One-sided messaging MPI Put is used to move data from every process to every other process to where it belongs.

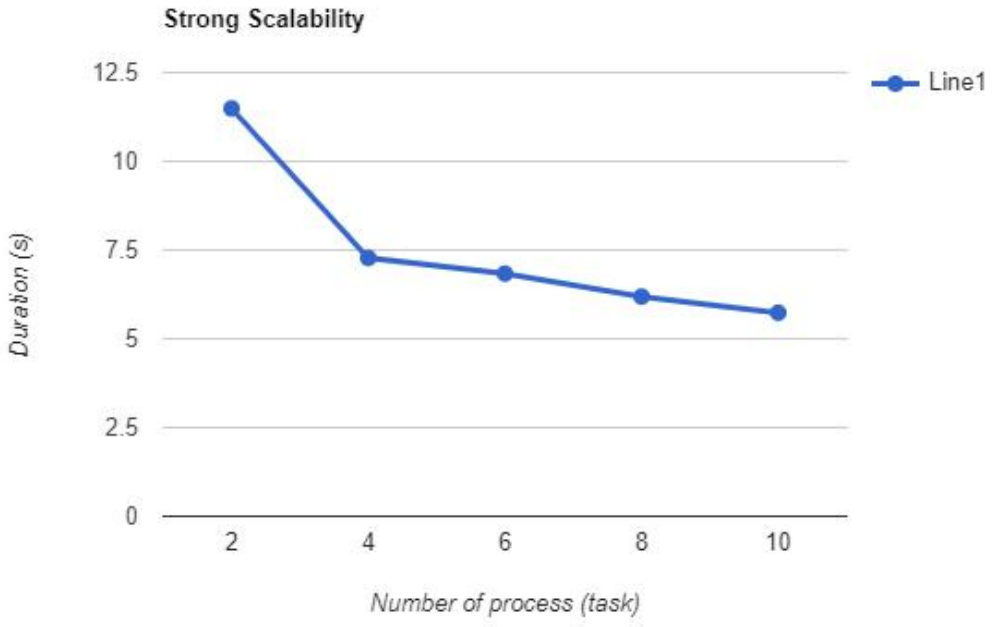
Related command line options in srun/sbatch:
-p, --partition: controls which partition is used for the job
-c, --cpus-per-task: controls the number of CPUs allocated per task
-N, --nodes: controls the minimum/maximum number of nodes allocated to the job
--cpu-bind: controls binding of tasks to CPUs (srun only)
--ntasks-per-node: controls the maximum number of tasks per allocated node
-n, --ntasks: controls the number of tasks to be created for the job

To make the total data size be controlled, -z=2 distribution is used. Srun is directly run instead of sbatch.

Command:
srun -p secondary-fdr --mpi=pmi2 --time=01:00:00 --cpu-bind=cores
--cpus-per-task=4 --nodes=2 **--ntasks=N**
/projects/cs/cs484/sing_exec.sh ./build/bin/sorter -z 2 -a **A** -b **B** &

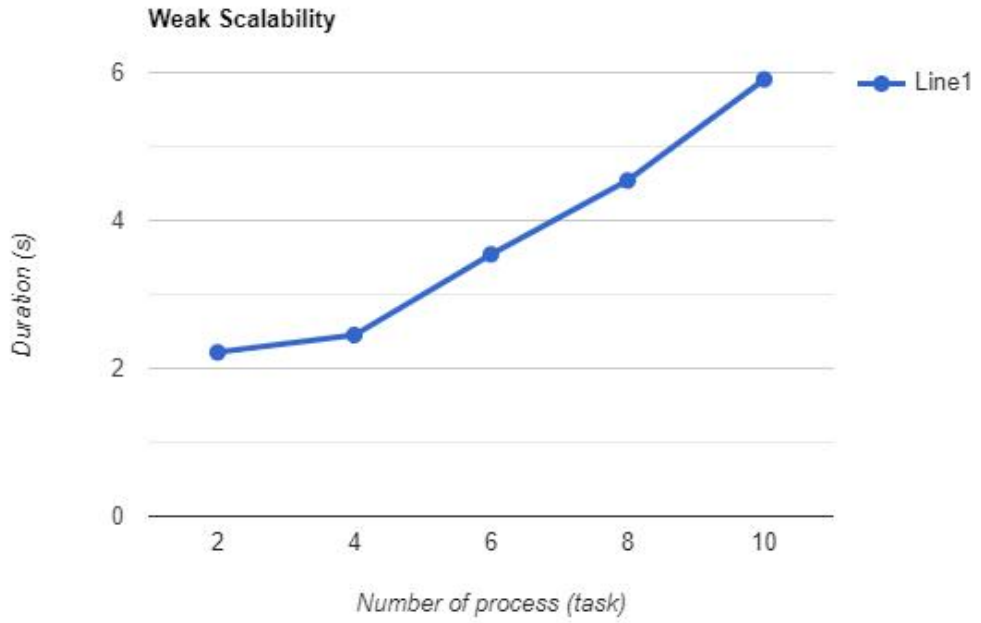
1. strong scaling: total data size constant and changes the number of ranks
Configuration:

N	**A**	**B**
2	5000000	10000000
4	2500000	5000000
6	1666666	3333333
8	1250000	2500000
10	1000000	2000000



2. weak scaling: keeps the data-size per rank roughly constant and adds more ranks
Configuration:

N	A	B
2	1000000	2000000
4	1000000	2000000
6	1000000	2000000
8	1000000	2000000
10	1000000	2000000



Appendix:

1. Strong Scaling Experiment:

Command:
srun -p secondary-fdr --mpi=pmi2 --time=01:00:00 --cpu-bind=cores
--cpus-per-task=4 --nodes=2 **--ntasks=2**
/projects/cs/cs484/sing_exec.sh ./build/bin/sorter -z 2 **-a 5000000 -b 10000000** &
Result:
RESULTS: Total_Data : 15000000
RESULTS: Duration_Rebalance 2.5916 s
RESULTS: Duration_Sort_1 0.579686 s
RESULTS: Duration_Splitters 0.366971 s
RESULTS: Duration_Move 7.21942 s

RESULTS: Duration_Sort_2 0.731384 s
RESULTS: Duration_Total 11.4891 s

Command:
srun -p secondary-fdr --mpi=pmi2 --time=01:00:00 --cpu-bind=cores
--cpus-per-task=4 --nodes=2 **--ntasks=4**
/projects/cs/cs484/sing_exec.sh ./build/bin/sorter -z 2 **-a 2500000 -b 5000000** &
Result:
RESULTS: Total_Data : 15000000
RESULTS: Duration_Rebalance 0.36545 s
RESULTS: Duration_Sort_1 0.281882 s
RESULTS: Duration_Splitters 0.183722 s
RESULTS: Duration_Move 6.28073 s
RESULTS: Duration_Sort_2 0.165302 s
RESULTS: Duration_Total 7.27709 s

Command:
srun -p secondary-fdr --mpi=pmi2 --time=01:00:00 --cpu-bind=cores
--cpus-per-task=4 --nodes=2 **--ntasks=6**
/projects/cs/cs484/sing_exec.sh ./build/bin/sorter -z 2 **-a 1666666 -b 3333333** &
Result:
RESULTS: Total_Data : 14999997
RESULTS: Duration_Rebalance 0.866643 s
RESULTS: Duration_Sort_1 0.180355 s
RESULTS: Duration_Splitters 0.125609 s
RESULTS: Duration_Move 5.56372 s
RESULTS: Duration_Sort_2 0.0996543 s
RESULTS: Duration_Total 6.83598 s

Command:
srun -p secondary-fdr --mpi=pmi2 --time=01:00:00 --cpu-bind=cores
--cpus-per-task=4 --nodes=2 **--ntasks=8**
/projects/cs/cs484/sing_exec.sh ./build/bin/sorter -z 2 **-a 1250000 -b 2500000** &
Result:
RESULTS: Total_Data : 15000000
RESULTS: Duration_Rebalance 0.338173 s
RESULTS: Duration_Sort_1 0.134349 s
RESULTS: Duration_Splitters 0.101353 s
RESULTS: Duration_Move 5.54381 s
RESULTS: Duration_Sort_2 0.0710045 s
RESULTS: Duration_Total 6.18869 s

Command:
srun -p secondary-fdr --mpi=pmi2 --time=01:00:00 --cpu-bind=cores

--cpus-per-task=4 --nodes=2 **--ntasks=10**
/projects/cs/cs484/sing_exec.sh ./build/bin/sorter -z 2 **-a 1000000 -b 2000000** &
Result:
RESULTS: Total_Data : 15000000
RESULTS: Duration_Rebalance 0.573223 s
RESULTS: Duration_Sort_1 0.111823 s
RESULTS: Duration_Splitters 0.087199 s
RESULTS: Duration_Move 4.89991 s
RESULTS: Duration_Sort_2 0.0620677 s
RESULTS: Duration_Total 5.73422 s

2. Weak Scaling Experiment:

Command:
srun -p secondary-fdr --mpi=pmi2 --time=01:00:00 --cpu-bind=cores
--cpus-per-task=4 --nodes=2 **--ntasks=2**
/projects/cs/cs484/sing_exec.sh ./build/bin/sorter -z 2 **-a 1000000 -b 2000000** &
Result:
RESULTS: Total_Data : 3000000
RESULTS: Duration_Rebalance 0.501827 s
RESULTS: Duration_Sort_1 0.10371 s
RESULTS: Duration_Splitters 0.0666019 s
RESULTS: Duration_Move 1.42112 s
RESULTS: Duration_Sort_2 0.12336 s
RESULTS: Duration_Total 2.21662 s

Command:
srun -p secondary-fdr --mpi=pmi2 --time=01:00:00 --cpu-bind=cores
--cpus-per-task=4 --nodes=2 **--ntasks=4**
/projects/cs/cs484/sing_exec.sh ./build/bin/sorter -z 2 **-a 1000000 -b 2000000** &
Result:
RESULTS: Total_Data : 6000000
RESULTS: Duration_Rebalance 0.155234 s
RESULTS: Duration_Sort_1 0.105459 s
RESULTS: Duration_Splitters 0.103121 s
RESULTS: Duration_Move 2.01664 s
RESULTS: Duration_Sort_2 0.0701045 s
RESULTS: Duration_Total 2.45055 s

Command:
srun -p secondary-fdr --mpi=pmi2 --time=01:00:00 --cpu-bind=cores
--cpus-per-task=4 --nodes=2 **--ntasks=6**
/projects/cs/cs484/sing_exec.sh ./build/bin/sorter -z 2 **-a 1000000 -b 2000000** &

Result:
RESULTS: Total_Data : 9000000
RESULTS: Duration_Rebalance 0.53346 s
RESULTS: Duration_Sort_1 0.105748 s
RESULTS: Duration_Splitters 0.0825828 s
RESULTS: Duration_Move 2.7617 s
RESULTS: Duration_Sort_2 0.0586041 s
RESULTS: Duration_Total 3.5421 s

Command:
srun -p secondary-fdr --mpi=pmi2 --time=01:00:00 --cpu-bind=cores
--cpus-per-task=4 --nodes=2 **--ntasks=8**
/projects/cs/cs484/sing_exec.sh ./build/bin/sorter -z 2 **-a 1000000 -b 2000000** &
Result:
RESULTS: Total_Data : 12000000
RESULTS: Duration_Rebalance 0.275282 s
RESULTS: Duration_Sort_1 0.105948 s
RESULTS: Duration_Splitters 0.0856285 s
RESULTS: Duration_Move 4.01583 s
RESULTS: Duration_Sort_2 0.0574447 s
RESULTS: Duration_Total 4.54013 s

Command:
srun -p secondary-fdr --mpi=pmi2 --time=01:00:00 --cpu-bind=cores
--cpus-per-task=4 --nodes=2 **--ntasks=10**
/projects/cs/cs484/sing_exec.sh ./build/bin/sorter -z 2 **-a 1000000 -b 2000000** &
Result:
RESULTS: Total_Data : 15000000
RESULTS: Duration_Rebalance 0.541384 s
RESULTS: Duration_Sort_1 0.11326 s
RESULTS: Duration_Splitters 0.0884146 s
RESULTS: Duration_Move 5.10181 s
RESULTS: Duration_Sort_2 0.062663 s
RESULTS: Duration_Total 5.90753 s

Default:
RESULTS: Total_Data : 13709001
RESULTS: Duration_Rebalance 1.45115 s
RESULTS: Duration_Sort_1 0.16658 s
RESULTS: Duration_Splitters 0.818473 s
RESULTS: Duration_Move 5.20701 s
RESULTS: Duration_Sort_2 0.187534 s
RESULTS: Duration_Total 7.83075 s

RESULTS: Total_Data : 21734533
RESULTS: Duration_Rebalance 1.14828 s
RESULTS: Duration_Sort_1 0.314924 s
RESULTS: Duration_Splitters 1.35704 s
RESULTS: Duration_Move 9.71272 s
RESULTS: Duration_Sort_2 0.377721 s
RESULTS: Duration_Total 12.9107 s

RESULTS: Total_Data : 18961101
RESULTS: Duration_Rebalance 1.87821 s
RESULTS: Duration_Sort_1 0.26287 s
RESULTS: Duration_Splitters 1.1649 s
RESULTS: Duration_Move 10.4317 s
RESULTS: Duration_Sort_2 0.265555 s
RESULTS: Duration_Total 14.0032 s

-N2:
RESULTS: Total_Data : 19849286
RESULTS: Duration_Rebalance 0.859286 s
RESULTS: Duration_Sort_1 0.27194 s
RESULTS: Duration_Splitters 1.22086 s
RESULTS: Duration_Move 10.4809 s
RESULTS: Duration_Sort_2 0.341623 s
RESULTS: Duration_Total 13.1746 s

sbatch -p secondary-fdr ./scripts/batch_script.slurm -n **N** --ntasks-per-node=**6**
./bin/sorter -a **A** -b **B**
12 250,000 500,000
RESULTS: Total_Data : 3908743
RESULTS: Duration_Rebalance 0.315679 s
RESULTS: Duration_Sort_1 0.0221222 s
RESULTS: Duration_Splitters 0.0197733 s
RESULTS: Duration_Move 0.984673 s
RESULTS: Duration_Sort_2 0.0121891 s
RESULTS: Duration_Total 1.35444 s

sbatch -p secondary-fdr ./scripts/batch_script.slurm -n **N** --ntasks-per-node=**6**
./bin/sorter -a **A** -b **B**
2 1,500,000 3,000,000
RESULTS: Total_Data : 16792843
RESULTS: Duration_Rebalance 0.875609 s
RESULTS: Duration_Sort_1 0.150399 s
RESULTS: Duration_Splitters 0.116703 s
RESULTS: Duration_Move 6.26736 s
RESULTS: Duration_Sort_2 0.0789628 s
RESULTS: Duration_Total 7.48903 s

sbatch -p secondary-fdr ./scripts/batch_script.slurm -n **N** --ntasks-per-node=**6**
./bin/sorter -a **A** -b **B**
2 1,500,000 3,000,000
RESULTS: Total_Data : 18829874
RESULTS: Duration_Rebalance 0.621269 s
RESULTS: Duration_Sort_1 0.170297 s
RESULTS: Duration_Splitters 0.118785 s
RESULTS: Duration_Move 6.17761 s
RESULTS: Duration_Sort_2 0.0976252 s
RESULTS: Duration_Total 7.18558 s

sbatch -p secondary-fdr ./scripts/batch_script.slurm -n **N** --ntasks-per-node=**6**
./bin/sorter -a **A** -b **B**
12 250,000 500,000
RESULTS: Total_Data : 3143501
RESULTS: Duration_Rebalance 0.156826 s
RESULTS: Duration_Sort_1 0.025582 s
RESULTS: Duration_Splitters 0.0219123 s
RESULTS: Duration_Move 0.942171 s
RESULTS: Duration_Sort_2 0.0143323 s
RESULTS: Duration_Total 1.16082 s

sbatch -p secondary-fdr ./scripts/batch_script.slurm -n **N** --ntasks-per-node=**12**
--nodes=1
./bin/sorter -a **A** -b **B**
12 250,000 500,000
RESULTS: Total_Data : 3008763
RESULTS: Duration_Rebalance 0.247186 s
RESULTS: Duration_Sort_1 0.0244928 s
RESULTS: Duration_Splitters 0.0193101 s
RESULTS: Duration_Move 0.972213 s
RESULTS: Duration_Sort_2 0.0129909 s

RESULTS: Duration_Total 1.27619 s

sbatch -p secondary-fdr ./scripts/batch_script.slurm -n **N** --ntasks-per-node=**6**
./bin/sorter -a **A** -b **B**
12 1,500,000 3,000,000
RESULTS: Total_Data : 18002263
RESULTS: Duration_Rebalance 2.9909 s
RESULTS: Duration_Sort_1 0.162395 s
RESULTS: Duration_Splitters 0.117475 s
RESULTS: Duration_Move 6.78754 s
RESULTS: Duration_Sort_2 0.0887563 s
RESULTS: Duration_Total 10.1471 s

sbatch -p secondary-fdr ./scripts/batch_script.slurm
--ntasks-per-node 6 --ntasks 12
./bin/sorter -a **A** -b **B**
1,500,000 3,000,000
srun: error: Unable to create step for job 5405265: More processors requested than permitted
srun: Warning: can't honor --ntasks-per-node set to 4 which doesn't match the requested tasks 12 with the number of requested nodes 4. Ignoring --ntasks-per-node.
FATAL ERROR: Checksums did not match after rebalancing data. Data must have changed.srun: error: golub129: tasks 0-2: Exited with exit code 1
srun: error: golub131: tasks 6-8: Exited with exit code 1
srun: error: golub132: tasks 9-11: Exited with exit code 1
srun: error: golub130: tasks 3-5: Exited with exit code 1

srun -p secondary-fdr --mpi=pmi2 --cpu-bind=cores --nodes=4 --ntasks 12 /projects/cs/cs484/sing_exec.sh ./build/bin/sorter -a 1500000 -b 3000000 &
29872356

srun -p secondary-fdr --mpi=pmi2 --cpu-bind=cores --nodes=2 --ntasks 4 /projects/cs/cs484/sing_exec.sh ./build/bin/sorter -a 1500000 -b 3000000 &
3558582

```
srun --mpi=pmi2 --ntasks-per-node 6 \
    --cpu-bind=cores --ntasks 12 \
    /projects/cs/cs484/sing_exec.sh ./bin/sorter -a 1500000 -b 3000000
```

Experiment draft:
mpirun -n 2 bin/sorter
In total, there are 4197600 elements

RESULTS: Total_Data : 4197600
RESULTS: Duration_Rebalance 0.373457 s
RESULTS: Duration_Sort_1 0.189644 s
RESULTS: Duration_Splitters 0.12349 s
RESULTS: Duration_Move 1.39126 s
RESULTS: Duration_Sort_2 0.196214 s
RESULTS: Duration_Total 2.27407 s

mpirun -n 2 bin/sorter -a 1500000 -b 3000000
In total, there are 4591299 elements
RESULTS: Total_Data : 4591299
RESULTS: Duration_Rebalance 0.251928 s
RESULTS: Duration_Sort_1 0.209653 s
RESULTS: Duration_Splitters 0.202875 s
RESULTS: Duration_Move 1.59939 s
RESULTS: Duration_Sort_2 0.231093 s
RESULTS: Duration_Total 2.49494 s

mpirun -n 8 bin/sorter -a 1500000 -b 3000000
In total, there are 16396282 elements
RESULTS: Total_Data : 16396282
RESULTS: Duration_Rebalance 3.11495 s
RESULTS: Duration_Sort_1 0.263911 s
RESULTS: Duration_Splitters 0.578989 s
RESULTS: Duration_Move 8.43402 s
RESULTS: Duration_Sort_2 0.115048 s
RESULTS: Duration_Total 12.5069 s

mpirun -n 8 bin/sorter -a 375000 -b 750000
In total, there are 4402233 elements
RESULTS: Total_Data : 4402233
RESULTS: Duration_Rebalance 0.786732 s
RESULTS: Duration_Sort_1 0.0453481 s
RESULTS: Duration_Splitters 0.469132 s
RESULTS: Duration_Move 2.70409 s
RESULTS: Duration_Sort_2 0.0465152 s
RESULTS: Duration_Total 4.05182 s

mpirun -n 12 bin/sorter -a 250000 -b 500000
In total, there are 3702776 elements
RESULTS: Total_Data : 3702776
RESULTS: Duration_Rebalance 1.80787 s
RESULTS: Duration_Sort_1 0.0452967 s
RESULTS: Duration_Splitters 0.62806 s

RESULTS: Duration_Move 10.477 s
RESULTS: Duration_Sort_2 0.0236818 s
RESULTS: Duration_Total 12.9819 s