**ECSE 4961 ACS Project 3 Report**

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1. **Experiment Environment:**

|  |  |
| --- | --- |
| OS | Windows 10 Home |
| Processor | i7 9750H @ 2.6Ghz 2.59Ghz |
| RAM | 16GB |
| SSD | Intel 660p 512GB |

1. **Experiment Setting:**
2. Memory:

The team used intel MLC to test memory sequential read/write performance under different setting of r/w proportion and stride length.

|  |  |
| --- | --- |
| Random/sequential | Sequential r/w |
| r/w proportion | Read only, 3:1, 2:1, 1:1, write only |
| Stride length | 64B/256B |
| Tool | mlc |

1. SSD:

The team used Fio to test SSD random read/write performance given different r/w proportion and block size.

|  |  |
| --- | --- |
| Random/sequential | Random r/w |
| r/w proportion | Read only, 70:30, write only |
| numjobs | 5 |
| size | 1G |
| runtime | 100 |
| ioengine | windowsaio |
| Block size | 4k/32k |
| Tool | fio |

1. **Experiment Result**
2. Memory
3. Stride length=64B, Read only

Command= "--loaded\_latency"

|  |  |  |
| --- | --- | --- |
| Inject Delay | latency (ns) | Bandwidth (MB/sec) |
| 0 | 181.96 | 34581.3 |
| 2 | 174.54 | 34952 |
| 8 | 171.11 | 34912.9 |
| 15 | 169.29 | 34773.2 |
| 50 | 142.41 | 34631.6 |
| 100 | 103.89 | 32542.3 |
| 200 | 74.9 | 23358.4 |
| 300 | 65.9 | 16632.7 |
| 400 | 61.33 | 13104.3 |
| 500 | 59.75 | 10798.6 |
| 700 | 56.84 | 8175.3 |
| 1000 | 54.64 | 6140.3 |
| 1300 | 54.18 | 5025 |
| 1700 | 53.53 | 4149.4 |
| 2500 | 53.42 | 3212.9 |
| 3500 | 52.85 | 2653.2 |
| 5000 | 63.53 | 1983 |
| 9000 | 55.09 | 1720.3 |
| 20000 | 52.19 | 1479.6 |

1. Stride length=64B, r/w=3

Command= "--loaded\_latency -W9"

|  |  |  |
| --- | --- | --- |
| Inject Delay | latency (ns) | Bandwidth (MB/sec) |
| 0 | 277.62 | 29612.1 |
| 2 | 270.02 | 29667.8 |
| 8 | 259.47 | 29678.9 |
| 15 | 250.46 | 29877 |
| 50 | 203.48 | 30316.7 |
| 100 | 162.79 | 29769.5 |
| 200 | 89.44 | 23758.6 |
| 300 | 75.13 | 16648.4 |
| 400 | 69.3 | 13035.1 |
| 500 | 65.12 | 10775 |
| 700 | 60.89 | 8095.9 |
| 1000 | 57.66 | 6074 |
| 1300 | 56.41 | 4982.2 |
| 1700 | 54.97 | 4117.5 |
| 2500 | 54.35 | 3195.2 |
| 3500 | 53.81 | 2631.4 |
| 5000 | 53.09 | 2216.2 |
| 9000 | 53.21 | 1764.9 |
| 20000 | 52.69 | 1467.6 |

1. Stride length=64B, r/w=2

Command= "--loaded\_latency -W7"

|  |  |  |
| --- | --- | --- |
| Inject Delay | latency (ns) | Bandwidth (MB/sec) |
| 0 | 394.84 | 26746.2 |
| 2 | 358.73 | 29017.6 |
| 8 | 366.22 | 28247.5 |
| 15 | 337.7 | 27601.3 |
| 50 | 302.26 | 28099.1 |
| 100 | 234.98 | 29332.4 |
| 200 | 194.71 | 28562.1 |
| 300 | 96.92 | 23686.1 |
| 400 | 75.55 | 18899.3 |
| 500 | 69.84 | 15514.4 |
| 700 | 63.59 | 11588.3 |
| 1000 | 59.52 | 8534 |
| 1300 | 57.67 | 6887.3 |
| 1700 | 56.36 | 5563.2 |
| 2500 | 54.44 | 4197.2 |
| 3500 | 54.15 | 3346.8 |
| 5000 | 53.5 | 2705.9 |
| 9000 | 53.08 | 2050.5 |
| 20000 | 53 | 1588 |

1. Stride length=64B, r/w=1

Command= "--loaded\_latency -W8"

|  |  |  |
| --- | --- | --- |
| Inject Delay | latency (ns) | Bandwidth (MB/sec) |
| 0 | 355.14 | 26713.4 |
| 2 | 350.87 | 26699.8 |
| 8 | 350.33 | 26919.5 |
| 15 | 321.2 | 27426.2 |
| 50 | 271.43 | 27690.3 |
| 100 | 212.84 | 28230 |
| 200 | 112.64 | 22367.5 |
| 300 | 75.86 | 16628.3 |
| 400 | 78.69 | 12650.5 |
| 500 | 65.25 | 10728.8 |
| 700 | 61.39 | 8065.2 |
| 1000 | 57.48 | 6065.6 |
| 1300 | 56.33 | 4970.9 |
| 1700 | 55.59 | 4091.6 |
| 2500 | 56.85 | 3119.5 |
| 3500 | 56.02 | 2565.3 |
| 5000 | 60.22 | 2034.9 |
| 9000 | 53.06 | 1767.9 |
| 20000 | 52.21 | 1479 |

1. Stride length=64B, write only

Command = "--loaded\_latency -W6"

|  |  |  |
| --- | --- | --- |
| Inject Delay | latency (ns) | Bandwidth (MB/sec) |
| 0 | 322.91 | 32955.5 |
| 2 | 318.2 | 32958.6 |
| 8 | 328.83 | 32761.7 |
| 15 | 311.49 | 32994.3 |
| 50 | 85.85 | 22067.4 |
| 100 | 70.45 | 10771.3 |
| 200 | 66.62 | 6662.3 |
| 300 | 60.94 | 4991.2 |
| 400 | 59.35 | 4081.7 |
| 500 | 57.45 | 3540.1 |
| 700 | 54.89 | 2923.3 |
| 1000 | 54.26 | 2421 |
| 1300 | 53.11 | 2161.7 |
| 1700 | 52.91 | 1948 |
| 2500 | 52.76 | 1717.1 |
| 3500 | 52.49 | 1579.2 |
| 5000 | 52.9 | 1461.9 |
| 9000 | 51.85 | 1374.7 |
| 20000 | 51.86 | 1297.4 |

1. Stride length=256B, read only

Command = "--loaded\_latency -l256"

|  |  |  |
| --- | --- | --- |
| Inject Delay | latency (ns) | Bandwidth (MB/sec) |
| 0 | 118 | 28715.6 |
| 2 | 116.3 | 28819.8 |
| 8 | 118.27 | 27685.3 |
| 15 | 118.37 | 26175.9 |
| 50 | 101.8 | 24131.6 |
| 100 | 89.95 | 21992.1 |
| 200 | 79.97 | 17082.3 |
| 300 | 72.41 | 12874.5 |
| 400 | 76.4 | 10460.6 |
| 500 | 68.63 | 9026.7 |
| 700 | 64.97 | 7172.6 |
| 1000 | 64.26 | 5534.5 |
| 1300 | 62.06 | 4612.1 |
| 1700 | 61.81 | 3816 |
| 2500 | 59.83 | 3017.5 |
| 3500 | 58.45 | 2500.9 |
| 5000 | 58.83 | 2075.4 |
| 9000 | 57.12 | 1679 |
| 20000 | 57.54 | 1364.7 |

1. Stride length=256B, r/w = 3:1

Command = "--loaded\_latency -W9 -l256"

|  |  |  |
| --- | --- | --- |
| Inject Delay | latency (ns) | Bandwidth (MB/sec) |
| 0 | 186.96 | 25192.9 |
| 2 | 182.44 | 25445.6 |
| 8 | 175.88 | 25287.6 |
| 15 | 173.28 | 24755.2 |
| 50 | 145.93 | 21747.6 |
| 100 | 120.07 | 20984.2 |
| 200 | 107.54 | 17006.7 |
| 300 | 89.99 | 13338 |
| 400 | 80.85 | 10659.8 |
| 500 | 76.31 | 9083.1 |
| 700 | 70.88 | 7172 |
| 1000 | 66.66 | 5558.7 |
| 1300 | 62.88 | 4659.1 |
| 1700 | 62.19 | 3869.3 |
| 2500 | 60.64 | 3016.2 |
| 3500 | 58.84 | 2502.1 |
| 5000 | 58.48 | 2089.2 |
| 9000 | 57.15 | 1677.8 |
| 20000 | 57.31 | 1369.2 |

1. Stride length=256B, r/w = 2:1

Command = "--loaded\_latency -W7 -l256"

|  |  |  |
| --- | --- | --- |
| Inject Delay | latency (ns) | Bandwidth (MB/sec) |
| 0 | 316.14 | 20574.4 |
| 2 | 243.17 | 24112.3 |
| 8 | 195.87 | 25050.7 |
| 15 | 190.27 | 24476.2 |
| 50 | 157.66 | 23481.3 |
| 100 | 143.48 | 23235.2 |
| 200 | 121.6 | 21057.9 |
| 300 | 100.38 | 18011.3 |
| 400 | 87.94 | 14851.5 |
| 500 | 81.3 | 12699.4 |
| 700 | 77.47 | 9850.6 |
| 1000 | 70.11 | 7621.4 |
| 1300 | 66.31 | 6299.5 |
| 1700 | 65.8 | 5129.3 |
| 2500 | 69.27 | 3760.7 |
| 3500 | 60.44 | 3161.5 |
| 5000 | 62.55 | 2485.8 |
| 9000 | 58.51 | 1928.6 |
| 20000 | 57.59 | 1489.4 |

1. Stride length=256B, r/w = 1:1

Command = "--loaded\_latency -W8 -l256"

|  |  |  |
| --- | --- | --- |
| Inject Delay | latency (ns) | Bandwidth (MB/sec) |
| 0 | 250.36 | 26204.5 |
| 2 | 248.54 | 26100.7 |
| 8 | 234.82 | 26131.5 |
| 15 | 211.12 | 25678.4 |
| 50 | 159.91 | 23277.4 |
| 100 | 152.58 | 20634.1 |
| 200 | 130.17 | 17257 |
| 300 | 105.76 | 14016 |
| 400 | 87.86 | 11080.6 |
| 500 | 79.19 | 9541.6 |
| 700 | 73.66 | 7359.9 |
| 1000 | 67.19 | 5675 |
| 1300 | 64.65 | 4695 |
| 1700 | 61.49 | 3920.3 |
| 2500 | 60.07 | 3045.7 |
| 3500 | 58.25 | 2524.4 |
| 5000 | 57.71 | 2112.9 |
| 9000 | 57.23 | 1678.5 |
| 20000 | 56.38 | 1388.4 |

1. Stride length=256B, write only

Command = "--loaded\_latency -W6 -l256"

|  |  |  |
| --- | --- | --- |
| Inject Delay | latency (ns) | Bandwidth (MB/sec) |
| 0 | 330.53 | 8386.7 |
| 2 | 332.43 | 8299.1 |
| 8 | 332.7 | 8406.7 |
| 15 | 324.6 | 8360 |
| 50 | 88.86 | 6245 |
| 100 | 74.25 | 3294.3 |
| 200 | 69.09 | 2346.2 |
| 300 | 63.94 | 1986.3 |
| 400 | 62.22 | 1779.4 |
| 500 | 59.86 | 1676.8 |
| 700 | 58.04 | 1541.4 |
| 1000 | 56.8 | 1437.4 |
| 1300 | 56.63 | 1369.7 |
| 1700 | 56.74 | 1311.9 |
| 2500 | 55.82 | 1272.4 |
| 3500 | 55.87 | 1235.7 |
| 5000 | 55.44 | 1217.6 |
| 9000 | 56.48 | 1168.3 |
| 20000 | 56.54 | 1147.8 |

1. SSD

Command list:

|  |  |  |  |
| --- | --- | --- | --- |
| queue depth | data access size | r:w | command |
| 1 | 4k | r | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=1 -thread -rw=randread -bs=4k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 4 | 4k | r | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=4 -thread -rw=randread -bs=4k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 16 | 4k | r | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=16 -thread -rw=randread -bs=4k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 1 | 32k | r | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=1 -thread -rw=randread -bs=32k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 4 | 32k | r | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=4 -thread -rw=randread -bs=32k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 16 | 32k | r | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=16 -thread -rw=randread -bs=32k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 1 | 4k | 70:30 | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=1 -thread -rw=randrw -rwmixwrite=30 -bs=4k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 4 | 4k | 70:30 | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=4 -thread -rw=randrw -rwmixwrite=30 -bs=4k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 16 | 4k | 70:30 | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=16 -thread -rw=randrw -rwmixwrite=30 -bs=4k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 1 | 32k | 70:30 | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=1 -thread -rw=randrw -rwmixwrite=30 -bs=32k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 4 | 32k | 70:30 | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=4 -thread -rw=randrw -rwmixwrite=30 -bs=32k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 16 | 32k | 70:30 | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=16 -thread -rw=randrw -rwmixwrite=30 -bs=32k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 1 | 4k | w | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=1 -thread -rw=randwrite -bs=4k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 4 | 4k | w | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=4 -thread -rw=randwrite -bs=4k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 16 | 4k | w | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=16 -thread -rw=randwrite -bs=4k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 1 | 32k | w | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=1 -thread -rw=randwrite -bs=32k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 4 | 32k | w | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=4 -thread -rw=randwrite -bs=32k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |
| 16 | 32k | w | fio.exe -filename="C:\Users\xieyu\Documents\ACS\p3\test.txt" -ioengine=windowsaio -direct=1 -iodepth=16 -thread -rw=randwrite -bs=32k -size=1G -numjobs=5 -runtime=100 -group\_reporting -name=mytest |

Result:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| queue depth | data access size | r:w | read avg iops | read avg bw( KiB/s) | read avg lat(usec) | write avg iops | write avg bw( KiB/s) | write avg lat(usec) |
| 1 | 4k | r | 25597.63 | 102396.17 | 194.51 |  |  |  |
| 4 | 4k | r | 38582.21 | 154333.51 | 516.95 |  |  |  |
| 16 | 4k | r | 41993.68 | 167978.53 | 1903.94 |  |  |  |
| 1 | 32k | r | 11498.07 | 367978.18 | 433.93 |  |  |  |
| 4 | 32k | r | 13566.92 | 434193.58 | 1473.81 |  |  |  |
| 16 | 32k | r | 13554.79 | 433807.79 | 5903.73 |  |  |  |
| 1 | 4k | 70:30 | 23311.53 | 93250.28 | 198.06 | 10019.81 | 40083.4 | 34.68 |
| 4 | 4k | 70:30 | 36858.96 | 147440.08 | 523.83 | 15847.33 | 63393.61 | 36.98 |
| 16 | 4k | 70:30 | 35012.83 | 140055.98 | 2262.85 | 15054.65 | 60222.79 | 45.75 |
| 1 | 32k | 70:30 | 6200.42 | 198461.56 | 766.97 | 2675.36 | 85651.42 | 76.72 |
| 4 | 32k | 70:30 | 6608.97 | 211530.12 | 2652.49 | 2849.88 | 91252.79 | 852.65 |
| 16 | 32k | 70:30 | 7088.44 | 226863.38 | 8404.36 | 3059.88 | 97964.25 | 6670.06 |
| 1 | 4k | w |  |  |  | 109667 | 438672.39 | 44.73 |
| 4 | 4k | w |  |  |  | 189443.23 | 757780.92 | 103.49 |
| 16 | 4k | w |  |  |  | 194863.92 | 779461.51 | 382.89 |
| 1 | 32k | w |  |  |  | 28463.91 | 910907 | 175.46 |
| 4 | 32k | w |  |  |  | 28590.82 | 914974.18 | 699.98 |
| 16 | 32k | w |  |  |  | 28768.09 | 920642.36 | 2787.31 |

1. **Analysis**

In memory experiment, the team used intel MLC to test the memory bandwidth and latency under different settings of stride length and read/write proportion. According to the result of the experiment, when stride length and r/w proportion fixed, increasing the injection delay reduces the latency, but decreases the bandwidth. When stride length fixed, increasing the r/w proportion causes the latency increase under similar bandwidth. This indicates the fact that write operation has larger latency than read operation in memory. In addition, increase the stride length from 64B to 256B also increase the latency under similar bandwidth.

In SSD experiment, the team test the random read/write performance with Fio given different setting of read/write proportion and data access length. According to the experiment, when the queue depth increases from 1 to 4 and 16, both bandwidth and latency increases, resulting in an increasing of iosp. When queue depth and read/write proportion are fixed, increasing data access size increases bandwidth and latency, and the iosp decreases. When queue depth and data access size are fixed, increasing the read/write proportion have floated affect on read bandwidth/latency and write bandwidth/latency, but both read and write iosp decrease. In addition, the write latency is smaller than the read latency, but the write bandwidth is smaller than the read bandwidth. Overall, the write iosp is smaller than the read iosp.

1. **Conclusion**

By working on the experiment with both memory and SSD, the team realize that there is a tradeoff between bandwidth and latency when changing the queue depth and data access size. In addition, different rate of read and write option also changes the performance of SSD and memory.

Comparing to D7-5600, the team’s SSD have worse performance on read iosp, but the write iosp is better than D7-5600 when the queue depth increases to 16. This might because the D7-5600 has more functions on data security, error detection, and data duration, which decrease the write iops.