JAVA

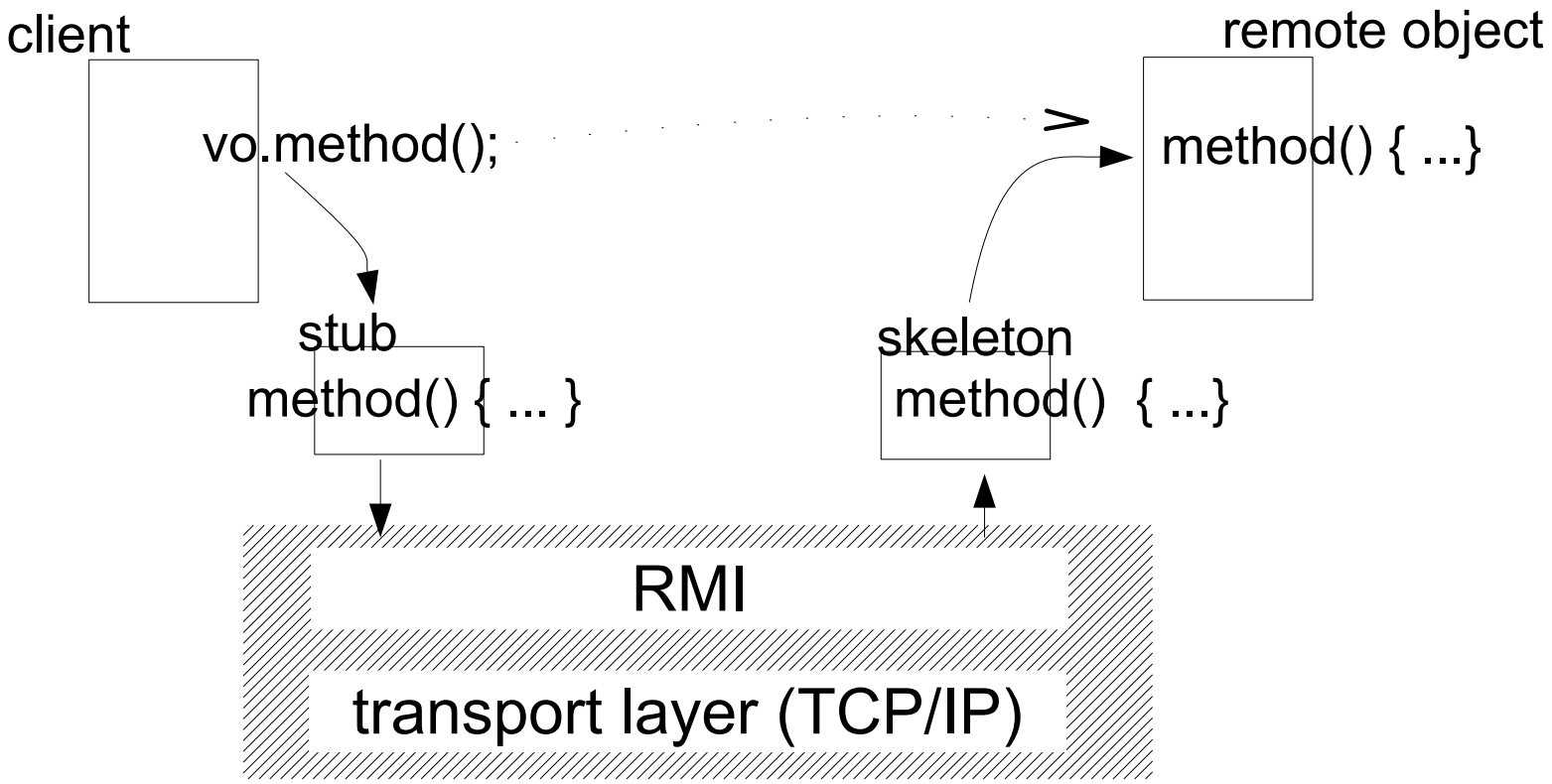
RMI

Overview

- Remote Method Invocation
- usage of remote object
  - objects in a different VM (on the same computer or over the network)
- as there would be local objects (almost)
  - calls just take longer time

- `java.rmi` module

Remote call in general



Example: interface

1. the interface for a remote object
   - must extend java.rmi.Remote
   - java.rmi.RemoteException declared by each methods

```
import java.rmi.Remote;
import java.rmi.RemoteException;

public interface Hello extends Remote {
    String sayHello() throws RemoteException;
}
```

Example: implementation

2. implementation of the interface

```
public class HelloImpl extends UnicastRemoteObject
  implements Hello {

  public HelloImpl() throws RemoteException {}

  public String sayHello() throws RemoteException{
    return "Hello, world!";
  }
}
```

Example: creating the object

3. create the object
4. register the object

```
public class HelloImpl implements Hello
                              extends UnicastRemoteObject {
  ...

  public static void main(String args[]) {
    try {
      HelloImpl obj = new HelloImpl();
      Naming.rebind("Hello", obj);
    } catch (Exception e) {
      ...
    }
  }
```

Example: client

```
public class HelloClient {

  public static void main(String[] args) {
    try {
      Hello robj = (Hello) Naming.lookup("Hello");
      String mesg = robj.sayHello();
      System.out.println(mesg);
    } catch (Exception e) {
      ....
    }
  }
}
```

5. obtaining a reference to the remote object
6. using the object

Example: compilation and run

7. compilation
   - as usually
8. launching
   a) rmiregistry
   b) java -Djava.rmi.server.codebase=file:/.../ HelloImpl
      - codebase ~ a path to the class files
   c) java HelloClient

Example: object implementation

- different way to implement an object
  - if UnicastRemoteObject cannot be extended

```
public class HelloImpl implements Hello {
  ...
  public static void main(String args[]) {
    try {
      HelloImpl obj = new HelloImpl();
      Hello robj = (Hello)
              UnicastRemoteObject.exportObject(obj, 0);
      Naming.rebind("Hello", robj);
    } catch (Exception e) {
      ...
    }
  }
```

Stubs & skeletons

- generated automatically
- JDK 1.4
  - automatically skeletons only
  - stubs generated “by-hand”
  - **rmic** compiler
    - executed after **javac** to Remote objects implementations
  - **codebase** must be set for the server
    - **-Djava.rmi.server.codebase=.....**
    - codebase point to the stubs
    - a client automacally downloads them from codebase
    - codebase is typically file:, ftp://, http://
    - must end with **/**
  - it is necessary to set the security policy
    - -Djava.security.policy=....
  - the security manager must be set
    - System.setSecurityManager(new SecurityManager());

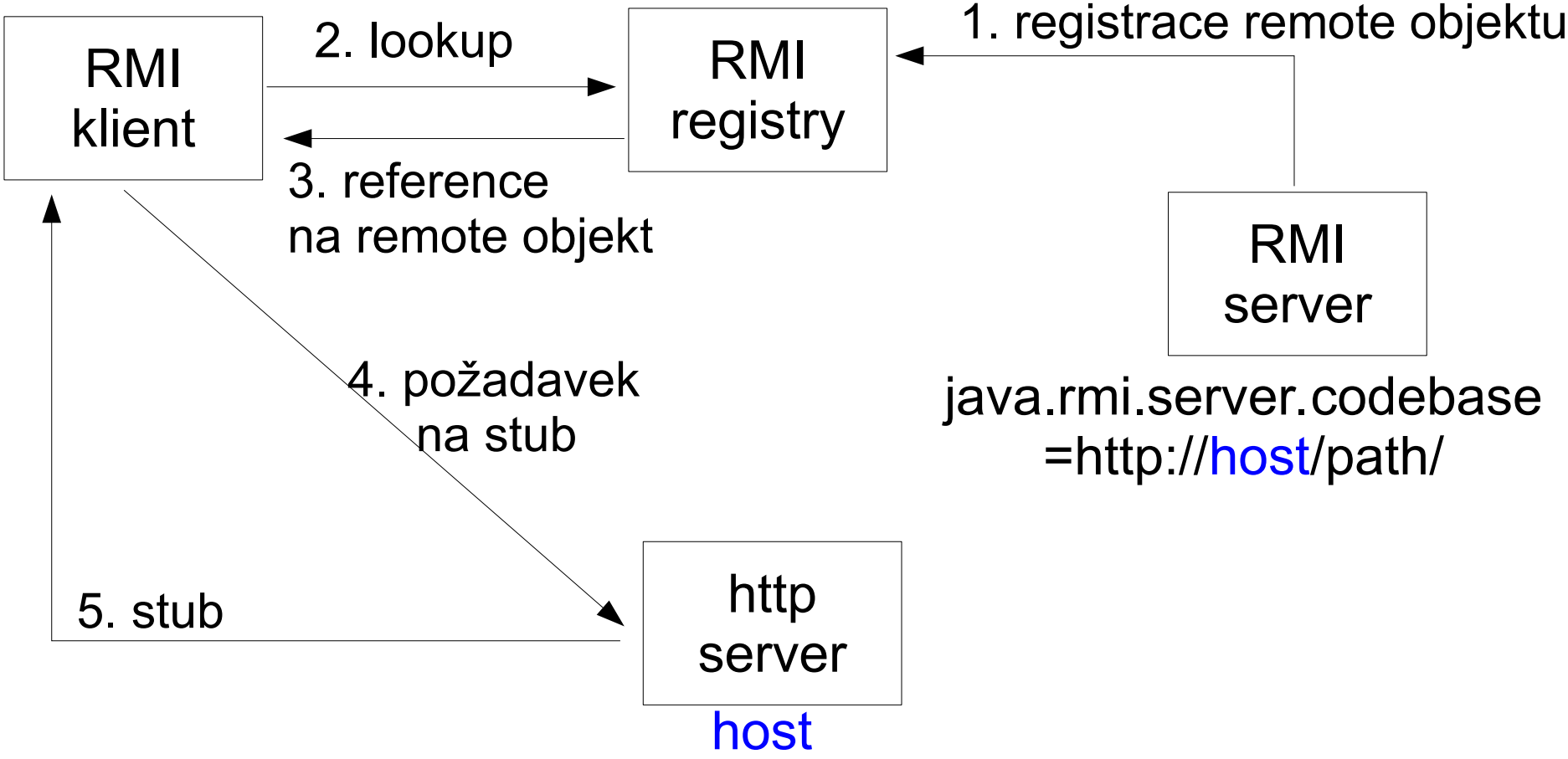
Stubs & skeletons

- JDK 1.4 (cont.)
  - **rmiregistry** must not have set CLASSPATH, in which are classes to be downloaded
- JDK 1.5
  - if stubs are available => they are not generated
  - for always generated stubs
    - set the property java.rmi.server.ignoreStubClasses to true
- JDK 1.1
  - nothing is generated
  - **rmic** generates both stubs and skeletons

Stubs & skeletons & codebase

- WARNING
  - since JDK 7 Update 21 change of behavior
  - the property **`java.rmi.server.useCodebaseOnly`** set to **true** by default
    - previously it was **false**
  - if it is set to true, automatic loading of classes is allowed only from locally set codebase
    - i.e. codebase has to be set also for the rmiregistry or the rmiregistry has to have the **`useCodebaseOnly`** set to **false**

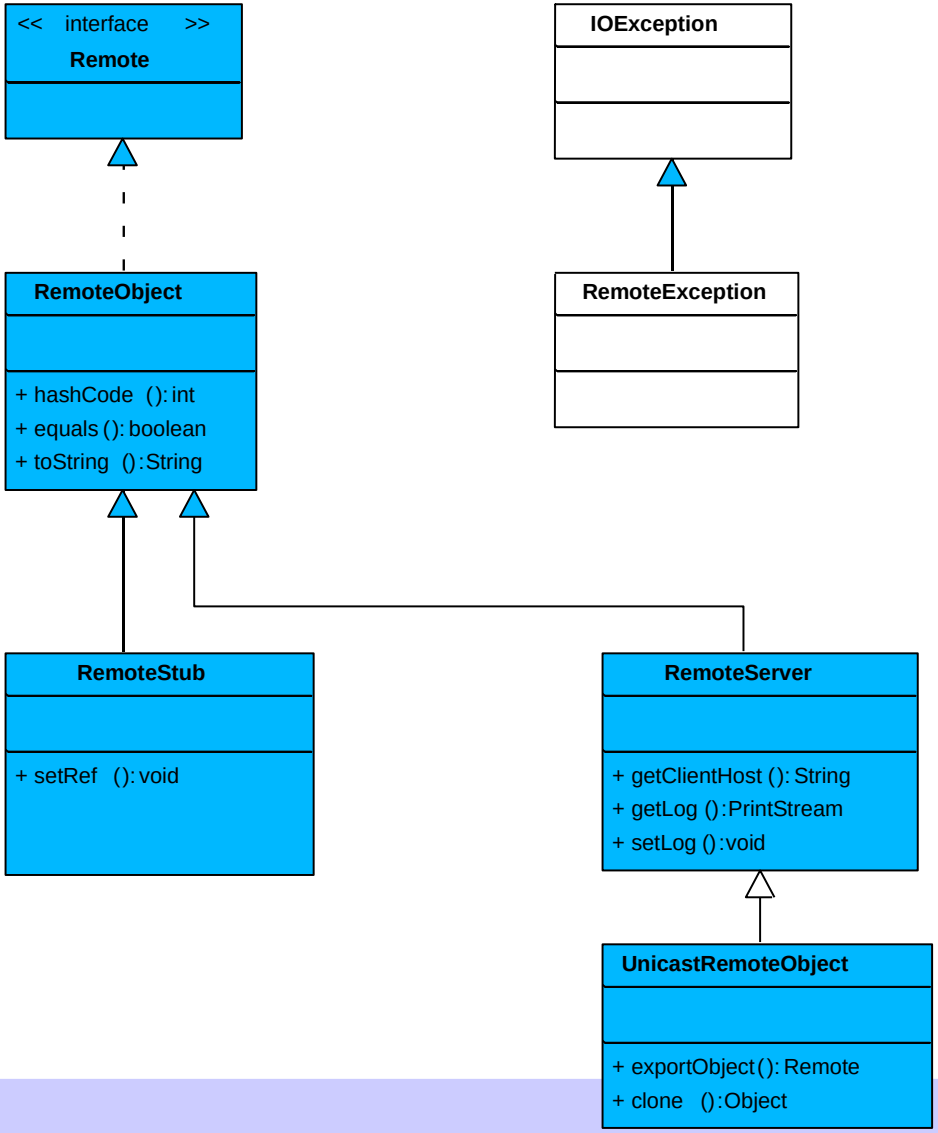
Code downloading



Distributed Object Model

- no differences from the plain Java Object Model
  - references to remote objects can be passed method parameters
  - remote objects can be cast to a remote interface
  - it is possible to use **instanceof** for remote interface tests
- differences from the plain Java Object Modelu
  - clients always work with a remote object via remote interface
    - i.e. no direct access to object fields
  - non-remote parameters passed by-value
  - several methods from **java.lang.Object** are overridden
    - hashCode, equals
  - methods throw RemoteException

Class hierarchy



Threads

- no guarantee how calls on a remote object are associated with threads
- calls on the same remote object can be executed concurrently

Naming

- obtaining an initial reference to remote object
- simple directory service
  - references to objects associated with strings
- implementation – ***rmiregistry***
  - a reference in the registry is either
    - till its explicit removal, or
    - till ***rmiregistry*** terminating
  - a reference to an object can be in the registry even the object has been already terminated
- accessible also via RMI
- how to obtain a reference to ***rmiregistry***?
  - (the chicken-egg problem)
  - the reference to ***rmiregistry*** is created from the address and port of the computer, where ***rmiregistry*** runs

Naming

- several rmiregistries can be used at the same moment
  - on different computers
  - on different ports
- to rmiregistry, only processes running on the same computer can register objects
  - reading from the registry from everywhere
  - work-around
    - create a remote object running on the same computer as the registry; the object will register objects running elsewhere

rmiregistry

- the program **rmiregistry**
  - one parameter – port
    - default 1099
  - typical usage
    - unix
      - rmiregistry &
    - Win
      - start rmiregistry

Naming: access

- **java.rmi.Naming**
- only static methods
  - bind, rebind, unbind
  - lookup
  - list
- first parameters is String – defines the name of an object and possibly the registry
  - //host:port/jmeno
    - **host** and **port** are optional
    - default – localhost and 1099

Naming: access

- the package **java.rmi.registry**
  - the class LocateRegistry
    - obtaining a reference to the registry
    - creating the registry
  - the interface Registry
    - the same methods as the **Naming** class
      - first parameter specifies only the name of an object

- JNDI – Java Naming and Directory Interface
  - unified access to different directory services
  - support also trading (yellow pages)
  - java.namig module
    - javax.naming package

Own sockets

- own sockects can be used for RMI
- create own *socket factory*
  - client socket factory
    - implements RMIClientSocketFactory and Serializable
  - server socket factory
    - implements RMIServerSocketFactory
- factories are specified during a remote object creation
- typical usage – encryption
  - javax.rmi.SSL
    - SSLRMIServerSocketFactory
    - SSLRMIClientSocketFactory

Activation

- an object activated when it is necessary
- **rmid**
  - activation daemon
  - a "database" of activation records

- objects
  - extends the class **java.rmi.activation.Activatable**
    - or export an object using the class
  - plus – registering the activation record to rmid
- during registration of the activation record, an **explicit** specification of **permissions** is necessary
  - AllPermissions is not enough

Activation

```
public interface MyRemoteInterface extends Remote {
  ... }

public class MyRemoteImpl extends Activatable
                              implements MyRemoteInterface {
  public MyRemoteImpl(ActivationID id, MarshaledObject m)
                                              throws RemoteException {
    super(id, 0);
  }
  ....
}
```

or

```
public class MyRemoteImpl implements MyRemoteInterface {
  public MyRemoteImpl(ActivationID id, MarshaledObject m)
                                              throws RemoteException {
    Activatable.exportObject(this, id, 0);
  }
  ....
}
```

Activation

- registration
  - create registration record
    - `public ActivationDesc(ActivationGroupID groupID, String className, String location, MarshalledObject data)`
  - register it
    - `static Remote Activatable.register(ActivationDesc desc)`
      - returns a stub
  - register the stub in rmiregistry
    - as usually

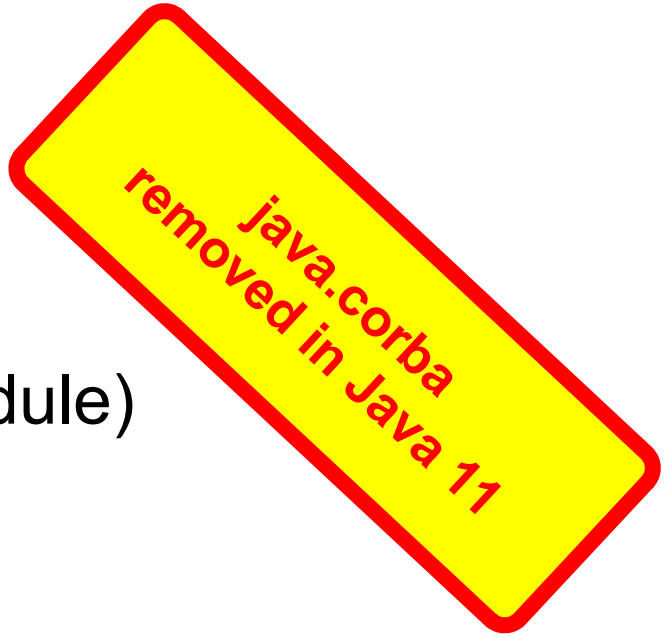
Distributed garbage collector

- garbage collector in distributed environment
- reference counting
- "leases"
- an object can be collected if there is no reference or lease has expired
- VMID – an identifier of VM
  - unique
  - lease contains it

RMI-IIOP

- transport protocol – JRMP
  - Java Remote Message Protocol

- IIOP can be used
  - CORBA interoperability
    - CORBA client – RMI server
- usage
  - javax.rmi package (java.corba module)
  - extend PortableRemoteObject
    - no UnicastRemoteObject
  - use **rmic** with the parameter -iiop
  - use the CORBA naming
    - javax.naming.... (JNDI)
    - instead of **rmiregistry,** use **orbd**



Other “RMIs”

gRPC

- https://grpc.io/
- multiplatform
  - Java, Python, C#, C++,…
- interfaces ~ protocol buffers

```
service Greeter {
  rpc SayHello (HelloRequest) returns (HelloReply) {}
}
message HelloRequest {
  string name = 1;
}
message HelloReply {
  string message = 1;
}
```

- protocol – HTTP + WebSockets

Další

- ...

Security
(Access control)

Overview

- originally in Java – a “sandbox” model
- later, other services added
  - next – managing access to resources

Security Manager

- java.lang.SecurityManager
  - before a resource is accessed, it checks, whether there are necessary permissions
  - not set by default
    - for “regular” applications
      - for JNLP executed application, it is set by default
- permissions – java.security.Permission
  - during class loading, the classloader assigns permissions to classes
- java.security.Policy
  - a set of permissions
  - only one in VM
  - typically, it is set via a text file

Security Manager

- setting SM
  - either in code
    - System.setSecurityManager(sm)
  - or from command-line
    - -Djava.security.manager
      - sets default sm
    - -Djava.security.manager=org.foo.SM
- default SM
  - implemented via java.security.AccessControler
  - tests all “elements” in the call stack
- own one can be implemented

Policy

- setting a Policy

  -Djava.security.policy=file.policy

- formát

```
grant [SignedBy "signer_names"] [, CodeBase "URL"]
        [, Principal [principal_class_name] "principal_name"]
        [, Principal [principal_class_name] "principal_name"] ... {
    permission permission_class_name [ "target_name" ]
            [, "action"] [, SignedBy "signer_names"];
    permission ...
};
```

  - příklad

```
grant codeBase "file:/home/sysadmin/" {
    permission java.io.FilePermission "/tmp/abc", "read";
};
```

Java Management Extensions
JMX

Overview

- part of JDK since version 5
  - previously an external set of jar archives
- MBean = Managed Java Bean
  - beans intended for managing something (device, application, anything)
  - provides an interface like std. beans
    - properties (get and set methods)
    - regular methods
    - notifications via events
  - several types
    - standard
    - dynamic
    - open
    - model
- (not only) universal client – JConsole

Architecture

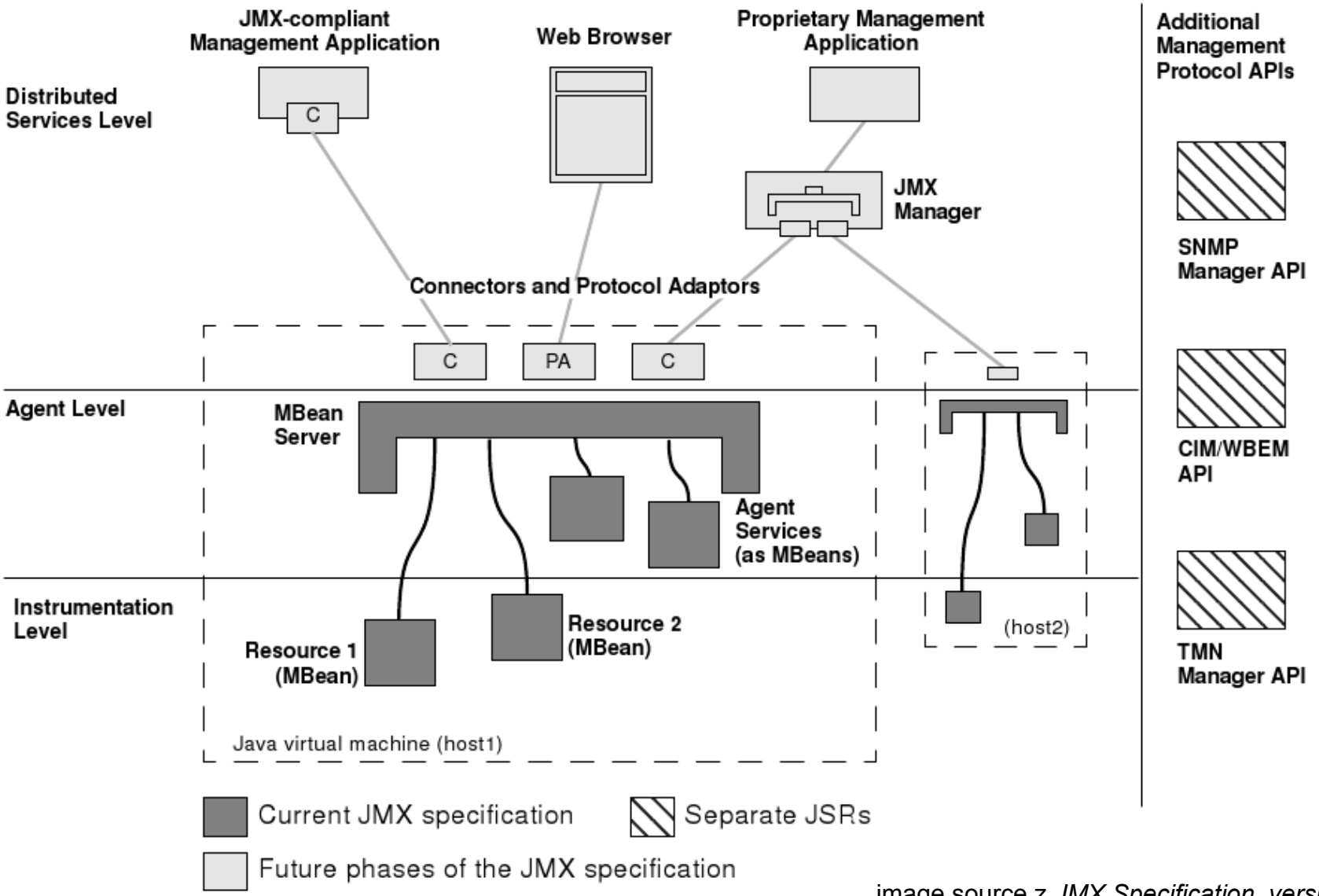


image source z *JMX Specification, version 1.4*

Types of MBeans

- Standard
  - the simplest type
  - its interface = all methods
- Dynamic
  - must implement a particular interface
  - more flexible
  - can be changed at runtime
- Open
  - dynamic
  - but can use only basic types
    - no need for a special descriptor
- Model
  - dynamic
  - fully configurable at run-time

Standard MBean

- defined explicitly by its interface and implementation (class)
  - the interface must have the same name as the class plus extension MBean
  - all methods in the MBean interface are provided
    - methods of the class but not in the interface are not visible via JMX
  - rules for naming properties and methods are the same as for regular beans
  - the interface is at run-time obtained via reflection

Example of a std. MBean

```
package example.mbeans;

public interface MyClassMBean {
    public int getState();
    public void setState(int s);
    public void reset();
}
```

```
package example.mbeans;

public class MyClass
     implements MyClassMBean {
  private int state = 0;
  private String hidden = null;
  public int getState() {
    return(state);
  }
  public void setState(int s) {
    state = s;
  }
  public String getHidden() {
    return(hidden);
  }
  public void setHidden(String h) {
    hidden = h;
  }
  public void reset() {
    state = 0;
    hidden = null;
  }
}
```

Using MBean

```
package example.mbeans;

import java.lang.management.*;
import javax.management.*;

public class Main {

  public static void main(String[] args) throws Exception {

    MBeanServer mbs = ManagementFactory.getPlatformMBeanServer();

    ObjectName name = new
                      ObjectName("example.mbeans:type=MyClass");

    MyClass mbean = new MyClass();
    mbs.registerMBean(mbean, name);

    System.out.println("Waiting forever...");
    Thread.sleep(Long.MAX_VALUE);
  }
}
```

Dynamic MBean

- intended for a changing interface
- implements the **`DynamicMBean`** interface
  - the bean's interface is obtained at run-time via calling methods of this interface

```
interface DynamicMBean {
  MBeanInfo getMBeanInfo();
  Object getAttribute(String attribute);
  AttributeList getAttributes(String[] attributes);
  void setAttribute(Attribute attribute);
  AttributeList setAttributes(AttributeList
                                          attributes);
  Object invoke(String actionName, Object[] params,
                                    String[] signature);
}
```

Dynamic MBean

- MBeanInfo
  - describes the MBean interface
  - for each call, a result of getMBeanInfo can be different
    - then, universal JMX clients cannot be (usually) used

Identification

- the class **`ObjectName`**
  - represent the name of a mbean or a pattern for searching
  - composed of a domain and properties
  - domain
    - string
    - must not contain colon and //
  - properties
    - name-value pairs
      - type – type of mbean
      - name
      - ...

JMX notification

- MBean can generate events
  - e.g. after change of its state
  - similar to regular beans
- the Notification class
  - represents an event
  - extends java.util.EventObject
  - can be used directly
    - but typically via its children (again as with regular beans)
- the NotificationListener interface
  - registering for event listening
- the NotificationBroadcaster interface
  - MBeans generating events must implement this interface
  - it is better to implement NotificationEmitter
    - extends NotificationBroadcaster

JMX notifikace

- the NotificationFilter interface
  - filtering notifications
  - a listener registers it
- types of event
  - it is not the class
  - a property of the event (String)
  - hierarchical
    - JMX.<something> reserved for JMX
- properties of the event (of the class Notification)
  - type
  - sequence number
  - timestamp (when the event was generated)
  - message
  - user data

JMX notification

- NotificationEmitter
  - void addNotificationListener(NotificationListener listener, NotificationFilter filter, Object handback)
    - handback
      - a utility object
      - the emitter does not use it
      - it is passed during event delivery
  - void removeNotificationListener(NotificationListener listener)
  - void removeNotificationListener(NotificationListener listener, NotificationFilter filter, Object handback)
  - MBeanNotificationInfo[] getNotificationInfo()

JMX notification

- NotificationListener
  - void handleNotification(Notification notification, Object handback)
- NotificationFilter
  - boolean isNotificationEnabled(Notification notification)
- support for notifying field changes
  - AttributeChangeNotification
  - AttributeChangeNotificationFilter
- the NotificationBroadcasterSupport class
  - a prepared implementation of NotificationBroadcaster

Notification example

```
public class Hello extends
   NotificationBroadcasterSupport implements HelloMBean {
      ....
  public synchronized void setCacheSize(int size) {
    int oldSize = this.cacheSize;
    this.cacheSize = size;
    Notification n = new AttributeChangeNotification(this,
      sequenceNumber++, System.currentTimeMillis(), "CacheSize
      changed", "CacheSize", "int", oldSize, this.cacheSize);
    sendNotification(n);
  }

  public MBeanNotificationInfo[] getNotificationInfo() {
    String[] types = new String[] {
      AttributeChangeNotification.ATTRIBUTE_CHANGE
    };
    String name = AttributeChangeNotification.class.getName();
    String description = "An attribute of this MBean has changed";
    MBeanNotificationInfo info = new MBeanNotificationInfo(types,
                                                    name, description);
    return new MBeanNotificationInfo[] {info};
  }
}
```

MBeanInfo

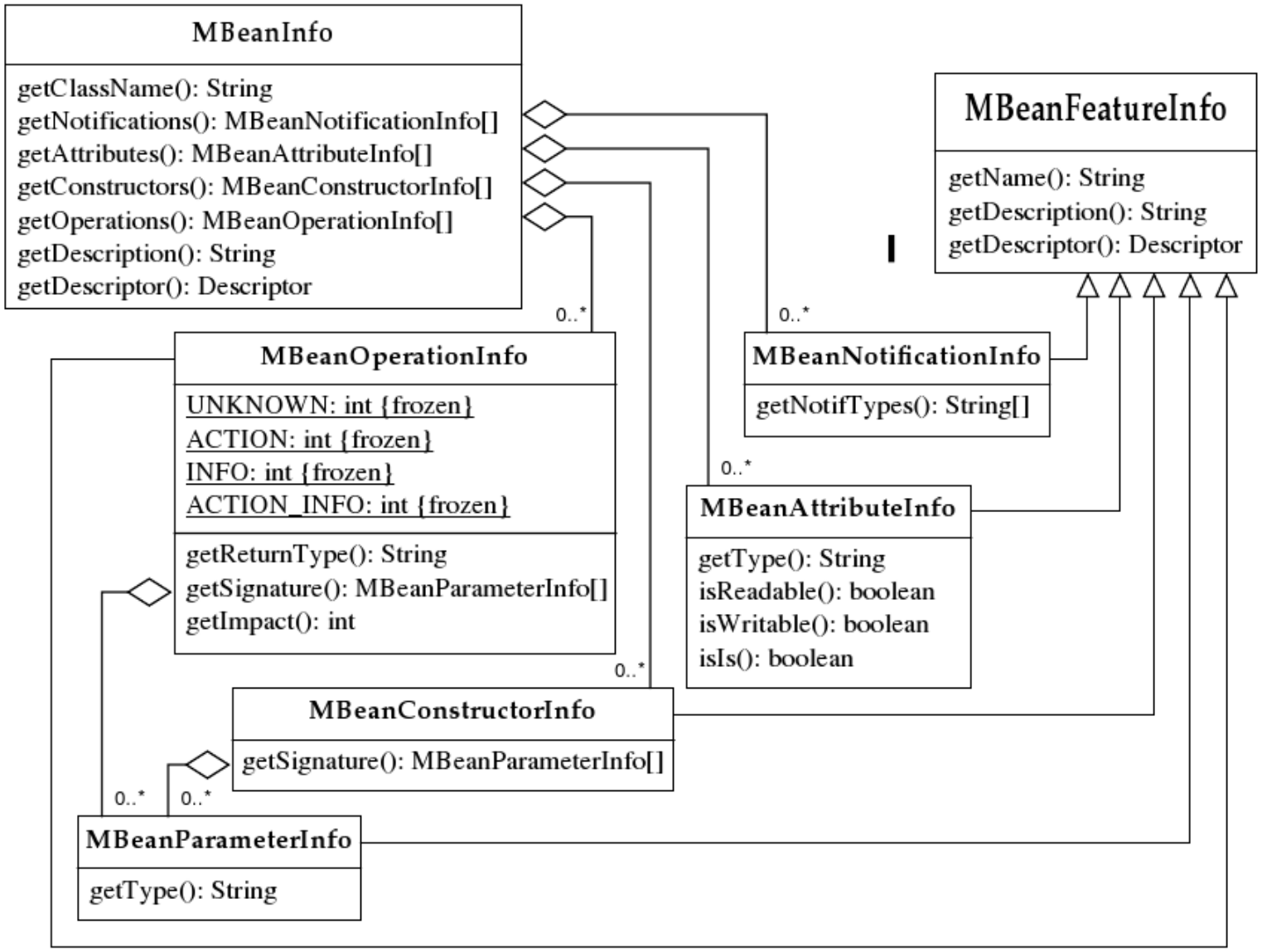


image source *JMX Specification, version 1.4*

Open MBean

- dynamic MBean
- uses only a limited set of data types
  - basic data types
    - primitive types (wrapper types)
    - String
    - BigDecimal, BigInteger
    - Date
    - javax.management.openbean.CompositeData
    - javax.management.openbean.CompositeTabular
    - arrays of these types
- can be used with universal clients
  - no need to recompile clients after the interface change

Open MBean

- javax.management.openbean.CompositeData
  - interface
  - represents composed types
  - “structures”
  - similar to a hash table
- javax.management.openbean.CompositeTabular
  - interface
  - represents arrays

- OpenMBeanInfo
  - extends MBeanInfo
  - plus other “Open” descriptors
    - OpenMBeanOperationInfo,...

Model MBean

- dynamic
- generic and fully configurable at run-time
  - no static interface, but elements are dynamically added

Model MBean example

```
MBeanServer mbs = ...

HashMap map = new HashMap();

Method getMethod = HashMap.class.getMethod("get", new Class[]
   {Object.class});
ModelMBeanOperationInfo getInfo =
    new ModelMBeanOperationInfo("Get value for key", getMethod);
ModelMBeanInfo mmbi =
     new ModelMBeanInfoSupport(HashMap.class.getName(),
                               "Map of keys and values",
                               null,  // no attributes
                               null,  // no constructors
                               new ModelMBeanOperationInfo[]{getInfo},
                               null); // no notifications

ModelMBean mmb = new RequiredModelMBean(mmbi);
mmb.setManagedResource(map, "ObjectReference");

ObjectName mapName = new ObjectName(":type=Map,name=whatever");
mbs.registerMBean(mmb, mapName);

mbs.invoke(mapName, "get", new Object[] {"key"}, new String[]
   {Object.class.getName()});
```

MXBean

- a new type of MBean
  - since JDK 6 (partially also in 5)
- a standard MBean
- plus rules for Open MBean
  - i.e. uses only a limited set of data types
- MXBean is a class implementing a **`<something>MXBean`** interface
  - the class can have any name
- instead of the extension **`MXBean`** the annotation **`@MXBean`** can be used
  - also **`@MXBean(false)`** can be used to set that the given interface is not a JMX interface even it has the **`MXBean`** extension

Architecture (recap.)

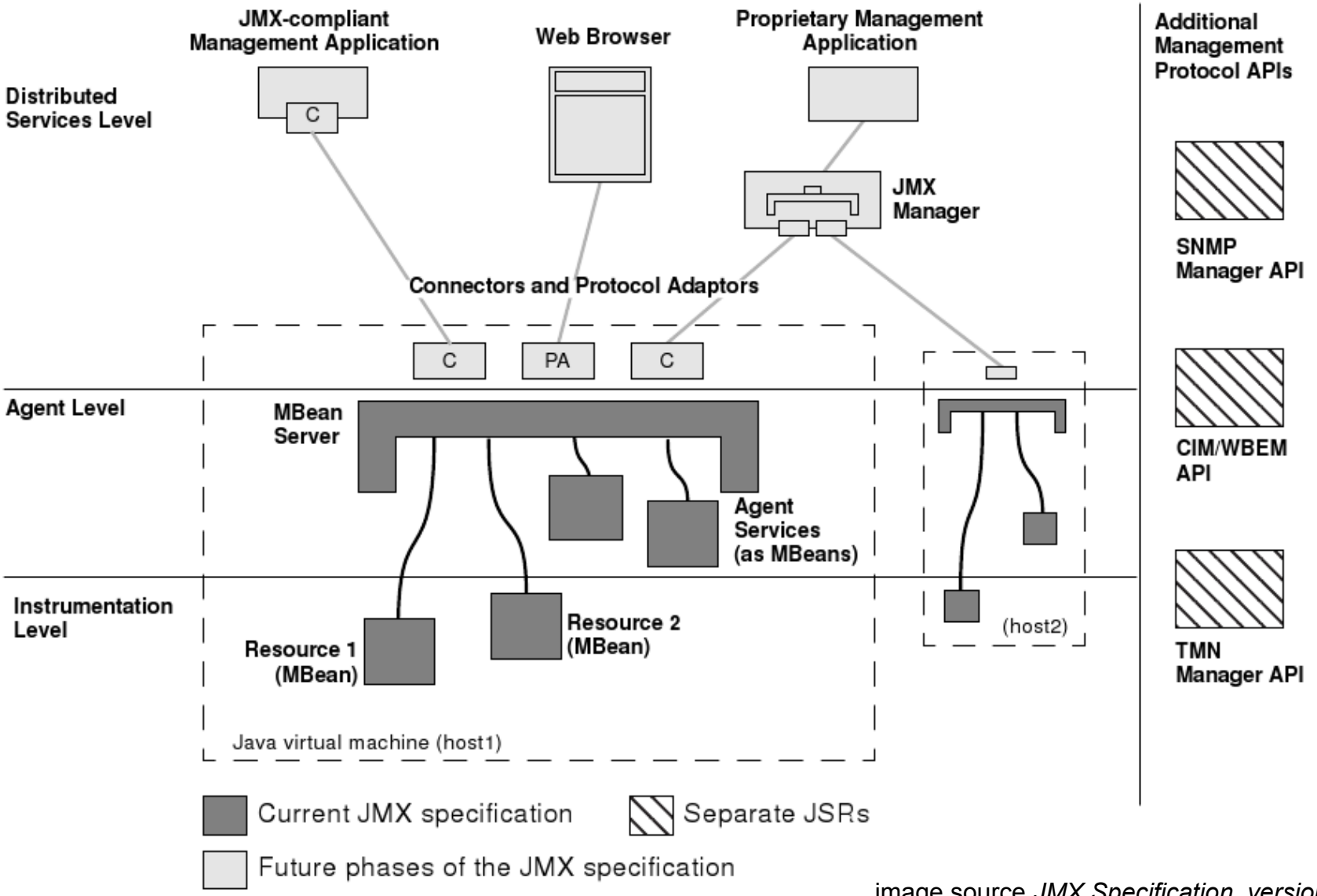


image source *JMX Specification, version 1.4*

JMX Remote

- remote access to JMX
- via *connectors*
  - composed of
    - connector client
    - connector server
- connectors can be created over (almost) anything
- the specification defines 2 particular connectors
  - RMI
  - generic
    - JMX Messaging Protocol (JMXMP)
      - directly over TCP
    - its implementation is optional

A connection creation

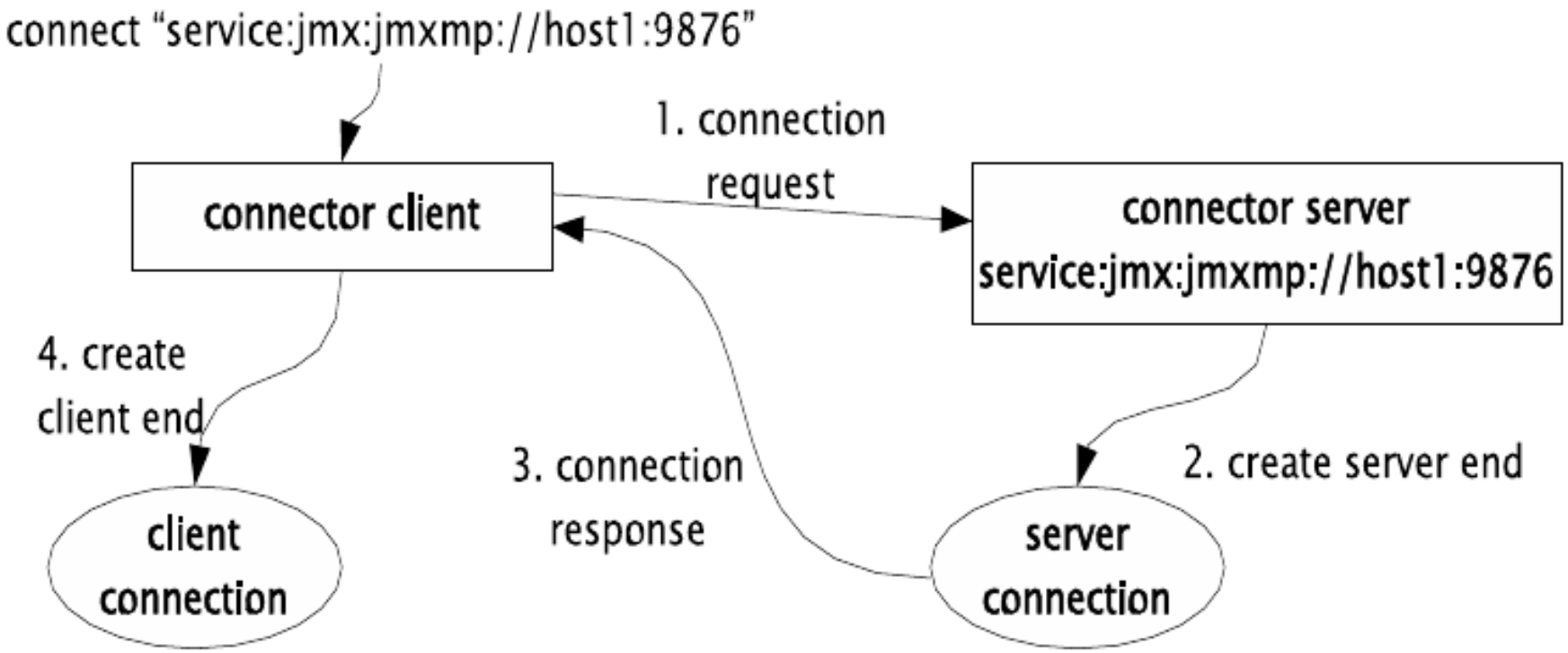


image source *JMX Specification, version 1.4*

JMX Remote

- creating a MBean, registration,... are as previously
- plus creating the connector server

```
MBeanServer mbs = MBeanServerFactory.createMBeanServer();

...

JMXServiceURL url = new
  JMXServiceURL("service:jmx:rmi:///jndi/rmi://localhost:
  9999/server");

JMXConnectorServer cs =
  JMXConnectorServerFactory.newJMXConnectorServer(url,
  null, mbs);

cs.start();
...
cs.stop();
```

JMX Remote

- JMXServiceURL
  - url of the connector server
  - depends on the type of a connector
  - common structure
    `service:jmx:<protocol>:...`
  - for own connectors it is not necessary to follow the structure
    - but it is recommended
- the JMX specification defines
  - message buffering
  - rules for parallel usage
  - how to deal with communication errors
  - dynamic class loading
  - security
  - ...

JMX Remote – RMI connector

- mandatory
  - every JMX implementation must contain it
- uses regular RMI
- usage of JRMP or IIOP can be specified
- using the RMI connector
  - service:jmx:rmi://host:port
    - the connector server creates a RMI server and returns a URL in a form service:jmx:rmi://host:port/stub/XXXX
      - XXXX is the serialized RMI server
  - service:jmx:iiop://host:port
    - the connector server creates a CORBA object and returns a URL in a form service:jmx:iiop://host:port/ior/IOR:XXXX
      - XXXX is std. ior
  - service:jmx:rmi://ignoredhost/jndi/rmi://myhost/myname
    - creates a server and registers it in the naming service
      - iiop can be written instead of rmi

JMX Remote – Generic connector

- optional
  - JMX implementations need not to contain it
- configurable
  - goal – a simple specification of transport protocols and wrapper objects for communication
- defines communication using messaging
  - a connection initialization
  - messages
  - ...
- JMXMP connector
  - a configuration of the generic connector for JMXMP

JMX Remote – client

- creating a connection to the server

```
JMXServiceURL url = new
  JMXServiceURL("service:jmx:rmi:///jndi/rmi://localho
  st:9999/server");
JMXConnector jmxc = JMXConnectorFactory.connect(url,
  null);

MBeanServerConnection mbsc =
  jmxc.getMBeanServerConnection();
```

- usage

```
mbsc.queryMBeans(ObjectName name, QueryExp query)
mbsc.getAttribute(ObjectName name, String attrName)
mbsc.setAttribute(ObjectName, Attribute attr)
```

JMX Remote – client

- creating a proxy object for direct access
  - it is necessary to know the interface
    - works for standard mbeans

```
T JMX.newMBeanProxy(MBeanServerConnection connection,
  ObjectName objectName, Class<T> interfaceClass)

T JMX.newMBeanProxy(MBeanServerConnection connection,
  ObjectName objectName, Class<T> interfaceClass,
  boolean notificationBroadcaster)
```