Alec Nipp, Jacob Brown
COMP 530 Lab 5

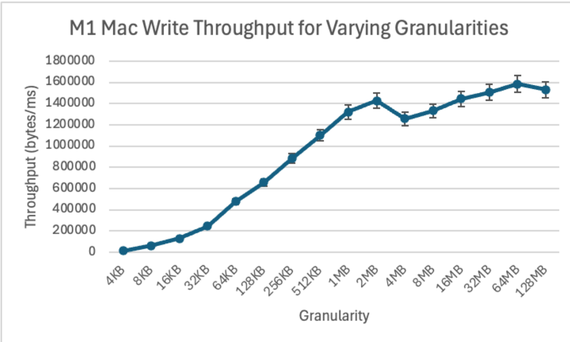
Abstract

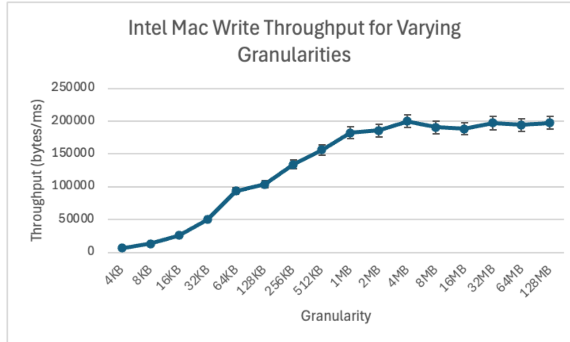
Read and write throughput can be influenced by a number of variables, including disk specs, caching behavior, and access patterns. The goal of this study was to evaluate the effect of access patterns and hardware on I/O throughput. A suite of I/O operations were performed on two devices — an Intel Mac and M1 Mac — and the completion times were benchmarked. The I/O tests included sequential, striding, and random access patterns with varying granularities (4KB to 128MB). Reads and writes were both evaluated. Across all three access patterns, disk throughput increased exponentially with granularity. This suggests larger I/O requests are more efficient, although the benefits begin to plateau past 2MB granularity. Additionally, the M1 Mac demonstrated far superior read and write throughput across all granularities. No firm conclusions can be drawn from this due to the presence of confounding variables, but it presents an interesting area for further investigation.

Methods

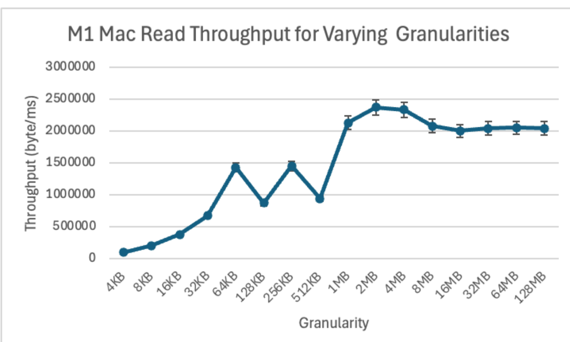
Given the unreliability of the testing server, our group decided to run our testing utility on two different machines to collect data for this lab and compare the results. The first machine is a 2020 MacBook Pro with an Apple M1 processor. The second is a 2019 MacBook Pro with a 2.3 GHz 8-Core Intel Core i9 processor. Both of these machines have SSD storage devices and were running MacOS Sequoia 15.1.1.

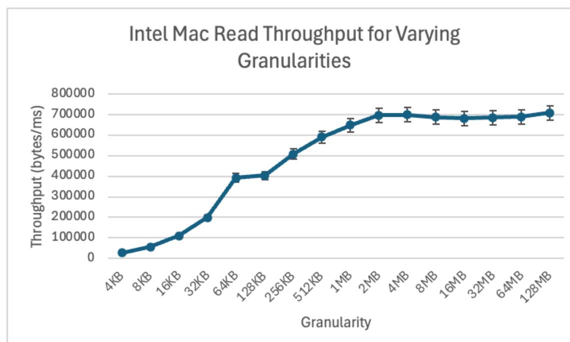
IO Size Testing





Our testing utility tested write granularity by writing a pattern of the specified size for 5 trials and recording the execution time for each trial. We then found the average of the 5 trials for each granularity to create the plots above. The above plots demonstrate that with larger write size, throughput increases. The benefits of increased throughput due to increased write sizes begin to plateau around 2 MB write granularities.

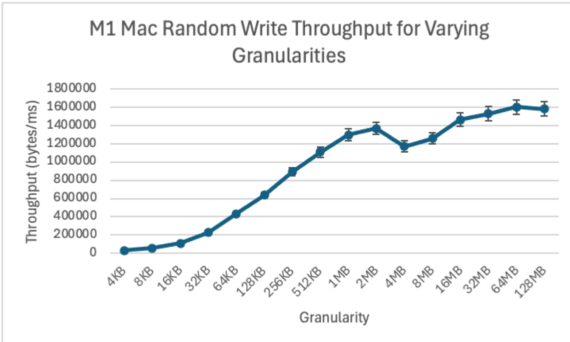


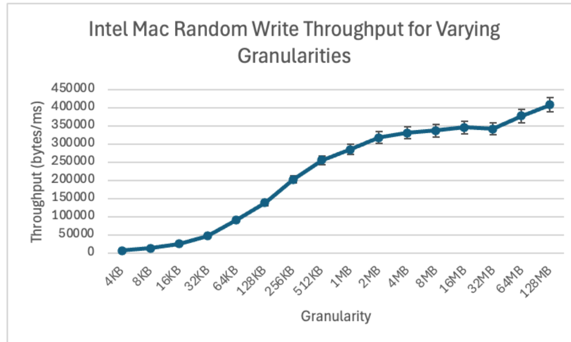


The plots for throughputs for varying read granularities were created using data collected in the same manner described above. The throughputs for varying read granularities have similar trends to the throughputs for varying write granularities, both reflecting an increase in throughput with an increase in IO size. Interestingly, the M1 Mac data has a sharp decline in throughput for the 128 MB and 512 MB tests. This pattern does not reflect any of the behavior we would expect or discussed in class, and is not reflected in the Intel Mac plot. We suspect that this irregularity is in part due to our lack of access to a dedicated server during data collection.

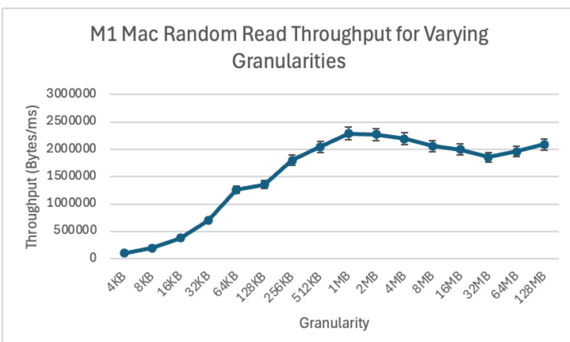
Random IO Testing

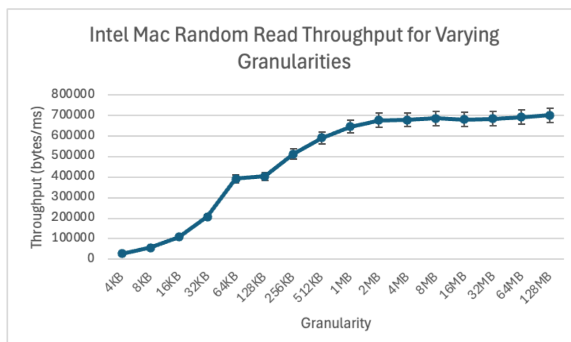
Data for our random read and write throughput tests was collected using the same methods described for the IO size tests.





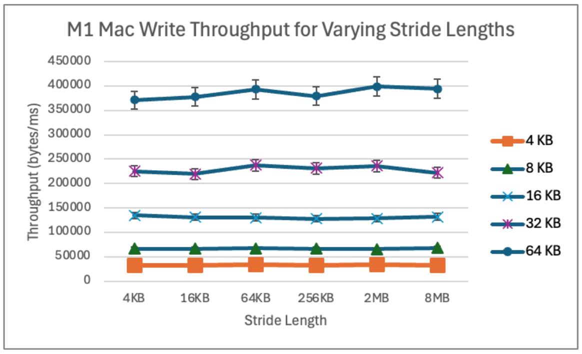
Our tests for random access writes at various granularities yielded similar results to the sequential writes on both machines. This is to be expected as both the M1 Mac and the Intel Mac have SSD storage devices, thus stride does not require any mechanical movement as it would with an HDD and its impact is negligible.

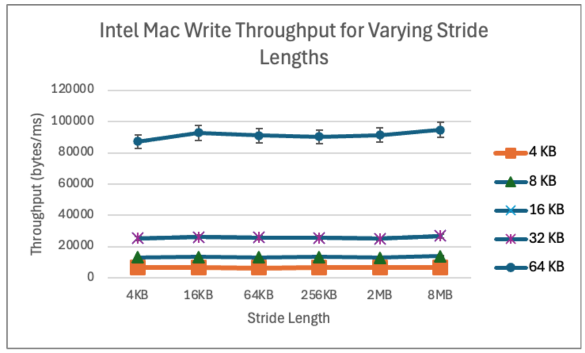




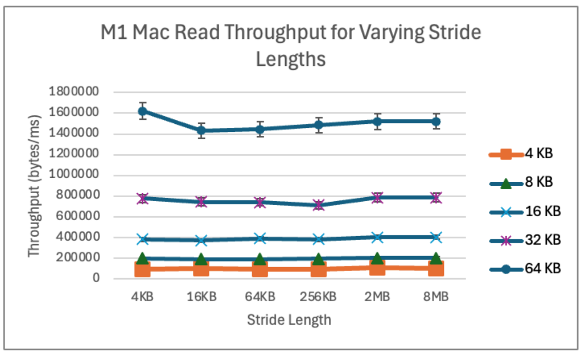
The tests for random access reads at several granularities produced results that showed a similar increase in throughput with increasing read granularity. These tests in particular demonstrated a stronger plateau in throughput increase at 1-2 MB than observed in other test results.

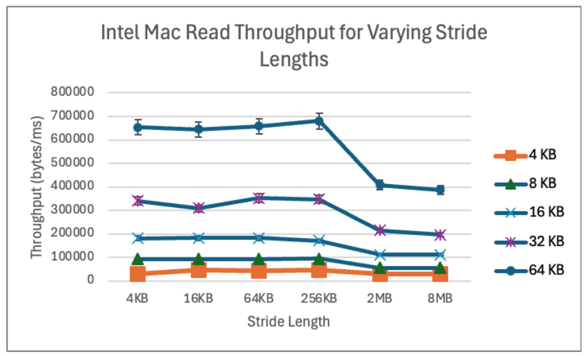
Stride Testing





The tests for varying stride length at different write granularities all reflected that stride has little to no impact on throughput when writing at any of the tested granularities. This is to be expected as both machines have SSD storage devices, thus seek time is negligible and stride has minimal impact.





Results for varying stride lengths at different read granularities reflected the same trends as the plots for varying stride lengths at different write granularities. We observe little to no impact on throughput in either of these tests on either machine. It is worth noting that on the Intel Mac, all granularities saw a decrease in throughput when stride reached 2 MB. We are not able to conclude anything using solely the data collected from this experiment, however this is an interesting outcome and could be worth investigating further.

Machine Comparison

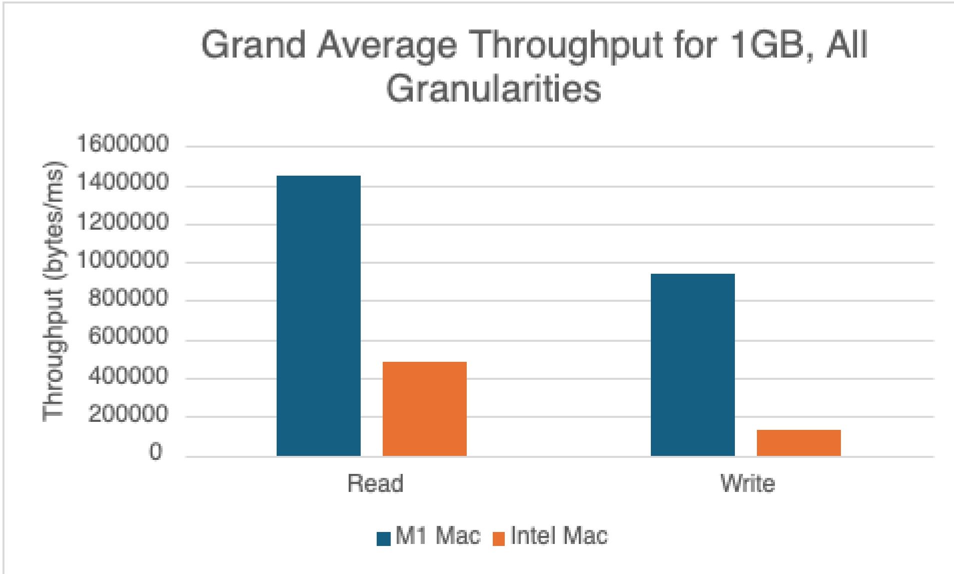


Figure 4. Comparison of M1 Mac and Intel Mac read and write throughputs, averaged across all granularities. The M1 Mac was 2.97x faster for reads and 7.07x times faster for writes.

Conclusion

Our results indicate larger I/O requests are better for higher throughput. This applies across all access patterns (sequential, random, stride) and operations (read and write). The benefits of a larger granularity, however, plateau around 2MB. This suggests operating systems should avoid I/O requests smaller than 1-2MB, and should target this granularity for reading and writing via techniques like write buffering.