

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 Cross-Site Request Forgery attack can be found in Chapter 9 of the SEED book, *Computer Security: A Hands-on Approach*, by Wenliang Du.

Lab environment. This lab has been tested on our pre-built Ubuntu 16.04 VM, which can be downloaded from the SEED website.

2 Lab Environment

This lab can only be conducted in our Ubuntu 16.04 VM, because of the configurations that we have performed to support this lab. We summarize these configurations in this section.

The 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 pre-built Ubuntu VM image. We have also created several user accounts on the Elgg server and the credentials are given below.

User	UserName	Password
Admin	admin	seedelgg
Alice	alice	seedalice
Boby	boby	seedboby
Charlie	charlie	seedcharlie
Samy	samy	seedsamy

DNS Configuration. This lab involves two websites, the victim website and the attacker's website. Both websites are set up on our VM. Their URLs and folders are described in the following:

```
Attacker's website
URL: http://www.csrf1abattacker.com
Folder: /var/www/CSRF/Attacker/

Victim website (Elgg)
URL: http://www.csrf1abelgg.com
Folder: /var/www/CSRF/Elgg/
```

The above URLs are is only accessible from inside of the virtual machine, because we have modified the `/etc/hosts` file to map the domain name of each URL to the virtual machine's local IP address (127.0.0.1). You may map any domain name to a particular IP address using `/etc/hosts`. For example, you can map `http://www.example.com` to the local IP address by appending the following entry to `/etc/hosts`:

```
127.0.0.1      www.example.com
```

If your web server and browser are running on two different machines, you need to modify `/etc/hosts` on the browser's machine accordingly to map these domain names to the web server's IP address, not to 127.0.0.1.

Apache Configuration. In our pre-built VM image, we used Apache server to host all the web sites used in the lab. The name-based virtual hosting feature in Apache could be used to host several web sites (or URLs) on the same machine. A configuration file named `000-default.conf` in the directory `"/etc/apache2/sites-available"` contains the necessary directives for the configuration:

Inside the configuration file, each web site has a `VirtualHost` block that specifies the URL for the web site and directory in the file system that contains the sources for the web site. The following examples show how to configure a website with URL `http://www.example1.com` and another website with URL `http://www.example2.com`:

```
<VirtualHost *>
    ServerName http://www.example1.com
    DocumentRoot /var/www/Example_1/
</VirtualHost>

<VirtualHost *>
    ServerName http://www.example2.com
    DocumentRoot /var/www/Example_2/
</VirtualHost>
```

You may modify the web application by accessing the source in the mentioned directories. For example, with the above configuration, the web application `http://www.example1.com` can be changed by modifying the sources in the `/var/www/Example_1/` directory. After a change is made to the configuration, the Apache server needs to be restarted. See the following command:

```
$ sudo service apache2 start
```

3 Lab Tasks

For the lab tasks, you will use two web sites that are locally setup in the virtual machine. The first web site is the vulnerable Elgg site accessible at `www.csrflabelgg.com` inside the virtual machine. The second web site is the attacker's malicious web site that is used for attacking Elgg. This web site is accessible via `www.csrfabattacker.com` inside the virtual machine.

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 (§ 4.1). 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 Bobby. Bobby wants to become a friend to Alice, but Alice refuses to add him to her Elgg friend list. Bobby 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 Bobby's web site: `www.csrfabattacker.com`. Pretend that you are Bobby, describe how you can construct the content of the web page, so as soon as Alice visits the web page, Bobby 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 wired-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.

3.3 Task 3: CSRF Attack using POST Request

After adding himself to Alice's friend list, Bobby wants to do something more. He wants Alice to say "Bobby is my Hero" in her profile, so everybody knows about that. Alice does not like Bobby, let alone putting that

statement in her profile. Bobby 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., Bobby's) malicious web site `www.csrflabattacker.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.csrflabelgg.com/action/profile/edit

POST /action/profile/edit HTTP/1.1
Host: www.csrflabelgg.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.csrflabelgg.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. 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. Replace 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.

3.4 Task 4: Implementing a countermeasure for Elgg

Elgg does have a built-in countermeasures to defend against the CSRF attack. We have commented out the countermeasures to make the attack work. CSRF is not difficult to defend against, and there are several common approaches:

- *Secret-token approach:* Web applications can embed a secret token in their pages, and all requests coming from these pages will carry this token. Because cross-site requests cannot obtain this token, their forged requests will be easily identified by the server.
- *Referrer header approach:* Web applications can also verify the origin page of the request using the *referrer* header. However, due to privacy concerns, this header information may have already been filtered out at the client side.

The web application Elgg uses secret-token approach. It embeds two parameters `__elgg_ts` and `__elgg_token` in the request as a countermeasure to CSRF attack. The two parameters are added to the HTTP message body for the POST requests and to the URL string for the HTTP GET requests.

Elgg secret-token and timestamp in the body of the request. Elgg adds security token and timestamp to all the user actions to be performed. The following HTML code is present in all the forms where user action is required. This code adds two new hidden parameters `__elgg_ts` and `__elgg_token` to the POST request:

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

The `__elgg_ts` and `__elgg_token` are generated by the `views/default/input/securitytoken.php` module and added to the web page. The code snippet below shows how it is dynamically added to the web page.

```
$ts = time();
$token = generate_action_token($ts);

echo elgg_view('input/hidden', array('name' => '__elgg_token', 'value' =>
    $token));
echo elgg_view('input/hidden', array('name' => '__elgg_ts', 'value' => $ts));
```

Elgg also adds the security tokens and timestamp to the JavaScript which can be accessed by

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

Elgg security token is a hash value (md5 message digest) of the site secret value (retrieved from database), timestamp, user sessionID and random generated session string. There by defending against the CSRF attack. The code below shows the secret token generation in Elgg.

```
function generate_action_token($timestamp)
{
    $site_secret = get_site_secret();
    $session_id = session_id();
    // Session token
    $st = $_SESSION['__elgg_session'];
```

```

if (($site_secret) && ($session_id))
{
    return md5($site_secret . $timestamp . $session_id . $st);
}

return FALSE;
}

```

The PHP function `session_id()` is used to get or set the session id for the current session. The below code snippet shows random generated string for a given session `__elgg_session` apart from public user Session ID.

```

.....
// Generate a simple token (private from potentially public session id)
if (!isset($_SESSION['__elgg_session'])) {
    $_SESSION['__elgg_session'] =
        ElggCrypto::getRandomString(32, ElggCrypto::CHARS_HEX);
}
.....

```

Elgg secret-token validation. The elgg web application validates the generated token and timestamp to defend against the CSRF attack. Every user action calls `validate_action_token` function and this function validates the tokens. If tokens are not present or invalid, the action will be denied and the user will be redirected.

The below code snippet shows the function `validate_action_token`.

```

function validate_action_token($visibleerrors = TRUE, $token = NULL, $ts =
    NULL)
{
    if (!$token) { $token = get_input('__elgg_token'); }
    if (!$ts) { $ts = get_input('__elgg_ts'); }
    $session_id = session_id();
    if (($token) && ($ts) && ($session_id)) {
        // generate token, check with input and forward if invalid
        $required_token = generate_action_token($ts);

        // Validate token
        if ($token == $required_token) {

            if (_elgg_validate_token_timestamp($ts)) {
                // We have already got this far, so unless anything
                // else says something to the contrary we assume we're ok
                $returnval = true;
                .....
            }
            else {
                .....
                register_error(elgg_echo('actiongatekeeper:tokeninvalid'));
                .....
            }
        }
        .....
    }
}

```

Turn on countermeasure. To turn on the countermeasure, please go to the directory `/var/www/CSRF/Elgg/vendor/elgg/elgg/engine/classes/Elgg` and find the function `gatekeeper` in the `ActionsService.php` file. In function `gatekeeper()` please comment out the `"return true;"` statement as specified in the code comments.

```
public function gatekeeper($action) {  
    //SEED:Modified to enable CSRF.  
    //Comment the below return true statement to enable countermeasure  
    return true;  
    .....  
}
```

Task: After turning on the countermeasure above, try the CSRF attack again, and describe your observation. Please point out the secret tokens in the HTTP request captured using Firefox's HTTP inspection tool. 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?

4 Guidelines

4.1 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).

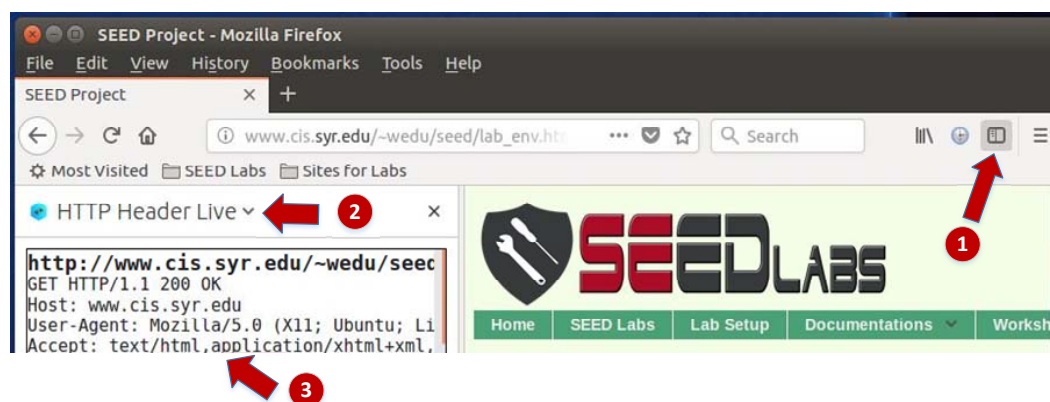


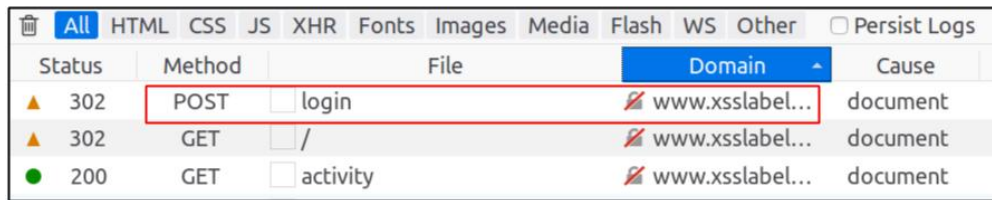
Figure 1: Enable the HTTP Header Live Add-on

4.2 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

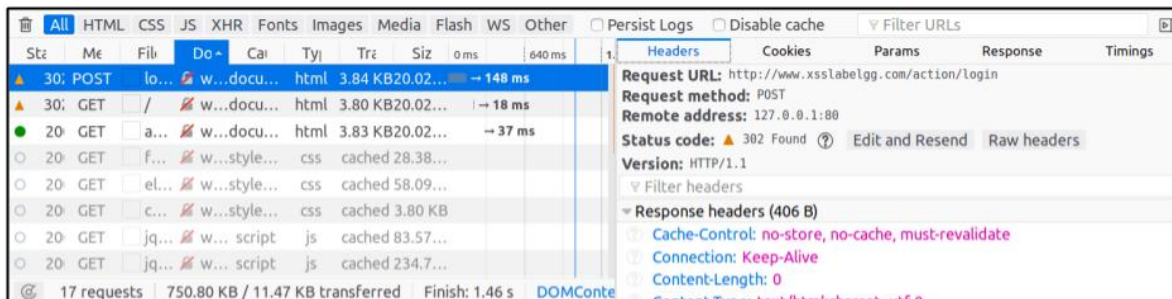
We use the user login page in Elgg as an example. Figure 2 shows the Network Tool showing the HTTP POST request that was used for login.



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).



Stz	Me	Fi	Do	Ca	Ty	Tr	Siz	0 ms	640 ms	1
30	POST	lo...	w...docu...	html	3.84 KB	20.02...	→ 148 ms			
30	GET	/	w...docu...	html	3.80 KB	20.02...	→ 18 ms			
20	GET	a...	w...docu...	html	3.83 KB	20.02...	→ 37 ms			
20	GET	f...	w...style...	css	cached	28.38...				
20	GET	el...	w...style...	css	cached	58.09...				
20	GET	c...	w...style...	css	cached	3.80 KB				
20	GET	jq...	w...script	js	cached	83.57...				
20	GET	jq...	w...script	js	cached	234.7...				

Headers	Cookies	Params	Response	Timings
Request URL: http://www.xsslabelgg.com/action/login Request method: POST Remote address: 127.0.0.1:80 Status code: 302 Found ? Edit and Resend Raw headers Version: HTTP/1.1 Filter headers Response headers (406 B) Cache-Control: no-store, no-cache, must-revalidate Connection: Keep-Alive Content-Length: 0 Content-Type: text/html; charset=utf-8				

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.

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.

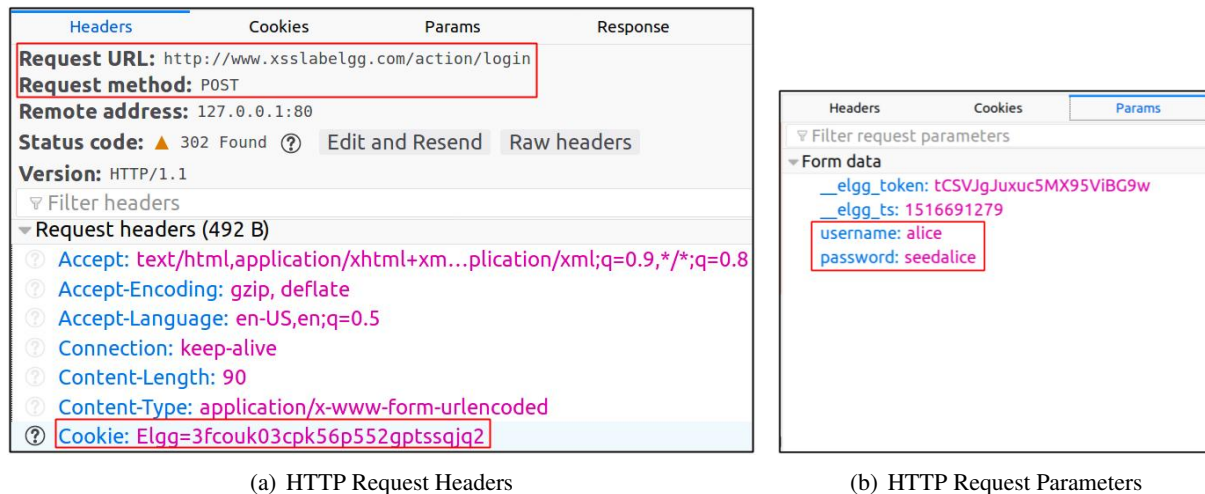


Figure 4: HTTP Headers and Parameters

4.3 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.

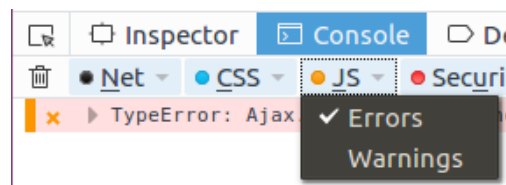


Figure 5: Debugging JavaScript Code (1)

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.

5 Submission

You need to submit a detailed lab report to describe what you have done and what you have observed. Please provide details using Firefox's add-on tools, Wireshark, and/or screenshots. You also need to provide explanation to the observations that are interesting or surprising.

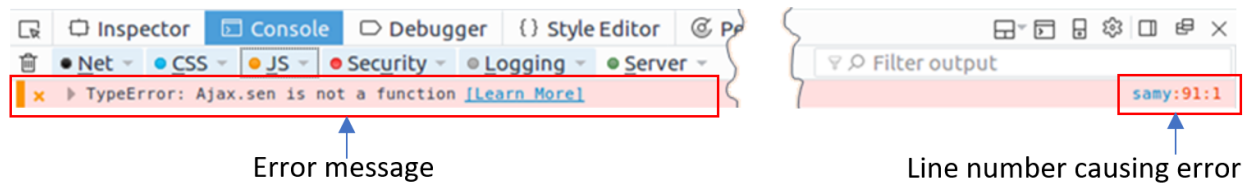


Figure 6: Debugging JavaScript Code (2)