Physical Disentanglement in a Container-Based File System

A Presentation for CS854

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Introduction

- Isolation is central to increased reliability and improved performance of modern computer systems.
- We say, for example, that two files are *entangled* if their blocks are allocated using the same bitmap.
- Entanglement mainly arises because:
  - Logically-independent file system entities are not physically independent.

Motivation

- Entanglement can cause three main problems:
  1. Global failure
  2. Slow recovery
  3. Bundled performance

Global Failure

- Single fault leads to a global failure.
- Current file systems crash entire system or mark whole file system read -only.
- For example:
  - Btrfs crashes entire OS when invariant is violated.
  - ext3 marks whole file-system read-only when it detects corruption in single inode bitmap.

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Crash	129	341	703
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Fault Type	Ext3	Ext4
Metadata read failure	70 (66)	95 (90)
Metadata write failure	57 (55)	71 (69)
Metadata corruption	25 (11)	62 (28)
Pointer fault	76 (76)	123 (85)
Interface fault	8 (1)	63 (8)
Memory allocation	56 (56)	69 (68)
Synchronization fault	17 (14)	32 (27)
Logic fault	6 (0)	17 (0)
Unexpected states	42 (40)	127 (54)

Slow Recovery

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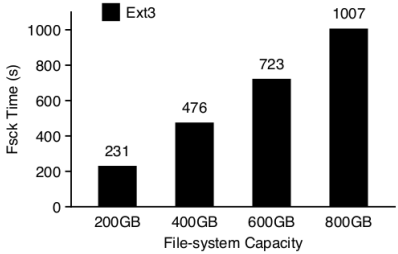

Bundled Performance

- File-systems, like ext3, use a journal to keep track of uncommitted changes, committing at periodic intervals.
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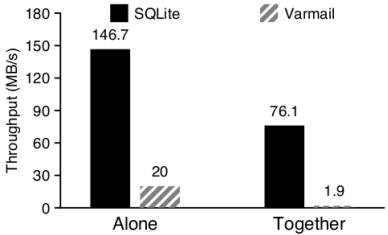

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  - Fails to address above problems.
  - Files from different namespaces may still share metadata, system states etc.,
- Static disk partitions: Multiple file systems can be created on separate partitions.
  - Single `panic()` or `BUG_ON()` can still crash entire OS.
  - Not flexible, and number of partitions limited.

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  - Redeployment and recovery require considerable downtime.
- Distributed File Systems:
  - Physical entanglement negatively impacts distributed file systems, especially multi-tenant settings.
  - Specifically, HDFS does not provide fault isolation for applications.
  - Scenario: four clients concurrently read different files, and the machine which stores the data blocks crashes.