Monitoring a z/OS Liberty server using JMX and REST clients

IBM Washington Systems Center

Monitoring a z/OS Liberty server

Table of Contents

Mitch Johnson (mitchj@us.ibm.com)

Using Java Management Extensions with Liberty

Monitoring the current settings and details about the general health of a Liberty server running on z/OS can easily be done by enabling Java Management Extensions (JMX) in the server. Once JMX is enabled, JMX clients can invoke the server's Java Virtual Machine (JVM) management beans (MBeans) to obtain important Java related information in real time. Note that the MBeans that will be available in a Liberty will vary based which features are or not installed as well as the presence of certain configuration elements.

For details on Liberty's support for remote JMX clients, see *Connecting to Liberty using JMX* at URL https://www.ibm.com/docs/en/was-liberty/zos?topic=SS7K4U_liberty/com.ibm.websphere.wlp.doc/ae/twlp_admin_jmx.htm. And for a list of Liberty provided MBeans, see URL https://www.ibm.com/docs/en/was-liberty/base?topic=liberty-list-provided-mbeans

In this document I describe the steps I followed to enable JMX and Mbean access to my Liberty server. When the server configured, the server's MBeans can be invoked from JMX clients like JConsole* and REST clients like Postman, cURL, and the IBM API Explorer. The document also provides examples of using these clients to monitor a Liberty server running on z/OS.

*Please note that most Java Developers Kit (JDK) or Java Runtime Environment (JRE) instances include a Java application known as the Java Console(JConsole). JConsole is a Java GUI client which uses JMX and REST to manage and monitor local and remote JVMs. For more details on JConsole, see URL https://docs.oracle.com/javase/8/docs/technotes/guides/troubleshoot/tooldescr009.html

Mitch Johnson (mitchj@us.ibm.com)

Liberty Server Considerations

This section describes the details of the required configuration changes and security resources needed to enable both JMX and REST access to a Liberty server endpoint.

Enable required Liberty features

Liberty features *monitor-1.0* and *restConnector-2.0* are required to enable JMX clients like JConsole and REST clients like Postman and cURL to access a Liberty Server. I ensured these features were configured in a *<featureManager/>* section of my server XML and then I ensure that they had been enabled in the target server.

Note: Liberty servers on z/OS require the use of TLS for REST client access. It is my opinion that enabling TLS connection and other required security features is easiest done using SAF security.

```
<!-- Enable features -->
<featureManager>
   <feature>appSecurity-2.0</feature>*
   <feature>zosSecurity-1.0</feature>*
   <feature>transportSecurity-1.0</feature>*
   <feature>apiDiscovery-1.0</feature>*
   <feature>monitor-1.0</feature>
   <feature>restConnector-2.0</feature>
</featureManager>
```

*I always automatically add these features when enabling SAF and TLS security.

The *monitor-1.0* adds standard monitoring MBeans as well as MXBeans, the latter provide monitoring for specific runtime components. For more information about the *monitor-1.0* feature including the MXBeans added by this feature, see URL https://www.ibm.com/docs/en/was-liberty/zos?topic=environment-monitoring-monitor-10. The restConnector-2.0 feature adds remote REST client access to a set of administrative APIs over HTTP. For more information about the *restConnector-2.0* feature, see URL https://www.ibm.com/docs/en/was-liberty/zos?topic=features-admin-rest-connector-20.

Mitch Johnson (mitchj@us.ibm.com)

Define and permit access to required SAF resources

Access to Liberty MBeans and REST administrative APIs is controlled by access to SAF EJBRole resources, see URL https://www.ibm.com/docs/en/was-liberty/zos?topic=liberty-mapping-management-roles-zos for more information.

Below are examples of the commands I used to define and permit access to the *Administrator* and *Reader* EJBRoles.

```
RDEFINE EJBROLE BBGZDFLT*.com.ibm.ws.management.security.resource.Administrator OWNER(SYS1)UACC(NONE)
RDEFINE EJBROLE BBGZDFLT*.com.ibm.ws.management.security.resource.Reader OWNER(SYS1) UACC(NONE)
PERMIT BBGZDFLT*.com.ibm.ws.management.security.resource.Administrator CLASS(EJBROLE) ID(ADMNUSRS) ACCESS(READ)
PERMIT BBGZDFLT*.com.ibm.ws.management.security.resource.Reader CLASS(EJBROLE) ID(OTHUSRS) ACCESS(READ)

SETR RACLIST(EJBROLE) REFRESH
```

Using the above RACF resources, members of group *ADMNUSRS* will have full access to the JMX resources and MBeans (REST GET, POST, PUT and DELETE). Members of group *OTHUSRS* have limited access to the MBeans (REST GET only). For example, members of the *OTHUSRS* group will have limited access to JMX resources but not be able to initiate a garbage collection. Members of *OTHUSRS* will not have access MBeans in JConsole but will be able to use REST clients to access MBeans using the GET method.

*Note: the value for *BBGZDFLT* used in the commands was derived from the value of the *profilePrefix* attribute used in the *<safCredentials/>* configuration element.

```
    <safCredentials unauthenticatedUser="WSGUEST"
       suppressAuthFailureMessages="false" profilePrefix="BBGZDFLT" />
```


Mitch Johnson (mitchj@us.ibm.com)

Monitoring a z/OS Liberty server

Securely connecting to a z/OS Liberty

Connecting to a z/OS Liberty server to access its MBeans and REST APIs requires a TLS handshake and the use of HTTPS. When a connection request from a client is received, the Liberty server, as the server endpoint in the TLS handshake, will use its personal certificate as a server certificate to prove its identity. To verify the server, the client, as the client endpoint in the TLS handshake, must have in its local trust store, the Certificate Authority (CA) chain that was used to sign the server's personal certificate.

This section describes what is required on the z/OS side

Locate the key ring used for TLS handshakes

- In the server's XML configuraton locate the *<sslDefault>* configuraton element and note the value of the *sslRef* attribute. The value of the *sslRef* attribute will match the *id* attribute of an *<ssl>* configuration element, the <ssl> configuration element is also known as an SSL *repertoire*. If an *<sslDefault>* configuration element is not present, the default value for *sslRef* is *defaultSSLSettings*.
- Find the *<ssl>* configuration element whose *id* attributes matches the value of the *<sslDefault>'s sslRef* attribute. The *<ssl>* configuration element has two attributes which identifies key stores. One is a key store for managing personal certificates and other is a trust store for managing certificate authority certificates. On z/OS images, these key stores are usually SAF key rings where one key ring will have both personal and certificate authority certificates.
- The *<ssl>* configuration element *trustStoreRef* attribute identifies the *<keyStore>* configuration element that identifies the key ring containing the certificate authority certificates that were used to sign the server's personal certificate. Note the name of the key ring, e.g. Liberty.KeyRing.

```
<sslDefault sslRef="DefaultSSLSettings" />
<ssl id="DefaultSSLSettings"
   keyStoreRef="CellDefaultKeyStore"
   trustStoreRef="CellDefaultKeyStore" />
<keyStore id="CellDefaultKeyStore"
   location="safkeyring:///Liberty.KeyRing"
   password="password" type="JCERACFKS"
   fileBased="false" readOnly="true" />
```

Note: the *location* value *safkeyring:///* means the key ring belongs to the identity under which the server is executing. If the key ring belonged to another user, the *location* value would have been provided as *safkeyring://otheruser/Liberty.KeyRing.*

Mitch Johnson (mitchj@us.ibm.com)

List the key ring's contents

Next, identify the complete Certificate Authority (CA) chain used to sign the server's personal certificate by displaying the contents of the key ring using a RACDCERT LISTRING command:

RACDCERT ID(LIBSERV) LISTRING(Liberty.KeyRing)

```
Digital ring information for user LIBSERV:

  Ring:
       >Liberty.KeyRing<
  Certificate Label Name                Cert Owner     USAGE      DEFAULT
  --------------------------------      ------------   --------   -------
  Liberty Client Cert                   ID(LIBSERV)    PERSONAL     YES
  Liberty CA                            CERTAUTH       CERTAUTH     NO
```

Export the CA chain

Export each certificate in Certificate Authority (CA) chain to a MVS dataset by using a RACDCERT EXPORT command as shown below:

RACDCERT CERTAUTH EXPORT(LABEL('Liberty CA')) DSN('USER1.LIBCA.PEM')

Note: Multiple CA certificates may have to be exported and made available on the client. To determine the CA certificates that need to be exported, use the *RACDCERT ID* command to display the Issuer's Name of the server's personal certificate, e.g.

RACDCERT ID(LIBSERV) LIST(LABEL('Liberty Client Cert')

Issuer's Name:
>CN=Liberty.OU=ATS<
Subject's Name:
>CN=wg31.washington.ibm.com.OU=LIBERTY.O=IBM<

Then use the **RACDCERT CERTAUTH** command to list, by label, the CERTUATH certificates connected to the keyring until you find a certificate whose *Subject's Name* matches the *Issuer's Name* (*CN=Liberty.OU=ATS*) of the server's personal certificate, e.g.,

RACDCERT CERTAUTH LIST(LABEL('Liberty CA')

Issuer's Name:
>CN=Liberty.OU=ATS<
Subject's Name:
>CN=Liberty.OU=ATS<

Record the labels of the certificate in the CA chain and repeat this process until you find a certificate whose *Issuer's Name* matches the *Subject's Name*. This is the root CA certificate.
Now export by label to different data sets all the intermediate CA certificates in the chain from the personal certificate until the root CA certificate is exported.

Mitch Johnson (mitchj@us.ibm.com)

Identify the JMX service endpoint

Obtain and record the service endpoint to be used with JConsole. Starting in the server's configuration directory, $*WLP_USER_DIR/servers/myServer/* and then go into the *logs/state subdirectory*, e.g., $*WLP_USER_DIR/servers/myServer/logs/state/*. Browse the file *com.ibm.ws.jmx.rest.address* and record the contents of this file for use for the JConsole server's endpoint. This endpoint will be used for the connection URL to the server in the JMX.

service:jmx:rest://wg31.washington.ibm.com:9443/IBMJMXConnectorREST

Mitch Johnson (mitchj@us.ibm.com)

Configuring the Java Console (JConsole) GUI

Locate an instance of the JConsole executable on the client. The JConsole GUI is started by invoking a *jconsole.exe* executable. If Java has been installed on the client, then this executable is already installed. The jconsole.exe executable can be located in the *bin* directory of any Java Developers Kit (JDK) or Java Runtime Environment (JRE) instance that has been installed on a client.

- I used the command ***dir jconsole* /s*** in a DOS command prompt in the client's root directory to search for the directories containing a *jconsole.exe* file. I had several copies on my client, and, in my case, I chose to use the version shipped with IBM Explorer, e.g., *C:\Program Files\IBM\zOS_Explorer\jdk\bin.*

```
C:\>dir jconsole* /s
 Volume in drive C is Windows
 Volume Serial Number is DA1F-5D24

 Directory of C:\Program Files\IBM\Developer_for_zOS\jdk\bin

08/24/2023  04:48 PM            23,912 jconsole.exe
               1 File(s)         23,912 bytes

 Directory of C:\Program Files\IBM\zOS_Explorer\jdk\bin

05/19/2023  07:57 AM            23,912 jconsole.exe
               1 File(s)         23,912 bytes

 Directory of
C:\Users\948478897\.p2\pool\plugins\org.eclipse.justj.openjdk.hotspot.jre.full.win3
2.x86_64_17.0.10.v20240120-1143\jre\bin


01/20/2024  12:28 PM            23,944 jconsole.exe

               1 File(s)         23,944 bytes



 Directory of C:\Users\948478897\.vscode\extensions\redhat.java-1.30.0-win32-
x64\jre\17.0.10-win32-x86_64\bin



04/30/2024  02:48 PM            23,944 jconsole.exe

               1 File(s)         23,944 bytes
```


Mitch Johnson (mitchj@us.ibm.com)

Create a JConsole command file

- Create a command file in a directory that was listed in the PATH environment variable. The command file should have the contents below (all on one line).

```
C:\Progra~1\IBM\zOS_Explorer\jdk\bin\jconsole
 -J-Djava.class.path=c:\z\jconsole\jconsole.jar;c:\z\jconsole\tools.jar;
c:\z\jconsole\restConnector.jar
 -J-Djavax.net.ssl.trustStore=C:\z\jconsole\jconsole.jks
 -J-Djavax.net.ssl.trustStorePassword=changeit
 -J-Djavax.net.ssl.trustStoreType=jceks
```

- The *java.class.path* directive added the required Java Archive files to the Java CLASSPATH. Remember that connecting or accessing a z/OS Liberty server from Jconsole requires the use of TLS. The *javax.net.ssl…* directives identify the local attributes required to complete a TLS handshake with the z/OS Liberty server, e.g., a local file to be used for a trust store, the trust store's password, and the trust store's type.

Completing the configuration of the client's environment

- Download the required JAR files from OMVS directories below and placed them on a local drive on the client, e.g., /z/jconsole.

/usr/lpp/java/J8.0_64/lib/jconsole.jar
/usr/lpp/java/J8.0_64/lib/tools.jar
/usr/lpp/IBM/zosconnect/v3r0/wlp/clients/restConnector.jar

The location of the last JAR file assume that z/OS Connect is installed. If it is not, an instance of the *restConnector.jar* can be found in your OMVS or USS directory by enter this command in the root directory in an OMVS shell. ***find . -name restConnector.jar***

```
JOHNSON:/:> find . -name restConnector.jar
./usr/lpp/liberty_zos/21.0.0.9/clients/restConnector.jar
./usr/lpp/liberty_zos/22.0.0.3/clients/restConnector.jar
./usr/lpp/cicsts/cicsts54/wlp/clients/restConnector.jar
./usr/lpp/cicsts/cicsts61/wlp/clients/restConnector.jar
./usr/lpp/mqm/V9R2M5/web/clients/restConnector.jar
./usr/lpp/mqm/V9R3M0/web/clients/restConnector.jar
./usr/lpp/IBM/zosconnect/v3r0/wlp/clients/restConnector.jar
```


Mitch Johnson (mitchj@us.ibm.com)

Configuring TLS support

- To complete the client's TLS setup, create a local trust store which will contain the public Certificate Authority (CA) certificates used to sign the certificate being sent by the server during the handshake.

Download the exported CA chain dataset(s) to the client, for example case using FTP.

```
C:\z>ftp wg31
Connected to wg31.washington.ibm.com.
220-FTP 20:17:47 on 2024-05-09.
220 Connection will close if idle for more than 200 minutes.
501 command OPTS aborted -- no options supported for UTF8
User (wg31.washington.ibm.com:(none)): user1
331 Send password please.
Password:

230 USER1 is logged on.  Working directory is "USER1.".
ftp> mget certauth.pem
200 Representation type is Ascii NonPrint
mget CERTAUTH.PEM? y
200 Port request OK.
125 Sending data set USER1.CERTAUTH.PEM
250 Transfer completed successfully.
ftp: 1236 bytes received in 0.00Seconds 1236000.00Kbytes/sec.
```


Mitch Johnson (mitchj@us.ibm.com)

Create a local trust store

Create the local JSE trust store that will be used with JConsole using the Java keytool command.

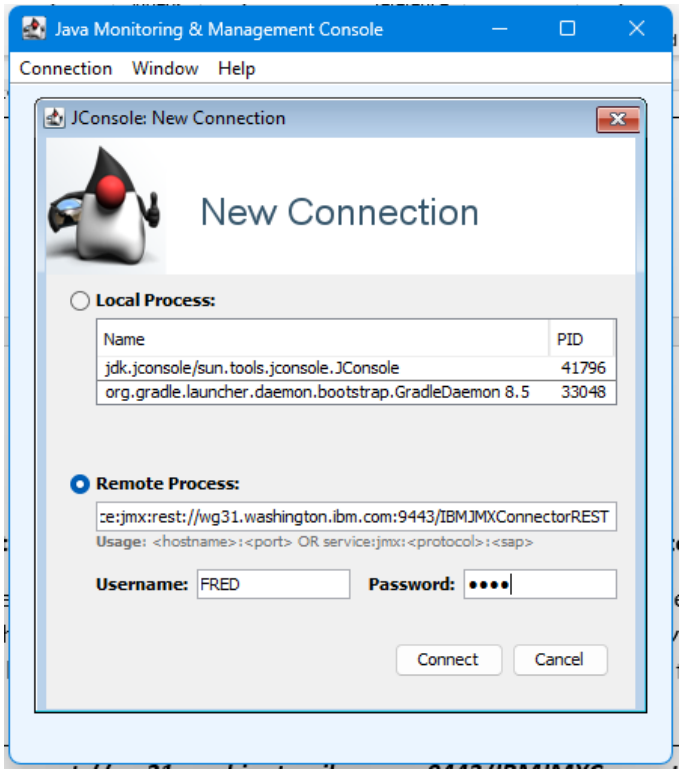
```
keytool -import -v -trustcacerts -alias "Liberty CA" -file CERTAUTH.PEM -keystore myTest.jks
```

```
Enter keystore password: changeit

Re-enter new password: changeit

Owner: CN=CA for Liberty, OU=LIBERTY
Issuer: CN=CA for Liberty, OU=LIBERTY
Serial number: 0
Valid from: Tue Mar 05 23:00:00 EST 2024 until: Tue Dec 31 22:59:59 EST 2024
Certificate fingerprints:
         SHA1: 23:DB:1B:2B:61:E9:14:9D:40:2A:65:39:1E:E0:B4:27:EB:3A:15:99
         SHA256:
CE:BC:52:C3:95:C7:EE:15:CA:15:A7:6E:82:4D:38:34:80:E1:03:A9:50:3D:E2:20:E2:41:18:58:12:C9:
E7:41
Signature algorithm name: SHA256withRSA
Subject Public Key Algorithm: 2048-bit RSA key
Version: 3

Extensions:

#1: ObjectId: 2.16.840.1.113730.1.13 Criticality=false
0000: 16 30 47 65 6E 65 72 61   74 65 64 20 62 79 20 74  .0Generated by t
0010: 68 65 20 53 65 63 75 72   69 74 79 20 53 65 72 76  he Security Serv
0020: 65 72 20 66 6F 72 20 7A   2F 4F 53 20 28 52 41 43  er for z/OS (RAC
0030: 46 29                                              F)


#2: ObjectId: 2.5.29.19 Criticality=true
BasicConstraints:[
  CA:true
  PathLen:2147483647
]

#3: ObjectId: 2.5.29.15 Criticality=true
KeyUsage [
  Key_CertSign
  Crl_Sign
]

#4: ObjectId: 2.5.29.14 Criticality=false
SubjectKeyIdentifier [
KeyIdentifier [
0000: 98 34 67 0E 58 B8 D4 C6   15 16 39 53 E3 05 E6 6F  .4g.X.....9S...o
0010: 60 1F 97 77                                        `..w
]
]

Trust this certificate? [no]:  yes
Certificate was added to keystore
[Storing myTest.jks]
```


Mitch Johnson (mitchj@us.ibm.com)

Using the JConsole

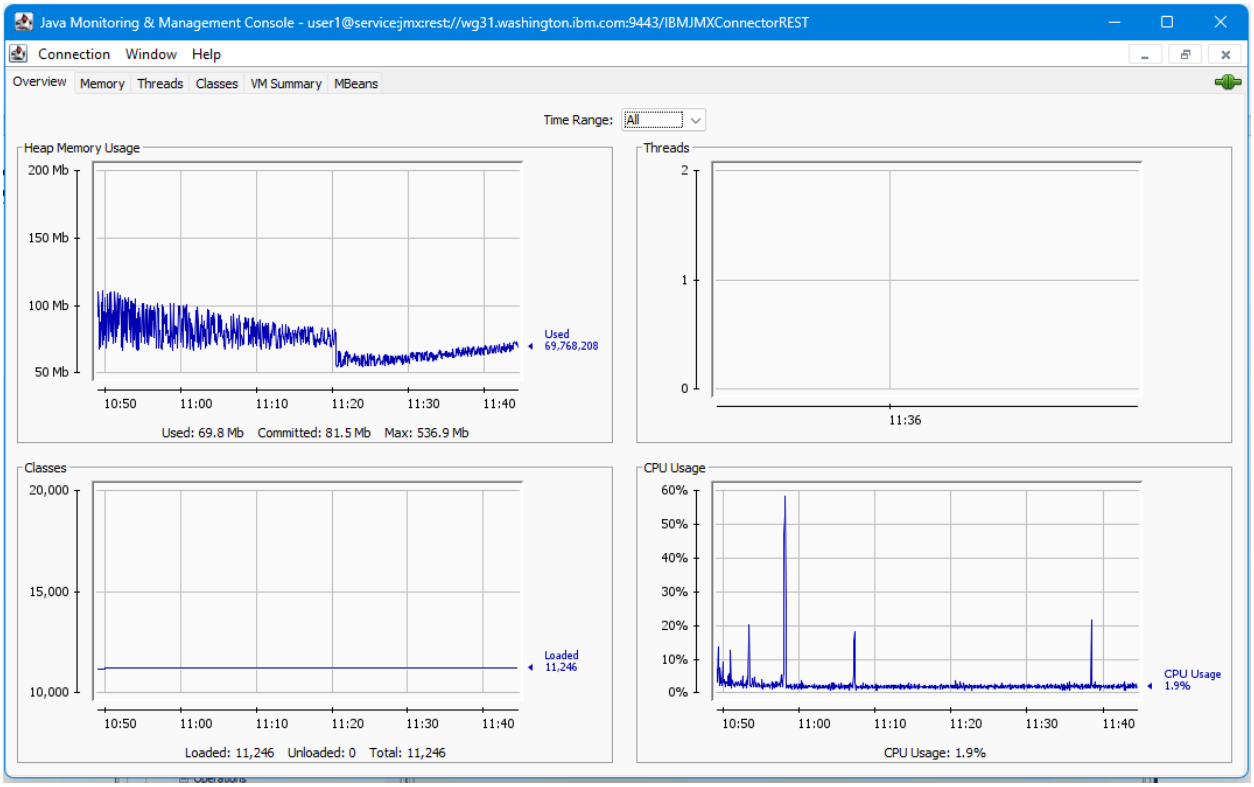
Invoked the command file created earlier to start the JConsole GUI and entered the service endpoint value obtained above for the *Remote Process* endpoint on the *JConsole: New Connection* window and enter an identity and password of a user who has READ access to the one of the EJBRole resources (Administrator or Reader).



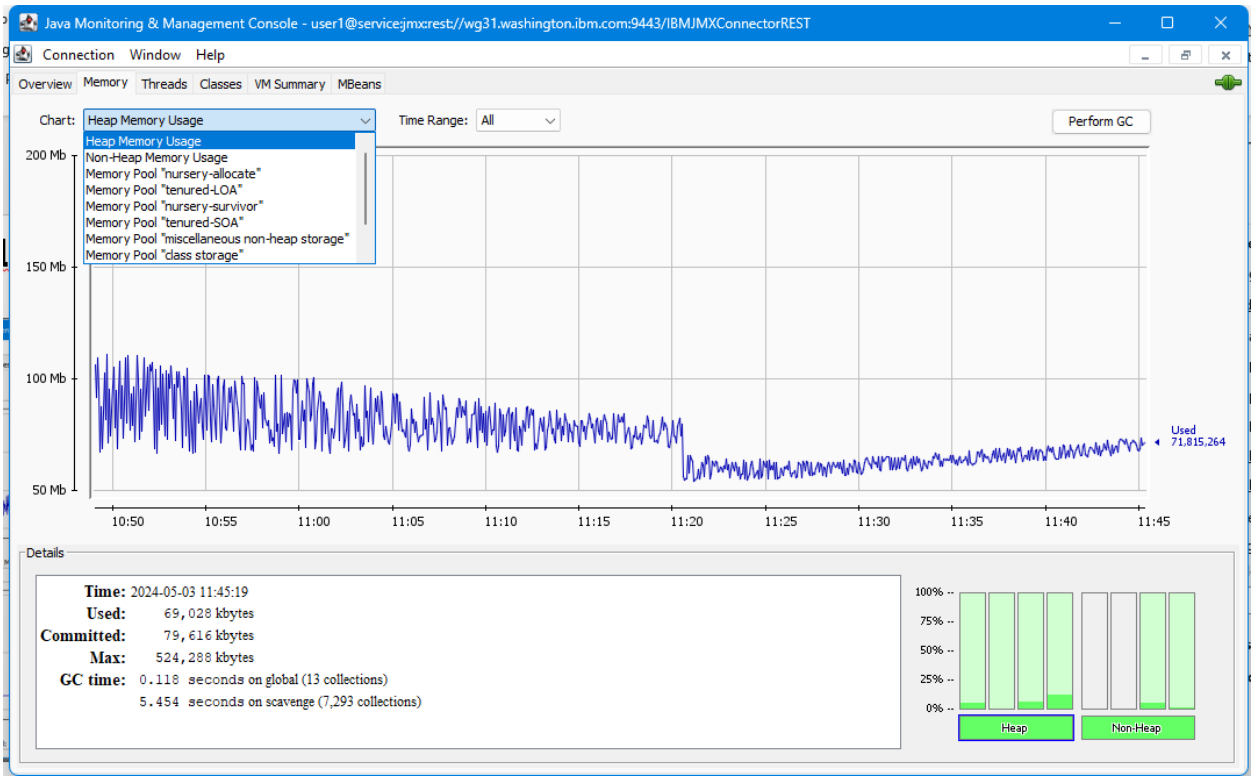
Mitch Johnson (mitchj@us.ibm.com)

Exploring the information available in the JConsole tabs

- The initial screen contains graphs for *Heap Memory Usage*, *Threads*, *Classes*, and *CPU Usage* which will be continuously updated.

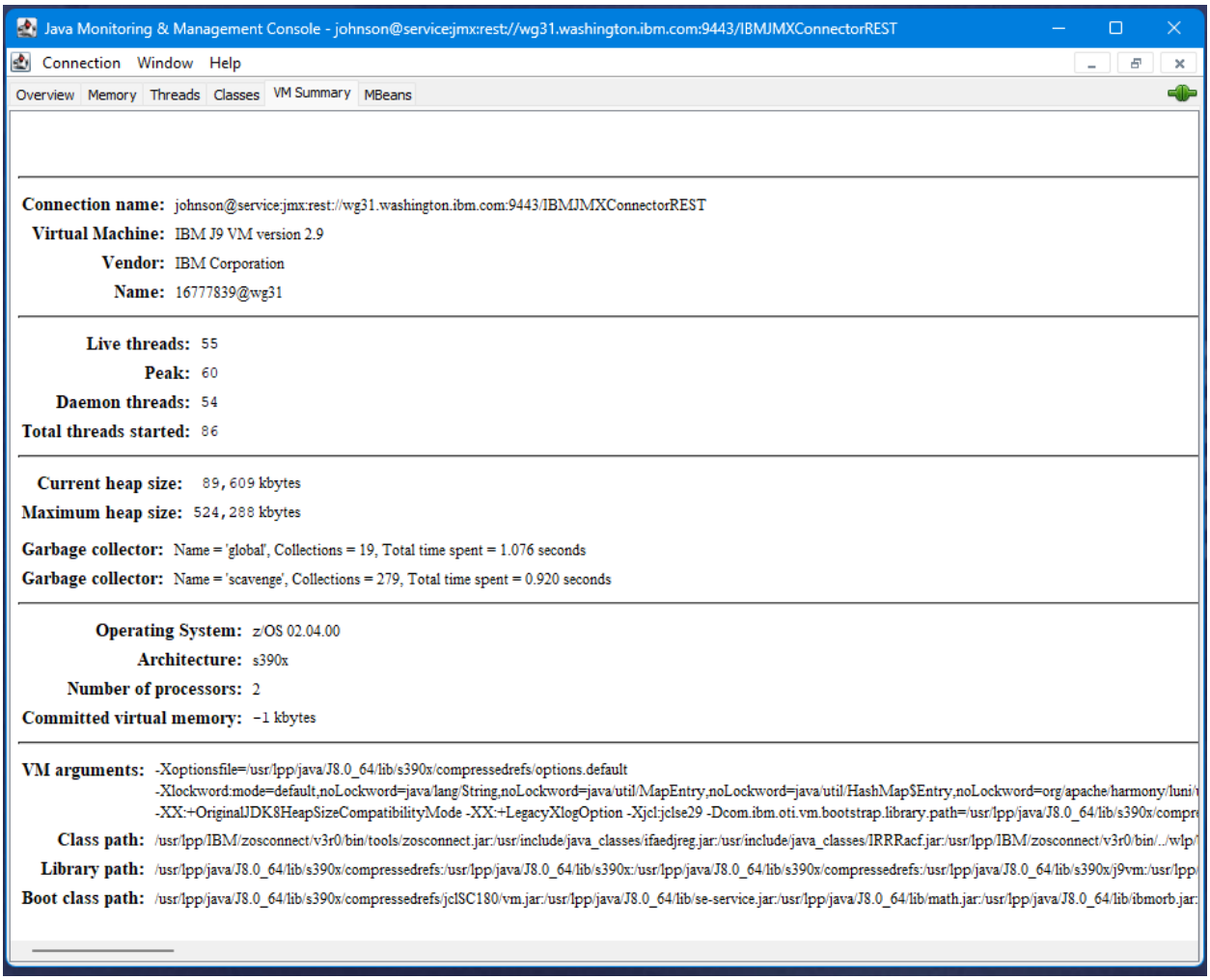


- Go to the *Memory* tab and use the pull-down arrow to select *Heap Memory Usage.* Note the details will be displayed at the bottom of the pane. The details at the bottom will change when switching between the various memory options. Go back to *Heap Memory Usage* and press the ***Perform GC*** button and note how the heap memory usage changes in both the chart and details pane.



Monitoring a z/OS Liberty server

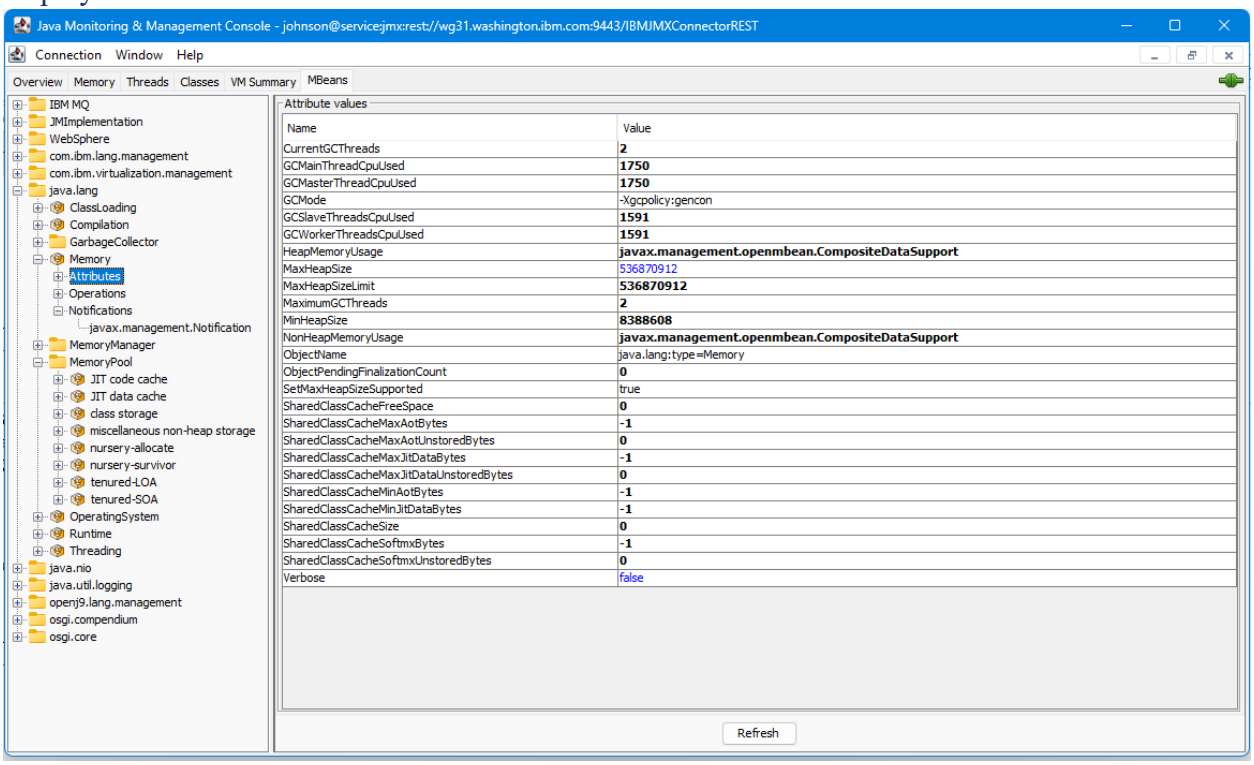
- Go to the *VM Summary* tab and review the information available on this window. Information regarding number of thread history, the current and maximum heaps size, details regarding garbage collections and details about the operating system and number of processors will be displayed.



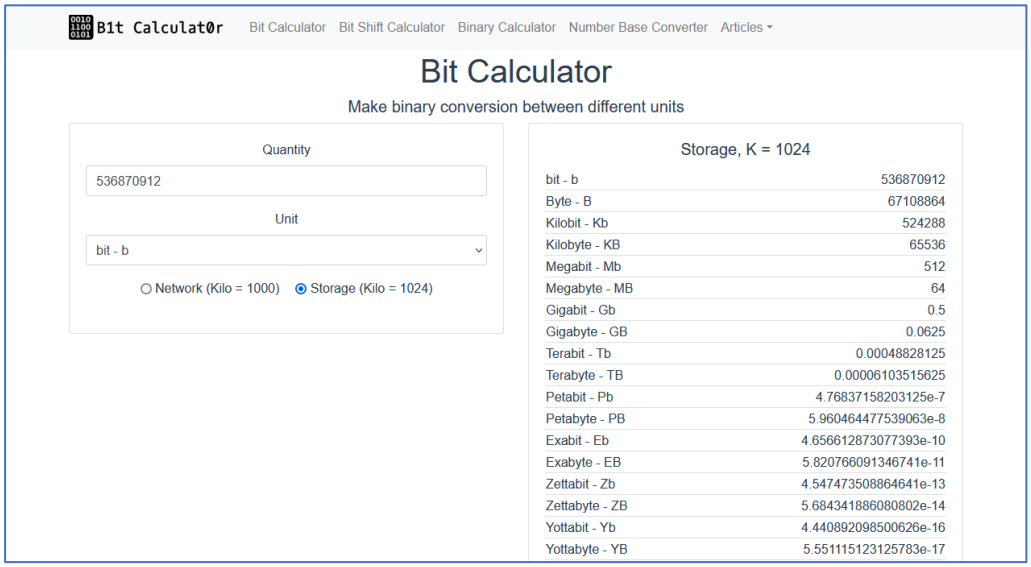
Explore the Liberty server's available MBeans

The *MBeans* tab will display the JMX message beans available in this server. The list of MBeans is built when the JConsole client connects to the Liberty server. The list of MBeans will vary based on the configuration of the server. Most of the MBeans are provided as part of the base Java platform or as part of the enhancements added by IBM Java. The MBeans provided by Liberty are in the WebSphere folder.

- In general, selecting an MBeans' s *Attributes* property displays the current values associated with that MBean. For example, selecting the attributes for the *java.lang:type=Memory* Mbean displays these attribute values:

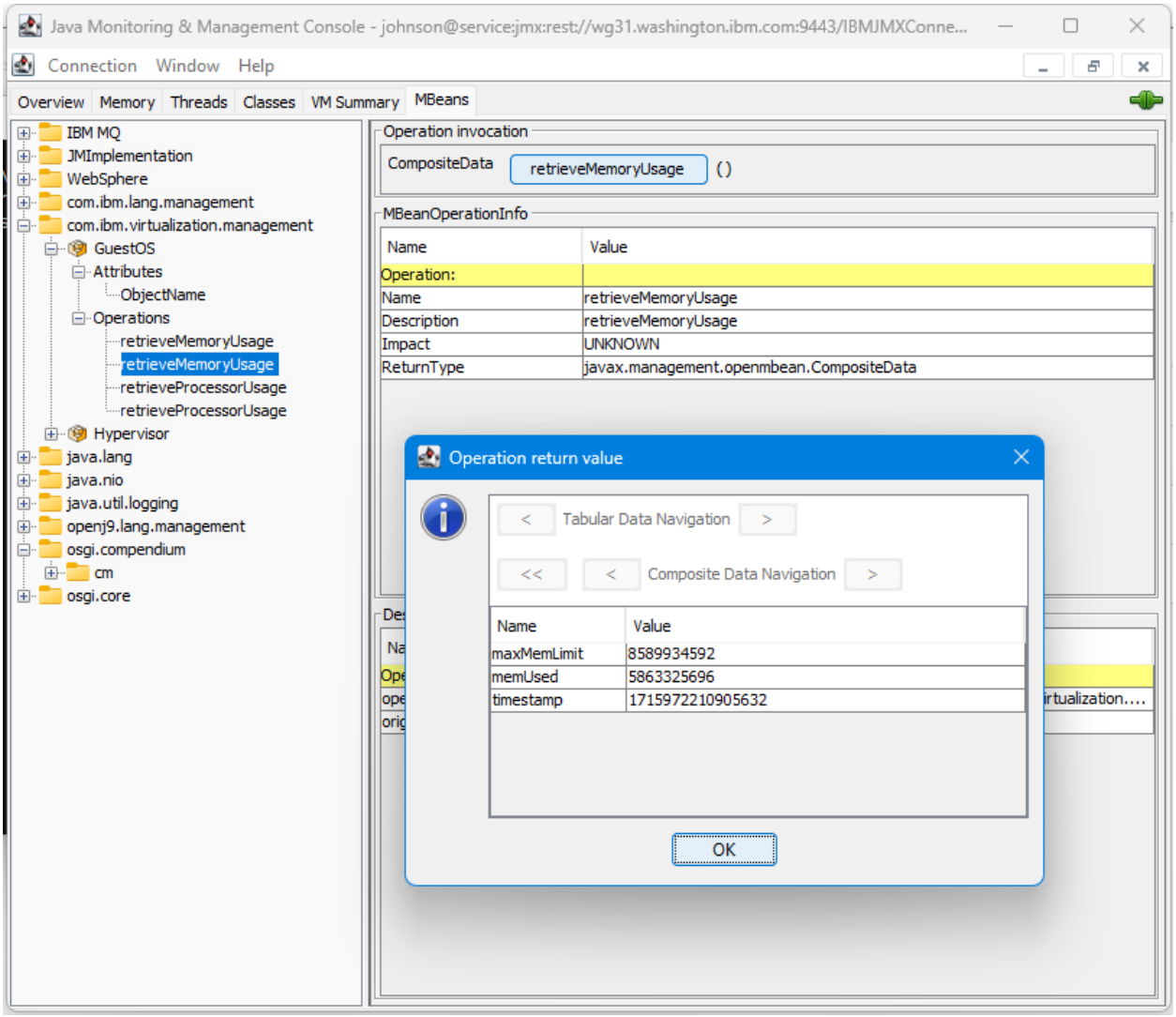


- Note: the units of the values displayed on screens like the one above for *MaxHeapSize* are in bits. These numbers can be converted using online tools like the one available at URL https://bit-calculator.com/bit-calculator. For example, the value for 536870912 bits can be converted as shown below:

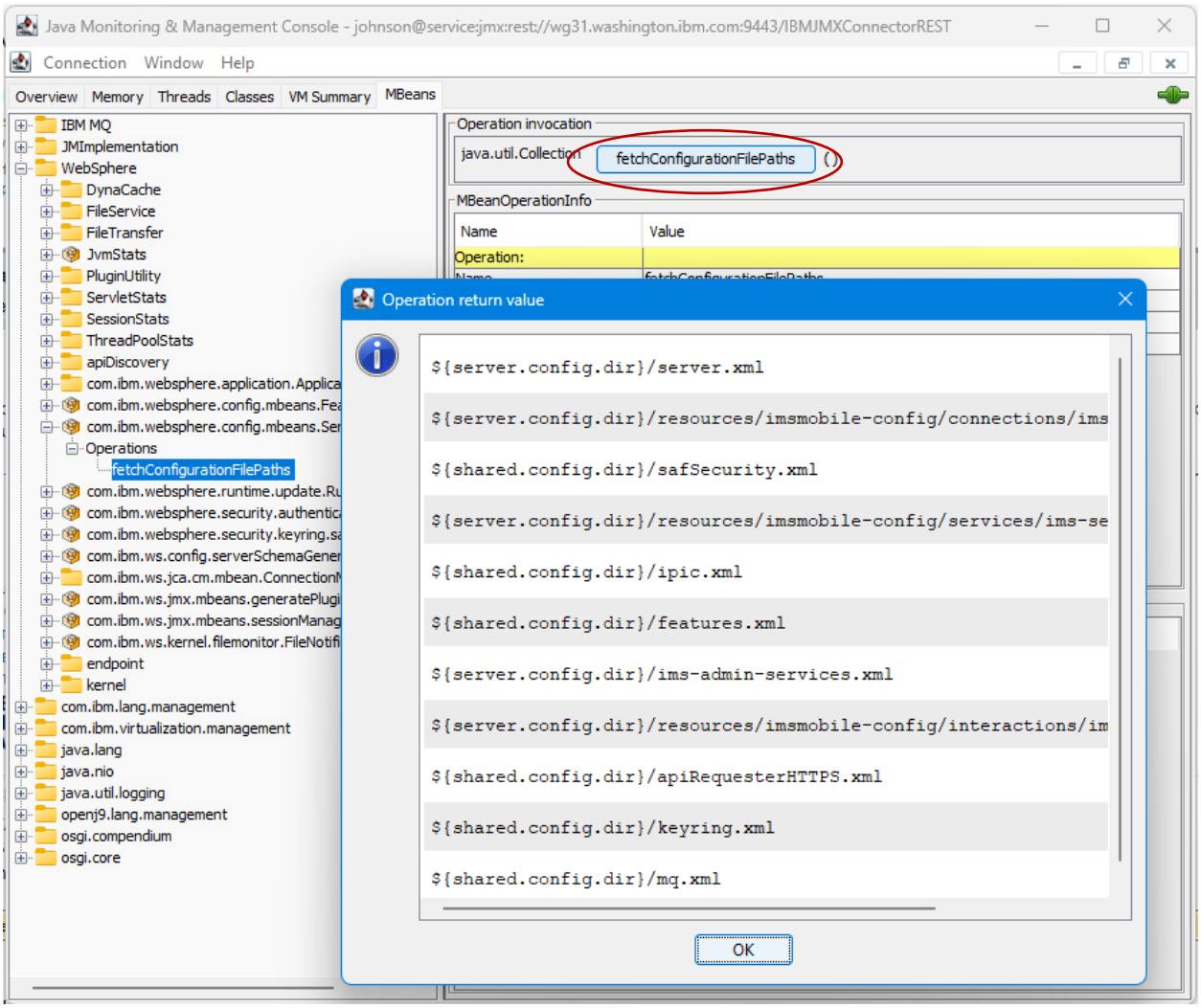


Mitch Johnson (mitchj@us.ibm.com)

• Expanding an MBean' s *Operations* displays a list of functions that MBean can perform. For example, selecting the *operations* for MBean *com.ibm.virtualization.management, GuestOS* displays these operations. Selecting operations *retrieveMemoryUsage* and clicking on *retrieveMemoryUsage* beside *CompositeData* on the *Operation invocation* page retrieves the results below:

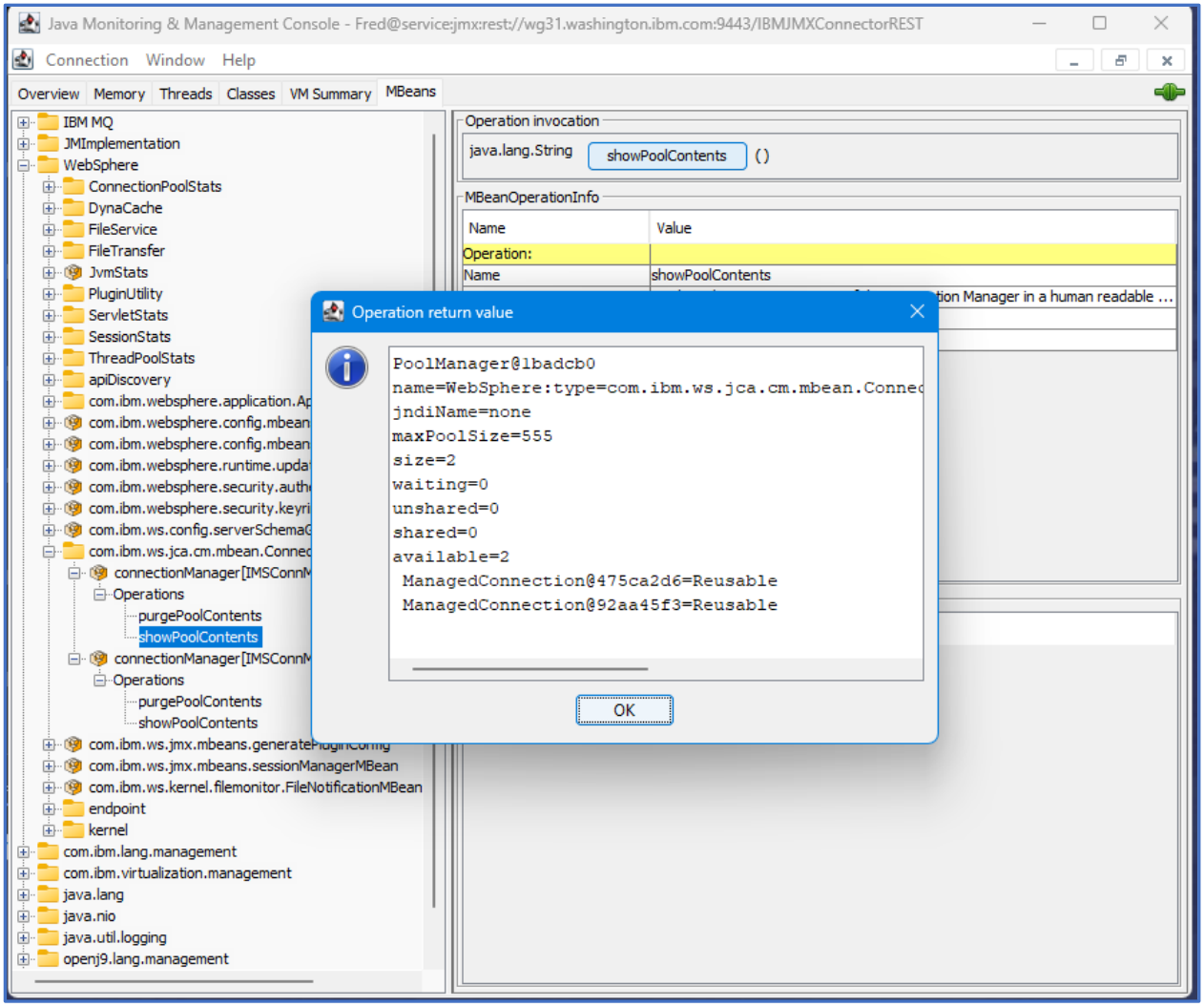


• Go to the *MBeans* tab and expand the *WebSphere* folder and then expand the *com.ibm.websphere.config.MBeans.ServerXMLConfigurationMBean* MBean. Expand *Operations* and then select operation *fetchConfigurationFilePaths*. On the *Operation invocation* pane, click operation area containing the string *fetchConfigurationFilePaths* beside *java.util.Collection*. This will invoke this MBean and display the results in a pop-up window as shown below:



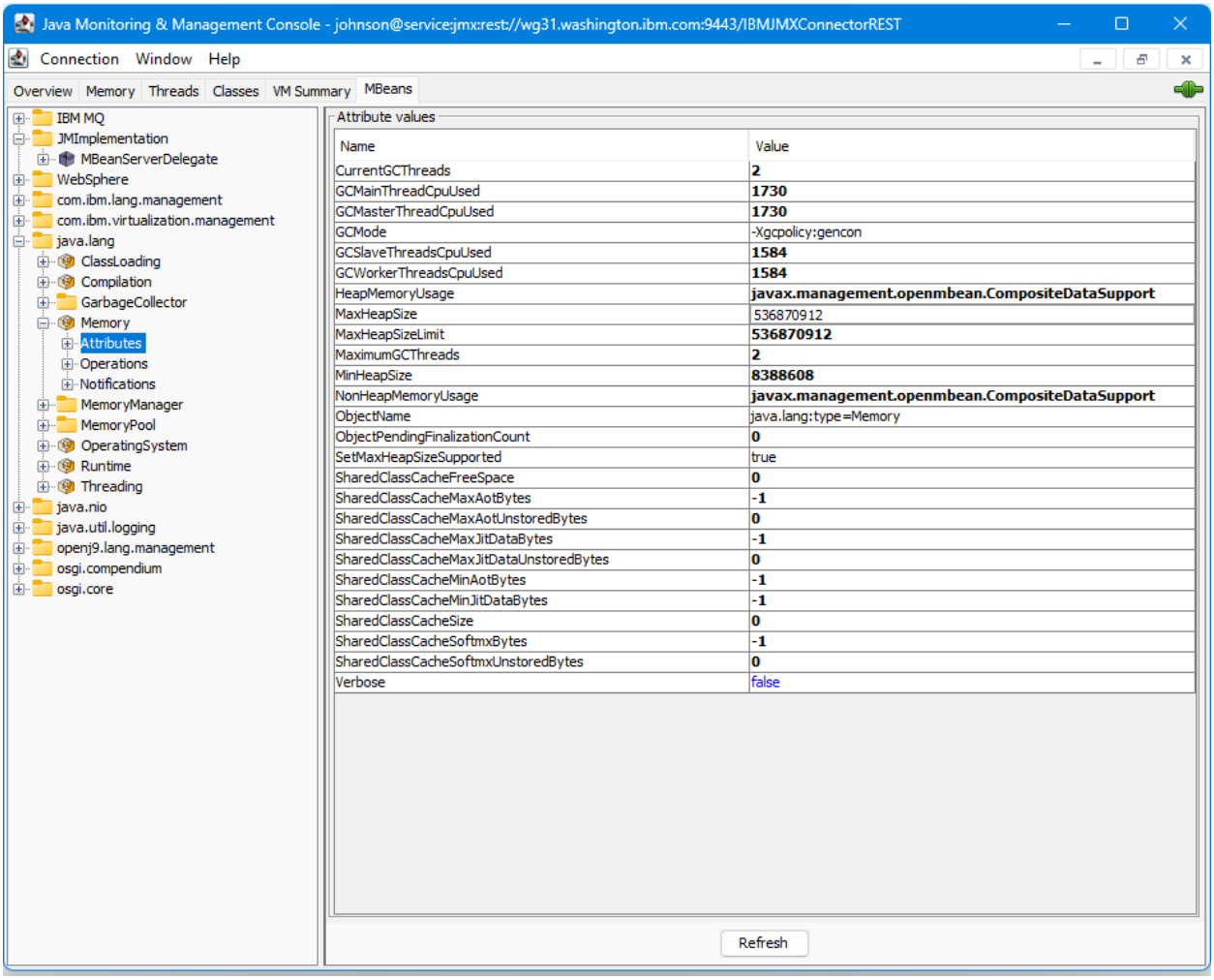
This displays the files used to configure the server.

- Expand the *WebSphere* folder and then expand the *com.ibm.ws.jca.cm.MBean.ConnectionManagerMBean* MBean. Note that this MBean will only appear if there is one or more connection managers configured in the server XML. Expand a connection manager configuration, e.g., *connectionManager[IMSConnMgr1]* and then then expand the *Operations* under that connection manager. There will be two operations available for a specific connection manger, *purgePoolContents* and *showPoolContents*. Select *showPoolContents*. On the *Operation invocation* pane, click the area containing the string *showPoolContents* beside *java.util.String* This will invoke this MBean and display the results in a pop-up window as shown below:



This is showing you real time status of the connection pool.

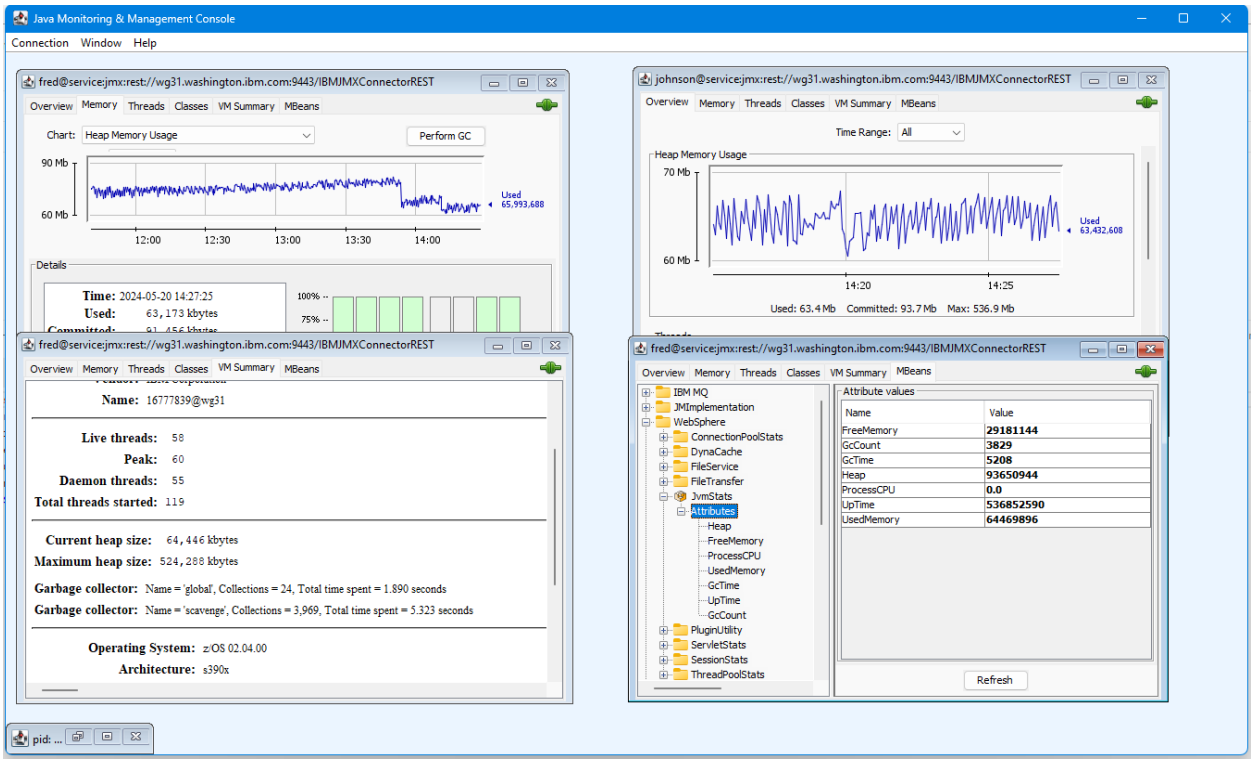
- On the *MBeans* tab, expand the *java.lang* folder and then expand the *Memory* MBean. Select *Attributes* and this will display the current values of memory related properties, i.e. *GCMode*, *MaxHeapSize, MaxHeapSize Limit,* and *MinHeapSize.*



Name	Value
CurrentGCThreads	2
GCMainThreadCpuUsed	1730
GCMasterThreadCpuUsed	1730
GCMode	-Xgcpolicy:gencon
GCSlaveThreadsCpuUsed	1584
GCWorkerThreadsCpuUsed	1584
HeapMemoryUsage	javax.management.openmbean.CompositeDataSupport
MaxHeapSize	536870912
MaxHeapSizeLimit	536870912
MaximumGCThreads	2
MinHeapSize	8388608
NonHeapMemoryUsage	javax.management.openmbean.CompositeDataSupport
ObjectName	java.lang:type=Memory
ObjectPendingFinalizationCount	0
SetMaxHeapSizeSupported	true
SharedClassCacheFreeSpace	0
SharedClassCacheMaxAotBytes	-1
SharedClassCacheMaxAotUnstoredBytes	0
SharedClassCacheMaxJitDataBytes	-1
SharedClassCacheMaxJitDataUnstoredBytes	0
SharedClassCacheMinAotBytes	-1
SharedClassCacheMinJitDataBytes	-1
SharedClassCacheSize	0
SharedClassCacheSoftmxBytes	-1
SharedClassCacheSoftmxUnstoredBytes	0
Verbose	false

Monitoring a z/OS Liberty server

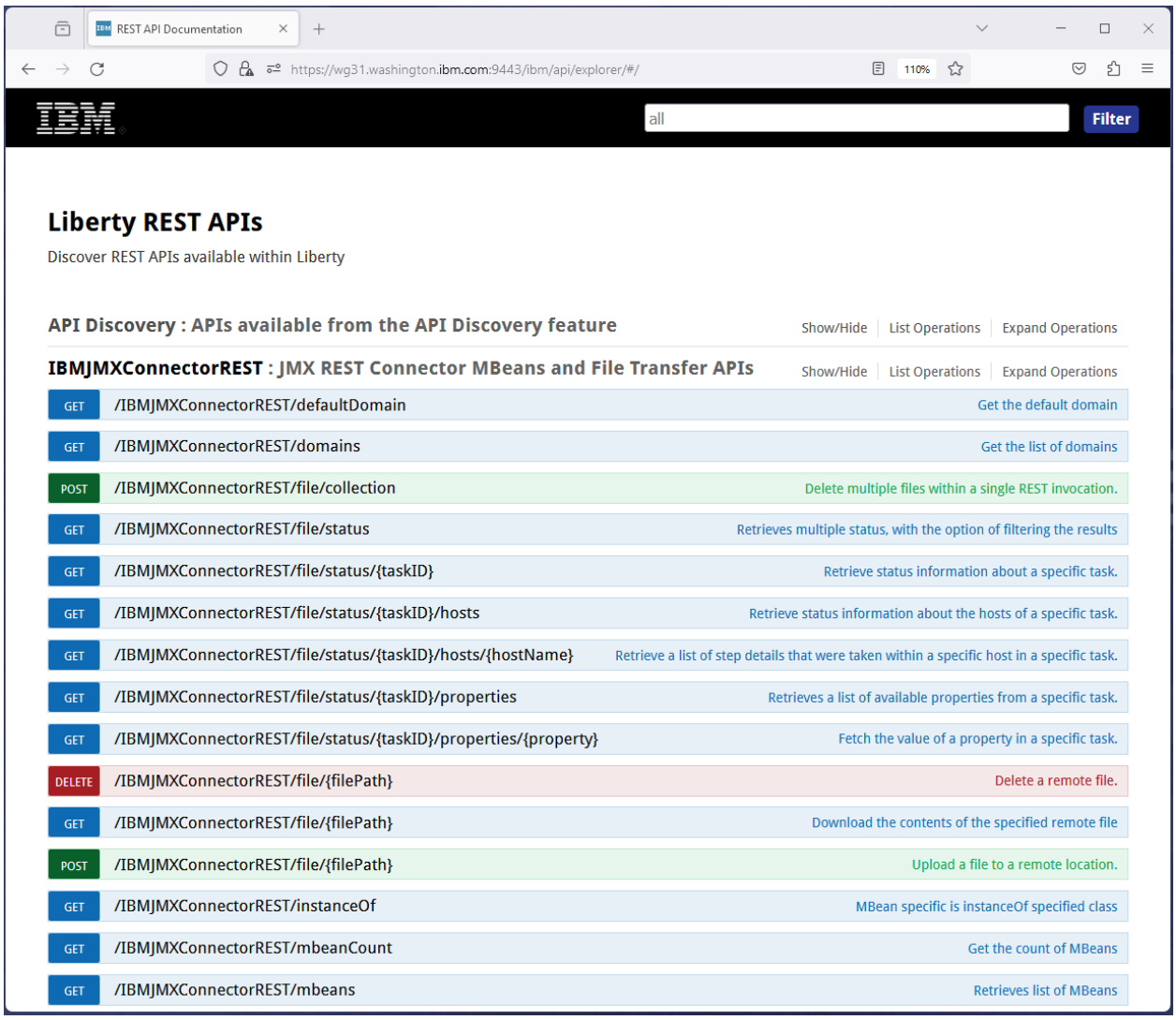
- Note that multiple connections can be established to the same Liberty server on z/OS from one instance of the JConsole GUI. This gives one the ability to monitor and manage multiple areas at the same time.



Using the IBM API Explorer to access MBeans using REST

Now access the Liberty MBeans from a REST client. Once such client is the *IBM API Explorer* which was added to the Liberty server by adding feature *apiDiscovery-1.0*. This enabled REST access to my server from a web browser.

- Begin by accessing the server's *IBM API Explorer* web page by using URL, e.g., https://wg31.washington.ibm.com:9443/ibm/api/explorer. Use the *List Operation* option to list the operations in **IBMJMXConnectorREST:JMX REST Connector MBeans and File Transfer APIs**.



Monitoring a z/OS Liberty server

When using *IBM API Explorer* focus on these selections.

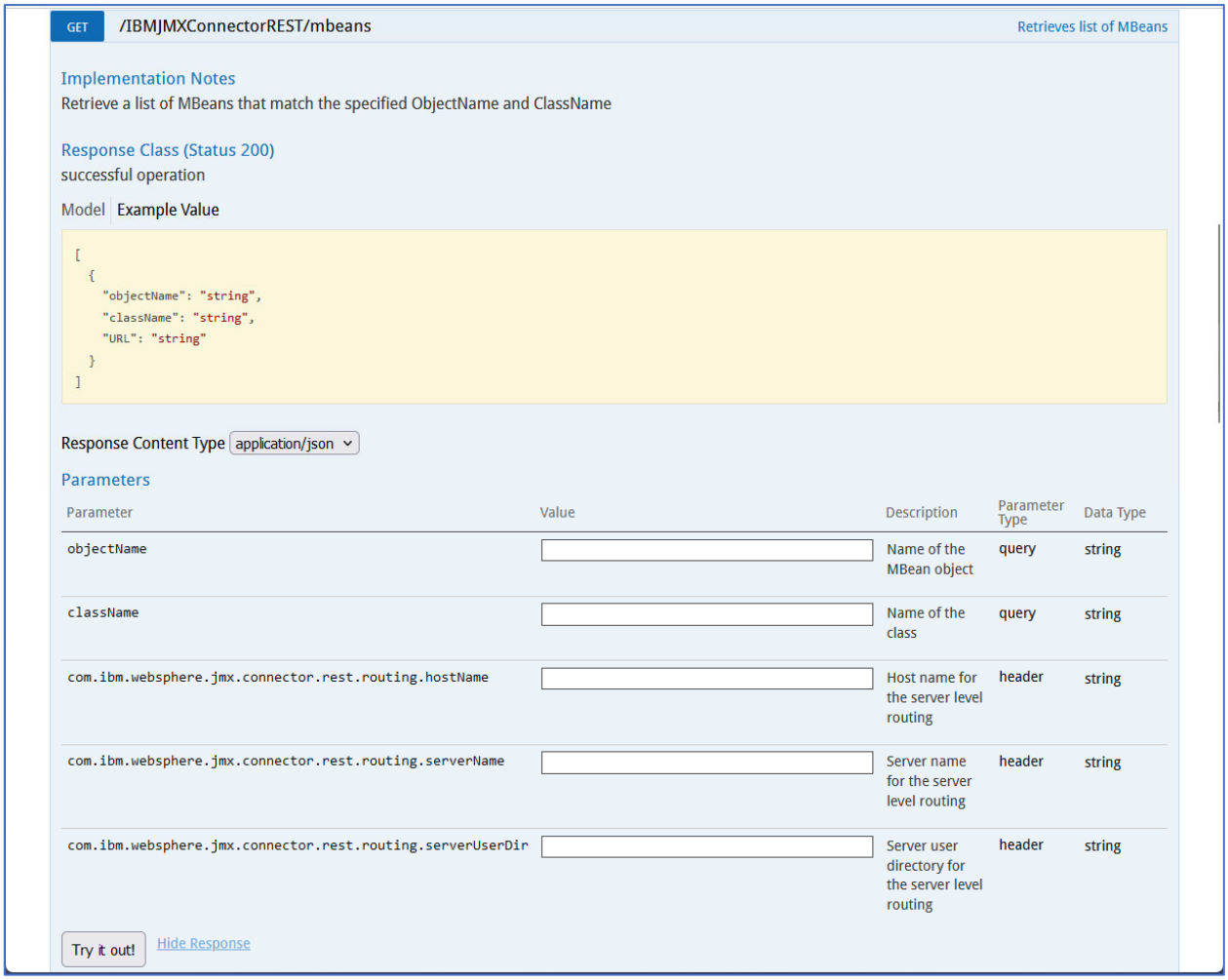
GET	/IBMJMXConnectorREST/mbeans	Retrieves list of MBeans
POST	/IBMJMXConnectorREST/mbeans	Retrieves list of MBeans by filtered Query Expression
POST	/IBMJMXConnectorREST/mbeans/factory	Create MBean
DELETE	/IBMJMXConnectorREST/mbeans/{objectName}	Deletes the MBean
GET	/IBMJMXConnectorREST/mbeans/{objectName}	Returns all endpoints
GET	/IBMJMXConnectorREST/mbeans/{objectName}/attributes	Retrives MBean values of several attributes
POST	/IBMJMXConnectorREST/mbeans/{objectName}/attributes	Sets MBean value attributes
GET	/IBMJMXConnectorREST/mbeans/{objectName}/attributes/{attribute}	Gets the value of a specific attribute of a named MBean.
PUT	/IBMJMXConnectorREST/mbeans/{objectName}/attributes/{attribute}	Sets the value of a specific attribute of a named MBean.
POST	/IBMJMXConnectorREST/mbeans/{objectName}/operations/{operation}	Invokes an operation on an MBean.

As you see there are REST APIs provide for obtaining a list of MBeans (GET). REST APIs for getting(GET) and setting(POST) an MBean's attributes. And a REST API for invoking (POST) and MBean's operation. The other REST APIs are interesting but beyond scope of the document.

Mitch Johnson (mitchj@us.ibm.com)

Monitoring a z/OS Liberty server

- I needed to display a list of the available MBeans. Select the *GET* method beside */IBMJMXConnectorREST/mbeans* to expose the interface as shown below. Note that you could have display a specific MBean by entering the MBean's object name or class name. But now we want to display them all so leave both fields empty.



Monitoring a z/OS Liberty server

- Pressing the **Try it out!** button will invoke this MBean and display the results in the *Response Body* section.

Try it out! Hide Response

Curl

```
curl -X GET --header 'Accept: application/json' 'https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans'
```

Request URL

```
https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans
```

Response Body


```
    "objectName": "WebSphere:type=com.ibm.ws.jca.cm.mbean.ConnectionManagerMBean,name=connectionManager[IMSConnMgr2]",
    "className": "com.ibm.ws.jca.cm.mbean.ConnectionManagerMBean",
    "URL": "/IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3DconnectionManager%5BIMSConnMgr2%5D%2Ctype%3Dcom.ibm.ws.jca.cm.mbean.ConnectionManagerMBe
  },
  {
    "objectName": "WebSphere:feature=apiDiscovery,name=APIDiscovery",
    "className": "com.ibm.ws.rest.api.discovery.internal.mbean.APIDiscovery",
    "URL": "/IBMJMXConnectorREST/mbeans/WebSphere%3Afeature%3DapiDiscovery%2Cname%3DAPIDiscovery"
  },
  {
    "objectName": "osgi.core:type=framework,version=1.7,framework=org.eclipse.osgi,uuid=63a83d8a-56db-4a3b-832a-80a2bce38eb5",
    "className": "org.apache.aries.jmx.framework.Framework",
    "URL": "/IBMJMXConnectorREST/mbeans/osgi.core%3Aframework%3Dorg.eclipse.osgi%2Ctype%3Dframework%2Cuuid%3D63a83d8a-56db-4a3b-832a-80a2bce38eb5%2
  },
  {
    "objectName": "WebSphere:name=com.ibm.ws.config.serverSchemaGenerator",
    "className": "com.ibm.ws.config.schemagen.internal.ServerSchemaGeneratorImpl",
    "URL": "/IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3Dcom.ibm.ws.config.serverSchemaGenerator"
  },
  {
    "objectName": "WebSphere:type=ThreadPoolStats,name=Default Executor",
```

Accessing MBean ConnectionManagerMBean

Now invoke the Mbean that provided access to the connection pool for connection pool *IMSConnMgr2*. So, in the *Response Body* area, search for all occurrences of the string *IMSConnMgr2*. The search found details of a ConnectionManagerMBean for this pool, see below. This provides the details(*objectName, className*, and *URL* (*URIPath*)) for this MBean. The MBean's *objectName* is needed to be able to invoke this MBean from the *IBM API Explorer*. The value for the URL(*URIPath*) will be useful when accessing this MBean from a REST client.

Response Body


```
    "objectName": "WebSphere:name=com.ibm.websphere.config.mbeans.FeatureListMBean",
    "className": "com.ibm.ws.config.featuregen.internal.FeatureListMBeanImpl",
    "URL": "/IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3Dcom.ibm.websphere.config.mbeans.FeatureListMBean"
  },
  {
    "objectName": "WebSphere:type=com.ibm.ws.jca.cm.mbean.ConnectionManagerMBean,name=connectionManager[IMSConnMgr2]",
    "className": "com.ibm.ws.jca.cm.mbean.ConnectionManagerMBean",
    "URL": "/IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3DconnectionManager%5BIMSConnMgr2%5D%2Ctype%3Dcom.ibm.ws.jca.cm.mbean.ConnectionManagerMBean"
  },
  {
    "objectName": "WebSphere:feature=apiDiscovery,name=APIDiscovery",
    "className": "com.ibm.ws.rest.api.discovery.internal.mbean.APIDiscovery",
    "URL": "/IBMJMXConnectorREST/mbeans/WebSphere%3Afeature%3DapiDiscovery%2Cname%3DAPIDiscovery"
  },
  {
    "objectName": "osgi.core:type=framework,version=1.7,framework=org.eclipse.osgi,uuid=63a83d8a-56db-4a3b-832a-80a2bce38eb5",
    "className": "org.apache.aries.jmx.framework.Framework",
    "URL": "/IBMJMXConnectorREST/mbeans/osgi.core%3Aframework%3Dorg.eclipse.osgi%2Ctype%3Dframework%2Cuuid%3D63a83d8a-56db-4a3b-832a-80a2bce38eb5%2Cve
  },
  {
```


Mitch Johnson (mitchj@us.ibm.com)

Monitoring a z/OS Liberty server

- Next obtain details about this MBean, e.g., operations, attributes, etc. locate the GET method for Mbean /*IBMJMXConnectorREST/mbeans/{objectName)* to expose this Mbean's interface. Enter the *objectName* for the IMSConnMgr2 connection pool MBean, *WebSphere:type=com.ibm.ws.jca.cm.mbean.ConnectionManagerMBean,name=connectionManager[IMSConnMgr2]*.

Response Content Type application/json

Parameters

Parameter	Value	Description	Parameter Type	Data Type
objectName	**WebSphere:type=com.ibm.ws.jca.cm.mbean**	**Name of the MBean object**	path	string
com.ibm.websphere.jmx.connector.rest.routing.hostName		Host name for the server level routing	header	string
com.ibm.websphere.jmx.connector.rest.routing.serverName		Server name for the server level routing	header	string
com.ibm.websphere.jmx.connector.rest.routing.serverUserDir		Server user directory for the server level routing	header	string

Try it out! Hide Response

- Pressing the **Try it Out** button provided the results below in the *Response Body*. Scrolling down, locate the *showPoolContents* operation, as well as the URL (URIPath) for use when accessing this operation from a REST client.

Response Body


```
      }
    }
  ],
  "URL": "/IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3DconnectionManager%5BIMSConnMgr2%5D%2Ctype%3Dcom.ibm.ws.jca.cm.mbean.ConnectionManagerMBean/operations/purgePoolContents"
},
{
  "name": "showPoolContents",
  "description": "Displays the current contents of the Connection Manager in a human readable format.",
  "descriptor": {
    "names": [],
    "values": []
  },
  "impact": "0",
  "returnType": "java.lang.String",
  "signature": [],
  "URL": "/IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3DconnectionManager%5BIMSConnMgr2%5D%2Ctype%3Dcom.ibm.ws.jca.cm.mbean.ConnectionManagerMBean/operations/showPoolContents"
}
]
}
```


Mitch Johnson (mitchj@us.ibm.com)

Monitoring a z/OS Liberty server

To invoke an operation of an MBean requires the use of a POST to URI path for MBean */IBMJMXConnectorREST/mbeans/{objectName}/operations/{operations}*

GET	/IBMJMXConnectorREST/mbeans	Retrieves list of MBeans
POST	/IBMJMXConnectorREST/mbeans	Retrieves list of MBeans by filtered Query Expression
POST	/IBMJMXConnectorREST/mbeans/factory	Create MBean
DELETE	/IBMJMXConnectorREST/mbeans/{objectName}	Deletes the MBean
GET	/IBMJMXConnectorREST/mbeans/{objectName}	Returns all endpoints
GET	/IBMJMXConnectorREST/mbeans/{objectName}/attributes	Retrives MBean values of several attributes
POST	/IBMJMXConnectorREST/mbeans/{objectName}/attributes	Sets MBean value attributes
GET	/IBMJMXConnectorREST/mbeans/{objectName}/attributes/{attribute}	Gets the value of a specific attribute of a named MBean.
PUT	/IBMJMXConnectorREST/mbeans/{objectName}/attributes/{attribute}	Sets the value of a specific attribute of a named MBean.
POST	/IBMJMXConnectorREST/mbeans/{objectName}/operations/{operation}	Invokes an operation on an MBean.

- Locate the POST method for this Mbean and exposed this Mbean's interface. Enter the MBean's object name, *WebSphere:type=com.ibm.ws.jca.cm.mbean.ConnectionManagerMBean,name=connectionManager[IMSConnMgr2],* along with the name of the *operations*, *showPoolContents,* in the areas beside *objectName* and *operations* respectively. Since this was a POST request, a simple JSON message consisting of a beginning and ending braces, *{}*, is required in the *JSON Request* area.

Parameters

Parameter	Value	Description	Parameter Type	Data Type
JSON Request	{} Parameter content type: application/json	JSON Request	body	Model | Example Value
objectName	n,name=connectionManager[IMSConnMgr2]	Name of the MBean object	path	string
operation	showPoolContents	Name of the specific operation	path	string
com.ibm.websphere.jmx.connector.rest.routing.hostName		Host name for the server level routing	header	string
com.ibm.websphere.jmx.connector.rest.routing.serverName		Server name for the server level routing	header	string
com.ibm.websphere.jmx.connector.rest.routing.serverUserDir		Server user directory for the server level routing	header	string

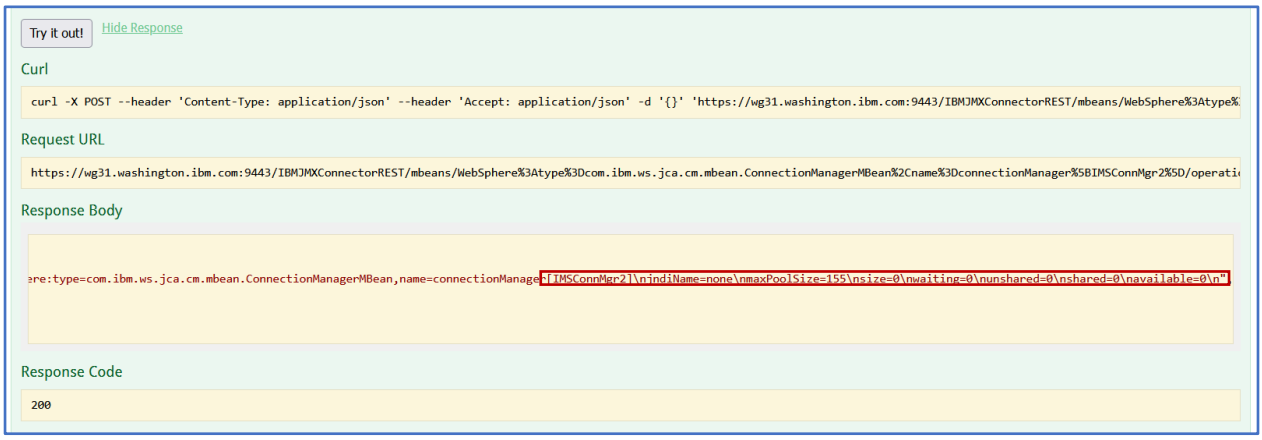
```
{
  "params": [
    {
      "value": "${server.output.dir}/server.xml",
      "type": "java.lang.String"
    }
  ],
  "signature": [
    "java.lang.String"
  ]
}
```

Try it out! Hide Response

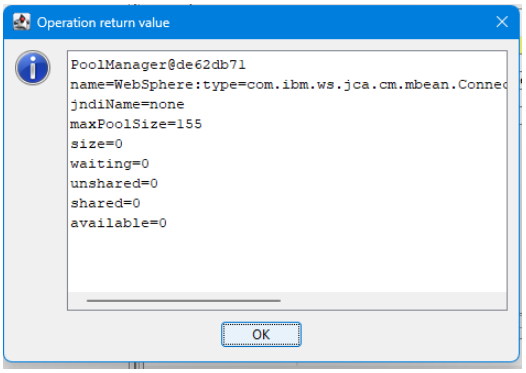
Mitch Johnson (mitchj@us.ibm.com)

Monitoring a z/OS Liberty server

- Pressing the **Try it Out** button invoked this operation provided the results showing the connection pool status in the *Response Body* as shown below.



This is same information displayed by JConsole.



Accessing MBean ServerXMLConfigurationMBean

Next, display the server XML configuration files. Use the same process as befor, that is starting with the list of MBeans, identifying the Mbean's *objectNam*e of *WebSphere:name=com.ibm.websphere.config.mbeans.ServerXMLConfigurationMBean* and *operation* name of *fetchConfigurationFilePath.*

Note that invoking this MBean required the use of the POST method and the addition of a simple JSON message with a beginning and ending braces, {}.

Parameters

Parameter	Value	Description	Parameter Type	Data Type
JSON Request	{} Parameter content type: application/json	**JSON Request**	body	Model Example Value { "params": [{ "value": "${server.output.dir}/server.xml", "type": "java.lang.String" }], "signature": ["java.lang.String"] }
objectName	nfig.mbeans.ServerXMLConfigurationMBean	**Name of the MBean object**	path	string
operation	fetchConfigurationFilePaths	**Name of the specific operation**	path	string
com.ibm.websphere.jmx.connector.rest.routing.hostName		Host name for the server level routing	header	string
com.ibm.websphere.jmx.connector.rest.routing.serverName		Server name for the server level routing	header	string
com.ibm.websphere.jmx.connector.rest.routing.serverUserDir		Server user directory for the server level routing	header	string

Try it out! Hide Response

With a response messge of:

Response Body


```
{
  "value": [
    "${server.config.dir}/server.xml",
    "${server.config.dir}/resources/imsmobile-config/connections/ims-connections.xml",
    "${shared.config.dir}/safSecurity.xml",
    "${server.config.dir}/resources/imsmobile-config/services/ims-services.xml",
    "${shared.config.dir}/ipic.xml",
    "${shared.config.dir}/features.xml",
    "${server.config.dir}/ims-admin-services.xml",
    "${server.config.dir}/resources/imsmobile-config/interactions/ims-interactions.xml",
    "${shared.config.dir}/apiRequesterHTTPS.xml",
    "${shared.config.dir}/keyring.xml",
    "${shared.config.dir}/mq.xml",
    "${shared.config.dir}/web.xml"
  ],
  "type": {
    "className": "java.util.HashSet",
    "items": [
      "java.lang.String",
```


Response Code

```
200
```


Mitch Johnson (mitchj@us.ibm.com)

Monitoring a z/OS Liberty server

- This same process, starting with the list of MBeans, identifying an Mbean's *objectNam*e and *attributes* can be used to the current value of key attributes, e.g. *heap, GcCount*, etc in the case of a *JvmStats* Mbean.

REST API Documentation

https://wg31.washington.ibm.com:9443/ibm/api/explorer/#!/IBMJMXConnectorREST/queryMultipleAttributes

GET /IBMJMXConnectorREST/mbeans/{objectName}/attributes — Retrives MBean values of several attributes

Implementation Notes

Retrieves the values of several attributes of a named MBean. 'value' is a POJO parameter. To get more information about declaring a POJO, do a GET request /IBMJMXConnectorREST/pojo

Response Class (Status 200)

Generated MBeans

Model | Example Value

```
{
  "name": "string",
  "value": [
    {
      "value": "${server.output.dir}/server.xml",
      "type": "java.lang.String"
    }
  ]
}
]
```

Response Content Type application/json

Parameters

Parameter	Value	Description	Parameter Type	Data Type
objectName	WebSphere:type=JvmStats	Name of the MBean object	path	string
attribute	Heap	Name of the attribute	query	Array[string]
com.ibm.websphere.jmx.connector.rest.routing.hostName		Host name for the server level routing	header	string
com.ibm.websphere.jmx.connector.rest.routing.serverName		Server name for the server level routing	header	string
com.ibm.websphere.jmx.connector.rest.routing.serverUserDir		Server user directory for the server level routing	header	string

Try it out! Hide Response

Curl

```
curl -X GET --header 'Accept: application/json' 'https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans/WebSphere%3Atype%3DJvmStats/attributes?attribute=Heap'
```

Request URL

```
https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans/WebSphere%3Atype%3DJvmStats/attributes?attribute=Heap
```

Response Body

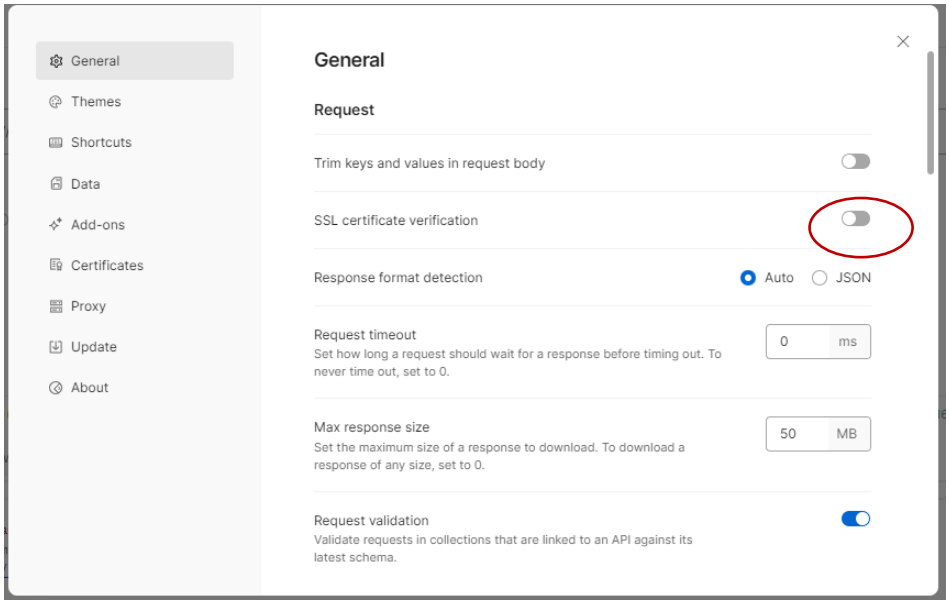
```
[
  {
    "name": "Heap",
    "value": {
      "value": "88604672",
      "type": "java.lang.Long"
```


Mitch Johnson (mitchj@us.ibm.com)

Using Postman to access MBeans using REST

Another useful tool for accessing the Liberty MBeans from a REST client is Postman.

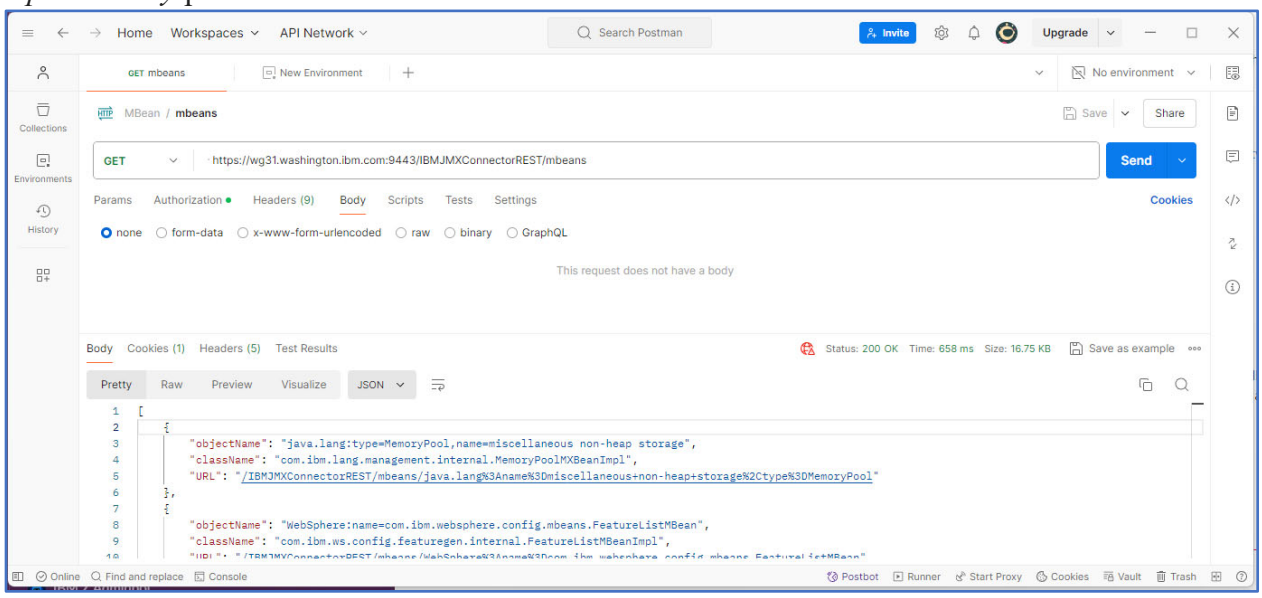
Some housekeeping is required before using Postman to access the Liberty MBeans. First, access the Postman *Settings* options using the sprocket on the toolbar and turned off *SSL certificate verification.* The same local key store used for JConsole could have been used but running with server verification is sufficient at this time.



• The next step is to provide some basic credentials. Select the *Authorization* tab and entered a valid *Username* and *Password*. This identity must have access to the RACF EJBRoles protecting the JMX and REST resources in the server.

Mitch Johnson (mitchj@us.ibm.com)

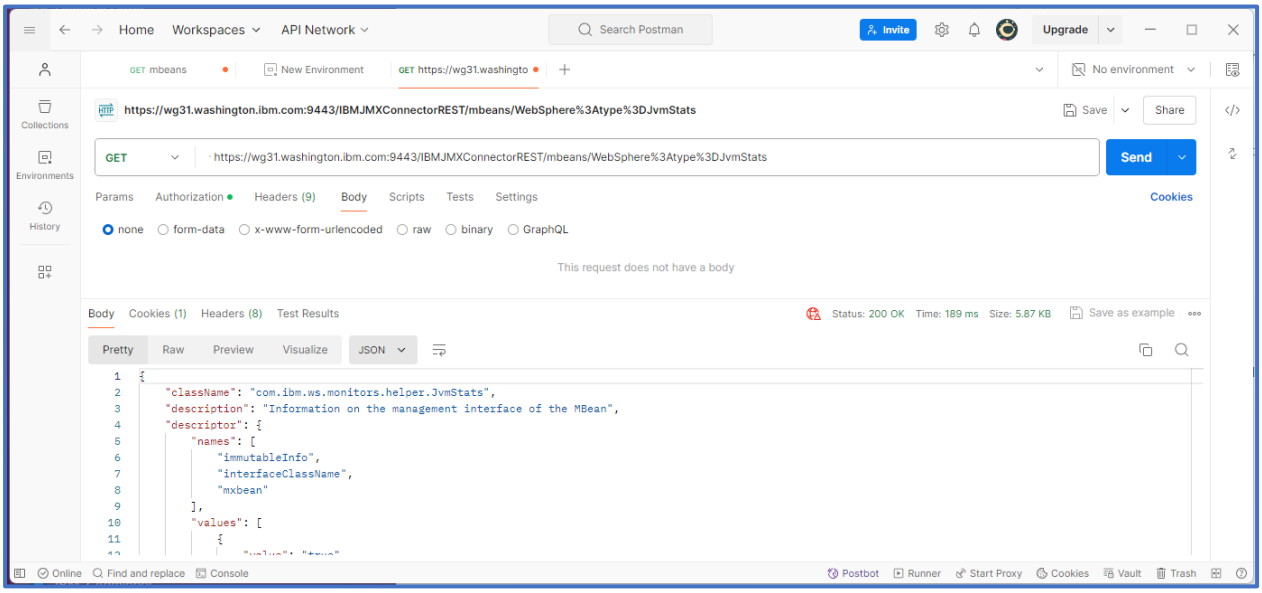
- Next select the *Body* tab and use the pull-down to select the **GET** method and enter this URL https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans. Pressing the **Send** button invoked this MBean and returned a list of the MBeans available at the server in the *Response Body* pane.



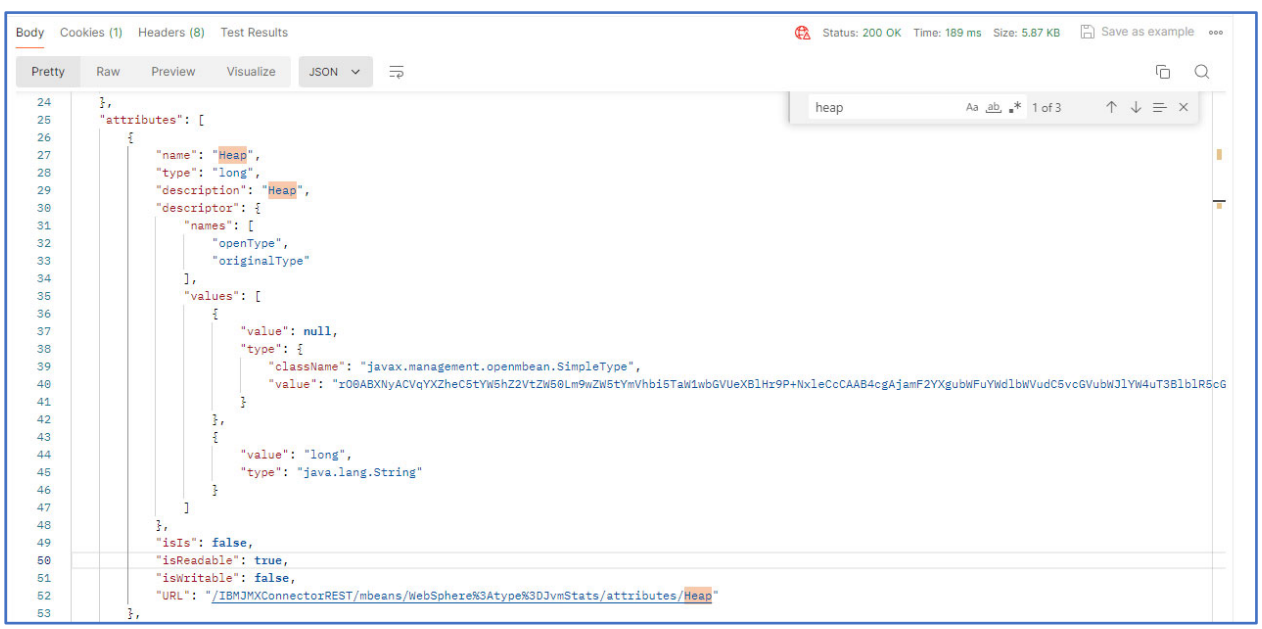
Accessing MBean JvmStats

- Use the search tool to locate the MBean in which we are interested, *JvmStats*.

• Simply click on the URL in the *Response*, e.g., "/IBMJMXConnectorREST/mbeans/WebSphere%3Atype%3DJvmStats" and this will open a new Postman window with the full URL already filled in. You may have to add the same credentials for this request, but then just click the **Send** button to invoke this new MBean.

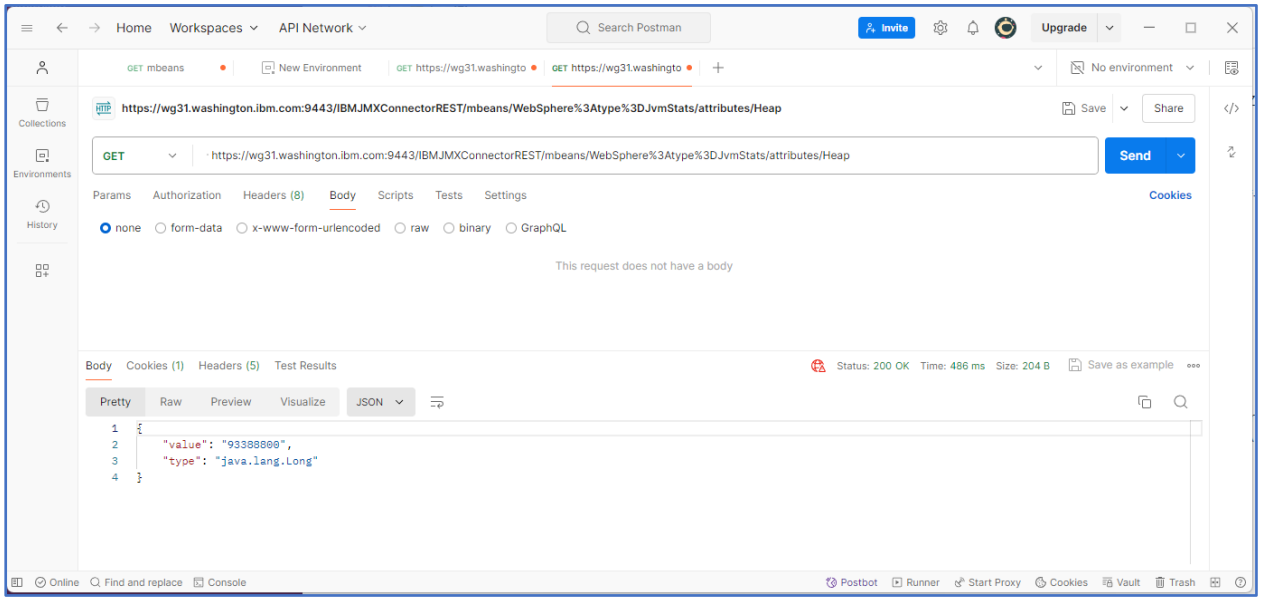


• Use the search tool again to search for a particular attribute, e.g. *heap*.



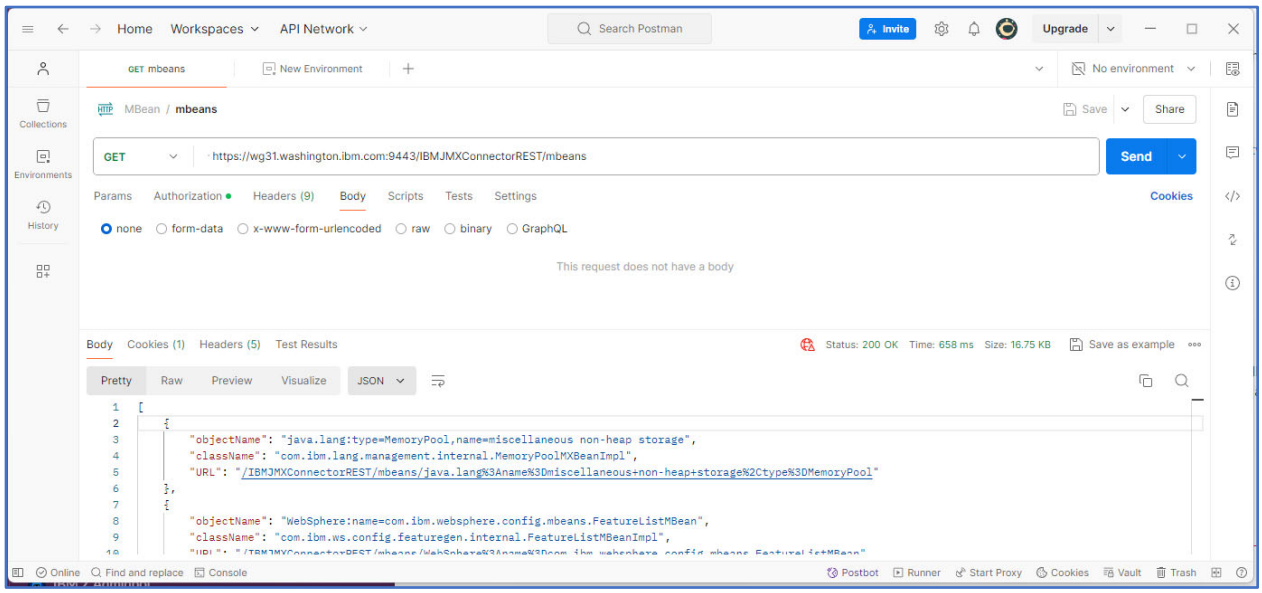
Note. The use of encoding for special characters in the URL, e.g., the %3A and %3D. The %3A represents the colon (:) character and %3D represents the equal sign(=). For the full list of available ASCII encoding sequences, see URL https://www.w3schools.com/tags/ref_urlencode.ASP

- Click on the URL, e.g., "/IBMJMXConnectorREST/mbeans/WebSphere%3Atype%3DJvmStats/attributes/Heap" and press the **Send** button on the new window to invoke this MBean.



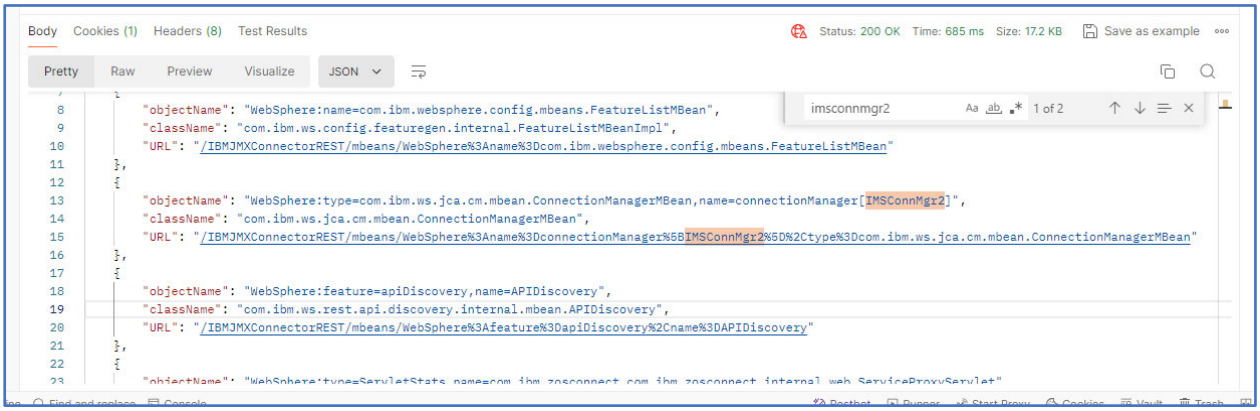
Next let's explore display connection pool information.

- Go back to the Postman tab where display the list of MBeans by sending a **GET** to URL https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans.



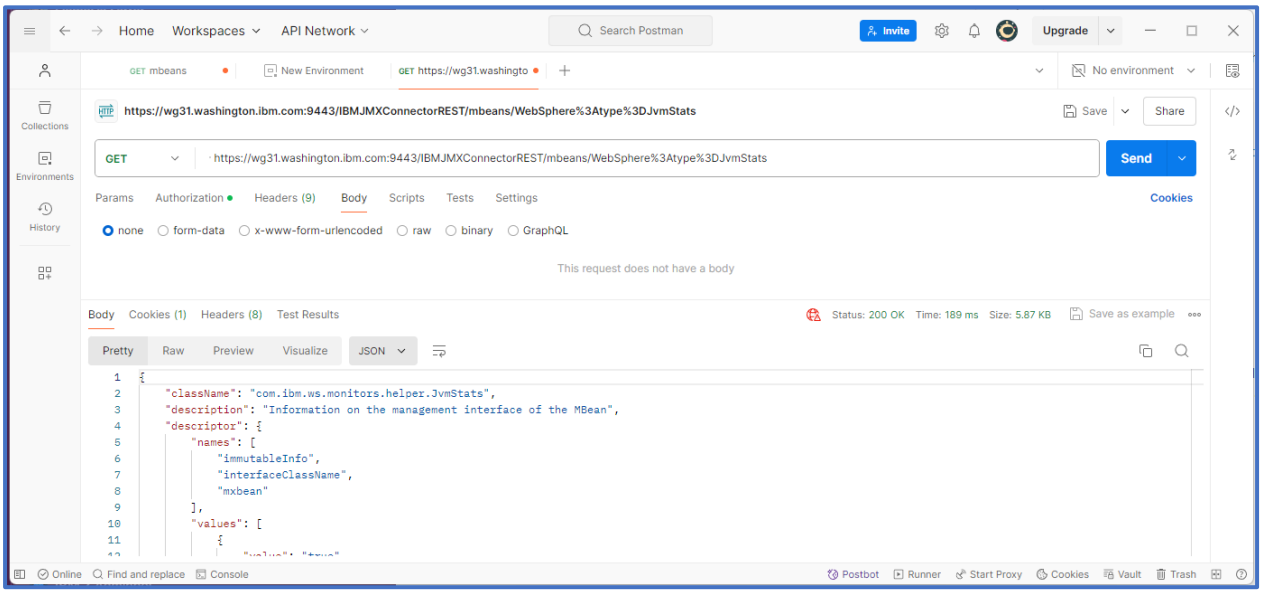
Accessing MBean ConnectionManagerMBean

- Use the search tool to locate the connection pool in which we are interested, *IMSConnMgr2*.



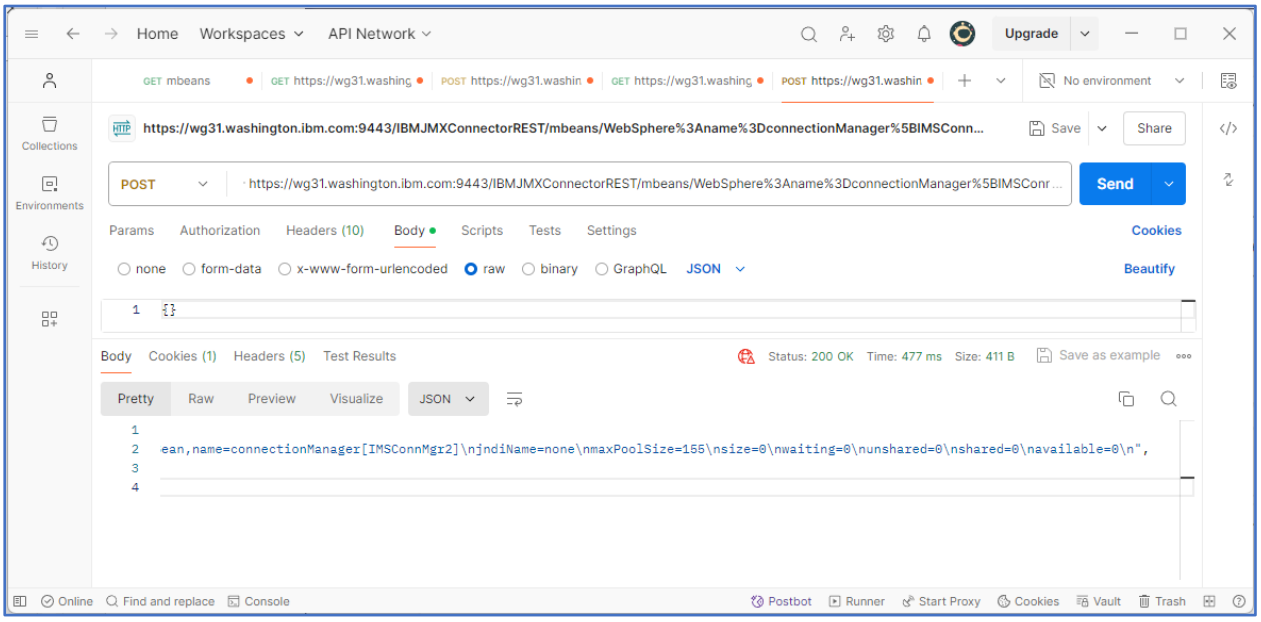
Monitoring a z/OS Liberty server

- Simply click on the URL in the *Response*, e.g., /IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3DconnectionManager%5BIMSConnMgr2%5D%2Ctype%3Dcom.ibm.ws.jca.cm.mbean.ConnectionManagerMBean and this will open a new Postman window with the full URL already filled in. A new set of credentials may be needed for this request but then just click the **Send** button to invoke this new MBean.



- Use the search tool again to search for a particular *operation*, e.g. *showPoolContents*.

- Click on the URL, e.g., /IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3DconnectionManager%5BIMSConnMgr2%5D%2Ctype%3Dcom.ibm.ws.jca.cm.mbean.ConnectionManagerMBean/operations/showPoolContents and press the **Send** button on the new window to invoke this MBean. Invoking the MBean should failed with an HTTP 405 error, *method not allowed*. To address this, changed the method to **POST.** Since we are now using a **POST,** a request message must be added. Simply checked the radio *Body* in the Postman request message section and used the pull down to select *raw*. Entered a simple JSON message consisting of a beginning and ending braces, ***{}***. Now pressing the **Send** button successfully accesses the MBean to display the connection pool details.



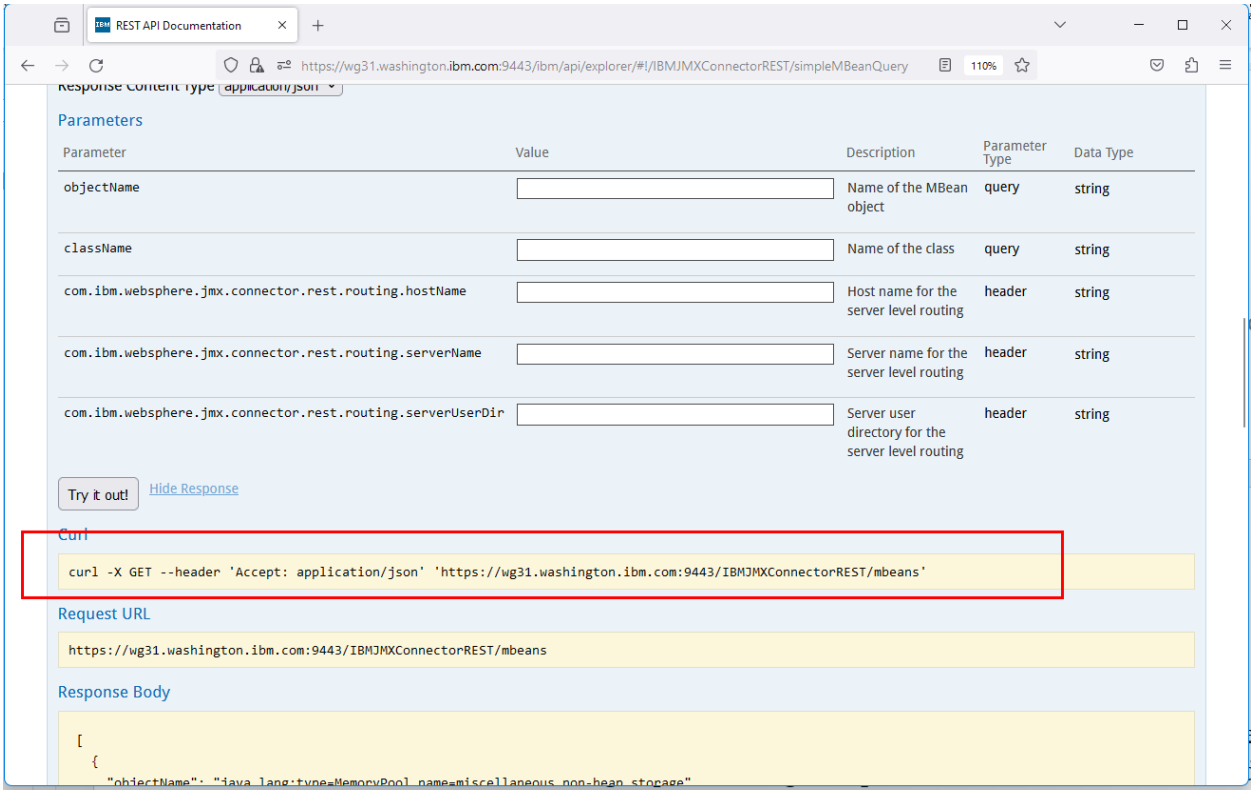
Mitch Johnson (mitchj@us.ibm.com)

Using cURL to access MBeans using REST

Accessing the MBeans form a REST client from a cURL (client URL) is another option. The best way to create the cURL command for accessing MBeans by using either the *IBM API Explorer* or *Postman* to invoke the MBean first. The advantage of using these tools first is once you are able to access an MBean with these tools, they will provide you with the syntax of cURL command to accomplish the same results.

Building cURL commands from IBM API Explorer

Note that when the *IBM API Explorer* provides the results, the "almost" equivalent cURL is also displayed (see below).



I said almost because there are some cURL parameters that must be added and the use of single quotes has to be replaced by double quotes. Using the above example, the curl command would need to be changed

From:

```
curl -X GET --header 'Accept: application/json'
'https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans'
```

To:

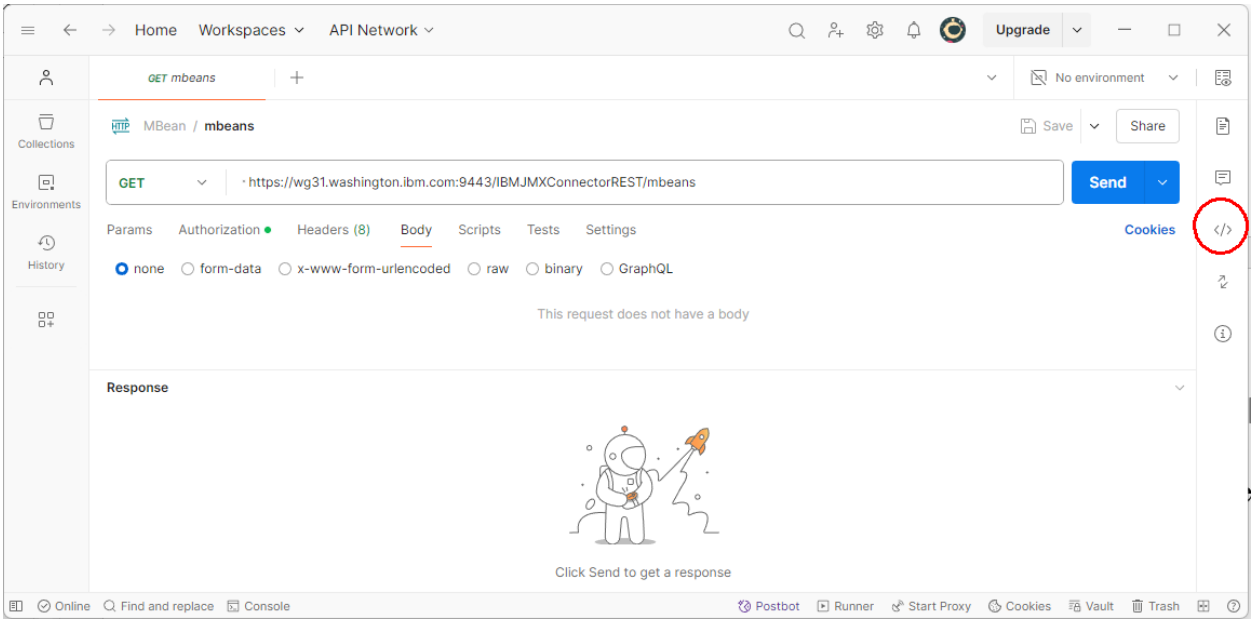
```
curl -X GET --cacert CERTAUTH.PEM --user USER1:USER1 --header "Accept:
application/json"
https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans
```

Where *--cacert* identifies a local trust store and *–user* provides basic authentication credentials. cURL has the option of providing *–insecure* as an alternative to providing a local truststore. With *–insecure* provided, the SSL handshake completes without verifying the server's certificate information.

Note in the above command, the certificate authority certificate file, CERTAUTH.PEM, is the same file used to configure TLS for the JConsole GUI client.

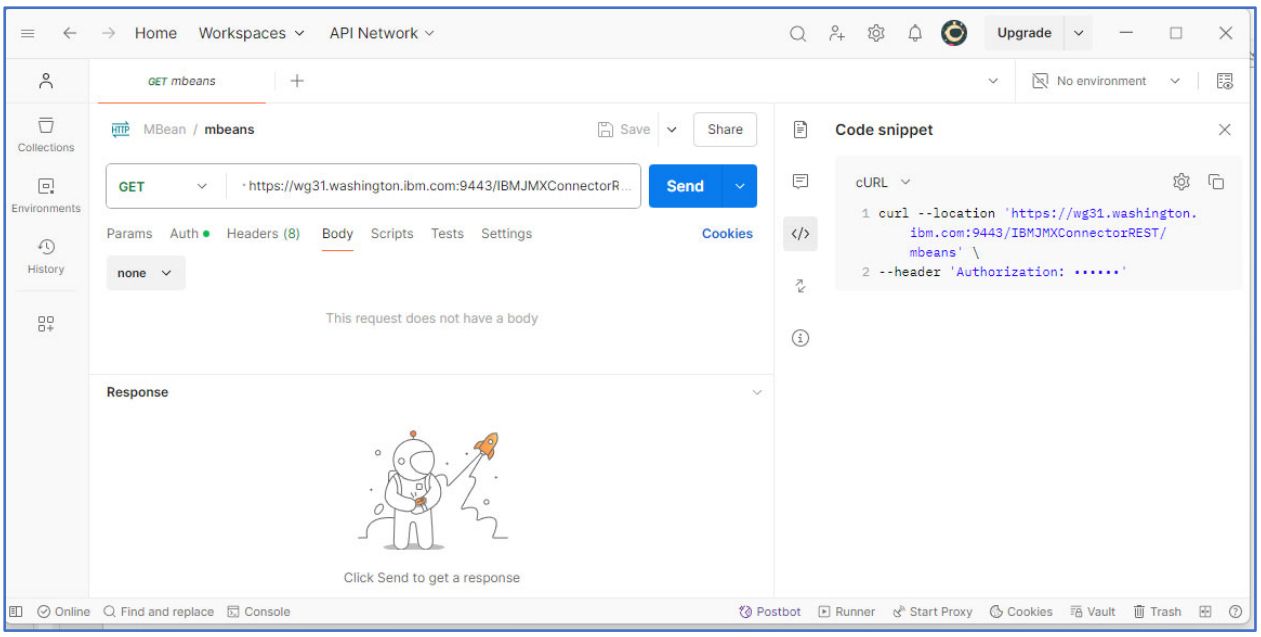
Building cURL commands from Postman

With Postman you can monitor the equivalent cURL command by pressing the </> icon on the side tab.

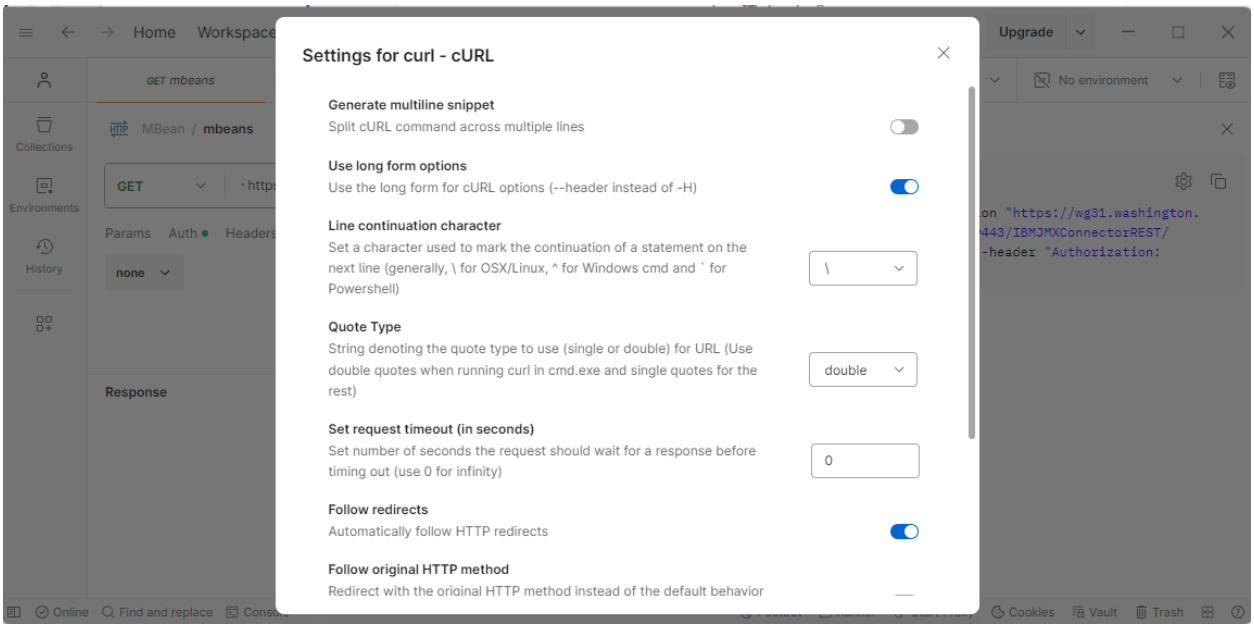


Select this option will display the equivalent cURL command. I selected the sprocket in this pane in order to customize the cURL command to way needed for a DOS command prompt.

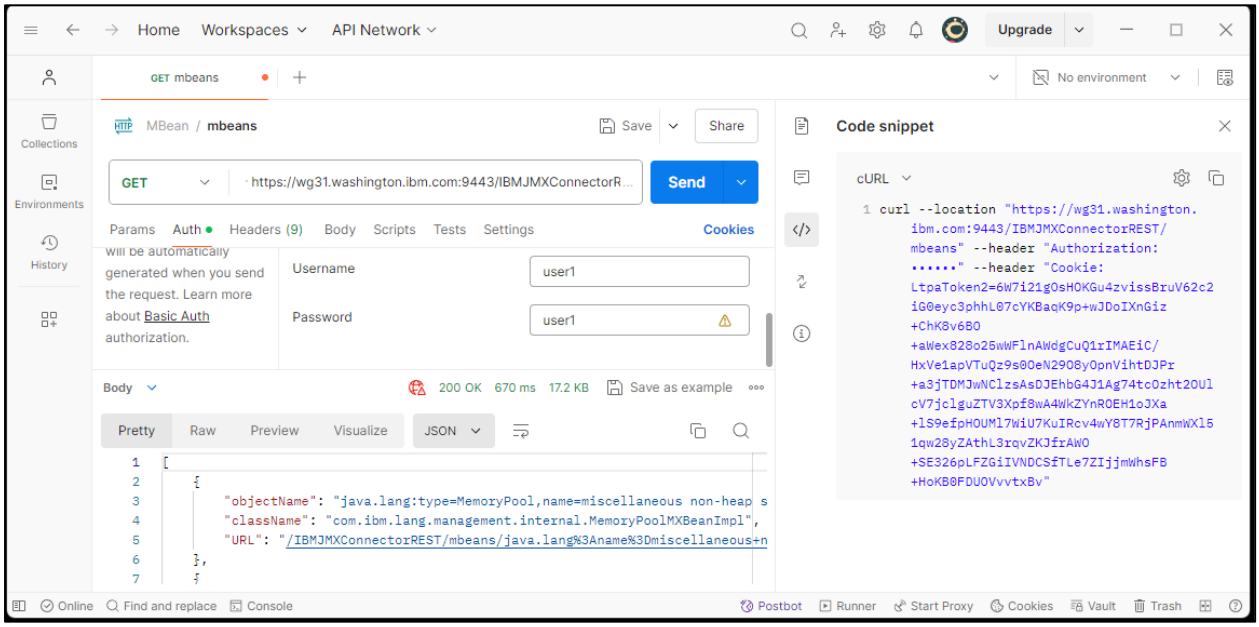
Monitoring a z/OS Liberty server



I changed the cURL settings so that *Generate multiline snippet* was turned off and the *Quote Type* would use double quotes rather than single quotes.



Now the cURL command in the Code snippet pane can be copied and used externally from Postman with a couple of exceptions. The *–header* for *Authorization* and the *–header* for *Cookie* should be remove before of after the cURL command is copied.



Below are some examples of using these techniques to build various cURL command and their results when invoked.

C:\z\jconsole>curl --cacert CERTAUTH.PEM --user USER1:USER1 https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3DDefault+Executor%2Ctype%3DThreadPoolStats/attributes

[{"name":"PoolSize","value":{"value":"20","type":"java.lang.Integer"}},{"name":"ActiveThreads","value":{"value":"1","type":"java.lang.Integer"}},{"name":"PoolName","value":{"value":"Default Executor","type":"java.lang.String"}}]

C:\z\jconsole>curl --cacert CERTAUTH.PEM --user USER1:USER1 https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3DDefault+Executor%2Ctype%3DThreadPoolStats/attributes/PoolName

{"value":"Default Executor","type":"java.lang.String"}

C:\z\jconsole>curl --cacert CERTAUTH.PEM --user USER1:USER1 https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3DDefault+Executor%2Ctype%3DThreadPoolStats/attributes/PoolSize

{"value":"20","type":"java.lang.Integer"}

C:\z\jconsole>curl --cacert CERTAUTH.PEM --user USER1:USER1 https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3DDefault+Executor%2Ctype%3DThreadPoolStats/attributes/ActiveThreads

{"value":"1","type":"java.lang.Integer"}

C:\z\jconsole>curl -X POST --cacert CERTAUTH.PEM --user USER1:USER1 -d "{}" --header "Content-Type: application/json" --header "Accept: application/json" https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans/WebSphere%3Aname%3DconnectionManager%5BIMSConnMgr2%5D%2Ctype%3Dcom.ibm.ws.jca.cm.mbean.ConnectionManagerMBean/operations/showPoolContents

{"value":"PoolManager@de62db71\nname=WebSphere:type=com.ibm.ws.jca.cm.mbean.ConnectionManagerMBean,name=connectionManager[IMSConnMgr2]\njndiName=none\nmaxPoolSize=155\nsize=0\nwaiting=0\nunshared=0\nshared=0\navailable=0\n","type":"java.lang.String"}

C:\z\jconsole>curl --location "https://wg31.washington.ibm.com:9443/IBMJMXConnectorREST/mbeans/WebSphere%3Atype%3DJvmStats/attributes" --insecure --user USER1:user1

[{"name":"Heap","value":{"value":"139067392","type":"java.lang.Long"}},{"name":"FreeMemory","value":{"value":"37360080","type":"java.lang.Long"}},{"name":"ProcessCPU","value":{"value":"1.0","type":"java.lang.Double"}},{"name":"UsedMemory","value":{"value":"101707312","type":"java.lang.Long"}},{"name":"GcTime","value":{"value":"977","type":"java.lang.Long"}},{"name":"UpTime","value":{"value":"93425998","type":"java.lang.Long"}},{"name":"GcCount","value":{"value":"347","type":"java.lang.Long"}}]

Mitch Johnson (mitchj@us.ibm.com)