REPORT

Advanced Operating Systems –CS6378

Project 3

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This document includes the experimental results and statistical analysis.

HOLD_TIME= 0.1

Client1
# of successful read:84
# of unsuccessful read:7
# of successful write:9
# of unsuccessful write:5
Time to get read grant (summary statistics in ms):min=1, max=69, avg=42.916
Time to get write grant (summary statistics in ms):min=41, max=45, avg=41.777
Number of messages sent:412
Number of messages received:524
Number of messages exchanged (total):936
Client2
# of successful read:80
# of unsuccessful read:11
# of successful write:9
# of unsuccessful write:0
Time to get read grant (summary statistics in ms):min=1, max=81, avg=44.1625
Time to get write grant (summary statistics in ms):min=40, max=48, avg=44.0
Number of messages sent:342
Number of messages received:406
Number of messages exchanged (total):748
Client3
# of successful read:78
# of unsuccessful read:9
# of successful write:11
# of unsuccessful write:0
Time to get read grant (summary statistics in ms):min=40, max=80, avg=44.820
Time to get write grant (summary statistics in ms):min=42, max=72, avg=46.272
Number of messages sent:373
Number of messages received:458
Number of messages exchanged (total):831
Client4
# of successful read:92
# of unsuccessful read:12
# of successful write:5
# of unsuccessful write:1
Time to get read grant (summary statistics in ms):min=0, max=63, avg=42.804
Time to get write grant (summary statistics in ms):min=40, max=41, avg=40.6
Number of messages sent:307
Number of messages received:350
Number of messages exchanged (total):657
Client5
# of successful read:87
# of unsuccessful read:6
# of successful write:10
# of unsuccessful write:0
Time to get read grant (summary statistics in ms):min=1, max=80, avg=43.321
Time to get write grant (summary statistics in ms):min=41, max=58, avg=46.9
Number of messages sent:367
Number of messages received:450
Number of messages exchanged (total):817

Total #of messages exchanged : 936+738+831+657+817 = 3979 messages
READ access times [min = 1ms, max=80ms, avg= 43.558ms]
WRITE access times [min = 40ms, max=72ms, avg= 44.384ms]

HOLD_TIME= 0.5

Client1
# of successful read:74
# of unsuccessful read:10
# of successful write:12
# of unsuccessful write:1
Time to get read grant (summary statistics in ms):min=1, max=81, avg=45.067
Time to get write grant (summary statistics in ms):min=40, max=42, avg=41.333
Number of messages sent:388
Number of messages received:504
Number of messages exchanged (total):892
Client2
# of successful read:80
# of unsuccessful read:10
# of successful write:9
# of unsuccessful write:0
Time to get read grant (summary statistics in ms):min=1, max=81, avg=44.925
Time to get write grant (summary statistics in ms):min=41, max=47, avg=43.222
Number of messages sent:338
Number of messages received:412
Number of messages exchanged (total):750
Client3
# of successful read:82
# of unsuccessful read:6
# of successful write:11
# of unsuccessful write:1
Time to get read grant (summary statistics in ms):min=1, max=78, avg=42.560
Time to get write grant (summary statistics in ms):min=41, max=58, avg=44.454
Number of messages sent:392
Number of messages received:482
Number of messages exchanged (total):874
Client4
# of successful read:86
# of unsuccessful read:11
# of successful write:5
# of unsuccessful write:1
Time to get read grant (summary statistics in ms):min=1, max=79, avg=43.627
Time to get write grant (summary statistics in ms):min=41, max=42, avg=41.2
Number of messages sent:295
Number of messages received:346
Number of messages exchanged (total):641
Client5
# of successful read:78
# of unsuccessful read:11
# of successful write:9
# of unsuccessful write:1
Time to get read grant (summary statistics in ms):min=1, max=80, avg=42.525
Time to get write grant (summary statistics in ms):min=37, max=72, avg=45.777
Number of messages sent:349
Number of messages received:432
Number of messages exchanged (total):781

Total #of messages exchanged : 892+750+874+641+781 = 3938 messages
READ access times [min = 1ms, max=80ms, avg= 43.719ms]
WRITE access times [min = 40ms, max=72ms, avg= 43.301ms]

HOLD_TIME= 1

Client1
# of successful read:81
# of unsuccessful read:8
# of successful write:11
# of unsuccessful write:2
Time to get read grant (summary statistics in ms):min=2, max=81, avg=43.246
Time to get write grant (summary statistics in ms):min=41, max=65, avg=43.727
Number of messages sent:405
Number of messages received:502
Number of messages exchanged (total):907
Client2
# of successful read:76
# of unsuccessful read:15
# of successful write:9
# of unsuccessful write:0
Time to get read grant (summary statistics in ms):min=1, max=81, avg=45.131
Time to get write grant (summary statistics in ms):min=40, max=66, avg=45.888
Number of messages sent:340
Number of messages received:406
Number of messages exchanged (total):746
Client3
# of successful read:82
# of unsuccessful read:6
# of successful write:11
# of unsuccessful write:1
Time to get read grant (summary statistics in ms):min=40, max=80, avg=44.670
Time to get write grant (summary statistics in ms):min=40, max=71, avg=45.818
Number of messages sent:390
Number of messages received:484
Number of messages exchanged (total):874
Client4
# of successful read:89
# of unsuccessful read:11
# of successful write:6
# of unsuccessful write:0
Time to get read grant (summary statistics in ms):min=40, max=67, avg=44.370
Time to get write grant (summary statistics in ms):min=41, max=43, avg=41.666
Number of messages sent:305
Number of messages received:349
Number of messages exchanged (total):654
Client5
# of successful read:74
# of unsuccessful read:17
# of successful write:9
# of unsuccessful write:1
Time to get read grant (summary statistics in ms):min=1, max=80, avg=41.594
Time to get write grant (summary statistics in ms):min=37, max=60, avg=46.111
Number of messages sent:354
Number of messages received:440
Number of messages exchanged (total):794

Total #of messages exchanged : 907+746+874+654+794 = 3975 messages
READ access times [min = 1ms, max=80ms, avg= 43.836ms]
WRITE access times [min = 37ms, max=71ms, avg= 44.825ms

HOLD_TIME= 1.5

Client1
# of successful read:80
# of unsuccessful read:9
# of successful write:11
# of unsuccessful write:2
Time to get read grant (summary statistics in ms):min=1, max=80, avg=44.0
Time to get write grant (summary statistics in ms):min=41, max=76, avg=44.818
Number of messages sent:404
Number of messages received:509
Number of messages exchanged (total):913
Client2
# of successful read:75
# of unsuccessful read:17
# of successful write:9
# of unsuccessful write:0
Time to get read grant (summary statistics in ms):min=0, max=80, avg=43.733
Time to get write grant (summary statistics in ms):min=42, max=49, avg=44.666
Number of messages sent:340
Number of messages received:406
Number of messages exchanged (total):746
Client3
# of successful read:77
# of unsuccessful read:11
# of successful write:11
# of unsuccessful write:1
Time to get read grant (summary statistics in ms):min=1, max=80, avg=43.090
Time to get write grant (summary statistics in ms):min=41, max=73, avg=47.272
Number of messages sent:391
Number of messages received:472
Number of messages exchanged (total):863
Client4
# of successful read:94
# of unsuccessful read:9
# of successful write:6
# of unsuccessful write:0
Time to get read grant (summary statistics in ms):min=1, max=62, avg=42.968
Time to get write grant (summary statistics in ms):min=41, max=67, avg=45.5
Number of messages sent:312
Number of messages received:357
Number of messages exchanged (total):669
Client5
# of successful read:76
# of unsuccessful read:16
# of successful write:8
# of unsuccessful write:2
Time to get read grant (summary statistics in ms):min=1, max=80, avg=43.078
Time to get write grant (summary statistics in ms):min=41, max=60, avg=47.25
Number of messages sent:350
Number of messages received:424
Number of messages exchanged (total):774

Total #of messages exchanged : 913+746+863+669+774 = 3965 messages
READ access times [min = 1ms, max=80ms, avg= 43.360ms]
WRITE access times [min = 41ms, max=76ms, avg= 45.910ms]

HOLD_TIME= 2

Client1
# of successful read:75
# of unsuccessful read:15
# of successful write:8
# of unsuccessful write:6
Time to get read grant (summary statistics in ms):min=5, max=69, avg=43.306
Time to get write grant (summary statistics in ms):min=40, max=44, avg=41.875
Number of messages sent:404
Number of messages received:468
Number of messages exchanged (total):872
Client2
# of successful read:62
# of unsuccessful read:29
# of successful write:6
# of unsuccessful write:3
Time to get read grant (summary statistics in ms):min=1, max=76, avg=44.241
Time to get write grant (summary statistics in ms):min=40, max=80, avg=48.666
Number of messages sent:330
Number of messages received:370
Number of messages exchanged (total):700
Client3
# of successful read:76
# of unsuccessful read:12
# of successful write:12
# of unsuccessful write:0
Time to get read grant (summary statistics in ms):min=1, max=80, avg=42.671
Time to get write grant (summary statistics in ms):min=42, max=71, avg=46.5
Number of messages sent:394
Number of messages received:481
Number of messages exchanged (total):875
Client4
# of successful read:82
# of unsuccessful read:20
# of successful write:5
# of unsuccessful write:1
Time to get read grant (summary statistics in ms):min=1, max=80, avg=42.378
Time to get write grant (summary statistics in ms):min=41, max=42, avg=41.4
Number of messages sent:305
Number of messages received:327
Number of messages exchanged (total):632
Client5
# of successful read:72
# of unsuccessful read:20
# of successful write:8
# of unsuccessful write:1
Time to get read grant (summary statistics in ms):min=1, max=80, avg=42.458
Time to get write grant (summary statistics in ms):min=41, max=80, avg=53.222
Number of messages sent:351
Number of messages received:426
Number of messages exchanged (total):777

Total #of messages exchanged : 872+700+875+632+777 = 3901 messages
READ access times [min = 1ms, max=80ms, avg= 42.958ms]
WRITE access times [min = 40ms, max=72ms, avg= 46.090ms]

HOLD_TIME= 5

Client1
# of successful read:77
# of unsuccessful read:12
# of successful write:10
# of unsuccessful write:3
Time to get read grant (summary statistics in ms):min=28, max=80, avg=43.584
Time to get write grant (summary statistics in ms):min=41, max=43, avg=41.6
Number of messages sent:400
Number of messages received:500
Number of messages exchanged (total):900
Client2
# of successful read:79
# of unsuccessful read:14
# of successful write:9
# of unsuccessful write:0
Time to get read grant (summary statistics in ms):min=2, max=81, avg=42.493
Time to get write grant (summary statistics in ms):min=42, max=64, avg=46.111
Number of messages sent:343
Number of messages received:420
Number of messages exchanged (total):763
Client3
# of successful read:82
# of unsuccessful read:6
# of successful write:11
# of unsuccessful write:1
Time to get read grant (summary statistics in ms):min=40, max=64, avg=43.963
Time to get write grant (summary statistics in ms):min=41, max=71, avg=45.909
Number of messages sent:391
Number of messages received:482
Number of messages exchanged (total):873
Client4
# of successful read:90
# of unsuccessful read:10
# of successful write:6
# of unsuccessful write:0
Time to get read grant (summary statistics in ms):min=39, max=80, avg=44.122
Time to get write grant (summary statistics in ms):min=40, max=43, avg=41.166
Number of messages sent:305
Number of messages received:351
Number of messages exchanged (total):651
Client5
# of successful read:80
# of unsuccessful read:12
# of successful write:8
# of unsuccessful write:2
Time to get read grant (summary statistics in ms):min=2, max=80, avg=44.3625
Time to get write grant (summary statistics in ms):min=40, max=46, avg=42.625
Number of messages sent:352
Number of messages received:436
Number of messages exchanged (total):788

Total #of messages exchanged : 900+763+873+651+788 = 3975 messages
READ access times [min = 1ms, max=80ms, avg= 43.720ms]
WRITE access times [min = 40ms, max=72ms, avg= 43.720ms]

ANALYSIS

In the analysis, we used the time unit as 4 milliseconds. If the time unit selected less, then the effect of network propagation time becomes significant. If we select it more, than we rarely observe an unsuccessful operation. This value is just the balanced value.

1. AVERAGE TIME TO GET A GRANT

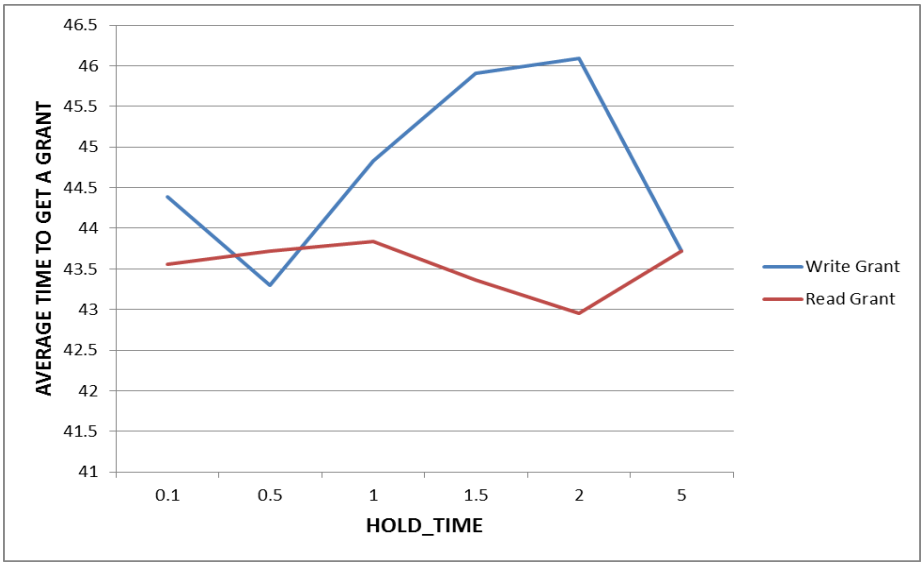


Figure 1-Average time to get a grant from the servers. See the project description for the definition of read and write grant.

Since there is not a high contention for the same data object, the effect of HOLD_TIME is not very apparent. If the contention was high, e.g. 100 clients were contending for the data objects, then we would see very different results. As the HOLD_TIME increases, the average time for getting a grant would also increase. Note that HOLD_TIME does not only affect the average time to get a grant, it also affects the number of successful/unsuccessful access operations. The reason is obvious. Increasing HOLD_TIME means that the client who gets the grant from the server, keeps it longer, which makes the pending requests wait more, and potentially the chance of timeout increases as the sender of the pending request does not get the grant on time.

We also observe that average time to get a grant for a READ_REQUEST is less than that of WRITE_REQUEST. That is very natural since the read operation requires grant only from the requested server, which is a single server. On the other hand, write operation requires a grant from several servers. More specifically, it requires a grant from the servers that form a quorum.

2. NUMBER OF SUCCESSFUL/UNSUCCESSFUL OPERATIONS

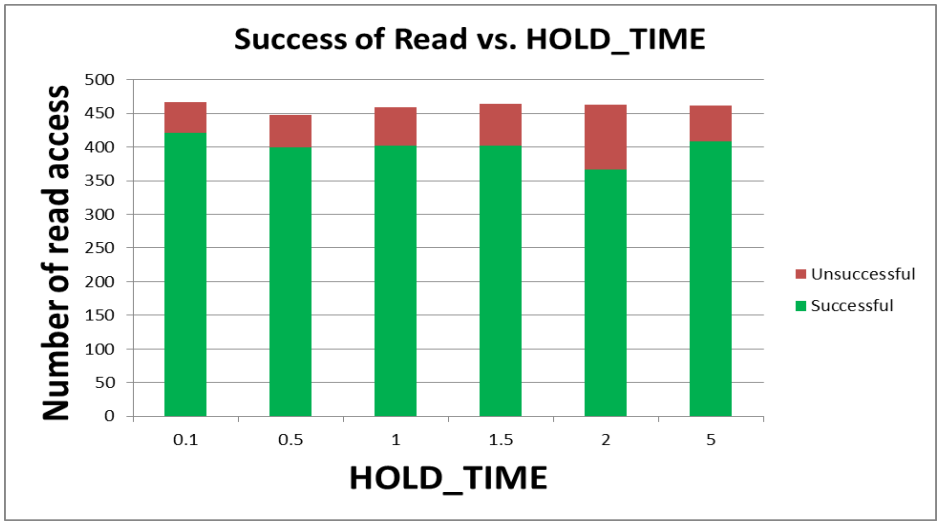
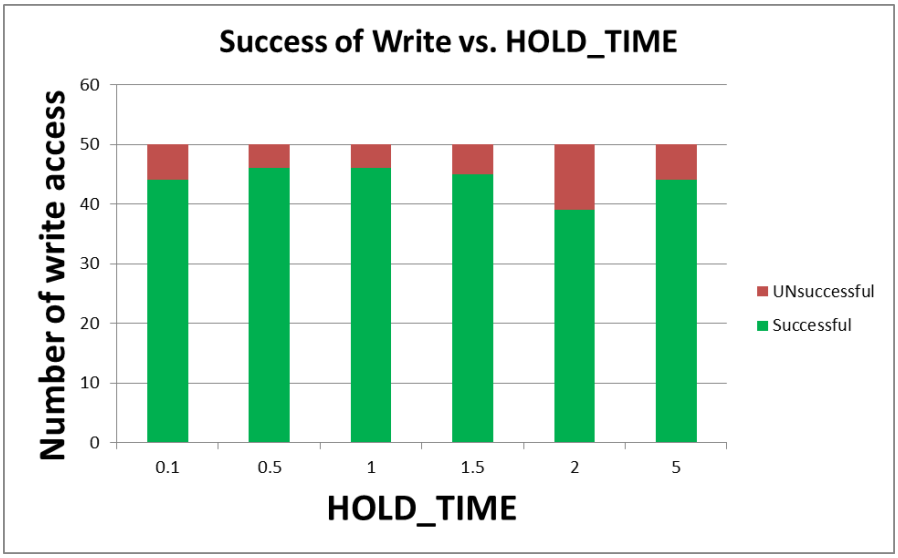


Figure 2-Effect of HOLD_TIME on the number of successful and unsuccessful read operations.

A little bit increase in unsuccessful read is observed when the HOLD_TIME is increased. This observation is expected but it is not very apparent due to low contention and the time unit selection. If the contention were high enough, we would expect to see increase in unsuccessful read operations as the HOLD_TIME increases. The reason is that as the HOLD_TIME for a grant increases, pending requests waits for grant more, which causes more number of timeouts.



We observe similar results as in read case. HOLD_TIME increases the number of unsuccessful write operations. The reason is same as in read case. The longer a client keeps a grant, the higher probability that the sender of a WRITE_REQUEST timeouts. Again, if the contention for the data objects were much higher, than we would observe the effect of HOLD_TIME more easily.

3. TOTAL NUMBER OF MESSAGES EXCHANGED

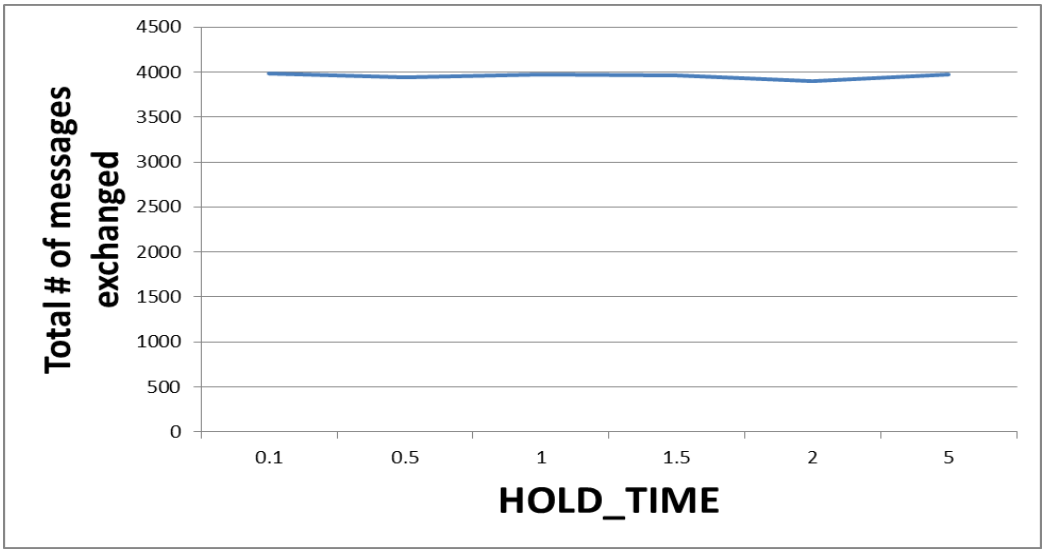


Figure 3-Total number of messages exchanged is not affected much from the value of HOLD_TIME

Lets first analyze the number of messages sent and received on successful and unsuccessful read and write operations.

READ operation:

- *If read request is successful, the number of messages exchanged (for this single read operation) is 3: 1 READ_REQUEST, 1 GRANT, and 1 READ_COMMIT.*

- *If read request is unsuccessful, the number of messages exchanged (for this single read operation) is between 2 and 3: 1 READ_REQUEST, 1 WITHDRAW (Note: The server may send a GRANT, which arrives after the timeout.)*

WRITE operation:

- *If write request is successful, the number of messages exchanged is between 24 and 28: 7 WRITE_REQUEST, [3-7] GRANT, 7 WRITE_COMMIT, 7ACK. (Note: All servers may send a GRANT even though it suffices to get grant from a servers that form a quorum. If a server gets a WRITE_COMMIT before sending a GRANT for the request, then it removes the request from the queue without sending a GRANT.)*

- *If write is unsuccessful, the number of messages exchanged is between 21 and 28: 7 WRITE_REQUEST, 7 WITHDRAW, 7 ACK. (Note: All servers may send a GRANT before receiving the WITHDRAW message, in the worst case 28 messages might be exchanged.)*

The above analysis shows that unsuccessful operations require fewer messages on the average. They require same number of messages as successful operations in the worst case. This fact implies that as the number of unsuccessful operations increases, the number of messages exchanged should decrease. Since there is not much contention for the data objects, we could not observe significant increase in unsuccessful operations; hence number of messages exchanged is almost the same. However, if the contention for data objects were

higher, then, number of unsuccessful operations would increase and total number of messages would decrease even though not significantly.