

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. type assertion (1)

```
type Shape interface {  
    Area() float64  
}  
  
type Rectangle struct {  
    W, H float64  
}  
  
func (r Rectangle) Area() float64 {  
    return r.W * r.H  
}
```

Interfaces vs. type assertion (2)

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

```
func Benchmark_type_assertion(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_type_assertion-8	1000000000	0.2912 ns/op

Concurrency: Mutex vs. chan (1)

```
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)

```
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()  
        })  
    }  
}
```

```
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)  
}
```

Pass on a buffer instead of returning it

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

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) }
}
```

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

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

```
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



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



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



```
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

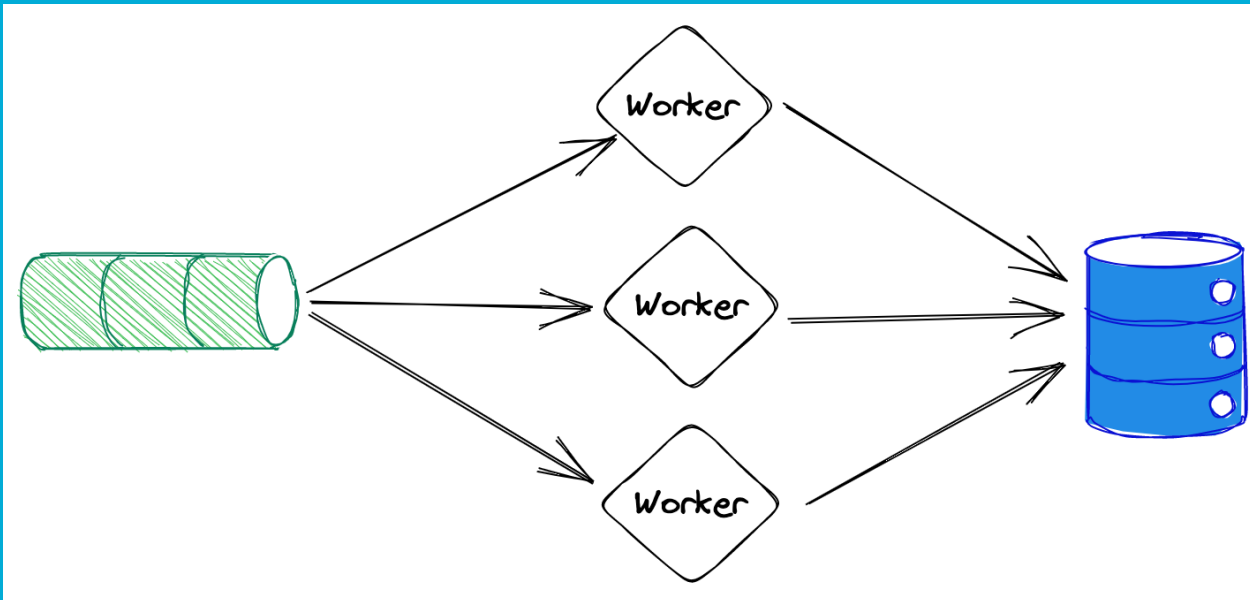
- The ability of a program or part of it to be executed out-of-order or in partial order, without affecting the outcome.

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

```
// 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!

