Distributed Programming in Java

Distribution (5)

RPC-style middleware

- Disadvantages:
  - Strongly coupled
  - Synchronous
  - Limited extensibility
- Advantages:
  - Transparency ….
  - Type safety

Space-based middleware

- Based upon tuple spaces
- A tuple space is an implementation of the associative memory paradigm for parallel/distributed computing.
- It provides a repository of tuples that can be accessed concurrently.
- Producers post their data as tuples in the space, and the consumers then retrieve data from the space that match a certain pattern. This is also known as the Blackboard metaphor.
- Tuple spaces were the theoretical underpinning of the Linda language developed by David Gelernter and Nicholas Carriero at Yale University.

Space-based Design

- Requires design of *distributed data structures* and *distributed protocols* that operate over them.
- Distributed data structure is made up of multiple objects stored in one or more spaces.
  - E.g., ordered list of items represented by a set of objects, each of which holds the value and position of a single list item.
- Using collection of objects in shared space allows multiple processes to concurrently access and modify the data structure.

4/24

JavaSpaces I

- JavaSpaces is a service specification providing a distributed object exchange and coordination mechanism (which may or may not be persistent) for Java objects.
- It can be used to store the system state and implement distributed algorithms.
- In a JavaSpace all communication partners (peers) communicate by sharing state.
- Using JavaSpaces, distributed applications are modeled as a flow of objects between participants, which is different from classic distributed models such as RMI.

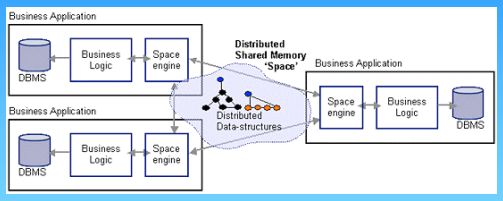
5/24

JavaSpaces II

- Achieves scalability through parallel processing
- Provides for reliable storage of objects while reducing the complexity of traditional distributed systems.
- Processes perform simple operations:
  - Write new objects into a JavaSpace,
  - Take objects from a JavaSpace, or
  - Make copies of objects the JavaSpace.
- JavaSpaces is part of Jini technology

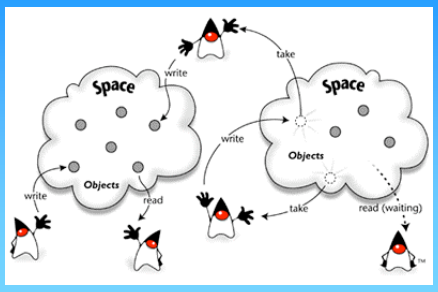
6/24

JavaSpaces Architecture



7/24

Coordination



8/24

JavaSpace Services and Operations

- Application components (or processes) use the persistent storage of a space to store objects and to communicate.
- The components coordinate actions by exchanging objects through spaces; the *objects do not communicate directly*.
- Processes interact with a space through a simple set of operations…

9/24

JavaSpace Primary Operations

- write(): Writes new objects into a space
- take(): Retrieves objects from a space
- read(): Makes a copy of objects in a space
- notify(): Notifies a specified object when entries that match the given template are written into a space

10/24

JavaSpaces Technology Application Model

- JavaSpaces service holds entries, each of which is a typed group of objects expressed in a class that implements the interface `net.jini.core.entry.Entry`.
- Once an entry is written into a JavaSpaces service, it can be used in future look-up operations.
- Looking up entries is performed using templates, which are entry objects that have some or all of their fields set to specified values that *must be matched exactly*. All remaining fields, which are not used in the lookup, are left as *wildcards*.

11/24

JavaSpace Entry Details

- Entries in a JavaSpace are simple Java Objects that follow a few simple rules:
  - All data persisted in the space must be exposed in public fields.
  - The Entry interface must be implemented.
  - This is a marker interface, requiring no methods to conform to the interface contract
  - Objects must be used for the properties (i.e., no primitive fields.)

12/24

Simple Server Example

```
// An Entry class
public class SpaceEntry implements Entry
{
    public final String message = "Hello World!";
    public Integer count = 0;

    public String service() {
        count = new Integer(count.intValue() + 1);
        return message;
    }

    public String toString() {
        return "Count: " + count.toString();
    }
}

// Hello World! server
public class Server
{
    public static void main(String[] args)
    {
        try {
            SpaceEntry entry = new SpaceEntry();          // Create the Entry object
            JavaSpace space = (JavaSpace)space();         // Create an Object Space
            // Register and write the Entry into the Space
            space.write(entry, null, Lease.FOREVER);
            // Pause for 10 minutes and then retrieve the Entry and check its state.
            Thread.sleep(10*60*1000);
            SpaceEntry e = space.read(new SpaceEntry(), null, Long.MAX_VALUE);
            System.out.println(e);
        } catch (Exception e) {}
    }
}
```

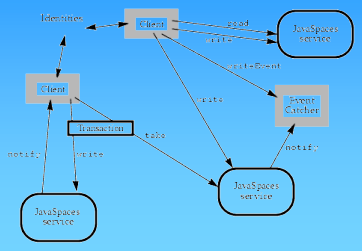
Fields must be public

Simple Client Example

```
// Client
public class Client
{
    public static void main(String[] args)
    {
        try {
            JavaSpace space = (JavaSpace) space();
            SpaceEntry e = space.take(new SpaceEntry(), null, Long.MAX_VALUE);
            system.out.println(e.service());
            space.write(e, null, Lease.FOREVER);
        } catch (Exception e) {}
    }
}
```

14/24

JavaSpaces Technology Application



15/24

JavaSpaces: Multi-user Chat System

- All the messages that make up the discussion are written to a space that acts as a chat area.
- Participants write message objects into the space, while other members wait for new message objects to appear, then read them out and display their contents.
- The list of participants can be kept in the space and updated whenever someone joins or leaves the discussion.
- Because the space is persistent, a new member can read and view the entire discussion.

16/24

Discussion: Advantages

- You can implement such a multi-user chat system in RMI by creating remote interfaces for the interactions discussed.
- Using JavaSpaces technology, you need only one interface

17/24

Multi-user Chat: The Message

```
import net.jini.core.entry.*;

public class MessageEntry implements Entry {
   public String content;

   public MessageEntry() {
   }

   public MessageEntry(String content) {
     this.content = content;
   }

   public String toString() {
     return "MessageContent: " + content;
   }
}
```

18/24

Multi-user Chat: Writing the Message

```
JavaSpace space = getSpace();
MessageEntry msg = new MessageEntry();
msg.content = "Hello there";
space.write(msg, null, Lease.FOREVER);
```

Leases can be shorter: e.g. 60*60*1000 ms

```
space.write(msg, null, 60 * 60 * 1000);
```

19/24

Multi-user Chat: Reading the Message

```
MessageEntry template = new MessageEntry();
MessageEntry output = (MessageEntry) space.read(template, null, Long.MAX_VALUE);
```

-- Template has null fields -- act as wildcards
-- Read will match any MessageEntry
-- Will block if no MessageEntry
-- Can use readIfExists(…) to avoid blocking

20/24

The "Full" Client

```
import net.jini.space.JavaSpace;

public class SpaceClient {
    public static void main(String argv[]) {
        try {
            MessageEntry msg = new MessageEntry();
            msg.content = "Hello there";
            System.out.println("Searching for a JavaSpace...");
            Lookup finder = new Lookup(JavaSpace.class);
            JavaSpace space = (JavaSpace) finder.getService();
            System.out.println("A JavaSpace has been discovered.");
            System.out.println("Writing a message into the space...");
            space.write(msg, null, 60*60*1000);
            MessageEntry template = new MessageEntry();
            System.out.println("Reading a message from the space...");
            MessageEntry result = (MessageEntry) space.read(template, null, Long.MAX_VALUE);
            System.out.println("The message read is: "+result.content);
        } catch(Exception e) {
            e.printStackTrace();
        }
    }
}
```

Code to find JavaSpace service (see course page)

21/24

Using JavaSpaces

- Download jini distribution (www.jini.org)
- Create subclasses of Entry for your application tuple(s)
- Compile including jini-ext.jar in classpath.
- Run Launch-All from installverify directory
- Select Register and choose IP address
- Run your clients including:
  - jini-ext.jar, jini-core.jar,
  - reggie.jar and outrigger.jar

22/24

JavaSpace Advantages

- Simple: very straightforward API
- Expressive: small set of operations but complex distributed applications possible.
- Supports loosely-coupled protocols:
  - Uncouples senders and receivers
  - Dynamic: servers can come and go
- Eases burden of writing client/server systems
  - Concurrency issues dealt with by space
  - Transactions supported (not described here).

23/24

Further Reading

- **Books**·
  - Eric Freeman, Susanne Hupfer, Ken Arnold: *JavaSpaces Principles, Patterns, and Practice.* Addison-Wesley Professional, 1. June 1999, ISBN 0-201-30955-6
  - Phil Bishop, Nigel Warren: *JavaSpaces in Practice.* Addison Wesley, 2002, ISBN 0-321-11231-8
- **Articles**
  - Brogden, William (2007). How Web services can use JavaSpaces. SearchWebServices.com
  - Angerer, Bernhard (2003). Space-Based Programming. onjava.com

24/24