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

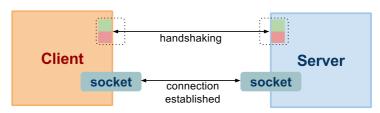
	All	People	Seem	То	Need	Data	Processing
OSI Model	Application	Presentation	Session	Transport	Network	Data Link	Physical
TCP/IP (services)	Application HTTP, XML-RPC, SOAP, RMI			Transport TCP	Network IP	Data Link	Physical

- 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
 - \rightarrow Java-specific, rather interface
 - → may use HTTP underneath (among other things)
 - XML-RPC Remote Procedure Call and SOAP
 - → Again, HTTP underneath
 - WebSocket new protocol part of HTML5

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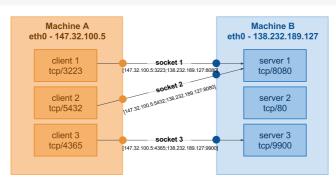
Socket



- 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

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Addressing in Application Protocol

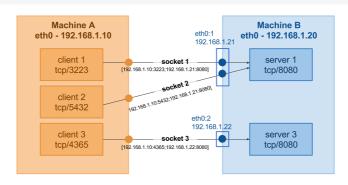


- IP addressing: IP is an address of a machine interface
 - A machine can have multiple interfaces (eth0, eth1, bond0, ...)
- TCP addressing: TCP port is an address of an app running on a machine and listening on a machine interface
 - Multiple applications with different TCP ports may listen on a machine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

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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

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Virtual IP Configuration

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

- 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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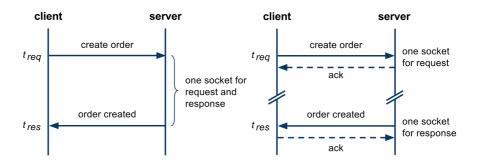
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Synchronous and Asynchronous Communication



Synchronous

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

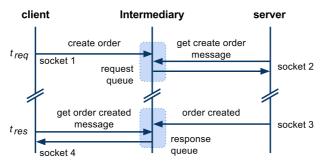
Asynchronous

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

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Asynchronous via Intermediary



Intermediary

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

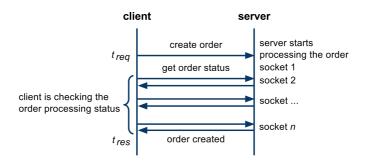
Further Concepts

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

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Asynchronous via Polling



- Polling only clients open sockets
 - A client performs multiple request-response interactions
 - \rightarrow The first interaction initiates a process on the server
 - → Subsequent interactions check for the processing status
 - \rightarrow 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)

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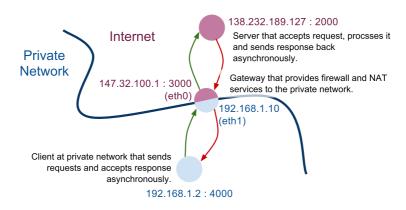
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Public/Private Network Configuration



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

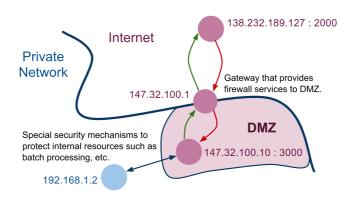
```
# enable ip forwarding from one interface to another within linux core
cho 1 > /proc/sys/net/ipv4/ip_forward

# redirect all communication coming to tcp/3000 to 192.168.1.2:4000
iptables -t nat -A PREROUTING -i eth0 -p tcp --dport 3000 -j DNAT \
--to-dest 192.168.1.2 --to-port 4000
```

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Demilitarized Zones

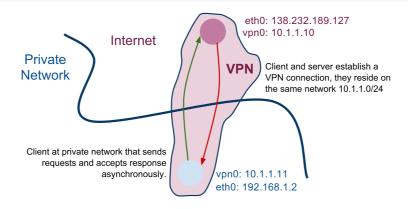


- DMZ = Demilitarized Zone
 - subnet within an organization's network on a public network
 - special care of security enforced through internal policies
 - For example:
 - \rightarrow no access to all live data, subsets copied in batches
 - \rightarrow frequent monitoring

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Virtual Private Network



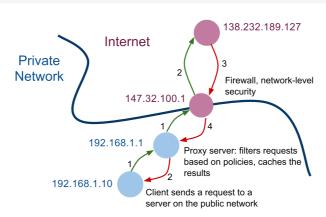
• VPN = Virtual Private Network

- 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

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Proxy Server



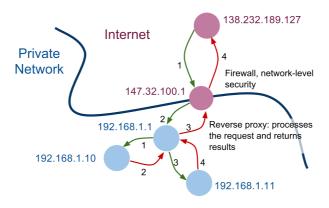
Proxy Server

- 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

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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
 - ightarrow 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".

* @author tomas@vitvar.com

* 
public class SimpleProtocol {

public static void main(String[] args) throws IOException {
    // info message to the console
    System.out.println("Listening on port 8080...");
```

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TCP Socket Protocol (Cont.)

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

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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
bye
Goodbye!
```

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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

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HTTP Request and Response

Request Syntax

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

Response Syntax

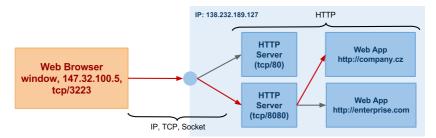
```
http-version response-code [ message ] <crlf>
(header : value <crlf>)*
<crlf>
[ data ]
```

• Semantics of terms

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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.

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HTTP Listener

- HTTP listener implementation in Java using Jetty <a>8
 - 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
5
          if (request.getHeader("Host").equals("company.cz")) {
              response.setStatus(200);
response.setHeader("Content-Type", "text/plain");
response.getWrite(".write("This is the response");
8
9
10
               response.flushBuffer();
11
12
               response.sendError(400); // bad request
    }
13
```

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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
```

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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

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Better Support for HTTP Testing

Use curl to test HTTP protocol

Example

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State Management

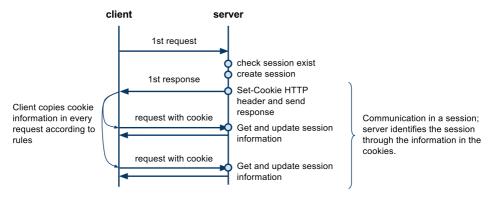
- HTTP is a stateless protocol original design
 - No information to relate multiple interactions at server-side
 - \rightarrow Except Authorization header is copied in every request
 - → IP addresses do not work, one public IP can be shared by multiple clients
- Solutions to check for a valid state at 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**

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Interaction with Cookies

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



- 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!

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Set-Cookie and Cookie Headers

• Set-Cookie response header

```
set-cookie = "Set-Cookie:" cookie ("," cookie)*

cookie = NAME "=" VALUE (";" cookie-av)*

cookie-av = "Comment" "=" value

"Domain" "=" value

"Max-Age" "=" value

"Path" "=" value
```

- − 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

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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>();
            /stst Returns session id based on the information in the http request stst
           public String getSessionID(HttpServletRequest request) throws Exception {
   String sid = null;
8
                // extract the session id from the cookie
if (request.getHeader("cookie") != null) {
   Pattern p = Pattern.compile(".*session-id=([a-zA-Z0-9]+).*");
   Matcher m = p.matcher(request.getHeader("cookie"));
   if (m.matches()) sid = m.group(1);
10
11
15
16
17
18
                }
                // create the session id md5 hash; use random number to generate a client-id
                19
20
21
22
23
24
                      sid = Utils.toHexString(md.digest());
                return sid;
26
           }
           public E getData(String sid) ... // returns session data from sessions object
28
           public void setData(String sid, E d) ... // sets session data to sessions object
30
```

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Stateful Server Implementation

• Simple per-client counter 💱

```
public void handleRequest(HttpServletRequest request,
               HttpServletResponse response) throws Exception {
           // get the session id
4
          String sid = sessions.getSessionID(request);
5
6
           // create the new data if none exists
           if (sessions.getData(sid) != null)
               sessions.setData(sid,
9
                    Integer.valueOf(sessions.getData(sid).intValue() + 1));
10
          else
11
               sessions.setData(sid, Integer.valueOf(1));
13
          // send the response
14
          response.setStatus(200);
          response.setJtatus(200);
response.setHeader("Set-Cookie", "session-id="+ sid + "; MaxAge=3600");
response.setHeader("Content-Type", "text/plain");
response.getWriter().write("Number of hits from you: " +
15
16
17
               sessions.getData(sid).toString());
18
19
          response.flushBuffer();
20
     }
```

X Task

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

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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
6
    < HTTP/1.1 200 OK
    < Set-Cookie: session-id=3a9c3cdc5ff36434aa1ba860727ca401;max-age=3600
8
9
    Number of hits from you: 1
    # copy the cookie session-id from previous response
11
    curl -v -b session-id=3a9c3cdc5ff36434aa1ba860727ca401 127.0.0.1:8080
12
    > GET / HTTP/1.1
    > Host: 127.0.0.1:9900
15
    > Cookie: session-id=3a9c3cdc5ff36434aa1ba860727ca401
16
17
    < HTTP/1.1 200 OK
18
    < Set-Cookie: session-id=3a9c3cdc5ff36434aa1ba860727ca401;max-age=3600
    Number of hits from you: 2
```

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