Σχεδίαση και Υλοποίηση Μηχανισμού Κρυφής Μνήμης για Κατανεμημένο Σύστημα Αποθήκευσης σε Περιβάλλον Υπολογιστικού Νέφους

Αλέξιος Πυργιώτης
Εθνικό Μετσόβιο Πολυτεχνείο
October 16, 2013

1. Καλημέρα σας, ονομάζομαι Αλέξιος Πυργιώτης
   Θα σας παρουσιάσω τη διπλωματική μου με τίτλο:..
2. Ακούγεται κάπως περίεργο στα ελληνικά...
   αυτό που πραγματεύται είναι την δημιουργία ενός caching μηχανισμού για το Archipelago, ένα distibuted, storage layer
3. Συγκεκριμένα, στην παρουσίαση αυτή θα μιλήσουμε για τον cached, δηλαδή τον caching μηχανισμό μας, αλλά και για το synapsed, ένα συμπληρωματικό εργαλείο που στόχος του είναι να δώσει στον cached δικτυακές δυνατότητες

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1. Ο κορμός της παρουσίασης είναι ο εξής:
   - Αρχικά, παρουσιάζουμε κάποια εισαγωγικά που αφορούν το background της εργασίας μας. Αναφέρουμε τι είναι το Synnefo, τι είναι η υπηρεσια okeanos και τι είναι το Αρχιπέλαγο
   - Έπειτα, δείχνουμε τον τρόπο με τον οποίο η υποδομή μας χειριζεται αιτήματα δεδομένων από ένα VM.

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Synnefo

synnefo

Open source, production-ready, cloud software.
Designed since 2010 by GRNET.

Synnefo, as most cloud software, has the following services:
- Compute Service
- Network Service
- Storage Service
- Image Service
- Identity Service

Ας ξεκινήσουμε με την παρούσα κατάσταση.
Το software που τα ξεκίνησε όλα είναι το Synnefo

..by GRNET -> Και φυσικά τα παιδιά που βλεπετε εδώ

- Compute service, είναι η υπηρεσία η οποία προμηθεύει τους χρήστες με VMs και επιτρέπει το χειρισμό τους
- Network service, είναι η υπηρεσία η οποία δίνει τη δυνατότητα στους χρήστες να δημιουργήσουν ιδιωτικά δίκτυα και να συνδέσουν τα VMs τους σε αυτά.
- Storage service, που κοινώς αποθηκεύει τα αρχεία των χρηστών. Στην περίπτωση του Synnefo όμως, έχουμε ένα κοινό σημείο για τα πάντα: είτε είναι αρχεία, είτε δίσκοι των VMS, είτε images
- Image Service, υπεύθυνο για το deployment ενός VM από ένα image. Επίσης, κάνει και παραμετροποιήσεις (παράδειγμα ssh κλειδιά)

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- Targeted at the Greek Academic and Research Community
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- IaaS είναι πρακτικά η παροχή εικονικής υποδομής σε χρήστες (δηλαδή πάρε υπολογιστή (VM), δίκτυα, αρχεία κτλ)
- Δωρεάν για τους Ακαδημαϊκους σκοπούς, ήδη γίνονται εργαστήρια στο EMP και απ' αυτό το εξάμηνο σε άλλες σχολές

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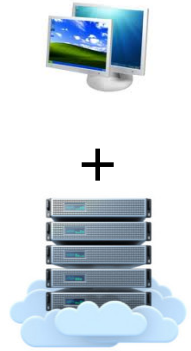

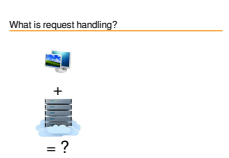

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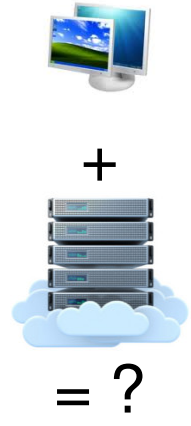

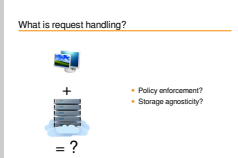

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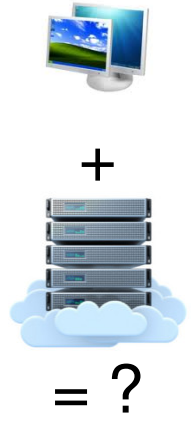
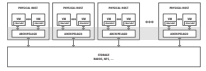


- Policy enforcement?
- Storage agnosticity?

Our solution
Archipelago



Key features: 1) Software-defined 2) Distributed) Modular Copy-On-Write Storage agnostic

Η λύση που χρησιμοποιήσαμε είναι το Archipelago

- Software-defined: αν και είναι ένα όρος μαρκετινγκ, εμείς κανονικά. Σημαίνει με το software ΟΡΙΖΕΙΣ το storage (εφαρμογή policy, αλλαγή πορείας του request)
- τρέχει σε πολλούς κόμβους
- αποτελείται από διακριτά κομμάτια
- κάνει CoW (εξήγησε ότι τα images είναι λίγα, τα VMs πολλά, όπως όταν ένα process κάνει fork)
- μπορούμε χρησιμοποιήσουμε ότι θέλουμε

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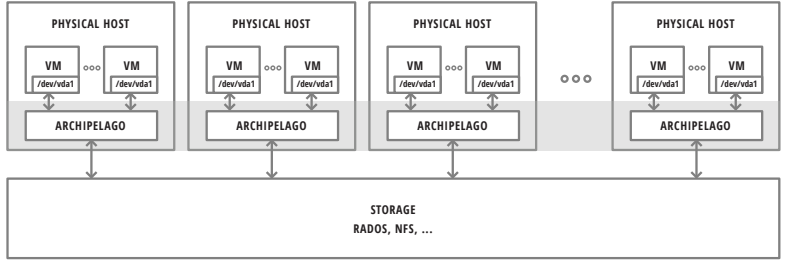

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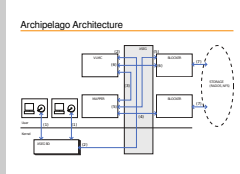
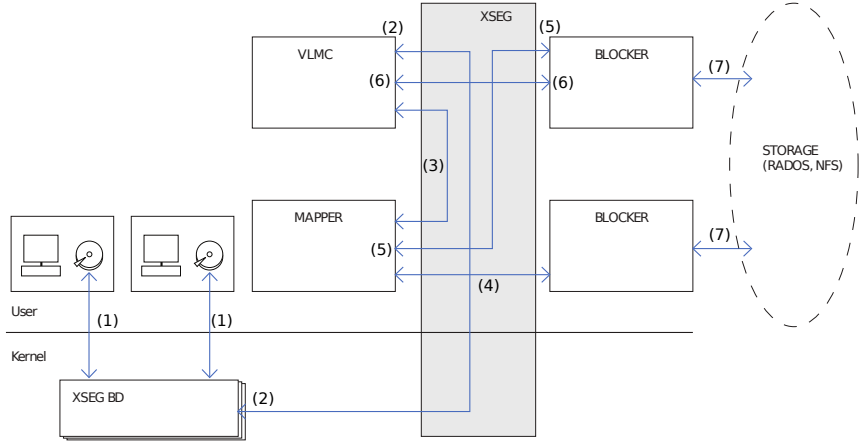


- Το VM στέλνει αίτημα στο δίσκο του, ο δίσκος είναι εικονικός, θα το δει ο hypervisor (εξήγησε τι είναι ο hypervisor) και θα το στείλει στον δίσκο που το έχουμε πει. (xsegbd)
- 2) **FIXME:**

Archipelago Architecture



RADOS
The object store component of Ceph filesystem.
Key features:
- Replication
- Fault tolerance
- Self-management
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1. Η κλασσική λύση σε τέτοια προβλήματα είναι η χρήση ενός γρηγορότερου αποθηκευτικού μέσου για caching.
2. Για όσους δεν ξέρουν τι σημαίνει caching, θα το εξηγήσουμε συνοπτικά: έχεις ροή, αργό μέσο, βάζεις ένα γρήγορο, speedup
3. Προφανώς αυτό το concept είναι γνωστό. Από που;

Intro

Solution: Caching

Caching is:
- We have a slow medium
- Add a fast medium in a data path
- Transparently store the data that are intended for the slower medium.
- Profit: later accesses to the same data are faster

Sounds familiar?

Intro

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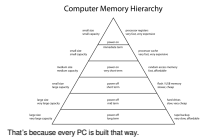
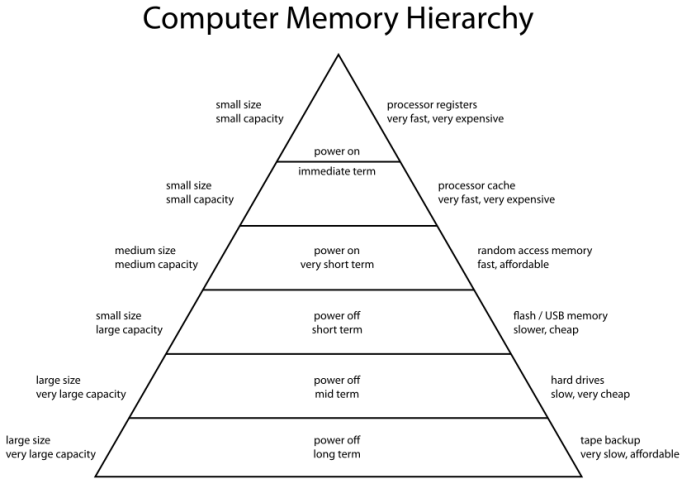


1. Από το ιεραρχικό μοντέλο του υπολογιστή: cpu cache vs ram, ram vs disk

Caching



That's because every PC is built that way.

Is there anything to help us?

FACT: We are not the first to have speed issues
Facebook, Twitter, Dropbox, every one has hit and surpassed their limits.

There are solutions separated in two categories:
- Block store
- Key-value store

1. Τώρα που ξέρουμε τη λύση, υπάρχει κάτι που μπορούμε να κάνουμε;
2. Υπάρχει κάτι έτοιμο; ΝΑΙ
3. Δυο κατηγορίες:
   - βλέπουν τα δεδομένα σαν blocks ενός δίσκου
   - βλέπουν τα δεδομένα σαν κομμάτια αντικειμένων

   Διαφορά: TODO:

Caching

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Block-store caching solutions

Most notable examples:
- Bcache
- Flashcache
- EnhanceIO

Typically scale-up solutions.

Pros: Simple, scale-up
Cons: Unaware of CoW, kernel solutions

1. Πρώτη κατηγορία που εξετάσαμε έχει αρκετά ενδιαφέρουσες λύσεις.
2. Δε θα επεκταθούμε γιατί έχουν κάποια βασικά κοινά:
   - Kernel modules
   - expose εικονικά block devices
3. Εξήγησε που μπαίνουν (xsegbd)

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Key-value caching solutions

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Pros: Distributed with no SPOF, can utilize unneeded RAM
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What if we used the page-cache?

Pros: Easy to activate, tested, very fast
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- Most solutions far from Archipelago's logic
- Block store might be good for the storage backend
- Must implement our own solution

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Design goals for cached:
- Create something close to the Archipelago logic
- Measure the best possible performance we can get

Stricter requirements for cached:
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- Pluggability
- In-memory
- Low indexing overhead

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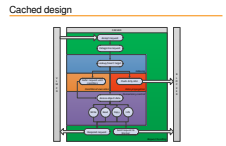
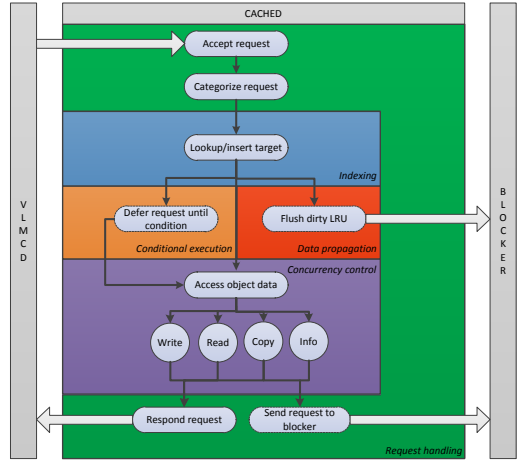


Cached design



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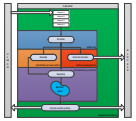

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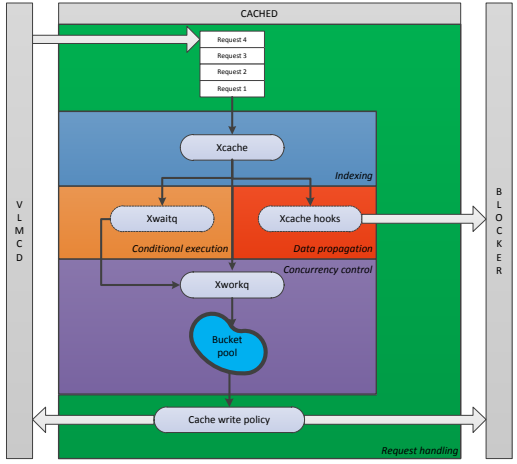

Xcache design

Xcache is responsible for: 1) entry indexing, 2) entry eviction, 3) concurrency control, 4) notification via event hooks

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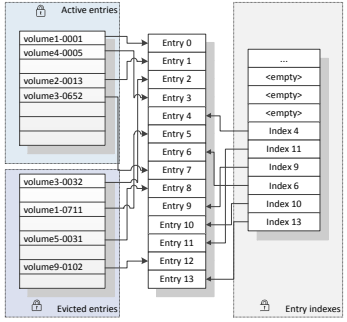

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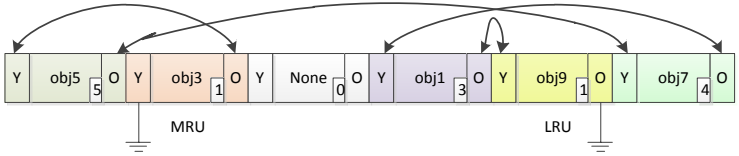

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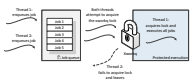
Xworkq design



Xworkq is responsible for concurrency control

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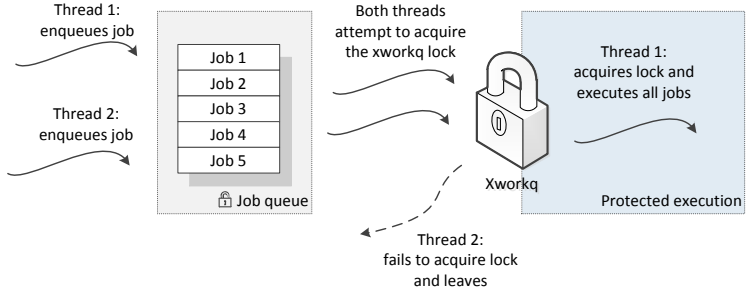

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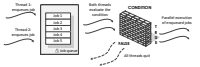
Xwaitq design



Xwaitq is responsible for deferred execution

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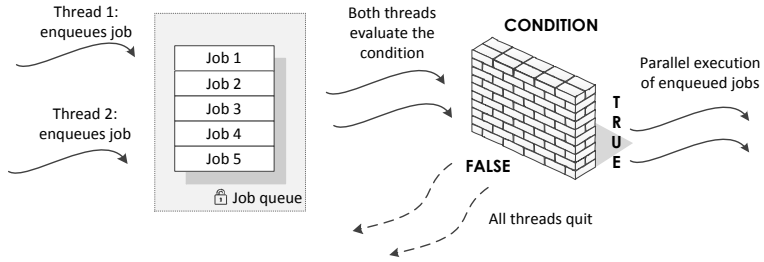

Xwaitq is responsible for deferred execution

Bucket pool

When an object is indexed, it does not have immediate access to 4MB size of data because:
- RAM is limited
- Leads to small number of entries

Ideally, we want to:
- Decouple the objects from their data
- Cache unlimited objects but put a limit on their data

Solution:
- Preallocated data space
- Every object request a bucket (typically 4KB)
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Other important cached tasks

Several other key-tasks are:
- Book-keeping
- Cache write policy
- Asynchronous task execution
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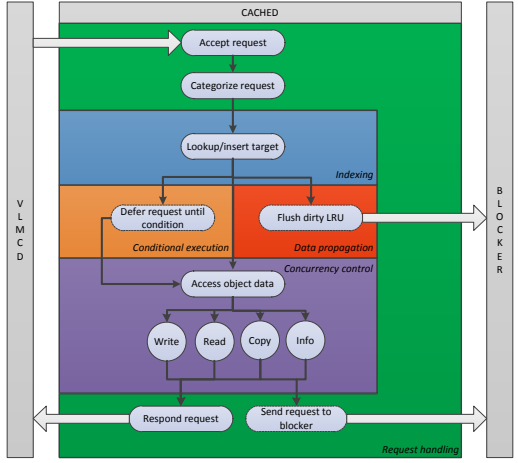
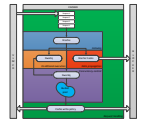
Cached flow

Cached flow


CACHED
Accept request
Categorize request
Lookup/insert target
Indexing
Defer request until condition
Flush dirty LRU
Conditional execution
Data propagation
Concurrency control
Access object data
Write
Read
Copy
Info
Respond request
Send request to blocker
Request handling
VLMCD
BLOCKER


Cached flow

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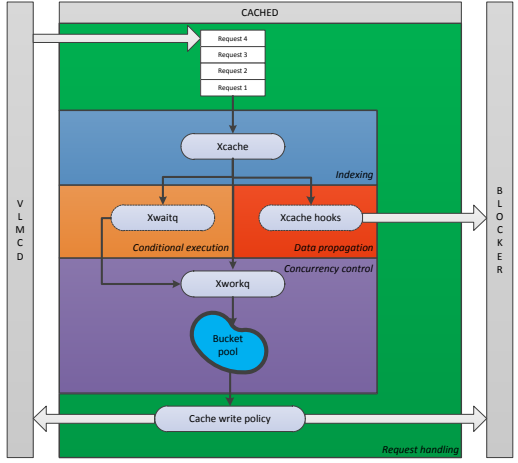
CACHED
Request 4
Request 3
Request 2
Request 1
Xcache
Indexing
Xwaitq
Xcache hooks
Conditional execution
Data propagation
Concurrency control
Xworkq
Bucket pool
Cache write policy
Request handling
VLMCD
BLOCKER

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Benchmark methodology

We have conducted exhaustive benchmarks.
They are separated in three categories:
- Comparison between cached and sosd
  - Peak behavior
  - Sustained behavior
- Internal comparison of cached
  - Multithreading overhead
  - Indexing mechanism overhead
- Evaluation of VM/Archipelago

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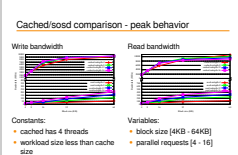
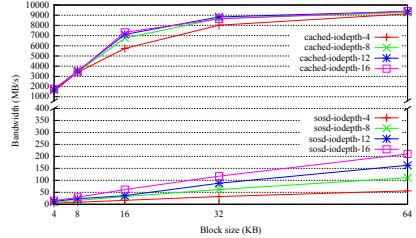
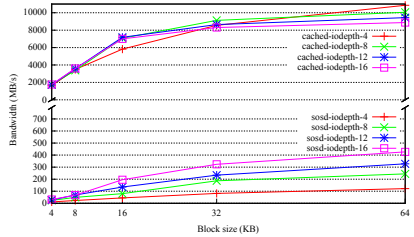


Cached/sosd comparison - peak behavior

Write bandwidth



Read bandwidth



Constants:

- cached has 4 threads
- workload size less than cache size

Variables:

- block size [4KB - 64KB]
- parallel requests [4 - 16]

Cached/sosd comparison - peak behavior
Write latency
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Constants:
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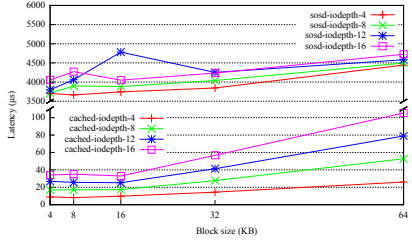

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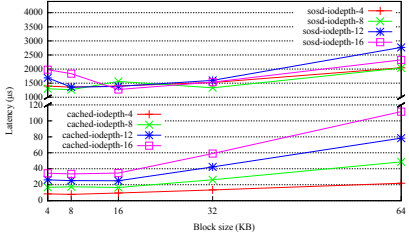

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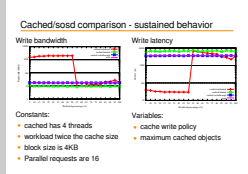
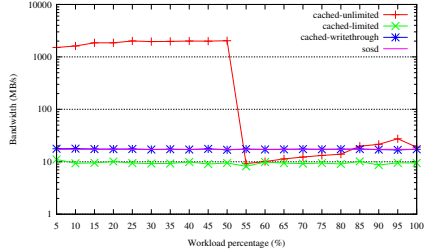
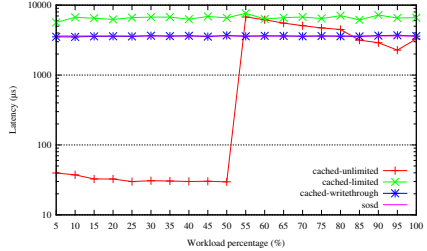


Cached/sosd comparison - sustained behavior

Write bandwidth



Write latency



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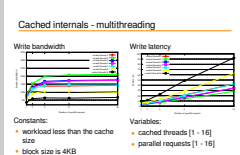
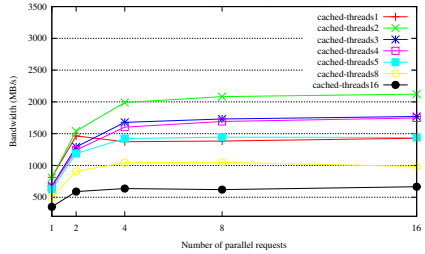
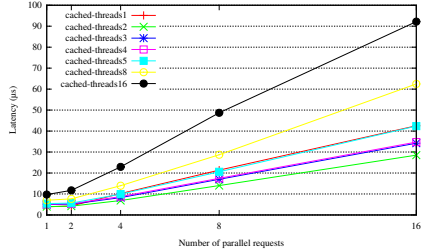


Cached internals - multithreading

Write bandwidth



Write latency



Constants:

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Variables:

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Cached internals - indexing
Latency of cold cache vs. warm cache
Constants:
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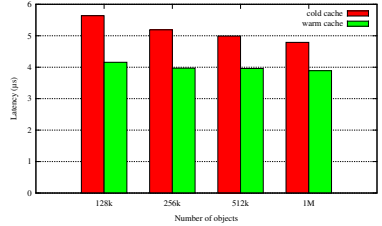
Latency of cold cache vs. warm cache



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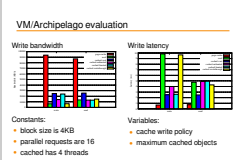
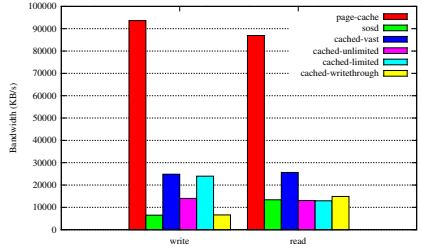
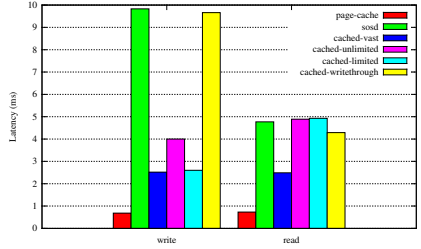


VM/Archipelago evaluation

Write bandwidth



Write latency



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Previous results show that:
- There is high lock contention
- The amount of RAM is important

If cached remains at the host, it will:
- Compete for CPU time
- Use a fraction of the host's RAM

Idea: what if cached ran on storage nodes?

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- Access to more RAM
- Major step towards a distributed cache

On the other hand, the cons would be:
- Network bottleneck
- Bigger complexity

Archipelago is network-unaware. Must create a proof-of-concept network peer to help us in this task.

Synapsed

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Synapsed is designed to do the following:
- Connect two Archipelago peers over network
- Forward read/write XSEG requests
- Use the TCP protocol
- Integrate with the Archipelago signaling mechanism
- Use zero-copy methods

Replication should be trivial to implement, but it is currently missing.

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The most important part is that synapsed works. We are **now** able to run cached or part of Archipelago in the storage nodes.

However, let's check its performance.
We will attempt to run most of the previous scenarios using synapsed this time.

Note, synapsed is proof-of-concept and not performance-tuned.
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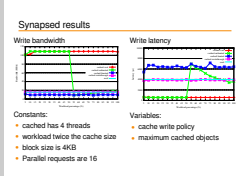
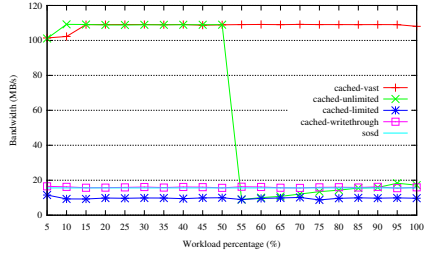


Synapsed results

Write bandwidth



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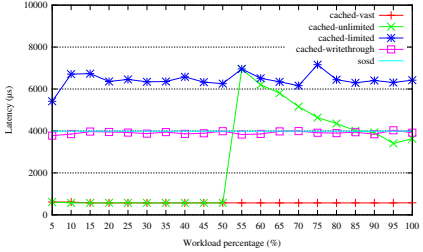

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Concluding remarks

We close this presentation with the following remarks:
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- Synthetic benchmarks show that cached can achieve 200x better performance than sosd
- In more real-life scenarios, cached speeds Archipelago up to 400%
- Synapsed can bridge two peers over network with minimum latency

Concluding remarks

We close this presentation with the following remarks:

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