APR 29, 2018 - 9 MINUTE READ - COMMENTS - GO FUZZING

Learning Go-Fuzz 1: iprange

Who am I?

I am Parsia, a security engineer at Electronic Arts.

I write about application security, reverse engineering, Go, cryptography, and (obviously) videogames.

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Collections

Go-Fuzz is like AFL but for Go. If you have a Go package that parses some input, you might be able fuzz it with Go-Fuzz (terms and conditions apply). Not everything can be fuzzed very easily. For example Go-Fuzz does not like cycling imports, so if one of your sub-packages imports the main package then you are in trouble (I am looking at your Chroma).

The rest of the article will show how to use Go-Fuzz to fuzz a Go library named `iprange` at:

- https://github.com/malfunkt/iprange

Code and fuzzing artifacts are at:

- https://github.com/parsiya/Go-Security/tree/master/go-fuzz/iprange

Go-Fuzz Quickstart

I have written a small quick-start guide for myself in my clone at:

- http://parsiya.io/categories/research/go-fuzz-quick-start/

These examples helped me immensely:

- https://medium.com/@dgryski/go-fuzz-github-com-arolek-ase-3c74d5a3150c
- https://mijailovic.net/2017/07/29/go-fuzz/

Thick Client Proxying

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Automation

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CTFs/Writeups

WinAppDbg

AWSome.pw - S3 bucket squatting - my very legit branded vulnerability

- https://blog.cloudflare.com/dns-parser-meet-go-fuzzer/
- https://go-talks.appspot.com/github.com/dvyukov/go-fuzz/slides/fuzzing.slide#1

Setup

The article assumes you have a working Go installation and have `go-fuzz` and `go-fuzz-build` executables in `PATH`. If not, use the quickstart or any other tutorial to do so and return here when you are done.

I am using a Windows 10 64-bit VM.

The Fuzz Function

The `Fuzz` function is the fuzzer's entry point. It's a function with the following signature:

- `func Fuzz(data []byte) int`

It takes a byte slice coming from the fuzzer and returns an integer. This gives us great flexibility in deciding what we want to fuzz. `Fuzz` is part of the target package so we can also fuzz internal (unexported) package functions.

The output of `Fuzz` is our feedback to the fuzzer. If the input was valid (usually in the correct format), it should return `1` and `0` otherwise.

Having roughly correctly formatted input is important. Usually, we are dealing with formatted data. Just randomly sending byte blobs to the program is not going to do much. We want data that can bypass format checks. We pass the blob to either the target package or another

function (e.g. some format converter) and check if it passes the parser check without any errors. If so, `Fuzz` must return `1` to tell `go-fuzz` that our format was good.

For a good example, look at the `PNG` fuzz function from the readme file:

PNG Fuzz

```
func Fuzz(data []byte) int {
    img, err := png.Decode(bytes.NewReader(data))
    if err != nil {
        if img != nil {
            panic("img != nil on error")
        }
        return 0
    }
    var w bytes.Buffer
    err = png.Encode(&w, img)
    if err != nil {
        panic(err)
    }
    return 1
}
```

Fuzzing iprange

We can use the usage section in the iprange readme to become familiar with the package.

Then we need to get the package with `go get github.com/malfunkt/iprange`. This will copy package files to `$GOPATH\src\github.com\malfunkt\iprange`.

Note: I am using commit `3a31f5ed42d2d8a1fc46f1be91fd693bdef2dd52`, if the bug gets fixed we need to `git clone` the directory instead and then do a `hard reset`.

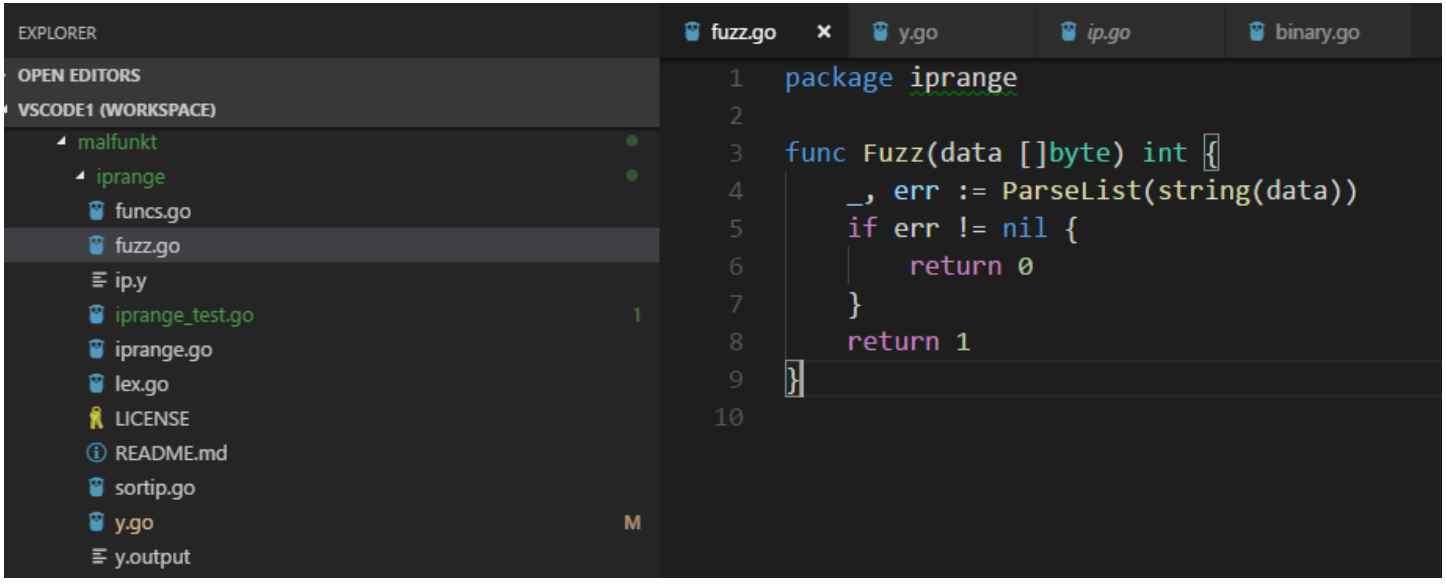
Fuzz Function

Now we create a new file inside the package named `Fuzz.go` and write our fuzz function:

Fuzz.go

```go
package iprange

func Fuzz(data []byte) int {
    _, err := ParseList(string(data))
    if err != nil {
        return 0
    }
    return 1
}
```



We are converting the input from `go-fuzz` to a string and passing it to `ParseList`. If the parser returns an error, then it's not good input and we will return `0`. If it passes the check, we return `1`. Good input will be added to the original corpus.

If `go-fuzz` achieves more code coverage with a specific input, it will be added to corpus even if we return `0`. But we do not need to care about that.

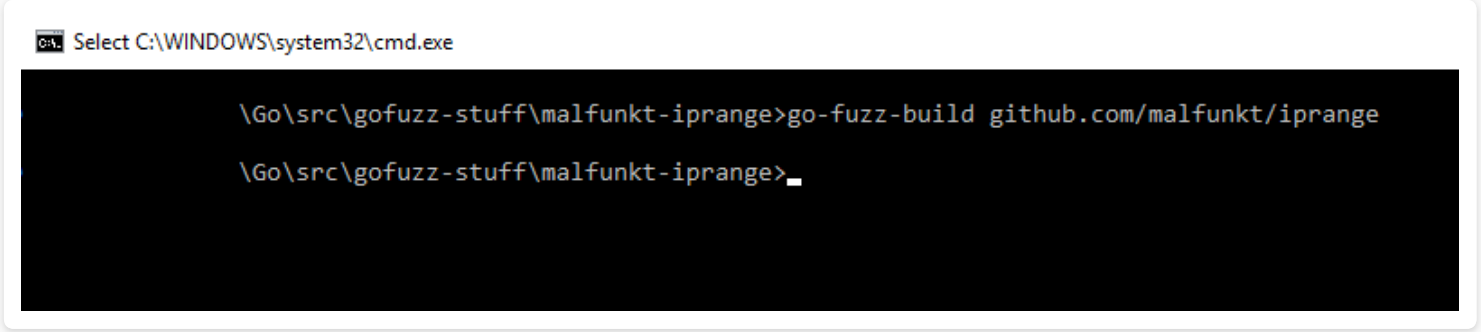
go-fuzz-build

Next step is using `go-fuzz-build` to make the magic blob. Create a directory (I always use my `src` directory`) and run this command inside it:

- `go-fuzz-build github.com/malfunkt/iprange`

Note you need to use forward slashes on Windows too. If `Fuzz` was written correctly we will get a zip file named `iprange-fuzz.zip`.

Note: This step usually takes a while. If the command line is not responsive after a few minutes, press enter a couple of times to check if it has finished. Sometimes the file is created but the command line does not display the results.



Corpus

To have meaningful fuzzing, we need to provide good/correct samples. This is done by creating a directory named `corpus` inside our work directory and providing one sample per file.

Copy the items from [supported formats] section of `iprange` readme. Each file will have one item. File name does not matter. I created three files `test1/2/3`:

```
test1: 10.0.0.1, 10.0.0.5-10, 192.168.1.*, 192.168.10.0/24

test2: 10.0.0.1-10,10.0.0.0/24,
10.0.0.0/24

test3: 10.0.0.*, 192.168.0.*, 192.168.1-256
```

Fuzzing

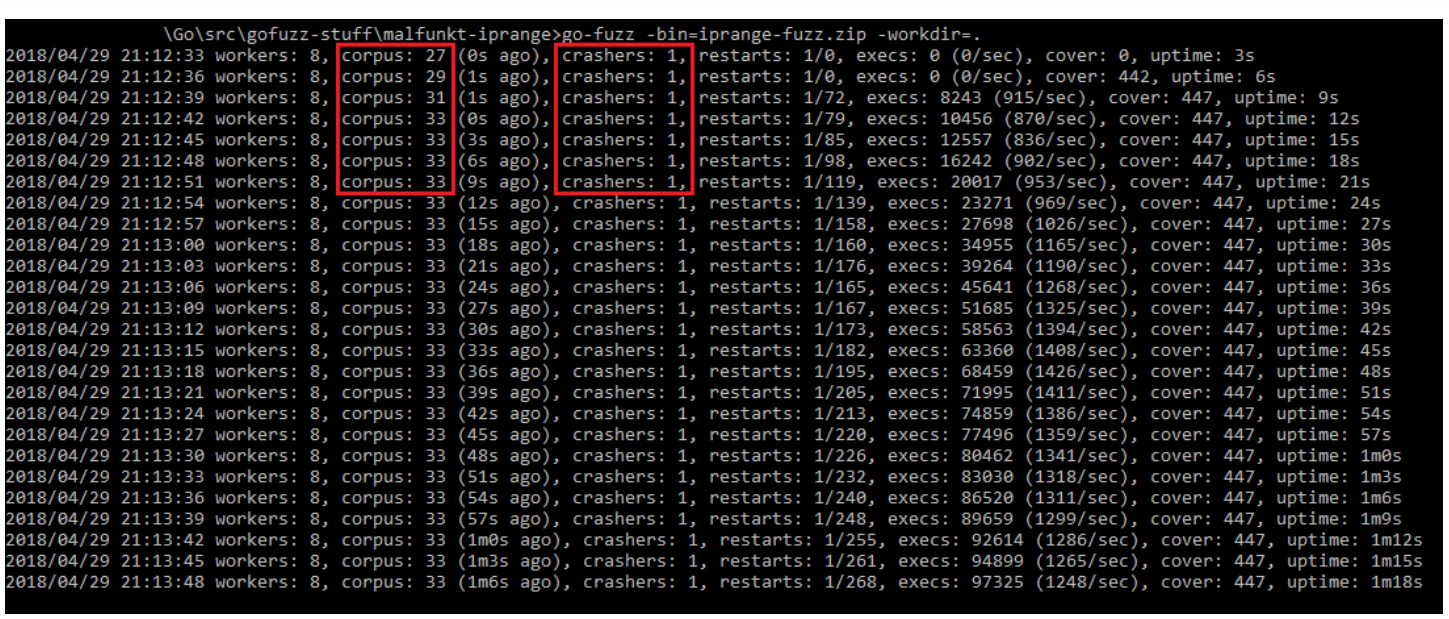
Now we can run `go-fuzz`.

- `go-fuzz -bin=iprange-fuzz.zip -workdir=.`

Note `workdir` should point to the path that contains the `corpus` directory.

Fuzzing Results

We will quickly get a crash and some new files are added to the `corpus`.



Analyzing the Crash

While we are fuzzing, we can analyze the current crash. `go-fuzz` has created two other directories besides `corpus`.

- `suppressions` contains crash logs. This allows `go-fuzz` to skip input that results in the same exact crash. This means you will not 500 crash test cases that all occur at the same place.
- `crashers` has our loot. Each crash has three files and the file name is `SHA-1` hash of input. In this crash we have:
  - `17ee301be06245aa20945bc3ff3c4838abe13b52` contains the input that caused the crash `0.0.0.0/40`.
  - `17ee301be06245aa20945bc3ff3c4838abe13b52.quoted` is the input but quoted as a string.

- `17ee301be06245aa20945bc3ff3c4838abe13b52.output` contains the crash dump.

```
panic: runtime error: index out of range

goroutine 1 [running]:
encoding/binary.binary.bigEndian.Uint32(...)
        /Temp/go-fuzz-build049016974/goroot/src/encoding/binary/binary.go:111
github.com/malfunkt/iprange.(*ipParserImpl).Parse(0xc04209d800, 0x526cc0, 0xc0420
        /Temp/go-fuzz-build049016974/gopath/src/github.com/malfunkt/iprange/y.go:
github.com/malfunkt/iprange.ipParse(0x526cc0, 0xc042083040, 0xa)
        /Temp/go-fuzz-build049016974/gopath/src/github.com/malfunkt/iprange/y.go:
github.com/malfunkt/iprange.ParseList(0xc042075ed0, 0xa, 0xa, 0x200000, 0xc042075
        /Temp/go-fuzz-build049016974/gopath/src/github.com/malfunkt/iprange/y.go:
github.com/malfunkt/iprange.Fuzz(0x3750000, 0xa, 0x200000, 0x3)
        /Temp/go-fuzz-build049016974/gopath/src/github.com/malfunkt/iprange/fuzz.
go-fuzz-dep.Main(0x5196e0)
        /Temp/go-fuzz-build049016974/goroot/src/go-fuzz-dep/main.go:49 +0xb4
main.main()
        /Temp/go-fuzz-build049016974/gopath/src/github.com/malfunkt/iprange/go.fu
exit status 2
```

bigEndian.Uint32

Our first stop is the Go standard library for `encoding/binary.binary.bigEndian.Uint32`. The source code for this method is at:

- https://github.com/golang/go/blob/master/src/encoding/binary/binary.go#L110

binary.BigEndian.Uint32

```
1 func (bigEndian) Uint32(b []byte) uint32 {
2     _ = b[3] // bounds check hint to compiler; see golang.org/issue/14808
```

```
    return uint32(b[3]) | uint32(b[2])<<8 | uint32(b[1])<<16 | uint32(b[0])<<24
}
```

Going to the issue in the comment, we land at https://github.com/golang/go/issues/14808. Looking at the issue we can see what the bounds check is for. It's checking if the input has enough bytes and if not, it will panic before bytes are accessed. So this part of the chain is "working as intended."

This small piece of code results in a panic:

test1.go

```
// Small program to test panic when calling Uint32(nil).
package main

import (
    "encoding/binary"
)

func main() {
    _ = binary.BigEndian.Uint32(nil)
    // _ = binary.BigEndian.Uint32([]byte(nil))
}
```

And the crash is similar to what we have seen:

```
$ go run test1.go
panic: runtime error: index out of range

goroutine 1 [running]:
encoding/binary.binary.bigEndian.Uint32(...)
        C:/Go/src/encoding/binary/binary.go:111
main.main()
```

```
        C:/Users/test-user/Go/src/gofuzz-stuff/malfunkt-iprange/test1.go:9 +0x11
exit status 2
```

Parse

Next item in the chain is at https://github.com/malfunkt/iprange/blob/master/y.go#L309. It's a huge method but we know the method that was called so we can just search for `Uint32`. The culprit is inside case 5.

Original y.go case 5

```
1  case 5:
2      ipDollar = ipS[ippt-3 : ippt+1]
3      //line ip.y:54
4      {
5          mask := net.CIDRMask(int(ipDollar[3].num), 32)
6          min := ipDollar[1].addrRange.Min.Mask(mask)
7          maxInt := binary.BigEndian.Uint32([]byte(min)) + // <----
8              0xffffffff -
9              binary.BigEndian.Uint32([]byte(mask)) // <----
10         maxBytes := make([]byte, 4)
11         binary.BigEndian.PutUint32(maxBytes, maxInt)
12         maxBytes = maxBytes[len(maxBytes)-4:]
13         max := net.IP(maxBytes)
14         ipVAL.addrRange = AddressRange{
15             Min: min.To4(),
16             Max: max.To4(),
17         }
18     }
```

We can see two calls. The first is for `min` and the second is for `mask`. `mask` comes from the output of net.CIDRMask. Looking at the source code, we can see that it returns `nil` if mask is not valid:

net.CIDRMask

```
// CIDRMask returns an IPMask consisting of `ones' 1 bits
// followed by 0s up to a total length of `bits' bits.
// For a mask of this form, CIDRMask is the inverse of IPMask.Size.
func CIDRMask(ones, bits int) IPMask {
    if bits != 8*IPv4len && bits != 8*IPv6len {
        return nil
    }
    if ones < 0 || ones > bits {
        return nil
    }
    // removed
}
```

We can investigate this by modifying the local `iprange` package code and printing `ipDollar[3].num` and `mask`.

Modified y.go case 5

```
case 5:
    ipDollar = ipS[ippt-3 : ippt+1]
    //line ip.y:54
    {
        fmt.Printf("ipdollar[3]: %v\n", ipDollar[3].num) // print ipdollar[3]
        mask := net.CIDRMask(int(ipDollar[3].num), 32)
        fmt.Printf("mask: %v\n", mask)                   // print mask
        min := ipDollar[1].addrRange.Min.Mask(mask)
        fmt.Printf("min: %v\n", min)                     // print min
        maxInt := binary.BigEndian.Uint32([]byte(min)) +
            0xffffffff -
            binary.BigEndian.Uint32([]byte(mask))
        maxBytes := make([]byte, 4)
        binary.BigEndian.PutUint32(maxBytes, maxInt)
```

```
        maxBytes = maxBytes[len(maxBytes)-4:]
        max := net.IP(maxBytes)
        ipVAL.addrRange = AddressRange{
            Min: min.To4(),
            Max: max.To4(),
        }
    }
```

Reproducing the Crash

Reproducing the crash is easy, we already have input and can just plug it into a small program using our `Fuzz` function:

test2.go

```
// Small program to investigate a panic in iprange for invalid masks.
package main

import "github.com/malfunkt/iprange"

func main() {
    _ = Fuzz([]byte("0.0.0.0/40"))
}

func Fuzz(data []byte) int {
    _, err := iprange.ParseList(string(data))
    if err != nil {
        return 0
    }
    return 1
}
```

Note: We could write an easier test but I wanted to keep the `Fuzz` function intact.

```
$ go run test2.go
ipdollar[3]: 40
mask: <nil>
min: <nil>
panic: runtime error: index out of range

goroutine 1 [running]:
encoding/binary.binary.bigEndian.Uint32(...)
        C:/Go/src/encoding/binary/binary.go:111
github.com/malfunkt/iprange.(*ipParserImpl).Parse(0xc04209e000, 0x500920, 0xc04209c050,
        yaccpar:354 +0x202f
github.com/malfunkt/iprange.ipParse(0x500920, 0xc04209c050, 0xa)
        yaccpar:153 +0x5f
github.com/malfunkt/iprange.ParseList(0xc042085ef8, 0xa, 0xa, 0x20, 0xc042085ef8, 0xa,
        ip.y:93 +0xbe
main.Fuzz(0xc042085f58, 0xa, 0x20, 0xc042085f58)
        C:/Users/test-user/Go/src/gofuzz-stuff/malfunkt-iprange/test1.go:10 +0x6c
main.main()
        C:/Users/test-user/Go/src/gofuzz-stuff/malfunkt-iprange/test1.go:6 +0x69
exit status 2
```

We can see `40` is passed to `net.CIDRMask` function and the result is `nil`. That causes the crash. We can see `min` is also `nil`.

Both min and mask are nil and result in a panic.

More Crashes?

I let the fuzzer run for another 20 minutes but it did not find any other crashes. Corpus was up to `60` items like:

- `2.8.0.0/4,0.0.0.5/0,2.8.0.0/4,0.0.0.5/0,2.8.0.0/4,0.0.0.5/0`

- `0.0.0.0/4,0.0.0.5-0,2.8.1.*,2.8.0.0/2`

Solution

Just pointing out bugs is not useful. Being a security engineer is not just finding vulnerabilities.

The quick solution is checking the values of `min` and `mask` before calling `Uint32`.

A better solution is to check the input for validity and good format before processing. For example, for IPv4 masks we can check if they are in in `16-30`.

Conclusion

Well that was it folks! We learned how to use `go-fuzz` and investigated a simple panic. I think this is a good first tutorial.

Posted by Parsia • Apr 29, 2018 • Tags: Go-Fuzz

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Learning Go-Fuzz 2: goexif2