

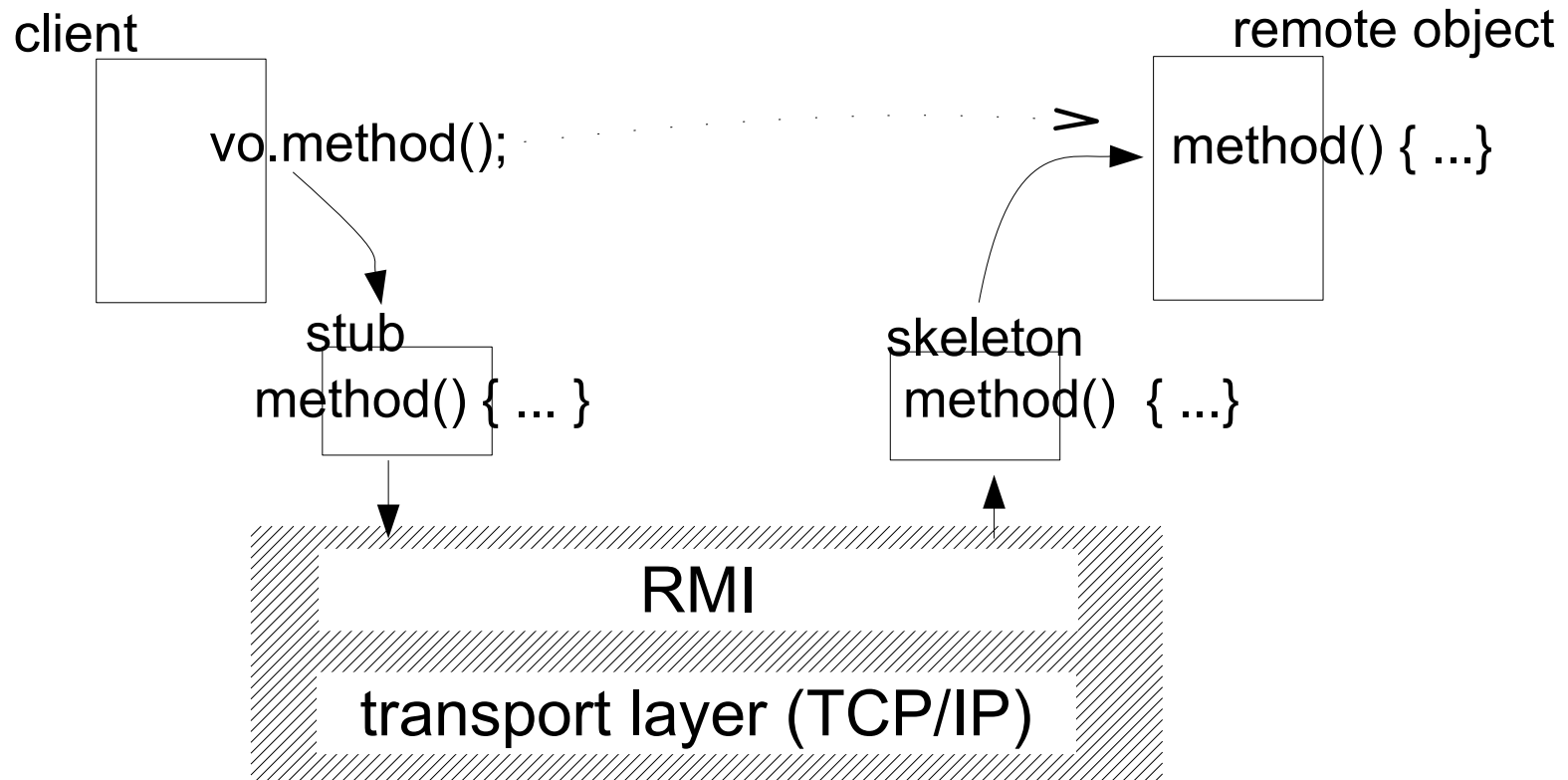
# JAVA

## 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 automatically 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());**

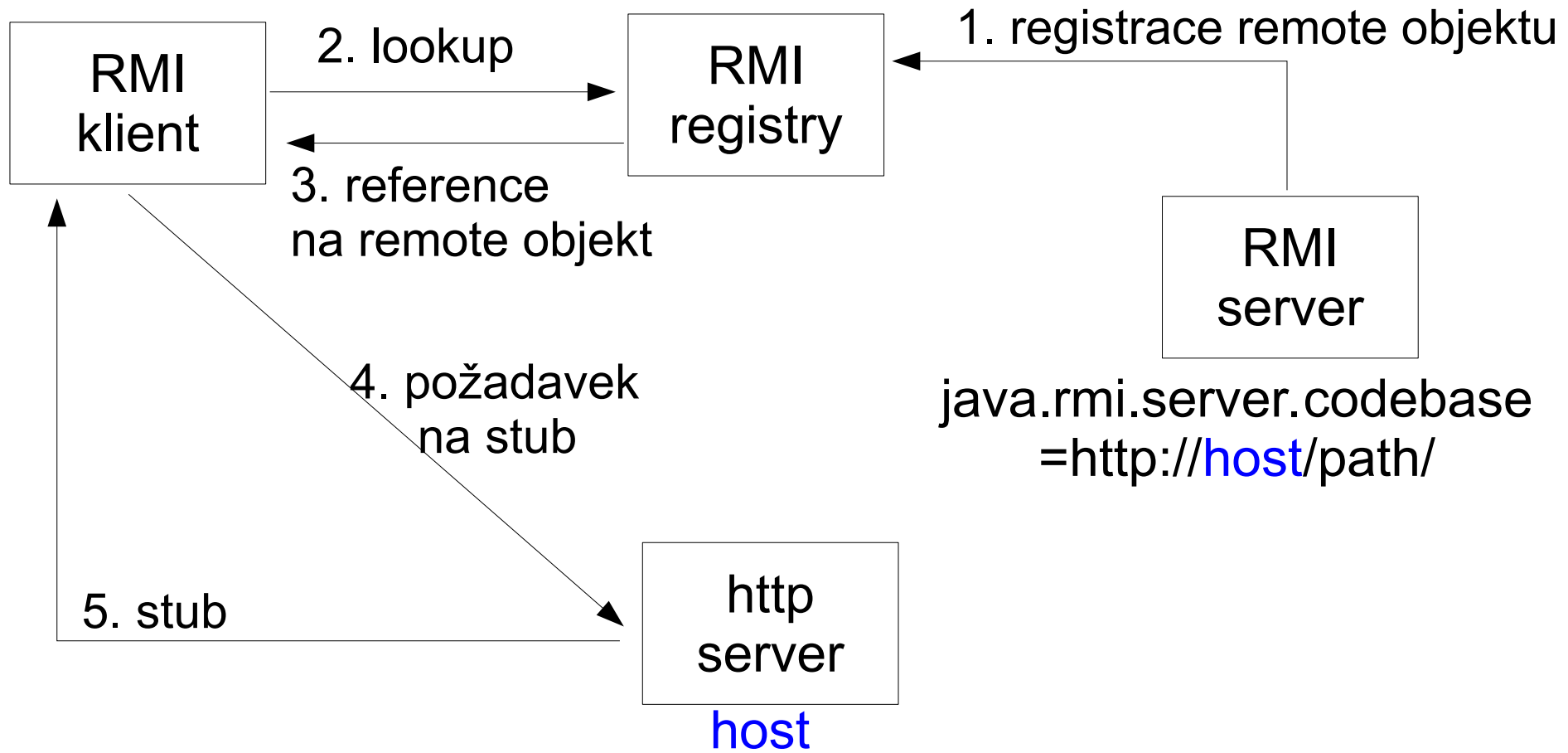
# Stubs & skeletons

- 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**

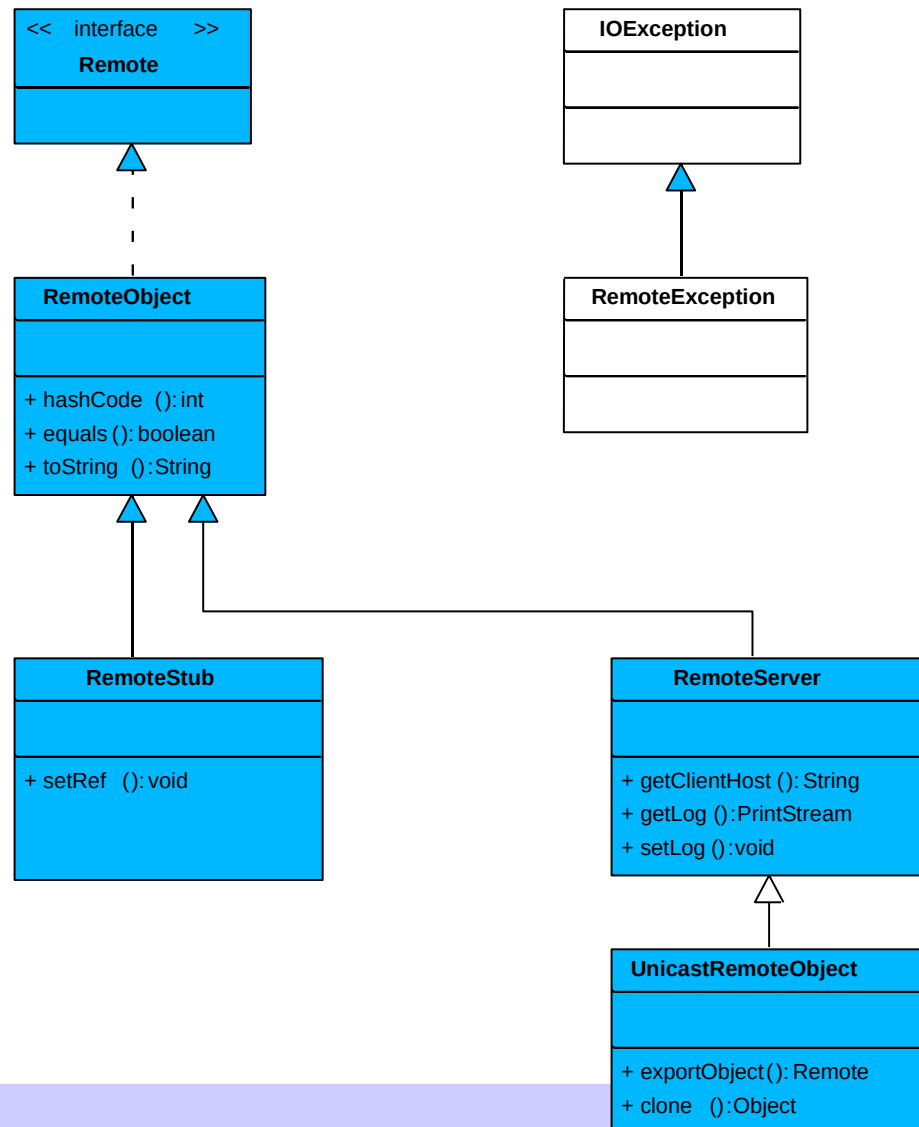
# Code downloading



# 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 Model
  - 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 rmi registries can be used at the same moment
  - on different computers
  - on different ports
- to rmi registry, 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.naming` module
    - `javax.naming` package

# Own sockets

- own sockets can be used for RMI
- create own *socket factory*
  - client socket factory
    - implements `RMIClientSocketFactory` and `Serializable`
  - server socket factory
    - implements `RMISServerSocketFactory`
- 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

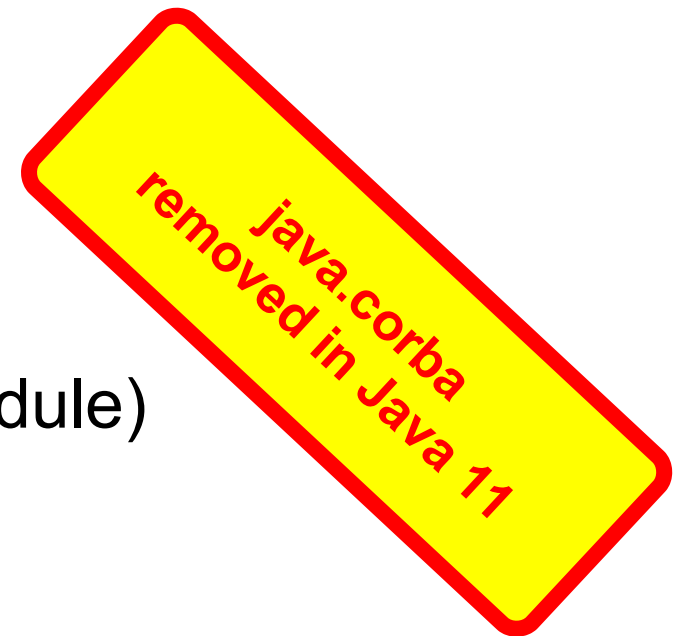
- registration
  - create registration record
    - `public ActivationDesc(ActivationGroupID groupID, String className, String location, MarshalledObject data)`
  - register it
    - `static Remote Activatable.register(ActivationDesc desc)`
      - returns a stub
  - register the stub in rmiregistry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



# JAVA

## Other “RMI”

# 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

- ...

# JAVA

## 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

## 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

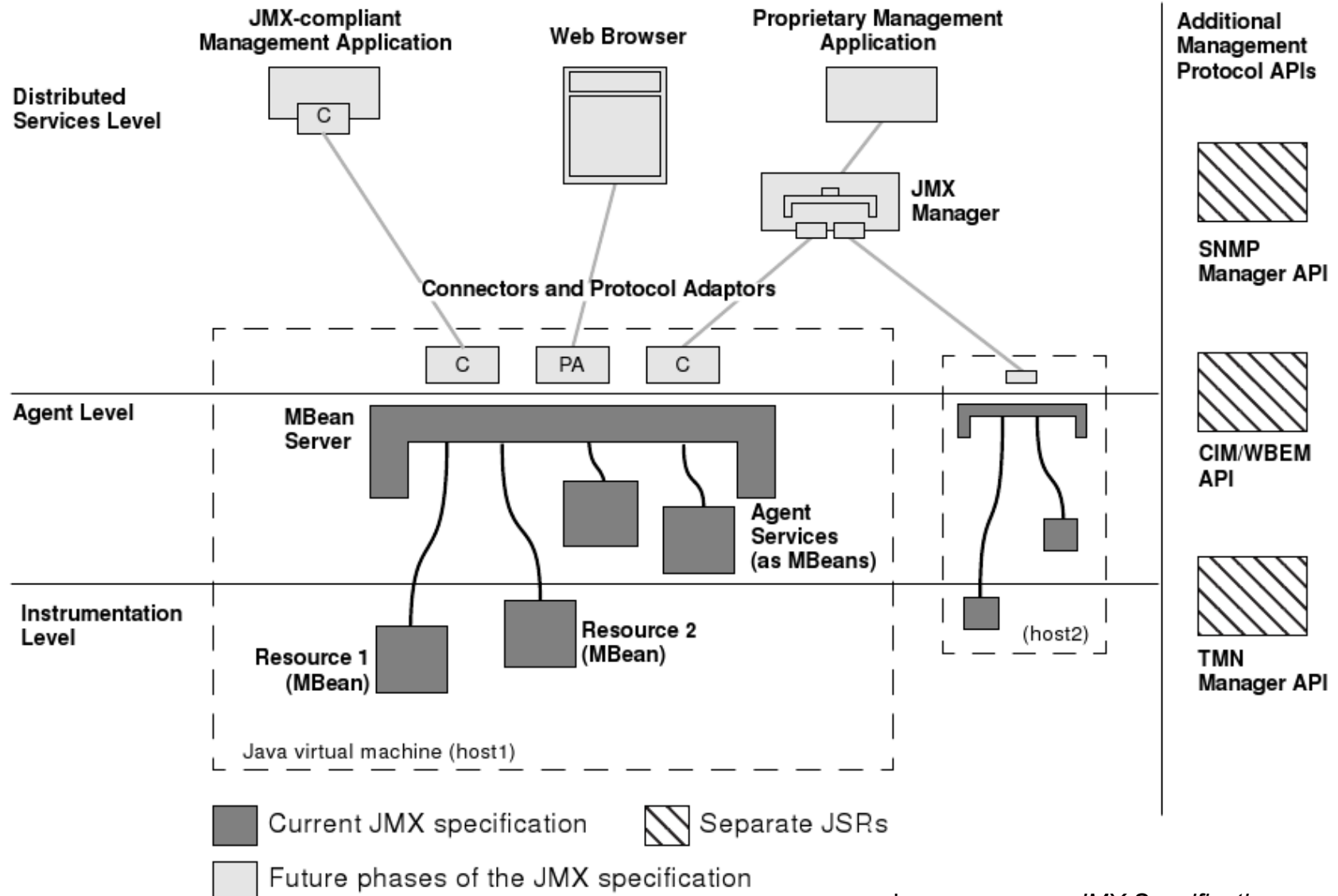


image source z JMX Specification, version 1.4

# 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 notification

- 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 isEnabled(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};
    }
}
} Java, summer semester 2019
```

# MBeanInfo

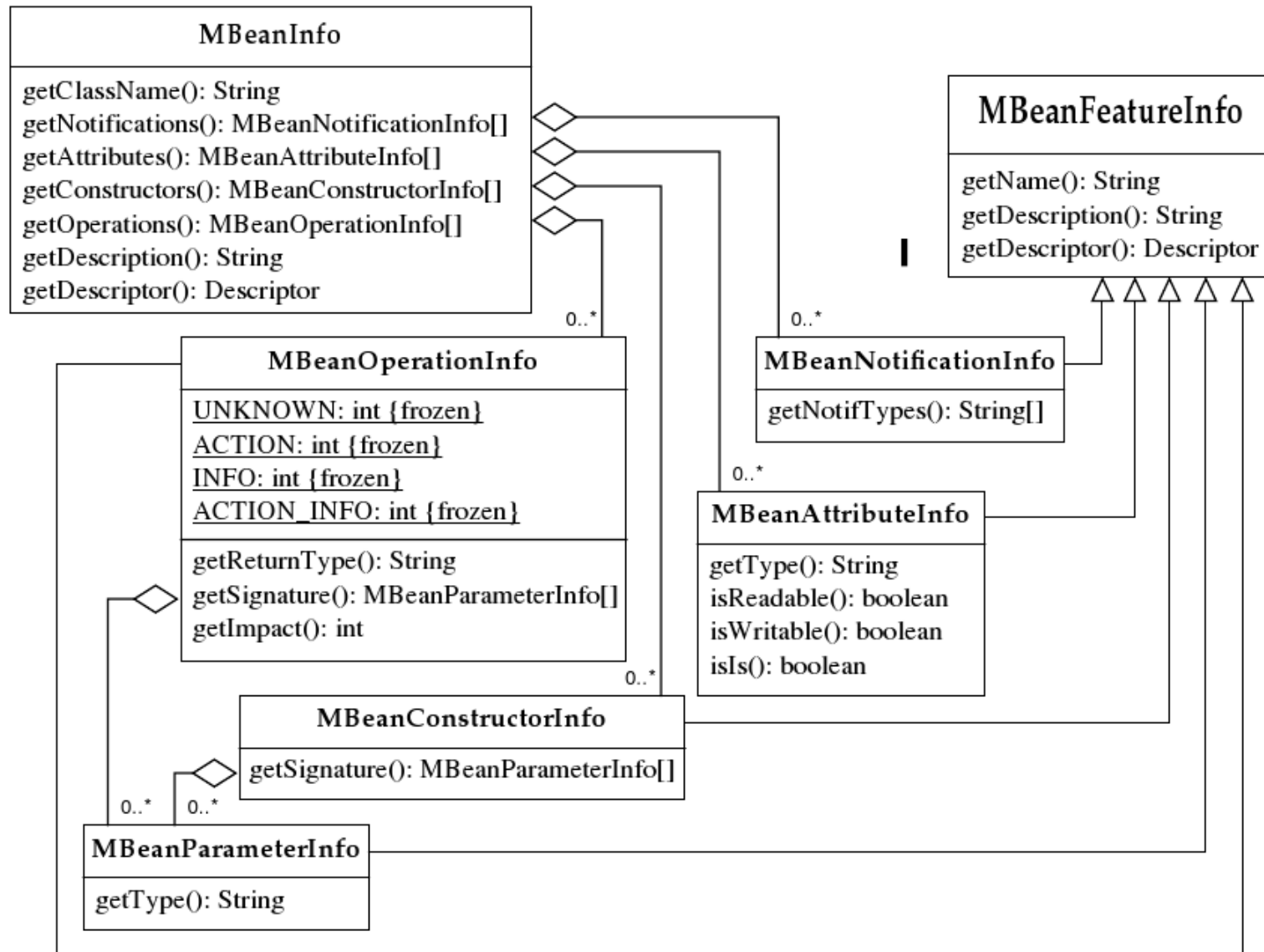


image source *JMX Specification, version 1.4*

# 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.)

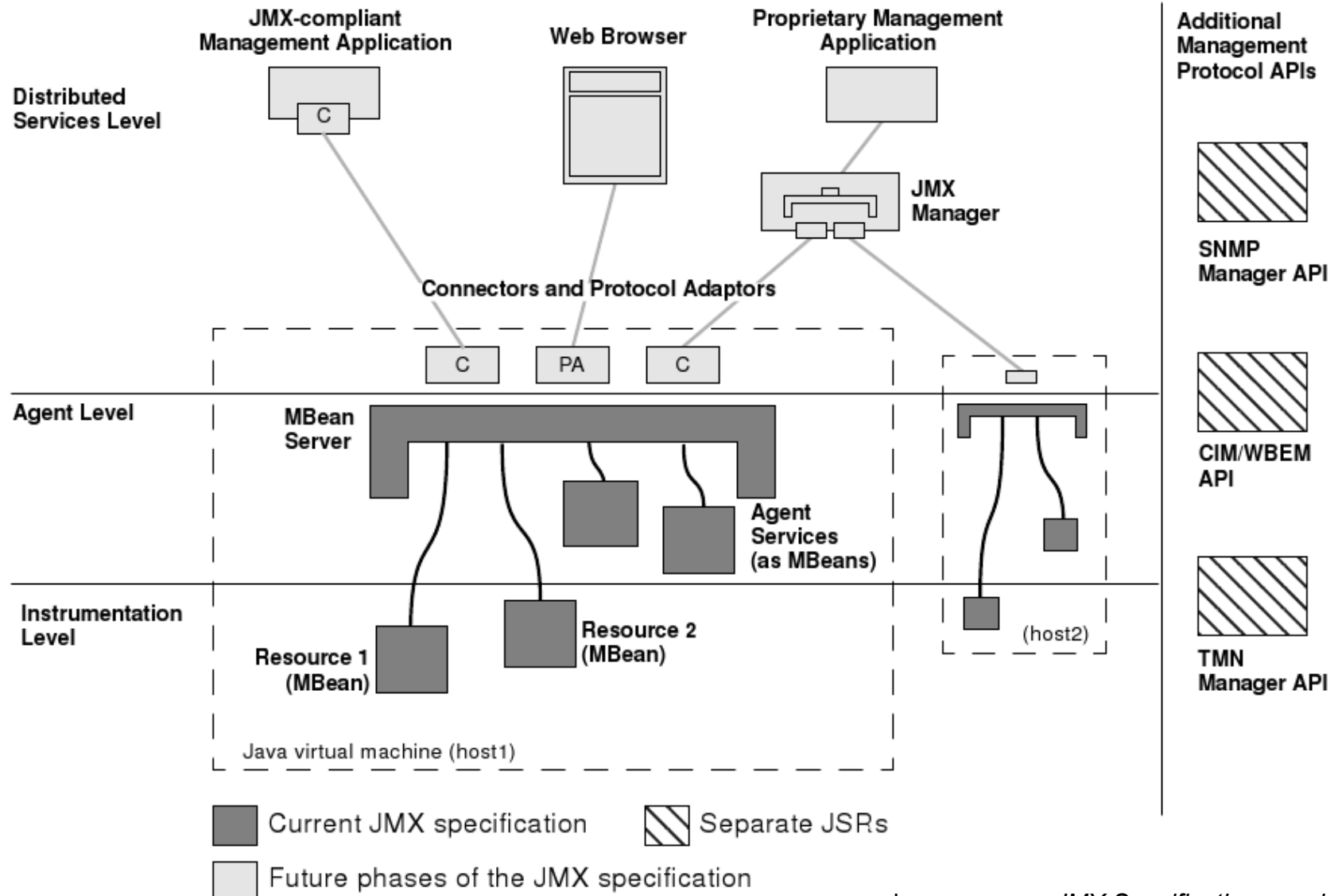


image source *JMX Specification, version 1.4*

# 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

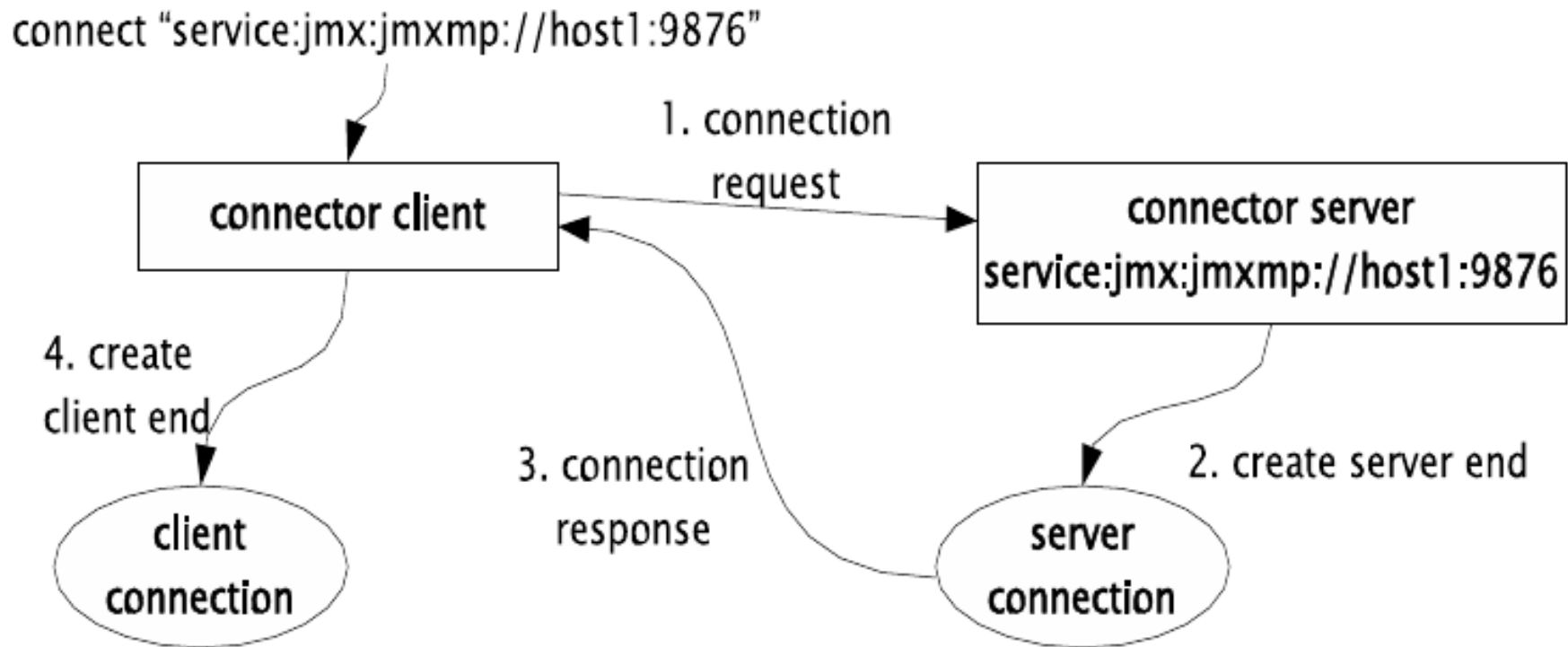


image source *JMX Specification, version 1.4*

# 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://localhost: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)
```



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