Table 1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| scale  Time(ms) | blas | basic | vectorized | omp-1 | omp-4 | omp-8 |
| 1024 | 526 | 970 | 627 | 2124 | 381 | 365 |
| 2048 | 334 | 4200 | 2431 | 2739 | 684 | 354 |
| 4096 | 1336 | 18162 | 12130 | 13642 | 2285 | 1152 |
| 8192 | 5454 | 76358 | 39848 | 11837 | 8148 | 4095 |
| 16384 | 217391 | 320218 | 231317 | 102535 | 307734 | 154084 |

Table 2

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| scale  ability | blas | basic | vectorized | omp-1 | omp-4 | omp-8 |
| 1024 | 7.792 | 4.208 | 6.481 | 1.914 | 10.829 | 11.242 |
| 2048 | 12.217 | 2.586 | 4.460 | 3.953 | 15.774 | 30.482 |
| 4096 | 9.996 | 1.939 | 2.911 | 2.572 | 12.296 | 21.547 |
| 8192 | 9.789 | 1.858 | 3.558 | 4.795 | 6.997 | 13.939 |
| 16384 | 6.157 | 1.663 | 2.290 | 5.144 | 1.711 | 3.420 |

Table 3

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| scale  utilization | blas | basic | vectorized | omp-1 | omp-4 | omp-8 |
| 1024 | 99.37% | 79.50% | 89.43% | 91.25% | 93.75% | 94.69% |
| 2048 | 99.27% | 79.24% | 89.29% | 91.25% | 93.60% | 94.67% |
| 4096 | 99.31% | 79.30% | 89.29% | 91.28% | 93.60% | 94.68% |
| 8192 | 99.36% | 79.35% | 89.32% | 91.27% | 93.62% | 94.68% |
| 16384 | 99.36% | 79.35% | 89.32% | 91.27% | 93.62% | 94.68% |

Answer

1. The vectorized implementation has better performance than the basic implementation at N=16384, increasing MFLOP/s by about 75%. The vectorized implementation also has better memory system utilization, improving bandwidth utilization by about 16%.

2. The OpenMP 8-way parallel implementation has better performance than the basic implementation when N=16384, increasing MFLOP/s by about 39%. However, the base implementation has better memory system utilization at about 3%.

3. When N=16384, the speedup ratio achieved by OpenMP is about 3.3 from 1 to 4 threads, and about 6.6 from 1 to 8 threads, using the data of MFLOP/s.