HW 4 (2021-27764 안지수)

1. MPI Test

(a) 0.08589934592초

(b) 57.362274181Gbit/s

```
shpc121@a00:~/snu_shpc21/hw4/pingpong$ make performance
salloc --nodes 2 --ntasks-per-node 1 --cpus-per-task=16 --partition=shpc mpirun --bind-to none --mca btl openib,self --mca btl_openib_all
ow_ib true ./pingpong
salloc: Pending job allocation 32028
salloc: job 32028 queued and waiting for resources
salloc: job 32028 has been allocated resources
salloc: Granted job allocation 32028
[rank 0] Ready to communicate...
[rank 1] Ready to communicate...
testing(send) : 1.000000
testing(receive) : 1.000000
testing(send) : 2.000000
testing(receive) : 2.000000
testing(send) : 3.000000
testing(receive) : 3.000000
testing(send) : 4.000000
testing(receive) : 4.000000
testing(send) : 5.000000
testing(receive) : 5.000000
testing(send) : 6.000000
testing(receive) : 6.000000
testing(send) : 7.000000
testing(receive) : 7.000000
testing(send) : 8.000000
testing(receive) : 8.000000
testing(send) : 9.000000
testing(receive) : 9.000000
testing(send) : 10.000000
testing(receive) : 10.000000
Elapsed time: 2.994977 sec
salloc: Relinquishing job allocation 32028
```

A →B 로 데이터가 이동하는 양 1GB , B →A 로 데이터가 이동하는 양 1GB

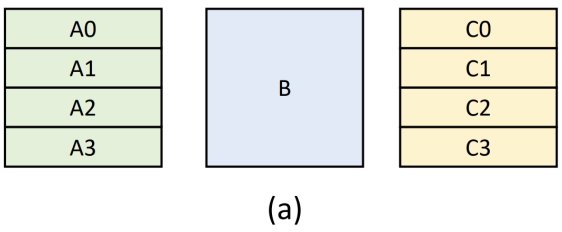
데이터의 총 이동량 : 20GByte

걸린 시간 : 2.994977 sec

전송 속도 : 57.362274181Gbit/s

OpenMP schedule Clause

(a) 아래와 같은 방식을 활용하여 병렬화를 수행하였다.



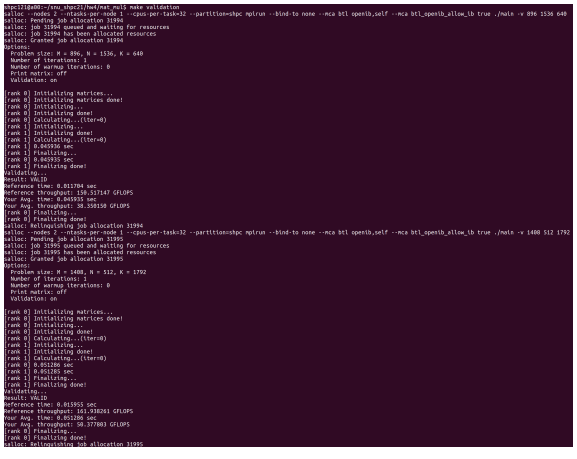
(a)

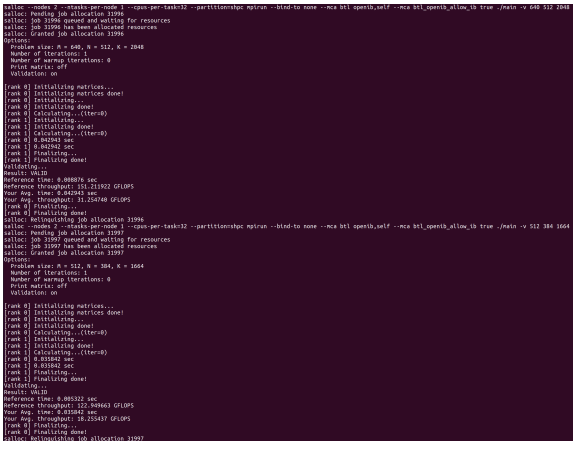
먼저 하나의 두개의 노드로 나누어 병렬화를 수행시켰고, 먼저 MPI의 경우 A0, A1을 B를 이용하여 C0, C1을 계산하는 rank 1 노드와 A2, A4 그리고 B를 이용하여 C2, C3을 계산하는 rank 2 노드를 만들었고, 행렬 B에 접근하는 횟수가 절반이 되도록 알고리즘을 작성한 뒤 OpenMP를 활용하여 병렬화를 했다.

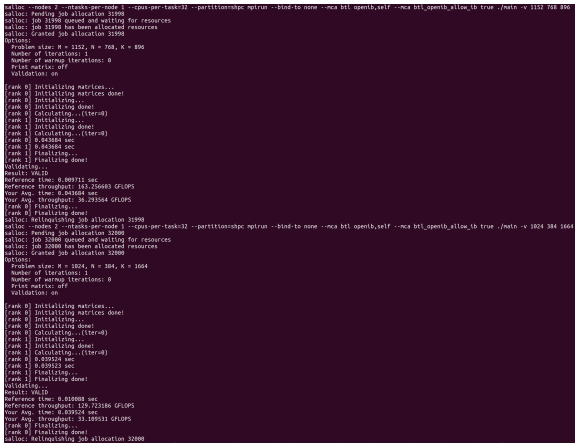
(b) MPI와 OpenMP를 둘 다 사용하여 병령화를 수행하면 노드 2개, M = N = K = 4096 기준으로270 GFLOPS의 성능을 얻을 수 있지만 MPI만 사용하여 병렬화를 수행한 경우 제한시간인 16GFLOPS의 성능을 얻을 수 있었다. 따라서 MPI 와 OpenMP를 둘다 사용할 경우가 훨신 더 좋은 성능을 얻을 수 있음을 확인할 수 있었다.

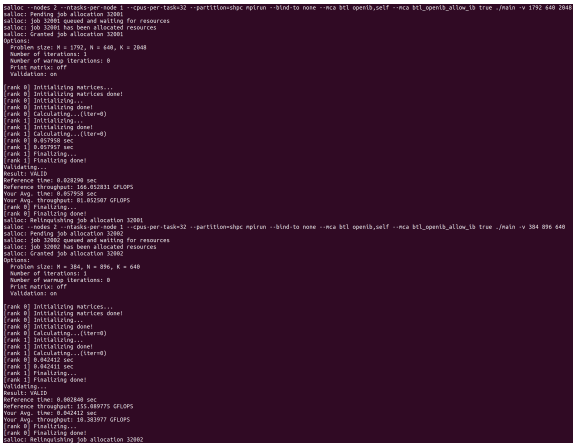
(c) 모두 Valid함

```
salloc --nodes 2 --ntasks-per-node 1 --cpus-per-task=32 --partition=shpc mpirun --bind-to none --mca btl openib,self --mca btl_openib_allow_ib true ./main -v 256 1024 1920
salloc: Pending job allocation 32004
salloc: job 32004 queued and waiting for resources
salloc: job 32004 has been allocated resources
salloc: Granted job allocation 32004
Options:
  Problem size: M = 256, N = 1024, K = 1920
  Number of iterations: 1
  Number of warmup iterations: 0
  Print matrix: off
  Validation: on

[rank 0] Initializing matrices...
[rank 0] Initializing matrices done!
[rank 0] Initializing...
[rank 0] Initializing done!
[rank 0] Calculating...(iter=0)
[rank 1] Initializing...
[rank 1] Initializing done!
[rank 1] Calculating...(iter=0)
[rank 0] 0.046840 sec
[rank 1] 0.046840 sec
[rank 1] Finalizing...
[rank 1] Finalizing done!
Validating...
Result: VALID
Reference time: 0.006077 sec
Reference throughput: 165.641213 GFLOPS
Your Avg. time: 0.046840 sec
Your Avg. throughput: 21.490701 GFLOPS
[rank 0] Finalizing...
[rank 0] Finalizing done!
salloc: Relinquishing job allocation 32004
salloc --nodes 2 --ntasks-per-node 1 --cpus-per-task=32 --partition=shpc mpirun --bind-to none --mca btl openib,self --mca btl_openib_allow_ib true ./main -v 1792 768 1152
salloc: Pending job allocation 32005
salloc: job 32005 queued and waiting for resources
salloc: job 32005 has been allocated resources
salloc: Granted job allocation 32005
Options:
  Problem size: M = 1792, N = 768, K = 1152
  Number of iterations: 1
  Number of warmup iterations: 0
  Print matrix: off
  Validation: on

[rank 0] Initializing matrices...
[rank 0] Initializing matrices done!
[rank 0] Initializing...
[rank 0] Initializing done!
[rank 0] Calculating...(iter=0)
[rank 1] Initializing...
[rank 1] Initializing done!
[rank 1] Calculating...(iter=0)
[rank 0] 0.048300 sec
[rank 1] 0.048299 sec
[rank 1] Finalizing...
[rank 1] Finalizing done!
Validating...
Result: VALID
Reference time: 0.019068 sec
Reference throughput: 166.291907 GFLOPS
Your Avg. time: 0.048300 sec
Your Avg. throughput: 65.649760 GFLOPS
[rank 0] Finalizing...
[rank 0] Finalizing done!
salloc: Relinquishing job allocation 32005
```






salloc --nodes 2 --ntasks-per-node 1 --cpus-per-task=32 --partition=shpc mpirun --bind-to none --mca btl openib,self --mca btl_openib_allow_ib true ./main -v 1152 768 896
salloc: Pending job allocation 31998
salloc: job 31998 queued and waiting for resources
salloc: job 31998 has been allocated resources
salloc: Granted job allocation 31998
Options:
Problem size: M = 1152, N = 768, K = 896
Number of iterations: 1
Number of warmup iterations: 0
Print matrix: off
Validation: on
[rank 0] Initializing matrices...
[rank 0] Initializing matrices done!
[rank 0] Initializing...
[rank 0] Initializing done!
[rank 0] Calculating...(iter=0)
[rank 1] Initializing...
[rank 1] Initializing done!
[rank 1] Calculating...(iter=0)
[rank 0] 0.043684 sec
[rank 1] 0.043684 sec
[rank 1] Finalizing...
[rank 1] Finalizing done!
Validating...
Result: VALID
Reference time: 0.009711 sec
Reference throughput: 163.256603 GFLOPS
Your Avg. time: 0.043684 sec
Your Avg. throughput: 36.293564 GFLOPS
[rank 0] Finalizing...
[rank 0] Finalizing done!
salloc: Relinquishing job allocation 31998
salloc --nodes 2 --ntasks-per-node 1 --cpus-per-task=32 --partition=shpc mpirun --bind-to none --mca btl openib,self --mca btl_openib_allow_ib true ./main -v 1024 384 1664
salloc: Pending job allocation 32000
salloc: job 32000 queued and waiting for resources
salloc: job 32000 has been allocated resources
salloc: Granted job allocation 32000
Options:
Problem size: M = 1024, N = 384, K = 1664
Number of iterations: 1
Number of warmup iterations: 0
Print matrix: off
Validation: on
[rank 0] Initializing matrices...
[rank 0] Initializing matrices done!
[rank 0] Initializing...
[rank 0] Initializing done!
[rank 0] Calculating...(iter=0)
[rank 1] Initializing...
[rank 1] Initializing done!
[rank 1] Calculating...(iter=0)
[rank 0] 0.039524 sec
[rank 1] 0.039523 sec
[rank 1] Finalizing...
[rank 1] Finalizing done!
Validating...
Result: VALID
Reference time: 0.010008 sec
Reference throughput: 129.723186 GFLOPS
Your Avg. time: 0.039524 sec
Your Avg. throughput: 33.109531 GFLOPS
[rank 0] Finalizing...
[rank 0] Finalizing done!
salloc: Relinquishing job allocation 32000


salloc --nodes 2 --ntasks-per-node 1 --cpus-per-task=32 --partition=shpc mpirun --bind-to none --mca btl openib,self --mca btl_openib_allow_ib true ./main -v 1792 640 2048
salloc: Pending job allocation 32001
salloc: job 32001 queued and waiting for resources
salloc: job 32001 has been allocated resources
salloc: Granted job allocation 32001
Options:
Problem size: M = 1792, N = 640, K = 2048
Number of iterations: 1
Number of warmup iterations: 0
Print matrix: off
Validation: on
[rank 0] Initializing matrices...
[rank 0] Initializing matrices done!
[rank 0] Initializing...
[rank 0] Initializing done!
[rank 0] Calculating...(iter=0)
[rank 1] Initializing...
[rank 1] Initializing done!
[rank 1] Calculating...(iter=0)
[rank 0] 0.057950 sec
[rank 1] 0.057957 sec
[rank 1] Finalizing...
[rank 1] Finalizing done!
Validating...
Result: VALID
Reference time: 0.020290 sec
Reference throughput: 160.032831 GFLOPS
Your Avg. time: 0.057958 sec
Your Avg. throughput: 81.852587 GFLOPS
[rank 0] Finalizing...
[rank 0] Finalizing done!
salloc: Relinquishing job allocation 32001
salloc --nodes 2 --ntasks-per-node 1 --cpus-per-task=32 --partition=shpc mpirun --bind-to none --mca btl openib,self --mca btl_openib_allow_ib true ./main -v 384 896 640
salloc: Pending job allocation 32002
salloc: job 32002 queued and waiting for resources
salloc: job 32002 has been allocated resources
salloc: Granted job allocation 32002
Options:
Problem size: M = 384, N = 896, K = 640
Number of iterations: 1
Number of warmup iterations: 0
Print matrix: off
Validation: on
[rank 0] Initializing matrices...
[rank 0] Initializing matrices done!
[rank 0] Initializing...
[rank 0] Initializing done!
[rank 0] Calculating...(iter=0)
[rank 1] Initializing...
[rank 1] Initializing done!
[rank 1] Calculating...(iter=0)
[rank 0] 0.042412 sec
[rank 1] 0.042411 sec
[rank 1] Finalizing...
[rank 1] Finalizing done!
Validating...
Result: VALID
Reference time: 0.002840 sec
Reference throughput: 155.089775 GFLOPS
Your Avg. time: 0.042412 sec
Your Avg. throughput: 10.381977 GFLOPS
[rank 0] Finalizing...
[rank 0] Finalizing done!
salloc: Relinquishing job allocation 32002

(d)

```
shpc121@a00:~/snu_shpc21/hw4/mat_mul$ make performance
salloc --nodes 2 --ntasks-per-node 1 --cpus-per-task=32
ow_ib true ./main -v -w 3 -n 3 8192 8192 8192
salloc: Pending job allocation 31610
salloc: job 31610 queued and waiting for resources
salloc: job 31610 has been allocated resources
salloc: Granted job allocation 31610
Options:
  Problem size: M = 8192, N = 8192, K = 8192
  Number of iterations: 3
  Number of warmup iterations: 3
  Print matrix: off
  Validation: on

[rank 0] Initializing matrices...
[rank 0] Initializing matrices done!
[rank 0] Initializing...
[rank 0] Initializing done!
[rank 0] Warming up...
[rank 1] Initializing...
[rank 1] Initializing done!
[rank 1] Warming up...
[rank 0] 4.799108 sec
[rank 0] Warming up...
[rank 1] 4.799122 sec
[rank 1] Warming up...
[rank 0] 4.539626 sec
[rank 0] Warming up...
[rank 1] 4.539651 sec
[rank 1] Warming up...
[rank 0] 4.342257 sec
[rank 0] Calculating...(iter=0)
[rank 1] 4.342289 sec
[rank 1] Calculating...(iter=0)
[rank 0] 4.242279 sec
[rank 0] Calculating...(iter=1)
[rank 1] 4.242320 sec
[rank 1] Calculating...(iter=1)
[rank 0] 3.858924 sec
[rank 0] Calculating...(iter=2)
[rank 1] 3.858953 sec
[rank 1] Calculating...(iter=2)
[rank 0] 4.090955 sec
[rank 1] 4.090983 sec
[rank 1] Finalizing...
[rank 1] Finalizing done!
Validating...
Result: VALID
Reference time: 8.362420 sec
Reference throughput: 131.482464 GFLOPS
Your Avg. time: 4.064053 sec
Your Avg. throughput: 270.545625 GFLOPS
[rank 0] Finalizing...
[rank 0] Finalizing done!
salloc: Relinquishing job allocation 31610
```