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SYCL FOR HPC: ADAPTING TO DIVERSE CPU ARCHITECTURE

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INTRODUCTION

- Modern HPC systems comprise of diverse range of hardware processing units
  - CPU
  - GPU
  - AI Accelerators or any other XPU
- Every processing hardware has its own programming language.

Lot of efforts towards porting of applications.

WHAT IS SYCL?

SYCL is a standard by Khronos. It offers following features:

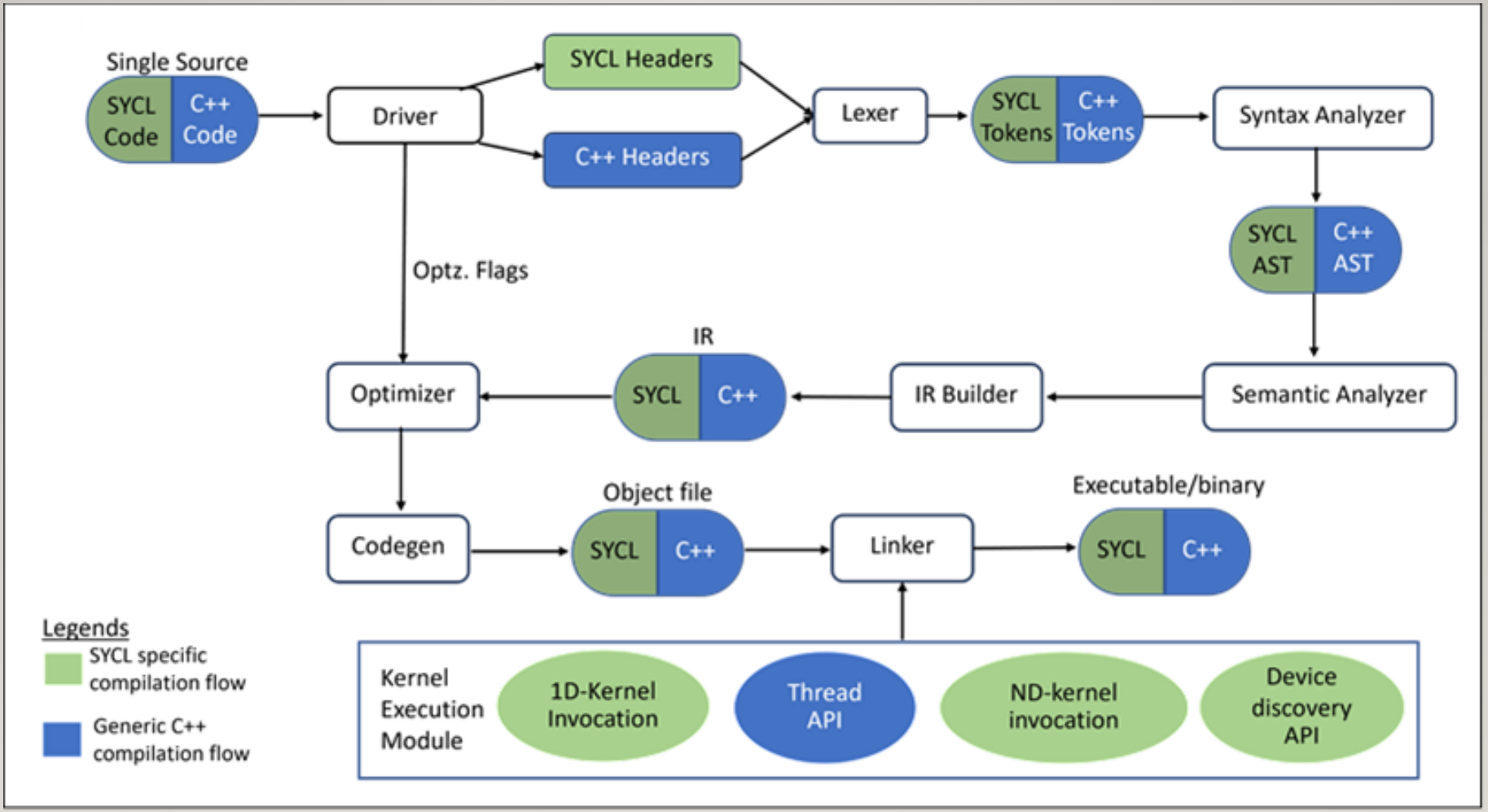
- Programming for Heterogeneous Computing
- Uses modern C++ features
- Single source

MOTIVATION

- Architectures present in CPUs:
  - X86 (Intel & AMD)
  - ARM (NVIDIA's Grace, Fujitsu A64FX)
  - RISC (IBM's POWER-x)
- To develop a scalable and flexible implementation which is not associated to only one specific hardware.

APPROACH

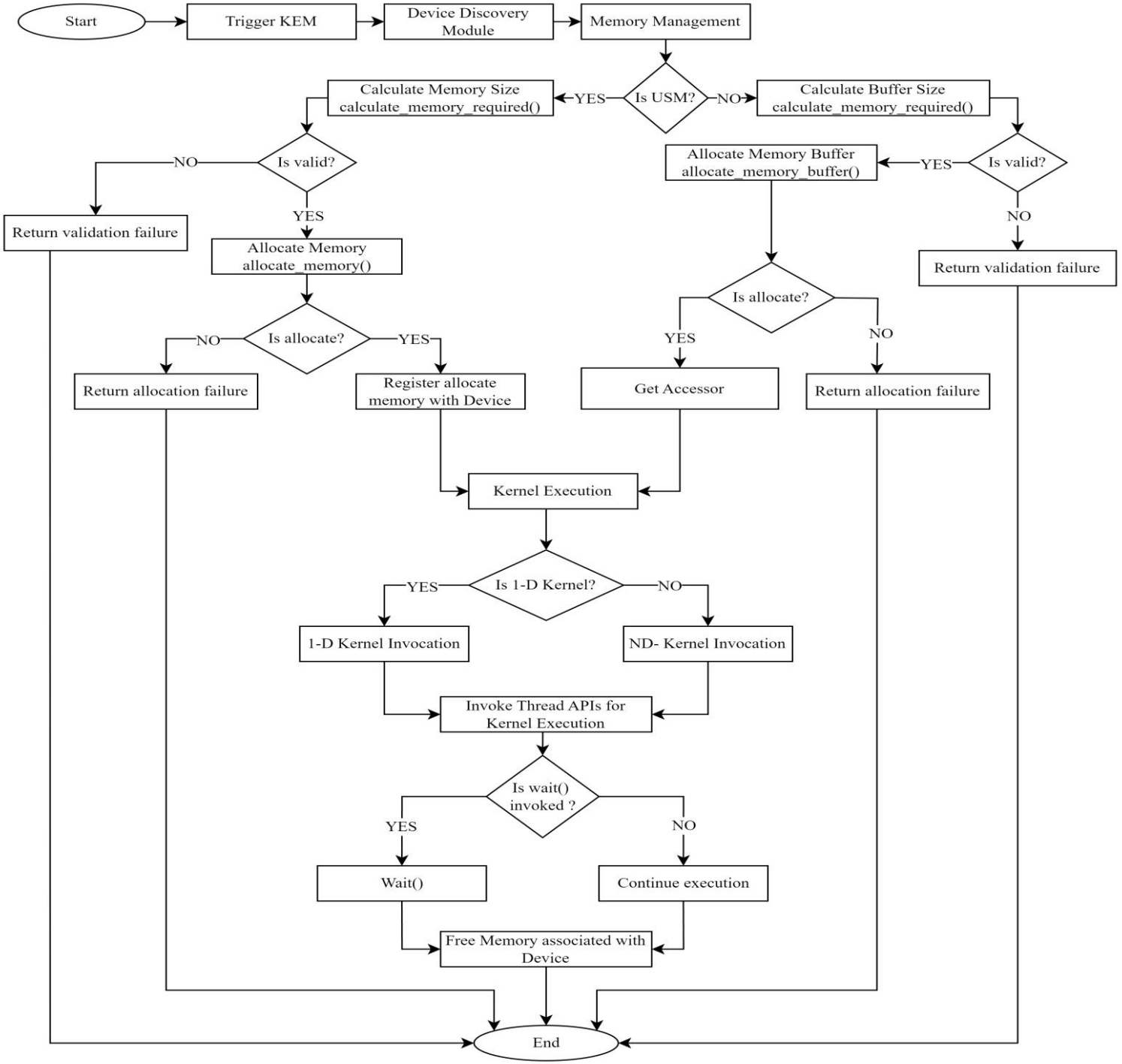
COMPILATION MODEL

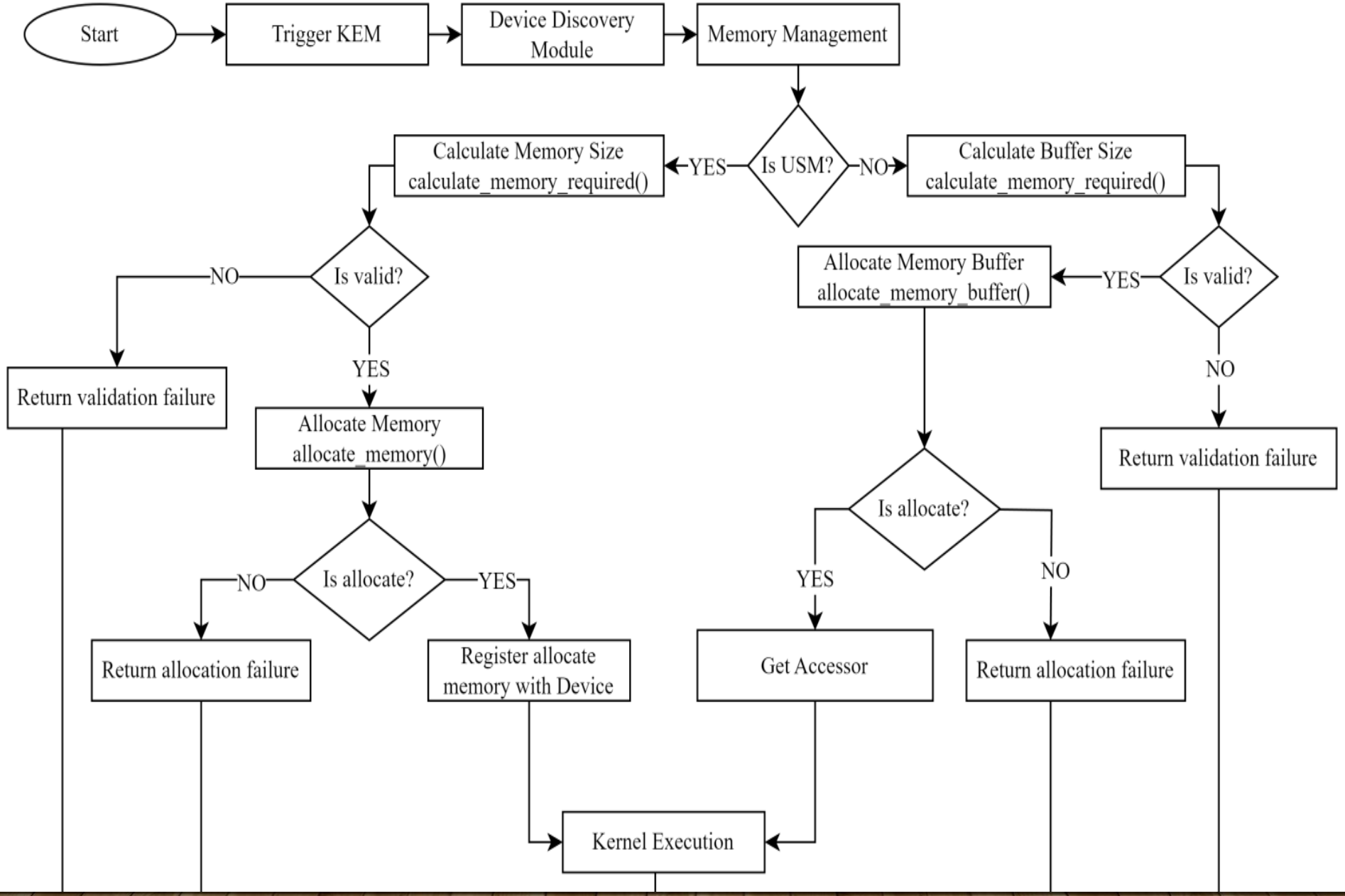


KERNEL EXECUTION MODULE

- **Device Discovery API**
  - Identify the underlying CPU architecture
  - Stores the hardware info
- **1-D Kernel invocation**
  - Creates and manages threads based on device info
  - Leverages the native thread APIs
- **N-D kernel invocation**
  - Converts n-dimensional kernels into single dimensional
  - Leverages the native thread APIs
- Thread API

EXECUTION MODEL


Start
Trigger KEM
Device Discovery Module
Memory Management
Is USM?
YES
Calculate Memory Size
calculate_memory_required()
NO
Calculate Buffer Size
calculate_memory_required()
Is valid?
NO
Return validation failure
YES
Allocate Memory
allocate_memory()
Is allocate?
NO
Return allocation failure
YES
Register allocate memory with Device
Allocate Memory Buffer
allocate_memory_buffer()
YES
Is valid?
NO
Return validation failure
Is allocate?
YES
Get Accessor
NO
Return allocation failure
Kernel Execution
Is 1-D Kernel?
YES
1-D Kernel Invocation
NO
ND- Kernel Invocation
Invoke Thread APIs for Kernel Execution
Is wait() invoked ?
YES
Wait()
NO
Continue execution
Free Memory associated with Device
End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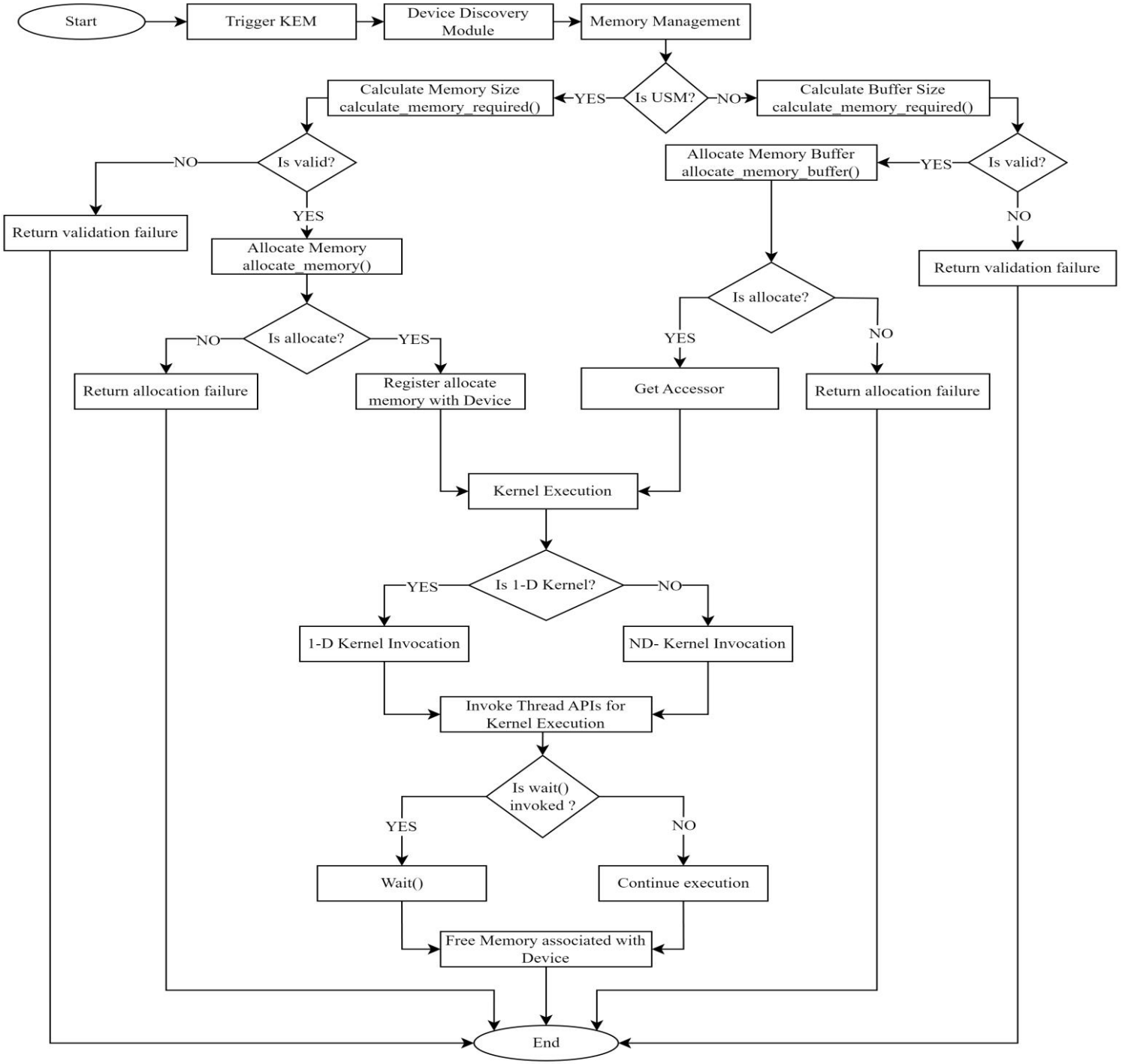
Kernel Execution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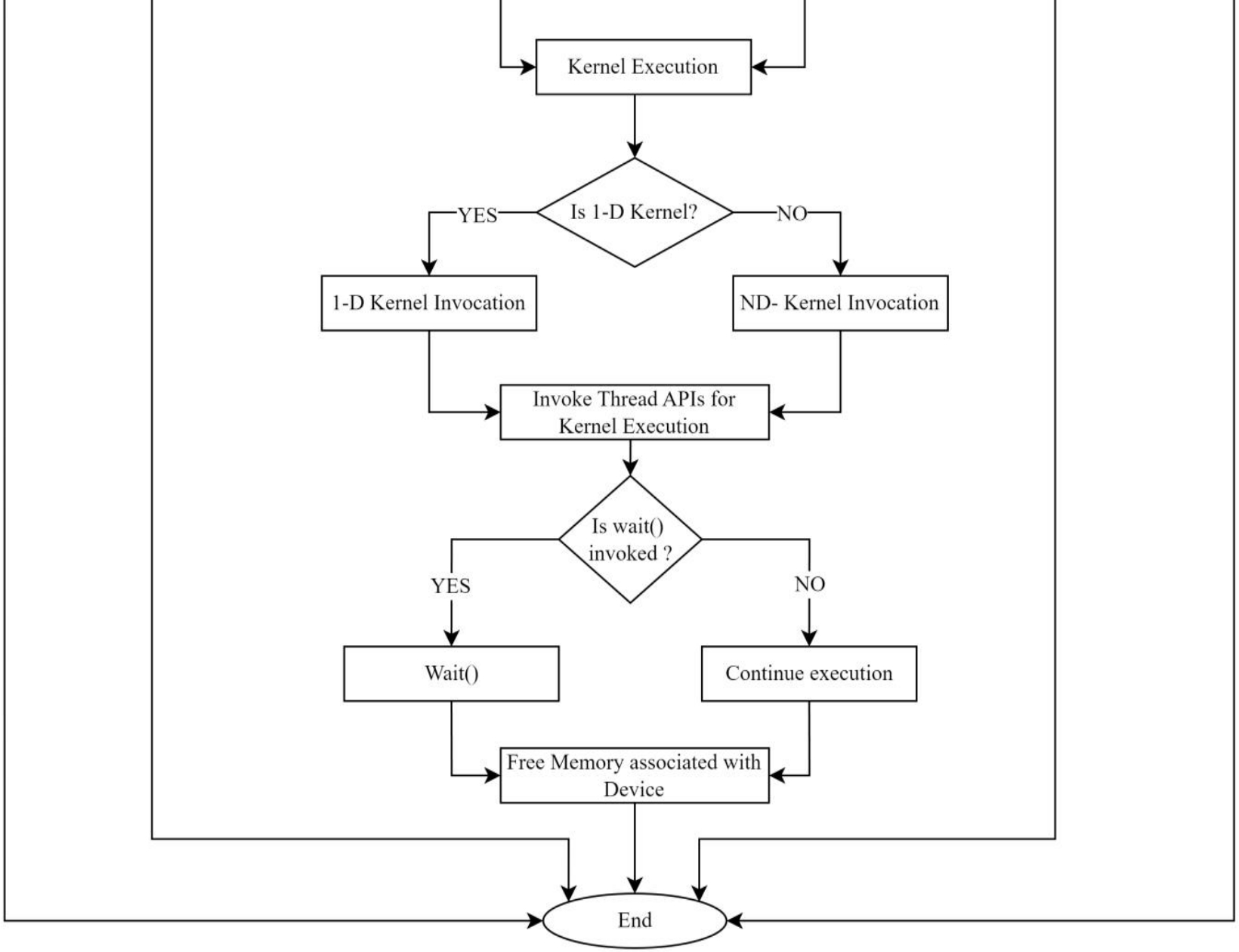
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Wait()
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PERFORMANCE

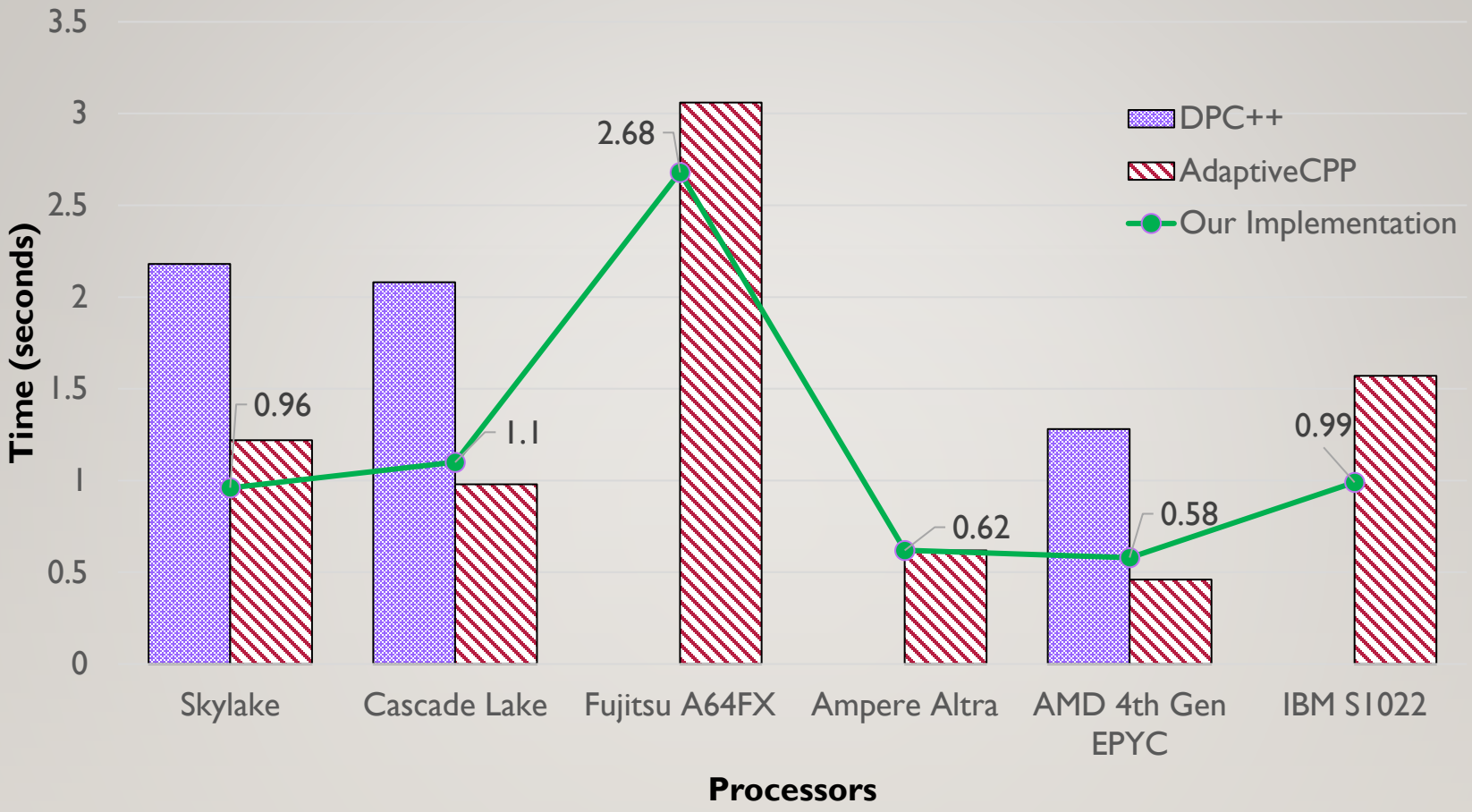
ARCHITECTURES/PROCESSORS USED

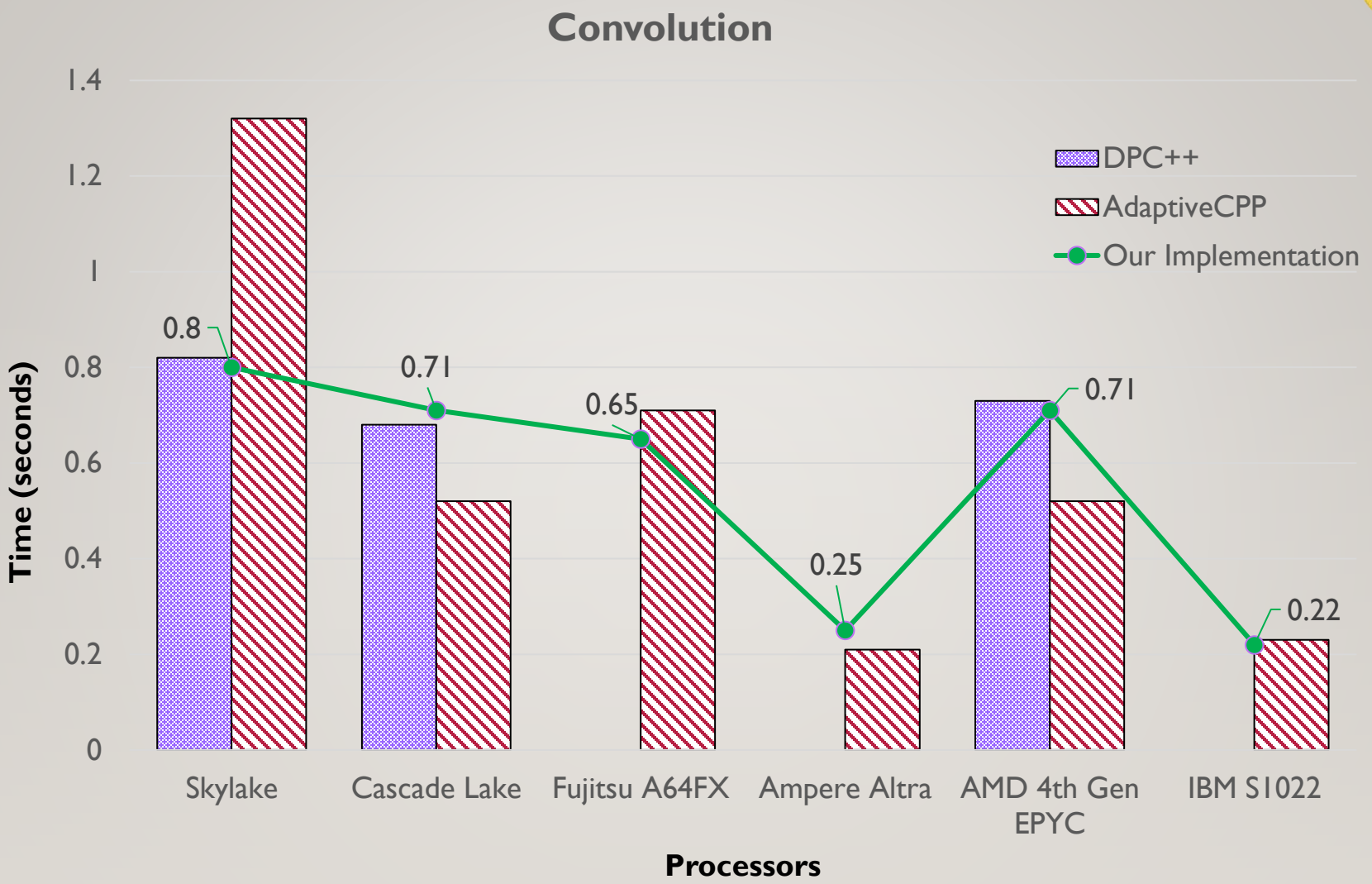
- X86
  - Intel Xeon Gold 6312 (Skylake)
  - Intel Xeon Platinum 8268 (Cascade Lake)
  - AMD Xeon EPYC 4th Gen
- ARM
  - Fujitsu A64FX
  - Ampere Altra
- Power 10
  - IBM S1022

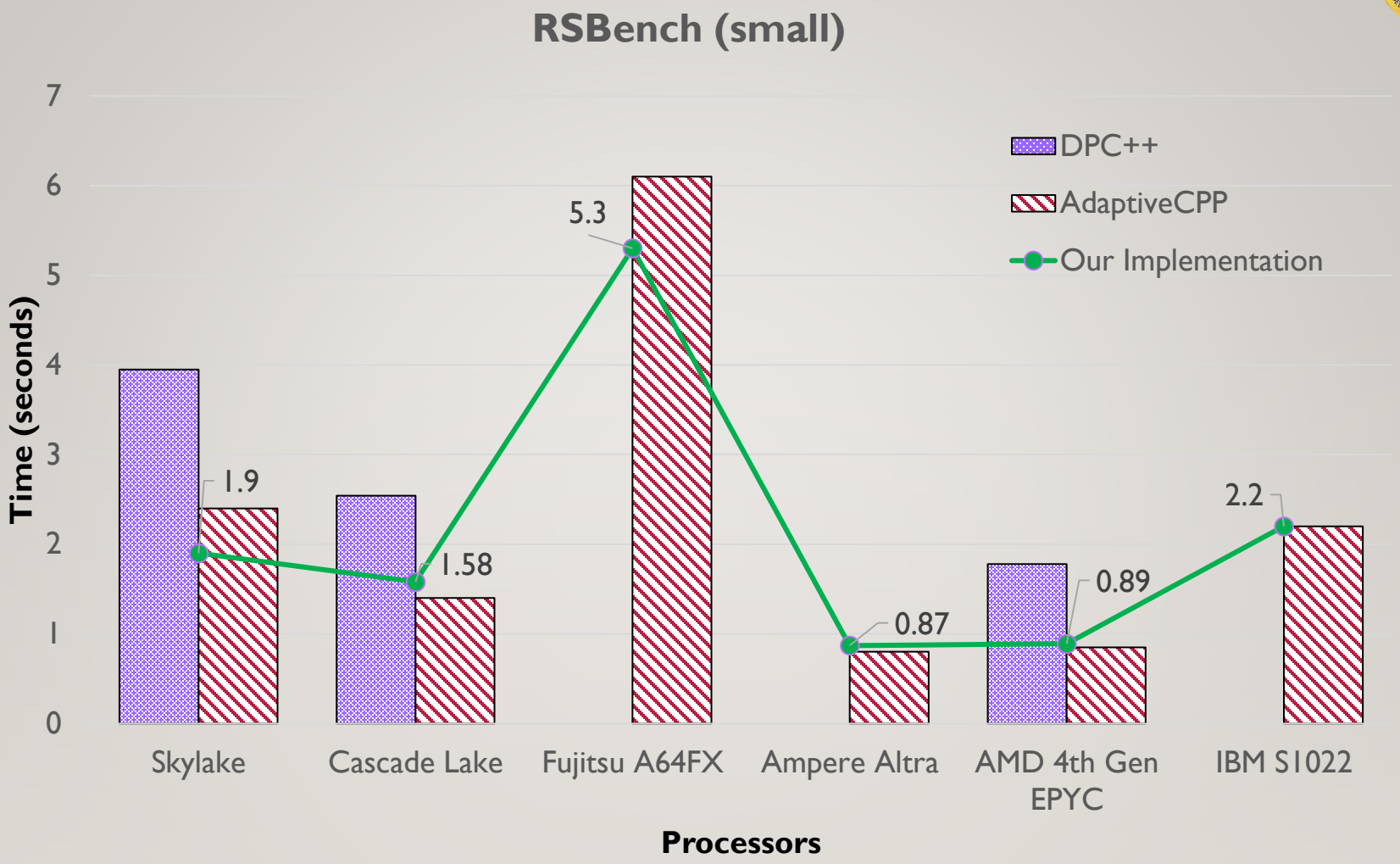
APPLICATIONS

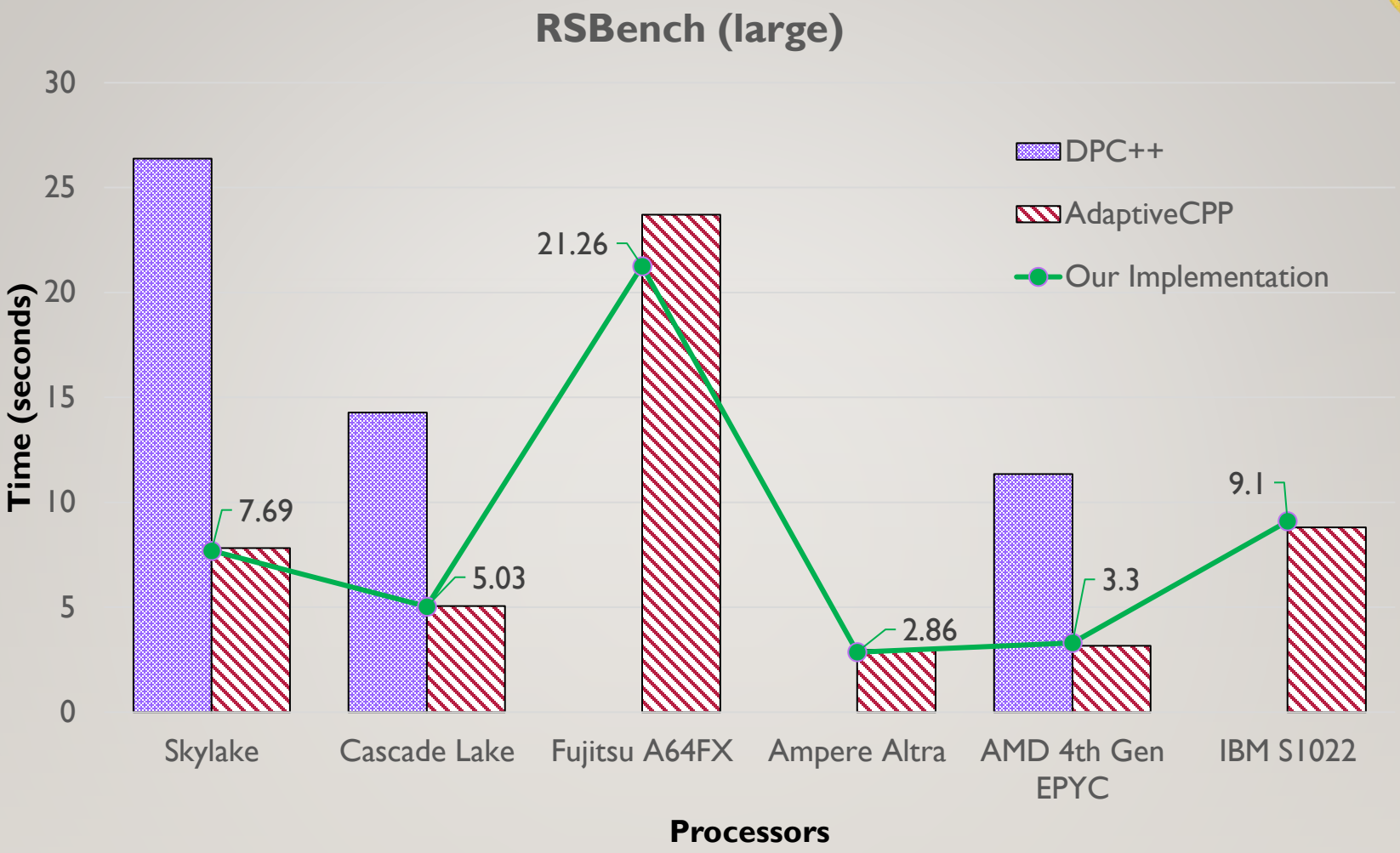
- Heat Equation
  - This application is used to describe the distribution of heat or variation in temperature in a given region over time.
- Convolution
  - Fundamental operation in image processing and computer vision used for tasks like edge detection, image filtering and feature extraction.
- RSBench
  - Represents a key computational kernel of the Monte Carlo neutron transport algorithm.

Heat Equation




Convolution
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Time (seconds)
DPC++
AdaptiveCPP
Our Implementation
0.8
0.71
0.65
0.25
0.71
0.22
Skylake
Cascade Lake
Fujitsu A64FX
Ampere Altra
AMD 4th Gen EPYC
IBM S1022
Processors


RSBench (small)
Time (seconds)
0
1
2
3
4
5
6
7
DPC++
AdaptiveCPP
Our Implementation
1.9
1.58
5.3
0.87
0.89
2.2
Skylake
Cascade Lake
Fujitsu A64FX
Ampere Altra
AMD 4th Gen EPYC
IBM S1022
Processors

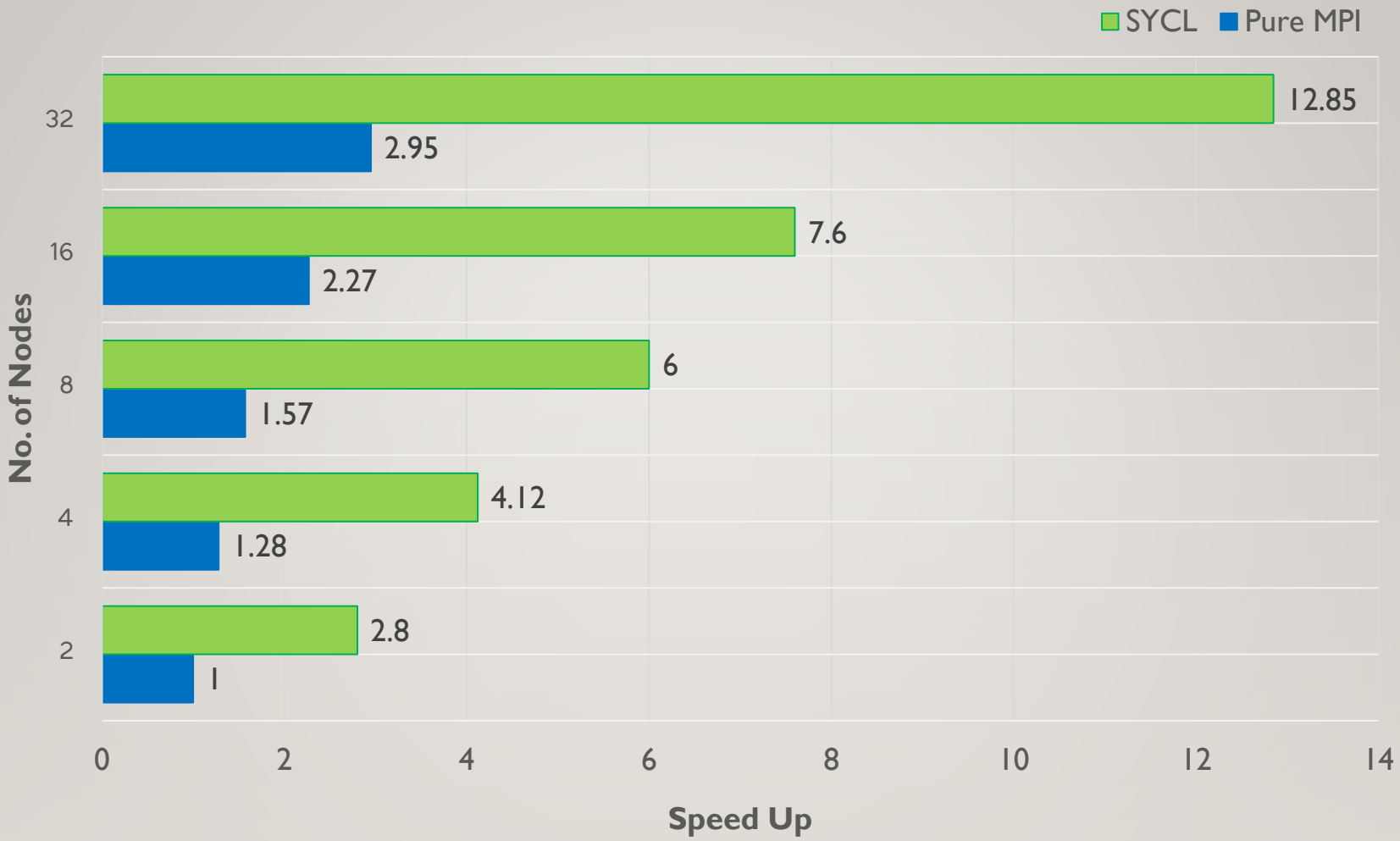

RSBench (large)
30
25
20
15
10
5
0
Time (seconds)
DPC++
AdaptiveCPP
Our Implementation
7.69
5.03
21.26
2.86
3.3
9.1
Skylake
Cascade Lake
Fujitsu A64FX
Ampere Altra
AMD 4th Gen EPYC
IBM S1022
Processors

APPLICATION SCALING

How it performs on a HPC cluster ?

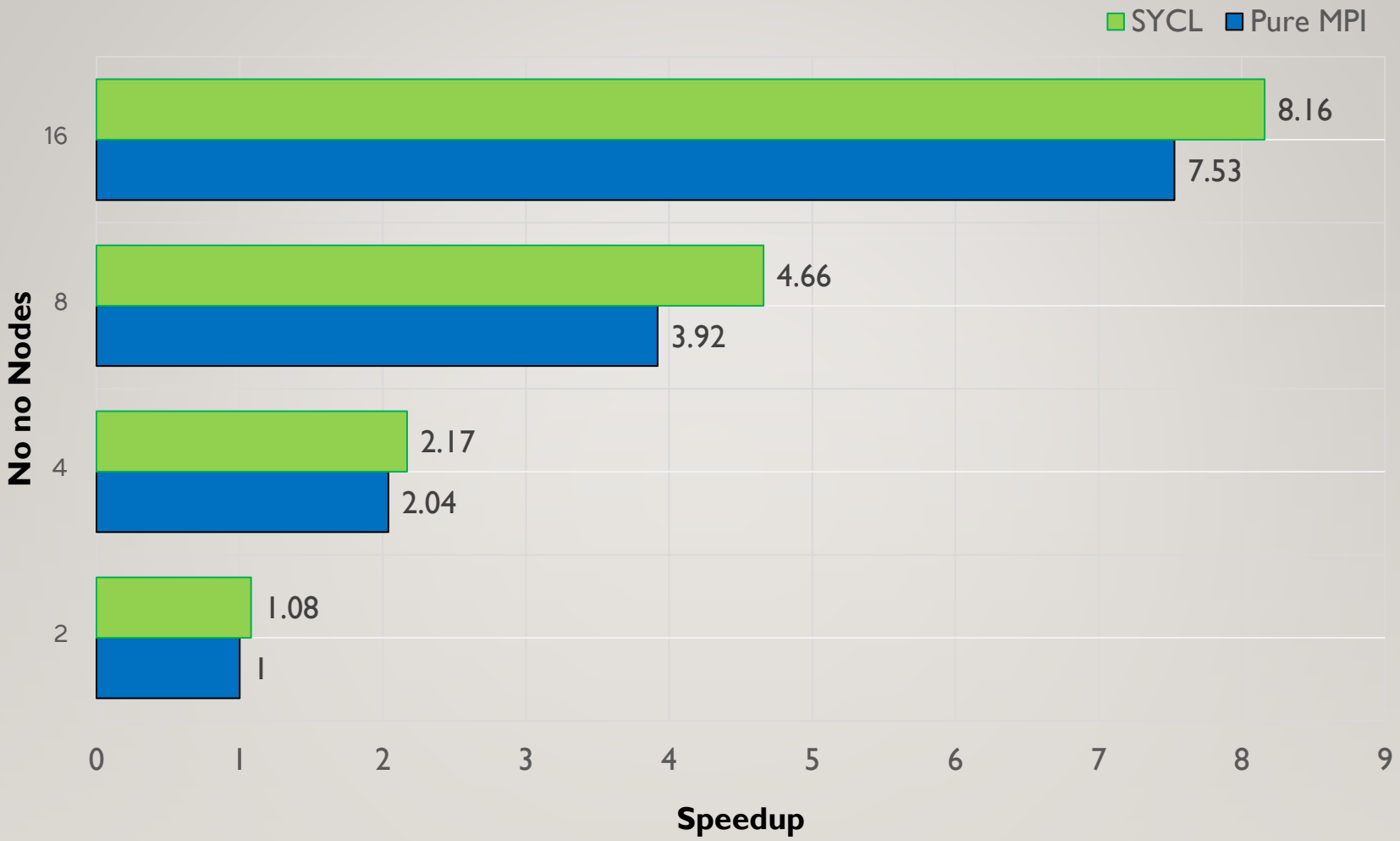
Configuration	Value
Processor	Intel Xeon Platinum 8268
Memory	192 GB
No. of cores/socket	24
No of socket/node	2
Cluster topology	Fat-tree
Peak Bandwidth	100 Gbps
Interconnect	Mellanox Infiniband

MonteCarlo PI (Cluster)



Using Monte-Carlo method for 10 million points.

GEMM (cluster)



Matrix size = 8192 x 8192

CONCLUSION

- We are able to maintain the portability across multiple architectures like X86, ARM and POWER.
- Our implementations performs better by a factor of 1.2x to 1.5x on Fujitsu A64FX and Intel Skylake architectures, while delivering comparable performance to existing SYCL implementations on AMD and Power platforms.
- Our implementation uses native thread APIs making it a versatile SYCL solution.
- Our implementation showcases scaling on HPC cluster environment.

QUERIES ?