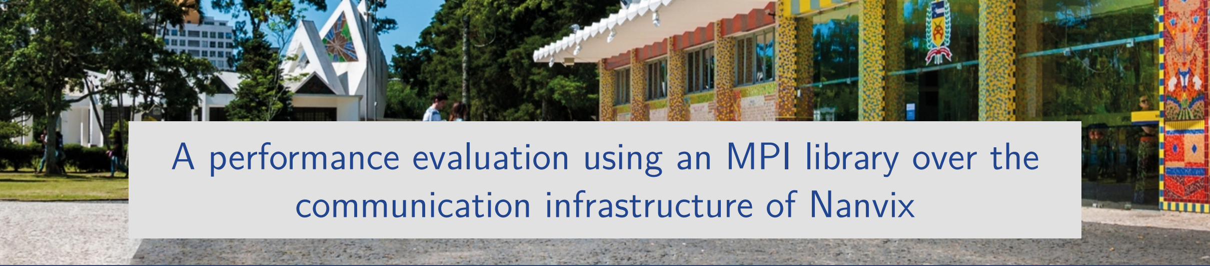

A performance evaluation using an MPI library over the communication infrastructure of Nanvix

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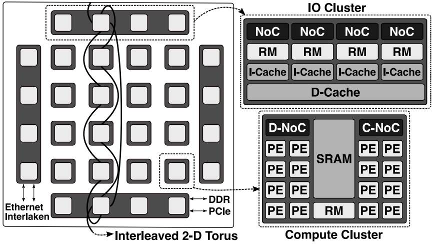
Introduction

- Computational power vs energy consumption
- Lightweight manycores emerged to address high performance and energy efficiency demands (FRANCESQUINI et al., 2015)

Characteristics

- Hundreds or thousands of low-power cores on a single chip
- Heterogeneous environment
- Distributed memory system with small local memories
- Communication through message passing on a rich Network-on-Chip (NoC)



MPPA-256 Architecture

Software Development Challenges

- Data fetching
- Data tiling
- Asynchronous communications (HASCOËT et al., 2017)
- Hand-operated routing

Approaches to address programmability in lightweight manycores:

- **Operating Systems**
  - **Pros**: Bridges hardware intricacies and programmability gaps, providing **portability**
  - **Cons:** Provided interface may be complex, retarding software development
- **Baremetal Runtime Systems**
  - **Pros**: Expose rich and performance-oriented interfaces narrowed to the underlying architecture
  - **Cons:** Mostly vendor-specific, resulting in non-portable software

Duality: fast development process OR better software portability?

Message Passing Interface

- A **portable** message passing standard
- Maintained and defined by the **MPI-Forum**[1]
- Widespread between **industry** and **academia**

- **De facto standard for message passing in HPC!**

[1] MPI-Forum website: https://www.mpi-forum.org

Goal

Provide a **light MPI-compliant library**, designed to cope with **architectural intricacies** of **lightweight manycores**, that is **portable** across multiple architectures and **easily extensible**.

LWMPI

Overview

LWMPI: **L**ightweight **M**essage **P**assing **I**nterface

- Compatible with 3.1 MPI specification (2015)
- Designed **from scratch** to be **light**
- Copes with **architectural intricacies** of lightweight manycores
- Implemented on top of a **POSIX-compliant distributed OS** (Nanvix[2]) to enable **portability** across different lightweight manycore architectures (PENNA et al., 2019)

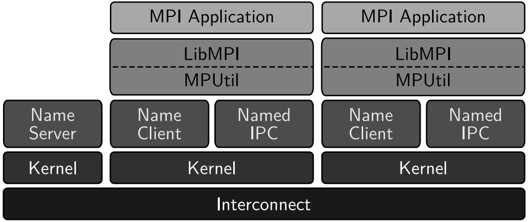
[2] http://www.github.com/nanvix

Actual Support

LWMPI currently supports the following MPI features:

- *Runtime Management* (`MPI_Init` / `MPI_Finalize`)
- *Communicators*
- *Communication groups*
- *Error handlers*
- Standard *datatypes* for the C language
- Point-to-point communication (`MPI_Send` and `MPI_Recv`) in **synchronous mode**

Architecture

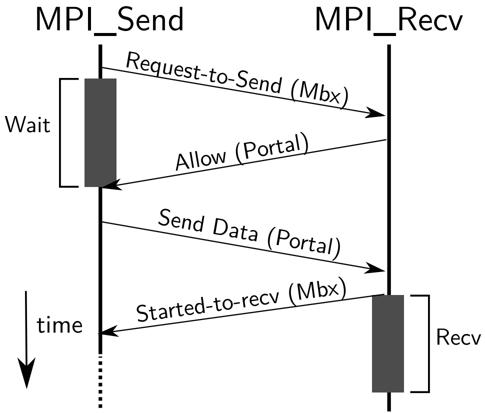


LWMPI Architecture

- `LibMPI`: top-level library that implements the MPI functions in a OS-independent way
- `MPUtil`: interface between `LibMPI` and the OS-level IPC system
  - Includes OS-dependent code

Nanvix Support to LWMPI

- **IPC Abstractions** (SOUTO et al., 2020)
  - `Mailbox`
  - `Portal`
  - `Sync`
- **Runtime Services**
  - Name Server
  - Name Client
  - Named IPC



Communication Protocol

Evaluation

Evaluation Method

- **Applications**: CAP Bench Suite[3] (SOUZA et al., 2017)
  - Exercise different *parallel patterns*, *task types*, *comm. intensities* and *task loads*

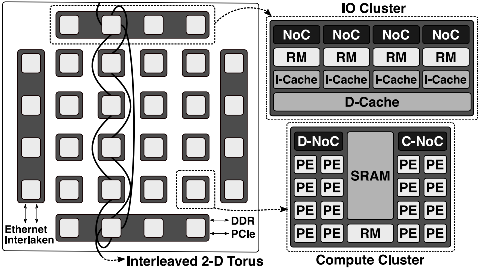
App	Boundary	Parallel Pattern	Comm. Intensity
FN	CPU-bound	MapReduce	Light
GF	CPU/IO Bound	Stencil	Average
KM	IO-bound	Map	Heavy

- **Performance evaluation**
  - **Target architecture**: Kalray MPPA-256 (DINECHIN et al., 2013)
  - **Baseline**: vendor-specific runtime (Kalray Runtime)
  - **Performance metric**: speedup

[3] Publicly available at: https://github.com/nanvix/benchmarks

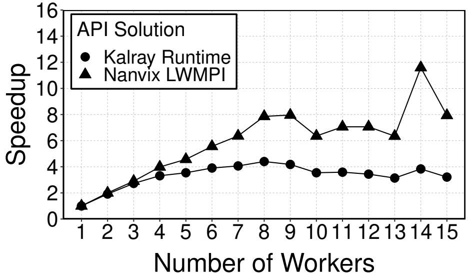
Kalray MPPA-256

- 288 cores (256 GP cores + 32 firmware cores)
- 16 Compute Clusters (CCs)
- 4 I/O Clusters (IOs)
- 2 Network-on-Chips (C-NoC + D-NoC)



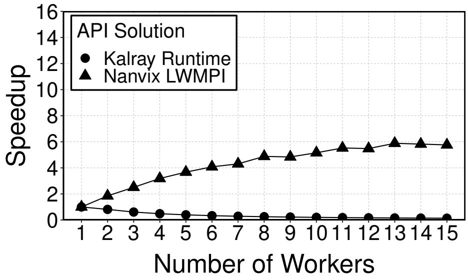
Experimental Scenarios

- CAP Bench apps have a single leader that coordinates the execution, with worker processes varying from 1 to 15 (max.)
- **Problems sizes**:
  - **FN**: numbers ranging from 1000001 to 1000129
  - **GF**: 512 x 512 image and 7 x 7 mask
  - **KM**: 30720 points and 64 centroids
- **Experimental design**
  - 30 trials for each configuration
  - Maximum CV $< 1\%$

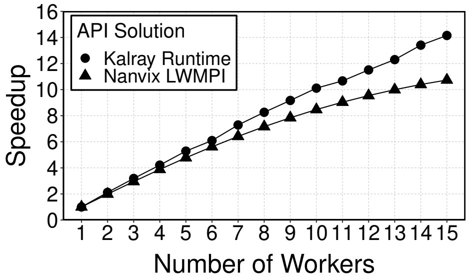


- Communication has little interference, since the kernel is CPU-bound
- Load imbalance with more than 8 workers
- LWMPI shows better scalability
- Easy adaptation of the kernel without significant overheads

GF



- Small problem sizes resulted in insufficient workloads for the Kalray runtime
- Seems to be attenuated as the parallelism increases in LWMPI, proving better scalability also in these situations
- **Possibility of improvement:** asynchronous communications



- LWMPI and Kalray Runtime achieved similar speedups
- LWMPI showed slightly worse scalability due to coarse grain data transfers
- **Possibility of improvement:** a mechanism that dynamically chooses which OS-level comm. abstraction fits better the data transfer granularity

Conclusions

Conclusions

- **Our solution provides better programmability for lightweight manycores, because:**
  - It is based on an industry-standard interface (MPI)
  - It leverages a POSIX-compliant OS
  - It is portable across different lightweight manycore architectures

- **Experimental results**
  - LWMPI presents similar scalability for parallel and distributed problems, when compared to the vendor-specific runtime library (Kalray Runtime)

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Thank you!
Questions?

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Nanvix

- An Open-Source, POSIX compliant, ditributed OS that targets lightweight manycores (<https://github.com/nanvix/>)
- Designed in a distributed fashion ***multikernel***
  - Multiple instances of an assymetric *microkernel*