cMsg 6.0 User's Guide

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Chapter 1

1. Introduction

The cMsg package is designed to provide client programs with a uniform interface to an underlying messaging system via an API powerful enough to encompass asynchronous publish/subscribe and synchronous peer-to-peer messaging. The advantage of using the cMsg API is that client programs need not change if the underlying messaging system is modified or replaced.

But cMsg provides much more than a simple API. The package includes a number of built-in messaging systems, including a complete, stand-alone, asynchronous publish/subscribe and synchronous peer-to-peer messaging system, as well as a persistent network queuing system. Although cMsg is highly customizable and extendable, most users will simply use one of the built-in messaging systems. In addition, a number of useful utilities and examples are provided.

If you are familiar with the publish/subscribe and peer-to-peer paradigms and want to jump right in and learn how to use the cMsg package, skip to the tutorial sections or look at the example programs, and refer back to the next few sections as needed.
The cMsg package can be used at a number of levels, i.e. as an:

- 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

The first three levels are primarily of interest to cMsg developers (see the cMsg Developer's Guide). In the rest of this document we describe how to use the built-in messaging systems.

1.1. Asynchronous publish/subscribe messaging

The publish/subscribe messaging paradigm is quite powerful, and is commonly used in business and industry. Briefly, in a publish/subscribe system producers publish messages to abstract subjects, and consumers subscribe to subjects they are interested in. A message published to a subject may be delivered to any number of consumers (one-to-many messaging). A client can be both a producer and consumer of messages.

Producers do not know nor care if any clients are subscribed to the subjects they publish to, and consumers neither know nor care about the producers who publish to the subjects they subscribe to.

Note that an additional message field, “type”, plays a similar role as the subject field described above.

1.2. Synchronous peer-to-peer messaging

Publish/subscribe messaging is asynchronous in that neither producer nor consumer know about each other’s existence. The cMsg API also includes a number of synchronous messaging mechanisms, in which there is some level of direct communication between the producer and consumer of a message. These range from simple status notifications, which may provide only partial information concerning the status of the producer/consumer transaction, to direct, end-to-end communication between a single producer and a single consumer.

1.3. Implementation

cMsg clients can be written in Java (8 or higher), and in C/C++ on Unix (Linux, MacOS X). We provide javadoc and doxygen docs to document the full Java and C/C++ client API. Note for developers: cMsg domains can be written in C or Java, but subdomains only in Java.

1.4. Domains

One term that will be used constantly through this manual is “domain”. In the full implementation of pub/sub and other messaging systems that we are now describing, the cMsg API is actually a top layer which provides multiplexing between different underlying communication systems. Each of these underlying communication systems is referred to as a “domain”. The domain which includes the full pub/sub implementation we call the cMsg domain. Other domains exist which, for example, talk to EPICS channel access or write messages to a file for archiving.

1.5. Difference with cMsg 5.2

The only ways in which this version is different from cMsg 5.2 are bug fixes and a change in the emu domain communication protocol in which the client can make multiple socket connections to the server in order to increase the data rate.

Chapter 2

2. Getting, Building, and Installing cMsg

You must install Java version 8 or higher since all pre-built CODA jar files are compiled with it. If you only plan to run C/C++ clients (i.e. if you will use someone else's cMsg server) you can skip the Java installation. If you only plan to use Java domains and clients you can skip the C/C++ installation.

2.1. Getting cMsg

The cMsg package documentation can be found on the JLab Data Acquisition Group CODA wiki at http://coda.jlab.org. However, all this site does is direct one to the github repository in which the package is stored. For Java users, a pre-built jar file is already contained in the code downloaded from github and usually is all that is needed.

To install all of cMsg do:

1) git clone https://github.com/JeffersonLab/cMsg.git

This will give you a full cMsg distribution with the top level directory being cMsg. The documentation is available on the above-mentioned web site but also exists in the **doc** subdirectory of the full distribution.

2.2. Compiling C/C++ Code

This software is compiled using a software package called SCons. SCons is written in python, thus to use this build system with cMsg, both python and SCons packages need previous installation. If your system does not have one or the other, go to the http://www.python.org/ and http://www.scons.org/ websites for downloading.

The SCons files needed for compiling are already included as part of the cMsg distribution. To compile, the user needs merely to run "scons" in the top level cMsg directory. To compile and install libraries and header files, first define the CODA

environmental variable containing the directory in which to install things and then run "scons install". Listed below are options that can be given to the “scons” command:

scons option	action
-h	print out help
-c	remove all generated files
install	make C and C++ library code and binaries; place libraries & binaries in architecture-specific directories and headers in an include directory
install -c	remove all installed headers, libraries, and executables for C, C++
tar	create a tar file (cMsg-5.x.tgz) of the cMsg top level directory and put in ./tar directory
doc	generate html documentation from javadoc and doxygen comments in the source code and put in ./doc directory
undoc	remove the doc/javadoc and doc/doxygen/C & CC directories containing all the generated documentation
--prefix=<dir>	use base directory <dir> when doing install. Defaults to CODA environmental variable. Libs go in <dir>/<arch>/lib, headers in <dir>/<arch>/include and executables in <dir>/<arch>/bin
--dbg	compile with debug flag
--32bits	compile 32-bit libraries & executables on 64-bit system
--incdir=<dir>	copy header files to directory <dir> when doing install
--libdir=<dir>	copy library files to directory <dir> when doing install
--bindir=<dir>	copy executable files to directory <dir> when doing install

Note that currently only Linux, and Mac OS operating systems are supported. The libraries and executables are installed into the $CODA/<arch>/lib and bin subdirectories (eg. ...Linux-x86_64/lib). Be sure to change your LD_LIBRARY_PATH environmental variable to include the correct lib directory.

2.3. Compiling Java

One can find the pre-built cMsg-5.2.jar file in the repository in the **java/jars/java8** directory or it can be generated. In either case, put the jar file into your classpath and run your java application.

If you're using the pre-built jar file, java version 8 or higher is necessary since it was compiled with that version. Also, when generating it, it’s advisable to use java version 8 or higher since all other pre-built CODA jar files have been compiled with java 8.

If you wish to recompile the java jar, ant must be installed on your system (http://ant.apache.org). Simply execute “ant jar” in the top level directory. To get a list of options with ant, type “ant help”. Following is a table of the available options:

ant command	action
ant, ant compile	compile all java source code
ant help	print out usage
ant env	print out value of build file variables
ant clean	remove all class files
ant cleanall	remove all generated files - not including documentation
ant jar	compile and create cmsg jar file
ant install	create cmsg jar file and install all jars into 'prefix' if given on command line by -Dprefix=dir', else install into CODA if defined (ET jar file is not installed)
ant uninstall	remove all jar files previously installed into 'prefix' if given on command line by -Dprefix=dir', else installed into CODA if defined (ET jar file is not removed)
ant all	do clean, compile, then create cmsg jar file
ant javadoc	create javadoc documentation for user
ant developdoc	create javadoc documentation for user & developer
ant undoc	remove all javadoc documentation
ant prepare	create necessary directories

The generated jar file is placed in **build/lib**. Included in the **java/jars** subdirectory are all auxiliary jar files used by the built-in domains and subdomains. Thus, to use the Channel Access or the SmartSockets (sub)domains the user must include the necessary jar files in the classpath. These (all except the ET jar file) are installed when executing "ant install". Check the individual package web sites for more information.

2.4. Building Documentation

All documentation is available from http://coda.jlab.org.

However, if using the downloaded distribution, some of the documentation needs to be generated and some already exists. For existing docs look in **doc/users_guide** and **doc/developers_guide** for pdf and Word format documents.

Some of the documentation is in the source code itself and must be generated and placed into its own directory. The java code is documented with javadoc and the C/C++ code is documented with doxygen comments.

To generate all the these docs, from the top level directory type:

```
scons doc
```

To remove it all type:

```
scons undoc
```

The javadoc is placed in the **doc/javadoc** directory. The doxygen docs for C code are placed in the **doc/doxygen/C/html** directory, and the doxygen docs for C++ code are placed in the **doc/doxygen/CC/html** directory. To view the html documentation, just point your browser to the index.html file in each of those directories.

Alternatively, just the java documentation can be generated by typing

```
ant Javadoc
```

for user-level documentation, or

```
ant developdoc
```

for developer-level documentation. To remove it:

```
ant undoc
```

Chapter 3

3. Messaging Basics

The one thing that ties together all messaging systems under a single umbrella (besides the top layer API) is the type of messages sent between cMsg users. These messages are containers that hold a number of user and system settable fields. The cMsg system itself takes care of setting many fields, including sender, senderHost, senderTime, receiver, receiverHost, receiverTime. In fact, a history can be kept in each message of where it has been.

3.1. Settable fields

For the user there are two types of settable fields. The first type of field is limited in number but efficiently handled. This consists of the subject and type fields (strings) which are used to determine who receives the message and also the text (string), byteArray, userInt (32 bit integer), and userTime (64 bit integer) fields. The second type is contained in a "payload" which (though handled less efficiently than the first type) can contain any number of any type of int, float, double, strings, cMsg messages, binary arrays, and arrays of any of these types. This allows tremendous flexibility. After the fields are set, the message can be published. A message can be published many times, and user fields can be modified in between as desired.

Note that the ability for a message to carry other messages as part of its load allows for some interesting possibilities. One such possibility is storing/archiving and restoration of stored/archived messages. Also note that the cMsg system uses the payload to store message metadata. It reserves all payload items whose names begin with the string "cmsg" for itself. For example, the history of a message's sender name, send time, and send host are stored in the payload fields called cMsgSenderNameHistory, cMsgSenderHostHistory, and cMsgSenderTimeHistory.

There are too many methods/routines that modify messages to list them all here. View the API documentation in either the javadocs or doxygen docs to see the whole list and get an explanation of each.

3.2. Matching with subscriptions

In all cases, the subject and type fields determine how messages are delivered. Consumers can subscribe to any number of subject/type combinations, and must provide a callback for each (callbacks need not be unique). For those unfamiliar with the term, a callback is a function (C) or an object's method (Java/C++) that is called when a message matching the subscription's subject and type arrives at the client. The message is passed in as a parameter to the function/method.

In the cMsg (pub/sub) domain, the wildcard characters "*", "?", and "#" are allowed in subscriptions' subject and type, where "*" matches any number of characters, "?" matches a single character, and "#" matches one or no positive integer. Also, wildcard constructs like {i>5 | i=4} can be used to match a range of positive integers which meet the conditions in the parentheses. The logic symbols >, <, =, |, & are allowed along with the letter i, any positive integers, and spaces. As an example, a subscription to the subject abc{i>22 & i<26} will match a message with the subjects abc23, abc24, and abc25.

The start() method enables delivery of messages to the callbacks, and the stop() method stops delivery. If delivery is not enabled, messages will be lost to the client. A single message may be delivered to many callbacks in a single client. Note that if a client subscribes to a subject/type and then publishes to the same subject/type, it will receive the message it published.

3.3. XML

A message may be converted into an XML string. In the Java implementation, the various ***toString*** methods do this and the capability to form a message object from an XML string exists as well. In C/C++ only the ability to convert the message into a string exists. There is some control over whether binary is converted, a compact form is used, or if message metadata is made visible.

Chapter 4

4. Domains and Universal Domain Locators

Fundamental to cMsg is the notion of a domain, or messaging space. The cMsg API is actually a top layer which provides multiplexing between different underlying communication systems. Each of these underlying communication systems is referred to as a "domain". Clients can connect to one or more domains, but subscriptions and messaging activity generally are specific to individual domains. I.e. a publication or subscription in one domain normally has no effect in any other domain. Note that although inter-domain communication in general is not supported, the cMsg gateway utility can bridge domains under certain circumstances. Also, user-written domains may implement inter-domain communication.

Domains are specified via a Universal Domain Locator or UDL. When connecting to a domain, clients supply three pieces of information: the client name, which often needs to be unique (depending on the domain type); a short client description; and the UDL. In analogy with http and other resource locators, the general form of a UDL is:

```
cMsg:domainName://domainInfo?dpar1=val1&dpar2=val2...
```

where the leading cMsg (optional) refers to the cMsg package, domainName identifies the domain, and domainInfo is interpreted by the domain. The optional parameters are domain-specific, and any number of them may be specified. Note that the leading cMsg along with the domainName are NOT case sensitive.

Chapter 5

5. cMsg API

There are a handful of methods/functions that do the main work in cMsg. This interface plus the message-manipulating methods are what the user mainly works with. The following table contains a simplified, generic form of the client API (since the Java and C, and C++ versions have slightly different syntax and differ in the number of methods):

Generic cMsg API	
API Call	**Description**
connect(UDL, description, name)	Connect to cMsg system specified by UDL for client "name"
reconnect()	Reconnect to cMsg system
disconnect()	Disconnect from cMsg system
isConnected()	Is client connected to cMsg system?
send(msg)	Send message asynchronously
flush(timeout)	Flush messages sent from client
syncSend(msg, timeout)	Send message and wait for cMsg system response
sendAndGet(msg, timeout)	Send message and synchronously wait for receiving client to send directed response
subscribe(subject, type, callback, userArg)	Subscribe to messages of given subject & type, registering callback for incoming messages
unsubscribe(sub)	Remove subscription
subscribeAndGet(subject, type, timeout)	Subscribe to subject & type and synchronously wait for one such message
start()	Start receiving messages
stop()	Stop receiving messages
monitor(command)	Synchronous call to request monitoring data
shutdownClients(clients**)**	Command certain clients to shutdown
shutdownServers(servers**)**	Command certain servers to shutdown
setShutdownHandler(handler**)**	Install a shutdown handler
subscriptionPause(sub**)**	Pause message delivery to callback
subscriptionResume(sub**)**	Resume message delivery to callback
subscriptionQueueClear(sub**)**	Clear subscription's message queue
subscriptionQueueCount(sub**)**	Number of messages in subscription's queue
subscriptionQueueIsFull(sub**)**	Is subscription's message queue full?

subscriptionMessagesTotal(sub**)**	Number of messages delivered to callback
setUDL(udl**)**	Reset the UDL for use with reconnect or failover
getCurrentUDL()	Gets the current UDL
getServerHost()	Gets host of server that client is connected to
getServerPort()	Gets TCP port of server that client is connected to
getInfo(command**)**	General purpose I/O routine returns string which depends on the particular domain and command arg

This API contains a number of synchronous functions (syncSend, subscribeAndGet, sendAndGet) simply for the convenience of the user, as each could be constructed from sends and subscribes. The function sendAndGet requires a more detailed explanation. It sends a message in a normal manner while marking it as having been sent by a call to the sendAndGet function. A receiver of that message can then construct a special response that will directed back to the original sender (regardless of its subject and type).

An important detail to keep in mind is that this API may function differently depending on the particulars of each domain's implementation. For example, in one domain "flush" can mean that messages are kept in a buffer until the flush command is issued. In another, however, flush may do nothing as messages are sent immediately during the "send" command. Of course, simply providing an API is of little practical use which is why cMsg contains a single implementation of great flexibility.

Chapter 6

6. Available Domain Implementations

A number of domains are implemented by default in the cMsg package. The most important is the cMsg domain, which implements a full publish/subscribe and peer-to-peer messaging system in one of its subdomains (see below). Note that calls to API functions not supported by a given domain return a "Not Implemented" error (or throw an exception). Developers can easily implement additional Java and/or C domains.

6.1. File Domain

The File domain implements simple logging of messages to a local file, and the form of the UDL is:

```
cMsg:File://<filename>?textOnly=<booleanVal>
```

where filename specifies the name of a file locally accessible to the client, and the file is opened in append mode. By default, the entire message is logged to the file as an XML fragment. If textOnly=true is specified only a timestamp and the text field is logged. Only the send() and syncSend() messaging API functions are supported. Client names need not be unique in this domain. Implemented in both C and Java.

6.2. CA Domain

The CA domain implements a simple interface to EPICS Channel Access, similar to the EZCA package, and the form of the UDL is:

```
cMsg:CA://<channelName>?addr_list=<list>
```

where addr_list specifies the UDP broadcast address list. Supported messaging API functions are send(), which implements a CA put; flush(); subscribeAndGet() which gets the channel value one time and the timeout is in milliseconds; subscribe(), which implements CA "monitor on"; and unsubscribe, which implements "monitor off". Callbacks are executed in their own threads.

Currently access is only supported for dbl values, and the dbl resides in the text field as a string. Also, the CA domain is currently only implemented for Java clients. Client names need not be unique in this domain. Java only.

6.3. CODA online domains

There are three domains not generally accessed directly by cMsg users. They're only used in the CODA online code for run control to talk to or to move data between CODA components (roc, event builder, event recorder, etc.).

There is a special relationship between the rc, rcMulticast, and rcServer domains as they work together to establish run control communications. To find out more about this and about the rcMulticast and rcServer domains, read the cMsg developer's guide.

6.3.1. RC domain

Run control client communication is implemented in this domain. It is used when the user wishes to create a CODA component -- a component aware of all the CODA state transitions. In order to be informed of the transitions, the correct subscriptions must be made in order to receive the appropriate messages. A full treatment of this topic is beyond the scope of this little user guide, so anyone interested in doing this should contact Vardan Gyurjyan. This section on the rc domain is included merely to inform users that this capability is available. For completeness, the UDL is of the form:

```
cMsg: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 is in dotted decimal which the rc server or agent must use to connect to this client

Implemented in C and Java.

6.3.2. Emu domain

The emu domain is used to move data between CODA components. Essentially it is a TCP socket over which data flows. Only the client (data sender) code exists in the cMsg software package. The server (data receiver) side of this domain exists only in the emu software package since that's the only place it's used and it was easier to integrate that way. To find it, look at the org.jlab.code.emu.support.transport directory of the emu java code, at the EmuDomainServer, EmuDomainTcpServer, and EmuDomainUdpListener classes. The UDL is of the form:

```
cMsg:emu://<port>/<expid>/<destCompName>?codaId=<id>&timeout=<sec>&
      bufSize=<size>&tcpSend=<size>&subnet=<ip>&sockets=<count>&noDelay
```

where destCompName is the name of the destination CODA component receiving data (server), id is the sender's CODA component's id, sec is the timeout in seconds to wait for a TCP connection before throwing exception, bufSize is the maximum number of bytes in one message, tcpSend is the TCP send buffer size in bytes, ip the preferred dot-decimal subnet address (broadcast or local ip addr) to communicate over, and noDelay is to turn on TCP_NODELAY.

The only significant way in which cMsg 6.0 is different from 5.2 is that the emu domain communication protocol is different. This is encapsulated in the sockets=<count> portion of the UDL. Multiple sockets can be specified to send data from the client to the server. This was necessary to overcome the observed performance limitations when sending data between ROCs and EBs on a single socket. As such it will only work with emu version 3.0 or later. Implemented in C and Java.

6.4. cMsg domain

6.4.1. Server communication

The cMsg domain involves use of a proxy server whereby client requests are not handled in the client itself, but instead are forwarded to a remote cMsg server that actually performs the work on behalf of the client. Communication between client and server is handled transparently so the user does not know that a server is involved. The server passes the client's request on to a subdomain (a handler object existing in the server). A cMsg server has many subdomain types to choose from and more can easily be added by a developer. Each subdomain handles the client requests in a particular way. Currently the cMsg domain has cMsg, Channel Access, database, queue, file queue, log file, SmartSockets, and Tcpserver subdomains which are described in the next section.

The general form of the cMsg domain UDL is:

```
cMsg:cMsg://<host>:<port>/<subdomain>/<subdomainInfo>?<tag1>=<val1>&<tag2>=<val2>
```

For the host parameter, the user may supply a host name or set it to be “multicast” or “localhost”. If it is set to “localhost”, it resolves to the name of the host running the client. If it is set to “multicast”, then the client does a multicast to find the server using the multicast address of 239.220.0.0. Of course, the user may specify a multicast address in dotted decimal form as well. The port used is the one given, or if nothing is given the defaults for both multicasting and TCP connections are 45000. If multicasting is used, the first cMsg server to respond is chosen. If this is not the desired behavior, just make sure your server is running at a unique multicast address and/or a unique port.

The subdomain parameter specifies a particular subdomain implementation, and subdomainInfo is interpreted by the subdomain as are the subdomain parameters. Some of the peculiarities of this UDL include being able to leave off the initial “cMsg” and if the subdomain is missing it will default to the cMsg subdomain. There are 5 tags that can be used in all subdomains (go here for details):

Tag Name	Description
cmsgpassword	This is the password needed to connect to the server.
multicastTO	This is the timeout in seconds to wait for server responses to multicasting.
regime	It may be “low”, “medium”, or “high” and defaults to “medium”. This refers to the expected data rate from the client. It’s a hint to the server how best to handle this client. The “high” specification is best used by experts. “Low” is for clients sending normal size messages less than 10Hz or so.
domainPort	TCP port of server within cMsg server
subnet	Preferred subnet over which to connect to server (broadcast addr or local IP address)

Clients can chose to send messages to the server using either TCP or UDP. This is done by setting a field in the message to be sent. If using a C client, the UDP send is roughly twice as fast as the TCP. In Java there is little difference, but see the API for details. The call to flush() does nothing in the cMsg domain.

Clients using the cMsg domain have the capability to failover to another server when the server they are connected to dies. To use this feature simply supply a semicolon separated list of UDLs in place of a single UDL when connecting to the server. If the client cannot connect to the first UDL on the list, the next is tried and so on until a valid connection is made.

If the server should die during the sending or receipt of messages, the software will try to connect to a UDL on the list and continue on. Any subscriptions are propagated to the new server. Of course, a client who has a subscription will potentially miss messages sent during the brief time it is not connected. Take note that any syncSend(),

subscribeAndGet() or sendAndGet() calls will NOT failover, only send(), subscribe(), and unsubscribe() will failover.

The semicolon separated list of UDLs should place the preferred UDL(s) first since it will be given higher priority. If a client is connected to a UDL which is not first in the list and that connection fails, the software will attempt to establish a connection starting with the first UDL on the list and work its way from there (skipping over the UDL that just failed).

A slight variation on the idea of failing over is that of reconnection. Reconnections are possible in the cMsg domain, meaning that all subscriptions (but not the synchronous syncSend, sendAndGet, subscribeAndGet) are maintained through a client's connection to the server being broken and reestablished. For example, if a client only specifies one UDL (and thus will not failover), and the connection to the server has been broken and disconnect has ***not*** been called, the user can call connect() again (reconnect() if using C) to reestablish the connection.

Similarly, if a client has a good connection, the user can force a reconnection to another server. To keep subscriptions and switch to another server, the user can reset the UDL by calling setUDL() and then simply call connect() again. This attempts to make a connection starting with the first UDL of the new list. If a connection to another server already exists, it will be terminated before the new one is made.

6.4.2. Client subscriptions

There are a number of callback issues users should be aware of when using this domain. All subscription callbacks are run in their own thread with their own messages queues. Thus, use thread-safe programming practices when writing callbacks by either not using shared global resources or by protecting them with mutexes. Also, each callback gets delivered a copy of the message arriving at the client, so there is no issue of callbacks interfering with each other by sharing messages.

Since it is possible to have different subscriptions using the same callback, thread-safe coding must be used in such circumstances. It is also possible to have a single callback run in multiple threads by proper configuration of a single subscription. In this case, if the message queue for the subscription begins to fill up, additional threads are started to process messages using the same callback. The above warning about writing a thread-safe callback applies here too.

If the user writes a callback which is designed to accept all matching messages serially, it must be able to "keep up" with the rate of messages arriving in its queue. What happens when that's not the case? Well, TCP provides a back pressure mechanism which will eventually stop message producers from producing any more. The exact chain of events is that once the callback queue is full, the receiving client's TCP buffer will fill up. Once that is full, the cMsg server will not be able to send any more messages to that particular

client. Thus, the threads in the server sending to this client will block. That may mean that queues of messages (waiting to be sent) in the server fill up which, in turn, may mean that some of the server's TCP buffers fill up. And finally, message producing clients may not be able to send to the server any more due to those full TCP buffers. If the producing client is sending messages using UDP, they will simply be dropped (lost). This is a very unlikely scenario but can actually happen.

The way to avoid this problem is to either produce messages at a reasonable rate, make sure the callback does not take an excessive amount of time to run, configure the callback to automatically delete old messages from its queue when the queue fills up, or configure the callback to be run in multiple threads.

There are method/function calls that the user can make to see if a callback's queue is full, see how many messages are in it, or to completely clear the queue. The user may also pause the callback, resume its operation, and find out how many messages in total have been passed to it.

Implemented in C and Java.

Chapter 7

7. Starting the cMsg Domain Server

You must run a cMsg server if you want to connect to the cMsg domain and its subdomains. The server is not needed for the other domains. There are many options some of which require specialized knowledge of how the server(s) work.
The cMsg domain server will produce the following output if run "java org.jlab.coda.cMsg.cMsgDomain.server.cMsgNameServer –h" :

```
Usage: java [-Dport=<tcp listening port>]
            [-DdomainPort=<domain server listening port>]
            [-Dudp=<udp listening port>]
            [-DsubdomainName=<className>]
            [-Dserver=<hostname:serverport>]
            [-Ddebug=<level>]
            [-Dstandalone]
            [-DmonitorOff]
            [-Dpassword=<password>]
            [-Dcloudpassword=<password>]
            [-DlowRegimeSize=<size>]  cMsgNameServer

port           is the TCP port this server listens on
domainPort     is the TCP port this server listens on for connection to
               domain server
udp            is the UDP port this server listens on for multicasts
subdomainName  is the name of a subdomain and className is the name of the
               java class used to implement the subdomain
server         punctuation (not colon) or white space separated list of
               servers in host:port format to connect to in order to gain
               entry to cloud of servers. First successful connection used.
               If no connections made, no error indicated.
 debug         debug output level has acceptable values of:
                      info   for full output
                      warn   for severity of warning or greater
                      error  for severity of error or greater
                      severe for severity of "cannot go on"
                      none   for no debug output (default)
standalone     means no other servers may connect or vice versa,
               is incompatible with "server" option
monitorOff     means monitoring data is NOT sent to client
password       is used to block clients without this password in their UDL's
cloudpassword  is used to join a password-protected cloud or to allow
               servers with this password to join this cloud
lowRegimeSize  for clients of "regime=low" type, this sets the number of
               clients serviced by a single thread
```

7.1. Port Numbers

Starting off with the simplest of options, the default TCP listening port is 45000 but may be set with the "port" option. For a connecting client, be sure to specify that port number in your client's UDL if you use this option and are not using the default. Similarly, the udp listening port (default 45000) can be specified with the "udp" option. Without going into too much detail, this server has another server within. Two connections are made to this interior server, and its TCP listening port may be set with the "domainPort" option (defaults to 45100). Note that multiple cMsg servers on the same node must use different ports for each of these options.

7.2. Subdomains

Developers can easily implement additional subdomains in Java. One can use a subdomain that is ***not*** built in without too much trouble. When starting up the server, add the following option, "-D<subdomainName>=<className>" where subdomainName is the case insensitive name of the subdomain of interest and className is the name of the Java class implementing the subdomain. When the server starts up and the client connects to it, it first checks to see if the subdomain given by the client's UDL matches the above option's subdomain name. If there is no such flag, the environmental variable "CMSG_SUBDOMAIN" is checked to see if it contains the name of the Java class implementing the subdomain. If not, it tries to find the subdomain in the list of those that are built in. More on subdomains can be found in the developer's guide.

7.3. Passwords

The password option is used not so much as a security measure but simply to avoid confusion by isolating servers from each other. Servers that set the password will allow only clients that specify that password to connect. Similarly, clients that specify a password cannot connect to a server that does not. In this way, a password acts as a server name. Clients can multicast to find the server while specifying that password and get a response from that server only (if password is unique). The end of the client's UDL must contain the string "?cmsgpassword=<password>" if it's the first option parameter or the string "&cmsgpassword=<password>" if it's not the first. The cmsgpassword string is case insensitive.

Some of the options are specific to the cMsg subdomain only. These include –Dserver, -Dstandalone, and –Dcloudpassword. These will be explained in the chapter on the cMsg subdomain.

7.4. Clouds

cMsg servers can be grouped or connected into clouds (note: this has nothing to do with cloud computing). In these clouds, clients of a server in a particular cloud can send and receive messages transparently with clients of other servers in the same cloud. The purpose of this is both to load balance and to distribute computing resources. In principle,

there is no reason why all clients couldn't be using the same server. In practice, it might be nice to have clients and their server all on the same node for performance reasons. It might also be nice to occasionally talk to other, remote clients. By having servers join together as part of the same cloud, most of the message traffic can remain local while the occasional message may be sent to or received from a remote client.

To join another cMsg server as part of a cloud, just specify the:

```
-Dserver=host1:port1;host2:port2;hostN:portN
```

option when starting up. The listed host/port combinations may be separated by white space or by any punctuation (except a colon). If white space is used, the whole string will need to be quoted:

```
-Dserver="myhost:33555 yourhost:44555 theirhost:22233"
```

The server being started will try to connect to one of the listed servers starting with the first (left most) and moving to the end (right most). It stops at the first connection made. Once it connects to a single server, it asks that server which other servers it is connected to and connects to those as well. Thus, in a cloud, each server is connected to all of the other servers. These "connections" are nothing more than each server acting as a cMsg client to each of the other servers. I hope that's not too confusing.

The first server in a cloud may specify a password that it expects joining servers to know. That password is given in the:

```
-Dcloudpassword=<password>
```

option. This feature is not meant for security but only to avoid having extraneous servers join random clouds (i.e. for organization).

If a server does not want other servers to join with him (her?) to form a cloud, it needs to be started with the –Dstandalone option.

7.5. Client throughput regime

Last but not least, let me add a word here on the -DlowRegimeSize flag. In order to make a server perform better when serving large numbers (100's to 1000's) of clients, having clients specifying "regime=low" in their UDLs can greatly help. What this tells the server is that "hey, I'm a client that makes few demands" and so the server diverts fewer resources to that client. For any client that sends and receives normal size messages at no more than 10-20 Hz, it would help to use "regime=low". Inside the server, a single thread will service several of these low regime clients by use of the "select" statement or at least its Java equivalent. The –DlowRegimeSize flag sets how many clients are served by such a single thread. It defaults to 20.

For example, if one server has 3000 such clients and the lowRegimeSize is set to 30, then only 100 threads are needed to handle all the clients and everything should work fine. On the other hand, if these clients do not specify “regime=low” in their UDLs, then 3000 threads would be needed on the server to handle them all. This bogs the server down and will cause it to run out of resources such as file descriptors.

Chapter 8

8. Available Subdomain Implementations

A number of subdomains are implemented in the cMsg server, including the cMsg subdomain, which implements a complete asynchronous publish/subscribe and synchronous peer-to-peer system (see below).

8.1. LogFile subdomain

The LogFile subdomain is similar to the File domain, except that the cMsg server performs the logging. Thus multiple clients can log to the same file, whereas in the File domain the file is unique to the client. Only the send() and syncSend() messaging functions are supported. The general form of the LogFile subdomain UDL is:

```
cMsg:cMsg://<host>:<port>/LogFile/<filename>
```

where filename is the name of the logging file used by the server. Messages are logged as XML fragments. Client names need not be unique in this subdomain.

8.2. CA subdomain

The CA subdomain is similar to the CA domain, but again the cMsg server actually executes the CA library commands, not the client. Only the send(), syncSend(), subscribe(), unSubscribe(), and subscribeAndGet() messaging functions are supported. The general form of the CA subdomain UDL is:

```
cMsg:cMsg://<host>:<port>/CA/<channelName>?addr_list=<list>
```

where addr_list specifies the UDP broadcast address list. Client names need not be unique in this subdomain.

8.3. Database subdomain

In the Database subdomain the cMsg server connects to a database and executes the SQL statement appearing in the text field of a message. Currently SQL queries that return data are not supported (e.g. select). Only the send() and syncSend() messaging functions are supported. The general form of the Database subdomain UDL is:

```
cMsg:cMsg://<host>:<port>/Database?driver=<myDriver>&url=<myURL>&
         account=<myAccount>&password=<myPassword>
```

where myDriver is the JDBC driver to use to connect to the database, myURL is the JDBC URL of the database, and optional myAccount and myPassword may be required by the database. Client names need not be unique in this subdomain.

8.4. Queue subdomain

The Queue subdomain implements network-accessible persistent message queues via a JDBC-accessible database. Clients can post messages to the queue via send() or syncSend(), and retrieve messages from the head of the queue via sendAndGet(). The general form of the queue subdomain UDL is:

```
cMsg:cMsg://<host>:<port>/Queue/<queueName>?driver=<myDriver>&
         url=<myURL>&account=<myAccount>&password=<myPassword>
```

where queueName identifies the queue, myDriver is the JDBC driver to use to connect to the database, myURL is the JDBC URL of the database, and optional myAccount and myPassword may be required by the database.

Note that tables are created in the database by the cMsg server to implement the queue. Also, client names need not be unique in this subdomain.

8.5. FileQueue subdomain

The FileQueue subdomain is identical to the queue subdomain except that the message queue is stored in files rather than in a table in a database. This results in lowered performance, but of course no database is needed. If multiple cMsg servers will access the same FileQueue then the file system on which the queue files reside must support Java 1.5-compatible file locking. Only the send(), syncSend(), and sendAndGet() messaging functions are supported. The general form of the FileQueue subdomain UDL is:

```
cMsg:cMsg://<host>:<port>/FileQueue/<queueName>?dir=<myDir>
```

where queueName identifies the queue, and optional myDir specifies the directory in which to store the queue files (default is the current working directory of the cMsg server).

Note that many files are created by the cMsg server to implement the queue, so choose the queue directory carefully. Also, a single directory can support multiple file queues. Client names need not be unique in this subdomain.

8.6. SmartSockets subdomain

The SmartSockets subdomain provides a gateway to the SmartSockets (commercial) publish/subscribe interprocess communication package. Only send(), subscribe(), and

unsubscribe() messaging functions are supported. The general form of the SmartSockets subdomain UDL is:

```
cMsg:cMsg://<host>:<port>/SmartSockets/<projectName>
```

where projectName identifies the SmartSockets project.

Note that since in SmartSockets the messaging system is implemented by a "cloud" of interconnected servers, inter-domain messaging is possible if domains connect to SmartSockets servers within the same cloud. Client names must be unique in this subdomain.

8.7. TcpServer subdomain

The TcpServer subdomain provides access to tcpserver processes running on Unix (tcpserver is part of the CODA data acquisition package at JLab). Only the sendAndGet() messaging function is supported, and communication with the tcpserver is stateless. Commands placed in the request message text field are forwarded to the tcpserver for execution, and the resulting output is returned in the text field of the response message. The general form of the tcpserver subdomain UDL is:

```
cMsg:cMsg://<host>:<port>/TcpServer/<srvHost>:<srvPort>
```

where srvHost and srvPort refer to the host name and port where the tcpserver process is running. Client names need not be unique in this subdomain.

8.8. cMsg subdomain

The cMsg subdomain implements a complete asynchronous publish/subscribe and synchronous peer-to-peer inter-process communication package. All cMsg messaging API functions are supported. Inter-server communication is supported. The general form of the cMsg subdomain UDL is:

```
cMsg:cMsg://<host>:<port>/cMsg/<namespace>/?<tag>=<val>&<tag2>=<val2> ...
```

For the host parameter, the user may supply a host name or set it to be "multicast" or "localhost". If it is set to "localhost", it resolves to the name of the host running the client. If it is set to "multicast", then the client does a multicast to find a server on an unknown host using the multicast address of 239.220.0.0. Of course, the user may specify a multicast address in dotted decimal form as well. The port used is the one given, or if nothing is given the defaults for both multicasting and TCP connections are 45000. If multicasting is used, the first cMsg server to respond is chosen. If this is not the desired behavior, server passwords can be used or just make sure your server is running at a unique multicast address and/or a unique port.

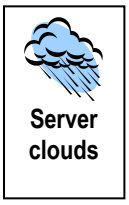
The optional namespace identifies a messaging namespace. A namespace starts with a forward slash and after that may contain only ASCII word characters [a-zA-Z0-9_]. If not supplied, a default namespace is used ("/default"). Client names must be unique in the given namespace. Messages do not cross namespaces. Thus, a client who subscribes to a

subject/type in a particular namespace will only be able to receive messages from a producing client in that same namespace. There are a number of tags that can be used:

Tag Name	Description
cmsgpassword	This is the password needed to connect to the server. Valid for all cMsg subdomains.
multicastTO	This is the timeout in seconds to wait for server responses to multicasting. Valid for all cMsg subdomains.
regime	It may be "low", "medium", or "high" and defaults to "medium". This refers to the expected data rate from the client. It's a hint to the server how best to handle this client. The "high" specification is best used by experts. "Low" is for clients sending normal size messages less than 10Hz or so. Valid for all cMsg subdomains.
domainPort	TCP port of server within cMsg server
failover	It may be "cloud", "cloudonly", or "any" and defaults to "any". This specifies the manner in which to failover from one server to another. If set to "any", failover of client can go to any of the UDLs given in the argument to connect(). If set to "cloud", failover will go to servers in the cloud first, and if none are available, then go to any of the UDLs given to connect(). If set to "cloudonly", failover will only go to servers in the cloud. Valid for the cMsg subdomain only. More on this below.
cloud	It may be "local" or "any" and defaults to "any". This specifies the manner in which to failover to a cloud. If set to "any", failover of client to a server in the cloud will go to any of the cloud servers. If set to "local", failover of client to a server in the cloud will go to a local cloud server first before others are considered. Valid for the cMsg subdomain only. More on this below.
subnet	Preferred dot-decimal subnet over which to connect to server. It may be a broadcast or local IP address. Valid for all cMsg subdomains.

Some of the peculiarities of this UDL include being able to leave off the initial "cMsg" and if the subdomain is missing it will default to the cMsg subdomain.

8.8.1. Servers



The cMsg subdomain is the most complex of all the subdomains. Let's start out by describing the servers and how they connect together (see also 7.4). cMsg servers may be connected together into what is called a cloud. This cloud is only meaningful to clients which use the cMsg subdomain. A client of one of the servers in a cloud can subscribe to messages produced by any client connected to any server in that cloud within the cMsg subdomain. Similarly, a message-producing client can sent to any subscribers in the cloud if it is connected to one of the cloud servers.

To get servers to connect to each other, the "–Dserver=<hostname:serverport>" option must be given to the JVM when starting up all except the first server. In the other words, the first server is started up normally. A second (connecting) server must be started with the above option giving the host and port of the first server as described. Any subsequent servers joining the cloud must also use the above option giving the host and port of any one of the servers already in the cloud.

For example, let's say that we start up a server on the host "hal" on port 45001:

```
Java –server org.jlab.coda.cMsg.cMsgDomain.server.cMsgNameServer
```

Then the second server would be started like:

```
Java –server –Dserver=hal:45001 org.jlab.coda.cMsg.cMsgDomain.server.cMsgNameServer
```

It may be that the first server does not want any one joining him and forming a cloud. In that case the first server would start up with the flag "–Dstandalone" and all joiners would be rejected.

It is also possible to protect a cloud from having just anyone join. A password can be instituted by having the first server start up with the "-Dcloudpassword=<password>" option. If the password were set to say … abracadabra, then we would type the following at the command line:

```
Java –server –Dcloudpassword=abracadabra ... cMsgNameServer
```

Any server which wanted to join that server to make a cloud must have the same option given. All others will be refused.

8.8.2. Clients

Clients using the cMsg subdomain have the capability to failover to another server when the server they are connected to dies. To use this feature simply supply a semicolon separated list of UDLs in place of a single UDL when connecting to the server. If the client cannot connect to the first UDL on the list, the next is tried and so on until a valid connection is made.

If the server should die during the sending or receipt of messages, the software will try to connect to a UDL on the list and continue on. Any subscriptions are propagated to the new server. Of course, a client who has a subscription will potentially miss messages sent during the brief time it is not connected. Take note that any subscribeAndGet() or sendAndGet() calls will NOT failover, only send(), syncSend(), subscribe(), and unsubscribe() will failover.

The semicolon separated list of UDLs should place the preferred UDL(s) first since it will be given higher priority. If a client is connected to a UDL which is not first in the list and that connection fails, the software will attempt to establish a connection starting with the first UDL on the list and work its way from there.

Some of the additional details of failing over are controlled by the tags given in the UDLs used in connecting (see the table above). Each UDL may specify one of its tag/val pairs as “failover=cloud” which allows failing over to the cloud (if the server is a member of one). As long as there is a viable server in the cloud, failovers will only happen to servers in that cloud (as long as they both shall live). If, on the other hand, there are no other servers in the cloud, failovers will continue to the next UDL in the list originally given while connecting. Again, if the client was not at the head of that list at the time of failure, the first UDL is tried again, and the software makes its way down the list from there (but skipping the failed UDL). If the tag/val is specified as “failover=cloudonly”, failovers will only happen to servers in the same cloud. If no other servers exist in that cloud, the client’s connection is broken for good – no more failovers. Finally, if the user specifies “failover=any”, then the client works its way down the UDL list. If a particular UDL in that list specifies “failover=cloud”, then that’s what happens. If it specifies “failover=cloudonly”, that’s what happens from there.

Wait! There are other complications in failovers to take note of. The tag/val pair of “cloud=any” specifies that if failing over to a server in the cloud, it may choose any member of that cloud. However, the tag/val pair of “cloud=local” means that failover will first go to a server in that cloud running on the same host as the client. If there are no local servers available, failover will happen to a remote server.

Let me add a final word here on tag/val pairs which involve the performance of both clients and servers. In order to make the server perform better when serving large numbers (100’s to 1000’s) of clients, specifying “regime=low” can greatly help performance of the server (and therefore all the attached clients as well). What this tells the server is that “hey, I’m a client that makes few demands” and so the server diverts fewer resources to that client. For any client that sends and receives normal size messages at no more than 10-20 Hz, it would help to use “regime=low”.

Chapter 9

9. Utilities and Example Programs

A number of general purpose utility applications are provided. These are fairly simple programs, and may easily be customized.

9.1. cMsgLogger

The cMsgLogger logs messages that match subject/type to the screen, a file, and/or a database. Similar functionality exists in the File domain, and in the LogFile and Queue subdomains:

```
$ java org.jlab.coda.cMsg.apps.cMsgLogger -h
Usage:
 java cMsgLogger [-name name] [-descr description] [-udl domain]
      [-subject subject] [-type type]
      [-screen] [-file filename]
      [-url url] [-table table] [-driver driver] [-account account]
      [-pwd password]
      [-debug] [-verbose]
```

where udl is required, subject and type default to * and *, and display to the screen is default. url is a JDBC url, table is the name of the table to use, and driver, account, and password are used when connecting to the database.

9.2. cMsgQueue

The cMsgQueue utility queues messages to either a database or file-based queuing system, same as the Queue and FileQueue subdomains. Some differences are that in the Queue and FileQueue subdomains all messages are queued, whereas here only messages that match subject/type, specified on the cMsgLogger command line, get queued. Also, here only the creator and user-settable fields are queued, whereas all fields are stored in the two subdomains. Finally, in the subdomains the cMsg server does the work, whereas here the cMsgQueue application does the work.

Clients retrieve from the queue by executing the sendAndGet() method, where the message must be sent to getSubject/getType, also specified on the command line. The

response message returned by the sendAndGet() method is taken off the head of the queue.

To run the cMsgQueue application:

```
$ java org.jlab.coda.cMsg.apps.cMsgQueue -h
Usage:
 java cMsgQueue [-name name] [-descr description] [-udl domain]
                [-subject subject] [-type type]
                [-queue queueName]
                [-getSubject getSubject] [-getType getType]
                [-dir queueDir] [-base fileBase]
                [-url url] [-driver driver] [-account account]
                [-pwd password] [-table table]
```

where udl is required, and queueName, subject, and type default to “default”, “*” and “*”. name defaults to “cMsgQueue:queueName”, and getSubject and getType default to name and “*”.

For file queuing, queueDir specifies the directory to hold the queue files, and fileBase specifies the base for all file names (default is “cMsgQueue_queueName_”).
For database queuing url and driver must be specified, and account and password may be required by the database. table defaults to “cMsgQueue_queueName”. One instance of cMsgQueue can queue to either a file or database, not both.

9.3. cMsgGateway

The cMsgGateway implements simple inter-domain communication for domains that support the send() and subscribe() messaging API functions. The cMsgGateway connects to two domains and subscribes to the same subject/type combination in each. Messages that match the subscription criteria in one domain are cross-posted to the other.
Note that a number of message fields get reset when the gateway forwards or cross-posts the message (senderTime, senderHost, etc.) Unchanged are the creator, subject, type, text, userInt, and userTime fields.

```
$ java org.jlab.coda.cMsg.apps.cMsgGateway  -h
 Usage:
 java cMsgGateway [-subject subject] [-type type]
                  [-name1 name1] [-udl1 udl1] [-descr1 descr1]
                  [-name2 name2] [-udl2 udl2] [-descr2 descr2]
                  [-debug]
```

where udl1 and udl2 are required, and the remainder are optional. Subject and type default to * and * (i.e. subscribe to all subjects and types), and both name1 and name2 default to cMsgGateway.

9.4. cMsgCAGateway

(this utility is not completed yet…ejw, 17-feb-2005)

The cMsgCAGateway utility serves out client data published via cMsg messages as Channel Access or EPICS channels, and thus forms a bridge between the cMsg and EPICS worlds. It is located in the xxx subdirectory.

The cMsgCAGateway is written in C++ and uses the Portable Channel Access Server library. Upon startup it reads a configuration file containing a list of channels to serve, as well as information describing what subjects to subscribe to, how to extract the channel data from the messages, etc. The gateway can also create and serve out new channels on the fly. The initial version serves out read-only data (i.e. no support for CA put() yet), but read-write support is planned for a future release.

To start the cMsgCAGateway:

```
$ cMsgCAGateway -h
 Usage:
 cMsgCAGateway [-name name] [-udl udl] [-descr descr]
               [-cfg config_file] [-debug]
```

Note that due to channel access limitations only one cMsgCAGateway can run on a node at a time.

9.5. cMsgAlarmServer

The cMsgAlarmServer logs alarm messages to a database, file, or to the screen.
The server subscribes to a special subject, set on the command line, and logs specially formatted alarm messages.

The server looks at three fields in the incoming alarm message, other than the subject. The type field contains the alarm channel name, an arbitrary string. The userInt field contains the alarm severity, an arbitrary integer (e.g. you might use 0,1,2,3 for ok,warn,error,severe_error). Finally the text field contains an arbitrary string that is logged along with the channel name, alarm time, and severity.

The server can simultaneously log to a database, file, or the screen, but the nature of the logging is not the same for all three, as the latter two are effectively write-only. Thus for the file or screen the server simply logs the alarm information sequentially.

Database logging is more sophisticated, and four modes are possible, each using a different table. The first two modes record full or partial histories, and the tables may contain many entries per channel. In the second two modes only one entry per channel is kept. Any or all modes may be active simultaneously.

In “fullHistory” mode all messages are logged. In “history” mode only severity changes are logged. I.e. if a message for a channel arrives with severity 1 but the channel is already has severity 1, then the message is ignored.

In “change” mode the latest severity state of each channel is logged, and the time is only modified if the channel changes severity state (analogous to history mode). In “latest” mode only information from the most recent alarm message is kept. To understand the difference between the two modes, imagine a channel that is monitored every minute and has been in severity 0 for a week. In change mode the time field is set to a week ago, while in latest mode it is set to one minute ago.

To start cMsgAlarmServer:

```
$ java cMsgAlarmServer -h
 Usage:
  cMsgAlarmServer [-name name] [-udl udl] [-descr descr]
                  [-subject alarmSubject]
                  [-screen] [-file filename] [-noAppend]
                  [-fullHistory fullHistoryTable] [-history historyTable]
                  [-change changeTable] [-latest latestTable]
                  [-url url] [-driver driver] [-account account]
                  [-pwd password]
                  [-force] [-debug]
```

where name is the unique name of the server (default cMsgAlarmServer), udl denotes the domain to connect to, default descr is “cMsg Alarm Server”, alarmSubject is the subject to subscribe to (default cMsgAlarm), filename is the name of the file to log messages to (default is append mode, use –noAppend to force opening of a new file), url is the database url, driver is the database driver class, and account and password may be required by the database. The four table names correspond to the four logging modes described above. The tables are created if they do not exist. If a table, filename, or screen is not specified that mode is inactive.

9.6. cMsgCommand

```
$ cMsgCommand -h
 Usage:
  cMsgCommand [-u udl] [-n name] [-d description] [-sleep sleepTime]
              [-s subject] [-type type] [-i userInt] [-text text]
```

cMsgCommand is a C++ command line utility that sends a message based on command line parameters. Only the subject, type, userInt, and text fields may be set. sleepTime sets how long after sending the program disconnects (units in microsec, default 1000).

9.7. cMsgReceive

```
$ cMsgReceive -h
usage:
   cMsgReceive [-udl udl] [-n name] [-d description] [-s subject] [-t type]
```

cMsgReceive is a C++ command line utility that subscribes to a subject/type combination and prints a notice when messages arrive. It is a much simplified version of cMsgLogger.

9.8. Example Programs

The cMsg distribution contains a number of Java example programs in java/org/jlab/coda/cMsg/apps, and C/C++ examples in the src/examples and src/execsrc directories (relative to top level directory).

The utility programs described above, also in the Java or C/C++ directories, should be useful as examples as well.

Chapter 10

10. Client and Server Control and Monitoring

10.1. Control

API calls exist to implement selective shutdown of clients and servers. The default client shutdown handler causes the client to exit. Programmers can override this behavior by supplying a custom handler that, e.g., causes the client to simply disconnect from the cMsg system rather than exiting. See the API docs for details.

10.2. Monitoring

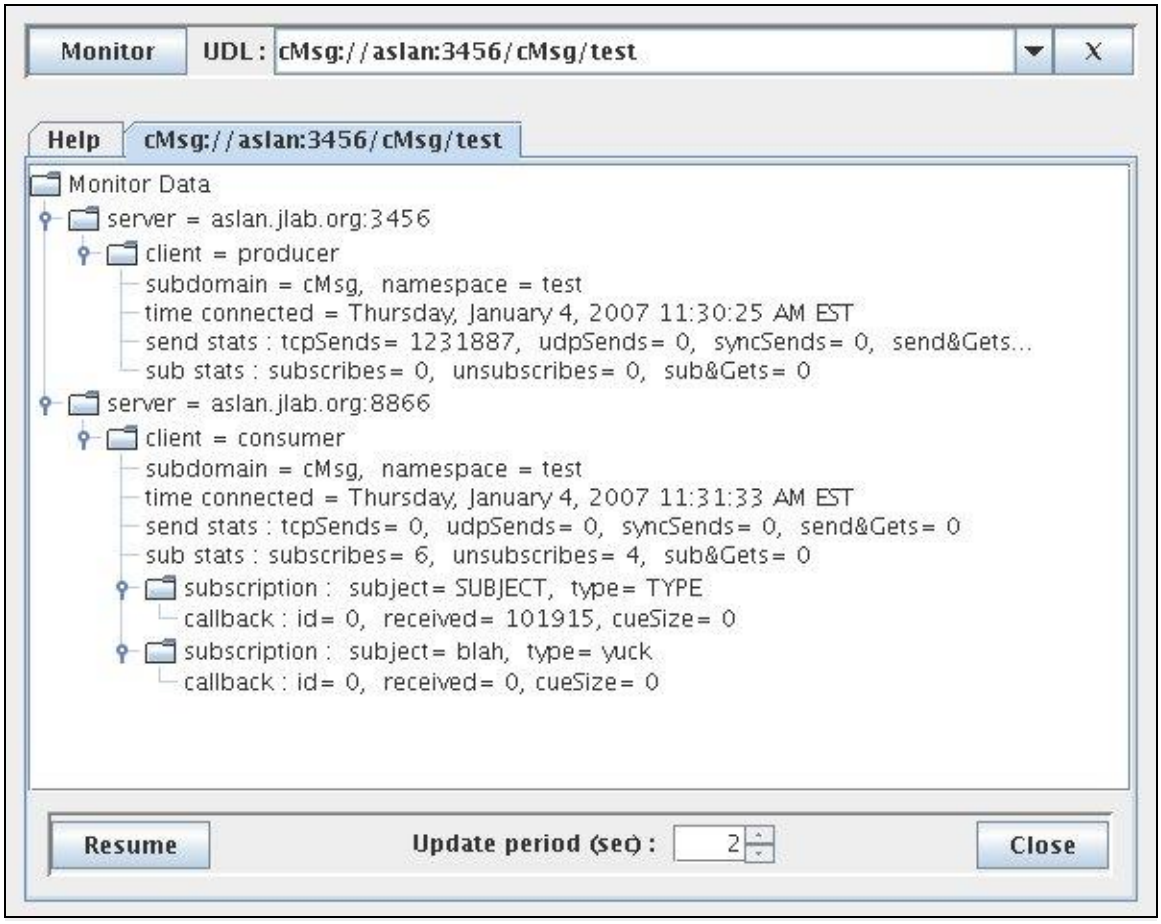
Monitoring is implemented through the **cMsgMonitor**(void *domainId, const char *command, void **replyMsg) function in C and the **monitor**(String command) method in Java, and is completely dependent on the domain implementation. See the API docs for details.

The only monitoring available to date is for the cMsg domain with the most complete information available for the cMsg subdomain. The monitoring data is collected in xml format and can be accessed either through text-based programs which print the xml or through a Java GUI which presents data in a tree.

The “monitor.c” program is an example of how to print out the xml using a C program and the Java class apps.cMsgMonitor is an example of how to do that in Java. However, to get a nice monitor GUI run the following:

```
java org/jlab/coda/cMsg/cMsgDomain/cMsgMonitor/Monitor
```

and the following GUI will appear:



It's fairly self-explanatory. Just type in the UDL, hit "Monitor", and a new tab will be added with all the monitoring information about the cMsg cloud of servers and all their clients. The monitoring can be paused/resumed, closed, and the update period can be changed.

It is possible for the user to add an XML fragment to the monitoring data being sent from a client to the server. In java, the previously mentioned "command" string contains the XML to be added. In C, it is also given in the "command" arg while simultaneously setting the "replyMsg" arg to NULL.

Chapter 11

11. Java Tutorial

An application can connect to many different domains, and publications and subscriptions in different domains are independent.

11.1. Connect to a domain

```
import org.jlab.coda.cMsg.*;
import org.jlab.coda.cMsg.cMsgException;

cMsg cMsgSys;      // the cMsg system object
try {
    cMsgSys = new cMsg(myUDL,myName,myDescr);
    cMsgSys.connect();
} catch (cMsgException e) {
    e.printStackTrace();
}
```

To disconnect from the domain:

```
cMsgSys.disconnect();
```

After calling disconnect(), all subscriptions and other connection information are lost. Reconnections and failovers are possible in the cMsg domain (see 6.4.1).

Note that most cMsg calls throw cMsgException, so they must be in try blocks, as shown above. Below I do not include the try blocks for clarity.

11.2. Create a message

```
// create message
cMsgMessage msg = new cMsgMessage();

// set regular fields
int myInt = 1;
long myTime = System.currentTimeMillis();
String mySubject = "s", myType = "t", myText = "txt";
```

```
msg.setSubject(mySubject);
msg.setType(myType);
msg.setUserInt(myInt);
msg.setUserTime(myTime);
msg.setText(myText);

// add a payload item (array of strings)
String[] myStrings = new String[]{"one", "two", "three"};
cMsgPayloadItem item1 = new cMsgPayloadItem("STR_ARRAY", myStrings);
msg.addPayloadItem(item1);

// add another payload item (cMsg message)
cMsgMessage myMsg = new cMsgMessage();
myMsg.setSubject("sub");
myMsg.setType("type");
cMsgPayloadItem item2 = new cMsgPayloadItem("MSG", myMsg);
msg.addPayloadItem(item2);
```

11.3. Send a message

To send a message call send then flush the outgoing message queue. Note that the system is free to flush the queue at will and in the cMsg domain flush actually does nothing.

```
cMsgSys.send(msg);
cMsgSys.flush(null);
```

To synchronously send a message:

```
int status = cMsgSys.syncSend(msg);
// The returned status depends on domain and/or subdomain,
// and is zero for cMsg domain & subdomain.
```

where the nature of any failure is indicated in the thrown exception. The returned value is dependent on the domain or in the case of the cMsg domain, it depends on the subdomain. For the subdomain normally used, cMsg, the return value is always 0.

11.4. Subscriptions

To subscribe and unsubscribe with callback and user object:

```
import org.jlab.coda.cMsg.cMsgSubscriptionHandle;
cMsgSubscriptionHandle handle = cMsgSys.subscribe(mySubject, myType, myCB,
                                                  myUserObject);
cMsgSys.unsubscribe(handle);
```

where the callback class is:

```
import org.jlab.coda.cMsg.cMsgCallbackAdapter;
class myCB extends cMsgCallbackAdapter {
   public void callback(cMsgMessage msg, Object userObject) {
        System.out.println("Subject is:    " + msg.getSubject());
        System.out.println("Type is:       " + msg.getType());
```

```
            System.out.println("Text is:       " + msg.getText());
        }
    }
```

and the userObject may be anything and exists solely for the programmer's convenience. The handle object is used for unsubscribing and interacting with the subscription.
In the cMsg domain the received messages are queued and delivered serially to the callback in the order received. Configuration options (overriding of various methods) allow for parallelizing callback processing into multiple threads, discard of messages after a maximum number are waiting to be processed, etc. See the API docs for details.

To enable message receipt and delivery to callbacks:

```
cMsgSys.start();
```

To disable message receipt:

```
cMsgSys.stop();
```

ATTENTION: No messages will be delivered at all unless the start() method is called!

11.5. Synchronous methods

The subscribeAndGet() method performs a synchronous one-shot subscribe. That is, it temporarily subscribes to mySubject/myType (existing subscriptions and callbacks are unaffected), waits for a matching message to arrive, then returns the message. If none arrives within the timeout a timeout exception is thrown.

```
long myTimeout = 1000; /* 1 sec */
cMsgMessage m = cMsgSys.subscribeAndGet(mySubject, myType, myTimeout);
// exception thrown if no message arrived within timeout
```

The sendAndGet() method synchronously sends a message and gets a private response from the receiver:

```
long myTimeout = 1000; /* 1 sec */
cMsgMessage response = cMsgSys.sendAndGet(msg, myTimeout);
// exception thrown if no message arrived within timeout
```

When the receiver gets the message it has to first recognize that this is a synchronous request, then create the response message via a special method (and NOT via the usual cMsgMessage constructor). Receiver code might look like:

```
// ...just got a message via a callback
// ...send a response if it is a synchronous request message
If (msg.isGetRequest()) {
   cMsgMessage response = msg.response();  // create special response
   response.setSubject(mySubject);
   response.setType(myType);
```

```
        response.setText(myText);
        cMsgSys.send(response);
        cMsgSys.flush();
    }
```

If two receivers synchronously respond to the message as above the first one sent gets returned by the sendAndGet() method in the client. The second response is treated as a normally published message.

Chapter 12

12. C Tutorial

An application can connect to many different domains, and publications and subscriptions in different domains are independent.

12.1. Connect to a domain

```
#include <cMsg.h>

int stat;
void *domainId;
char *myUDL, *myName, *myDescription;

stat = cMsgConnect(myUDL, myName, myDescription, &domainId);
if (stat!=CMSG_OK) {
   /* something is wrong */
}
```

where domainId is used in many subsequent calls to identify the connection to this particular UDL. In the following, error checking is not done for brevity and readability. To disconnect from the domain:

```
cMsgDisconnect(&domainId);
```

After calling cMsgDisconnect(), all subscriptions and other connection information are lost. Any attempt to use the domainId again will return an error. Reconnections and failovers are possible in the cMsg domain (see 6.4.1).

12.2. Create a message

```
/* create a message */
void *msg = cMsgCreateMessage();  /* be sure to free message when done */

/* set regular fields */
int myInt = 1;
struct timespec myTime;
char *mySubject = "s", *myType = "t", *myText = "txt";
```

```
clock_gettime(CLOCK_REALTIME, &myTime);

cMsgSetSubject(msg, mySubject);
cMsgSetType(msg, myType);
cMsgSetUserInt(msg, myInt);
cMsgSetUserTime(msg, myTime);
cMsgSetText(msg, myText);

/* add a payload item (array of strings) */
char *myStrings[] = {"one", "two", "three"};
cMsgAddStringArray(msg, "STR_ARRAY", (const char **) myStrings, 3);

/* add another payload item (cMsg message) */
void *myMsg = cMsgCreateMessage();
cMsgSetSubject(myMsg, "sub");
cMsgSetType(myMsg, "type");
cMsgAddMessage(msg, "MSG", myMsg);
```

12.3. Send a message

To send a message call send then flush the outgoing message queue. Note that the system is free to flush the queue at will and in the cMsg domain, flush actually does nothing. Be sure to free messages when you are done with them.

```
struct timespec timeout = {0,0};
cMsgSend(domainId, msg);
cMsgFlush(domainId, &timeout);
cMsgFreeMessage(&msg);
```

To synchronously send a message:

```
int stat, statusCode;
stat = cMsgSyncSend(domainId, msg, NULL, &statusCode);
if (stat != CMSG_OK) {
   // something went wrong...
}
```

where the nature of the failure, if indicated, is domain specific, and statusCode holds a domain-specific return value.

12.4. Subscriptions

To subscribe and unsubscribe with callback and user arg:

```
void *myHandle;
cMsgSubscribeConfig *myConfig = cMsgSubscribeConfigCreate();
cMsgSubscribe(domainId, mySubject, myType, myCB, (void*)myUserArg, myConfig,
                &myHandle);
cMsgUnSubscribe(domainId, myHandle);
cMsgSubscribeConfigDestroy(myConfig);
```

where the callback function is:

```
void myCB(void* msg, void* userArg) {
        char *s;
        cMsgGetSubject(msg, &s);  printf("Subject is:    %s\n",s);
        cMsgGetType(msg, &s);     printf("Type is:       %s\n",s);
        cMsgGetText(msg, &s);     printf("Text is:       %s\n",s);
        cMsgFreeMessage(&msg);
}
```

and the user arg, myUserArg, may be anything and exists solely for the programmer's convenience. The sixth argument of cMsgSubscribe() (myConfig) is a pointer to a subscription configuration created with cMsgSubscribeConfigCreate() and modified by the use of many other functions. Finally, the last argument, myHandle, is just a void pointer which is used for unsubscribing and interacting with the subscription.
In the cMsg domain the received messages are queued and delivered serially to the callback in the order received. Configuration options allow for parallelizing callback processing into multiple threads, discard of messages after a maximum number are waiting to be processed, etc. See the API docs for details.

To enable message receipt and delivery to callbacks:

```
cMsgReceiveStart(domainId);
```

To disable message receipt use:

```
 cMsgReceiveStop(domainId);
```

ATTENTION: No messages will be delivered at all unless cMsgReceiveStart() is called!

12.5. Synchronous Routines

The cMsgSubscribeAndGet() function performs a synchronous one-shot subscribe. That is it temporarily subscribes to mySubject/myType (existing subscriptions and callbacks are unaffected), waits for a matching message to arrive, then returns the message. Be sure to free the message when done with it.

```
void *msg;
struct timespec myTimeout = {1,0}; /* 1 sec */
stat = cMsgSubscribeAndGet(domainId, mySubject, myType, &myTimeout, &msg);
if (stat!=CMSG_OK) {
   /* timeout or error */
}
```

The cMsgSendAndGet() function synchronously send a message and get a private response from the receiver:

```
void *reply;
struct timespec myTimeout = {1,0}; /* 1 sec */
stat = cMsgSendAndGet(domainId, msg, &myTimeout, &reply);
```

```
if (stat!=CMSG_OK) {
   /* timeout or error */
}
```

When the receiver gets the message, it has to first recognize that this is a synchronous request, then create the response message via a special function (and NOT via cMsgCreateMessage()). Be sure to free the message when done with it.
Receiver code might look like:

```
/*
 * Just got a message via a callback...
 *  ...send a response if it is a synchronous request message
 */
if (cMsgGetGetRequest(msg)) {
   void *response = cMsgResponse(msg);  /* create special response */
   cMsgSetSubject(response, mySubject);
   cMsgSetType(response, myType);
   cMsgSetText(response, myText);
   cMsgSend(domainId, response);
   cMsgFlush(domainId, &myTimeout);
   cMsgFreeMessage(&response);
}
```

If two receivers synchronously respond to the message as above the first one sent gets returned by the sendAndGet() method in the client. The second response is treated as a normally published message.

Chapter 13

13. C++ Tutorial

An application can connect to many different domains, and publications and subscriptions in different domains are independent.

13.1. Connect to a domain

To create the cMsg system object and connect to a domain:

```
#include <cMsg.hxx>

string myUDL, myName, myDescription;
cMsg cMsgSys(myUDL, myName, myDescription)

try {
    cMsgSys.connect();
} catch (cMsgException e) {
    cout << e.toString() << endl;
}
```

To disconnect from the domain:

```
cMsgSys.disconnect();
```

After calling disconnect(), all subscriptions and other connection information are lost. Reconnections and failovers are possible in the cMsg domain (see 6.4.1). Note that most cMsg calls throw cMsgException, so they must be in try blocks, as shown above. Below I do not include the try blocks for clarity.

13.2. Create a message

```
// create a message
cMsgMessage msg;

// set regular fields
int myInt = 1;
struct timespec myTime;
string mySubject = "s", myType = "t", myText = "txt";
```

```
clock_gettime(CLOCK_REALTIME, &myTime);

msg.setSubject(mySubject);
msg.setType(myType);
msg.setUserInt(myInt);
msg.setUserTime(myTime);
msg.setText(myText);

// add payload item (array of strings)
string name = "STR_ARRAY", name2 = "MSG";
string strs[3] = {"one", "two", "three"};
msg.add(myName, strs, 3);

// add another payload item (cMsg message)
cMsgMessage myMsg;
myMsg.setSubject("sub");
myMsg.setType("type");
msg.add(name2, myMsg);
```

13.3. Send a message

To send a message and flush the outgoing message queue:

```
cMsgSys.send(msg);
cMsgSys.flush();
```

Many messages can be sent before flushing the outgoing queue. Note that the system is free to flush the queue at will.

To synchronously send a message:

```
int val = cMsgSys.syncSend(msg);
```

where the nature of any failure is indicated in the thrown exception. The returned value is dependent on the domain or in the case of the cMsg domain, it depends on the subdomain. For the subdomain normally used, cMsg, the return value is always 0.

13.4. Subscriptions

To subscribe and unsubscribe with callback and user object:

```
void *handle = cMsgSys.subscribe(mySubject, myType, myCB,
                                 (void*)myUserObject);
cMsgSys.unsubscribe(handle);
```

where the callback class is:

```
class myCB:public cMsgCallbackAdapter {
   void callback(cMsgMessage msg, void* userObject) {
        cout << "Subject is:    " << msg.getSubject()) << endl;
        cout << "Type is:       " << msg.getType()) << endl;
        cout << "Text is:       " << msg.getText()) << endl;
```

```
    }
}
```

and the userObject may be anything and exists solely for the programmer's convenience. In the cMsg domain the received messages are queued and delivered serially to the callback in the order received. Configuration options allow for parallelizing callback processing into multiple threads, discard of messages after a maximum number are waiting to be processed, etc. See the API docs for details.

To enable message receipt and delivery to callbacks:

```
cMsgSys.start();
```

To disable message receipt:

```
cMsgSys.stop();
```

ATTENTION: No messages will be delivered at all unless the start() method is called!

13.5. Synchronous methods

The subscribeAndGet() method performs a synchronous one-shot subscribe. That is, it temporarily subscribes to mySubject/myType (existing subscriptions and callbacks are unaffected), waits for a matching message to arrive, then returns the message. If none arrives within the timeout an exception is thrown.

```
struct timespec myTimeout = {1,0}; /* 1 sec */
cMsgMessage m = cMsgSys.subscribeAndGet(mySubject, myType, &myTimeout);
// timeout exception thrown if no message arrives within timeout
```

The sendAndGet() method synchronously sends a message and gets a private response from the receiver:

```
struct timespec myTimeout = {1,0}; /* 1 sec */
cMsgMessage response = cMsgSys.sendAndGet(msg, &myTimeout);
// timeout exception thrown if no message arrives within timeout
```

When the receiver gets the message it has to first recognize that this is a synchronous request, then create the response message via a factory (and NOT via the usual cMsgMessage constructor). Receiver code might look like:

```
// ...just got a message via a callback
// ...send a response if it is a synchronous request message
If (msg.isGetRequest()) {
   cMsgMessage *response = msg.response();  // create special response
   response->setSubject(mySubject);
   response->setType(myType);
   response->setText(myText);
```

```
        cMsgSys.send(response);
        cMsgSys.flush();
    }
```

If two receivers synchronously respond to the message as above the first one sent gets returned by the sendAndGet() method in the client. The second response is treated as a normally published message.