Hot path optimizations for latency-critical applications in GO

Hot Path (Definition)

Part of the application that runs significantly frequent

Why should I care?

- Inefficiency in hot-path will have exponential effect
- Efficiency in hot-path is what determines your scalability

Benchmarking

- Don’t trust your intuition
- GO's benchmark does almost everything for you
- Reporting allocations will help you catch the big fishes

Examples

Interfaces vs. Cast (1)

```
type Shape interface {
    Area() float64
}

type Rectangle struct {
    W, H float64
}

func (r Rectangle) Area() float64 {
    return r.W * r.H
}
```

Interfaces vs. Cast (2)

```
func Benchmark_interface(b *testing.B) {
    var shape Shape = Rectangle{4, 2}
    for i := 0; i < b.N; i++ {
        shape.Area()
    }
}
```

```
func Benchmark_cast(b *testing.B) {
    var shape Shape = Rectangle{4, 2}
    for i := 0; i < b.N; i++ {
        if rec, ok := shape.(Rectangle); ok {
            rec.Area()
        }
    }
```

Results

```
Benchmark_interface-8     742840539      1.493 ns/op
Benchmark_cast-8          1000000000     0.2912 ns/op
```

Concurrency: Mutex vs. chan (1)

```go
func runConcurrently(concurrency int, fn func()) {
	wg := sync.WaitGroup{}
	for i := 0; i < concurrency; i++ {
		wg.Add(1)
		go func() {
			fn()
			wg.Done()
		}()
	}
	wg.Wait()
}
```

Concurrency: Mutex vs. chan (2)

```go
func Benchmark_Mutex(b *testing.B) {
	var counter int
	var mu sync.Mutex
	for i := 0; i < b.N; i++ {
		runConcurrently(10000, func() {
			mu.Lock()
			counter += 1
			mu.Unlock()
		})
	}
}
```

```go
func Benchmark_chan(b *testing.B) {
	var counter int
	ch := make(chan int)
	for i := 0; i < b.N; i++ {
		runConcurrently(10000, func() {
			counter <- 1
		})
	}
}
```

Results

```
Benchmark_Mutex-8    396          2956641 ns/op
Benchmark_chan-8     181          6066474 ns/op
```

The charm of GO's `io` Package

The `Reader` interface makes a good base for stream processing

```
type Reader interface {
    Read(p []byte) (n int, err error)
}
```

Well known successors:

```
// bufio.Reader
str = bufio.NewReader(r.Body)
for {
    line, _ := r.ReadBytes('\n')
}
```

```
// json.Decoder
decoder := json.NewDecoder(r.Body)
for {
    var obj MyStruct
    if err := decoder.Decode(&obj); err != nil { return err }
        else { doSomething(obj) }
}
```

You can use your own buffer

- Allocations are expensive operation that occurs when ref moves up in stack
- Allocations have additional cost in GC cycles
- Using external buffer for read allows re-use of memory and save allocations

Example

```
type myBufferedReader struct {
    rd     io.Reader
    buf    []byte
    offset int
}
func (r *myBufferedReader) ReadLine() ([]byte, error) {
    n, _ := r.Read(r.buf[r.offset:])
    eol := bytes.IndexByte('\n')
    res := r.buf[:eol]
    r.buf = r.buf[eol+1:]

    return res
}
```

Experiment: Count word occurrences in a file

Size:	6M
Lines:	1,000
Words:	1,000,000

Using `bufio.Scanner` vs my optimized Line reader

```go
for i := 0; i < b.N; i++ {
    scanner := bufio.NewScanner(f)
    for scanner.Scan() {
        total += strings.Count(scanner.Text(), word)
    }
}
```

```go
for i := 0; i < b.N; i++ {
    var (err error; buf = make([]byte, 4096))
    for ; err == nil; n, err = f.Read(buf) {
        count = bytes.Count(buf[:n], []byte(word))
        total += count
        buf = buf[:]
    }
}
```

Results

```
bufio.Scanner    226    5250797 ns/op    6537876 B/op    1002 allocs/op
own_buffer       301    3972222 ns/op    0 B/op          0 allocs/op
```

Concurrency bottlenecks and resolutions

```go
func add(n int) {
    mu.Lock()
    count += n
    mu.Unlock()
}
```

```go
func add(n int64) {
    // lock free increment 💪
    atomic.AddInt64(&count, n)
}
```

```go
mu.Lock()
defer mu.Unlock()
if _, ok := check(key); ok {
    return
}
do()
set(key)
```

Check-Lock-Check pattern --->

Check-Lock-Check

```
mu.RLock()
_, ok := check(key)
mu.RUnlock()
if ok { return } // early return 💪

mu.Lock()
defer mu.Unlock()
_, ok := check(key)
if ok { return }
do()
set(key)
```

```
res := process(<-ch)
mu.Lock()
update(res)
mu.Unlock()
```

Commit the update in batches --->

Worker sends to aggregated channel

```
agg := make(chan *Res)
for {
    agg <- process(<-ch)
}
```

Worker process results

```
var batch []*Res
for res := range <-agg:
    batch = append(batch, res)
    batchLoop: for {
        select {
        case res := <-agg:
            batch = append(batch, res)
        default:
            break batchLoop
        }
    }
    mu.Lock()
    update(batch) // batch update 💪
    mu.Unlock()
    batch = batch[:]
}
```

The difference between parallelism and concurrency

Concurrency

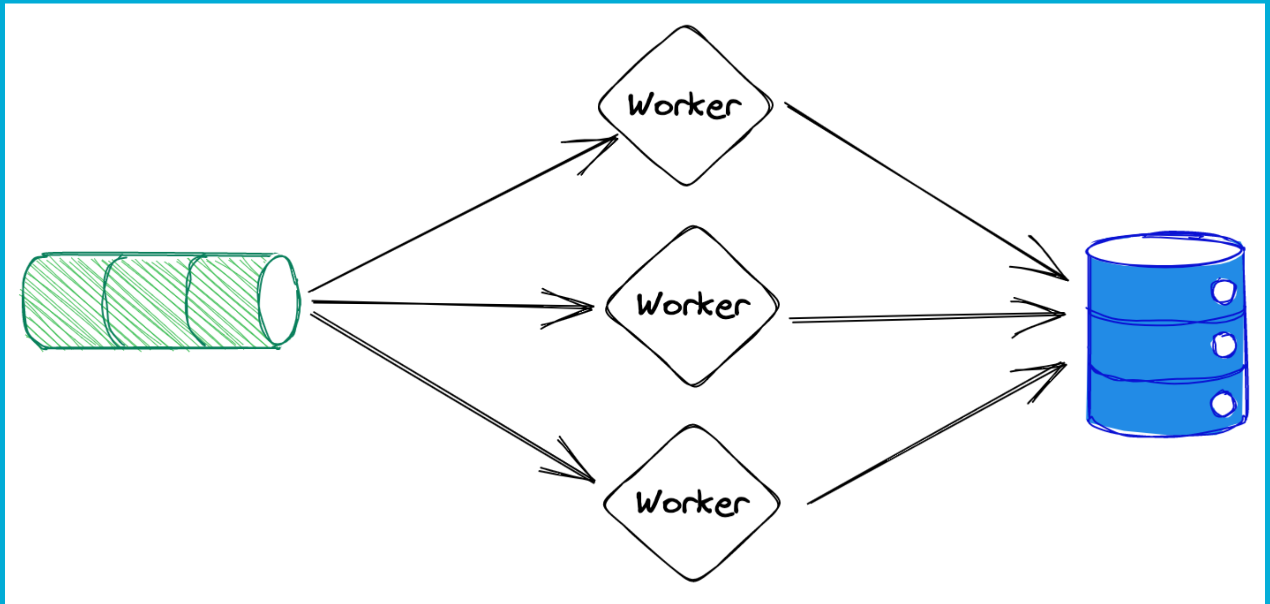
- The ability of a program or part of it to be executed out-of-order or in partial order, without affecting the outcome.

Parallelism

- Execution of simultaneous of (possibly related) computations by a program

Common false designs

- Multiple worker routines that take jobs from a channel is not necessarily parallelism
- Using a global mutex because you need to concurrently update the same object creates unpredictable scalability
- Ignoring CPU count misses the point of parallelism and creates an illusion of efficiency



Practice

Results worker - split by the work

```go
// processing worker
go func() {
    for {
        results <-process(<-jobs)
    }
}()
// results worker
go func() {
    for {
        update(<-results)
    }
}()
```

Sharded locks - split by the data

```
type shard struct {
        mu sync.Mutex
        m  map[string]result
}
func (s *shard) update(r result) {
        s.mu.Lock()
        s.m[r.id] = r
        s.mu.Unlock()
}
for job := range <-jobs {
        res := <-process(job)
        h := hash(res)
        shards[h%4].update(res)
}
```

Execute according to your actual CPUs

```
for i := 0; i < runtime.NumCPU(); i++ {
        go worker()
}
```

Recap

- Sometimes it is worth it to write lower level and avoid GC overhead
- Eliminate concurrency bottlenecks
- Try to parallelize the work for effective concurrency

Q&A

Thank You!