` command again.

The `fabric-ca-server init` command generates a self-signed CA certificate unless the `-u <parent-fabric-ca-server-URL>` option is specified. If the `-u` is specified, the server's CA certificate is signed by the parent Fabric CA server. In order to authenticate to the parent Fabric CA server, the URL must be of the form `<scheme>://<enrollmentID>:<secret>@<host>:<port>`, where <enrollmentID> and <secret> correspond to an identity with an 'hf.IntermediateCA' attribute whose value equals 'true'. The `fabric-ca-server init` command also generates a default configuration file named **fabric-ca-server-config.yaml** in the server's home directory.

If you want the Fabric CA server to use a CA signing certificate and key file which you provide, you must place your files in the location referenced by `ca.certfile` and `ca.keyfile` respectively. Both files must be PEM-encoded and must not be encrypted. More specifically, the contents of the CA certificate file must begin with `-----BEGIN CERTIFICATE-----` and the contents of the key file must begin with `-----BEGIN PRIVATE KEY-----` and not `-----BEGIN ENCRYPTED PRIVATE KEY-----`.

Algorithms and key sizes

The CSR can be customized to generate X.509 certificates and keys that support Elliptic Curve (ECDSA). The following setting is an example of the implementation of Elliptic Curve Digital Signature Algorithm (ECDSA) with curve `prime256v1` and signature algorithm `ecdsa-with-SHA256`:

```
key:
   algo: ecdsa
   size: 256
```

The choice of algorithm and key size are based on security needs.

Elliptic Curve (ECDSA) offers the following key size options:

size	ASN1 OID	Signature Algorithm
256	prime256v1	ecdsa-with-SHA256
384	secp384r1	ecdsa-with-SHA384
521	secp521r1	ecdsa-with-SHA512

Starting the server

Start the Fabric CA server as follows:

```
fabric-ca-server start -b <admin>:<adminpw>
```

If the server has not been previously initialized, it will initialize itself as it starts for the first time. During this initialization, the server will generate the ca-cert.pem and ca-key.pem files if they don't yet exist and will also create a default configuration file if it does not exist. See the *Initialize the Fabric CA server* section.

Unless the Fabric CA server is configured to use LDAP, it must be configured with at least one pre-registered bootstrap identity to enable you to register and enroll other identities. The `-b` option specifies the name and password for a bootstrap identity.

To cause the Fabric CA server to listen on `https` rather than `http`, set `tls.enabled` to `true`.

To limit the number of times that the same secret (or password) can be used for enrollment, set the `registry.maxenrollments` in the configuration file to the appropriate value. If you set the value to 1, the Fabric CA server allows passwords to only be used once for a particular enrollment ID. If you set the value to -1, the Fabric CA server places no limit on the number of times that a secret can be reused for enrollment. The default value is -1. Setting the value to 0, the Fabric CA server will disable enrollment for all identitiies and registeration of identities will not be allowed.

The Fabric CA server should now be listening on port 7054.

You may skip to the *Fabric CA Client* section if you do not want to configure the Fabric CA server to run in a cluster or to use LDAP.

Configuring the database

This section describes how to configure the Fabric CA server to connect to PostgreSQL or MySQL databases. The default database is SQLite and the default database file is `fabric-ca-server.db` in the Fabric CA server's home directory.

If you don't care about running the Fabric CA server in a cluster, you may skip this section; otherwise, you must configure either PostgreSQL or MySQL as described below. Fabric CA supports the following database versions in a cluster setup:

- PostgreSQL: 9.5.5 or later
- MySQL: 5.7 or later

PostgreSQL

The following sample may be added to the server's configuration file in order to connect to a PostgreSQL database. Be sure to customize the various values appropriately. There are limitations on what characters are allowed in the database name. Please refer to the following Postgres documentation for more information: https://www.postgresql.org/docs/current/static/sql-syntax-lexical.html#SQL-SYNTAX-IDENTIFIERS

```
db:
  type: postgres
  datasource: host=localhost port=5432 user=Username password=Password dbname=fabric_
↪ca sslmode=verify-full
```

Specifying *sslmode* configures the type of SSL authentication. Valid values for sslmode are:

Mode	Description
disable	No SSL
require	Always SSL (skip verification)
verify-ca	Always SSL (verify that the certificate presented by the server was signed by a trusted CA)
verify-full	Same as verify-ca AND verify that the certificate presented by the server was signed by a trusted CA and the server hostname matches the one in the certificate

If you would like to use TLS, then the `db.tls` section in the Fabric CA server configuration file must be specified. If SSL client authentication is enabled on the PostgreSQL server, then the client certificate and key file must also be specified in the `db.tls.client` section. The following is an example of the `db.tls` section:

```
db:
  ...
  tls:
      enabled: true
      certfiles:
        - db-server-cert.pem
      client:
            certfile: db-client-cert.pem
            keyfile: db-client-key.pem
```

certfiles - A list of PEM-encoded trusted root certificate files.

certfile and **keyfile** - PEM-encoded certificate and key files that are used by the Fabric CA server to communicate securely with the PostgreSQL server

PostgreSQL SSL Configuration

Basic instructions for configuring SSL on the PostgreSQL server:

1. In postgresql.conf, uncomment SSL and set to "on" (SSL=on)
2. Place certificate and key files in the PostgreSQL data directory.

Instructions for generating self-signed certificates for: https://www.postgresql.org/docs/9.5/static/ssl-tcp.html

Note: Self-signed certificates are for testing purposes and should not be used in a production environment

PostgreSQL Server - Require Client Certificates

1. Place certificates of the certificate authorities (CAs) you trust in the file root.crt in the PostgreSQL data directory
2. In postgresql.conf, set "ssl_ca_file" to point to the root cert of the client (CA cert)
3. Set the clientcert parameter to 1 on the appropriate hostssl line(s) in pg_hba.conf.

For more details on configuring SSL on the PostgreSQL server, please refer to the following PostgreSQL documentation: https://www.postgresql.org/docs/9.4/static/libpq-ssl.html

MySQL

The following sample may be added to the Fabric CA server configuration file in order to connect to a MySQL database. Be sure to customize the various values appropriately. There are limitations on what characters are allowed in the database name. Please refer to the following MySQL documentation for more information: https://dev.mysql.com/doc/refman/5.7/en/identifiers.html

On MySQL 5.7.X, certain modes affect whether the server permits '0000-00-00' as a valid date. It might be necessary to relax the modes that MySQL server uses. We want to allow the server to be able to accept zero date values.

In my.cnf, find the configuration option *sql_mode* and remove *NO_ZERO_DATE* if present. Restart MySQL server after making this change.

Please refer to the following MySQL documentation on different modes available and select the appropriate settings for the specific version of MySQL that is being used.

https://dev.mysql.com/doc/refman/5.7/en/sql-mode.html

```
db:
  type: mysql
  datasource: root:rootpw@tcp(localhost:3306)/fabric_ca?parseTime=true&tls=custom
```

If connecting over TLS to the MySQL server, the `db.tls.client` section is also required as described in the **PostgreSQL** section above.

MySQL SSL Configuration

Basic instructions for configuring SSL on MySQL server:

1. Open or create my.cnf file for the server. Add or uncomment the lines below in the [mysqld] section. These should point to the key and certificates for the server, and the root CA cert.

   Instructions on creating server and client-side certficates: http://dev.mysql.com/doc/refman/5.7/en/creating-ssl-files-using-openssl.html

   [mysqld] ssl-ca=ca-cert.pem ssl-cert=server-cert.pem ssl-key=server-key.pem

   Can run the following query to confirm SSL has been enabled.

   mysql> SHOW GLOBAL VARIABLES LIKE 'have_%ssl';

   Should see:

Variable_name	Value
have_openssl	YES
have_ssl	YES

2. After the server-side SSL configuration is finished, the next step is to create a user who has a privilege to access the MySQL server over SSL. For that, log in to the MySQL server, and type:

   mysql> GRANT ALL PRIVILEGES ON . TO 'ssluser'@'%' IDENTIFIED BY 'password' REQUIRE SSL; mysql> FLUSH PRIVILEGES;

   If you want to give a specific IP address from which the user will access the server change the '%' to the specific IP address.

MySQL Server - Require Client Certificates

Options for secure connections are similar to those used on the server side.

- ssl-ca identifies the Certificate Authority (CA) certificate. This option, if used, must specify the same certificate used by the server.
- ssl-cert identifies MySQL server's certificate.
- ssl-key identifies MySQL server's private key.

Suppose that you want to connect using an account that has no special encryption requirements or was created using a GRANT statement that includes the REQUIRE SSL option. As a recommended set of secure-connection options, start the MySQL server with at least –ssl-cert and –ssl-key options. Then set the `db.tls.certfiles` property in the server configuration file and start the Fabric CA server.

To require that a client certificate also be specified, create the account using the REQUIRE X509 option. Then the client must also specify proper client key and certificate files; otherwise, the MySQL server will reject the connection. To specify client key and certificate files for the Fabric CA server, set the `db.tls.client.certfile` , and `db.tls.client.keyfile` configuration properties.

Configuring LDAP

The Fabric CA server can be configured to read from an LDAP server.

In particular, the Fabric CA server may connect to an LDAP server to do the following:

- authenticate an identity prior to enrollment
- retrieve an identity's attribute values which are used for authorization.

Modify the LDAP section of the Fabric CA server's configuration file to configure the server to connect to an LDAP server.

```
ldap:
   # Enables or disables the LDAP client (default: false)
   enabled: false
   # The URL of the LDAP server
   url: <scheme>://<adminDN>:<adminPassword>@<host>:<port>/<base>
   userfilter: <filter>
   attribute:
      # 'names' is an array of strings that identify the specific attributes
      # which are requested from the LDAP server.
      names: <LDAPAttrs>
      # The 'converters' section is used to convert LDAP attribute values
      # to fabric CA attribute values.
      #
      # For example, the following converts an LDAP 'uid' attribute
      # whose value begins with 'revoker' to a fabric CA attribute
      # named "hf.Revoker" with a value of "true" (because the expression
      # evaluates to true).
      #    converters:
      #       - name: hf.Revoker
      #         value: attr("uid") =~ "revoker*"
      #
      # As another example, assume a user has an LDAP attribute named
      # 'member' which has multiple values of "dn1", "dn2", and "dn3".
      # Further assume the following configuration.
      #    converters:
      #       - name: myAttr
      #         value: map(attr("member"),"groups")
      #    maps:
      #       groups:
      #          - name: dn1
      #            value: orderer
      #          - name: dn2
      #            value: peer
      # The value of the user's 'myAttr' attribute is then computed to be
      # "orderer,peer,dn3".  This is because the value of 'attr("member")' is
      # "dn1,dn2,dn3", and the call to 'map' with a 2nd argument of
      # "group" replaces "dn1" with "orderer" and "dn2" with "peer".
      converters:
        - name: <fcaAttrName>
          value: <fcaExpr>
      maps:
        <mapName>:
            - name: <from>
              value: <to>
```

Where:

- `scheme` is one of *ldap* or *ldaps*;
- `adminDN` is the distinquished name of the admin user;
- `pass` is the password of the admin user;
- `host` is the hostname or IP address of the LDAP server;
- `port` is the optional port number, where default 389 for *ldap* and 636 for *ldaps*;
- `base` is the optional root of the LDAP tree to use for searches;
- `filter` is a filter to use when searching to convert a login user name to a distinquished name. For example, a value of `(uid=%s)` searches for LDAP entries with the value of a `uid` attribute whose value is the login user name. Similarly, `(email=%s)` may be used to login with an email address.
- `LDAPAttrs` is an array of LDAP attribute names to request from the LDAP server on a user's behalf;
- the attribute.converters section is used to convert LDAP attributes to fabric CA attributes, where * `fcaAttrName` is the name of a fabric CA attribute; * `fcaExpr` is an expression whose evaluated value is assigned to the fabric CA attribute. For example, suppose that <LDAPAttrs> is ["uid"], <fcaAttrName> is 'hf.Revoker', and <fcaExpr> is 'attr("uid") =~ "revoker*"'. This means that an attribute named "uid" is requested from the LDAP server on a user's behalf. The user is then given a value of 'true' for the 'hf.Revoker' attribute if the value of the user's 'uid' LDAP attribute begins with 'revoker'; otherwise, the user is given a value of 'false' for the 'hf.Revoker' attribute.
- the attribute.maps section is used to map LDAP response values. The typical use case is to map a distinquished name associated with an LDAP group to an identity type.

The LDAP expression language uses the govaluate package as described at https://github.com/Knetic/govaluate/blob/master/MANUAL.md. This defines operators such as "=~" and literals such as "revoker*", which is a regular expression. The LDAP-specific variables and functions which extend the base govaluate language are as follows:

- `DN` is a variable equal to the user's distinguished name.
- `affiliation` is a variable equal to the user's affiliation.
- `attr` is a function which takes 1 or 2 arguments. The 1st argument is an LDAP attribute name. The 2nd argument is a separator string which is used to join multiple values into a single string; the default separator string is ",". The `attr` function always returns a value of type 'string'.
- `map` is a function which takes 2 arguments. The 1st argument is any string. The second argument is the name of a map which is used to perform string substitution on the string from the 1st argument.
- `if` is a function which takes a 3 arguments where the first argument must resolve to a boolean value. If it evaluates to true, the second argument is returned; otherwise, the third argument is returned.

For example, the following expression evaluates to true if the user has a distinguished name ending in "O=org1,C=US", or if the user has an affiliation beginning with "org1.dept2." and also has the "admin" attribute of "true".

> **DN =~ "*O=org1,C=US" || (affiliation =~ "org1.dept2.*" && attr('admin') = 'true')**

NOTE: Since the `attr` function always returns a value of type 'string', numeric operators may not be used to construct expressions. For example, the following is NOT a valid expression:

```
value: attr("gidNumber) >= 10000 && attr("gidNumber) < 10006
```

Alternatively, a regular expression enclosed in quotes as shown below may be used to return an equivalent result:

```
value: attr("gidNumber") =~ "1000[0-5]$" || attr("mail") == "root@example.com"
```

The following is a sample configuration section for the default setting for the OpenLDAP server whose docker image is at `https://github.com/osixia/docker-openldap`.

```
ldap:
   enabled: true
   url: ldap://cn=admin,dc=example,dc=org:admin@localhost:10389/dc=example,dc=org
   userfilter: (uid=%s)
```

See `FABRIC_CA/scripts/run-ldap-tests` for a script which starts an OpenLDAP docker image, configures it, runs the LDAP tests in `FABRIC_CA/cli/server/ldap/ldap_test.go`, and stops the OpenLDAP server.

When LDAP is configured, enrollment works as follows:

- The Fabric CA client or client SDK sends an enrollment request with a basic authorization header.
- The Fabric CA server receives the enrollment request, decodes the identity name and password in the authorization header, looks up the DN (Distinquished Name) associated with the identity name using the "userfilter" from the configuration file, and then attempts an LDAP bind with the identity's password. If the LDAP bind is successful, the enrollment processing is authorized and can proceed.

Setting up a cluster

You may use any IP sprayer to load balance to a cluster of Fabric CA servers. This section provides an example of how to set up Haproxy to route to a Fabric CA server cluster. Be sure to change hostname and port to reflect the settings of your Fabric CA servers.

haproxy.conf

```
global
      maxconn 4096
      daemon

defaults
      mode http
      maxconn 2000
      timeout connect 5000
      timeout client 50000
      timeout server 50000

listen http-in
      bind *:7054
      balance roundrobin
      server server1 hostname1:port
      server server2 hostname2:port
      server server3 hostname3:port
```

Note: If using TLS, need to use `mode tcp` .

Setting up multiple CAs

The fabric-ca server by default consists of a single default CA. However, additional CAs can be added to a single server by using *cafiles* or *cacount* configuration options. Each additional CA will have its own home directory.

cacount:

The *cacount* provides a quick way to start X number of default additional CAs. The home directory will be relative to the server directory. With this option, the directory structure will be as follows:

```
--<Server Home>
  |--ca
    |--ca1
    |--ca2
```

Each additional CA will get a default configuration file generated in it's home directory, within the configuration file it will contain a unique CA name.

For example, the following command will start 2 default CA instances:

```
fabric-ca-server start -b admin:adminpw --cacount 2
```

cafiles:

If absolute paths are not provided when using the cafiles configuration option, the CA home directory will be relative to the server directory.

To use this option, CA configuration files must have already been generated and configured for each CA that is to be started. Each configuration file must have a unique CA name and Common Name (CN), otherwise the server will fail to start as these names must be unique. The CA configuration files will override any default CA configuration, and any missing options in the CA configuration files will be replaced by the values from the default CA.

The precedence order will be as follows:

1. CA Configuration file

2. Default CA CLI flags
3. Default CA Environment variables
4. Default CA Configuration file

A CA configuration file must contain at least the following:

```
ca:
# Name of this CA
name: <CANAME>

csr:
  cn: <COMMONNAME>
```

You may configure your directory structure as follows:

```
--<Server Home>
  |--ca
    |--ca1
      |-- fabric-ca-config.yaml
    |--ca2
      |-- fabric-ca-config.yaml
```

For example, the following command will start two customized CA instances:

```
fabric-ca-server start -b admin:adminpw --cafiles ca/ca1/fabric-ca-config.yaml
--cafiles ca/ca2/fabric-ca-config.yaml
```

Enrolling an intermediate CA

In order to create a CA signing certificate for an intermediate CA, the intermediate CA must enroll with a parent CA in the same way that a fabric-ca-client enrolls with a CA. This is done by using the -u option to specify the URL of the parent CA and the enrollment ID and secret as shown below. The identity associated with this enrollment ID must have an attribute with a name of "hf.IntermediateCA" and a value of "true". The CN (or Common Name) of the issued certificate will be set to the enrollment ID. An error will occur if an intermediate CA tries to explicitly specify a CN value.

```
fabric-ca-server start -b admin:adminpw -u http://<enrollmentID>:<secret>@
↪<parentserver>:<parentport>
```

For other intermediate CA flags see *Fabric CA server's configuration file format* section.

Upgrading the server

The Fabric CA server must be upgraded before upgrading the Fabric CA client. Prior to upgrade, it is suggested that the current database be backed up:

- If using sqlite3, backup the current database file (which is named fabric-ca-server.db by default).
- For other database types, use the appropriate backup/replication mechanism.

To upgrade a single instance of Fabric CA server:

1. Stop the fabric-ca-server process.
2. Ensure the current database is backed up.

3. Replace previous fabric-ca-server binary with the upgraded version.
4. Launch the fabric-ca-server process.
5. Verify the fabric-ca-server process is available with the following command where <host> is the hostname on which the server was started:

   ```
   fabric-ca-client getcacert -u http://<host>:7054
   ```

Upgrading a cluster:

To upgrade a cluster of fabric-ca-server instances using either a MySQL or Postgres database, perform the following procedure. We assume that you are using haproxy to load balance to two fabric-ca-server cluster members on host1 and host2, respectively, both listening on port 7054. After this procedure, you will be load balancing to upgraded fabric-ca-server cluster members on host3 and host4 respectively, both listening on port 7054.

In order to monitor the changes using haproxy stats, enable statistics collection. Add the following lines to the global section of the haproxy configuration file:

```
stats socket /var/run/haproxy.sock mode 666 level operator
stats timeout 2m
```

Restart haproxy to pick up the changes:

```
# haproxy -f <configfile> -st $(pgrep haproxy)
```

To display summary information from the haproxy "show stat" command, the following function may prove useful for parsing the copious amount of CSV data returned:

```
haProxyShowStats() {
   echo "show stat" | nc -U /var/run/haproxy.sock |sed '1s/^# *//'|
      awk -F',' -v fmt="%4s %12s %10s %6s %6s %4s %4s\n" '
         { if (NR==1) for (i=1;i<=NF;i++) f[tolower($i)]=i }
         { printf fmt, $f["sid"],$f["pxname"],$f["svname"],$f["status"],
                       $f["weight"],$f["act"],$f["bck"] }'
}
```

1. Initially your haproxy configuration file is similar to the following:

   ```
   server server1 host1:7054 check
   server server2 host2:7054 check
   ```

   Change this configuration to the following:

   ```
   server server1 host1:7054 check backup
   server server2 host2:7054 check backup
   server server3 host3:7054 check
   server server4 host4:7054 check
   ```

2. Restart the HA proxy with the new configuration as follows:

   ```
   haproxy -f <configfile> -st $(pgrep haproxy)
   ```

   `"haProxyShowStats"` will now reflect the modified configuration, with two active, older-version backup servers and two (yet to be started) upgraded servers:

```
sid   pxname      svname  status  weig  act  bck
  1   fabric-cas  server3   DOWN     1    1    0
  2   fabric-cas  server4   DOWN     1    1    0
  3   fabric-cas  server1     UP     1    0    1
  4   fabric-cas  server2     UP     1    0    1
```

3. Install upgraded binaries of fabric-ca-server on host3 and host4. The new upgraded servers on host3 and host4 should be configured to use the same database as their older counterparts on host1 and host2. After starting the upgraded servers, the database will be automatically migrated. The haproxy will forward all new traffic to the upgraded servers, since they are not configured as backup servers. Verify using the `"fabric-ca-client getcacert"` command that your cluster is still functioning appropriately before proceeding. Also, `"haProxyShowStats"` should now reflect that all servers are active, similar to the following:

   ```
   sid   pxname      svname  status  weig  act  bck
     1   fabric-cas  server3    UP     1    1    0
     2   fabric-cas  server4    UP     1    1    0
     3   fabric-cas  server1    UP     1    0    1
     4   fabric-cas  server2    UP     1    0    1
   ```

4. Stop the old servers on host1 and host2. Verify using the `"fabric-ca-client getcacert"` command that your new cluster is still functioning appropriately before proceeding. Then remove the older server backup configuration from the haproxy configuration file, so that it looks similar to the following:

   ```
   server server3 host3:7054 check
   server server4 host4:7054 check
   ```

5. Restart the HA proxy with the new configuration as follows:

   ```
   haproxy -f <configfile> -st $(pgrep haproxy)
   ```

   `"haProxyShowStats"` will now reflect the modified configuration, with two active servers which have been upgraded to the new version:

   ```
   sid   pxname      svname  status  weig  act  bck
     1   fabric-cas  server3   UP        1    1    0
     2   fabric-cas  server4   UP        1    1    0
   ```

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Fabric CA Client

This section describes how to use the fabric-ca-client command.

The Fabric CA client's home directory is determined as follows:

- if the –home command line option is set, use its value
- otherwise, if the `FABRIC_CA_CLIENT_HOME` environment variable is set, use its value
- otherwise, if the `FABRIC_CA_HOME` environment variable is set, use its value
- otherwise, if the `CA_CFG_PATH` environment variable is set, use its value
- otherwise, use `$HOME/.fabric-ca-client`

The instructions below assume that the client configuration file exists in the client's home directory.

Enrolling the bootstrap identity

First, if needed, customize the CSR (Certificate Signing Request) section in the client configuration file. Note that `csr.cn` field must be set to the ID of the bootstrap identity. Default CSR values are shown below:

```
csr:
  cn: <<enrollment ID>>
  key:
    algo: ecdsa
    size: 256
  names:
    - C: US
      ST: North Carolina
      L:
      O: Hyperledger Fabric
      OU: Fabric CA
  hosts:
   - <<hostname of the fabric-ca-client>>
  ca:
    pathlen:
    pathlenzero:
    expiry:
```

See *CSR fields* for description of the fields.

Then run `fabric-ca-client enroll` command to enroll the identity. For example, following command enrolls an identity whose ID is **admin** and password is **adminpw** by calling Fabric CA server that is running locally at 7054 port.

```
export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/admin
fabric-ca-client enroll -u http://admin:adminpw@localhost:7054
```

The enroll command stores an enrollment certificate (ECert), corresponding private key and CA certificate chain PEM files in the subdirectories of the Fabric CA client's `msp` directory. You will see messages indicating where the PEM files are stored.

Registering a new identity

The identity performing the register request must be currently enrolled, and must also have the proper authority to register the type of the identity that is being registered.

In particular, three authorization checks are made by the Fabric CA server during registration as follows:

1. The registrar (i.e. the invoker) must have the "hf.Registrar.Roles" attribute with a comma-separated list of values where one of the values equals the type of identity being registered; for example, if the registrar has the "hf.Registrar.Roles" attribute with a value of "peer,app,user", the registrar can register identities of type peer, app, and user, but not orderer.
2. The affiliation of the registrar must be equal to or a prefix of the affiliation of the identity being registered. For example, an registrar with an affiliation of "a.b" may register an identity with an affiliation of "a.b.c" but may not register an identity with an affiliation of "a.c". If root affiliation is required for an identity, then the affiliation request should be a dot (".") and the registrar must also have root affiliation. If no affiliation is specified in the registration request, the identity being registered will be given the affiliation of the registrar.
3. The registrar can register a user with attributes if all of the following conditions are satisfied:
   - Registrar can register Fabric CA reserved attributes that have the prefix 'hf.' only if the registrar possesses the attribute and it is part of the value of the hf.Registrar.Attributes' attribute. Furthermore, if the attribute

is of type list then the value of attribute being registered must be equal to or a subset of the value that the registrar has. If the attribute is of type boolean, the registrar can register the attribute only if the registrar's value for the attribute is 'true'.

- Registering custom attributes (i.e. any attribute whose name does not begin with 'hf.') requires that the registrar has the 'hf.Registar.Attributes' attribute with the value of the attribute or pattern being registered. The only supported pattern is a string with a "*" at the end. For example, "a.b.*" is a pattern which matches all attribute names beginning with "a.b.". For example, if the registrar has hf.Registrar.Attributes=orgAdmin, then the only attribute which the registrar can add or remove from an identity is the 'orgAdmin' attribute.
- If the requested attribute name is 'hf.Registrar.Attributes', an additional check is performed to see if the requested values for this attribute are equal to or a subset of the registrar's values for 'hf.Registrar.Attributes'. For this to be true, each requested value must match a value in the registrar's value for 'hf.Registrar.Attributes' attribute. For example, if the registrar's value for 'hf.Registrar.Attributes' is 'a.b.*, x.y.z' and the requested attribute value is 'a.b.c, x.y.z', it is valid because 'a.b.c' matches 'a.b.*' and 'x.y.z' matches the registrar's 'x.y.z' value.

Examples:

Valid Scenarios:

1. If the registrar has the attribute 'hf.Registrar.Attributes = a.b.*, x.y.z' and is registering attribute 'a.b.c', it is valid 'a.b.c' matches 'a.b.*'.
2. If the registrar has the attribute 'hf.Registrar.Attributes = a.b.*, x.y.z' and is registering attribute 'x.y.z', it is valid because 'x.y.z' matches the registrar's 'x.y.z' value.
3. If the registrar has the attribute 'hf.Registrar.Attributes = a.b.*, x.y.z' and the requested attribute value is 'a.b.c, x.y.z', it is valid because 'a.b.c' matches 'a.b.*' and 'x.y.z' matches the registrar's 'x.y.z' value.
4. If the registrar has the attribute 'hf.Registrar.Roles = peer,client' and the requested attribute value is 'peer' or 'peer,client', it is valid because the requested value is equal to or a subset of the registrar's value.

Invalid Scenarios:

1. If the registrar has the attribute 'hf.Registrar.Attributes = a.b.*, x.y.z' and is registering attribute 'hf.Registar.Attributes = a.b.c, x.y.*', it is invalid because requested attribute 'x.y.*' is not a pattern owned by the registrar. The value 'x.y.*' is a superset of 'x.y.z'.
2. If the registrar has the attribute 'hf.Registrar.Attributes = a.b.*, x.y.z' and is registering attribute 'hf.Registar.Attributes = a.b.c, x.y.z, attr1', it is invalid because the registrar's 'hf.Registrar.Attributes' attribute values do not contain 'attr1'.
3. If the registrar has the attribute 'hf.Registrar.Attributes = a.b.*, x.y.z' and is registering attribute 'a.b', it is invalid because the value 'a.b' is not contained in 'a.b.*'.
4. If the registrar has the attribute 'hf.Registrar.Attributes = a.b.*, x.y.z' and is registering attribute 'x.y', it is invalid because 'x.y' is not contained by 'x.y.z'.
5. If the registrar has the attribute 'hf.Registrar.Roles = peer,client' and the requested attribute value is 'peer,client,orderer', it is invalid because the registrar does not have the orderer role in its value of hf.Registrar.Roles attribute.
6. If the registrar has the attribute 'hf.Revoker = false' and the requested attribute value is 'true', it is invalid because the hf.Revoker attribute is a boolean attribute and the registrar's value for the attribute is not 'true'.

The table below lists all the attributes that can be registered for an identity. The names of attributes are case sensitive.

Name	Type	Description
hf.Registrar.Roles	List	List of roles that the registrar is allowed to manage
hf.Registrar.DelegateRoles	List	List of roles that the registrar is allowed to give to a registree for its 'hf.Registrar.Roles' attribute
hf.Registrar.Attributes	List	List of attributes that registrar is allowed to register
hf.GenCRL	Boolean	Identity is able to generate CRL if attribute value is true
hf.Revoker	Boolean	Identity is able to revoke a user and/or certificates if attribute value is true
hf.AffiliationMgr	Boolean	Identity is able to manage affiliations if attribute value is true
hf.IntermediateCA	Boolean	Identity is able to enroll as an intermediate CA if attribute value is true

Note: When registering an identity, you specify an array of attribute names and values. If the array specifies multiple array elements with the same name, only the last element is currently used. In other words, multi-valued attributes are not currently supported.

The following command uses the **admin** identity's credentials to register a new user with an enrollment id of "admin2", an affiliation of "org1.department1", an attribute named "hf.Revoker" with a value of "true", and an attribute named "admin" with a value of "true". The ":ecert" suffix means that by default the "admin" attribute and its value will be inserted into the user's enrollment certificate, which can then be used to make access control decisions.

```
export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/admin
fabric-ca-client register --id.name admin2 --id.affiliation org1.department1 --id.
↪attrs 'hf.Revoker=true,admin=true:ecert'
```

The password, also known as the enrollment secret, is printed. This password is required to enroll the identity. This allows an administrator to register an identity and give the enrollment ID and the secret to someone else to enroll the identity.

Multiple attributes can be specified as part of the –id.attrs flag, each attribute must be comma separated. For an attribute value that contains a comma, the attribute must be encapsulated in double quotes. See example below.

```
fabric-ca-client register -d --id.name admin2 --id.affiliation org1.department1 --id.
↪attrs '"hf.Registrar.Roles=peer,user",hf.Revoker=true'
```

or

```
fabric-ca-client register -d --id.name admin2 --id.affiliation org1.department1 --id.
↪attrs '"hf.Registrar.Roles=peer,user"' --id.attrs hf.Revoker=true
```

You may set default values for any of the fields used in the register command by editing the client's configuration file. For example, suppose the configuration file contains the following:

```
id:
  name:
  type: user
  affiliation: org1.department1
  maxenrollments: -1
  attributes:
    - name: hf.Revoker
      value: true
    - name: anotherAttrName
      value: anotherAttrValue
```

The following command would then register a new identity with an enrollment id of "admin3" which it takes from the command line, and the remainder is taken from the configuration file including the identity type: "user", affiliation: "org1.department1", and two attributes: "hf.Revoker" and "anotherAttrName".

```
export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/admin
fabric-ca-client register --id.name admin3
```

To register an identity with multiple attributes requires specifying all attribute names and values in the configuration file as shown above.

Setting *maxenrollments* to 0 or leaving it out from the configuration will result in the identity being registered to use the CA's max enrollment value. Furthermore, the max enrollment value for an identity being registered cannot exceed the CA's max enrollment value. For example, if the CA's max enrollment value is 5. Any new identity must have a value less than or equal to 5, and also can't set it to -1 (infinite enrollments).

Next, let's register a peer identity which will be used to enroll the peer in the following section. The following command registers the **peer1** identity. Note that we choose to specify our own password (or secret) rather than letting the server generate one for us.

```
export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/admin
fabric-ca-client register --id.name peer1 --id.type peer --id.affiliation org1.
↪department1 --id.secret peer1pw
```

Note that affiliations are case sensitive except for the non-leaf affiliations that are specified in the server configuration file, which are always stored in lower case. For example, if the affiliations section of the server configuration file looks like this:

```
affiliations:
  BU1:
    Department1:
      - Team1
  BU2:
    - Department2
    - Department3
```

BU1, *Department1*, *BU2* are stored in lower case. This is because Fabric CA uses Viper to read configuration. Viper treats map keys as case insensitive and always returns lowercase value. To register an identity with *Team1* affiliation, *bu1.department1.Team1* would need to be specified to the *–id.affiliation* flag as shown below:

```
export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/admin
fabric-ca-client register --id.name client1 --id.type client --id.affiliation bu1.
↪department1.Team1
```

Enrolling a peer identity

Now that you have successfully registered a peer identity, you may now enroll the peer given the enrollment ID and secret (i.e. the *password* from the previous section). This is similar to enrolling the bootstrap identity except that we also demonstrate how to use the "-M" option to populate the Hyperledger Fabric MSP (Membership Service Provider) directory structure.

The following command enrolls peer1. Be sure to replace the value of the "-M" option with the path to your peer's MSP directory which is the 'mspConfigPath' setting in the peer's core.yaml file. You may also set the FABRIC_CA_CLIENT_HOME to the home directory of your peer.

```
export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/peer1
fabric-ca-client enroll -u http://peer1:peer1pw@localhost:7054 -M $FABRIC_CA_CLIENT_
↪HOME/msp
```

Enrolling an orderer is the same, except the path to the MSP directory is the 'LocalMSPDir' setting in your orderer's orderer.yaml file.

All enrollment certificates issued by the fabric-ca-server have organizational units (or "OUs" for short) as follows:

1. The root of the OU hierarchy equals the identity type

2. An OU is added for each component of the identity's affiliation

For example, if an identity is of type *peer* and its affiliation is *department1.team1*, the identity's OU hierarchy (from leaf to root) is *OU=team1, OU=department1, OU=peer*.

Getting a CA certificate chain from another Fabric CA server

In general, the cacerts directory of the MSP directory must contain the certificate authority chains of other certificate authorities, representing all of the roots of trust for the peer.

The `fabric-ca-client getcacerts` command is used to retrieve these certificate chains from other Fabric CA server instances.

For example, the following will start a second Fabric CA server on localhost listening on port 7055 with a name of "CA2". This represents a completely separate root of trust and would be managed by a different member on the blockchain.

```
export FABRIC_CA_SERVER_HOME=$HOME/ca2
fabric-ca-server start -b admin:ca2pw -p 7055 -n CA2
```

The following command will install CA2's certificate chain into peer1's MSP directory.

```
export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/peer1
fabric-ca-client getcacert -u http://localhost:7055 -M $FABRIC_CA_CLIENT_HOME/msp
```

By default, the Fabric CA server returns the CA chain in child-first order. This means that each CA certificate in the chain is followed by its issuer's CA certificate. If you need the Fabric CA server to return the CA chain in the opposite order, then set the environment variable `CA_CHAIN_PARENT_FIRST` to `true` and restart the Fabric CA server. The Fabric CA client will handle either order appropriately.

Reenrolling an Identity

Suppose your enrollment certificate is about to expire or has been compromised. You can issue the reenroll command to renew your enrollment certificate as follows.

```
export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/peer1
fabric-ca-client reenroll
```

Revoking a certificate or identity

An identity or a certificate can be revoked. Revoking an identity will revoke all the certificates owned by the identity and will also prevent the identity from getting any new certificates. Revoking a certificate will invalidate a single certificate.

In order to revoke a certificate or an identity, the calling identity must have the `hf.Revoker` and `hf.Registrar.Roles` attribute. The revoking identity can only revoke a certificate or an identity that has an affiliation that is equal to or prefixed by the revoking identity's affiliation. Furthermore, the revoker can only revoke identities with types that are listed in the revoker's `hf.Registrar.Roles` attribute.

For example, a revoker with affiliation **orgs.org1** and 'hf.Registrar.Roles=peer,client' attribute can revoke either a **peer** or **client** type identity affiliated with **orgs.org1** or **orgs.org1.department1** but can't revoke an identity affiliated with **orgs.org2** or of any other type.

The following command disables an identity and revokes all of the certificates associated with the identity. All future requests received by the Fabric CA server from this identity will be rejected.

```
fabric-ca-client revoke -e <enrollment_id> -r <reason>
```

The following are the supported reasons that can be specified using `-r` flag:

1. unspecified
2. keycompromise
3. cacompromise
4. affiliationchange
5. superseded
6. cessationofoperation
7. certificatehold
8. removefromcrl
9. privilegewithdrawn
10. aacompromise

For example, the bootstrap admin who is associated with root of the affiliation tree can revoke **peer1**‘s identity as follows:

```
export FABRIC_CA_CLIENT_HOME=$HOME/fabric-ca/clients/admin
fabric-ca-client revoke -e peer1
```

An enrollment certificate that belongs to an identity can be revoked by specifying its AKI (Authority Key Identifier) and serial number as follows:

```
fabric-ca-client revoke -a xxx -s yyy -r <reason>
```

For example, you can get the AKI and the serial number of a certificate using the openssl command and pass them to the `revoke` command to revoke the said certificate as follows:

```
serial=$(openssl x509 -in userecert.pem -serial -noout | cut -d "=" -f 2)
aki=$(openssl x509 -in userecert.pem -text | awk '/keyid/ {gsub(/ *keyid:|:/,"",$1);
↪print tolower($0)}')
fabric-ca-client revoke -s $serial -a $aki -r affiliationchange
```

The *–gencrl* flag can be used to generate a CRL (Certificate Revocation List) that contains all the revoked certificates. For example, following command will revoke the identity **peer1**, generates a CRL and stores it in the **<msp folder>/crls/crl.pem** file.

```
fabric-ca-client revoke -e peer1 --gencrl
```

A CRL can also be generated using the *gencrl* command. Refer to the *Generating a CRL (Certificate Revocation List)* section for more information on the *gencrl* command.

Generating a CRL (Certificate Revocation List)

After a certificate is revoked in the Fabric CA server, the appropriate MSPs in Hyperledger Fabric must also be updated. This includes both local MSPs of the peers as well as MSPs in the appropriate channel configuration blocks. To do this, PEM encoded CRL (certificate revocation list) file must be placed in the *crls* folder of the MSP. The `fabric-ca-client gencrl` command can be used to generate a CRL. Any identity with `hf.GenCRL` attribute can create a CRL that contains serial numbers of all certificates that were revoked during a certain period. The created CRL is stored in the *<msp folder>/crls/crl.pem* file.

The following command will create a CRL containing all the revoked certficates (expired and unexpired) and store the CRL in the *~/msp/crls/crl.pem* file.

```
export FABRIC_CA_CLIENT_HOME=~/clientconfig
fabric-ca-client gencrl -M ~/msp
```

The next command will create a CRL containing all certficates (expired and unexpired) that were revoked after 2017-09-13T16:39:57-08:00 (specified by the *–revokedafter* flag) and before 2017-09-21T16:39:57-08:00 (specified by the *–revokedbefore* flag) and store the CRL in the *~/msp/crls/crl.pem* file.

```
export FABRIC_CA_CLIENT_HOME=~/clientconfig
fabric-ca-client gencrl --caname "" --revokedafter 2017-09-13T16:39:57-08:00 --
↪revokedbefore 2017-09-21T16:39:57-08:00 -M ~/msp
```

The *–caname* flag specifies the name of the CA to which this request is sent. In this example, the gencrl request is sent to the default CA.

The *–revokedafter* and *–revokedbefore* flags specify the lower and upper boundaries of a time period. The generated CRL will contain certificates that were revoked in this time period. The values must be UTC timestamps specified in RFC3339 format. The *–revokedafter* timestamp cannot be greater than the *–revokedbefore* timestamp.

By default, 'Next Update' date of the CRL is set to next day. The *crl.expiry* CA configuration property can be used to specify a custom value.

The gencrl command will also accept *–expireafter* and *–expirebefore* flags that can be used to generate a CRL with revoked certificates that expire during the period specified by these flags. For example, the following command will generate a CRL that contains certficates that were revoked after 2017-09-13T16:39:57-08:00 and before 2017-09-21T16:39:57-08:00, and that expire after 2017-09-13T16:39:57-08:00 and before 2018-09-13T16:39:57-08:00

```
export FABRIC_CA_CLIENT_HOME=~/clientconfig
fabric-ca-client gencrl --caname "" --expireafter 2017-09-13T16:39:57-08:00 --
↪expirebefore 2018-09-13T16:39:57-08:00  --revokedafter 2017-09-13T16:39:57-08:00 --
↪revokedbefore 2017-09-21T16:39:57-08:00 -M ~/msp
```

The fabric-samples/fabric-ca sample demonstrates how to generate a CRL that contains certificate of a revoked user and update the channel msp. It will then demonstrate that querying the channel using the revoked user credentials will result in an authorization error.

Enabling TLS

This section describes in more detail how to configure TLS for a Fabric CA client.

The following sections may be configured in the `fabric-ca-client-config.yaml`.

```
tls:
  # Enable TLS (default: false)
  enabled: true
  certfiles:
    - root.pem
  client:
    certfile: tls_client-cert.pem
    keyfile: tls_client-key.pem
```

The **certfiles** option is the set of root certificates trusted by the client. This will typically just be the root Fabric CA server's certificate found in the server's home directory in the **ca-cert.pem** file.

The **client** option is required only if mutual TLS is configured on the server.

Attribute-Based Access Control

Access control decisions can be made by chaincode (and by the Hyperledger Fabric runtime) based upon an identity's attributes. This is called **Attribute-Based Access Control**, or **ABAC** for short.

In order to make this possible, an identity's enrollment certificate (ECert) may contain one or more attribute name and value. The chaincode then extracts an attribute's value to make an access control decision.

For example, suppose that you are developing application *app1* and want a particular chaincode operation to be accessible only by app1 administrators. Your chaincode could verify that the caller's certificate (which was issued by a CA trusted for the channel) contains an attribute named *app1Admin* with a value of *true*. Of course the name of the attribute can be anything and the value need not be a boolean value.

So how do you get an enrollment certificate with an attribute? There are two methods:

1. When you register an identity, you can specify that an enrollment certificate issued for the identity should by default contain an attribute. This behavior can be overridden at enrollment time, but this is useful for establishing default behavior and, assuming registration occurs outside of your application, does not require any application change.

   The following shows how to register *user1* with two attributes: *app1Admin* and *email*. The ":ecert" suffix causes the *appAdmin* attribute to be inserted into user1's enrollment certificate by default, when the user does not explicitly request attributes at enrollment time. The *email* attribute is not added to the enrollment certificate by default.

```
fabric-ca-client register --id.name user1 --id.secret user1pw --id.type user --id.
↪affiliation org1 --id.attrs 'app1Admin=true:ecert,email=user1@gmail.com'
```

2. When you enroll an identity, you may explicitly request that one or more attributes be added to the certificate. For each attribute requested, you may specify whether the attribute is optional or not. If it is not requested optionally and the identity does not possess the attribute, an error will occur.

   The following shows how to enroll *user1* with the *email* attribute, without the *app1Admin* attribute, and optionally with the *phone* attribute (if the user possesses the *phone* attribute).

```
fabric-ca-client enroll -u http://user1:user1pw@localhost:7054 --enrollment.attrs
↪"email,phone:opt"
```

The table below shows the three attributes which are automatically registered for every identity.

Attribute Name	Attribute Value
hf.EnrollmentID	The enrollment ID of the identity
hf.Type	The type of the identity
hf.Affiliation	The affiliation of the identity

To add any of the above attributes **by default** to a certificate, you must explicitly register the attribute with the ":ecert" specification. For example, the following registers identity 'user1' so that the 'hf.Affiliation' attribute will be added to an enrollment certificate if no specific attributes are requested at enrollment time. Note that the value of the affiliation (which is 'org1') must be the same in both the '–id.affiliation' and the '–id.attrs' flags.

```
fabric-ca-client register --id.name user1 --id.secret user1pw --id.type user --id.
↪affiliation org1 --id.attrs 'hf.Affiliation=org1:ecert'
```

For information on the chaincode library API for Attribute-Based Access Control, see https://github.com/hyperledger/fabric/tree/release/core/chaincode/lib/cid/README.md

For an end-to-end sample which demonstrates Attribute-Based Access Control and more, see https://github.com/hyperledger/fabric-samples/tree/release/fabric-ca/README.md

Dynamic Server Configuration Update

This section describes how to use fabric-ca-client to dynamically update portions of the fabric-ca-server's configuration without restarting the server.

All commands in this section require that you first be enrolled by executing the *fabric-ca-client enroll* command.

Dynamically updating identities

This section describes how to use fabric-ca-client to dynamically update identities.

An authorization failure will occur if the client identity does not satisfy all of the following:

- The client identity must possess the "hf.Registrar.Roles" attribute with a comma-separated list of values where one of the values equals the type of identity being updated; for example, if the client's identity has the "hf.Registrar.Roles" attribute with a value of "client,peer", the client can update identities of type 'client' and 'peer', but not 'orderer'.
- The affiliation of the client's identity must be equal to or a prefix of the affiliation of the identity being updated. For example, a client with an affiliation of "a.b" may update an identity with an affiliation of "a.b.c" but may not update an identity with an affiliation of "a.c". If root affiliation is required for an identity, then the update request should specify a dot (".") for the affiliation and the client must also have root affiliation.

The following shows how to add, modify, and remove an affiliation.

Getting Identity Information

A caller may retrieve information on a identity from the fabric-ca server as long as the caller meets the authorization requirements highlighted in the section above. The following command shows how to get an identity.

```
fabric-ca-client identity list --id user1
```

A caller may also request to retrieve information on all identities that it is authorized to see by issuing the following command.

```
fabric-ca-client identity list
```

Adding an identity

The following adds a new identity for 'user1'. Adding a new identity performs the same action as registering an identity via the 'fabric-ca-client register' command. There are two available methods for adding a new identity. The first method is via the *–json* flag where you describe the identity in a JSON string.

```
fabric-ca-client identity add user1 --json '{"secret": "user1pw", "type": "user",
↪"affiliation": "org1", "max_enrollments": 1, "attrs": [{"name": "hf.Revoker", "value
↪": "true"}]}'
```

The following adds a user with root affiliation. Note that an affiliation name of "." means the root affiliation.

```
fabric-ca-client identity add user1 --json '{"secret": "user1pw", "type": "user",
↪"affiliation": ".", "max_enrollments": 1, "attrs": [{"name": "hf.Revoker", "value":
↪"true"}]}'
```

The second method for adding an identity is to use direct flags. See the example below for adding 'user1'.

```
fabric-ca-client identity add user1 --secret user1pw --type user --affiliation . --
↪maxenrollments 1 --attrs hf.Revoker=true
```

The table below lists all the fields of an identity and whether they are required or optional, and any default values they might have.

Fields	Required	Default Value
ID	Yes	
Secret	No	
Affiliation	No	Caller's Affiliation
Type	No	client
Maxenrollments	No	0
Attributes	No	

Modifying an identity

There are two available methods for modifying an existing identity. The first method is via the *–json* flag where you describe the modifications in to an identity in a JSON string. Multiple modifications can be made in a single request. Any element of an identity that is not modified will retain its original value.

NOTE: A maxenrollments value of "-2" specifies that the CA's max enrollment setting is to be used.

The command below make multiple modification to an identity using the –json flag.

```
fabric-ca-client identity modify user1 --json '{"secret": "newPassword", "affiliation
↪": ".", "attrs": [{"name": "hf.Regisrar.Roles", "value": "peer,client"},{"name":
↪"hf.Revoker", "value": "true"}]}'
```

The commands below make modifcations using direct flags. The following updates the enrollment secret (or password) for identity 'user1' to 'newsecret'.

```
fabric-ca-client identity modify user1 --secret newsecret
```

The following updates the affiliation of identity 'user1' to 'org2'.

```
fabric-ca-client identity modify user1 --affiliation org2
```

The following updates the type of identity 'user1' to 'peer'.

```
fabric-ca-client identity modify user1 --type peer
```

The following updates the maxenrollments of identity 'user1' to 5.

```
fabric-ca-client identity modify user1 --maxenrollments 5
```

By specifying a maxenrollments value of '-2', the following causes identity 'user1' to use the CA's max enrollment setting.

```
fabric-ca-client identity modify user1 --maxenrollments -2
```

The following sets the value of the 'hf.Revoker' attribute for identity 'user1' to 'false'. If the identity has other attributes, they are not changed. If the identity did not previously possess the 'hf.Revoker' attribute, the attribute is added to the identity. An attribute may also be removed by specifiying no value for the attribute.

```
fabric-ca-client identity modify user1 --attrs hf.Revoker=false
```

The following removes the ‘hf.Revoker’ attribute for user ‘user1’.

```
fabric-ca-client identity modify user1 --attrs hf.Revoker=
```

The following demonstrates that multiple options may be used in a single *fabric-ca-client identity modify* command. In this case, both the secret and the type are updated for user ‘user1’.

```
fabric-ca-client identity modify user1 --secret newpass --type peer
```

Removing an identity

The following removes identity ‘user1’ and also revokes any certificates associated with the ‘user1’ identity.

```
fabric-ca-client identity remove user1
```

Note: Removal of identities is disabled in the fabric-ca-server by default, but may be enabled by starting the fabric-ca-server with the *–cfg.identities.allowremove* option.

Dynamically updating affiliations

This section describes how to use fabric-ca-client to dynamically update affiliations. The following shows how to add, modify, remove, and list an affiliation.

Adding an affiliation

An authorization failure will occur if the client identity does not satisfy all of the following:

- The client identity must possess the attribute ‘hf.AffiliationMgr’ with a value of ‘true’.
- The affiliation of the client identity must be hierarchically above the affiliation being updated. For example, if the client’s affiliation is “a.b”, the client may add affiliation “a.b.c” but not “a” or “a.b”.

The following adds a new affiliation named ‘org1.dept1’.

```
fabric-ca-client affiliation add org1.dept1
```

Modifying an affiliation

An authorization failure will occur if the client identity does not satisfy all of the following:

- The client identity must possess the attribute ‘hf.AffiliationMgr’ with a value of ‘true’.
- The affiliation of the client identity must be hierarchically above the affiliation being updated. For example, if the client’s affiliation is “a.b”, the client may add affiliation “a.b.c” but not “a” or “a.b”.
- If the ‘–force’ option is true and there are identities which must be modified, the client identity must also be authorized to modify the identity.

The following renames the ‘org2’ affiliation to ‘org3’. It also renames any sub affiliations (e.g. ‘org2.department1’ is renamed to ‘org3.department1’).

```
fabric-ca-client affiliation modify org2 --name org3
```

If there are identities that are affected by the renaming of an affiliation, it will result in an error unless the '–force' option is used. Using the '–force' option will update the affiliation of identities that are affected to use the new affiliation name.

```
fabric-ca-client affiliation modify org1 --name org2 --force
```

Removing an affiliation

An authorization failure will occur if the client identity does not satisfy all of the following:

- The client identity must possess the attribute 'hf.AffiliationMgr' with a value of 'true'.
- The affiliation of the client identity must be hierarchically above the affiliation being updated. For example, if the client's affiliation is "a.b", the client may remove affiliation "a.b.c" but not "a" or "a.b".
- If the '–force' option is true and there are identities which must be modified, the client identity must also be authorized to modify the identity.

The following removes affiliation 'org2' and also any sub affiliations. For example, if 'org2.dept1' is an affiliation below 'org2', it is also removed.

```
fabric-ca-client affiliation remove org2
```

If there are identities that are affected by the removing of an affiliation, it will result in an error unless the '–force' option is used. Using the '–force' option will also remove all identities that are associated with that affiliation, and the certificates associated with any of these identities.

Note: Removal of affiliations is disabled in the fabric-ca-server by default, but may be enabled by starting the fabric-ca-server with the *–cfg.affiliations.allowremove* option.

Listing affiliation information

An authorization failure will occur if the client identity does not satisfy all of the following:

- The client identity must possess the attribute 'hf.AffiliationMgr' with a value of 'true'.
- Affiliation of the client identity must be equal to or be hierarchically above the affiliation being updated. For example, if the client's affiliation is "a.b", the client may get affiliation information on "a.b" or "a.b.c" but not "a" or "a.c".

The following command shows how to get a specific affiliation.

```
fabric-ca-client affiliation list --affiliation org2.dept1
```

A caller may also request to retrieve information on all affiliations that it is authorized to see by issuing the following command.

```
fabric-ca-client affiliation list
```

Contact specific CA instance

When a server is running multiple CA instances, requests can be directed to a specific CA. By default, if no CA name is specified in the client request the request will be directed to the default CA on the fabric-ca server. A CA name can be specified on the command line of a client command as follows:

```
fabric-ca-client enroll -u http://admin:adminpw@localhost:7054 --caname <caname>
```

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HSM

By default, the Fabric CA server and client store private keys in a PEM-encoded file, but they can also be configured to store private keys in an HSM (Hardware Security Module) via PKCS11 APIs. This behavior is configured in the BCCSP (BlockChain Crypto Service Provider) section of the server's or client's configuration file.

Configuring Fabric CA server to use softhsm2

This section shows how to configure the Fabric CA server or client to use a software version of PKCS11 called softhsm (see https://github.com/opendnssec/SoftHSMv2).

After installing softhsm, create a token, label it "ForFabric", set the pin to '98765432' (refer to softhsm documentation).

You can use both the config file and environment variables to configure BCCSP For example, set the bccsp section of Fabric CA server configuration file as follows. Note that the default field's value is PKCS11.

```
#############################################################################
# BCCSP (BlockChain Crypto Service Provider) section is used to select which
# crypto library implementation to use
#############################################################################
bccsp:
  default: PKCS11
  pkcs11:
    Library: /usr/local/Cellar/softhsm/2.1.0/lib/softhsm/libsofthsm2.so
    Pin: 98765432
    Label: ForFabric
    hash: SHA2
    security: 256
    filekeystore:
      # The directory used for the software file-based keystore
      keystore: msp/keystore
```

And you can override relevant fields via environment variables as follows:

FABRIC_CA_SERVER_BCCSP_DEFAULT=PKCS11 FABRIC_CA_SERVER_BCCSP_PKCS11_LIBRARY=/usr/local/Cellar/sofths
FABRIC_CA_SERVER_BCCSP_PKCS11_PIN=98765432 FABRIC_CA_SERVER_BCCSP_PKCS11_LABEL=ForFabric

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File Formats

Fabric CA server's configuration file format

A default configuration file is created in the server's home directory (see *Fabric CA Server* section for more info). The following link shows a sample Server configuration file.

Fabric CA client's configuration file format

A default configuration file is created in the client's home directory (see *Fabric CA Client* section for more info). The following link shows a sample Client configuration file.

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Troubleshooting

1. If you see a `Killed: 9` error on OSX when trying to execute `fabric-ca-client` or `fabric-ca-server`, there is a long thread describing this problem at https://github.com/golang/go/issues/19734. The short answer is that to work around this issue, you can run the following command:

   ```
   # sudo ln -s /usr/bin/true /usr/local/bin/dsymutil
   ```

2. The error `[ERROR] No certificates found for provided serial and aki` will occur if the following sequence of events occurs:

   (a) You issue a *fabric-ca-client enroll* command, creating an enrollment certificate (i.e. an ECert). This stores a copy of the ECert in the fabric-ca-server's database.

   (b) The fabric-ca-server's database is deleted and recreated, thus losing the ECert from step 'a'. For example, this may happen if you stop and restart a docker container hosting the fabric-ca-server, but your fabric-ca-server is using the default sqlite database and the database file is not stored on a volume and is therefore not persistent.

   (c) You issue a *fabric-ca-client register* command or any other command which tries to use the ECert from step 'a'. In this case, since the database no longer contains the ECert, the `[ERROR] No certificates found for provided serial and aki` will occur.

   To resolve this error, you must enroll again by repeating step 'a'. This will issue a new ECert which will be stored in the current database.

3. When sending multiple parallel requests to a Fabric CA Server cluster that uses shared sqlite3 databases, the server occasionally returns a 'database locked' error. This is most probably because the database transaction timed out while waiting for database lock (held by another cluster member) to be released. This is an invalid configuration because sqlite is an embedded database, which means the Fabric CA server cluster must share the same file via a shared file system, which introduces a SPoF (single point of failure), which contradicts the purpose of cluster topology. The best practice is to use either Postgres or MySQL databases in a cluster topology.

4. Suppose an error similar to `Failed to deserialize creator identity,err The supplied identity is not valid,Verify() returned x509: certificate signed by unknown authority` is returned by a peer or orderer when using an enrollment certificate issued by the Fabric CA Server. This indicates that the signing CA certificate used by the Fabric CA Server to issue certificates does not match a certificate in the *cacerts* or *intermediatecerts* folder of the MSP used to make authorization checks.

   The MSP which is used to make authorization checks depends on which operation you were performing when the error occurred. For example, if you were trying to install chaincode on a peer, the local MSP on the file system of the peer is used; otherwise, if you were performing some channel specific operation such as instantiating chaincode on a specific channel, the MSP in the genesis block or the most recent configuration block of the channel is used.

   To confirm that this is the problem, compare the AKI (Authority Key Identifier) of the enrollment certificate to the SKI (Subject Key Identifier) of the certificate(s) in the *cacerts* and *intermediatecerts* folder of appropriate MSP. The command *openssl x509 -in <PEM-file> -noout -text | grep -A1 "Authority Key Identifier"* will display the AKI and *openssl x509 -in <PEM-file> -noout -text | grep -A1 "Subject Key Identifier"* will display the SKI. If they are not equal, you have confirmed that this is the cause of the error.

This can happen for multiple reasons including:

(a) You used *cryptogen* to generate your key material but did not start *fabric-ca-server* with the signing key and certificate generated by *cryptogen*.

   To resolve (assuming *FABRIC_CA_SERVER_HOME* is set to the home directory of your *fabric-ca-server*):

   i. Stop *fabric-ca-server*.

   ii. Copy *crypto-config/peerOrganizations/<orgName>/ca/*pem* to *$FABRIC_CA_SERVER_HOME/ca-cert.pem*.

   iii. Copy *crypto-config/peerOrganizations/<orgName>/ca/*_sk* to *$FABRIC_CA_SERVER_HOME/msp/keystore/*.

   iv. Start *fabric-ca-server*.

   v. Delete any previously issued enrollment certificates and get new certificates by enrolling again.

(b) You deleted and recreated the CA signing key and certificate used by the Fabric CA Server after generating the genesis block. This can happen if the Fabric CA Server is running in a docker container, the container was restarted, and its home directory is not on a volume mount. In this case, the Fabric CA Server will create a new CA signing key and certificate.

   Assuming that you can not recover the original CA signing key, the only way to recover from this scenario is to update the certificate in the *cacerts* (or *intermediatecerts*) of the appropriate MSPs to the new CA certificate.