Container Checkpointing

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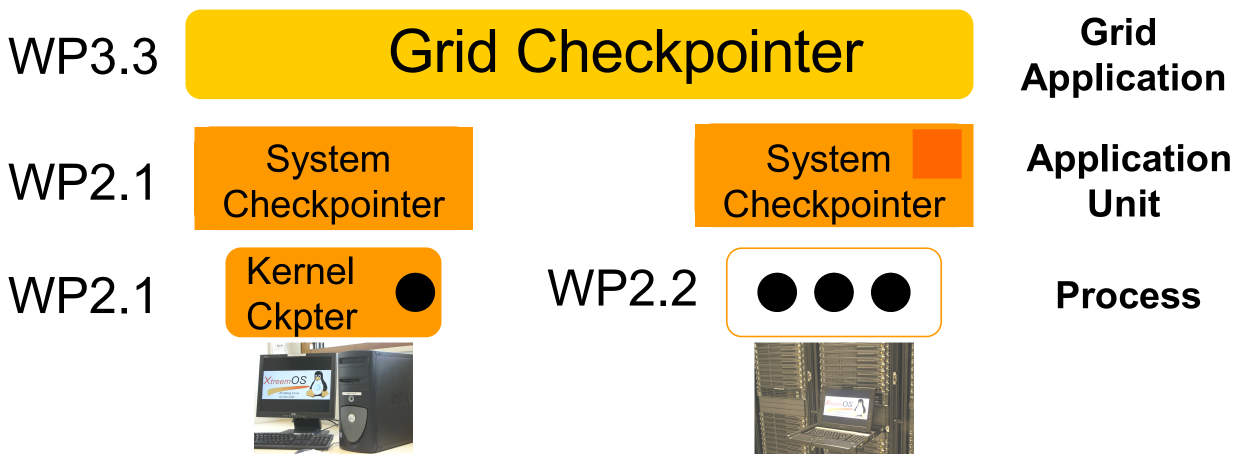
Overview

- Introduction – where do we want to go?
- Containers & Ghosts
- Container Checkpointing

Checkpointing in XtreemOS

- Kernel Checkpointer: saving states of nodes and <u>Kerrighed clusters</u>
- System Checkpointer: periodic incremental chkp. & garbage collection
- Grid Checkpointer: scalable hierarchical chkp., failure detection & recovery



Checkpointing in Kerrighed

- belongs to WP2.2 of XtreemOS
- Kernel Checkpointer: saving state of a process
  - shared memory: UDUS
  - open files and network communication: IRISA
- System Checkpointer:
  - WP2.1 code will be extended
  - a cluster appears as a single grid node
  - LinuxSSI/Kerrighed manages periodic checkpointing, failure detection and recovery of a cluster in interaction with the grid Checkpointer

UDUS' research perspective

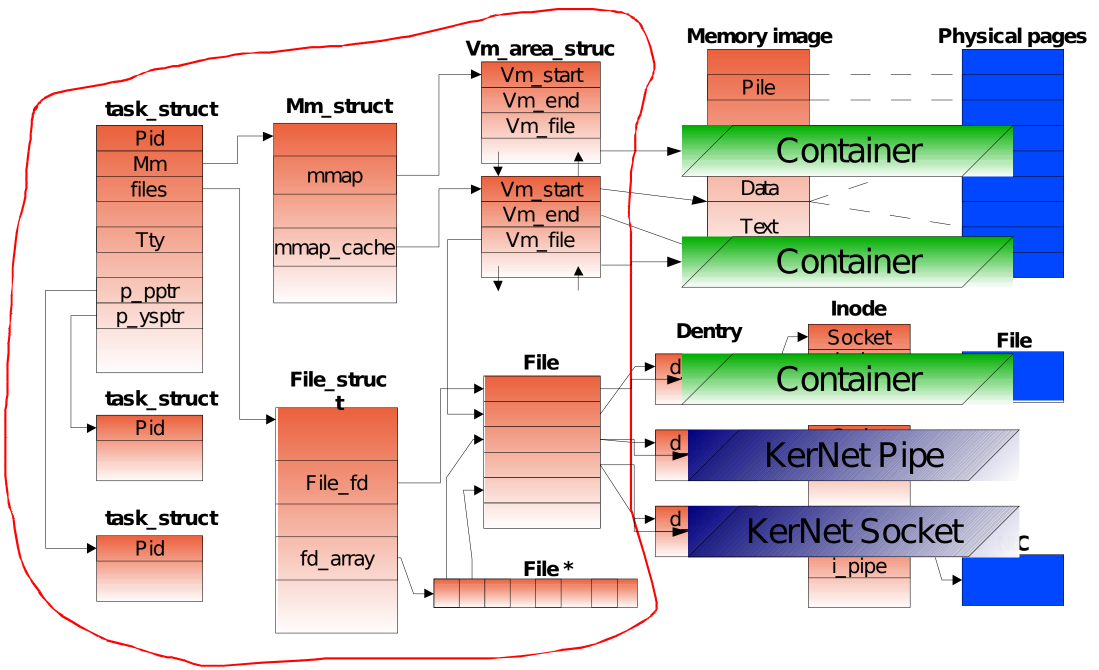
- WP2.2: container-based checkpointing in Kerrighed
  - simplified checkpointing of different resources
  - ghosts for saving & restoring kernel states
  - checkpointing strategies for large scale clusters
- WP3.3: grid-level checkpointing & recovery strategies
  - adaptive strategies (coordinated versus independent ones)
  - hierarchical approaches for applications spanning multiple clusters (interaction of Kerrighed System Checkpointer and Grid Checkpointer)
  - hetereogenous environments (mobile, PC, clusters)

Containers

- Containers: for sharing data objects cluster wide
  - transparent access to remote data
  - MESI-like protocol for consistency
  - building block for Single System Image
- Linkers
  - Defines the type of objects to be managed by the linked container
  - Interface between containers and host OS resources
  - For memory, network streams, files, ...

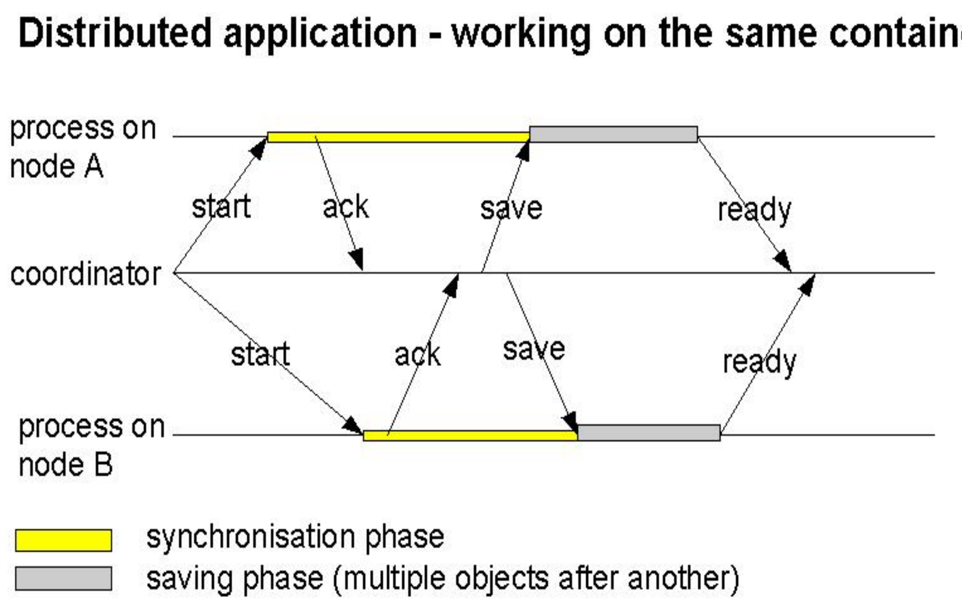
Ghosts

- Ghosts: for process migration
  - handle kernel data structures of a process
  - dynamically interweaving containers for resources of a process



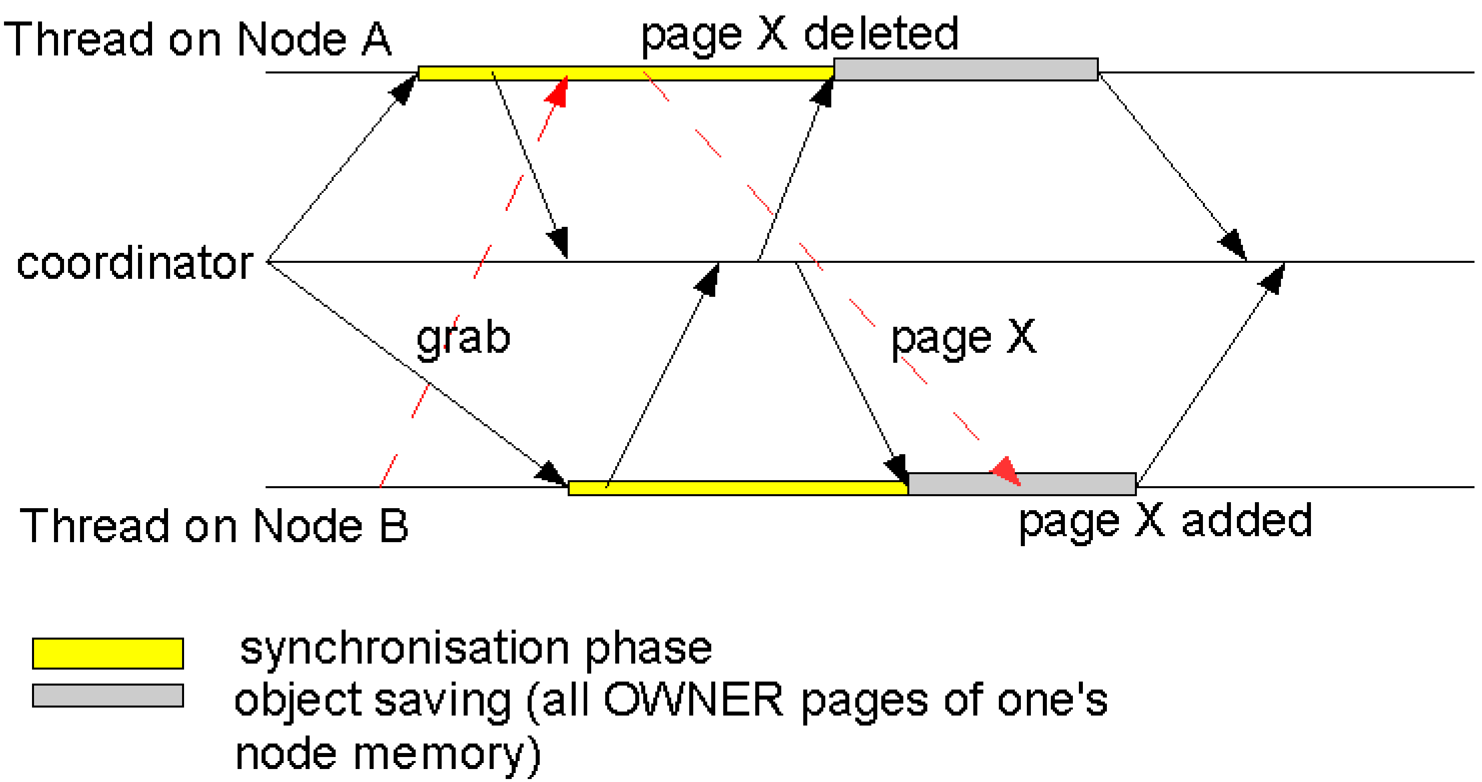
Container Checkpointing

- coordinated checkpointing approach
  (synchronize processes, start checkpointing, resume work)
- what can happen **within synch phase (yellow bar)** in Kerrighed?
  - Case 1: change of ownership
    (grab page request, page eviction to a remote node)
  - Case 2: swapping pages to local disk



Container Locking

Distributed application - working on the same container



Case 1: Change of ownership

- caused by:
  - application unit B, stopped after application unit A
  - Message(s) in transfer
- risk: owner object can be left without saving it
  - owner object is not sent immediately after grab to requesting node
  - might be forgotten to save on requesting node ...
    - ... if object arrival follows decision which data to be saved has already been made
- => consistency issue

Case 2

- I/O operation required to retrieve objects from disk during the checkpointing operation
- Does not cause faults but a performance issue

Realising CP – Approach I

- solution: insert new state into state machine
- define that *ownership changes* and *evictions* must NOT be executed within new state – **block requests**
- approach: “An efficient and scalable approach for implementing fault-tolerance DSM architectures“ (Morin,Kermarrec, Banatre, Gefflaut)
  - Extended Coherence Protocol (Precommit, Shared-CK, Inv-CK)
  - recovery data in memory, use for computation
- PRO: solves case 1 and case 2
  new state ensures “undisturbed” synch phase
  if extended: use replica data for computation
- CON: implementation; performance overhead
  state machine modification

Realising CP – Approach II A

- Idea: stop senders and wait until container event queue is empty
- avoid impact of container protocol actions on objects on the recipient side
- wait until container event queue gets empty
- PRO: no modification to state machine
- CON: at what time will queue be empty?
  not all processes, that could send container msg's can be stopped, otherwise system halts
  => queue is not guaranteed to be empty

Realising CP – Approach II B

- solution: avoid impact of protocol actions on sender side
- do not send protocol actions for certain containers
- realisation:
  - stop processes using signals (SIGSTOP, SIGCONT)
  - wrapper for protocol actions – do not block all containers
  - export objects
  - create disk structure (page data & meta data for recovery)
- PRO: solves case 1 and case 2
  no modification of state machine

Conclusion

- Container code is complex
- Still a lot of work ahead