

Process Migration for Lightweight Manycore Processors in a Distributed Operating System

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September 29, 2020

Presentation Outline

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Virtualization

Migration

Pre-Copy Migration

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LW Processors

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Motivation and Justification

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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)

Process Migration

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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:
 - Open files stored in the source node
 - Open communicators with other processes
 - Shared resources
 - Internal kernel state.
- Solution: Virtualization

Process Migration

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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



Virtualization

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Virtualization

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Virtual Machines (VM)

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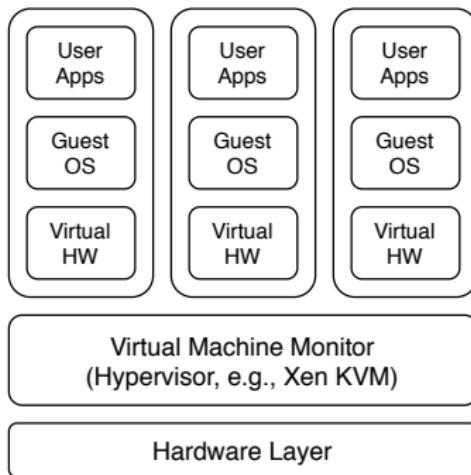
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Motivation and Justification

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



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



Migration of VMs

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Motivation and
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■ Memory content

- Hypervisor allocated memory
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- Application requested memory

■ Disk content

- Hypervisor allocated blocks
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Containers

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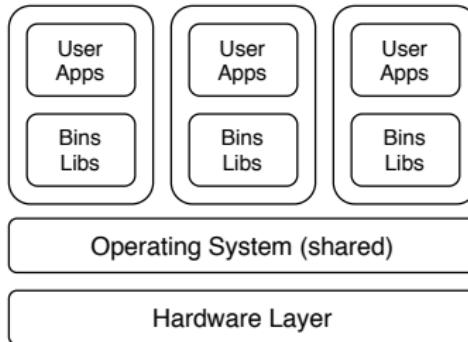
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Motivation and
Justification

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



Migration of Containers

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Motivation and
Justification

- 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 Techniques

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Motivation and
Justification

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



Migration Techniques

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Motivation and
Justification

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

Pre-Copy Migration

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Pre-Copy Migration

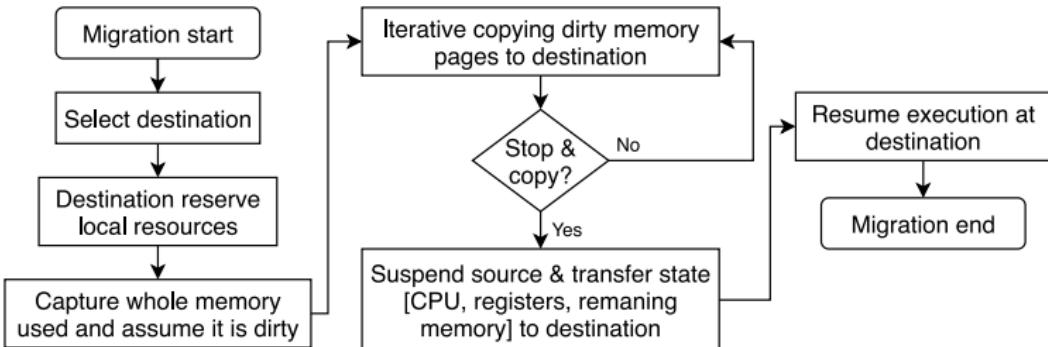
Post-Copy Migration

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Motivation and
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Pre-Copy Scenario

Pre-Copy Migration

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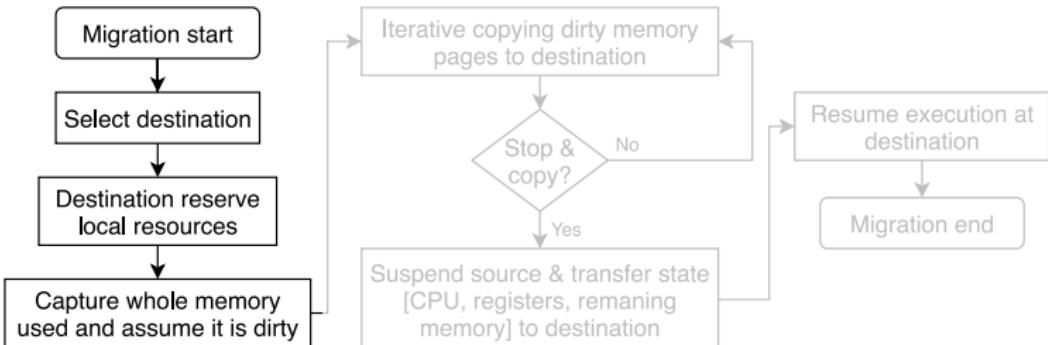
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Motivation and
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Resource reservation and **transfer preparation**

Pre-Copy Migration

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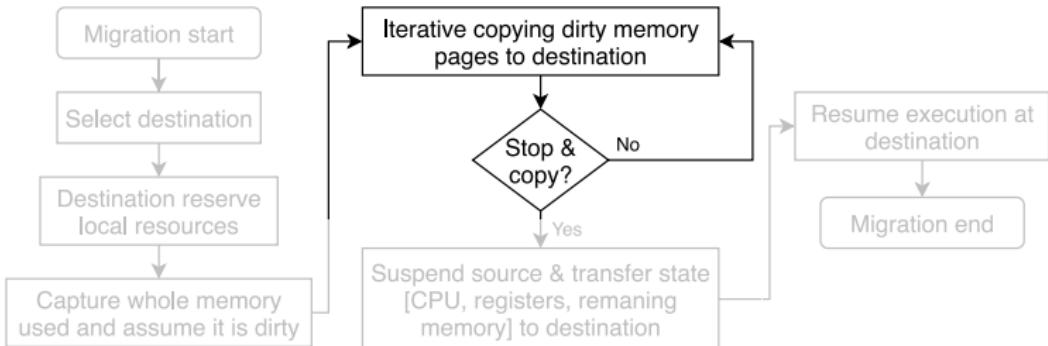
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Motivation and Justification



Sending the memory pages before the execution context

Push Copy Stage

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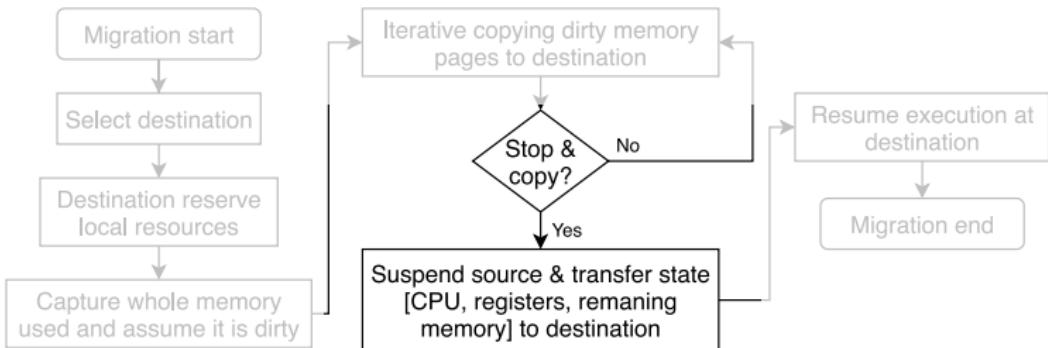
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Motivation and Justification



When enough memory has been transferred, send the execution context
Stop-and-Copy Stage

Pre-Copy Migration

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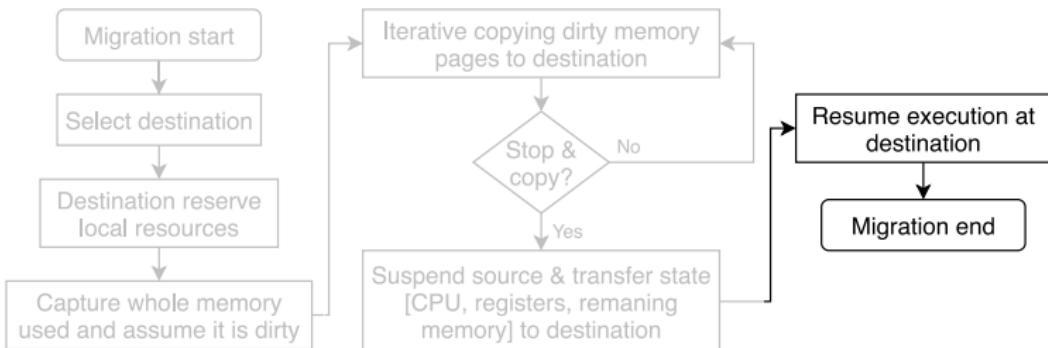
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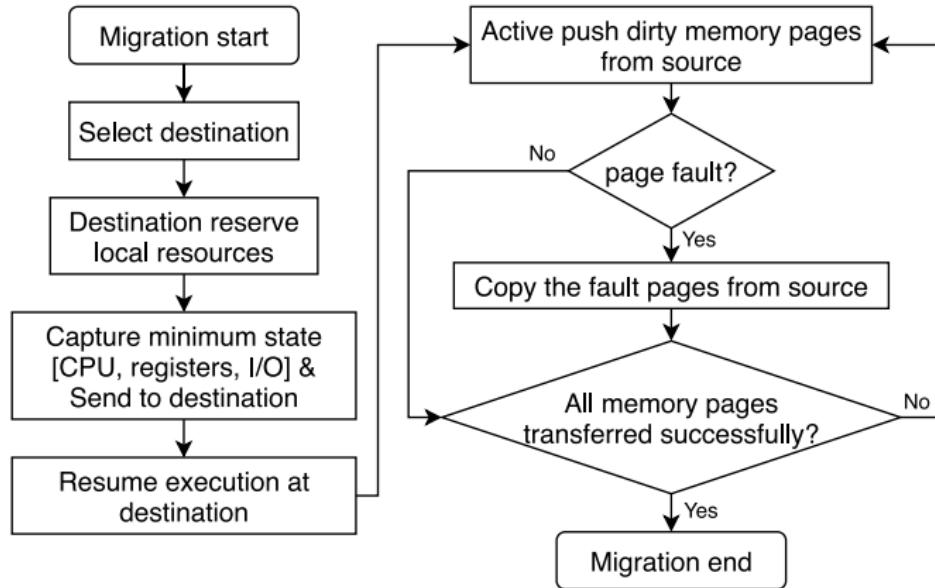
Motivation and Justification



Resume stopped execution context in the destination

Post-Copy Migration

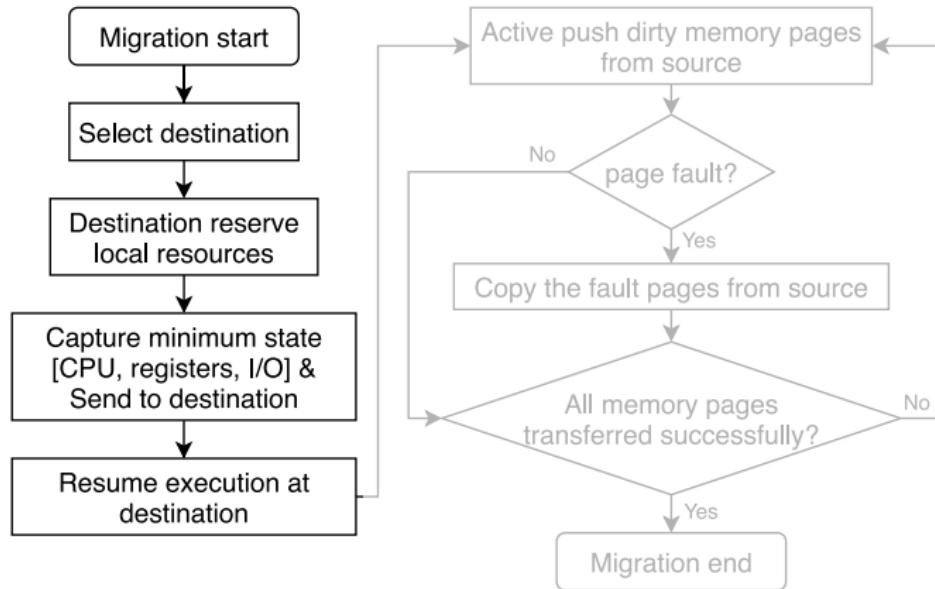
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Post-Copy Scenario

Post-Copy Migration

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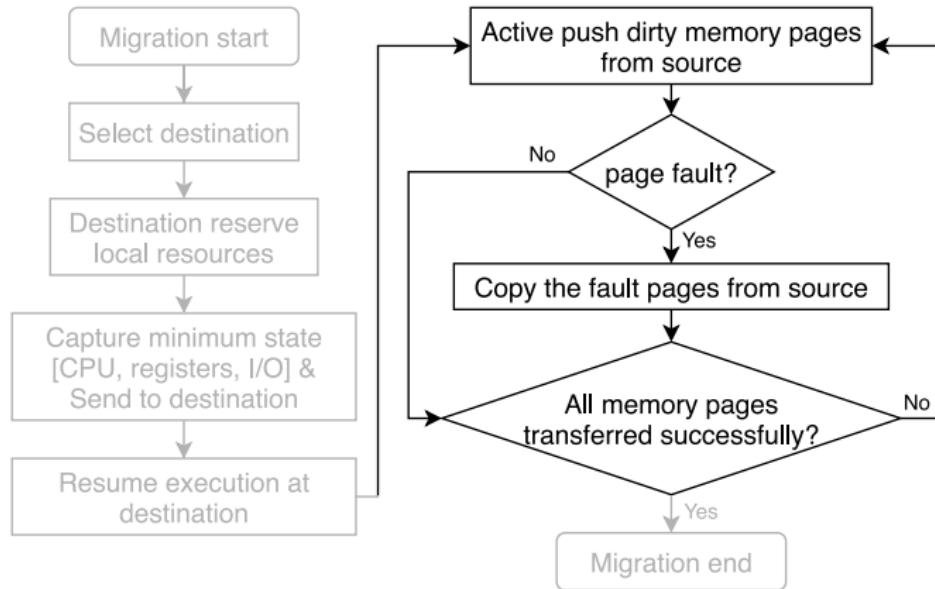


Sends execution context before memory pages

Stop-and-Copy Stage

Post-Copy Migration

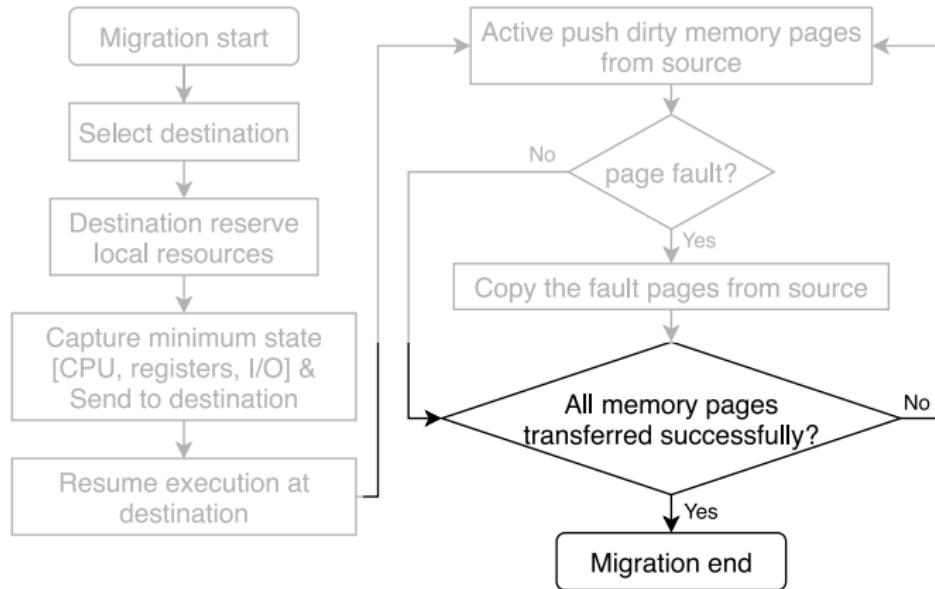
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Merges **pull rest of memory pages** and any page that generate **page faults**
Pull Copy Stage

Post-Copy Migration

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Continues execution normally

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Performance Metrics

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Motivation and
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- Total Migration Time
- Downtime
- Pages Transferred
- Preparation Time
- Resume Time
- Application Degradation
- Page Dirty Rate
- Link Degradation



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Lightweight Manycores Processors

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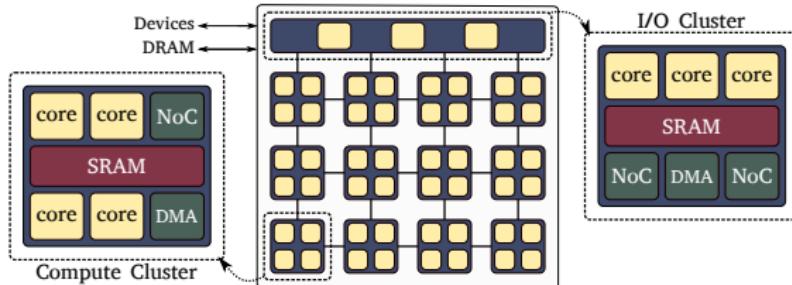
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Motivation and Justification



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

Lightweight Manycores Processors

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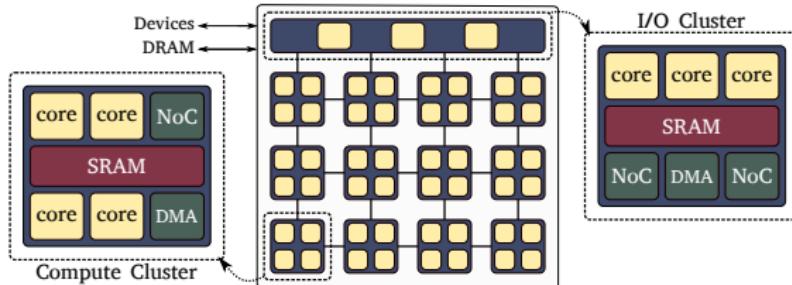
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Motivation and Justification



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

Lightweight Manycores Processors

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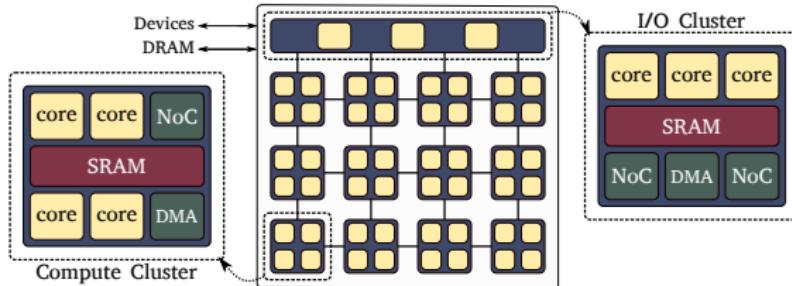
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Motivation and Justification



Overview of a Manycore

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

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A Lightweight Manycore Processor

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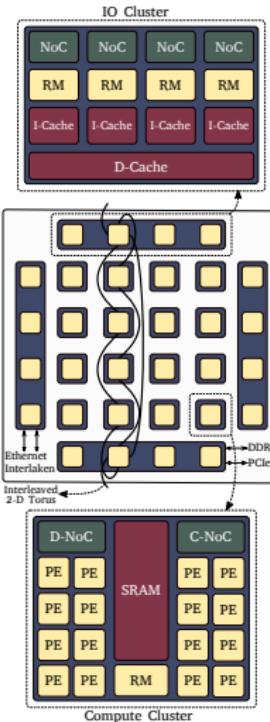
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Motivation and
Justification

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



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Motivation and
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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

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

Motivation

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Motivation and
Justification

- 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

Motivation

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Motivation and
Justification

- 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

Motivation

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Motivation and
Justification

- 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

Motivation

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Motivation and
Justification

- 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

Motivation

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Motivation and
Justification

- 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

Justification

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Motivation and
Justification

- **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

Justification

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- Parallel and distributed nature of lightweight manycores
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- Explore **lighter forms of virtualization**, e.g., OS-level
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Justification

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- Explore lighter forms of virtualization, e.g., OS-level
- Integrate virtualization into a **distributed OS designed for lightweight manycores**



Thank you!
Questions?

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References I

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References II

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 WANG, Z. et al. Ada-things: An adaptive virtual machine monitoring and migration strategy for internet of things applications. *Journal of Parallel and Distributed Computing*, v. 132, p. 164 – 176, 2019. ISSN 0743-7315. Disponível em: <<http://www.sciencedirect.com/science/article/pii/S0743731518304404>>.

Citations

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Motivation and
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- (MILOJICIĆ et al., 2000)
- (CLARK et al., 2005)
- (CHOUDHARY et al., 2017)
- (Tao et al., 2019)
- (Hosseini Shirvani; RAHMANI; SAHAFI, 2020)
- (WANG et al., 2019)