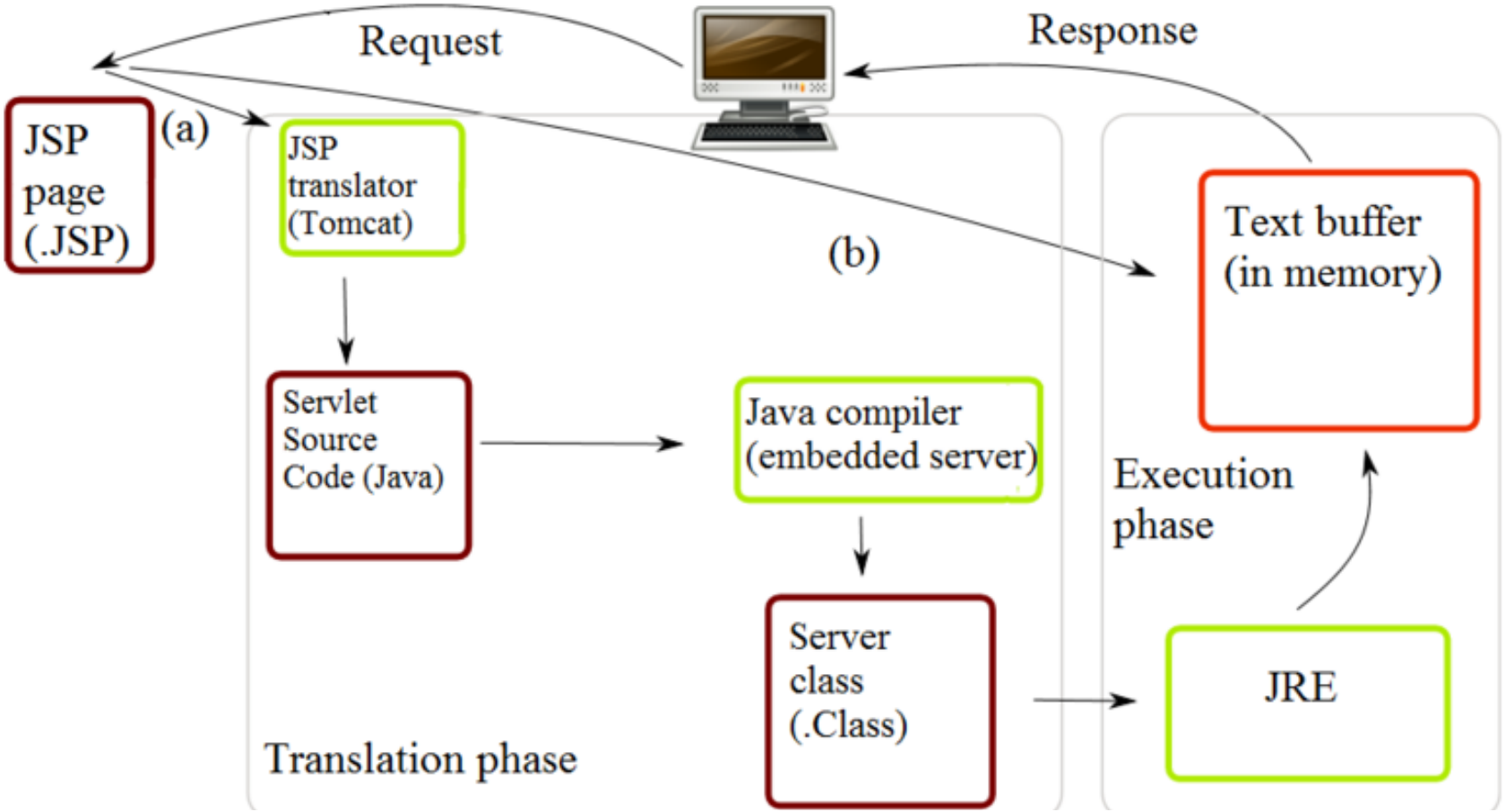
Java servlets



Overview

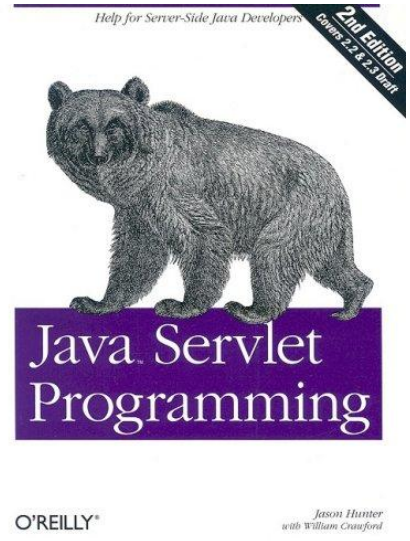
- Dynamic web content generation (thus far)
  - CGI
  - Web server modules
  - Server-side scripting, e.g. PHP, ASP, JSP
  - Custom web server
- Java servlets (today)
  - Java class implementing a specific interface
    - Override `doGet()`, `doPost()`
  - Hosted in a web-server with servlet support
    - e.g. Apache Tomcat, JBoss, Jetty, IBM Websphere
  - Or embedded in a standalone app

Why servlets?

- Portability
  - Written in Java, works across different OSs
- Power
  - Functionality of Java API and 3rd party classes
- Efficiency and endurance
  - Servlets stay in memory as single object instance
  - Can maintain persistent state
- Safety
  - Strong typing
  - Exception-handling
  - Automatic garbage collection

Why servlets?

- Elegance
  - Develop web-app in high-level OO language
- Integration
  - Tightly integrated with server compared to CGI
    - e.g. translate file paths, access to logging
- Extensibility and flexibility
  - Easy to extend to specialized needs
    - e.g. WebSocket server

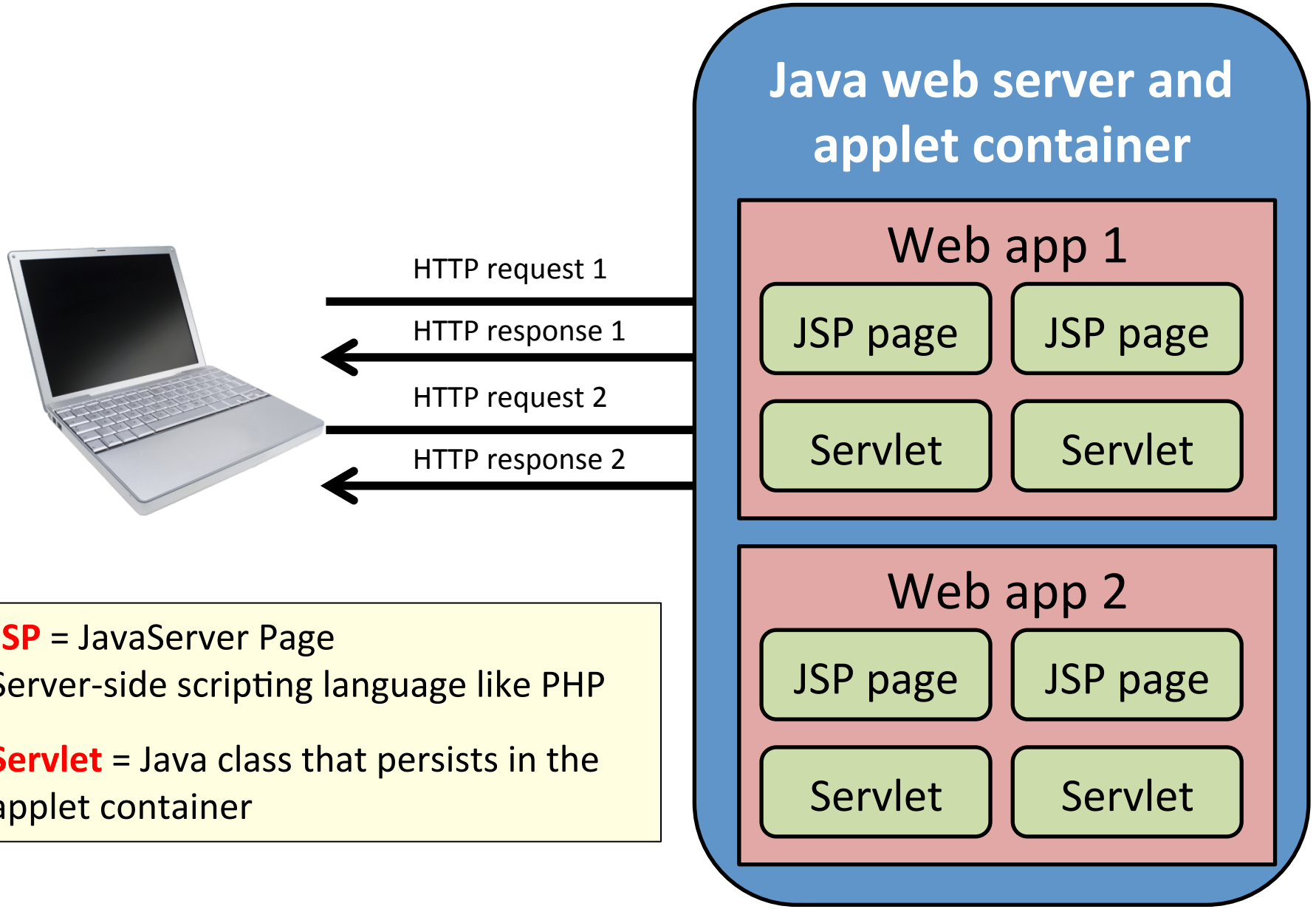


What about applets?

- Applets
  - Java programs embedded in a web page
    - `<applet>` tag in the HTML
    - Appears in a box like other page elements (e.g. images)
      - But you can interact with it, pushing buttons, etc.
    - Requires Java plug-in, not always available (iPhone)
  - Operates in a security "sandbox"
    - Not allowed to access:
      - Local file system, clipboard, arbitrary web sites, etc.

```
<html>
  <body>
    <h2>Don't panic about frogs!</h2>
    <applet code="PanicAppletParam.class" width="500" height="500">
      <param name="image" value="frog.jpg">
      <param name="sound" value="frog.wav">
Java plugin not installed
    </applet>
  </body>
</html>
```

Java servlets



JSP = JavaServer Page
Server-side scripting language like PHP

Servlet = Java class that persists in the applet container

Servlet API

- Java servlet
  - Normal Java class implementing the interface `javax.servlet.Servlet`
  - Usually extend `HttpServlet`
    - A HTTP protocol specific servlet, override:

```
void doGet(HttpServletRequest request,
           HttpServletResponse response)
void doPost(HttpServletRequest request,
            HttpServletResponse response)
```

  - Could extend `GenericServlet`
    - Generic protocol independent servlet, override:

```
void service(ServletRequest request,
             ServletResponse response)
```

  - No `main()` method

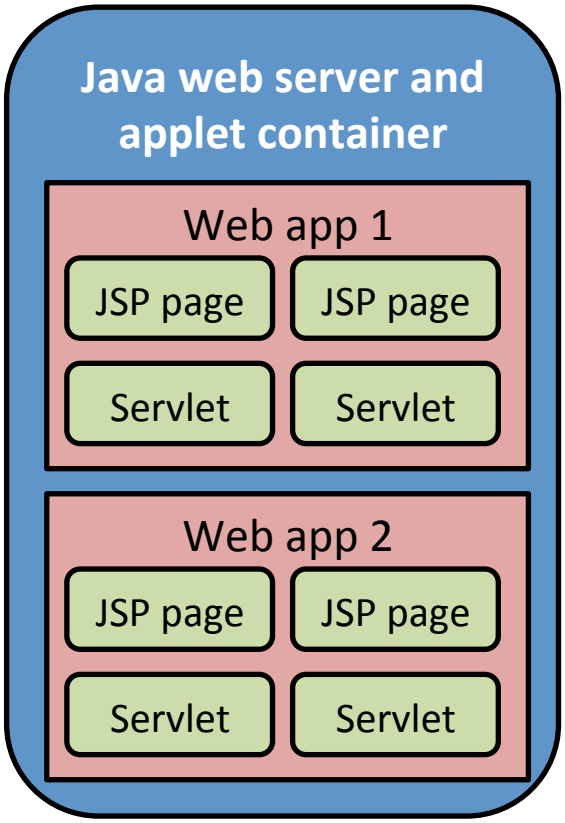
Hello World servlet

```
import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

public class HelloServlet extends HttpServlet
{
    protected void doGet(HttpServletRequest req, HttpServletResponse resp)
        throws ServletException, IOException
    {
        String      q   = req.getParameter("q");
        PrintWriter out = resp.getWriter();

        out.println("<html>");
        out.println("<body>");
        out.println("The parameter q was \"" + q + "\".");
        out.println("</body>");
        out.println("</html>");
    }

    protected void doPost(HttpServletRequest req, HttpServletResponse resp)
        throws ServletException, IOException
    {
        String      field = req.getParameter("field");
        PrintWriter out   = resp.getWriter();

        out.println("<html>");
        out.println("<body>");
        out.println("You entered \"" + field + "\" into the text box.");
        out.println("</body>");
        out.println("</html>");
    }
}
```

Servlet container

- Servlets live in a container
  - *Standalone* web server with servlet support
    - Bundle application in a Web application ARchive (WAR)
    - e.g. Apache Tomcat, Jetty, GlassFish,

  - *Add-on* to existing web server
    - e.g. Tomcat plugged into Apache
  - *Embedded* in an application
    - e.g. Lightweight servlet deployment embedded in another application



```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE web-app
    PUBLIC "-//Sun Microsystems, Inc.//DTD Web Application 2.2//EN"
    "http://java.sun.com/j2ee/dtds/web-app_2_2.dtd">

<web-app>
    <servlet>
        <servlet-name>HelloServlet</servlet-name>
        <servlet-class>mypackage.HelloServlet</servlet-class>
    </servlet>

    <servlet-mapping>
        <servlet-name>HelloServlet</servlet-name>
        <url-pattern>/HelloServlet</url-pattern>
    </servlet-mapping>

    <resource-ref>
        <description>
            Resource reference to a factory for javax.mail.Session
            instances that may be used for sending electronic mail messages,
            preconfigured to connect to the appropriate SMTP server.
        </description>
        <res-ref-name>mail/Session</res-ref-name>
        <res-type>javax.mail.Session</res-type>
        <res-auth>Container</res-auth>
    </resource-ref>
</web-app>
```

An embedded diversion

- Embedding Jetty
  - "Don't deploy your application in Jetty, deploy Jetty in your application"

```
public class HelloWorldEmbedded extends AbstractHandler
{
    public void handle(String target, Request baseRequest,
                       HttpServletRequest request, HttpServletResponse response)
                       throws IOException, ServletException
    {
        response.setContentType("text/html;charset=utf-8");
        response.setStatus(HttpServletResponse.SC_OK);
        baseRequest.setHandled(true);
        response.getWriter().println("<h1>Hello World</h1>");
    }

    public static void main(String[] args) throws Exception
    {
        Server server = new Server(8080);
        server.setHandler(new HelloWorldEmbedded());
        server.start();
        server.join();
    }
}
```

A Java application with an embedded web server.

HelloServlet v2.0

```
public class HelloServlet extends HttpServlet
{
    private String greeting = "Hello World";
    private int    count    = 0;

    public HelloServlet()
    {
    }

    public HelloServlet(String greeting)
    {
        this.greeting = greeting;
    }

    public int getCountIncrement()
    {
        return ++count;
    }

    protected void doGet(HttpServletRequest request, HttpServletResponse response)
                   throws ServletException, IOException
    {
        response.setContentType("text/html");
        response.setStatus(HttpServletResponse.SC_OK);
        response.getWriter().println("<h1>" + greeting+"</h1>");
        response.getWriter().println("<h1>You are visitor " + getCountIncrement() + "</h1>");
        response.getWriter().println("session=" + request.getSession(true).getId());
    }
}
```

Simple servlet that prints a greeting and a count of hits to the servlet.

Embedded servlet container

```
public class OneServletContext
{
    public static void main(String[] args) throws Exception
    {
        Server server = new Server(8080);

        ServletContextHandler context = new ServletContextHandler(ServletContextHandler.SESSIONS);
        context.setContextPath("/");
        server.setHandler(context);

        context.addServlet(new ServletHolder(new HelloServlet()),"/*");
        context.addServlet(new ServletHolder(new HelloServlet("Buongiorno Mondo")),"/it/*");
        context.addServlet(new ServletHolder(new HelloServlet("Bonjour le Monde")),"/fr/*");

        server.start();
        server.join();
    }
}
```

Main program that hosts three versions of the Hello World servlet.

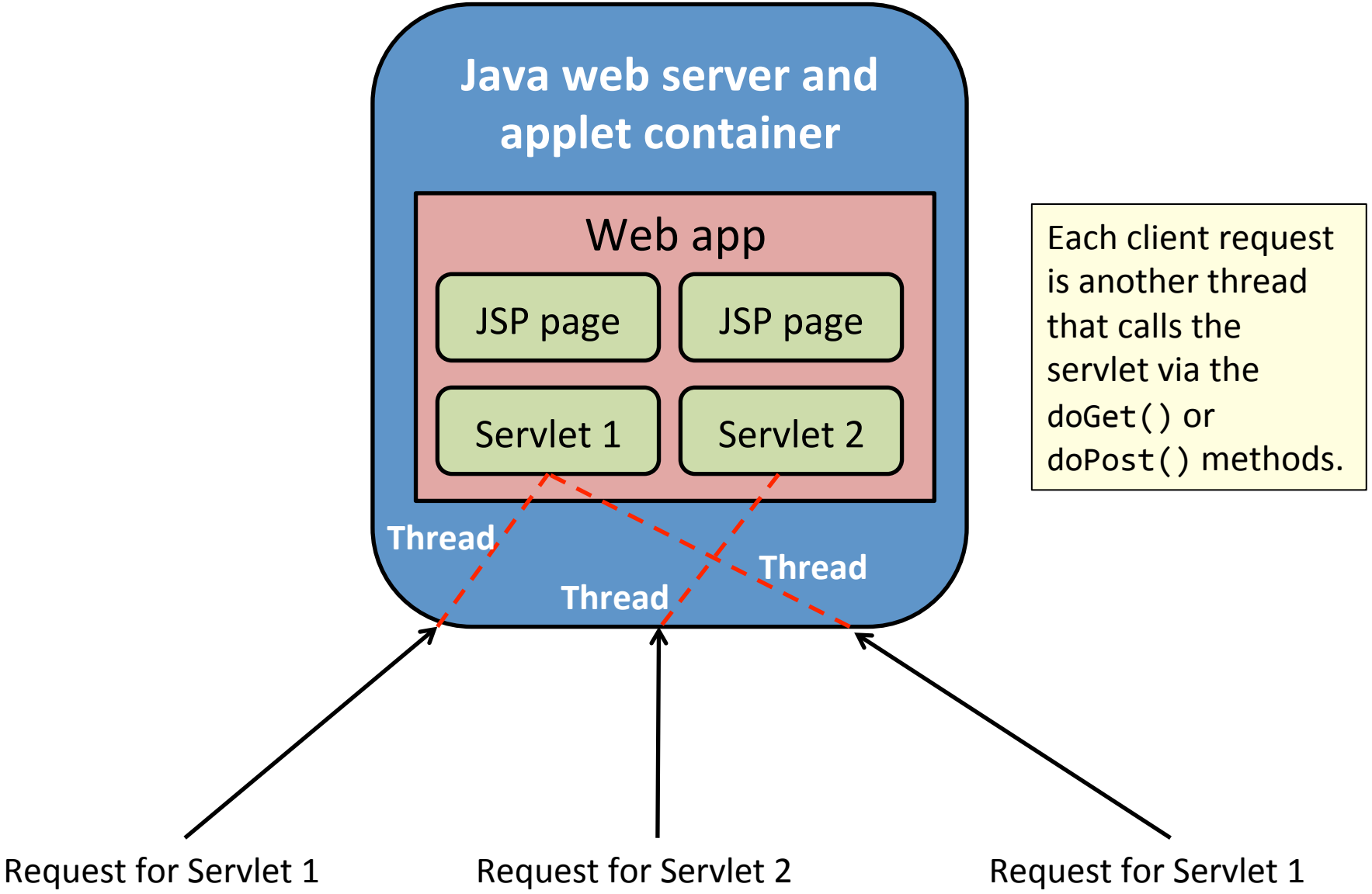
Servlet life cycle

- If instance of servlet does not exist, container:
  - Loads the servlet class
  - Creates an instance of the servlet class
  - Initialized the servlet by call to `init` method
    - May be called when server starts, when first requested, or at request of administrator
- Invokes the `service` method
  - Passing request and response objects
- If container needs to remove servlet:
  - Finalizes by calling `destroy` method

Servlet instance persistence

- Servlets persist between requests
  - Container holds an instance of an object
  - Requests to a given servlet serviced by same object
  - Improves performance:
    - Keeps memory footprint small
    - Eliminates object creation expense
    - Avoid process startup expense (as with CGI)
    - Servlet can reuse resources

Servlet thread model



Each client request is another thread that calls the servlet via the `doGet()` or `doPost()` methods.

Thread safety

- Non-local variables are not thread-safe!
  - e.g. instance variables of the class

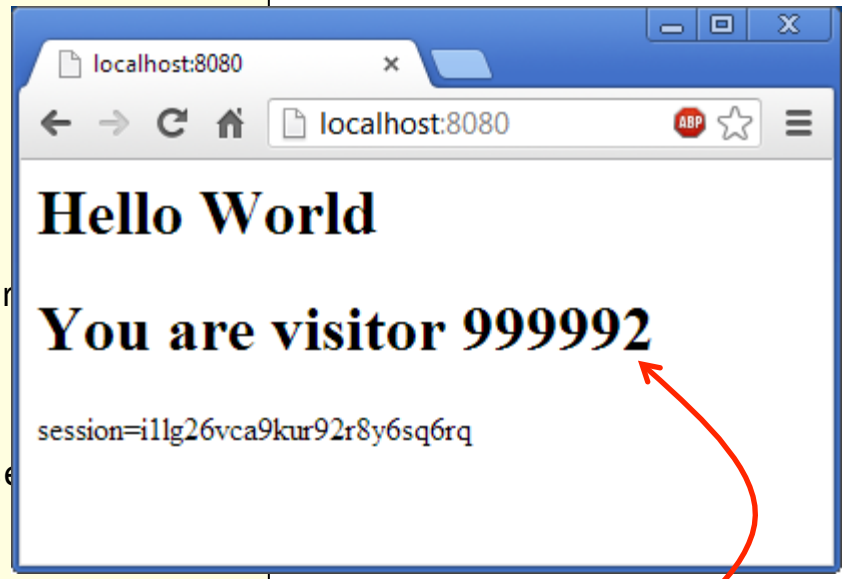
```
public class HelloServlet extends HttpServlet
{
    private String greeting = "Hello World";
    private int    count    = 0;

    public HelloServlet(String greeting)
    {
        this.greeting = greeting;
    }

    public int getCountIncrement()
    {
        return ++count;
    }

    protected void doGet(HttpServletRequest request, HttpServletResponse response)
                   throws ServletException, IOException
    {
        response.setContentType("text/html");
        response.setStatus(HttpServletResponse.SC_OK);
        response.getWriter().println("<h1>" + greeting+"</h1>");
        response.getWriter().println("<h1>You are visitor " + getCountIncrement() + "</h1>");
        response.getWriter().println("session=" + request.getSession(true).getId());
    }
}
```

Testing our servlet's safety…

```
% ab -n 1000000 -c 1 http://localhost:8080/

Benchmarking localhost (be patient)
Completed 100000 requests
Completed 200000 requests
Completed 300000 requests
Completed 400000 requests
Completed 500000 requests
Completed 600000 requests
Completed 700000 requests
Completed 800000 requests
Completed 900000 requests
Completed 1000000 requests
Finished 1000000 requests

...

Requests per second:    2627.27 [#/sec] (me
Time per request:       0.381 [ms] (mean)
Time per request:       0.381 [ms] (mean, a
concurrent requests)
Transfer rate:          761.43 [Kbytes/sec]

...
```

Testing our servlet's safety…

```
% ab -n 1000000 -c 10 http://localhost:8080/

Benchmarking localhost (be patient)
Completed 100000 requests
Completed 200000 requests
Completed 300000 requests
Completed 400000 requests
Completed 500000 requests
Completed 600000 requests
Completed 700000 requests
Completed 800000 requests
Completed 900000 requests
Completed 1000000 requests
Finished 1000000 requests

...

Requests per second:    6569.71 [#/sec] (r
Time per request:       1.522 [ms] (mean)
Time per request:       0.152 [ms] (mean,
concurrent requests)
Transfer rate:          1904.04 [Kbytes/se

...
```



9 updates went missing!

Thread safety

- Synchronize access to shared data!
  - e.g. instance variables of the class

```
public class HelloServlet extends HttpServlet
{
    private String greeting = "Hello World";
    private int    count    = 0;

    public HelloServlet(String greeting)
    {
        this.greeting = greeting;
    }

    public int synchronized getCountIncrement()
    {
        return ++count;
    }

    protected void doGet(HttpServletRequest request, HttpServletResponse response)
                   throws ServletException, IOException
    {
        response.setContentType("text/html");
        response.setStatus(HttpServletResponse.SC_OK);
        response.getWriter().println("<h1>" + greeting+"</h1>");
        response.getWriter().println("<h1>You are visitor " + getCountIncrement() + "</h1>");
        response.getWriter().println("session=" + request.getSession(true).getId());
    }
}
```

Now you can really bang on it…

```
% ab -n 1000000 -c 10 http://localhost:8080/

Benchmarking localhost (be patient)
Completed 100000 requests
Completed 200000 requests
Completed 300000 requests
Completed 400000 requests
Completed 500000 requests
Completed 600000 requests
Completed 700000 requests
Completed 800000 requests
Completed 900000 requests
Completed 1000000 requests
Finished 1000000 requests

...

Requests per second:    6690.28 [#/sec] (me
Time per request:       1.495 [ms] (mean)
Time per request:       0.149 [ms] (mean, a
concurrent requests)
Transfer rate:          1938.98 [Kbytes/sec

...
```

HttpServletRequest

- Encapsulates all info from client request
  - HTTP request header and body
- Retrieve data using methods
  - Inherited from `ServletRequest`:
    - `String getParameter(String name)`
    - `Enumeration<String> getParameterNames()`
    - `String[] getParameterValues(String name)`
    - `Map<String, String> getParameterMap()`
    - `ServletInputStream getInputStream()`
    - `BufferedReader getReader()`

```
protected void  doGet(HttpServletRequest request, HttpServletResponse response);
protected void doPost(HttpServletRequest request, HttpServletResponse response);
```

HttpServletResponse

- Encapsulates all data returned to client
  - Set HTTP response header:
    - `void setStatus(int sc)`
    - `void setHeader(String name, String value)`
    - `void setContentType(String type)`
    - `void sendRedirect(String location)`
    - `void sendError(int sc)`
  - Set HTTP response body:
    - Obtain `PrintWriter` or `ServletOutputStream` to return data to client
    - `PrintWriter getWriter()`
    - `ServletOutputStream getOutputStream()`

```
protected void  doGet(HttpServletRequest request, HttpServletResponse response);
protected void doPost(HttpServletRequest request, HttpServletResponse response);
```

Session management: adding cookies

- Tracking user's state with cookies
  - `Cookie` class:
    - `Cookie(String name, String value)`
    - `void setMaxAge(int expiry)`
    - `void setDomain(String pattern)`
    - `void setPath(String uri)`
    - `void setSecure(boolean flag)`
  - `HttpServletResponse` class:
    - `void addCookie(Cookie cookie)`

```
HTTP/1.1 200 OK
Date: Thu, 17 Nov 2011 15:54:10 GMT
Server: Jetty(9.0.0.RC2)
Content-Length: 285
Set-Cookie: sessionID=528fa623; path=/; Expires=Wed,  09 Mar 2014 11:00:00 GMT

<html><body>
…
```

Session management: retrieving cookies

- Check what cookies are set in HTTP request
  - `HttpServletRequest` class:
    - `Cookie[] getCookies()`
  - `Cookie` class:
    - `String  getName()`
    - `String  getValue()`
    - `String  getDomain()`
    - `String  getPath()`
    - `boolean getSecure()`

```
GET / HTTP/1.1
Host: katie.mtech.edu
User-agent: Mozilla/4.0
Cookie: sessionID=528fa623
```

Servlet's built-in session tracking

- Most servers support session tracking
  - HTTP cookie provides session key
  - Servlet uses key to retrieve session state
- Session objects maintained in memory
  - Some servers allow writing to file system or database
  - Objects stored in session need to be serializable
- User associated with `HttpSession` object:
  - `HttpSessionRequest` class
    - Get current session or create new one:
    - `HttpSession getSession()`

HttpSession

- Getting data:
  - `Object getAttribute(String name)`
  - `Enumeration<String> getAttributeNames()`
- Setting data:
  - `void setAttribute(String name, Object val)`
- Moving data:
  - `void removeAttribute(String name)`

Session lifecycle

- Sessions do not last forever
  - Automatically expire after period of inactivity
    - `int  getMaxInactiveInterval()`
    - `void setMaxInactiveInterval()`
  - Explicitly invalidated by servlet
    - `void invalidate()`
- Inactive or invalidated session
  - `HttpSession` object removed along with data values it contains

Summary

- Java servlets
  - Another way to do dynamic content generation
    - Run a web server with servlet support or embedded in an existing app
    - Development in high-level object-oriented language
  - Persistent servlet object that services requests
    - Efficient reuse of the same object
    - Can be hit in parallel by multiple threads
    - Protect concurrent access to shared data!
  - Support for tracking session state