

cMsg 6.0 Developer's Guide

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Chapter 1

1. Introduction

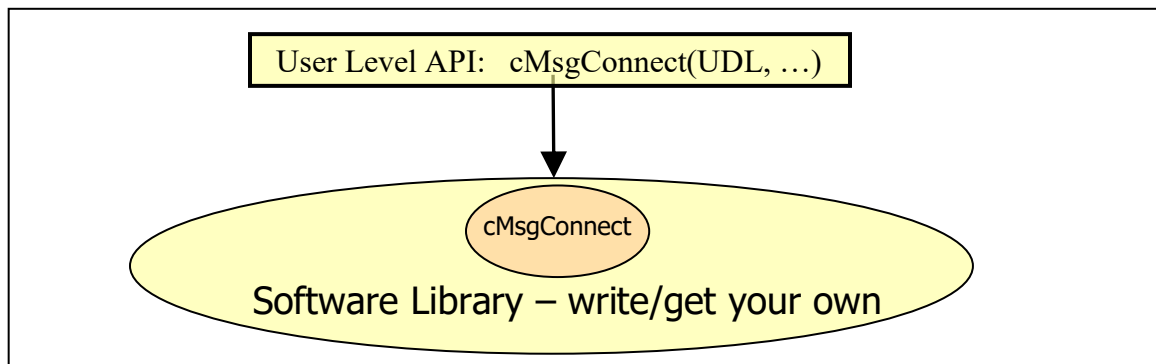
In the following we describe how to customize the cMsg package by adding new domains and subdomains. Users of this guide should be familiar with the basic concepts and strategies of the cMsg package. See the *cMsg User's Guide* for more information. As noted in the user's guide, the cMsg package can be used at a number of levels:

- Abstract API to an arbitrary, underlying message system
- Framework for implementation of underlying messaging systems
- Proxy system to connect to remote messaging systems
- Full implementation of publish/subscribe and other messaging systems

This guide describes how to work with the first three levels above. The user's guide discusses the fourth level, i.e. how to use the built-in messaging systems provided with the cMsg package.

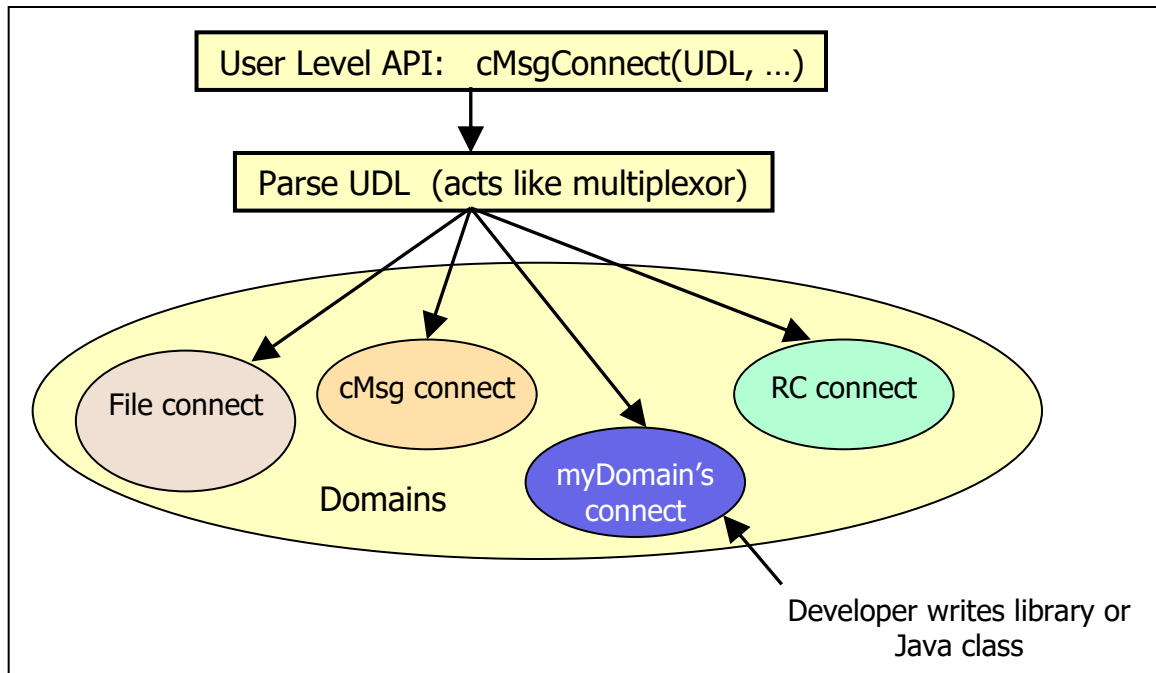
1.1. Abstract API

At the most basic level the cMsg API can simply be implemented as a façade on top of an arbitrary, asynchronous publish/subscribe or synchronous peer-to-peer messaging system. This approach may be useful since user code need not change if the underlying messaging system is changed; however, this will not be discussed further as there is little to say. Look at the diagram below to see a graphical view of how the API is implemented in this fashion. Far more powerful customizations of the cMsg package are described in the next two sections. See the API docs for details of the cMsg API.



1.2. Framework

A more interesting use of the cMsg package is as a framework for implementation of user-written domains. The cMsg client framework allows new domains to be easily added, dynamically in Java (8 or later), and dynamically or statically in C. The framework supports connection of clients to multiple domains, keeps track of separate callbacks and subscriptions, etc. Developers simply have to implement a basic set of messaging functions via an adapter class or interface in Java, or via a set of function pointers in C. See the graphical example below and Section 2 for details.



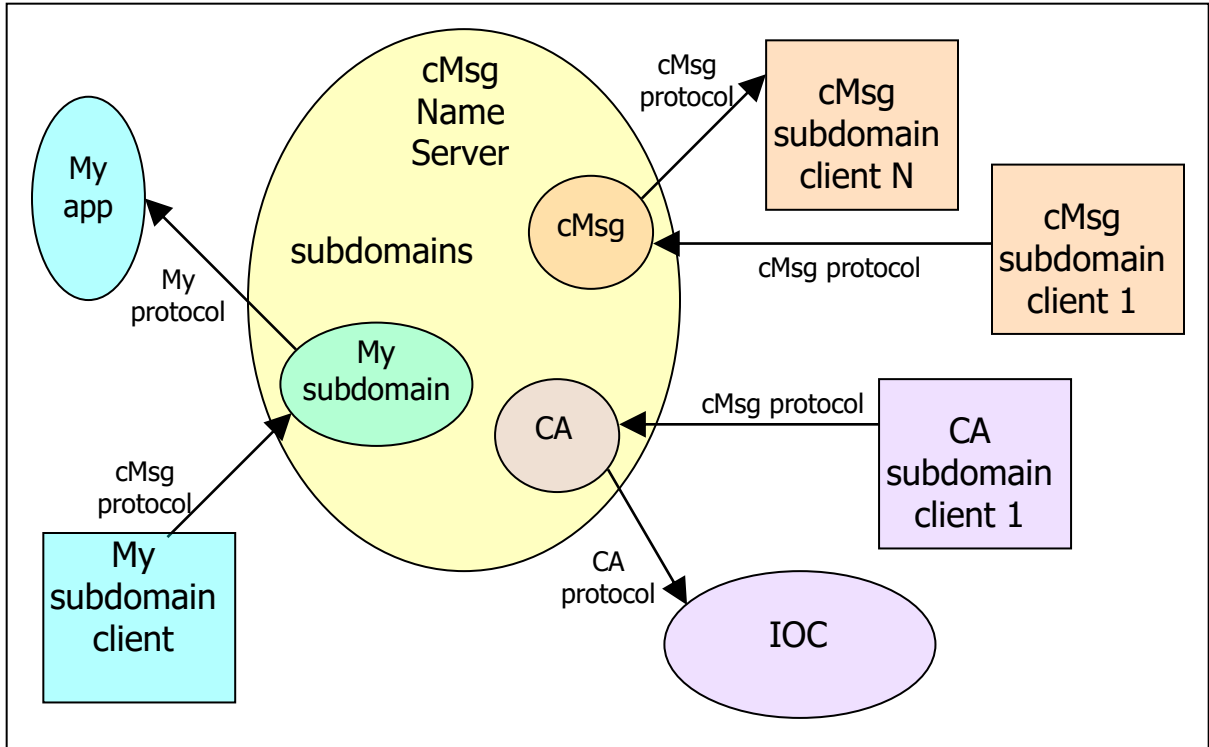
1.3. Proxy system

The most powerful customization of the cMsg package involves adding new subdomains to the built-in cMsg domain. In the cMsg domain a proxy server (provided) actually implements the messaging system and does all the work. The cMsg domain client code simply transports messages, subscription requests, etc. to the server. This is done in a completely transparent manner so that the client does not know that a remote server is involved.

Developers implement the messaging system using a subdomain interface (Java 8 or later) which is used by the cMsg domain server to actually do the work. Furthermore, subdomain classes can be loaded dynamically by the server as long as the class files are in the server classpath.

The major advantage of using proxy implementations is that the client nodes do not need access to licenses, libraries, etc. that are specific to the underlying messaging system.

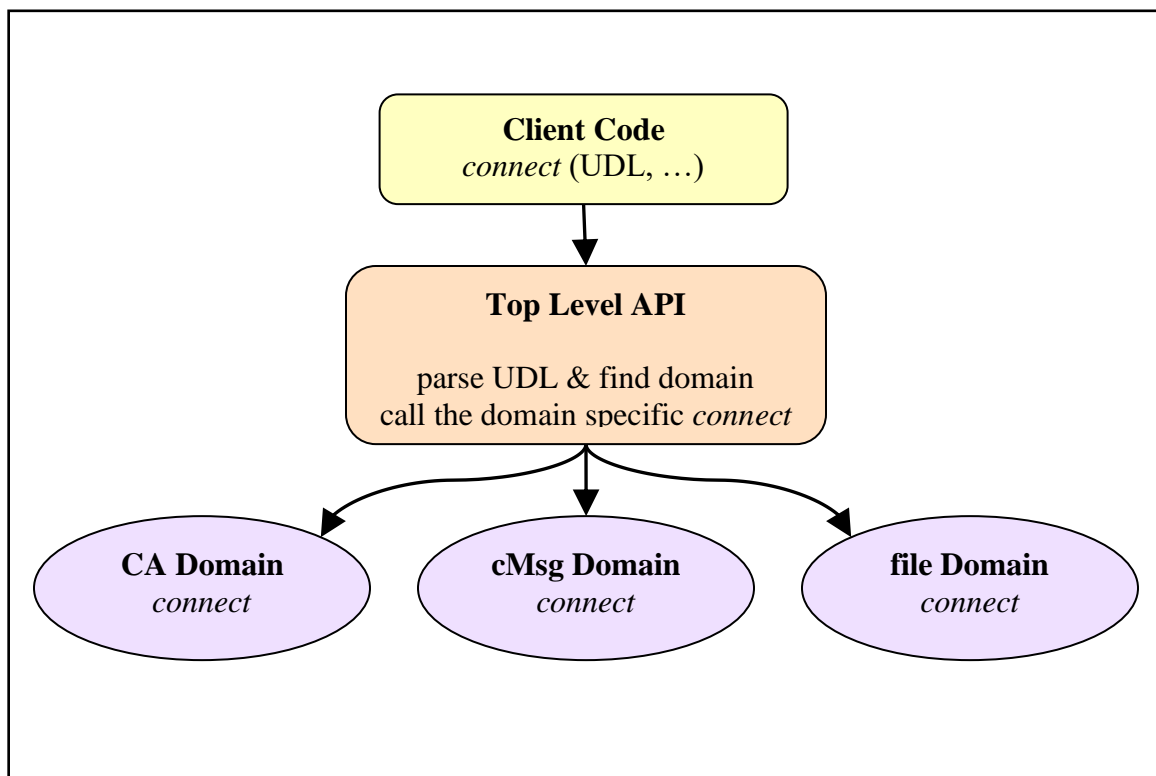
These need only be available on the machine where the server runs. For example, access to messaging systems that are not available under VxWorks or on Solaris can be made available to VxWorks or Solaris clients through the proxy server. See the example below and Section 3 for details.



Chapter 2

2. Framework

Let's begin by describing the general way in which both Java and C domains are structured. The `cMsg` package acts as a multiplexer. The top level user interface simply redirects the API calls to a specific implementation or domain. This is done simply by parsing the UDL in the "connect" call, determining the domain from the UDL and then passing the calls on to the domain level. The figure below shows graphically what happens to the connect call, but the same applies to all API calls.



There are some domains which exist only in Java and those that exist in C, C++, and Java. A domain with versions written in multiple languages must all use the same communication protocol. Another important note for the domain developer is that because clients can be multithreaded, there is the possibility that each function or method

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may be called simultaneously by different threads. In other words, **code which implements a domain must be thread-safe**.

2.1. Java

In order to create a new cMsg domain that plugs into the cMsg client framework, developers need to create a class that implements the cMsgDomainInterface interface or (much easier) extends the domain adapter class cMsgDomainAdapter. Both of these java files are in the <cMsg dir>/java/org/jlab/coda/cMsg/common directory. The best way to learn how to do this is to view the programmer's guide (the javadocs). The comments in the javadocs give a nice explanation about what each class and method is about. For examples of domains look at the domains listed in the table below.

Start by choosing a **unique** (case insensitive) name for your domain. Already existing names and their associated implementations are in the following table.

Domain Name	Class File Name
cMsg	org/jlab/coda/cMsg/cMsgDomain/client/cMsg.java
rc	org/jlab/coda/cMsg/RCDomain/RunControl.java
rcm	org/jlab/coda/cMsg/RCMulticastDomain/RCMulticast.java
rCS	org/jlab/coda/cMsg/RCServerDomain/RCServer.java
emu	org/jlab/coda/cMsg/EmuDomain/EmuClient.java
TCPS	org/jlab/coda/cMsg/TCPSDomain/TCPS.java
file	org/jlab/coda/cMsg/FileDomain/File.java
CA	org/jlab/coda/cMsg/CADomain/CA.java

Once you have a unique name, the UDL to access your domain's server will look like:

```
cMsg:<domain name>://<domain specific stuff>
```

In your domain-implementing class, you will have access to strings containing both the full UDL and just the <domain specific stuff>. Parse the UDL and pull out all necessary information. Usually information on how to reach the server is contained in the <domain specific stuff> as well as anything else you find necessary.

After the new domain is created, the question remains as to how a cMsg client can access it. The means by which this is achieved can be seen by looking inside the org/jlab/coda/cMsg/cMsg.java file. The domains listed above are provided with the software package and their location is hard coded into that file in the "createDomainConnection" method. The user is free, of course, to edit cMsg.java to include new domains and then recompile. However, an easier alternative is to give a flag to the JVM when running the client. This flag must be of the form:

```
-D<myDomain>=<myDomain'sClassName>,
```

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where the specified class must be in your classpath. For example, if I have a domain called “pow” and that is implemented in a java file whose full name (including package) is bam.java and my client code is in a class called crash.java, then I would run my client with a command like:

```
java -Dpow=bam crash
```

Note that domain names are not case sensitive, but dots are not allowed in domain names.

2.2. C

Similarly, developers need to provide a library that contains an appropriate set of functions that implement the API in the C language. In this case, new domains may be added either dynamically or statically.

2.2.1. Static

If adding statically, a bit of code editing must be done. In the C code directory there is a file called cMsgPrivate.h. This file contains 2 structures that must be filled – domainFunctions and domainTypeInfo. To get a good idea of how to do this, see the doxygen html pages. A good example of a functioning domain can be found in cMsgDomain.c which is the C implementation of the cMsg domain. Alternatively, a dummy domain implementation exists in src/libsrc/dummyDomain.c and can be used as a template – just fill in the functions with your code and change the “dummy” string with your domain name. This works in conjunction with a dummy client found in src/examples/dummy.c

Just follow these steps:

- 1) Create and fill a structure of type “domainFunctions” with pointers to all the functions implementing the cMsg API.
- 2) In the global space, create and fill a structure of type “domainTypeInfo” in which the first element is a string containing the name of the domain and the second element is the structure with all the function pointers. Make sure the name of this structure is globally unique.
- 3) Now add this structure to the cMsg.c file declaring it extern. For example,
 - a. `Extern domainTypeInfo myDomainTypeInfo;`
- 4) Again in cMsg.c, add it to an existing array of domainTypeInfo structures called dTypeInfo. To do this, go to the function registerPermanentDomains and add 2 lines:
 - a. `dTypeInfo[n].type = (char *)strdup(myDomainTypeInfo.type);`
 - b. `dTypeInfo[n].functions = myDomainTypeInfo.functions;`

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- 5) where n is the next available integer.
- 6) Finally, recompile.

2.2.2. *Dynamic*

If adding dynamically, a shared library must be created. In the shared library, certain functions must be present. The following is a list of the necessary functions:

```
/* Prototypes of the 25 functions which implement all the cMsg tasks. */
int  cmsg_<domain>_connect(const char *myUDL, const char *myName,
                          const char *myDescription, const char *UDLremainder, void **domainId);
int  cmsg_<domain>_reconnect(void *domainId);
int  cmsg_<domain>_send(void *domainId, void *msg);
int  cmsg_<domain>_syncSend(void *domainId, void *msg, int *response);
int  cmsg_<domain>_flush(void *domainId);
int  cmsg_<domain>_subscribe(void *domainId, const char *subject, const char *type,
                             cMsgCallbackFunc *callback, void *userArg,
                             cMsgSubscribeConfig *config, void **handle);
int  cmsg_<domain>_unsubscribe(void *domainId, void *handle);
int  cmsg_<domain>_subscriptionPause (void *domainId, void *handle);
int  cmsg_<domain>_subscriptionResume(void *domainId, void *handle);
int  cmsg_<domain>_subscriptionQueueClear(void *domainId, void *handle);
int  cmsg_<domain>_subscriptionQueueCount(void *domainId, void *handle, int *count);
int  cmsg_<domain>_subscriptionQueueIsFull(void *domainId, void *handle, int *full);
int  cmsg_<domain>_subscriptionMessagesTotal(void *domainId, void *handle,
                                             int *total);
int  cmsg_<domain>_subscribeAndGet(void *domainId, const char *subject,
                                   const char *type, const struct timespec *timeout,
                                   void **replyMsg);
int  cmsg_<domain>_sendAndGet(void *domainId, void *sendMsg,
                              const struct timespec *timeout, void **replyMsg);
int  cmsg_<domain>_monitor(void *domainId, const char *command, void **replyMsg);
int  cmsg_<domain>_start(void *domainId);
int  cmsg_<domain>_stop(void *domainId);
int  cmsg_<domain>_disconnect(void *domainId);
int  cmsg_<domain>_shutdownClients(void *domainId, const char *client, int flag);
int  cmsg_<domain>_shutdownServers(void *domainId, const char *server, int flag);
int  cmsg_<domain>_setShutdownHandler(void *domainId, cMsgShutdownHandler *handler,
                                      void *userArg);
int  cmsg_<domain>_isConnected(void *domainId, int *connected);
int  cmsg_<domain>_setUDL(void *domainId, const char *udl, const char *remainder);
int  cmsg_<domain>_getCurrentUDL(void *domainId, char **udl);
int  cmsg_<domain>_getServerHost(void *domainId, const char **ipAddress);
int  cmsg_<domain>_getServerPort(void *domainId, int *port);
int  cmsg_<domain>_getInfo(void *domainId, const char *command, char **string);
```

where “<domain>” is the domain name in all lowercase letters. Files containing these functions must be compiled into a shared library with the specific name `libcmsg<domain>.so` where `domain` is the domain name in all lowercase letters. In this way, a `cMsg` application will parse a given UDL, find the domain, and know which library to dynamically load. If the library is in the `LD_LIBRARY_PATH` environmental variable, then everything should be fine.

To reiterate, just follow these steps:

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- 1) Create a file or files of the above listed functions.
- 2) Compile everything into a shared library with the name libcmmsg<domain>.so, domain being all lowercase.
- 3) When compiling your cMsg application that uses this domain, link it with this shared library as well as against libcmmsg.so and libcmmsgRegex.so.
- 4) Run your application.

An example is provided in 2 files: dummyDomain.c and dummy.c. As the name indicates, the dummyDomain.c file implements an example domain which does nothing except print something out each time a function is called. The file dummy.c implements an application which uses the dummy domain. Using these 2 files as a template should make domain development quite simple.

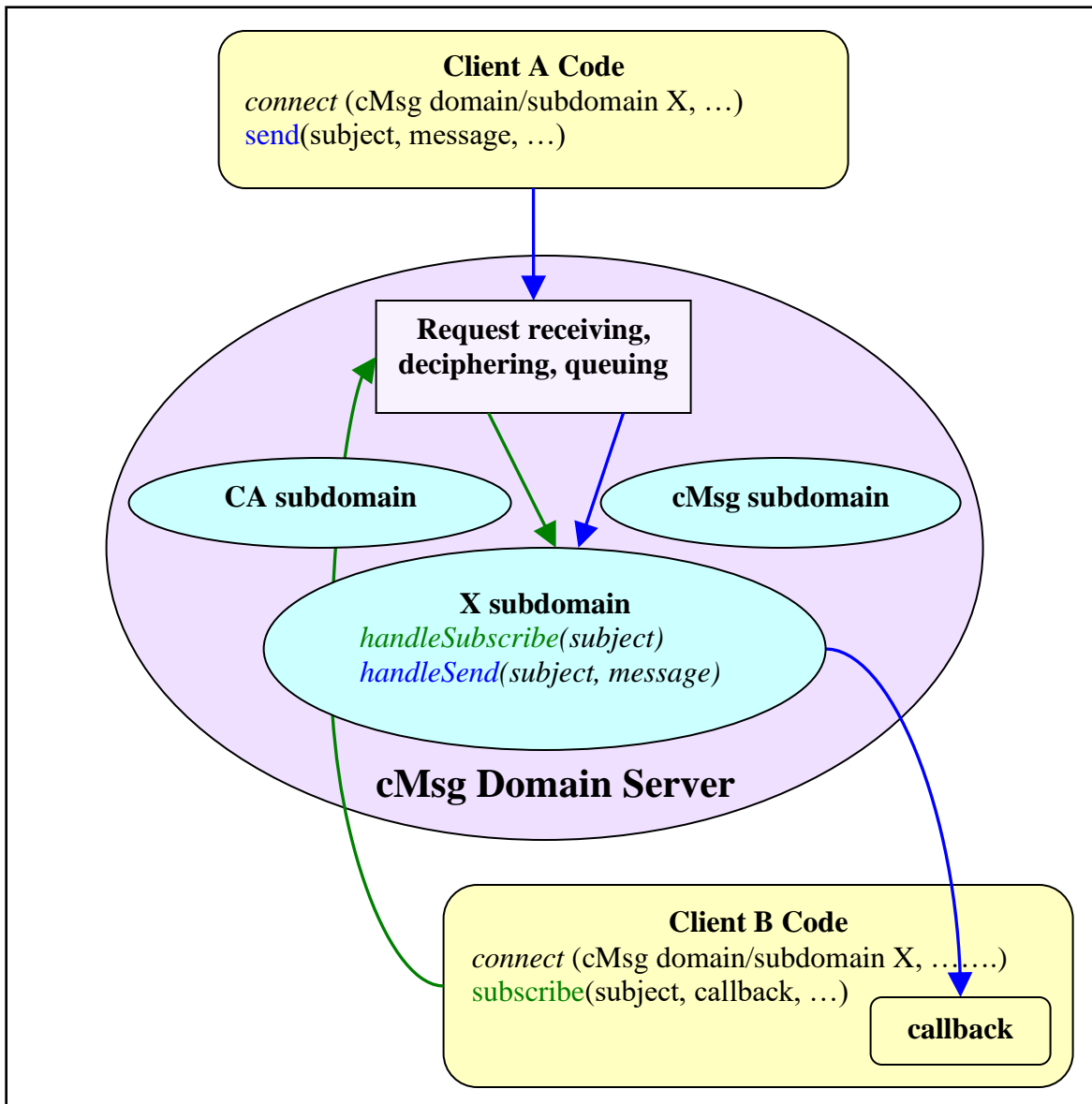
Chapter 3

3. Proxy Server

The cMsg domain is implemented with a server. All client API calls are directed to this server which carries out the desired actions. Because of the way this server is structured, it is also possible to use it as a proxy server. The part of the server which receives, deciphers, and queues up requests is distinct from the part which carries out the requests. In fact, for a single client, all requests are carried out by a single object which implements a specific interface – the cMsgSubdomainInterface. In actual practice, it is easier to subclass cMsgSubdomainAdapter which already implements some minimum functionality in which default methods return “Not Implemented” for all messaging functions. Instead of listing and describing all methods of the interface, it’s easier to read the javadoc where such is already done for a complete description of the interface.

The object that handles this real functionality we call a subdomain handler with the idea that different classes that implement this interface can handle the messages in their own way (their own subdomain). Creating a new cMsg subdomain is the most powerful way of customizing cMsg. Messages published to the cMsg domain are transparently transferred from the client to the server, then passed on to an instance of a subdomain class for transport and delivery.

The diagram below is a graphical representation of what goes on. There are 2 clients in yellow – client A and client B. The cMsg domain server is the large oval in purple which contains 1 section for receiving requests and 3 different subdomains. Each subdomain is created when a client connects to the cMsg domain server and that specific subdomain. Thus, both clients have already connected to cMsg domain & subdomain X. Client B has subscribed to messages of a certain subject which is shown by green arrows and is ultimately taken care of by the handleSubscribe method of the subdomain. Client A has sent messages with that same subject and is shown with blue arrows and is ultimately taken care of by the handleSend method. Finally, client B received those messages from the subdomain handler in a callback.



The developer needs to be aware of one very pertinent fact. Clients may connect to the name server in a manner in which there will be several threads processing a single client's requests on the domain server's request queue. Thus, **all methods in the subdomain handler object must be thread-safe**. It is also possible that more than one client of a particular subdomain may be simultaneously connected, thus the subdomain handler class must be careful in handling class static data – i.e. it must be thread-safe.

There are several subdomains already existing that will serve as templates for any developer. There are subdomains for talking to Channel Access (CA), a database (DB), smart sockets (SmartSockets), queuing messages in a database (Queue), queuing messages in files (FileQueue), and logging messages to a file (LogFile). There is also a dummy subdomain (Dummy) that provides a template.

Chapter 4

4. Run Control Communication

Run control communication is a tricky business. Part of the difficulty is getting things to work by means of the cMsg interface, which is not a natural way to implement it. There are 3 run control domains which must all work together:

1. rc domain
2. rc multicast domain
3. rc server domain

The rc domain is available in both C and Java in order to implement the rc client, while the 2 server domains (rc multicast and rc server) are only available in Java and are used by the run control platform.

4.1. RC Domain

When an rc client (CODA component) is created, the UDL is of the form:

```
rc://<host>:<port>/<expid>?&connectTO=<timeout>&ip=<addr>
```

where

- 1) port is the multicast server's UDP listening port and is optional with a default of 45200,
- 2) host is the host on which the multicast server is running and is required. It may be "multicast", "localhost", or in dotted decimal form. If the host = "multicast", multicast packets are sent to the 239.210.0.0 address.
- 3) the experiment id or expid is required and does NOT default to the environmental variable EXPID,
- 4) connectTO is the time to wait in seconds before connect returns a timeout while waiting for the rc server to send a concluding connect message. It defaults to 30 seconds with a value of 0 meaning wait forever,
- 5) ip is the IP address in dotted decimal which the rc server or agent must use to connect to this client

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How this works out in practice is that host="multicast" is used exclusively. This allows the run control platform to be located anywhere and yet allows all clients to find it. In the connect function, each second, one round of UDP multicast packets is sent. In each round, a single packet is sent on each interface that is "up, staggered by 0.2 seconds to prevent the rc multicast server from being bombarded on all interfaces at once. The multicasting continues until the rc server finishes the connect by making a TCP connection to the rc client's internal TCP listening socket and sending it a "this-is-the-connect-finish" message.

In its initial communication with a multicast server, the rc client sends its cMsg version, TCP port, current time (currently unused), name, expid, and a list of all its local network & broadcast addresses as strings in dotted-decimal. It only sends unique, IPv4, non-loopback addresses from network interfaces which are "up". An exception to this is if the UDL specifies the "ip" tag. In that case, only the single, given address and its corresponding broadcast address is sent in lieu of the entire list. The server takes this information and passes it to an rc server in the form of a list of UDLs which then uses the UDLs to connect back to the rc client.

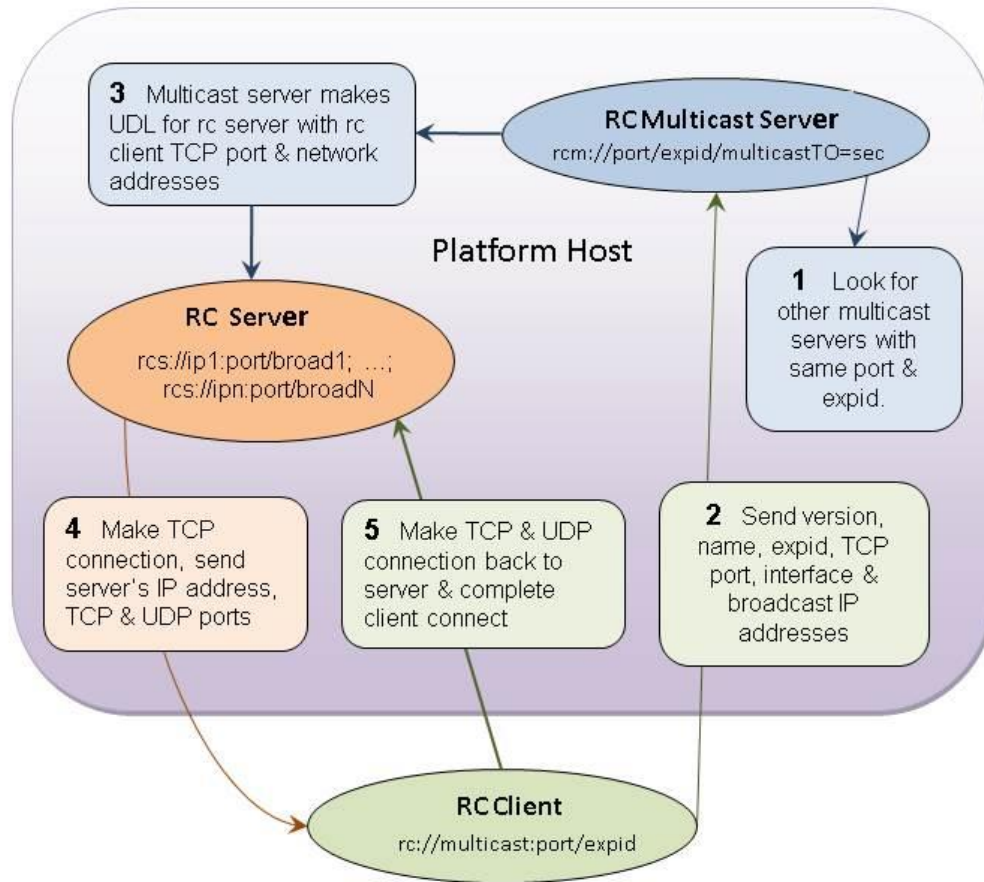
Meanwhile, the rc client waits for the rc server to complete the connect. By default, it waits 30 seconds before timing out. This can be changed by specifying a timeout in the UDL with a value of "0" meaning forever.

Eventually, the rc server connects to the client's TCP listening socket and sends a "this-is-the-connect-finish" message. Once received, the multicasting is stopped and the client makes 2 connections back to the server using information contained in that message. That information includes the server's IP address used to make the initial connection and the TCP & UDP ports it's listening on. When a UDP socket is "connected" to a remote address, packets may only be sent to and received from that address and provides a measure of security. These last connections are used to send messages to run control.

One more thing, the client can do a monitor call which pings the multicast server in order to obtain a list of its IP addresses and its host name. Although broadcast addresses, cMsg version, port, and expid are sent, they are not included in the message returned to the caller.

Below is a simplified diagram of the connection process:

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4.2. RC Multicast Domain

Creating an rc multicast server (rcm domain) to receive the communications of rc clients is done by specifying a UDL in the form:

```
rcm://<udpPort>/<expid>?multicastTO=<timeout>
```

The `udpPort` is the value of the UPD listening port which defaults to 45200 if not specified. The `expid` is required, and an optional timeout in seconds, which default to 2 seconds, can be specified to be used when searching for other rcm servers with the same port and expid.

The first thing an rc multicast server does is multicast trying to locate another rc multicast servers using the same port and expid. If one is found, an exception is thrown and no server started.

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The multicast server receives, among other things, lists of ip addresses from the client and if the client's expid matches it own, places them into cMsg message payloads as String arrays labeled "IpAddresses" and "BroadcastAddresses". This message also contains the client's TCP port and name. It is passed to all callbacks of the multicast server (at least one callback must be created in order to handle valid client connections). In the run control platform, this callback creates a UDL for the rc server domain which is a semicolon-separated list of smaller UDLs. Each small UDL looks like:

```
rcs://<ip>:<port>/<broadcast>
```

where "ip" and "broadcast" are corresponding network interface & broadcast addresses of the rc client and port is the TCP listening port of the client.

The callback does more than this since it must also handle special cases, such as what to do when a client dies and comes back. But the scenario above is what happens in a first time connection.

4.3. RC Server Domain

The rc server domain is the means that a run control agent uses to talk to its corresponding CODA component. As discussed immediately above, the full UDL is a semicolon-separated list of any number of smaller UDLs:

```
rcs://<ip1>:<port>/<broadcast1>; ... ;rcs://<ipN>:<port>/<broadcastN>
```

where "ip" is a dot-decimal format ip address of the rc client, "port" is the TCP port the rc client is listening on (there should be only one, first is used), and "broadcast" is the broadcast address corresponding to "ip".

By using a list of UDLs as the full UDL itself, all client ip addresses can be passed to the rc server object. When parsing the full UDL, that server will extract all ip addresses and make a list of them, ordered so that those on the same subnets as the rc server's host come first. These addresses are then tried one-by-one until a successful connection is made back to the client's TCP listening thread. The server can use this TCP connection to: 1) finish rc client connect, 2) abort rc client connect, 3) ping client, and 4) send messages client is subscribed to.

Once a TCP connection is made, the first thing the server does is send a cMsg message to it comprising the last part of the rc client connect call. This message contains the client ip address used to make the connection in a payload called "clientIp" (currently unused) and the server ip address used to make the connection in a payload called "serverIp". The text holds the UDP port and the userInt holds the TCP port which the server is listening on for client transmissions. The client takes this info and establishes a TCP connection back to the rc server on its given "serverIP" address and TCP port. It also creates a UDP connection back to the server on the same address and the given UDP port. At this point,

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the rc client's connect call is complete. All messages sent to the server go through these 2 connections and not the TCP connection established by the server to the client.