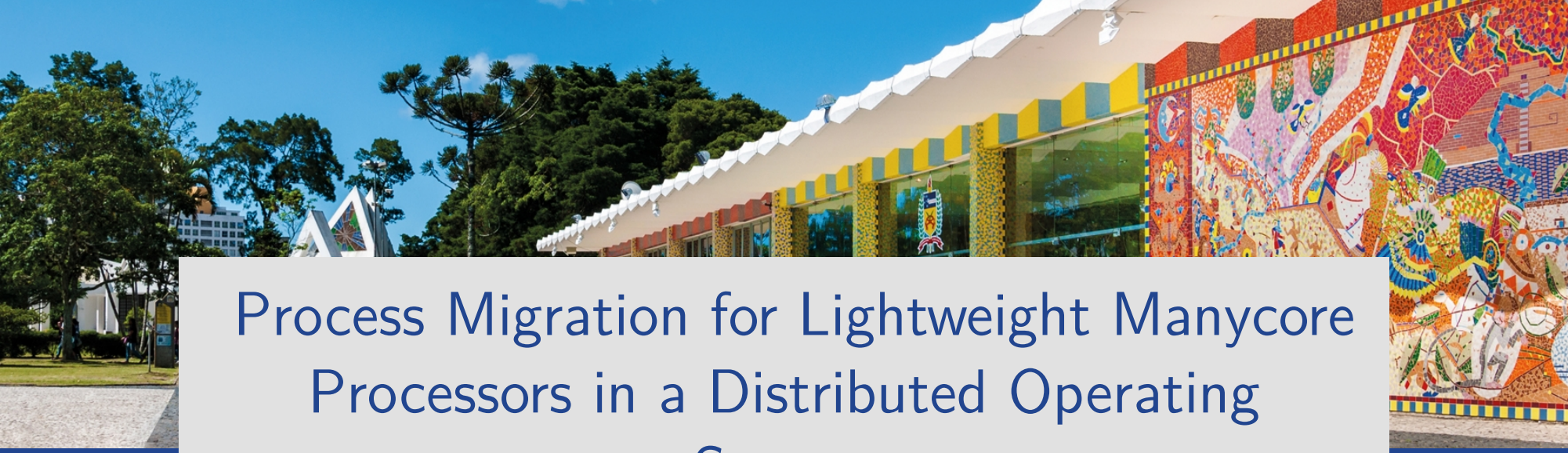

Process Migration for Lightweight Manycore Processors in a Distributed Operating System

João Vicente Souto

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Parallel Computing - Computer Science
INE/UFSC, Florianópolis

September 29, 2020

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Presentation Outline

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Pre-Copy Migration
Post-Copy Migration
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Process Migration

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Motivation and Justification

- **Transferring a process between machines**
- Proposed for:
  - Load balancing
  - Fault tolerance
  - System administration
  - Data access locality
- Arising of distributed systems
- Solutions established:
  - MOSIX (1985)
  - V (1988)
  - OSF/1 AD TNC (1995)

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Process Migration

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- Transferring a process between machines
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  - Improved system administration
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Process Migration

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Motivation and Justification

- Despite the research efforts, **migration has not achieved widespread use**
- Treating residual dependency is a difficult task:
  - Opened files stored in the source node
  - Opened communicators with other processes
  - Shared resources
  - Internal kernel state.
- Solution: Virtualization

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- Solution: **Virtualization**

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Virtualization

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Motivation and Justification

- Create a **Virtual Version** of Computing Resources
  - CPU
  - Memory
  - Storage device
  - Network device
- Features
  - Improved previous features
  - Power management
  - Security
- Two types
  - Virtual Machines (VM)
  - Containers

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Virtual Machines (VM)

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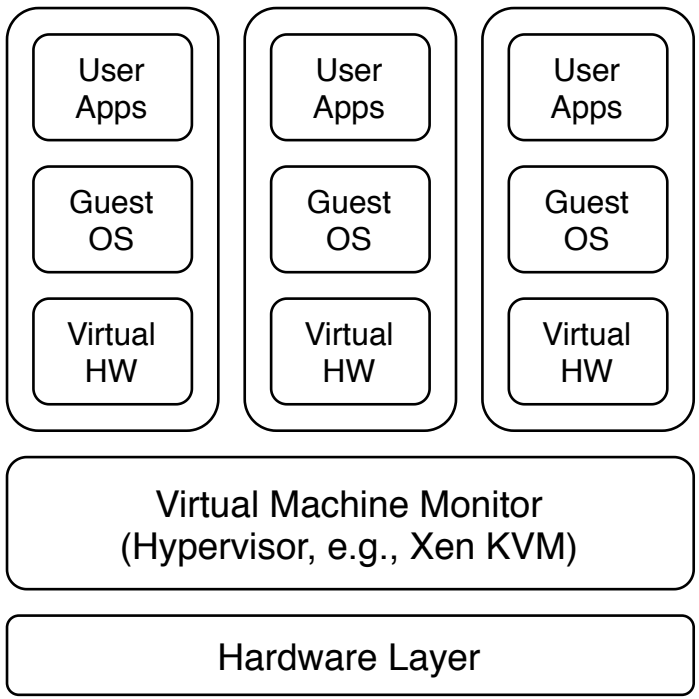
Motivation and Justification

- Encapsulates a whole operating system
- Depends on a Hypervisor to provide the hardware resources
  - Full virtualization
  - Paravirtualization



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Migration of VMs

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Motivation and Justification

- **Memory content**
  - Hypervisor allocated memory
  - Guest OS allocated memory
  - Application requested memory
- Disk content
  - Hypervisor allocated blocks
  - Guest OS used blocks
  - Application used blocks

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Migration of VMs

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- Memory content
  - Hypervisor allocated memory
  - Guest OS allocated memory
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- **Disk content**
  - Hypervisor allocated blocks
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Containers

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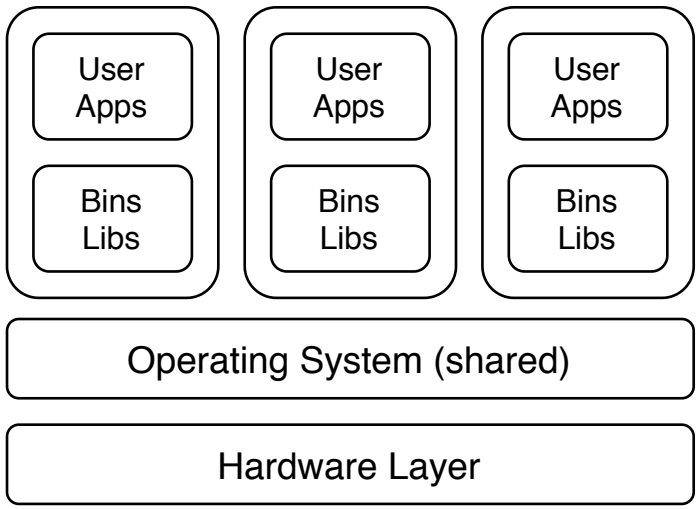
Motivation and Justification

- OS-level virtualization
- Multiple isolated user space instances (Shared OS)
- Lightweight compared to VMs
  - Linux Containers
  - Docker



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Migration of Containers

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- Transfer the file system of the container
- Save the state of the container into a file (all processes and their resources)
- Transfer the container file
- Restart the container

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Migration

Migration Techniques

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Motivation and Justification

- Generally, there are **three stages of memory transfer**:
  - Push Copy (iteration copy) stage
  - Stop-and-Copy stage
  - Pull Copy (On-demand copy) stage
- Migration techniques
  - Stop-and-Copy
  - *Pre-Copy*
  - *Post-Copy*
  - Hybrid

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Migration Techniques

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  - Pull Copy (On-demand copy) stage
- **Migration techniques**:
  - Stop-and-Copy
  - ***Pre-Copy***
  - ***Post-Copy***
  - Hybrid

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Pre-Copy Migration

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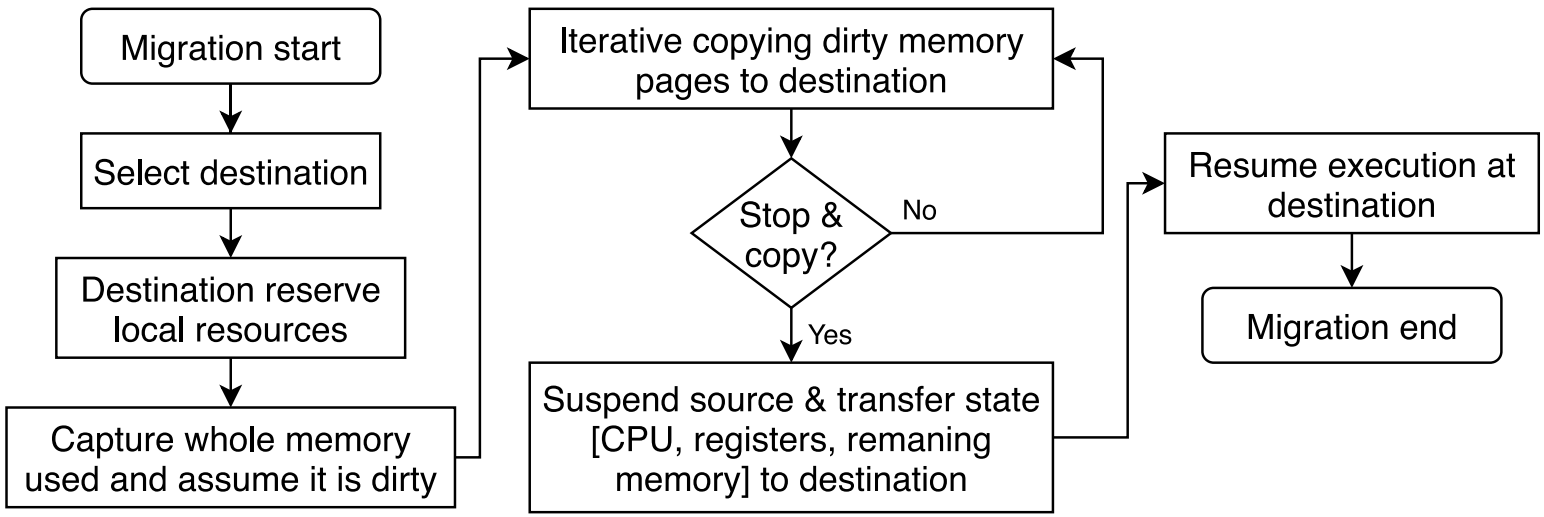
Motivation and Justification



Pre-Copy Scenario

Pre-Copy Migration

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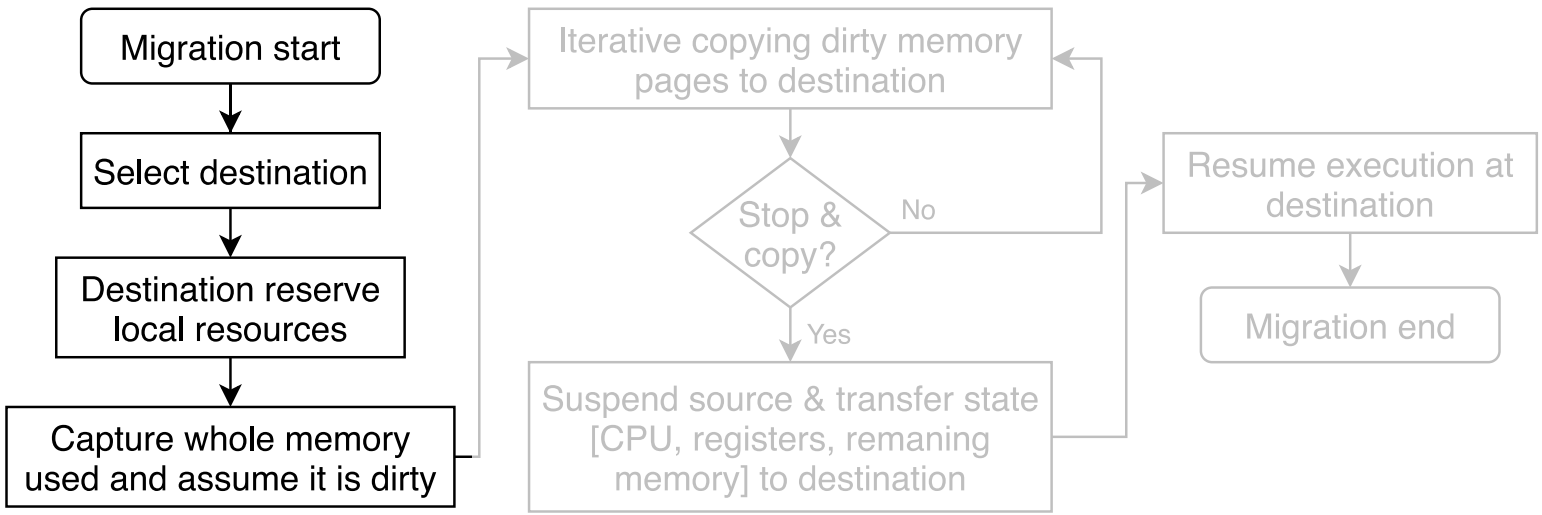
Motivation and Justification



Resource reservation and **transfer preparation**

Pre-Copy Migration

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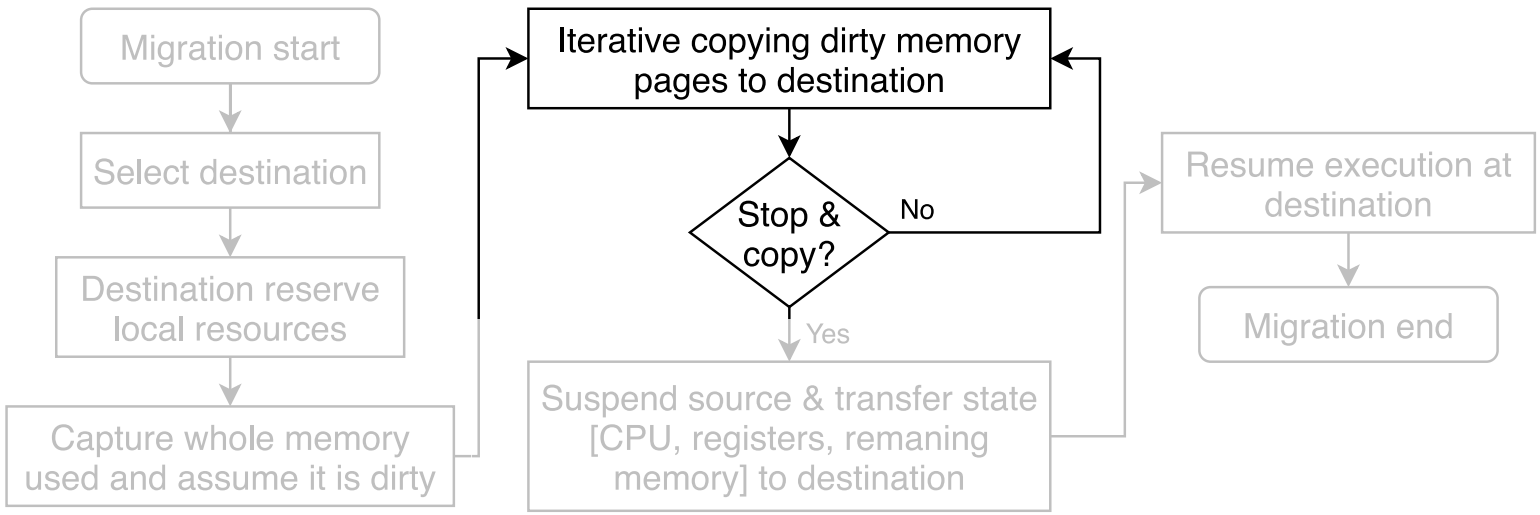
Motivation and Justification



Sending the memory pages before the execution context

Push Copy Stage

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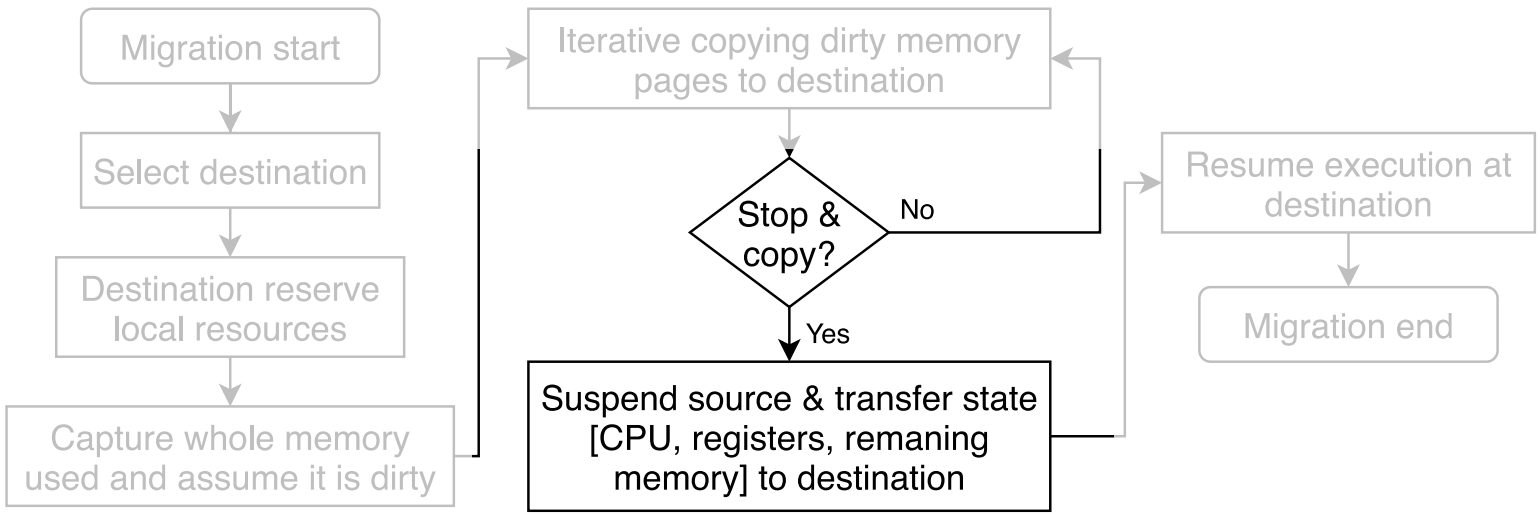
Motivation and Justification



When enough memory has been transferred, send the execution context

Stop-and-Copy Stage

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Pre-Copy Migration

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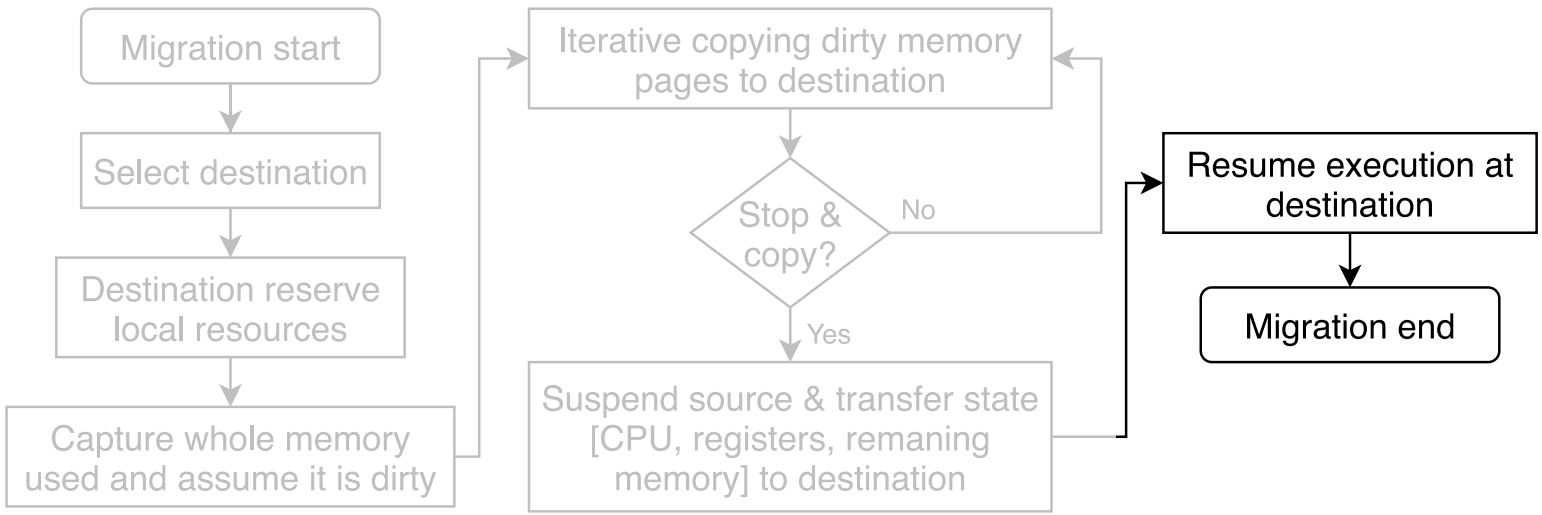
Motivation and Justification



Resume stopped execution context in the destination

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Post-Copy Migration

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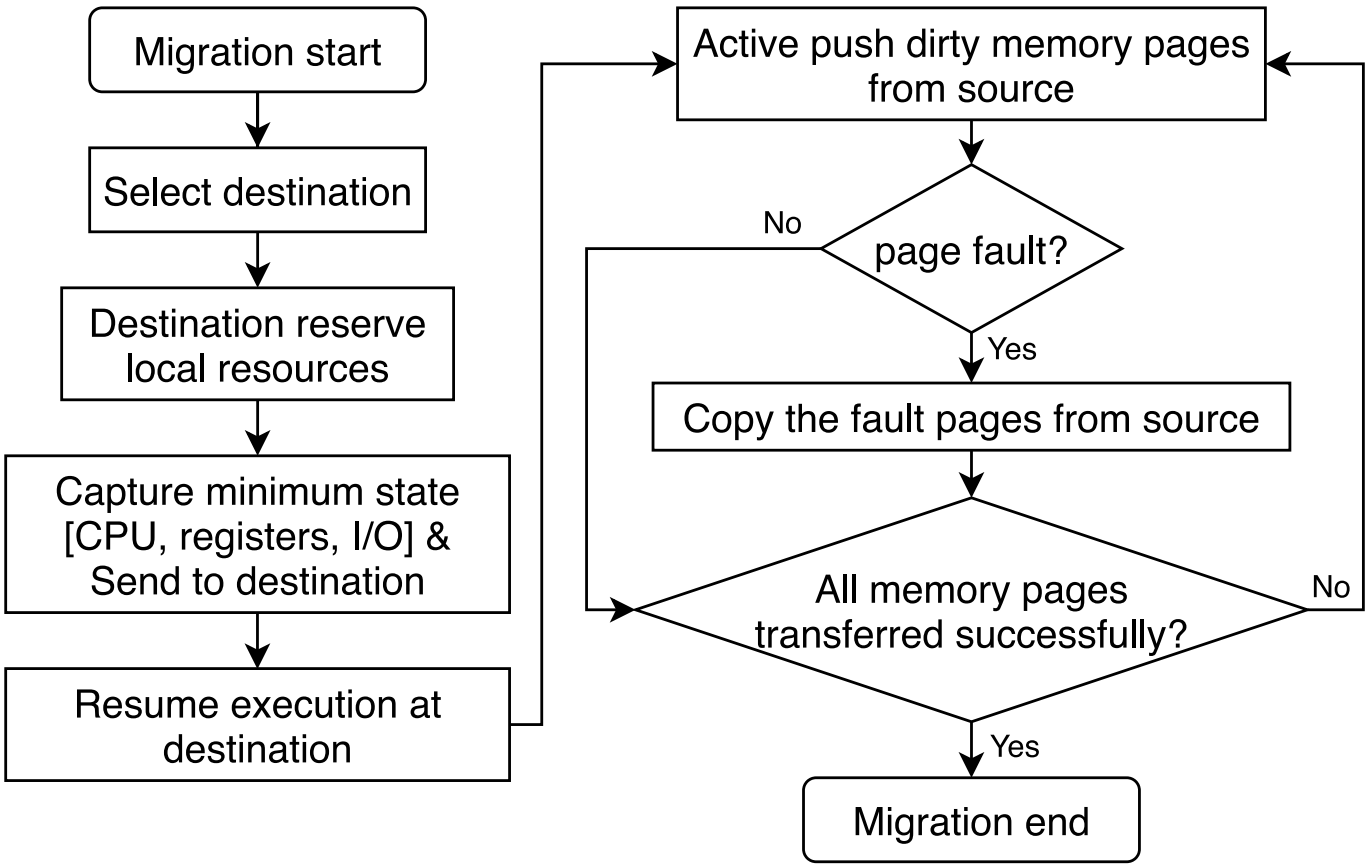

Post-Copy Scenario

Post-Copy Migration

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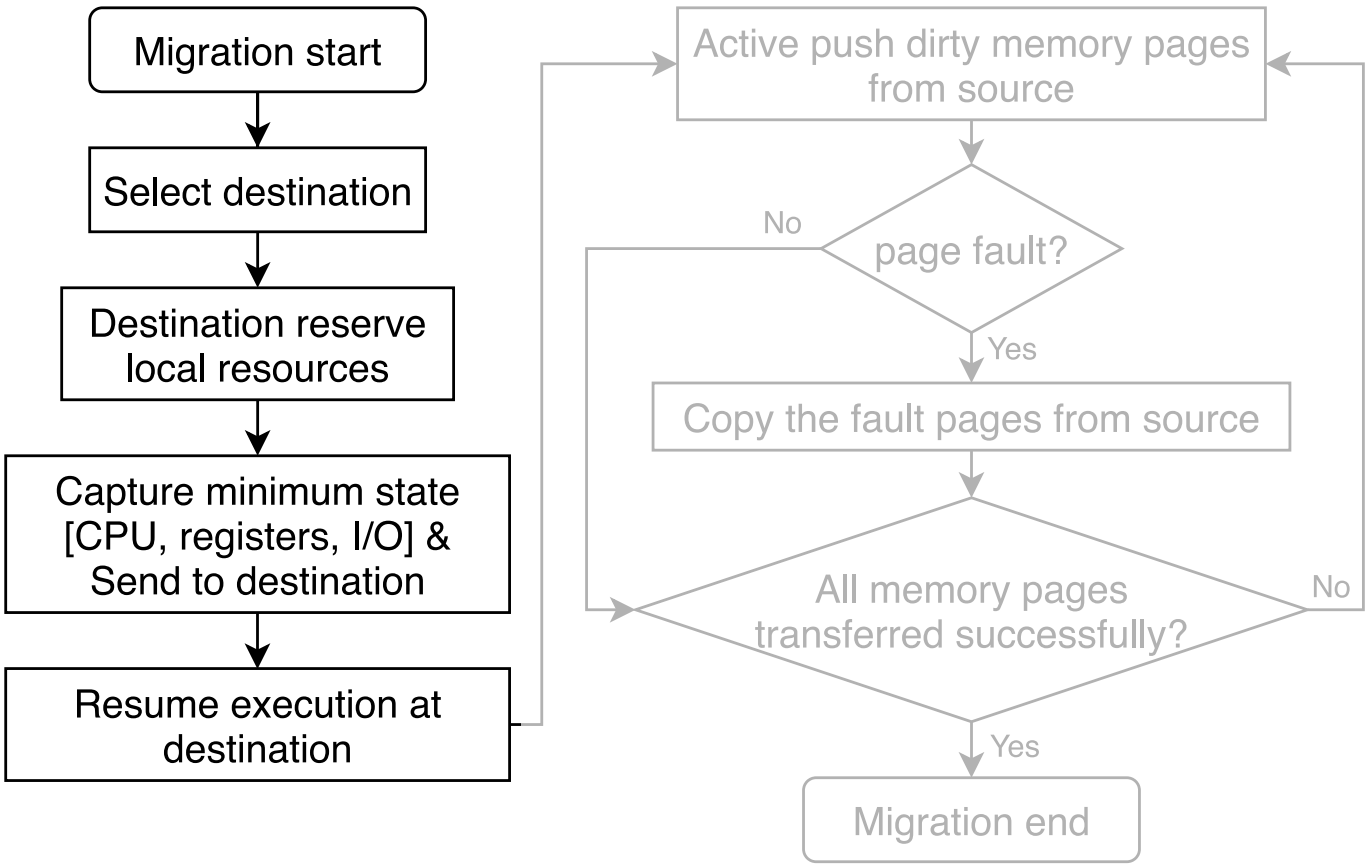

Sends execution context before memory pages

Stop-and-Copy Stage

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Post-Copy Migration

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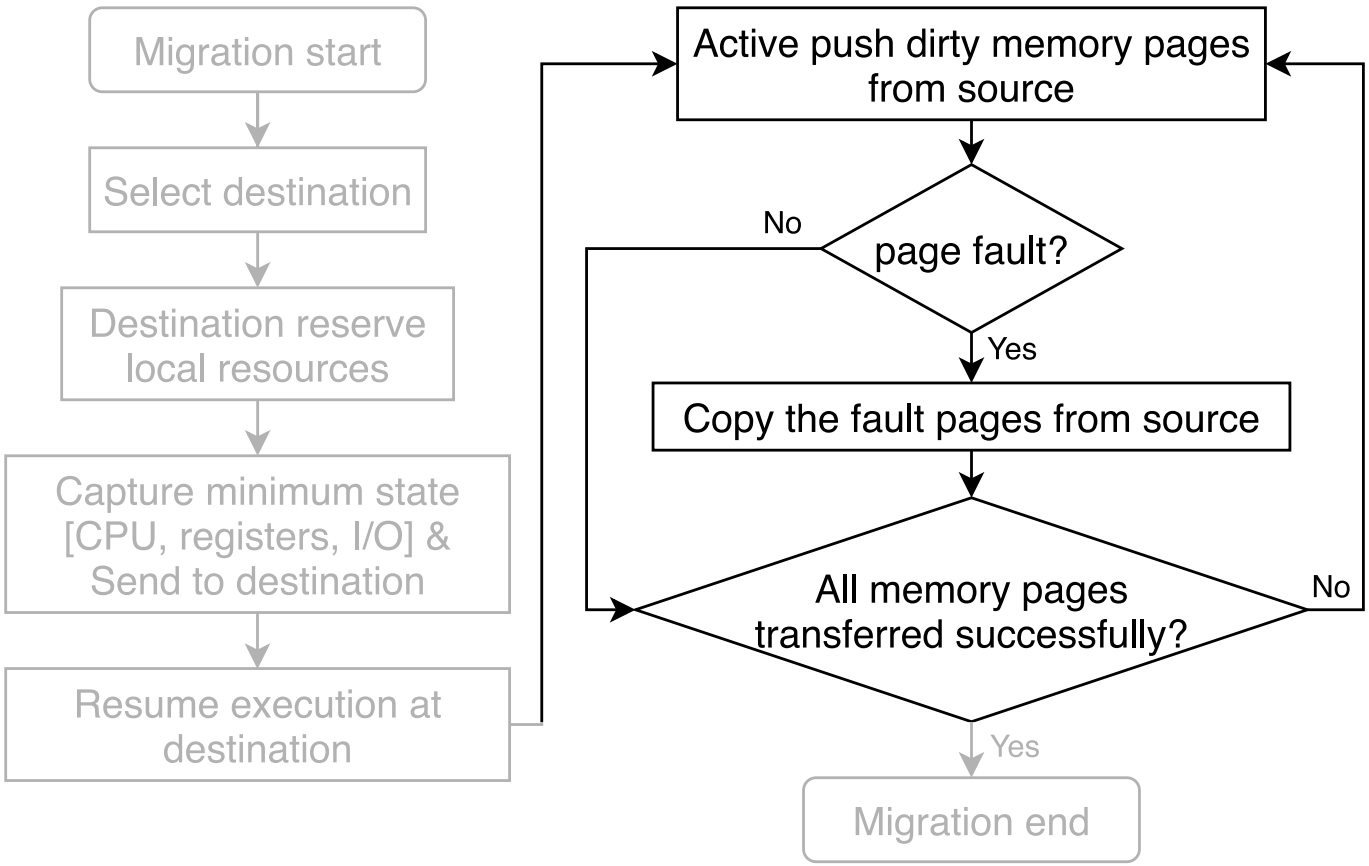

Merges **pull rest of memory pages** and any page that generate **page faults**

Pull Copy Stage

Post-Copy Migration

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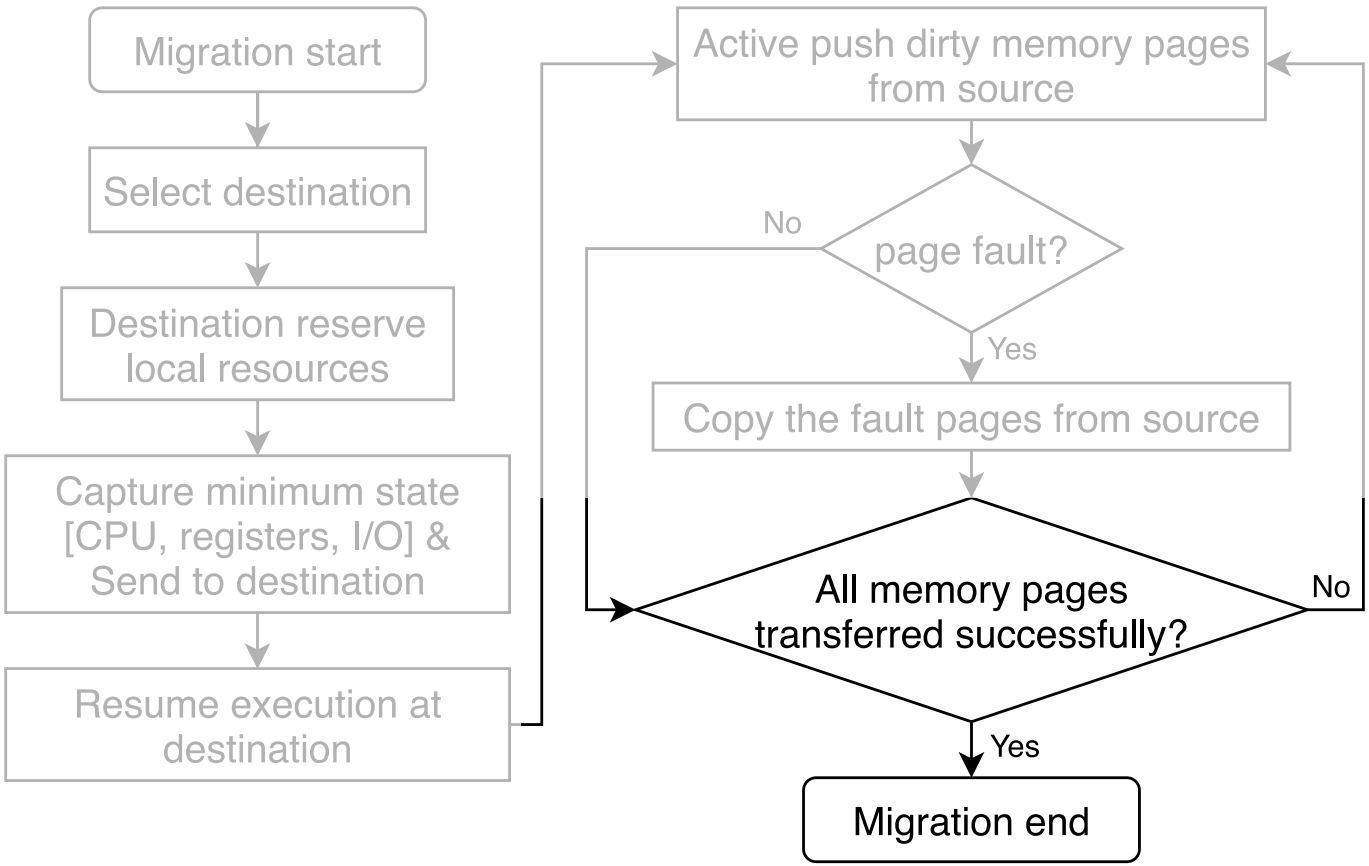
Motivation and Justification



Continues execution normally

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Performance Metrics

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Motivation and Justification

- Total Migration Time
- Downtime
- Pages Transfered
- Preparation Time
- Resume Time
- Application Degradation
- Page Dirty Rate
- Link Degradation

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Lightweight Manycores Processors

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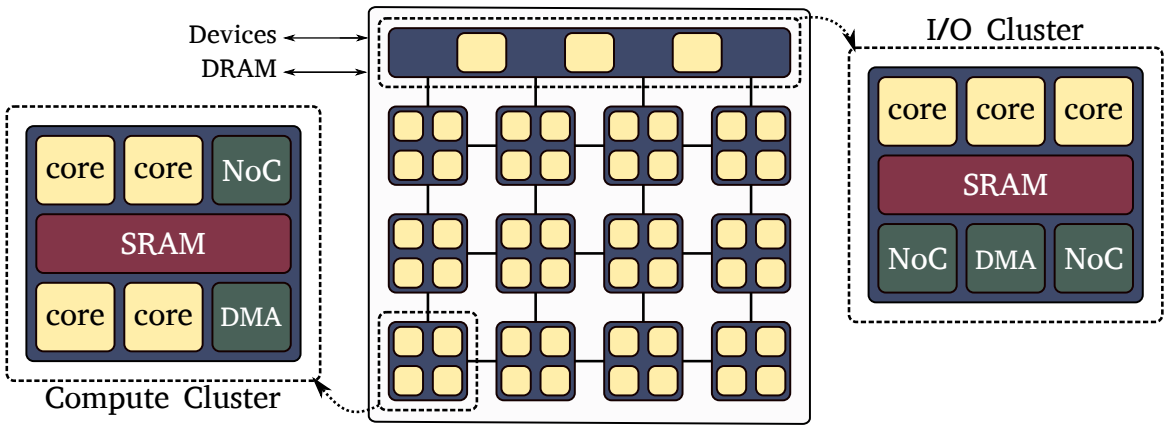

Overview of a Manycore

- **Hundreds of Lightweight Cores**
  - Expose Massive thread-level parallelism
  - Feature low-power consumption
  - Target MIMD workloads
- Distributed Memory Architecture
- On-Chip Heterogeneity

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Lightweight Manycores Processors

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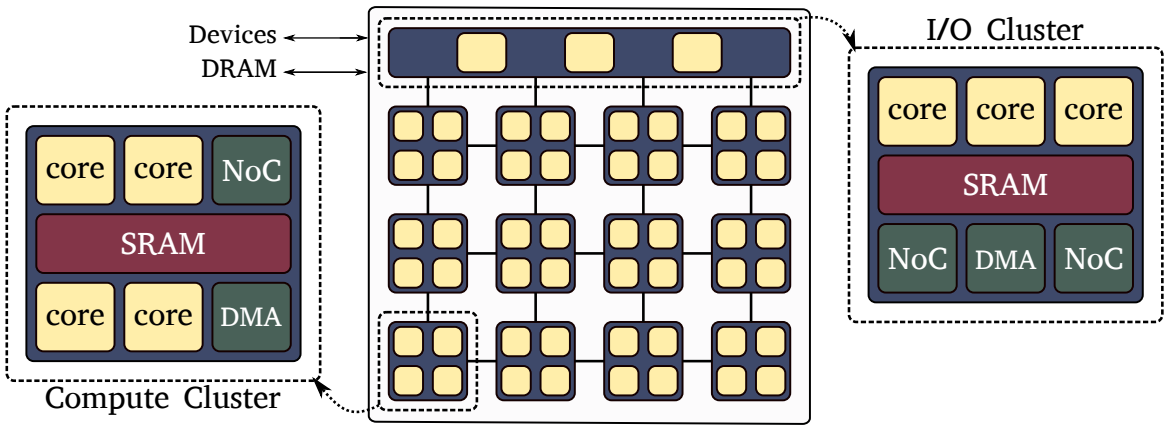
Motivation and Justification



Overview of a Manycore

- Hundreds of Lightweight Cores
- **Distributed Memory Architecture**
  - Grants scalability
  - Relies on a Network-on-Chip (NoC)
  - Has constrained memory systems
- On-Chip Heterogeneity

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Lightweight Manycores Processors

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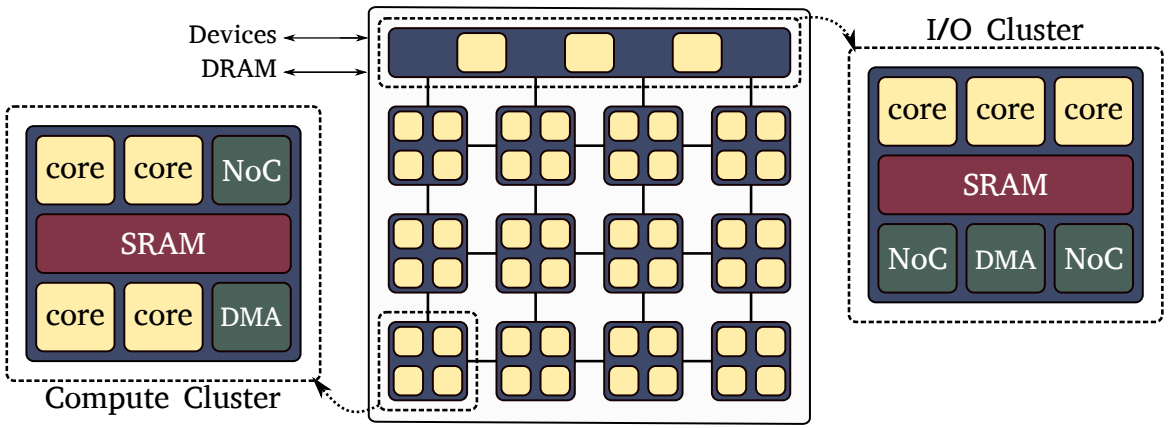

Overview of a Manycore

- Hundreds of Lightweight Cores
- Distributed Memory Architecture
- **On-Chip Heterogeneity**
  - Features different components

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Kalray MPPA-256

A Lightweight Manycore Processor

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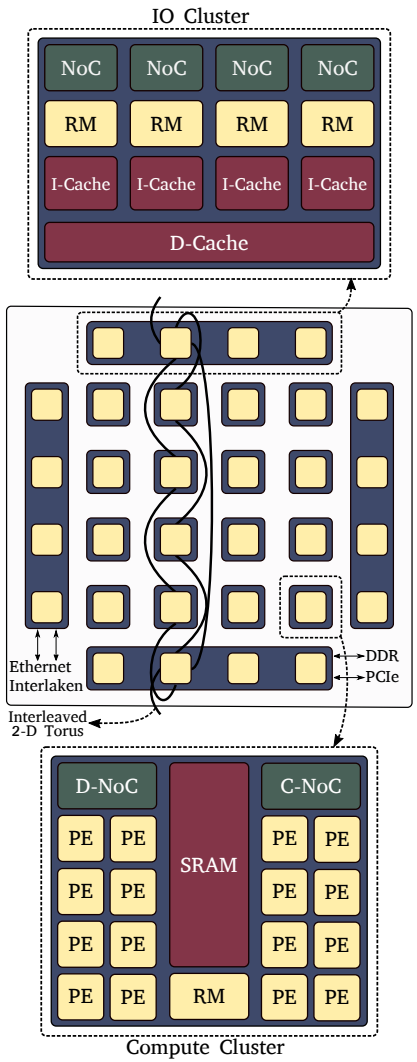
Motivation and Justification

- **288 processing cores**
  - 16 Compute Cluster (CC)
  - 4 I/O Cluster (IO)
- **Data NoC (D-NoC)**
  - 256 RX slots
  - 8 TX channels
  - 8 μthreads for async TX
- **Control NoC (C-NoC)**
  - 128 RX slots
  - 4 TX channels



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Motivation

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- Bring the **benefits of migration and process virtualization to lightweight manycores**
- Load balancing
- Fault tolerance
- System administration
- Data locality
- Power management
- Security

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Motivation

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Motivation and Justification

- Bring the benefits of migration and process virtualization to lightweight manycores
- **Load balancing**
  - Better work distribution
- Fault tolerance
- System administration
- Data locality
- Power management
- Security

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Motivation

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- Bring the benefits of migration and process virtualization to lightweight manycores
- Load balancing
- **Fault tolerance**
  - Save/restore processes state
- System administration
- Data locality
- Power management
- Security

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- Bring the benefits of migration and process virtualization to lightweight manycores
- Load balancing
- Fault tolerance
- **System administration**
  - Allow multiuser execution and management
- Data locality
- Power management
- Security

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Motivation

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- Bring the benefits of migration and process virtualization to lightweight manycores
- Load balancing
- Fault tolerance
- System administration
- **Data locality**
  - Move processes to closer to the data source
- Power management
- Security

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- Bring the benefits of migration and process virtualization to lightweight manycores
- Load balancing
- Fault tolerance
- System administration
- Data locality
- **Power management**
  - Separate CPU-bound processes to improve heat dissipation
- Security

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Motivation

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- Bring the benefits of migration and process virtualization to lightweight manycores
- Load balancing
- Fault tolerance
- System administration
- Data locality
- Power management
- **Security**
  - Better isolation and kill suspicious processes

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Justification

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- **Parallel and distributed nature** of lightweight manycores
- Memory restrictions do not support a complete virtual environment like VMs
- Explore lighter forms of virtualization as at the OS level
- Integrate virtualization into a distributed OS designed for lightweight manycores

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Justification

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Thank you!
Questions?

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