

---

---

# CS 301

## High-Performance Computing

---

---

### Lab 4

Bhavya Shah (202101426)  
Yash Kodwani (202101418)

February 28, 2024

# Contents

<b>1</b>	<b>Hardware Details</b>	<b>3</b>
1.1	HPC Cluster . . . . .	3
1.2	Lab 207 PC . . . . .	4
<b>2</b>	<b>Description of Problem</b>	<b>4</b>
<b>3</b>	<b>Complexity of algorithm (serial)</b>	<b>5</b>
<b>4</b>	<b>Optimization strategy</b>	<b>5</b>
<b>5</b>	<b>Graphs</b>	<b>5</b>
<b>6</b>	<b>Explanation of results</b>	<b>6</b>

# 1 Hardware Details

## 1.1 HPC Cluster

```
[202101418@gics0 ~]$ lscpu
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Byte Order:            Little Endian
CPU(s):                24
On-line CPU(s) list:   0-23
Thread(s) per core:    2
Core(s) per socket:    6
Socket(s):             2
NUMA node(s):          2
Vendor ID:             GenuineIntel
CPU family:            6
Model:                 63
Model name:            Intel(R) Xeon(R) CPU E5-2620 v3 @ 2.40GHz
Stepping:              2
CPU MHz:               2600.062
BogoMIPS:              4804.69
Virtualization:        VT-x
L1d cache:             32K
L1i cache:             32K
L2 cache:              256K
L3 cache:              15360K
NUMA node0 CPU(s):    0-5,12-17
NUMA node1 CPU(s):    6-11,18-23
[202101418@gics0 ~]$
```

Figure 1: lscpu in cmd

As we can see from the above image

- CPU - 16
- Socket - 2
- Cores per Socket - 8
- Size of L1 cache - 32K
- Size of L2 cache - 256K
- Size of L3 cache - 15360K

## 1.2 Lab 207 PC

```
student@test-OptiPlex-3020:~$ lscpu
Architecture: x86_64
CPU op-mode(s): 32-bit, 64-bit
Address sizes: 39 bits physical, 48 bits virtual
Byte Order: Little Endian
CPU(s): 4
On-line CPU(s) list: 0-3
Vendor ID: GenuineIntel
Model name: Intel(R) Core(TM) i5-4590 CPU @ 3.30GHz
CPU family: 6
Model: 60
Thread(s) per core: 1
Core(s) per socket: 4
Socket(s): 1
Stepping: 3
CPU max MHz: 3700.0000
CPU min MHz: 800.0000
BogoMIPS: 6585.05
Flags: fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mc
a cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss
ht tm pbe syscall nx pdpe1gb rdtscp lm constant_tsc arc
h_perfmnon pebs bts rep_good nopl xtopology nonstop_tsc
cpuid aperfmperf pni pclmulqdq dtes64 monitor ds_cpl vm
x_smx est tm2 sse3 sdbg fma cx16 xtpr pdcm pcid sse4_1
sse4_2 x2apic movbe popcnt tsc_deadline_timer aes xsave
e_avx f16c rdrand lahf_lm abm cpuid_fault epb invpcid_s
ingle pti ssbd lbrs lbrp stibp tpr_shadow vnmi flexprio
rity ept vpid ept_ad fsgsbase tsc_adjust bmi1 avx2 smep
bmi2 erms invpcid xsaveopt dtherm ida arat pln pts md_
clear flush_lid

Virtualization features:
Virtualization: VT-x
Caches (sum of all):
L1d: 128 KiB (4 instances)
L1i: 128 KiB (4 instances)
L2: 1 MiB (4 instances)
L3: 6 MiB (1 instance)
NUMA:
NUMA node(s): 1
NUMA node0 CPU(s): 0-3
Vulnerabilities:
Gather data sampling: Not affected
Itlb multihit: KVM: Mitigation: VMX disabled
L1tf: Mitigation; PTE Inversion; VMX conditional cache flushe
s, SMT disabled
Mds: Mitigation; Clear CPU buffers; SMT disabled
Meltdown: Mitigation; PTI
Mmio stale data: Unknown: No mitigations
Retbleed: Not affected
Spec rstack overflow: Not affected
Spec store bypass: Mitigation; Speculative Store Bypass disabled via prctl
Spectre v1: Mitigation; usercopy/swapgs barriers and __user pointer
sanitization
Spectre v2: Mitigation; Retpolines, IBPB conditional, IBRS_FW, STIB
P disabled, RSB filling, PBRSSB-eIBRS Not affected
Srbds: Mitigation; Microcode
```

Figure 2: lscpu in cmd

- CPU - 4
- Socket - 1
- Cores per Socket - 4
- Size of L1 cache - 32K
- Size of L2 cache - 256K
- Size of L3 cache - 6144K

## 2 Description of Problem

Sorting arrays with merge sort algorithm optimized with multiple threads

### 3 Complexity of algorithm (serial)

$O(N \cdot \log N)$

### 4 Optimization strategy

1. used iterative approach instead of recursive
2. Parallelized merging of sorted arrays

### 5 Graphs

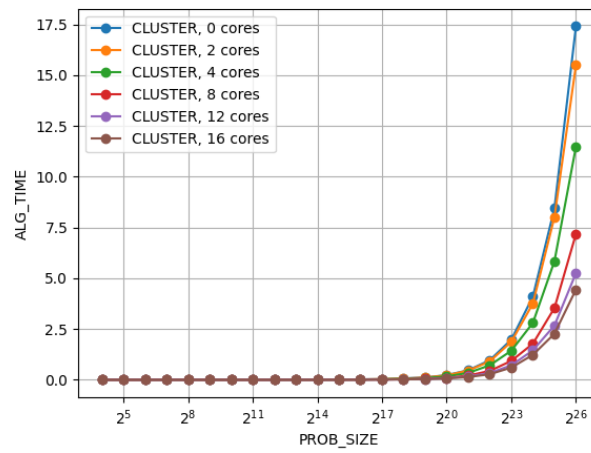


Figure 3: Cluster results

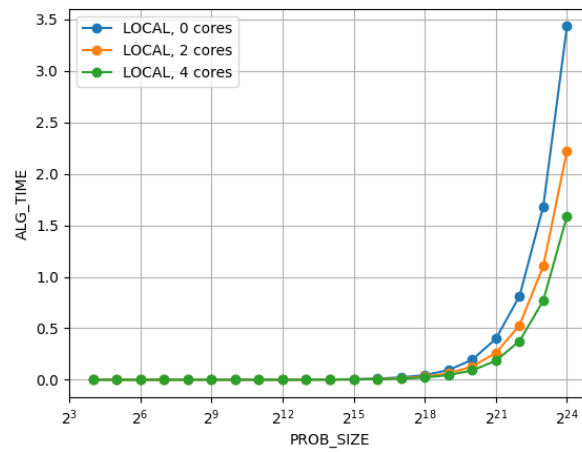


Figure 4: Lab results

## 6 Explanation of results

As the number of threads increases, time decreases as more operations are done simultaneously.