数据中心实验报告

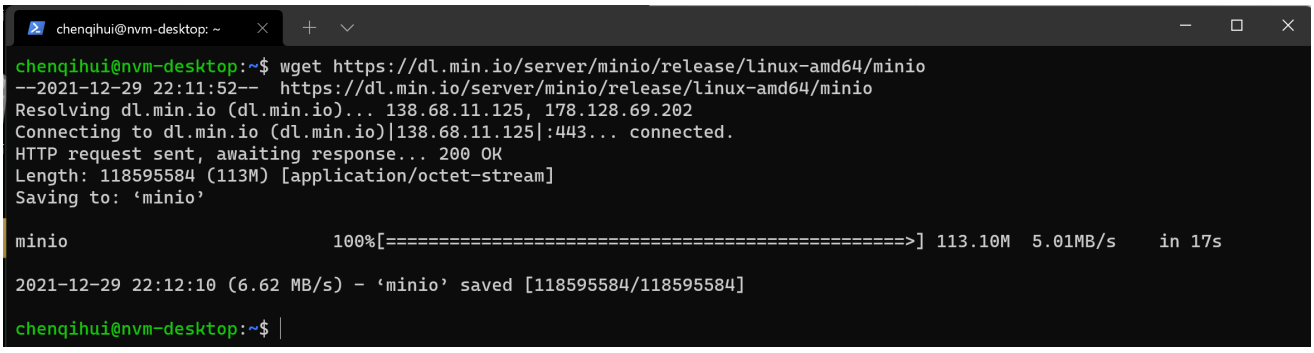
姓名：陈祺汇 学号：M202173480 班级：国光硕2104班

目录

实验一：系统搭建

1. 下载minio服务器：`minio`

```
wget https://dl.min.io/server/minio/release/linux-amd64/minio
```



2. 给minio可执行权限

```
chmod +x minio
```

3. 编写minio运行脚本，并运行

```
#!/bin/bash
export MINIO_ROOT_USER=cqh
export MINIO_ROOT_PASSWORD=hust_cqh

# Export metrics
export MINIO_PROMETHEUS_AUTH_TYPE="public"

# Use "-C" flag to store configuration file in local directory "./".
# Use server command to start object storage server with "./root" as
root directory, in which holds all buckets and objects.
./minio -C ./ server ./root --console-address ":9090"
```

```
chenqihui@nvm-desktop:~$ ./run_minio.sh
API: http://192.168.123.125:9000  http://10.242.133.27:9000  http://172.30.133.27:9000  http://10.147.20.22:9000  http:/
/127.0.0.1:9000
RootUser: cqh
RootPass: hust_cqh

Console: http://192.168.123.125:9090 http://10.242.133.27:9090 http://172.30.133.27:9090 http://10.147.20.22:9090 http:/
/127.0.0.1:9090
RootUser: cqh
RootPass: hust_cqh

Command-line: https://docs.min.io/docs/minio-client-quickstart-guide
   $ mc alias set myminio http://192.168.123.125:9000 cqh hust_cqh

Documentation: https://docs.min.io
```

4. 下载minio客户端：mc，并赋予其可执行权限

```
wget https://dl.min.io/client/mc/release/linux-amd64/mc
chmod +x mc
```

```
chenqihui@nvm-desktop:~$ wget https://dl.min.io/client/mc/release/linux-amd64/mc
--2021-12-29 22:18:44--  https://dl.min.io/client/mc/release/linux-amd64/mc
Resolving dl.min.io (dl.min.io)... 138.68.11.125, 178.128.69.202
Connecting to dl.min.io (dl.min.io)|138.68.11.125|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 21782528 (21M) [application/octet-stream]
Saving to: ‘mc’

mc                          100%[=============================================>]  20.77M  4.75MB/s    in 4.4s

2021-12-29 22:18:49 (4.75 MB/s) - ‘mc’ saved [21782528/21782528]

chenqihui@nvm-desktop:~$ chmod +x mc
chenqihui@nvm-desktop:~$
```

5. 并根据服务器的提示，设置IP、RootUser和RootPass

```
chenqihui@nvm-desktop:~$ ./mc alias set myminio http://192.168.123.125:9000 cqh hust_cqh
Added `myminio` successfully.
chenqihui@nvm-desktop:~$
```

6. 创建一个名为myminio/document的桶，并查看桶

```
# 创建桶
./mc mb myminio/document
# 查看桶
./mc ls myminio
```

```
chenqihui@nvm-desktop:~$ ./mc mb myminio/document
Bucket created successfully `myminio/document`.
chenqihui@nvm-desktop:~$ ./mc ls myminio/
[2021-12-29 22:34:46 CST]     0B document/
chenqihui@nvm-desktop:~$
```

7. 实现 ①拷贝`1.txt`到桶中；② 移动`2.txt`到桶中；③ 删除桶

```
chenqihui@nvm-desktop:~$ ./mc cp 1.txt myminio/document
1.txt:                 11 B / 11 B ┃▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓┃ 1.48 KiB/s 0s
chenqihui@nvm-desktop:~$ ./mc mv 2.txt myminio/document
2.txt:                 15 B / 15 B ┃▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓┃ 1.71 KiB/s 0s
chenqihui@nvm-desktop:~$ ./mc ls myminio/document
[2021-12-29 22:46:29 CST]    11B 1.txt
[2021-12-29 22:46:37 CST]    15B 2.txt
chenqihui@nvm-desktop:~$
```

```
chenqihui@nvm-desktop:~$ ./mc rm -r --force myminio/document
chenqihui@nvm-desktop:~$ ./mc ls myminio/document
chenqihui@nvm-desktop:~$
```

8. 安装`S3cmd`

```
sudo apt install s3cmd
```

9. 配置`S3cmd`使其运行在`minio`上。主要是编辑`~/.s3cfg`文件如下：

```
# Setup endpoint
access_key = cqh
secret_key = hust_cqh
host_base = http://192.168.123.125:9000
host_bucket = http://192.168.125.125/myminio
use_https = False
```

```
chenqihui@nvm-desktop:~$ vim .s3cfg
chenqihui@nvm-desktop:~$ s3cmd ls
2021-12-29 14:34  s3://document
2021-12-30 15:26  s3://s3bench-test-cqh
```

10. 配置`aws`

执行如下指令安装`awscli`

```
sudo apt install awscli
```

然后完成aws的配置，并查看当前的bucket

```
# 直接在bash里输入
aws configure
AWS Access Key ID [None]: cqh
AWS Secret Access Key [None]: hust_cqh
Default region name [None]: us-east-1
Default output format [None]: ENTER
```

```
chenqihui@nvm-desktop:~$ aws --endpoint-url http://192.168.123.125:9000 s3 ls
2021-12-29 22:34:46 document
2022-01-01 21:08:14 loadgen
2021-12-30 23:26:44 s3bench-test-cqh
chenqihui@nvm-desktop:~$
```

实验二：性能观测

Option 1: S3 Bench

s3- bench的使用方法可参考官方文档。

1. 下载安装S3Bench

```
go get -u github.com/igneous-systems/s3bench
```

> 这个过程中遇到了一个问题：由于网络原因*go get*无法访问*GitHub*，从而无法完成下载。其解决方案在问题1中进行了说明。

```
chenqihui@nvm-desktop:~$ go get -u github.com/igneous-systems/s3bench
go: finding github.com/igneous-systems/s3bench latest
go: finding github.com/jmespath/go-jmespath v1.5.1
chenqihui@nvm-desktop:~$
```

2. 编写脚本进行测试

```
#!/bin/sh
# locate s3bench

s3bench=~/go/bin/s3bench

if [ -n "$GOPATH" ]; then
    s3bench=$GOPATH/bin/s3bench
fi

$s3bench \
        -endpoint=http://192.168.123.125:9000 \
        -accessKey=cqh -accessSecret=hust_cqh \
        -bucket=loadgen -objectNamePrefix=loadgen \
        -objectSize=1024 -numClients=2 -numSamples=10240
```

```
chenqihui@nvm-desktop:~$ vim run_s3bench.sh
chenqihui@nvm-desktop:~$ ./run_s3bench.sh
Test parameters
endpoint(s):      [http://192.168.123.125:9000]
bucket:           loadgen
objectNamePrefix: loadgen
objectSize:       0.0010 MB
numClients:       2
numSamples:       10240
verbose:       %!d(bool=false)


Generating in-memory sample data... Done (28.83µs)

Running Write test...
```

输出格式如下：

```
Results Summary for Write Operation(s)
Total Transferred: 10.000 MB
Total Throughput:  0.93 MB/s
Total Duration:    10.716 s
Number of Errors:  0
-----------------------------------
Write times Max:       0.008 s
Write times 99th %ile: 0.003 s
Write times 90th %ile: 0.002 s
Write times 75th %ile: 0.002 s
Write times 50th %ile: 0.002 s
Write times 25th %ile: 0.002 s
Write times Min:       0.002 s


Results Summary for Read Operation(s)
Total Transferred: 10.000 MB
Total Throughput:  2.18 MB/s
Total Duration:    4.595 s
Number of Errors:  0
-----------------------------------
Read times Max:       0.004 s
Read times 99th %ile: 0.002 s
Read times 90th %ile: 0.001 s
Read times 75th %ile: 0.001 s
Read times 50th %ile: 0.001 s
Read times 25th %ile: 0.001 s
Read times Min:       0.001 s
```

可以看到S3 Bench对读/写的整体性能以及百分比尾延迟都有较为详尽的展示。

Option 2：s3-benchmark

原始版本未更新依赖，且兼容性不足，我还尝试了选项**2**，也就是修补后的版本[s3-benchmark](s3-benchmark)。

1. 安装golang-go

```
sudo apt install golang-go
```

2. 安装S3 Benchmark（选项2）

```
# 将镜像地址换为阿里云，以解决GitHub无法访问的问题
go env -w GO111MODULE=on
go env -w GOPROXY=https://mirrors.aliyun.com/goproxy/,direct

go get -u github.com/chinglinwen/s3-benchmark
```

```
chenqihui@nvm-desktop:~$ go get -u github.com/chinglinwen/s3-benchmark
go: finding github.com/chinglinwen/s3-benchmark latest
go: finding code.cloudfoundry.org/bytefmt latest
go: finding github.com/jmespath/go-jmespath v1.5.1
go: finding github.com/jmespath/go-jmespath v0.4.0
chenqihui@nvm-desktop:~$
```

安装完成后，可执行文件会在~/go/bin目录下。

```
chenqihui@nvm-desktop:~/go/bin$ ls
s3-benchmark
```

3. 编写脚本文件进行测试

```
#!/bin/sh

# Locate s3bench

s3bench=~/go/bin/s3-benchmark

if [ -n "$GOPATH" ]; then
    s3bench=$GOPATH/bin/s3-benchmark
fi

# Usage of myflag:
#   -a string
#         Access key
#   -b string
#         Bucket for testing (default "loadgen")
#   -d int
#         Duration of each test in seconds (default 60)
#   -l int
#         Number of times to repeat test (default 1)
#   -r string
#         Region for testing (default "us-east-1")
#   -s string
#         Secret key
#   -t int
#         Number of threads to run (default 1)
#   -u string
#         URL for host with method prefix
#   -z string
```

```
#         Size of objects in bytes with postfix K, M, and G (default
"1M")

$s3bench \
        -a cqh \
        -s hust_cqh \
        -u http://192.168.123.125:9000 \
        -b s3bench-test-cqh \
        -d 60 \
        -t 2 \
        -z 1K
```

```
chenqihui@nvm-desktop:~$ ./run_s3bench.sh
Wasabi benchmark program v2.0
Parameters: url=http://192.168.123.125:9000, bucket=s3bench-test-cqh, region=us-east-1, duration=60, thr
eads=2, loops=1, size=1K
Loop 1: PUT time 60.0 secs, objects = 56581, speed = 943KB/sec, 943.0 operations/sec. Slowdowns = 0
Loop 1: GET time 45.0 secs, objects = 113162, speed = 2.5MB/sec, 2514.8 operations/sec. Slowdowns = 0
Loop 1: DELETE time 20.5 secs, 2764.5 deletes/sec. Slowdowns = 0
result title: name-concurrency-size, uloadspeed, downloadspeed
result csv: 192-2-1K,0.92,2.46
chenqihui@nvm-desktop:~$
```

上述测试的输入含义是：

- 创建并测试桶`s3bench-test-cqh`
- 测试时间为`60`秒
- `2`个线程
- 对象的大小是`1K`

上述测试的输出的含义是：

- `PUT`测试了60秒，56581个对象，速度为943KB/秒，943个操作/秒（因为object的大小设置为1KB，所以这两个值是一样的），slowdown为0；
- `GET`测试了45秒，113162个对象，速度为2.5MB/秒，2514.8个操作/秒，slowdowns为0；
- `DELETE`测试了20.5秒，平均每秒删除2764.5个对象，slowdown为0。

然而`s3-benchmark`输出了整体的速度，没有尾延迟等更细节的性能展示。

问题探究 1：对象尺寸如何影响性能

使用S3Bench分别改变了对象的size为1024、2048、4096、8192，分析其运行结果，指令分别如下。

```
./go/bin/s3bench -endpoint=http://192.168.123.125:9000 -accessKey=cqh -
accessSecret=hust_cqh -bucket=loadgen -objectNamePrefix=loadgen -
objectSize=1024 -numClients=2 -numSamples=102400 >
output/s3bench_size1024.txt

./go/bin/s3bench -endpoint=http://192.168.123.125:9000 -accessKey=cqh -
accessSecret=hust_cqh -bucket=loadgen -objectNamePrefix=loadgen -
objectSize=2048 -numClients=2 -numSamples=102400 >
output/s3bench_size2048.txt

./go/bin/s3bench -endpoint=http://192.168.123.125:9000 -accessKey=cqh -
accessSecret=hust_cqh -bucket=loadgen -objectNamePrefix=loadgen -
objectSize=4096 -numClients=2 -numSamples=102400 >
output/s3bench_size4096.txt

./go/bin/s3bench -endpoint=http://192.168.123.125:9000 -accessKey=cqh -
accessSecret=hust_cqh -bucket=loadgen -objectNamePrefix=loadgen -
objectSize=8192 -numClients=2 -numSamples=102400 >
output/s3bench_size8192.txt
```

测试结果如下：

- 写性能

Size	Throughput	Max Time	Time-99th %ile
1024	0.83 MB/s	0.123 s	0.006 s
2048	1.52 MB/s	0.275 s	0.009 s
4086	3.04 MB/s	0.460 s	0.008 s
8192	5.95 MB/s	0.239 s	0.009 s

- 读性能

Size	Throughput	Max Time	Time-99th %ile
1024	2.16 MB/s	0.017 s	0.002 s
2048	4.30 MB/s	0.087 s	0.002 s
4086	8.97 MB/s	0.086 s	0.002 s
8192	17.64 MB/s	0.105 s	0.002 s

通过分析读性能和写性能我们可以得到如下结论：

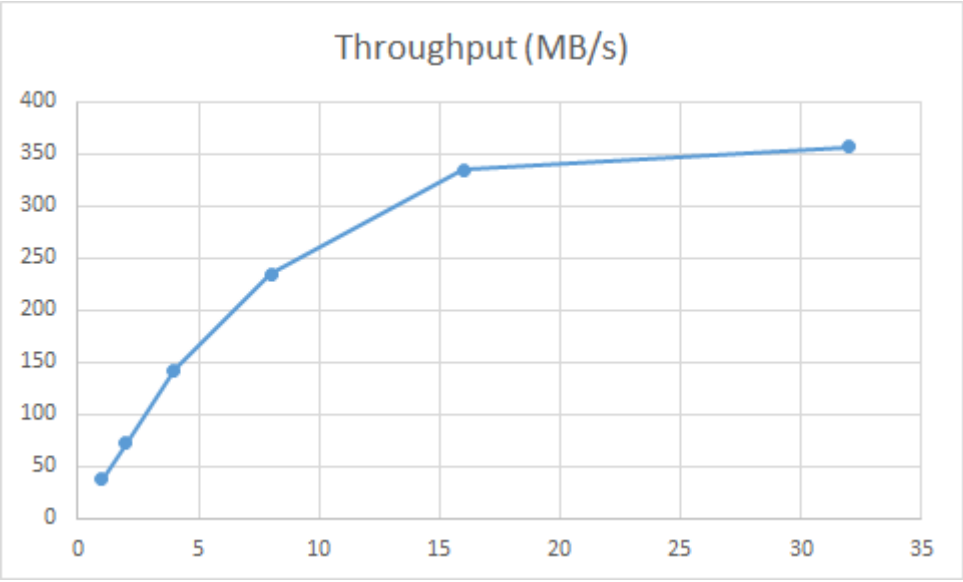
1. 在我们的测试样例下读写带宽和对象的大小是正比关系，也就是说单位时间内输入/输出的对象数目是一定的；
2. 对于写请求，对象大小为4096时的最大执行时间反而高于对象大小是8192时的最大执行时间，这个与直觉不相符；
3. 读请求的99% QoS十分稳定，在[1024, 8192]范围内，随着对象大小的增加，最大执行时间比较稳定。

问题探究 2：并发数如何影响写性能

设置对象大小为$128 \times 1024B$ 也就是128KB，分别设置并发数为1，2，4，8，16，32，分析系统性能。

- 写性能

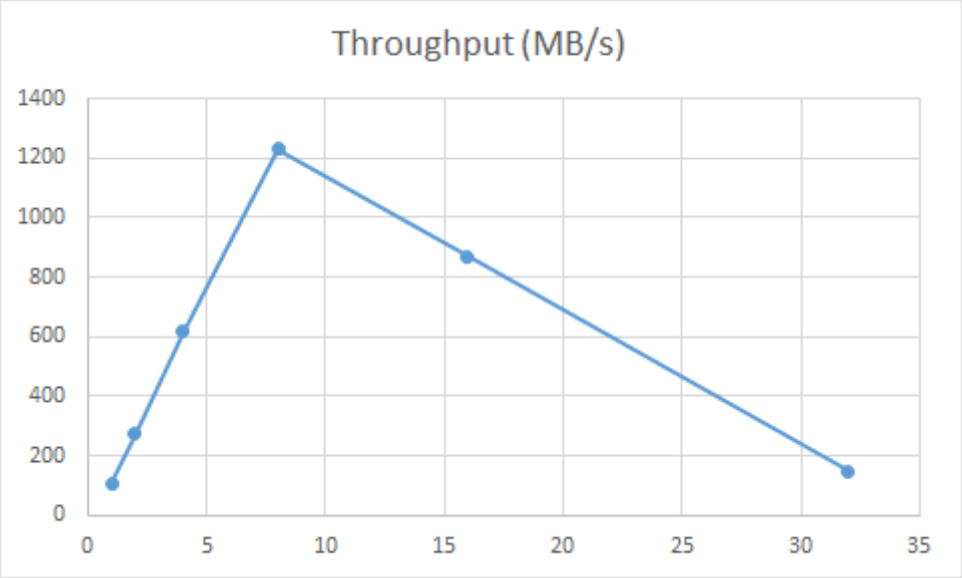
numClients	Throughput	Max Time	Time-99th %ile
1	37.62 MB/s	0.091 s	0.004 s
2	71.65 MB/s	0.338 s	0.009 s
4	141.53 MB/s	0.104 s	0.010 s
8	234.31 MB/s	0.131 s	0.019 s
16	334.10 MB/s	0.128 s	0.060 s
32	356.43 MB/s	0.140 s	0.026 s

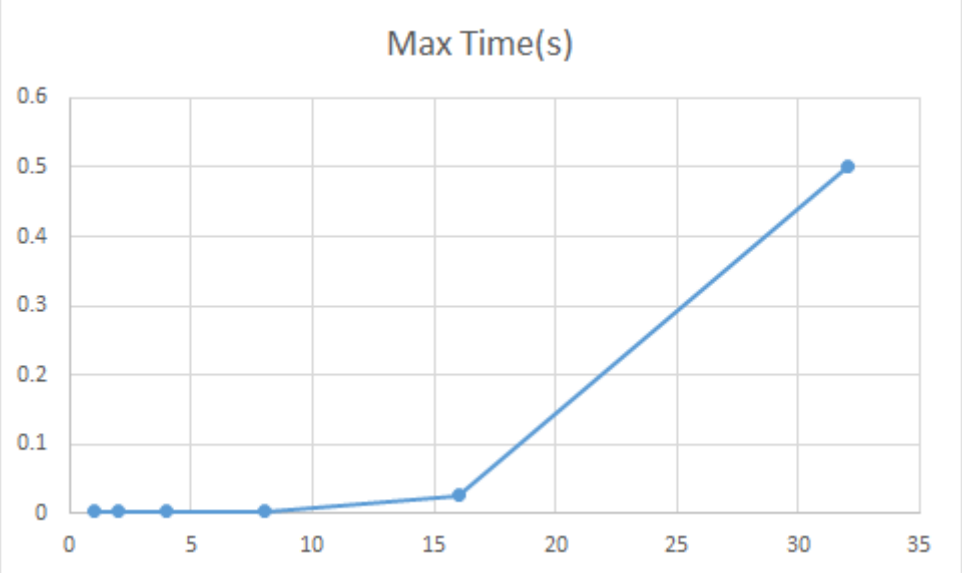


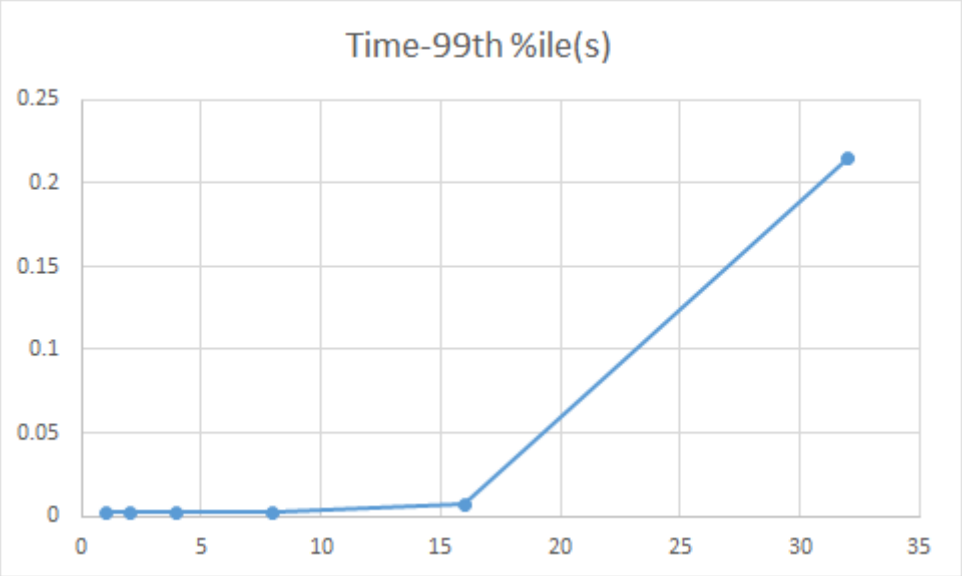
- 读性能

numClients	Throughput	Max Time	Time-99th %ile
1	109.05 MB/s	0.004 s	0.002 s

numClients	Throughput	Max Time	Time-99th %ile
2	272.44 MB/s	0.003 s	0.002 s
4	618.85 MB/s	0.004 s	0.002 s
8	1231.07 MB/s	0.004 s	0.002 s
16	870.08 MB/s	0.027 s	0.007 s
32	149.79 MB/s	0.500 s	0.215 s







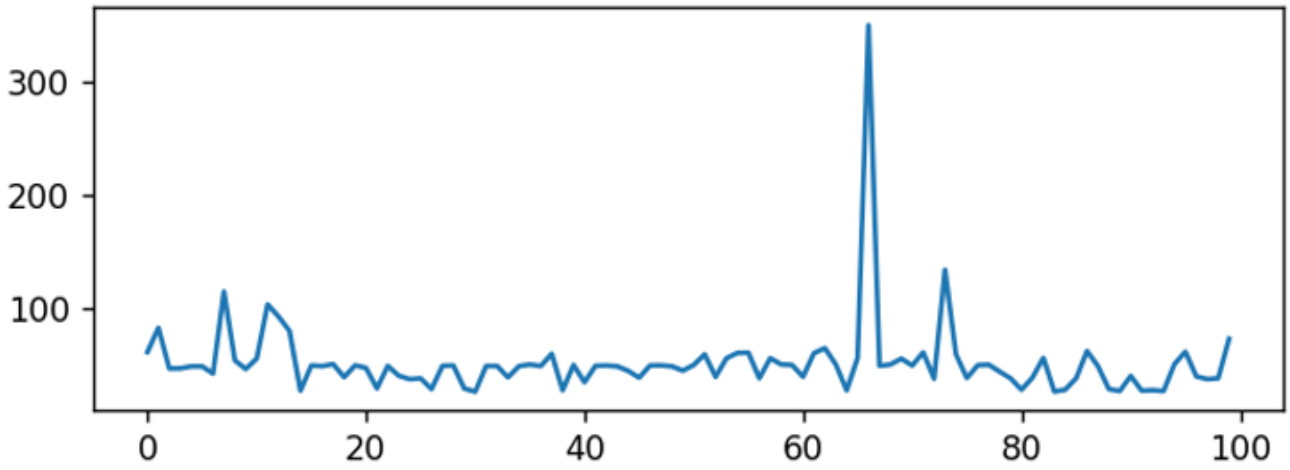
可以得到如下结论：

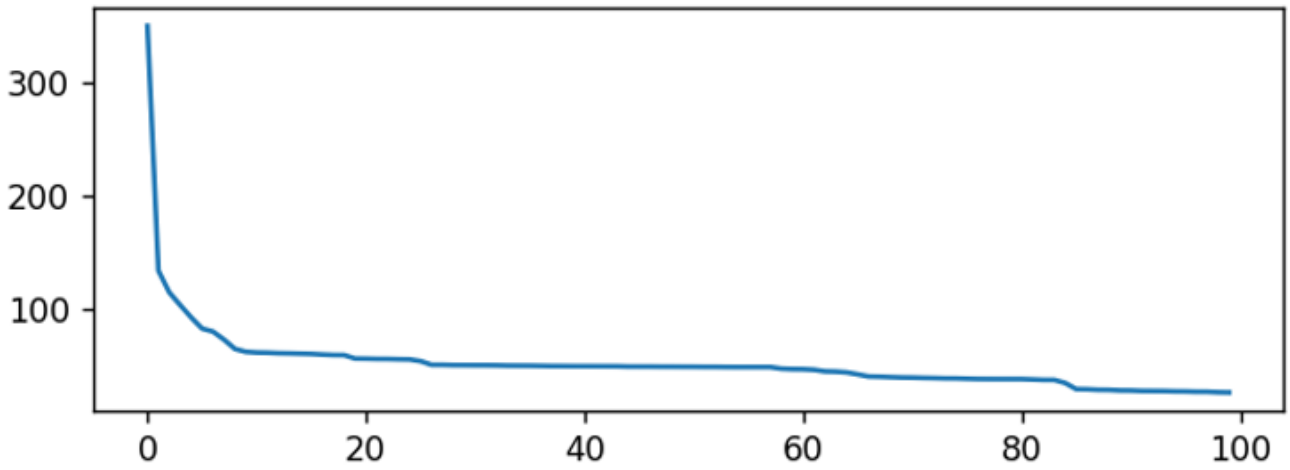
- 对与写操作，增加线程数可以增加总体吞吐，但是随着线程数的增加，吞吐量趋于稳定。
- 对于读操作，增加线程数：
    - 吞吐量先增加后减小
    - 尾延迟显著提升

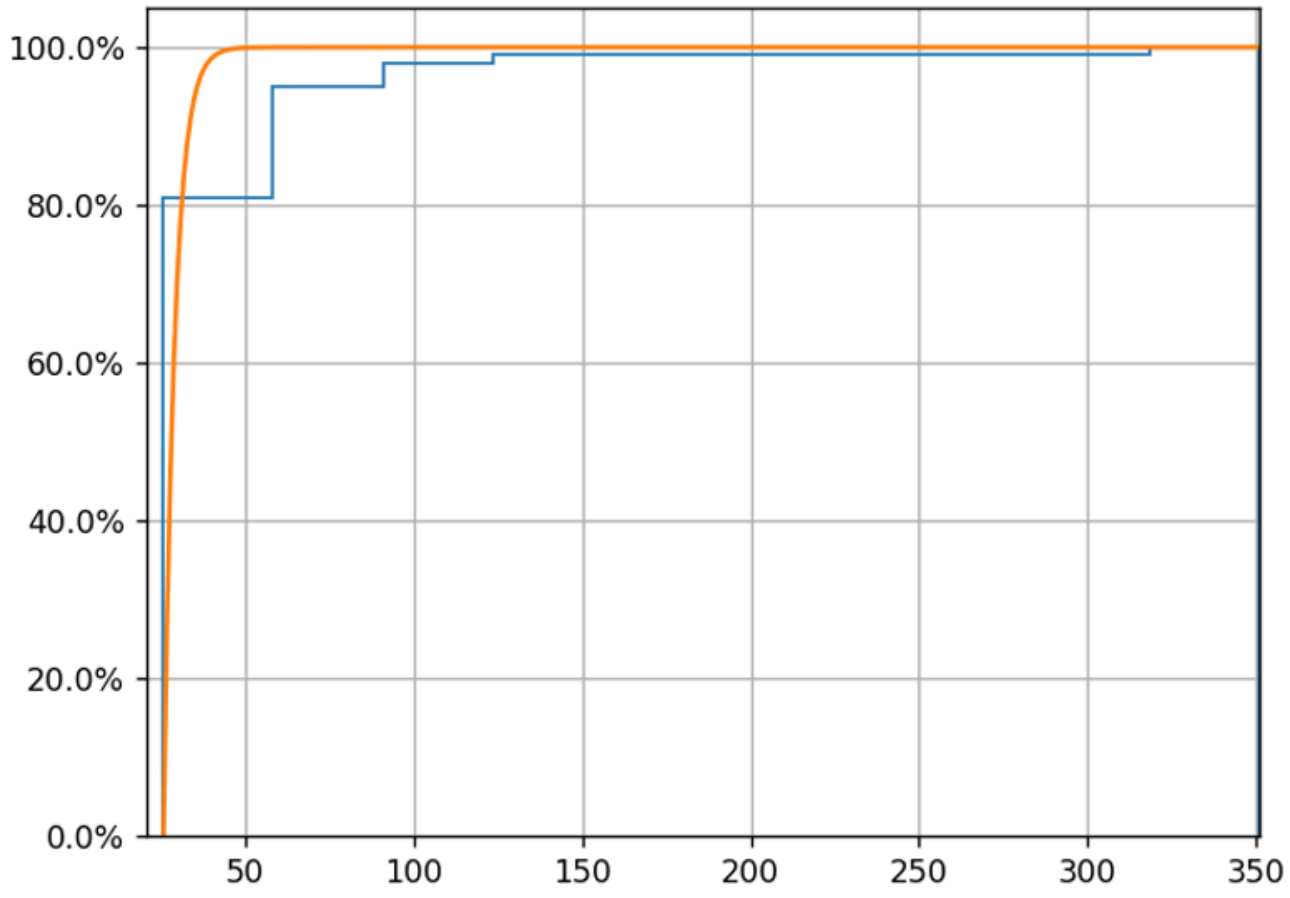
实验三：尾延迟挑战

观测尾延迟

运行`obs-tutorial`的脚本，观察尾延迟。





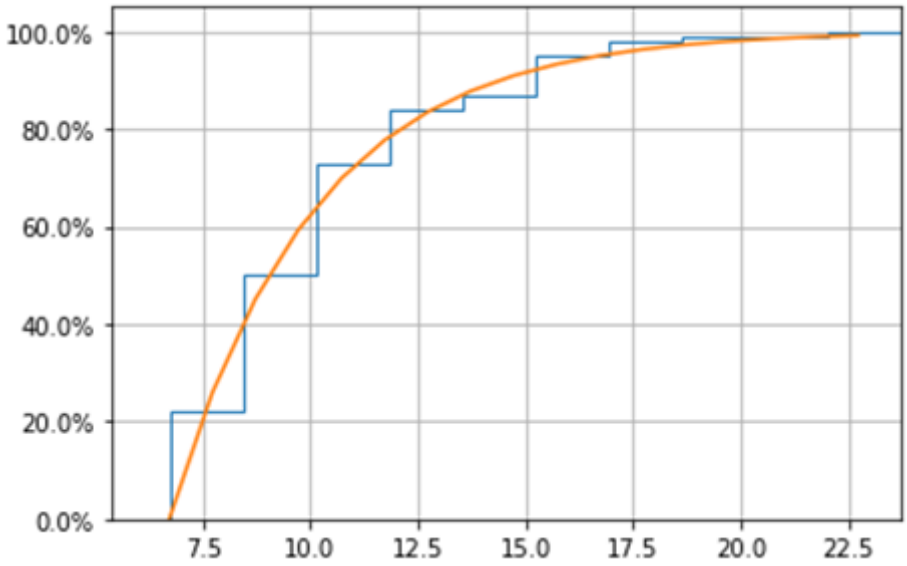


从图中可以看出，存在个别请求，其延迟远大于平均延迟，这就是尾延迟现象。接下来尝试使用不同的方法来消除尾延迟。

对冲请求

简单来说，对冲策略就是：一次请求会给对端发出多个相同请求，只要有一个成功就认为成功。延迟发送次要请求，直到第一个请求的未完成时间超过此类请求的95%预期延迟。这种方法将附加负载限制在5%左右，同时大大缩短了尾部延迟。

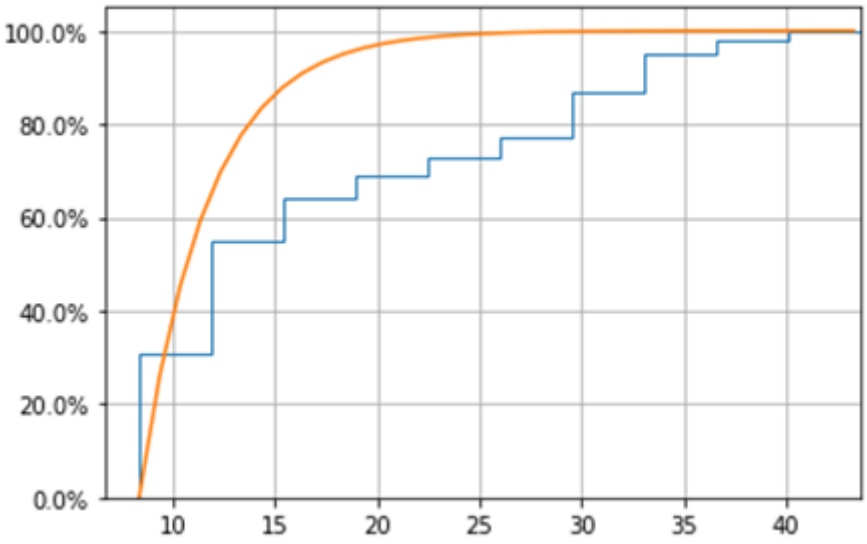
在应用对冲策略之后得到的延迟曲线如下。



可以看到尾延迟得到了极大降低（横坐标从原本的300多降低到了现在的20多）。

关联请求

关联请求，或者叫绑定请求，不是在发送对冲请求之前延迟，而是在多个服务器上模拟排队请求，但将它们绑定在一起，但告诉每个服务器还有哪些服务器在其队列中。当第一个服务器处理请求时，它告诉其他服务器从其队列中取消该请求。



可以看到，关联请求也极大降低了尾延迟。相比于对冲请求，关联请求的效果稍微差一点，但是其开销很小。

实验中遇到的问题及解决方案

问题1. go get无法访问GitHub

```
chenqihui@nvm-desktop:~$ go get -u github.com/igneous-systems/s3bench
go: finding github.com/igneous-systems/s3bench latest
build github.com/igneous-systems/s3bench: cannot load github.com/aws/aws-sdk-go/aws: git ls-remote -q https://github.com
/aws/aws-sdk-go in /home/chenqihui/go/pkg/mod/cache/vcs/b3c0b920408a036a00409211751cef8a0f1a5493ca7145bea33987ab25941e1c
: exit status 128:
        fatal: unable to access 'https://github.com/aws/aws-sdk-go/': GnuTLS recv error (-110): The TLS connection was n
on-properly terminated.
```

解决方案 **1**：执行如下指令，将镜像地址换为阿里云，然后再执行上述指令进行下载。

```
# 将镜像地址换为阿里云，以解决GitHub无法访问的问题
go env -w GO111MODULE=on
go env -w GOPROXY=https://mirrors.aliyun.com/goproxy/,direct
```

然而在实践过程中发现，这个操作虽然有所帮助（可以多向前推进几步），但是过程中一些依赖包依然无法下载。因次尝试了解决方案2。

解决方案 **2**：

1. 安装gopm

   ```
   go get -u github.com/gpmgo/gopm
   ```

2. 使用gopm安装包（用*gopm get -g*代替*go get*）

   ```
   gopm get -g github.com/igneous-systems/s3bench
   ```

问题2：S3 Bench运行失败

现象：

```
chenqihui@nvm-desktop:~$ ./run_s3bench.sh
Test parameters
endpoint(s):      [http://192.168.123.125:9000]
bucket:           loadgen
objectNamePrefix: loadgen
objectSize:       0.0010 MB
numClients:       2
numSamples:       256
verbose:       %!d(bool=false)


Generating in-memory sample data... Done (44.824µs)

Running Write test...

Running Read test...

Test parameters
endpoint(s):      [http://192.168.123.125:9000]
bucket:           loadgen
objectNamePrefix: loadgen
objectSize:       0.0010 MB
numClients:       2
numSamples:       256
verbose:       %!d(bool=false)


Results Summary for Write Operation(s)
Total Transferred: 0.000 MB
Total Throughput:  0.00 MB/s
Total Duration:    0.108 s
Number of Errors:  256
```

打开s3bench的verbose选项，看到写操作存在如下错误：

```
Write operation completed in 0.00s (255/256) - 0.00MB/s, error: NoSuchBucket: The specified bucket does not exist
        status code: 404, request id: 16C62568901276EF, host id:
Write operation completed in 0.00s (256/256) - 0.00MB/s, error: NoSuchBucket: The specified bucket does not exist
        status code: 404, request id: 16C62568901FF5D7, host id:

Running Read test...
Read operation completed in 0.00s (1/256) - 0.00MB/s, error: expected object length 1024, actual 0
Read operation completed in 0.00s (2/256) - 0.00MB/s, error: expected object length 1024, actual 0
```

重新配置了aws，s3cmd和aws-cli后问题得到了解决。