Checkpointing and Recovery of Shared Memory Parallel Applications in a Cluster

R. Badrinath – INRIA / IIT Kharagpur (India)

C. Morin – INRIA (France)

G. Vallee – EDF R&D (France)

Introduction

- Today, clusters are widely used as alternative of small parallel computer
- Targeted applications
  - Sequential applications
  - Message Passing applications
  - Shared Memory applications using a DSM
- An approach : Single System Image (SSI) (federation of all resources)
  - Failures of cluster nodes (due to the hardware): Fault Tolerance mechanisms

Kerrighed

- Kerrighed OS (INRIA - PARIS reseach team) is an OpenSource project (http://www.kerrighed.org)
- The current Kerrighed OS
  - Linux kernel +
  - Process Management Module (Aragorn)
  - Memory Management Module (Gandalf)
  - IPC object Management Module (Elrond)
  - Communication Management Module (Gimli/Gloin)

Background

- To support fault tolerance in a SSI
  - distributed system / cluster support DSM and MP
  - we use checkpointing and recovery to do this
- We have many options
  - coordinated checkpointing
  - uncoordinated checkpointing
  - partly coordinated checkpointing
    - … and corresponding recovery strategies too!
- We wish to implement common mechanisms
- We wish to try out several strategies

Goals

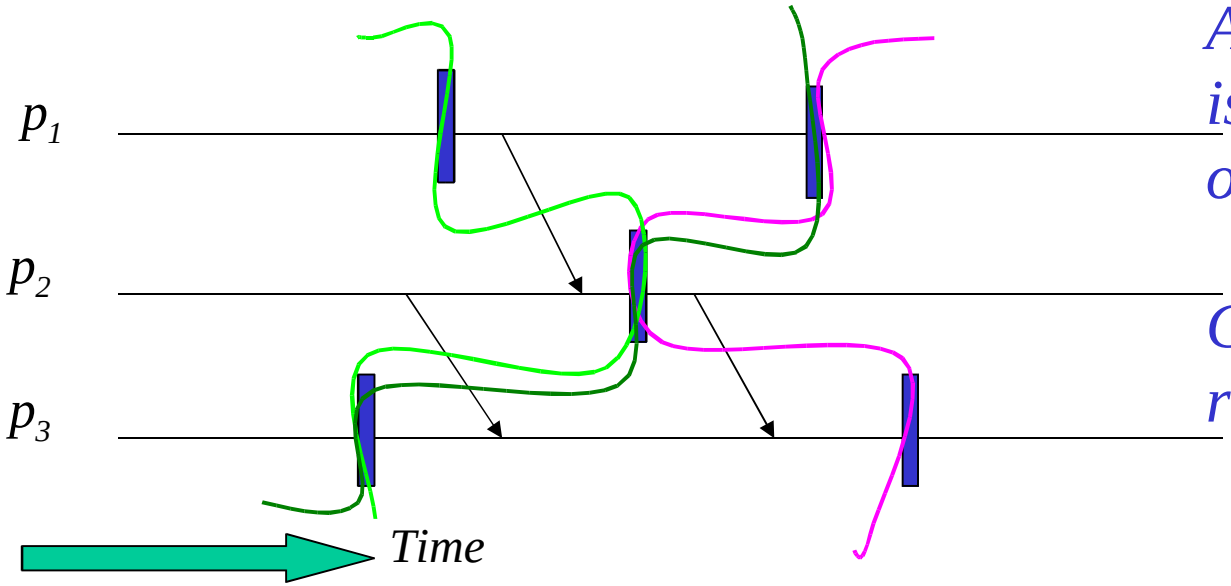
- Support checkpointing and recovery of parallel applications using both shared memory and message passing in a cluster.
- Support through some set of basic common mechanisms.
- Support to experiment with a variety of checkpoint / recovery protocols.

Outline

- Basic common mechanisms
  - Dependency tracking => memory
- Implementation of checkpoint policy: the case of coordinated checkpoint

Basic Common Mechanisms: Recovery lines

- Checkpointing must be such that we can compute recovery lines and rollback to them.
- What is a recovery line?



A recovery line is a consistent set of checkpoints

Consistent wrt send-receive relation.

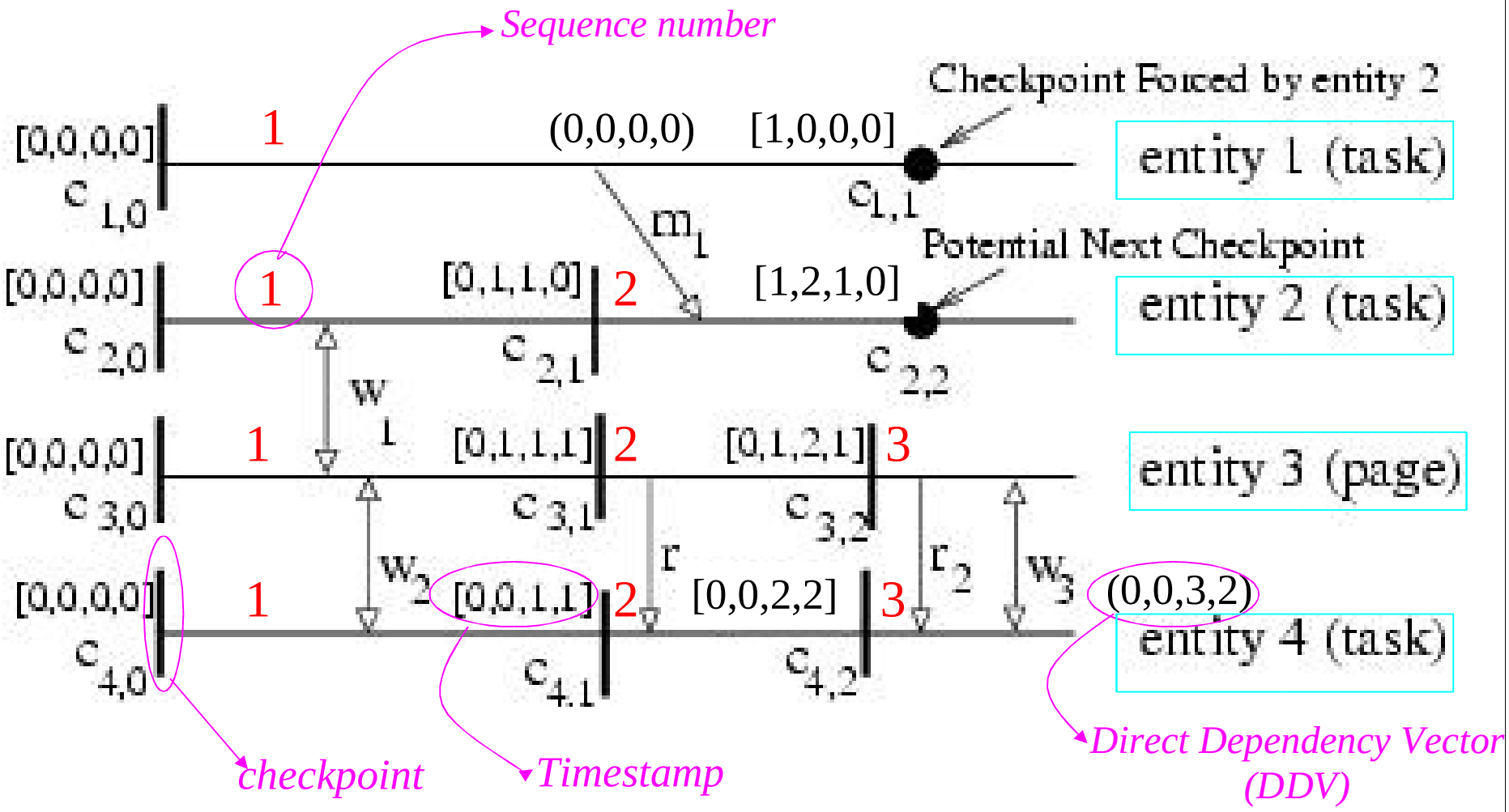
Basic Common Mechanisms: Dependencies

- To compute a recovery line requires to track dependencies caused by interactions.
- For a DSM, Interactions include:
  - DSM Read
  - DSM Write
- We will treat shared memory as entities!

Basic Commom Mechanisms: The Theory Says...

- Many things…
- We need to
  - Track *direct* dependencies between entities
  - Create the dependence graph
  - Compute the latest recovery line by reachability analysis
- In Practice
  - … we need to support optimisations

Basic Common Mechanisms: The Theory to Track Dependencies



Basic Common Mechanisms: Dependency tracking

- Add data items
  - A sequence number (*sn*)
  - A *DDV*
- Update actions on interactions
  - *sn*
  - *DDV*
- On checkpoint
  - Save timestamp, update *sn*
- On recovery
  - Re-initialise timestamps, *sn*

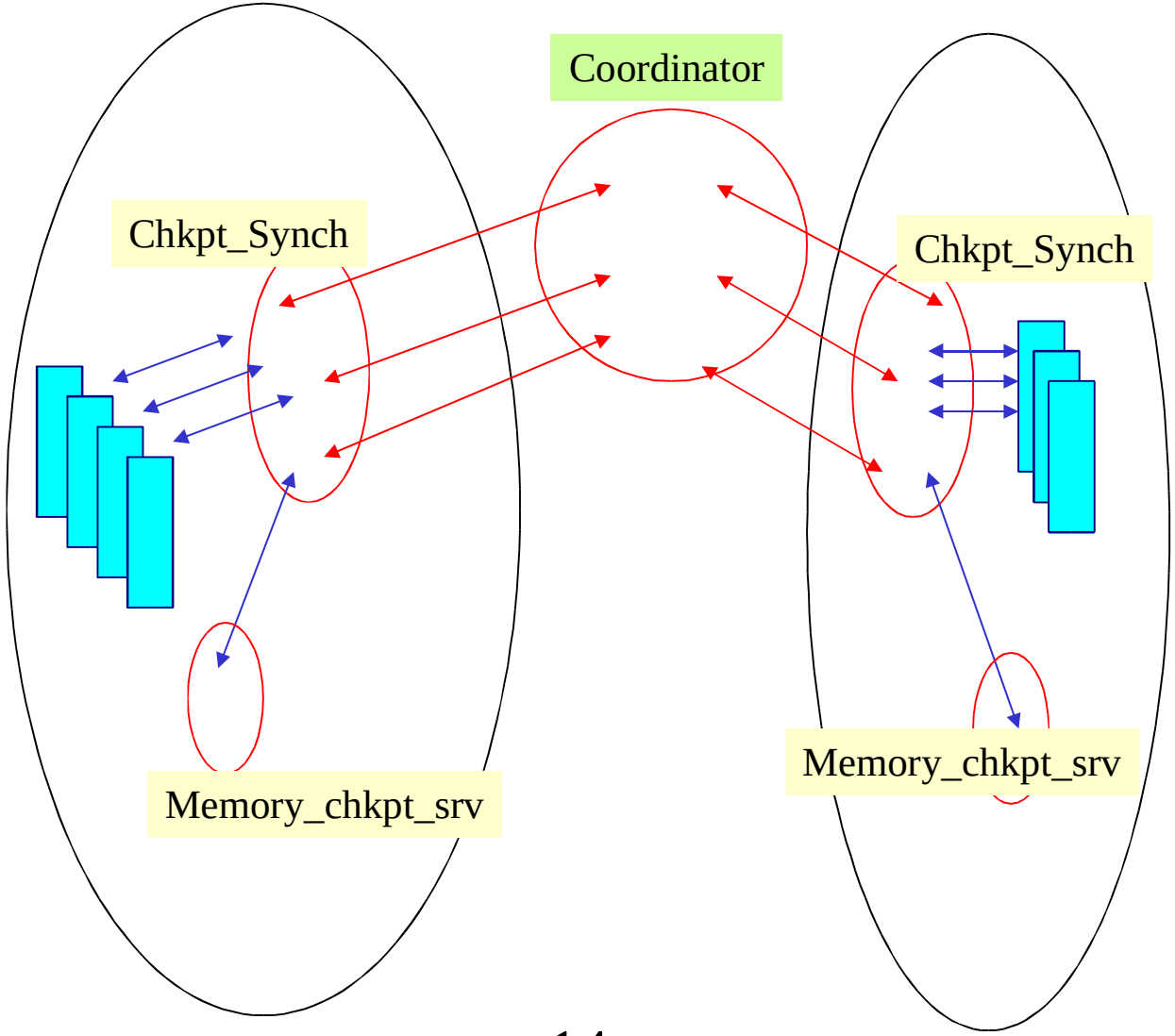
Basic Common Mechanisms: Entity states

- Task private states
  - process management module
- Shared memory states
  - in cooperation with memory manager module
- IPC states :
  - Locks, barriers states (native support of checkpointing in Kerrighed)

Policies - Checkpoint/Restart Protocols

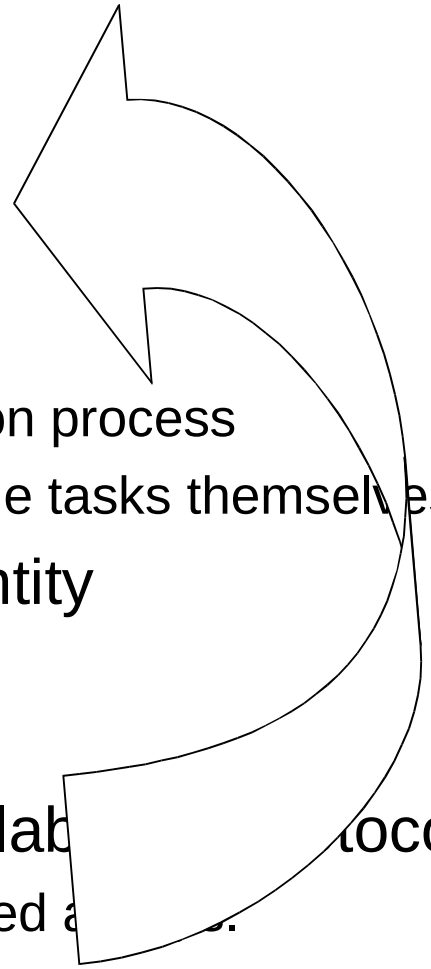
- Have threads to run the protocol for each entity.
  - Threads participate in:
    - Checkpointing
    - Restart / Rollback
- This would be an implementation of the policy.
  - We will initially focus on coordinated checkpointing and recovery.

Policy: How checkpointing works



Policy: Coordinated Checkpointing

- Interaction phase - *Nothing special*
- Checkpoint phase -
  - Checkpoint coordinator
    - Maybe the checkpoint initiator application process
    - Maybe an application call from one of the tasks themselves.
  - Protocol thread on behalf of each entity
    - Kernel mode of a task
    - Page manager thread
  - Optimisations may require a more elaborate protocol.
    - Ex. Not all entities need to be coordinated at once.



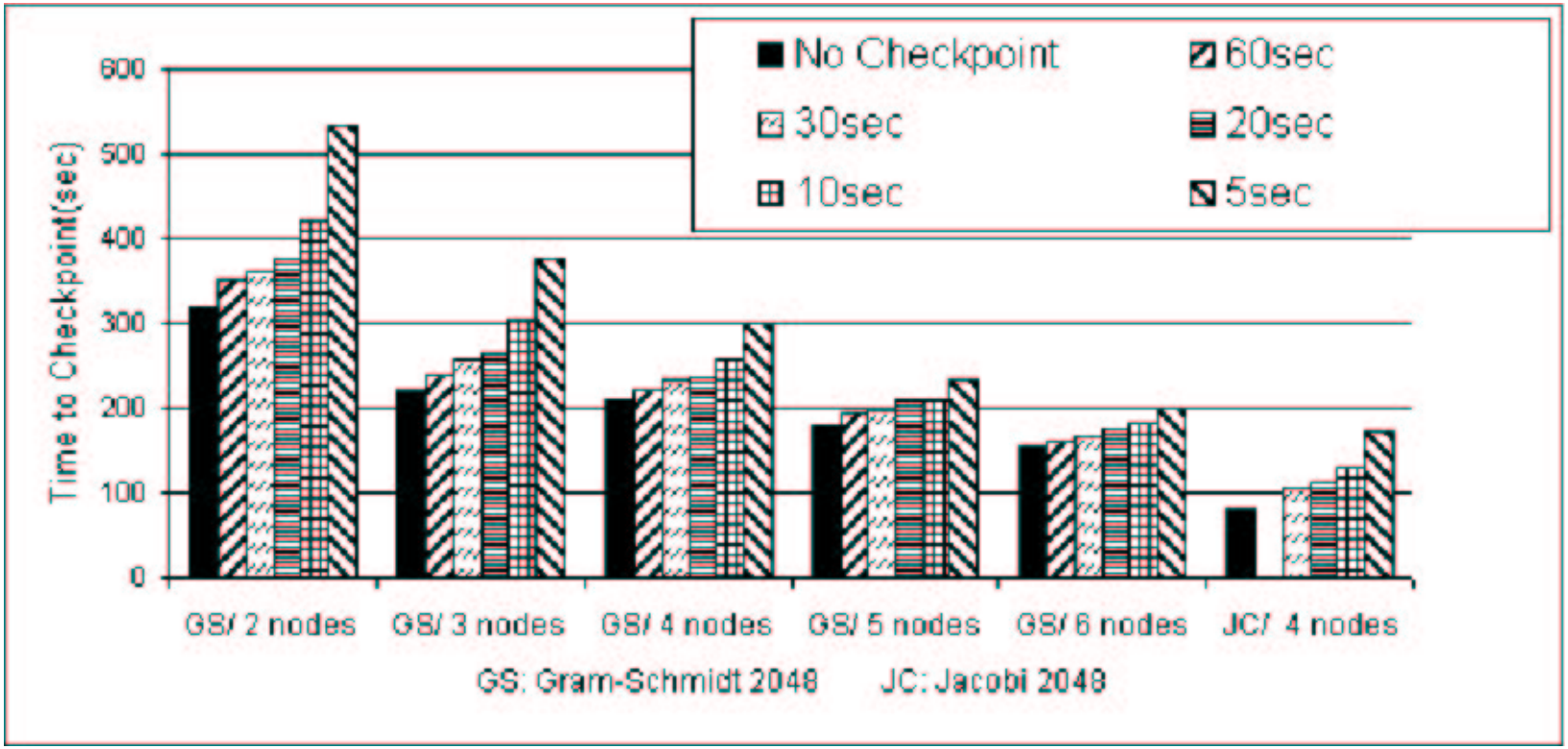
Policy: Coordinated Recovery

- Recovery phase -
  - Recovery initiator/coordinator
  - Recovery protocol handler for each entity
    - We may use kernel mode threads for tasks
    - Page managers for pages
  - Optimisations make use of the dependency tracking mechanism.

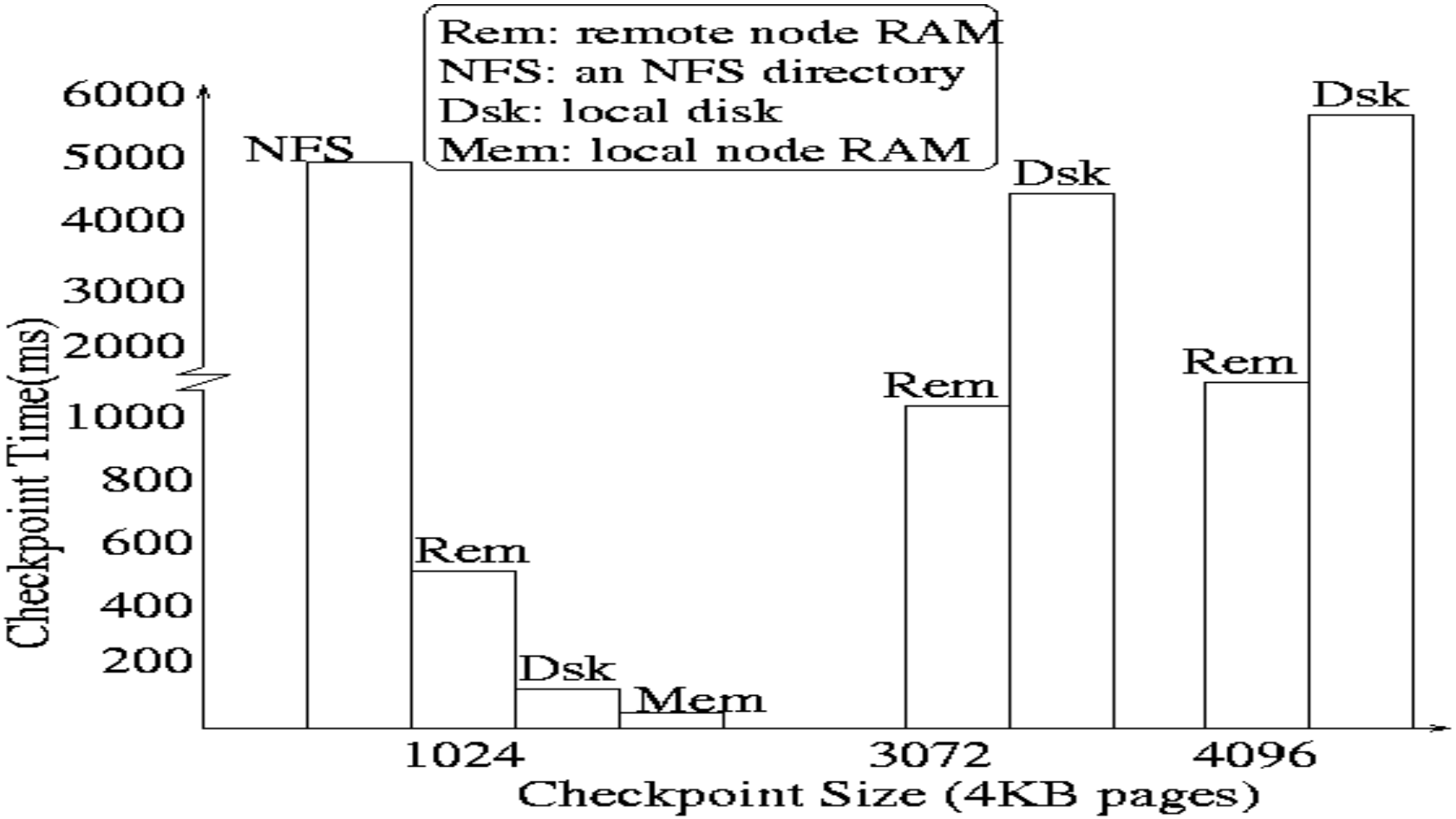
Prototype: Status

- We have a simple coordinator
  - System initiated coordinated checkpoint.
  - Protocol aborts if tasks not in « good » state.
  - Incremental Checkpointing of DSM states.
  - Recovery not yet complete.
- Checkpointing performance results say that the checkpointing protocol is not a bottleneck.
- Checkpoint saving time is the bottleneck
  - Motivation for a high speed reliable storage.. (containers for checkpoints?)

Effect of Checkpointing on Execution Time



Effect of Destination on Checkpointing Time



Conclusion / Future works

- Common mechanisms can support dependency tracking involving different IPC forms.
- Important to design tasks/memory/barriers in a way as to support « checkpointing » and « recovery » of their states.
- Coordinated checkpointing has been demonstrated on Kerrighed…. and motivates work on storage systems.
- Implement new checkpoint protocols
- Integrate to the Kerrighed's version available on the web

Thanks!