Coralogix

Optimizing string usage in Go programs

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Introduction

- Matej Gera
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- Maintainer @ Thanos

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Three things today

- Understanding Go strings behind the scenes
- String use cases prone to performance bottlenecks
- Optimization strategies

Inspiration behind this talk

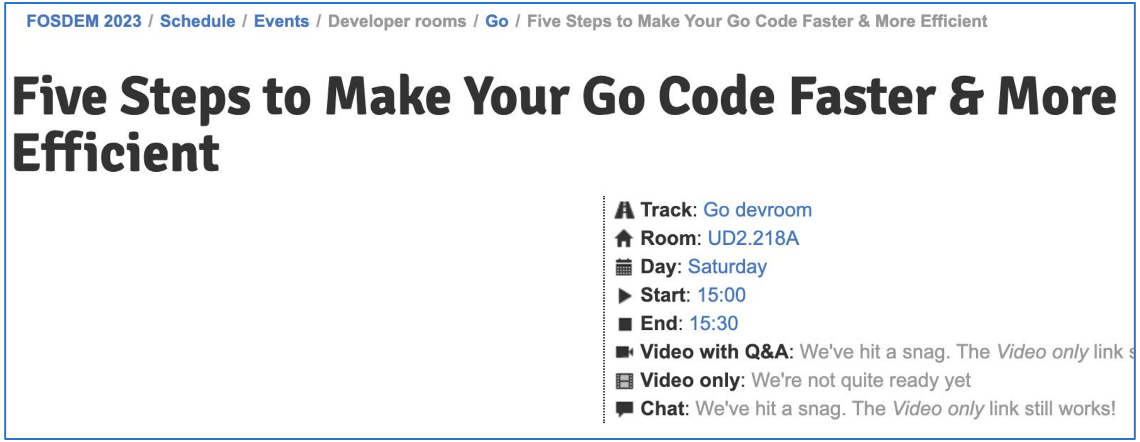
- (Data-driven) performance optimization
  - Working on Thanos project (distributed time-series database)

Thanos

Open source, highly available Prometheus setup with long term storage capabilities.

Inspiration behind this talk

- (Data-driven) performance optimization
  - Don’t miss talk from Bartek Plotka today!



Inspiration behind this talk

- Focus on strings

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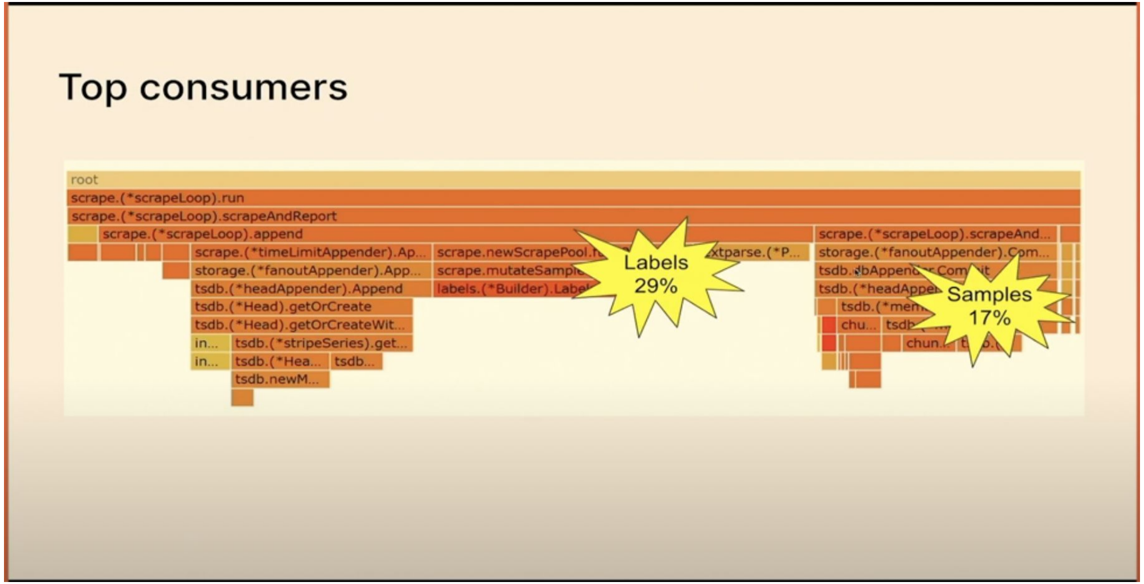


- Source: *[PromCon EU 2022: Why Is It so Big? Analysing the Memory Consumption of Prometheus]()* by Bryan Boreham

Strings behind the scene

- Immutable, can be converted to []byte, concatenable, slicable...
- **But** strings are not “just” strings
- Runtime representation of strings (/src/runtime/string.go):

```
type stringStruct struct
{   str unsafe.Pointer
    len int
}
```

reflect.StringHeader
=>

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

Strings behind the scene

- In actuality, it's slice of bytes
- Size stays the same during lifetime (remember, **immutable)**
- Size of string will correspond to
  - String header overhead **(16 bytes)** + actual string (length of the slice of bytes)

```go
// 'FOSDEM 👋' string size
str := "FOSDEM 👋"
reflect.TypeOf(str).Size() // 16 bytes (8 bytes pointer, 8 bytes len)
len(str)                   // 11 bytes
```

Strings behind the scene

- Copying string will create shallow copy
  - But results in a new string header!

```
str := "FOSDEM 👋"
// `newStr` will reference 'FOSDEM 👋' from `str`
newStr := str

fmt.Printf("%p\n", &str)                                     // 0xc000014240
fmt.Println((*reflect.StringHeader)(unsafe.Pointer(&str)))   //&{4826438 11}

// That's a brand new string header - another 16 bytes!
fmt.Printf("%p\n", &newStr)                                     // 0xc000014250
fmt.Println((*reflect.StringHeader)(unsafe.Pointer(&newStr)))   // &{4826438 11}
```

The problem zone

- In-memory stores
    - Can result in large number of strings being stored (billions)
    - Potential for repetition of strings (e.g. metadata, labels)
        - cluster=us-prod-1
    - Handling of incoming data
        - Often involves unmarshalling into structs
        - Strings from the request might be kept in memory long term
        - Garbage collection?

The problem zone

- One-off data processing
  - Documents that might require decoding (JSON, YAML)
  - Repeated keys

Optimization strategies

- Detaching strings from larger memory pools
    - To make sure we keep around only string
    - Rest of the struct can be garbage collected
    - Can be achieved by “detaching” of the string
    - This can be achieved by using [strings.Clone(s string) string]
        - Since **Go 1.18**

Optimization strategies

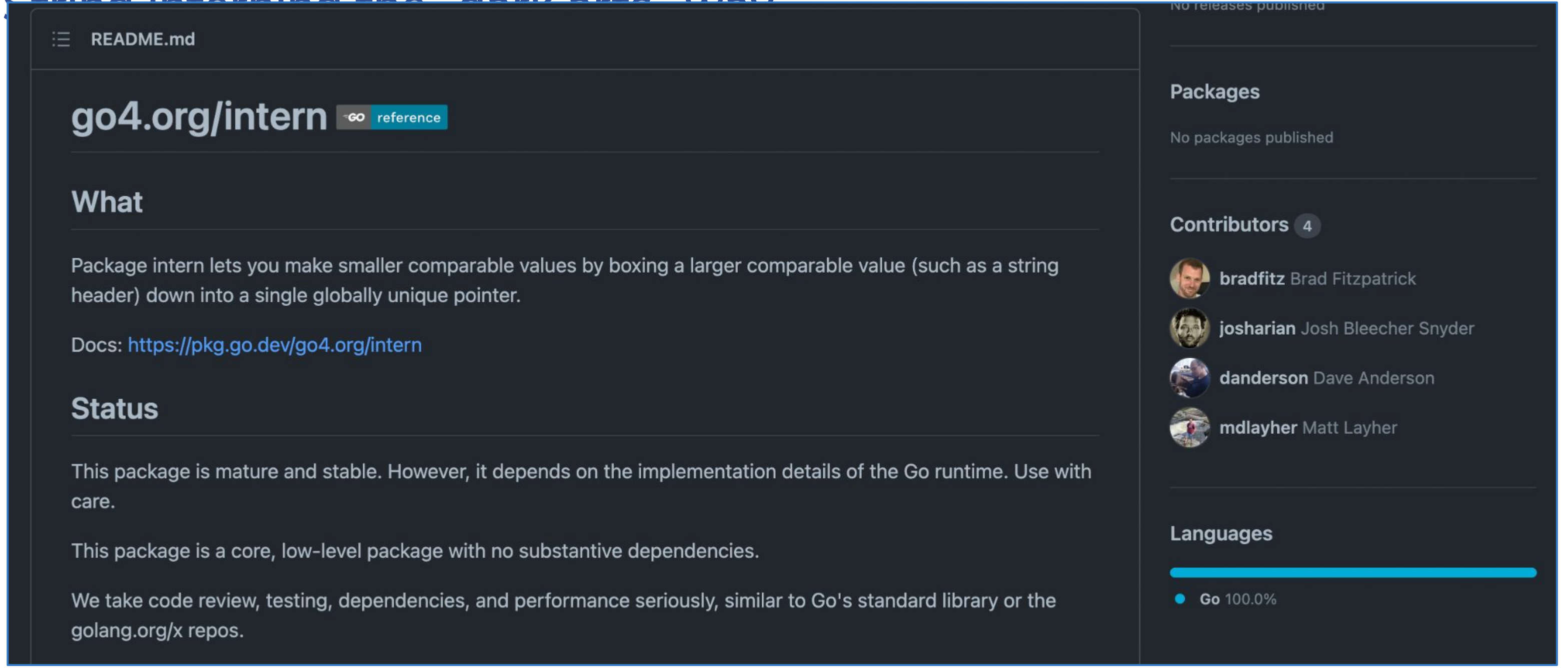
- String interning
    - Technique to store only one single copy of each distinct string value
    - At simplest, can be achieved by storing values in a **map[string]string{}**
    - Each reference carries the string header overhead (16 bytes)
    - How to know when to drop a string from interning map?
        - Won’t be garbage collected as long as map is around (possible DoS vector)
        - Possible solutions:
            - Periodically remove entries (akin to clearing cache)
            - Count references (see example: prometheus/prometheus/pull/5316)

Optimization strategies

- String interning the “dark arts” way
  - What if the unused string references could be dropped “automagically”?
  - Implementation in go4.org/intern
    - Enter the concept of finalizers
  - Boxes the interned values (string header) into a single pointer
    - 16 bytes -> 8 bytes overhead

Optimization strategies

- String interning the “dark arts” way



No releases published

README.md

go4.org/intern GO reference

What

Package intern lets you make smaller comparable values by boxing a larger comparable value (such as a string header) down into a single globally unique pointer.

Docs: https://pkg.go.dev/go4.org/intern

Status

This package is mature and stable. However, it depends on the implementation details of the Go runtime. Use with care.

This package is a core, low-level package with no substantive dependencies.

We take code review, testing, dependencies, and performance seriously, similar to Go's standard library or the golang.org/x repos.

Packages

No packages published

Contributors 4

- **bradfitz** Brad Fitzpatrick
- **josharian** Josh Bleecher Snyder
- **danderson** Dave Anderson
- **mdlayher** Matt Layher

Languages

- **Go** 100.0%

Optimization strategies

- String interning the “dark arts” way
    - What if the unused string references could be dropped “automagically”?
    - Implementation in go4.org/intern
        - Enter the concept of finalizers
    - Boxes the interned values (string header) into a single pointer
        - 16 bytes -> 8 bytes overhead
    - Example of use: thanos-io/thanos/pull/5926

Optimization strategies

Optimization strategies

- String interning with symbol table
    - Structure with key-value pairs to lookup strings
    - E.g. each int will correspond to given unique string
    - Can be beneficial in scenarios with lot of duplicate strings
        - to decrease network costs and number of allocations
    - Example: thanos-io/thanos/pull/5906

Optimization strategies

- String concatenation
    - Combining strings into single bigger backing string
    - Saves the overhead of each string header
    - Requires look up of individual strings within the structure
    - Example: prometheus/prometheus/pull/10991

Conclusion

- Still a balancing act (memory vs CPU)
- More empirical data needed

Thank you for your attention!

More useful resources:

- https://go101.org/article/string.html
- https://stackoverflow.com/questions/65419268/how-to-deep-copy-a-string-in-go/68972665#68972665
- https://mdlayher.com/blog/unsafe-string-interning-in-go/
- https://commaok.xyz/post/intern-strings/
- https://crawshaw.io/blog/tragedy-of-finalizers