

Cross-Site Request Forgery (CSRF) Attack Lab

(Web Application: Elgg)

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1 Overview

The objective of this lab is to help students understand the Cross-Site Request Forgery (CSRF) attack. A CSRF attack involves a victim user, a trusted site, and a malicious site. The victim user holds an active session with a trusted site while visiting a malicious site. The malicious site injects an HTTP request for the trusted site into the victim user session, causing damages.

In this lab, students will be attacking a social networking web application using the CSRF attack. The open-source social networking application is called Elgg, which has already been installed in our VM. Elgg has countermeasures against CSRF, but we have turned them off for the purpose of this lab. This lab covers the following topics:

- Cross-Site Request Forgery attack
- CSRF countermeasures: Secret token and Same-site cookie
- HTTP GET and POST requests
- JavaScript and Ajax

Readings. Detailed coverage of the CSRF attack can be found in the following:

- Chapter 10 of the SEED Book, *Computer & Internet Security: A Hands-on Approach*, 2nd Edition, by Wenliang Du. See details at <https://www.handsonsecurity.net>.

Lab environment. This lab has been tested on our pre-built Ubuntu 20.04 VM, which can be downloaded from the SEED website. Since we use containers to set up the lab environment, this lab does not depend much on the SEED VM. You can do this lab using other VMs, physical machines, or VMs on the cloud.

2 Lab Environment Setup

In this lab, we will use three websites. The first website is the vulnerable Elgg site accessible at `www.seed-server.com`. The second website is the attacker's malicious web site that is used for attacking Elgg. This web site is accessible via `www.attacker32.com`. The third website is used for the defense tasks, and its hostname is `www.example32.com`. We use containers to set up the lab environment.

2.1 Container Setup and Commands

Please download the `Labsetup.zip` file to your VM from the lab's website, unzip it, enter the `Labsetup` folder, and use the `docker-compose.yml` file to set up the lab environment. Detailed explanation of the content in this file and all the involved `Dockerfile` can be found from the user manual, which is linked

to the website of this lab. If this is the first time you set up a SEED lab environment using containers, it is very important that you read the user manual.

In the following, we list some of the commonly used commands related to Docker and Compose. Since we are going to use these commands very frequently, we have created aliases for them in the `.bashrc` file (in our provided SEEDUbuntu 20.04 VM).

```
$ docker-compose build # Build the container images
$ docker-compose up    # Start the containers
$ docker-compose down  # Shut down the containers

// Aliases for the Compose commands above
$ dcbuild              # Alias for: docker-compose build
$ dcup                 # Alias for: docker-compose up
$ dcdown               # Alias for: docker-compose down
```

All the containers will be running in the background. To run commands on a container, we often need to get a shell on that container. We first need to use the `"docker ps"` command to find out the ID of the container, and then use `"docker exec"` to start a shell on that container. We have created aliases for them in the `.bashrc` file.

```
$ dockps              // Alias for: docker ps --format "{{.ID}} {{.Names}}"
$ docksh <id>         // Alias for: docker exec -it <id> /bin/bash

// The following example shows how to get a shell inside hostC
$ dockps
b1004832e275  hostA-10.9.0.5
0af4ea7a3e2e  hostB-10.9.0.6
9652715c8e0a  hostC-10.9.0.7

$ docksh 96
root@9652715c8e0a:/#

// Note: If a docker command requires a container ID, you do not need to
//       type the entire ID string. Typing the first few characters will
//       be sufficient, as long as they are unique among all the containers.
```

If you encounter problems when setting up the lab environment, please read the “Common Problems” section of the manual for potential solutions.

2.2 Elgg Web Application

We use an open-source web application called Elgg in this lab. Elgg is a web-based social-networking application. It is already set up in the provided container images. We use two containers, one running the web server (10.9.0.5), and the other running the MySQL database (10.9.0.6). The IP addresses for these two containers are hardcoded in various places in the configuration, so please do not change them from the `docker-compose.yml` file.

The Elgg container. We host the Elgg web application using the Apache web server. The website setup is included in `apache_elgg.conf` inside the Elgg image folder. The configuration specifies the URL for the website and the folder where the web application code is stored.

```
<VirtualHost *:80>
    DocumentRoot /var/www/elgg
    ServerName    www.seed-server.com
    <Directory /var/www/elgg>
        Options FollowSymlinks
        AllowOverride All
        Require all granted
    </Directory>
</VirtualHost>
```

The Attacker container. We use another container (10.9.0.105) for the attacker machine, which hosts a malicious website. The Apache configuration for this website is listed in the following:

```
<VirtualHost *:80>
    DocumentRoot /var/www/attacker
    ServerName    www.attacker32.com
</VirtualHost>
```

Since we need to create web pages inside this container, for convenience, as well as for keeping the pages we have created, we mounted a folder (Labsetup/attacker on the hosting VM) to the container's /var/www/attacker folder, which is the DocumentRoot folder in our Apache configuration. Therefore, the web pages we put inside the attacker folder on the VM will be hosted by the attacker's website. We have already placed some code skeletons inside this folder.

DNS configuration. We access the Elgg website, the attacker website, and the defense site using their respective URLs. We need to add the following entries to the /etc/hosts file, so these hostnames are mapped to their corresponding IP addresses. You need to use the root privilege to change this file (using sudo). It should be noted that these names might have already been added to the file due to some other labs. If they are mapped to different IP addresses, the old entries must be removed.

```
10.9.0.5      www.seed-server.com
10.9.0.5      www.example32.com
10.9.0.105    www.attacker32.com
```

MySQL database. Containers are usually disposable, so once it is destroyed, all the data inside the containers are lost. For this lab, we do want to keep the data in the MySQL database, so we do not lose our work when we shutdown our container. To achieve this, we have mounted the mysql_data folder on the host machine (inside Labsetup, it will be created after the MySQL container runs once) to the /var/lib/mysql folder inside the MySQL container. This folder is where MySQL stores its database. Therefore, even if the container is destroyed, data in the database are still kept. If you do want to start from a clean database, you can remove this folder:

```
$ sudo rm -rf mysql_data
```

User accounts. We have created several user accounts on the Elgg server; the user name and passwords are given in the following.

```
-----
UserName | Password
-----
```

admin		seedelgg
alice		seedalice
boby		seedboby
charlie		seedcharlie
samy		seedsamy

3 Lab Tasks: Attacks

3.1 Task 1: Observing HTTP Request.

In Cross-Site Request Forget attacks, we need to forge HTTP requests. Therefore, we need to know what a legitimate HTTP request looks like and what parameters it uses, etc. We can use a Firefox add-on called "HTTP Header Live" for this purpose. The goal of this task is to get familiar with this tool. Instructions on how to use this tool is given in the Guideline section (§ 5.1). Please use this tool to capture an HTTP GET request and an HTTP POST request in Elgg. In your report, please identify the parameters used in this these requests, if any.

3.2 Task 2: CSRF Attack using GET Request

In this task, we need two people in the Elgg social network: Alice and Samy. Samy wants to become a friend to Alice, but Alice refuses to add him to her Elgg friend list. Samy decides to use the CSRF attack to achieve his goal. He sends Alice an URL (via an email or a posting in Elgg); Alice, curious about it, clicks on the URL, which leads her to Samy's web site: `www.attacker32.com`. Pretend that you are Samy, describe how you can construct the content of the web page, so as soon as Alice visits the web page, Samy is added to the friend list of Alice (assuming Alice has an active session with Elgg).

To add a friend to the victim, we need to identify what the legitimate Add-Friend HTTP request (a GET request) looks like. We can use the "HTTP Header Live" Tool to do the investigation. In this task, you are not allowed to write JavaScript code to launch the CSRF attack. Your job is to make the attack successful as soon as Alice visits the web page, without even making any click on the page (hint: you can use the `img` tag, which automatically triggers an HTTP GET request).

Elgg has implemented a countermeasure to defend against CSRF attacks. In Add-Friend HTTP requests, you may notice that each request includes two weird-looking parameters, `__elgg-ts` and `__elgg-token`. These parameters are used by the countermeasure, so if they do not contain correct values, the request will not be accepted by Elgg. We have disabled the countermeasure for this lab, so there is no need to include these two parameters in the forged requests.

Important note: If you use a cloud VM or other non-SEED VMs, the Firefox version in your VM may be quite recent, and some restrictions may be placed on cross-site cookies. In the more recent versions, using the image tag to forge an HTTP GET request will not succeed in the attack. This is because the browser blocks the cross-site cookies for this type of request. If you encounter this situation, you can choose one of the following methods to make the attack work:

- Instead of using the image tag, use another way to generate the GET request. For example, in the next task, we use JavaScript to forge a POST request. We can use the same method to forge a GET request.

- Change the Firefox setting to lift the restriction. Figuring out which restriction should be lifted is left to the students as part of the task. The restriction is set in the `Privacy & Security` page, which can be displayed by typing `about:preferences#privacy` in the URL field.

If you are using our provided SEEDUbuntu 20.04 VM, the image tag approach still works, unless you have upgraded the Firefox to the more recent version.

3.3 Task 3: CSRF Attack using POST Request

After adding himself to Alice’s friend list, Samy wants to do something more. He wants Alice to say “Samy is my Hero” in her profile, so everybody knows about that. Alice does not like Samy, let alone putting that statement in her profile. Samy plans to use a CSRF attack to achieve that goal. That is the purpose of this task.

One way to do the attack is to post a message to Alice’s Elgg account, hoping that Alice will click the URL inside the message. This URL will lead Alice to your (i.e., Samy’s) malicious web site `www.attacker32.com`, where you can launch the CSRF attack.

The objective of your attack is to modify the victim’s profile. In particular, the attacker needs to forge a request to modify the profile information of the victim user of Elgg. Allowing users to modify their profiles is a feature of Elgg. If users want to modify their profiles, they go to the profile page of Elgg, fill out a form, and then submit the form—sending a POST request—to the server-side script `/profile/edit.php`, which processes the request and does the profile modification.

The server-side script `edit.php` accepts both GET and POST requests, so you can use the same trick as that in Task 1 to achieve the attack. However, in this task, you are required to use the POST request. Namely, attackers (you) need to forge an HTTP POST request from the victim’s browser, when the victim is visiting their malicious site. Attackers need to know the structure of such a request. You can observe the structure of the request, i.e., the parameters of the request, by making some modifications to the profile and monitoring the request using the “HTTP Header Live” tool. You may see something similar to the following. Unlike HTTP GET requests, which append parameters to the URL strings, the parameters of HTTP POST requests are included in the HTTP message body (see the contents between the two ☆ symbols):

```
http://www.seed-server.com/action/profile/edit
```

```
POST /action/profile/edit HTTP/1.1
Host: www.seed-server.com
User-Agent: Mozilla/5.0 (X11; Ubuntu; Linux i686; rv:23.0) ...
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Referer: http://www.seed-server.com/profile/elgguser1/edit
Cookie: Elgg=p0dci8baqrl4i2ipv2mio3po05
Connection: keep-alive
Content-Type: application/x-www-form-urlencoded
Content-Length: 642
__elgg_token=fc98784a9fbd02b68682bbb0e75b428b&__elgg_ts=1403464813 ☆
&name=elgguser1&description=%3Cp%3Iamelgguser1%3C%2Fp%3E
&accesslevel%5Bdescription%5D=2&briefdescription= Iamelgguser1
&accesslevel%5Bbriefdescription%5D=2&location=US
..... ☆
```

After understanding the structure of the request, you need to be able to generate the request from your attacking web page using JavaScript code. To help you write such a JavaScript program, we provide a sample code in the following code fence. You can use this sample code to construct your malicious web site for the CSRF attacks. This is only a sample code, and you need to modify it to make it work for your attack.

```
<html>
<body>
<h1>This page forges an HTTP POST request.</h1>
<script type="text/javascript">

function forge_post()
{
    var fields;

    // The following are form entries need to be filled out by attackers.
    // The entries are made hidden, so the victim won't be able to see them.
    fields += "<input type='hidden' name='name' value='****'>";
    fields += "<input type='hidden' name='briefdescription' value='****'>";
    fields += "<input type='hidden' name='accesslevel[briefdescription]'
                                   value='2'>";                                     ①
    fields += "<input type='hidden' name='guid' value='****'>";

    // Create a <form> element.
    var p = document.createElement("form");

    // Construct the form
    p.action = "http://www.example.com";
    p.innerHTML = fields;
    p.method = "post";

    // Append the form to the current page.
    document.body.appendChild(p);

    // Submit the form
    p.submit();
}

// Invoke forge_post() after the page is loaded.
window.onload = function() { forge_post();}
</script>
</body>
</html>
```

In Line ①, the value 2 sets the access level of a field to public. This is needed, otherwise, the access level will be set by default to private, so others cannot see this field. It should be noted that when copy-and-pasting the above code from a PDF file, the single quote character in the program may become something else (but still looks like a single quote). That will cause syntax errors. Replacing all the single quote symbols with the one typed from your keyboard will fix those errors.

Questions. In addition to describing your attack in full details, you also need to answer the following questions in your report:

- **Question 1:** The forged HTTP request needs Alice's user id (guid) to work properly. If Bobby targets Alice specifically, before the attack, he can find ways to get Alice's user id. Bobby does not know Alice's Elgg password, so he cannot log into Alice's account to get the information. Please describe how Bobby can solve this problem.
- **Question 2:** If Bobby would like to launch the attack to anybody who visits his malicious web page. In this case, he does not know who is visiting the web page beforehand. Can he still launch the CSRF attack to modify the victim's Elgg profile? Please explain.

4 Lab Tasks: Defense

CSRF is not difficult to defend against. Initially, most applications put a secret token in their pages, and by checking whether the token is present in the request or not, they can tell whether a request is a same-site request or a cross-site request. This is called *secret token* approach. More recently, most browsers have implemented a mechanism called *SameSite cookie*, which is intended to simplify the implementation of CSRF countermeasures. We will conduct experiments on both methods.

4.1 Task 4: Enabling Elgg's Countermeasure

To defend against CSRF attacks, web applications can embed a secret token in their pages. All the requests coming from these pages must carry this token, or they will be considered as a cross-site request, and will not have the same privilege as the same-site requests. Attacker will not be able to get this secret token, so their requests are easily identified as cross-site requests.

Elgg uses this secret-token approach as its built-in countermeasures to defend against CSRF attacks. We have disabled the countermeasures to make the attack work. Elgg embeds two parameters `__elgg_ts` and `__elgg_token` in the request. The two parameters are added to the HTTP message body for the POST requests and to the URL string for the HTTP GET requests. The server will validate them before processing a request.

Embedding secret token and timestamp to web pages. Elgg adds security token and timestamp to all the HTTP requests. The following HTML code is present in all the forms where user action is required. These are two hidden fields; when the form is submitted, these two hidden parameters are added to the request:

```
<input type = "hidden" name = "__elgg_ts" value = "" />
<input type = "hidden" name = "__elgg_token" value = "" />
```

Elgg also assigns the values of the security token and timestamp to JavaScript variables, so they can be easily accessed by the JavaScript code on the same page.

```
elgg.security.token.__elgg_ts;
elgg.security.token.__elgg_token;
```

The secret token and timestamp are added to Elgg's web pages by the `vendor/elgg/elgg/views/default/input/securitytoken.php` module. The code snippet below shows how they are dynamically added to web pages.

```
$ts = time();
$token = elgg()->csrf->generateActionToken($ts);

echo elgg_view('input/hidden', ['name' => '__elgg_token', 'value' => $token]);
```

```
echo elgg_view('input/hidden', ['name' => '__elgg_ts', 'value' => $ts]);
```

Secret token generation. Elgg's security token is a hash value (md5 message digest) of the site secret value (retrieved from database), timestamp, user session ID and random generated session string. The code below shows the secret token generation in Elgg (in `vendor/elgg/elgg/engine/classes/Elgg/Security/Csrf.php`).

```
/**
 * Generate a token from a session token (specifying the user),
 * the timestamp, and the site key.
 */
public function generateActionToken($timestamp, $session_token = '') {
    if (!$session_token) {
        $session_token = $this->session->get('__elgg_session');
        if (!$session_token) {
            return false;
        }
    }

    return $this->hmac
        ->getHmac([(int) $timestamp, $session_token], 'md5')
        ->getToken();
}
```

Secret token validation. The elgg web application validates the generated token and timestamp to defend against the CSRF attack. Every user action calls the `validate` function inside `Csrf.php`, and this function validates the tokens. If tokens are not present or invalid, the action will be denied and the user will be redirected. In our setup, we added a `return` at the beginning of this function, essentially disabling the validation.

```
public function validate(Request $request) {
    return; // Added for SEED Labs (disabling the CSRF countermeasure)

    $token = $request->getParam('__elgg_token');
    $ts = $request->getParam('__elgg_ts');
    ... (code omitted) ...
}
```

Task: Turn on the countermeasure. To turn on the countermeasure, get into the Elgg container, go to the `/var/www/elgg/vendor/elgg/elgg/engine/classes/Elgg/Security` folder, remove the `return` statement from `Csrf.php`. A simple editor called `nano` is available from inside the container. After making the change, repeat the attack again, and see whether your attack will be successful or not. Please point out the secret tokens in the captured HTTP requests. Please explain why the attacker cannot send these secret tokens in the CSRF attack; what prevents them from finding out the secret tokens from the web page?

It should be noted (important) that when we launch the edit-profile attack while the countermeasure is enabled, the failed attempt will cause the attacker's page to be reloaded, which will trigger the forged POST request again. This will lead to another failed attempt, so the page will be reloaded again and another forged

POST request will be sent out. This endless loop will slow down your computer. Therefore, after verifying that the attack failed, kill the tab to stop the endless loop.

4.2 Task 5: Experimenting with the SameSite Cookie Method

Most browsers have now implemented a mechanism called SameSite cookie, which is a property associated with cookies. When sending out requests, browsers will check this property, and decide whether to attach the cookie in a cross-site request. A web application can set a cookie as SameSite if it does not want the cookie to be attached to cross-site requests. For example, they can mark the session ID cookie as SameSite, so no cross-site request can use the session ID, and will therefore not be able to launch CSRF attacks.

To help students get an idea on how the SameSite cookies can help defend against CSTF attacks, we have created a website called `www.example32.com` on one of the containers. Please visit the following URL (the hostname is already mapped to `10.9.0.5` in the `/etc/hosts` file; if you are not using the SEED VM, you should add this mapping to your machine):

URL: `http://www.example32.com/`

Once you have visited this website once, three cookies will be set on your browser, `cookie-normal`, `cookie-lax`, and `cookie-strict`. As indicated by the name, the first cookie is just a normal one, the second and third cookies are samesite cookies of two different types (`Lax` and `Strict` types). We have designed two sets of experiments to see which cookies will be attached when you send an HTTP request back to the server. Typically, all the cookies belonging to the server will be attached, but this is not the case if a cookie is a samesite type.

Please follow the links for the two experiments. Link A points to a page on `example32.com`, while Link B points to a page on `attacker32.com`. Both pages are identical (except for the background color), and they both send three different types of requests to `www.example32.com/showcookies.php`, which simply displays the cookies sent by the browser. By looking at the display results, you can tell which cookies were sent by the browser. Please do the following:

- Please describe what you see and explain why some cookies are not sent in certain scenarios.
- Based on your understanding, please describe how the SameSite cookies can help a server detect whether a request is a cross-site or same-site request.
- Please describe how you would use the SameSite cookie mechanism to help Elgg defend against CSRF attacks. You only need to describe general ideas, and there is no need to implement them.

Bonus points. Although it is not required, students are encouraged to modify the Elgg application, so they can use the samesite cookie mechanism to defend against CSRF attacks. We recommend instructors to give bonus points to the students who can do this. Students should check with their instructors regarding the bonus points.

5 Guidelines

5.1 Using the "HTTP Header Live" add-on to Inspect HTTP Headers

The version of Firefox (version 60) in our Ubuntu 16.04 VM does not support the `LiveHTTPHeader` add-on, which was used in our Ubuntu 12.04 VM. A new add-on called "HTTP Header Live" is used in its place. The instruction on how to enable and use this add-on tool is depicted in Figure 1. Just click the

icon marked by ①; a sidebar will show up on the left. Make sure that HTTP Header Live is selected at position ②. Then click any link inside a web page, all the triggered HTTP requests will be captured and displayed inside the sidebar area marked by ③. If you click on any HTTP request, a pop-up window will show up to display the selected HTTP request. Unfortunately, there is a bug in this add-on tool (it is still under development); nothing will show up inside the pop-up window unless you change its size (It seems that re-drawing is not automatically triggered when the window pops up, but changing its size will trigger the re-drawing).

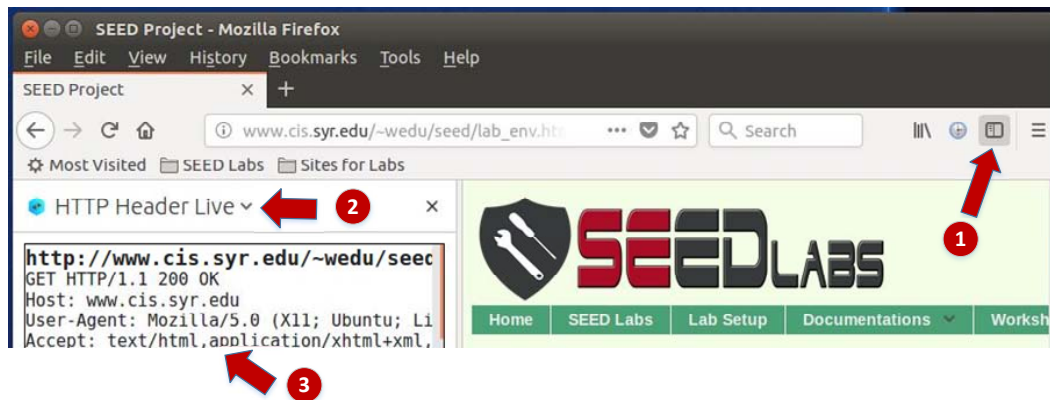


Figure 1: Enable the HTTP Header Live Add-on

5.2 Using the Web Developer Tool to Inspect HTTP Headers

There is another tool provided by Firefox that can be quite useful in inspecting HTTP headers. The tool is the Web Developer Network Tool. In this section, we cover some of the important features of the tool. The Web Developer Network Tool can be enabled via the following navigation:

Click Firefox's top right menu --> Web Developer --> Network
or
Click the "Tools" menu --> Web Developer --> Network

We use the user login page in Elgg as an example. Figure 2 shows the Network Tool showing the HTTP POST request that was used for login.

<div> 🗑️ All HTML CSS JS XHR Fonts Images Media Flash WS Other ❏ Persist Logs </div>					
Status	Method	File	Domain	Cause	
▲ 302	POST	login	www.xsslabel...	document	
▲ 302	GET	/	www.xsslabel...	document	
● 200	GET	activity	www.xsslabel...	document	

Figure 2: HTTP Request in Web Developer Network Tool

To further see the details of the request, we can click on a particular HTTP request and the tool will show the information in two panes (see Figure 3).

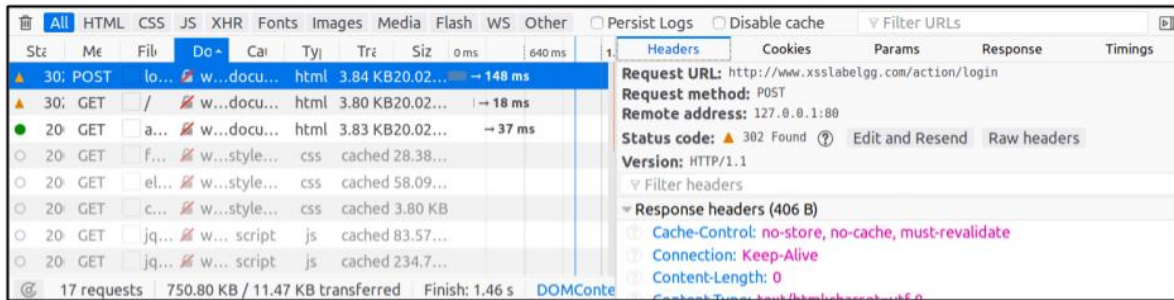
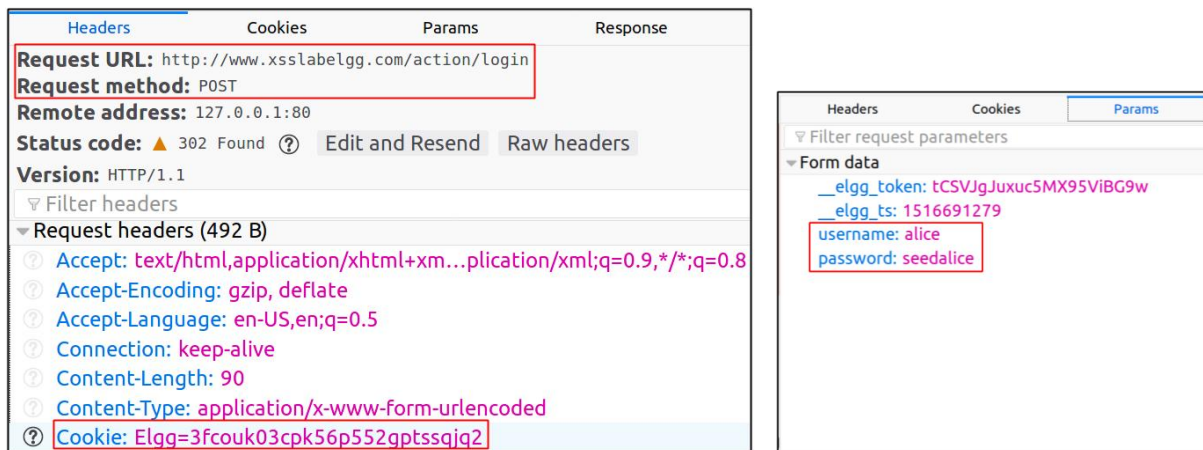


Figure 3: HTTP Request and Request Details in Two Panes

The details of the selected request will be visible in the right pane. Figure 4(a) shows the details of the login request in the Headers tab (details include URL, request method, and cookie). One can observe both request and response headers in the right pane. To check the parameters involved in an HTTP request, we can use the Params tab. Figure 4(b) shows the parameter sent in the login request to Elgg, including username and password. The tool can be used to inspect HTTP GET requests in a similar manner to HTTP POST requests.



(a) HTTP Request Headers

(b) HTTP Request Parameters

Figure 4: HTTP Headers and Parameters

Font Size. The default font size of Web Developer Tools window is quite small. It can be increased by focusing click anywhere in the Network Tool window, and then using `Ctrl` and `+` button.

5.3 JavaScript Debugging

We may also need to debug our JavaScript code. Firefox's Developer Tool can also help debug JavaScript code. It can point us to the precise places where errors occur. The following instruction shows how to enable this debugging tool:

```
Click the "Tools" menu --> Web Developer --> Web Console
or use the Shift+Ctrl+K shortcut.
```

Once we are in the web console, click the JS tab. Click the downward pointing arrowhead beside JS and ensure there is a check mark beside Error. If you are also interested in Warning messages, click Warning. See Figure 5.

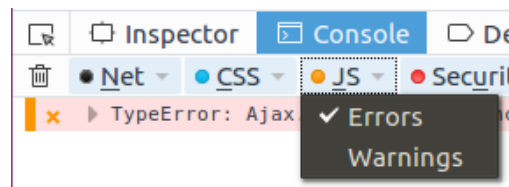


Figure 5: Debugging JavaScript Code (1)

If there are any errors in the code, a message will display in the console. The line that caused the error appears on the right side of the error message in the console. Click on the line number and you will be taken to the exact place that has the error. See Figure 6.

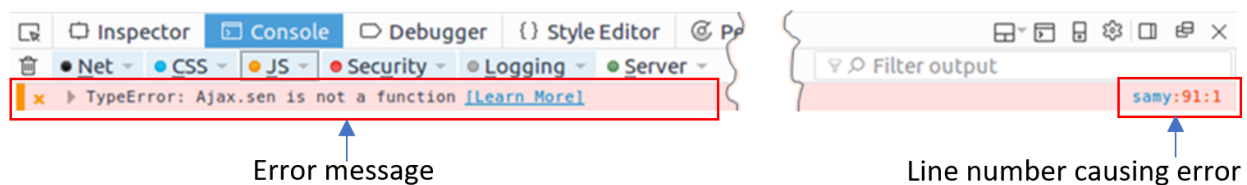


Figure 6: Debugging JavaScript Code (2)

6 Submission

You need to submit a detailed lab report, with screenshots, to describe what you have done and what you have observed. You also need to provide explanation to the observations that are interesting or surprising. Please also list the important code snippets followed by explanation. Simply attaching code without any explanation will not receive credits.