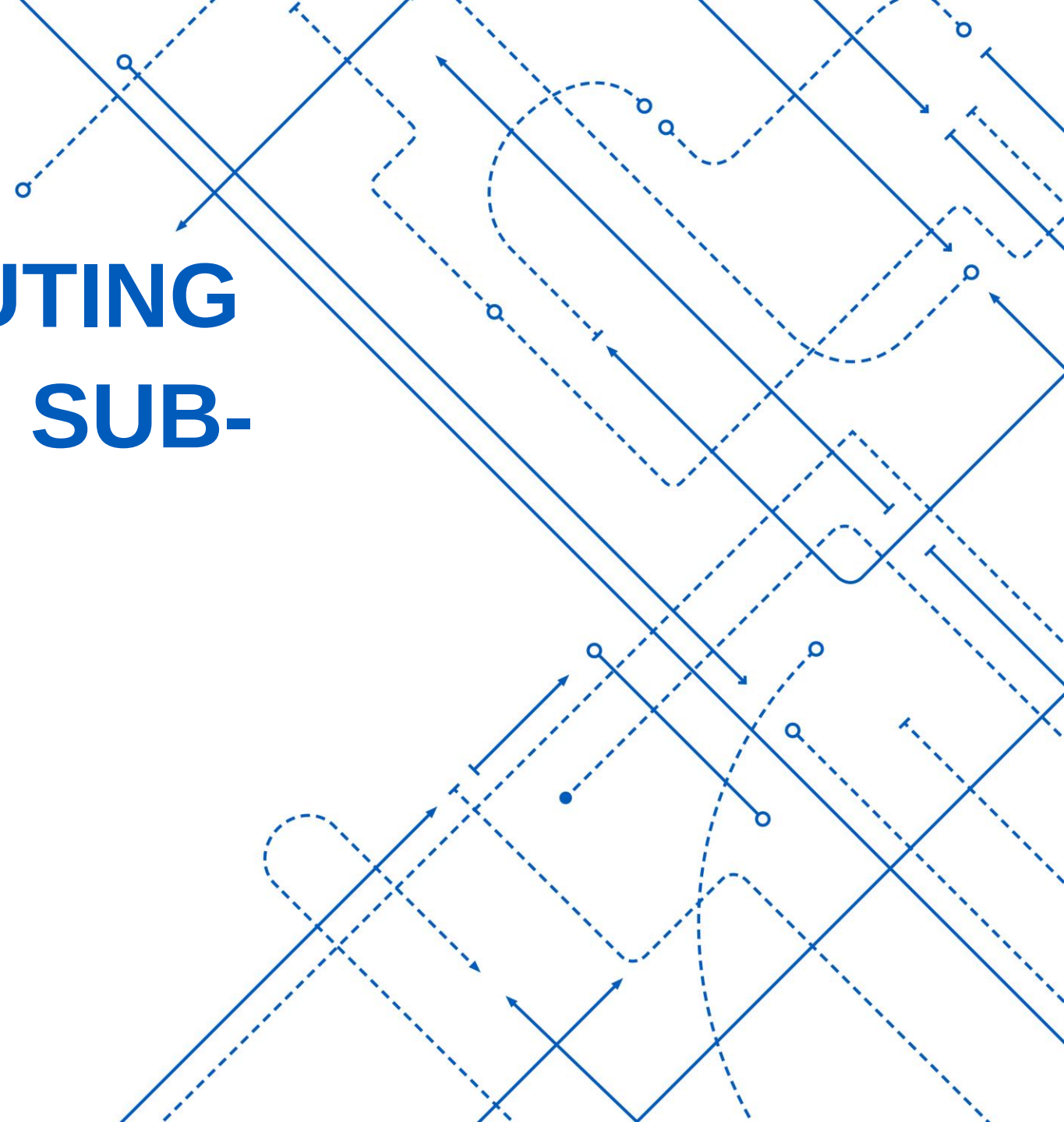

PARALLEL COMPUTING OF MAXIMUM SUM SUB-ARRAY

Using MPI

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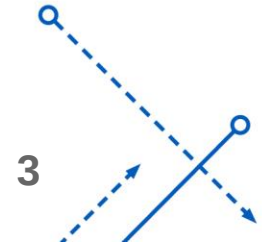
Contents

Objective

- To experience the power of parallel computing using MPI by implementing a parallel prefix operation.

Problem Statement

- Application of parallel prefix: Identifying the maximum sum that can be computed using contiguous elements in an array.
- Eg, Consider the Array = **{-2 , 1 , -3 , 4 , -1 , 2 , 1 , -5 , 4}**
- Maximum sum = 6



Parallel Prefix Algorithm

- Step 1: Perform a parallel prefix sum operation.

Eg:

Array = {-2 , 1 , -3 , 4 , -1 , 2 , 1 , -5 , 4} => {-2 , -1 , -4 , 0 , -1 , 1 , 2 , -3 , 1}

Parallel Prefix Sum

- Step 2: Perform a parallel postfix max operation on the resultant array

Max Array = {-2 , -1 , -4 , 0 , -1 , 1 , 2 , -3 , 1} => {2 , 2 , 2 , 2 , 2 , 2 , 2 , 1 , 1}

Parallel Postfix Max

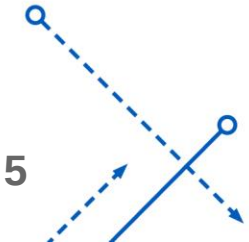
Parallel Prefix Algorithm

- Step 3: Compute the following formula in parallel for every element,

Max_Array[i] – Sum[i] + Array[i]:

{2 , 4 , 3 , 6 , 2 , 3 , 1 , -1 , 4}

- The maximum element in this array will be broadcasted to every processor.



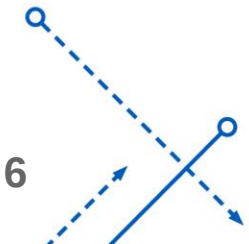
Parallel Prefix Algorithm

- Let the problem size be **“n”.**
- Let the number of processors we have be **“p”.**
- What if **n >> p** (very much greater)?
  - ✓ We can divide the problem so that each processor get a chunk of data of size **n/p.**
  - ✓ Consider,

Array = {-2 , 1 , -3 , 4 , -1 , 2 , 1 , -5 , 4, ...} size = n.

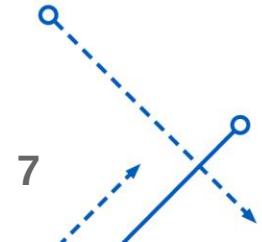
Size n/p Size n/p Size n/p ……

- ✓ Every processor will be responsible for a single chunk and will perform the parallel prefix/postfix operation in sequential manner within the n/p chunk of data.



Parallel Prefix Sum Simulation

- {-2, 1, -3 } {4, -1, 2} {1, -5, 4}
- {-2, -1, -4 } {4, 3, 5} {1, -4, 0}
- {-2, -1, -4 } {4, 3, 1} {1, -4, 1}
- {-2, -1, -4 } {0, -1, 1} {2, -3, 1} => Solution.



Slurm Script

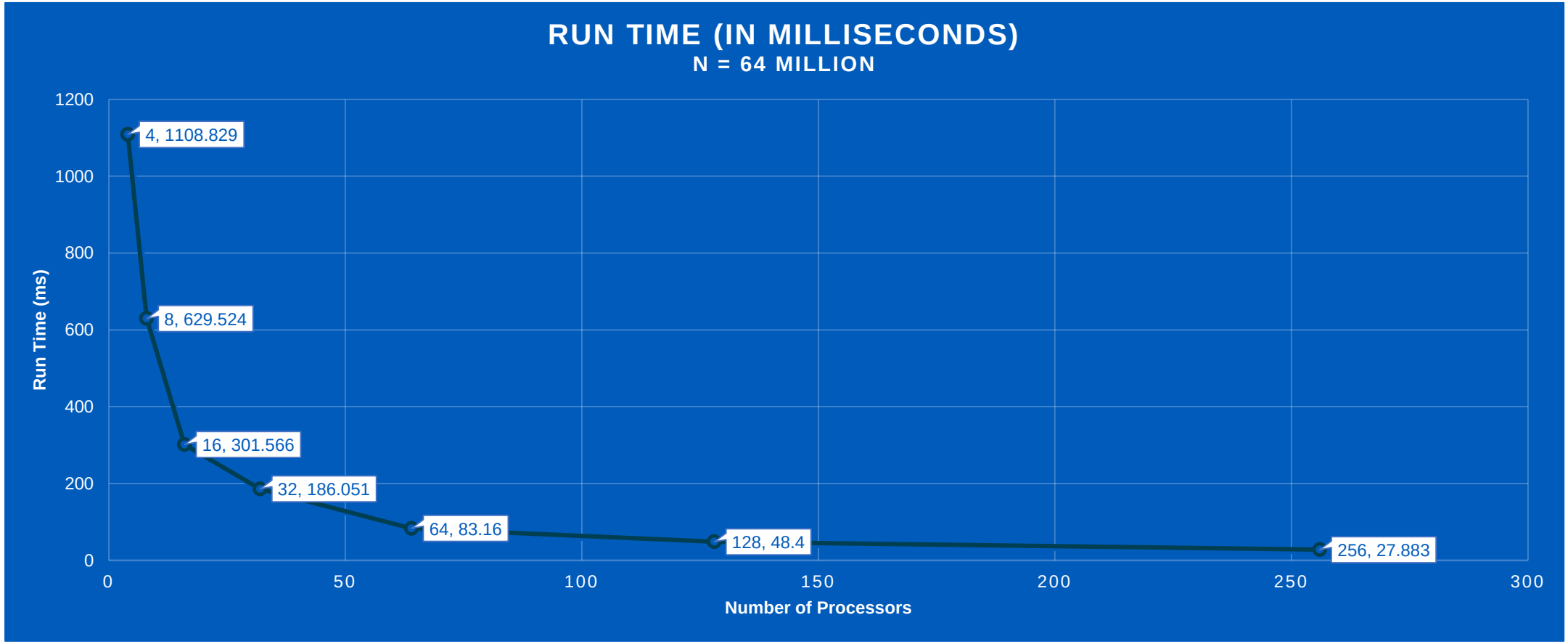
```
#!/bin/sh
#SBATCH --nodes=16
#SBATCH --ntasks-per-node=1
#SBATCH --constraint=IB
#SBATCH --partition=general-compute --qos=general-compute
#SBATCH --time=12:00:00
#SBATCH --mail-type=END
#SBATCH --mail-user=adityasu@buffalo.edu
#SBATCH --output=64m_output_16.out
#SBATCH --job-name=TestingMaxSum64m_mpi16
module load intel/14.0
module load intel-mpi/4.1.3
module list
mpicc -lm -o obj1 max_subarray.c
ulimit -s unlimited

export I_MPI_PMI_LIBRARY=/usr/lib64/libpmi.so

mpicc -lm -o obj1 max_subarray.c
srun ./obj1 4000000

#
echo "All done!"
```

Analysis – Constant ‘n’ & Variable Node ‘p’

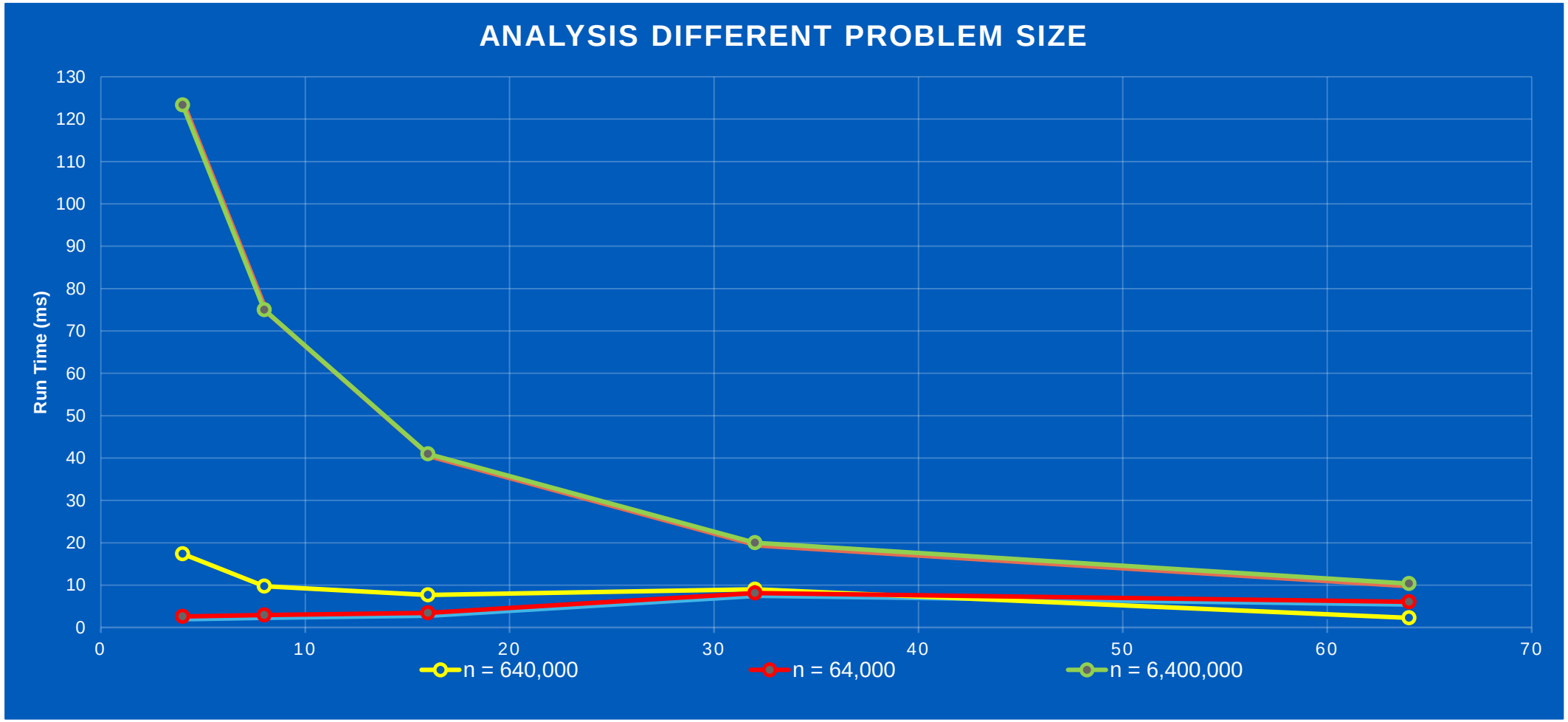
- Problem Size – 64,000,000 (64 Million)
- Sequential running time (in milliseconds) : 2780.9118 ms

Number of Processors	Run Time (in milliseconds)
4	1108.829 ms
8	629.524 ms
16	301.566 ms
32	186.051 ms
64	83.160 ms
128	48.400 ms
256	27.883 ms

Analysis – Constant ‘n’ & Variable Node ‘p’



Analysis - Different Problem Size



Analysis – Increasing Running Time

Observation

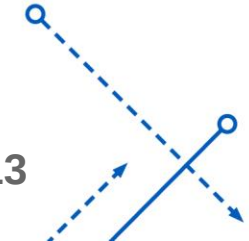
- Using more processors decreases the run time of an algorithm (Not in all cases!).

- For smaller problem size, (n = 64,000), lower number of processors lead to better performance.

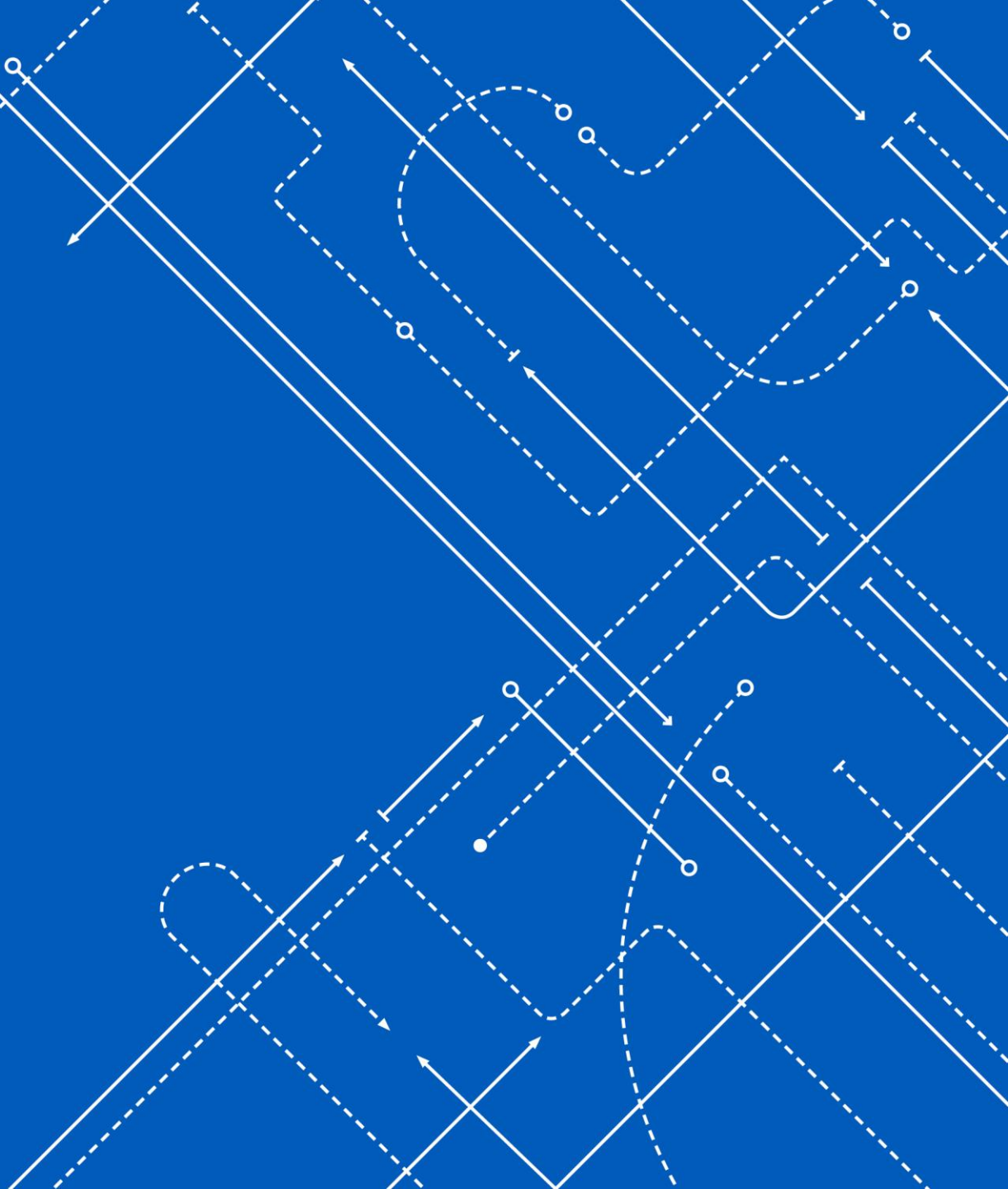
  Why? – Because the time taken to communicate between the nodes is more than the time taken to run the actual algorithm.

- This invalidates the assumption that “Throw in more processors for better performance”.

  For any problem of size ‘n’, after a certain number of processors ‘p’, the run time of the algorithm begins to increase due to the overhead of communication between the processors as stated above.



THANK YOU



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