# Middleware and Web Services Lecture 3: Application Protocols

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#### **Overview**

- Introduction to Application Protocols
  - Synchronous and Asynchronous Communication
  - Selected Networking Concepts
- Simple Protocol Example
- Introduction to HTTP

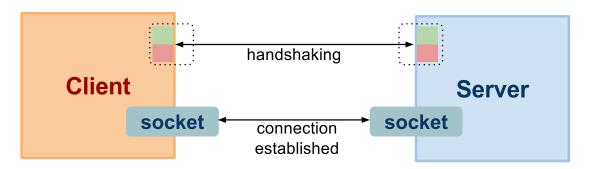
# **Application Protocols**

Remember this

OSI Model	All	People	Seem	То	Need	Data	Processing
	Application	Presentation	Session	Transport	Network	Data Link	Physical
TCP/IP (services)	Application HTTP, XML-RPC, SOAP, RMI			Transport TCP	Network IP	Data Link	Physical

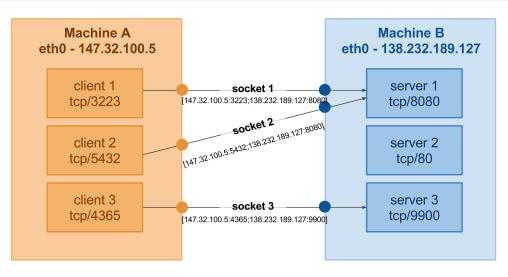
- App protocols mostly on top of the TCP Layer
  - use TCP socket for communication
- Major protocols
  - HTTP most of the app protocols layered on HTTP
    - → wide spread, but: implementors often break HTTP semantics
  - RMI Remote Method Invocation
    - → Java-specific, rather interface
    - → may use HTTP underneath (among other things)
  - XML-RPC Remote Procedure Call and SOAP
    - $\rightarrow$  Again, HTTP underneath
  - WebSocket new protocol part of HTML5

#### Socket



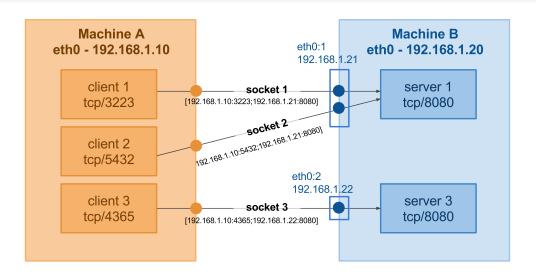
- Handshaking (connection establishment)
  - The server listens at [dst\_ip,dsp\_port]
  - Three-way handshake:
    - → the client at [src\_ip, src\_port] sends a connection request
    - $\rightarrow$  the server responds
    - → the client acknowledges the response, can send data along
  - Result is a socket (virtual communication channel) with unique identification: socket=[src\_ip,src\_port;dst\_ip,dst\_port]
- Data transfer (resource usage)
  - Client/server writes/reads data to/from the socket
  - TCP features: reliable delivery, correct order of packets, flow control
- Connection close

## **Addressing in Application Protocol**



- IP addressing: IP is an address of a machine interface
  - A machine can have multiple interfaces (eth0, eth1, bond0, ...)
- TCP addressing: TCP port is an address of an app running on a machine and listening on a machine interface
  - Multiple applications with different TCP ports may listen on a machine interface
- Application addressing
  - Additional mechanisms to address entities within an application
  - They are out of scope of IP/TCP, they are app specific
    - → for example, Web apps served by a single Web server

#### Virtual IP



#### Virtual IP

- Additional IP addresses assigned to a network interface
  - $\rightarrow$  For example, eth0 eth0:1, eth0:2, eth0:3, ...
  - $\rightarrow$  A process can bind to the virtual IP
  - → Multiple processes can listen on the same tcp port but on different virtual IPs

#### Benefits

- Floating IP a process can move transparently to another physical machine
- Network configuration can be preserved, no need to reconfigure
- Failover concept uses floating IPs

## **Virtual IP Configuration**

- Steps to configure virtual IP in Linux (example for eth0)
  - 1. Find out the interface's network mask

```
1  $ ifconfig eth0
2  eth0    Link encap:Ethernet HWaddr 00:0C:29:AB:5E:6A
3  inet addr:172.16.169.184 Bcast:172.16.169.255 Mask:255.255.25
4  ...
```

- 2. Create virtual IP using ifconfig
  - it should use the same network mask
  - it should be free, usually allocated to be used as a virtual IP

- 3. Update neighbours' ARP (Address Resolution Protocol) caches
  - to associate the virtual IP with MAC address of eth0
  - when the virtual IP was in use on other node or interface
  - 9 | \$ sudo arping -q -U -c 3 -I eht0 172.16.169.184

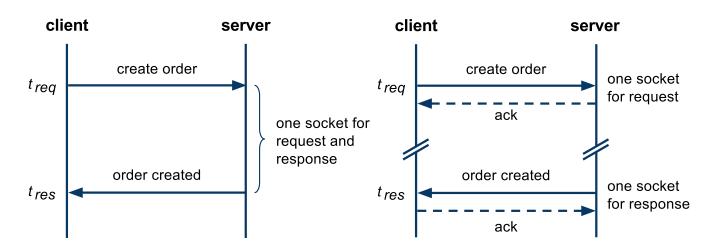


- Configure a virtual IP on your computer and test it using ping

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## Synchronous and Asynchronous Communication



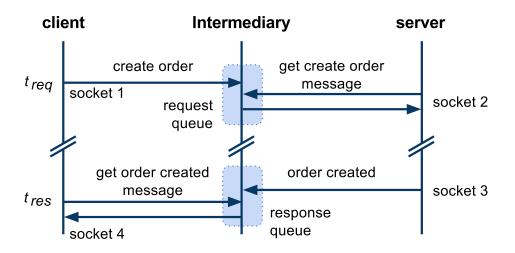
#### Synchronous

- one socket,  $|t_{reg} t_{res}|$  is small
- easy to implement and deploy, only standard firewall config
- only the server defines endpoint

#### Asynchronous

- request, response each has socket, client and server define endpoints
- $-|t_{reg}-t_{res}|$  can be large (hours, even days)
- harder to do across network elements (private/public networks issue)

## **Asynchronous via Intermediary**



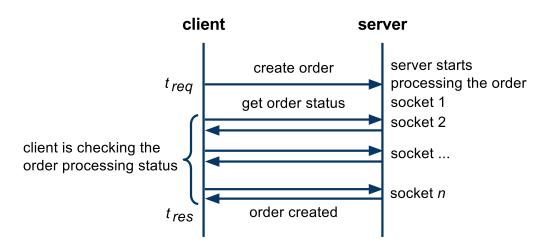
#### Intermediary

- A component that decouples a client-server communication
- It increases reliability and performance
  - → The server may not be available when a client sends a request
  - → There can be multiple servers that can handle the request

#### Further Concepts

- Message Queues (MQ) queue-based communication
- − Publish/Subscribe (P/S) − event-driven communication

# Asynchronous via Polling

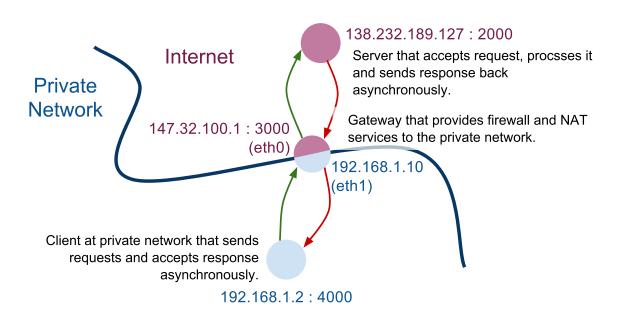


- Polling only clients open sockets
  - A client performs multiple request-response interactions
    - → The first interaction initiates a process on the server
    - → Subsequent interactions check for the processing status
    - → The last interaction retrieves the processing result
- Properties of environments
  - A server cannot open a socket with the client (network restrictions)
  - Typically on the Web (a client runs in a browser)

#### **Overview**

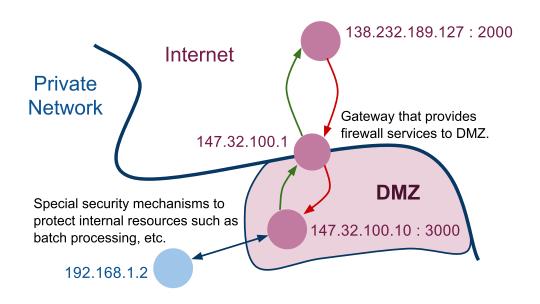
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# **Public/Private Network Configuration**



- Adds complexity to configuration of application
  - Config example at server with eth0 = 147.32.100.1 (iptables)

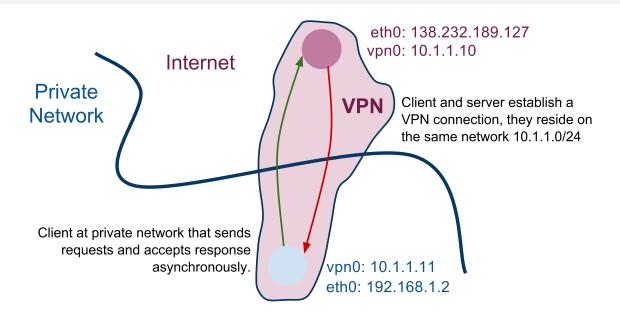
#### **Demilitarized Zones**



#### • DMZ = Demilitarized Zone

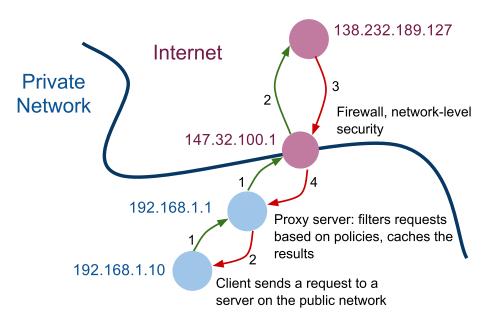
- subnet within an organization's network on a public network
- special care of security enforced through internal policies
- For example:
  - → no access to all live data, subsets copied in batches
  - $\rightarrow$  frequent monitoring

#### Virtual Private Network



- VPN = Virtual Private Network
  - an overlay network between a client and a server
  - the network spans accross underlying network elements
  - Example:
    - → VPN client starts a VPN connection with the VPN server via network interfaces
    - → VPN server assigns an IP address to the VPN client from the server's subnet
    - → Packets in VPN communication are encrypted and sent out in an outer VPN packet, e.g. IPSec packet

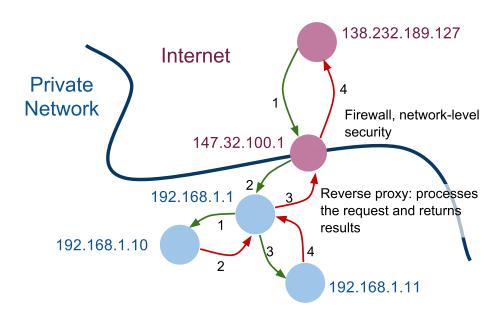
## **Proxy Server**



#### • Proxy Server

- Centralized access control based on content
- Perfoms request on behalf of the client
  - → Caches content to increase performance, limits network traffic
  - → Filters requests based on their destinations
- Widely used in private networks in companies
- Most of the proxy servers today are Web proxy servers

## **Reverse Proxy Server**



#### • Reverse Proxy Server

- Aggregates multiple request-response interactions with back-end systems
- Processes the request on behalf of the client
- Provides additional values to communication
  - $\rightarrow$  Data transformations
  - $\rightarrow$  Security authentication, authorization
  - → Orchestration of communication with back-end systems
- Examples: Enterprise Service Bus, Security Gateway

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#### **TCP Socket Protocol**

- Example simple TCP Socket protocol in Java 🔯
  - functions (verbs): add and bye
  - data syntax: add "^[0-9]+ [0-9]+\$", bye "^\$" (regular grammars)
  - data semantics: add decimal numbers, bye none
  - process: transitions S1-add-S1, S1-bye-S0, where S0, S1 are states such that S1=connection established, S0=connection closed.

```
package com.vitvar.ctu.mdw;
   import java.io.*;
   import java.net.*;
    import java.util.regex.*;
     * Simple protocol example. The class starts a listener on the port 8080.
     * When a client connects, the server parses the input in a form "add a b",
     * where "a" and "b" are integer values, adds the two numbers and sends
     * the result back to the client. The communication ends when the client sends "bye".
11
12
     * @author tomas@vitvar.com
13
14
15
    public class SimpleProtocol {
16
17
        public static void main(String[] args) throws IOException {
18
            // info message to the console
19
20
            System.out.println("Listening on port 8080...");
```

## TCP Socket Protocol (Cont.)

```
22
            // listen on port 8080
23
            ServerSocket serverSocket = new ServerSocket(8080);
            Socket clientSocket = serverSocket.accept();
24
25
26
            // create reader and writer to read from and write to the socket
             PrintWriter out = new PrintWriter(clientSocket.getOutputStream(), true);
27
28
             BufferedReader in = new BufferedReader(
                 new InputStreamReader(clientSocket.getInputStream()));
29
30
            // print information to the client
31
            out.println("verbs: add a b, bye");
32
33
34
            // grammar definition
            Pattern p = Pattern.compile("^add ([0-9]+) ([0-9]+)$");
35
36
            Matcher m; String message;
37
            // read input from the client and process the input
38
            while ((message = in.readLine()) != null) {
39
                 if ((m = p.matcher(message)).matches())
40
                     out.println("Result: " + (Integer.parseInt(m.group(1)) +
41
                         Integer.parseInt(m.group(2))));
42
43
                 else
                     if (message.equals("bye")) {
44
                         out.println("Goodbye!");
45
                         break;
46
47
                     } else
                         out.println("Do not understand: " + message);
48
49
50
51
```

## **Testing**

- Many app protocols communicate in plain text
  - messages in ASCII or Base64 encoded (printable chars only)
  - this allows to test them just with Telnet
    - → Telnet does not know about any protocol-specific semantics
    - → only opens, reads/writes, and closes the socket
- Testing our protocol

```
# 1. run the listener
   bin/simple protocol.sh
    Listening on port 8080...
    # 2. open the socket using telnet but first dig for DNS lookup
    telnet 127.0.0.1 8080
    Trying 127.0.0.1...
    Connected to localhost.
     Escape character is '^]'.
    Verbs: add a b, bye.
     add 3 4
    The result is: 7
    minus 7 5
     Do not understand: minus 7 5
14
15
     bve
     Goodbye!
```

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  - State Management

## **Hypertext Transfer Protocol – HTTP**

- Application protocol, basis of Web architecture
  - Part of HTTP, URI, and HTML family
  - Request-response protocol
- One socket for single request-response
  - original specification
  - have changed due to performance issues
    - → many concurrent requests
    - → overhead when establishing same connections
    - → HTTP 1.1 offers persistent connection and pipelining
- HTTP is stateless
  - Multiple HTTP requests cannot be normally related at the server
    - → "problems" with state management
    - → REST goes back to the original HTTP idea

## **HTTP Request and Response**

#### Request Syntax

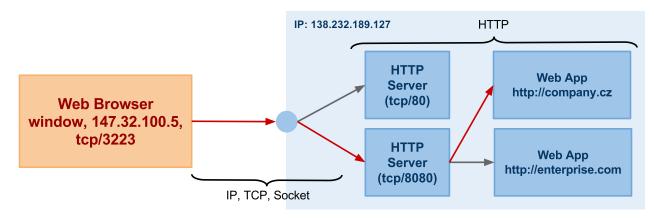
```
method uri http-version <crlf>
(header : value <crlf>)*
<crlf>
[ data ]
```

#### Response Syntax

```
http-version response-code [ message ] <crlf>
(header : value <crlf>)*
<crlf>
[ data ]
```

#### • Semantics of terms

# **Serving HTTP Request**



- IP and TCP addressing
  - 1. User enters URL http://company.cz:8080/orders to the browser
  - 2. Browser gets an IP address for company.cz, IP:138.232.189.127
  - 3. Browser and Web Server creates a socket [147.32.100.5:3223;138.232.189.127:8080]
- Application addressing
  - 4. Browser sends HTTP request, that is, writes following data to the socket
    - 1 | GET /orders HTTP/1.1
    - 2 Host: company.cz
  - 5. Web server passes the request to the web application company.cz which serves GET orders and that writes a response back to the socket.

#### **HTTP Listener**

- HTTP listener implementation in Java using Jetty 🗽

- Server listens on port 8080
- Jetty parses HTTP request data into HttpServletRequest object.
- When a client connects, the method handleRequest is called
- The method tests the value of the host header and responds back if the header matches company.cz value.

```
/** handles the request when client connects **/
     public void handleRequest(HttpServletRequest request,
             HttpServletResponse response) throws IOException, ServletException {
 4
         // test if the host is company.cz
         if (request.getHeader("Host").equals("company.cz")) {
             response.setStatus(200);
             response.setHeader("Content-Type", "text/plain");
             response.getWriter().write("This is the response");
             response.flushBuffer();
10
         } else
11
             response.sendError(400); // bad request
12
13
```

## **HTTP Listener (Cont.)**

• Test it using Telnet

```
telnet 127.0.0.1 8080

# ...lines omitted due to brevity
GET /orders HTTP/1.1
Host: company.cz

HTTP/1.1 201 OK
Content-Type: plain/text

This is the response...
```

- HTTP listener in bash
  - Use it to test incomming HTTP connections quickly
  - Uses nc utility (netcat)

```
# ctrl-c to stop http listener
control_c() {
    echo -en "\n* Exiting\n"
    exit $?
}

trap control_c SIGINT

for ((;;))

do
    echo -e "\n\n* Listening on port $1..."
    echo -e "\nHTTP/1.0 204 No Content\n\n" | nc -l $port
done
```

#### Virtual Web Server

- Virtual server
  - Configuration of a named virtual web server
  - Web server uses host request header to distinguish among multiple virtual web servers on a single physical host.
- Apache virtual Web server configuration
  - Two virtual servers hosted on a single physical host

```
# all IP addresses will be used for named virtual hosts
     NameVirtualHost *:80
    <VirtualHost *:80>
4
             ServerName company.com
             ServerAdmin admin@company.com
             DocumentRoot /var/www/apache/company.com
     </VirtualHost>
9
     <VirtualHost *:80>
10
             ServerName firm.cz
11
12
             ServerAdmin admin@firm.cz
             DocumentRoot /var/www/apache/firm.cz
13
14
     </VirtualHost>
```

## **Better Support for HTTP Testing**

#### • Use curl to test HTTP protocol

#### Example

```
curl -v -H "Host: company.cz" 127.0.0.1:8080
 2
     * About to connect() to 127.0.0.1 port 8080
         Trying 127.0.0.1... connected
4
     * Connected to 127.0.0.1 port 8080
     > GET / HTTP/1.1
     > User-Agent: curl/7.20.0 (i386-apple-darwin10.3.2) libcurl/7.20.0 OpenSSL/0.9.8n
     > Accept: */*
     > Host: company.cz
10
     >
     < HTTP/1.1 201 OK
11
     < Connection: keep-alive
12
     < Content-Type: plain/text
13
14
15
     < This is the response...</pre>
```

## **Overview**

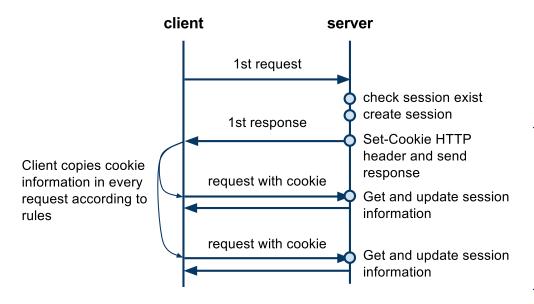
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## **State Management**

- HTTP is a stateless protocol original design
  - No information to relate multiple interactions at server-side
    - $\rightarrow$  Except Authorization header is copied in every request
    - → IP addresses do not work, one public IP can be shared by multiple clients
- Solutions to check for a valid state at server-side
  - Cookies obvious and the most common workaround
    - → RFC 2109 HTTP State Management Mechanism 🛂
    - → Allow clients and servers to talk in a context called **sessions**
  - Hypertext original HTTP design principle
    - → App states represented by resources (hypermedia), links define transitions between states
    - → Adopted by the REST principle **statelessness**

#### **Interaction with Cookies**

- Request-response interaction with cookies
  - Session is a logical channel maintained by the server



Communication in a session; server identifies the session through the information in the cookies.

- Stateful Server
  - Server remembers the session information in a server memory
  - Server memory is a non-persistent storage, when server restarts the memory content is lost!

#### **Set-Cookie and Cookie Headers**

• Set-Cookie response header

- − domain − a domain for which the cookie is applied
- Max-Age number of seconds the cookie is valid
- **− Path** − *URL path for which the cookie is applied*
- Cookie request header. A client sends the cookie in a request if:
  - domain matches the origin server's fully-qualified host name
  - path matches a prefix of the request-URI
  - Max-Age has not expired

```
cookie = "Cookie:" cookie-value (";" cookie-value)*
cookie-value = NAME "=" VALUE [";" path] [";" domain]
path = "$Path" "=" value
domain = "$Domain" "=" value
```

— domain, and path are values from corresponding attributes of the Set-Cookie header

## Session Management Java Class

Manages client sessions in a server memory

```
public class Sessions<E> {
        // storage for the session data;
        private Hashtable<String, E> sessions = new Hashtable<String, E>();
4
        /** Returns session id based on the information in the http request **/
6
        public String getSessionID(HttpServletRequest request) throws Exception {
            String sid = null;
            // extract the session id from the cookie
10
            if (request.getHeader("cookie") != null) {
11
                Pattern p = Pattern.compile(".*session-id=([a-zA-Z0-9]+).*");
12
                Matcher m = p.matcher(request.getHeader("cookie"));
13
                if (m.matches()) sid = m.group(1);
14
15
16
            // create the session id md5 hash; use random number to generate a client-id
17
            // note that this is a simple solution but not very reliable
18
19
            if (sid == null || sessions.get(sid) == null) {
20
                MessageDigest md = MessageDigest.getInstance("MD5");
                md.update(new String(request.getRemoteAddr() +
21
22
                    Math.floor(Math.random()*1000)).getBytes());
                sid = Utils.toHexString(md.digest());
23
24
25
            return sid;
26
27
28
        public E getData(String sid) ... // returns session data from sessions object
         public void setData(String sid, E d) ... // sets session data to sessions object
29
30
```

## **Stateful Server Implementation**

• Simple per-client counter 💱

```
public void handleRequest(HttpServletRequest request,
             HttpServletResponse response) throws Exception {
         // get the session id
         String sid = sessions.getSessionID(request);
4
 5
         // create the new data if none exists
         if (sessions.getData(sid) != null)
             sessions.setData(sid,
                 Integer.valueOf(sessions.getData(sid).intValue() + 1));
10
         else
             sessions.setData(sid, Integer.valueOf(1));
11
12
         // send the response
13
         response.setStatus(200);
14
         response.setHeader("Set-Cookie", "session-id="+ sid + "; MaxAge=3600");
         response.setHeader("Content-Type", "text/plain");
16
         response.getWriter().write("Number of hits from you: " +
17
             sessions.getData(sid).toString());
18
19
         response.flushBuffer();
20
```

## \* Task

- What happens when the server restarts?
- How do you change the code to count requests from all clients?

## **Testing**

- Testing
  - curl will require you to specify cookies in every request
  - Browser handles cookies automatically

```
# run curl for the first time
   curl -v 127.0.0.1:8080
   > GET / HTTP/1.1
   > Host: 127.0.0.1:8080
    < HTTP/1.1 200 OK
    < Set-Cookie: session-id=3a9c3cdc5ff36434aa1ba860727ca401;max-age=3600</pre>
9
    Number of hits from you: 1
10
     # copy the cookie session-id from previous response
11
     curl -v -b session-id=3a9c3cdc5ff36434aa1ba860727ca401 127.0.0.1:8080
    > GET / HTTP/1.1
    > Host: 127.0.0.1:9900
14
    > Cookie: session-id=3a9c3cdc5ff36434aa1ba860727ca401
16
     >
17
    < HTTP/1.1 200 OK
18
    < Set-Cookie: session-id=3a9c3cdc5ff36434aa1ba860727ca401;max-age=3600</pre>
19
     <
     Number of hits from you: 2
```