Enabling Space Elasticity in Storage Systems

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Motivation

Elasticity for CPU and memory well known

Storage use typically hard to decrease

Motivation

00s:

- Single cores
- 1 Gbps networks
- Large HDDs

Motivation

A lot of data is volatile:

Swap files

Constructed from other data (thumbnails, indices, memoized computations)

Fetched over the network (browser and package manager caches)

Case in point: up to 55% of stored data on our dev VMs is ephemeral

Motivation

Today:

- Many cores
- 40 Gbps networks
- Smaller SSDs

Storage systems still promise never to lose data.

Our goal

Create a system that:

- Identifies data that isn’t really needed
- Removes this data when space needs to be recovered
- In case you *do* need some data, recover it

Motif:

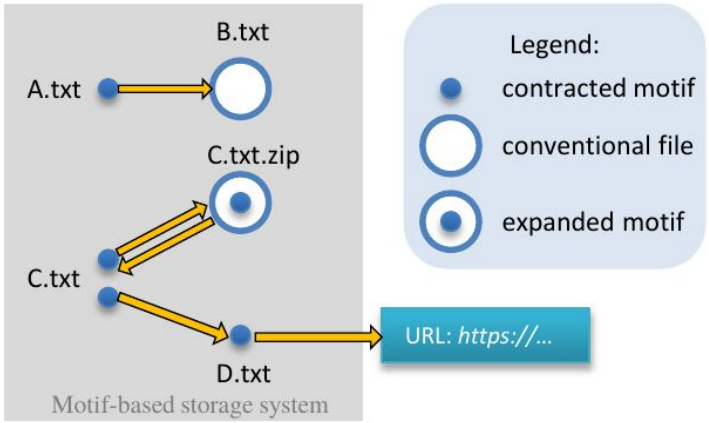
A piece of code that knows how to create a file.

Motifs

More specifically: An *expand* function and metadata

Key properties:

- A motif is stateful
- Motifs can be recursive
- A single file can have multiple motifs
- Can define circular dependencies
- Can be invalidated
- Support writes
  - Optional *contract* function



Carillon:

A system that utilizes motifs to provide space elasticity

Carillon

Two main components: **Runtime** and **storage shim**

Runtime is independent of the underlying storage layer
Shim is tailored to it

Operate in tandem to provide elasticity

Each different storage layer requires its own runtime/shim pair

Design goal: Add elasticity to existing storage with minimal effort

Carillon

The Carillon runtime is responsible for several things

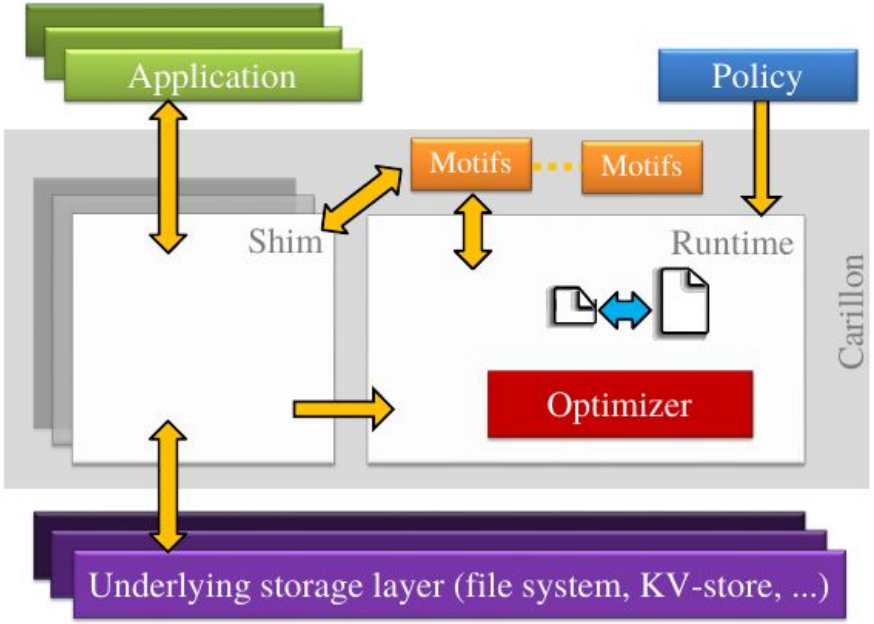
- Managing motif metadata
- Accept storage policies (eg. there is now less space available)
- Track statistics
- Execute motifs based on statistics and available space

Carillon

A Carillon shim, by contrast, does mostly one thing

- Intercept calls to the underlying storage layer and forward to runtime

Overview


Application
Policy
Motifs
Motifs
Shim
Runtime
Carillon
Optimizer
Underlying storage layer (file system, KV-store, ...)

What to delete?

Ideal goal: Never wait for expansion

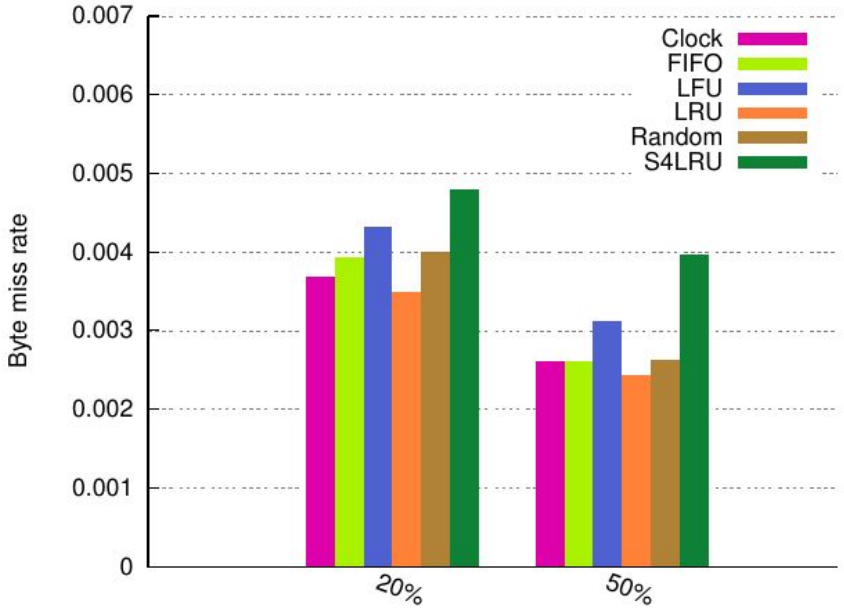
Can’t know the future

Actual goal: Minimize wait time

Model as a 0-1 knapsack problem; slow to solve

Cache algorithms!

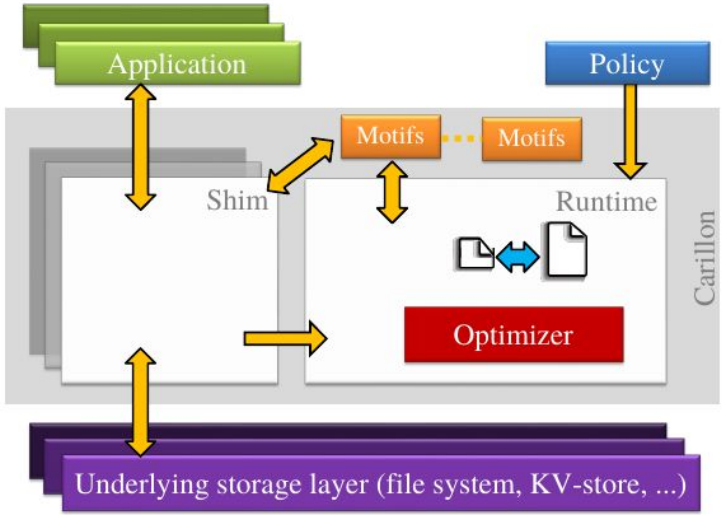
Cache algorithms



CarillonFS

Most operations forwarded without extra work.

Except: stat, open, unlink, rename, truncate, utime



CarillonKV

Key-value store

Graph database

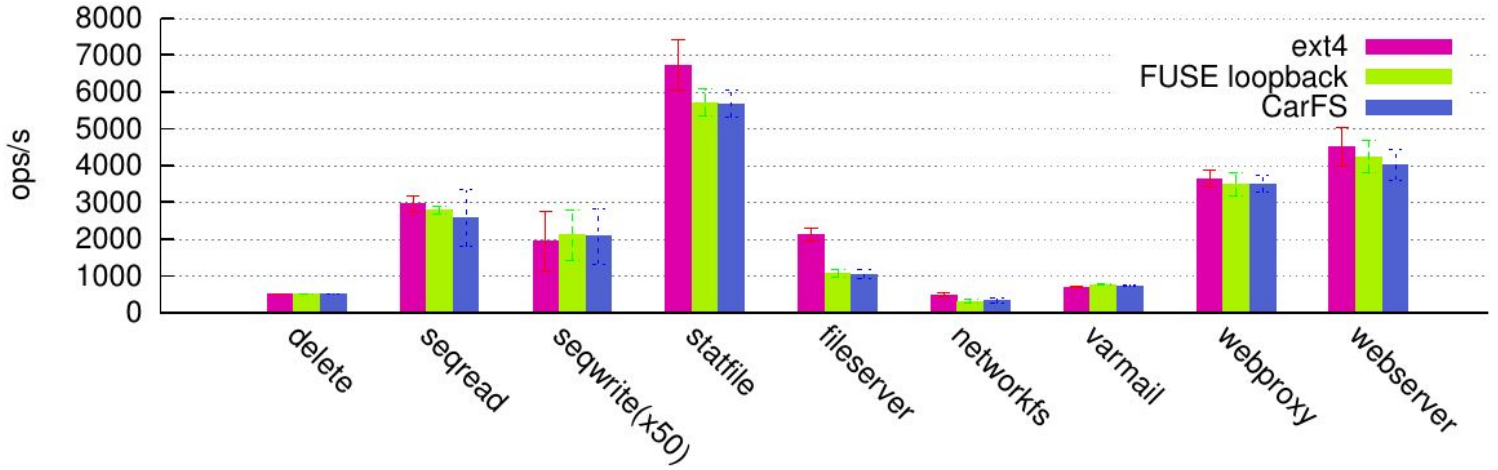
Route planner

Dijkstra’s algorithm has a lot of internal state that’s usually discarded

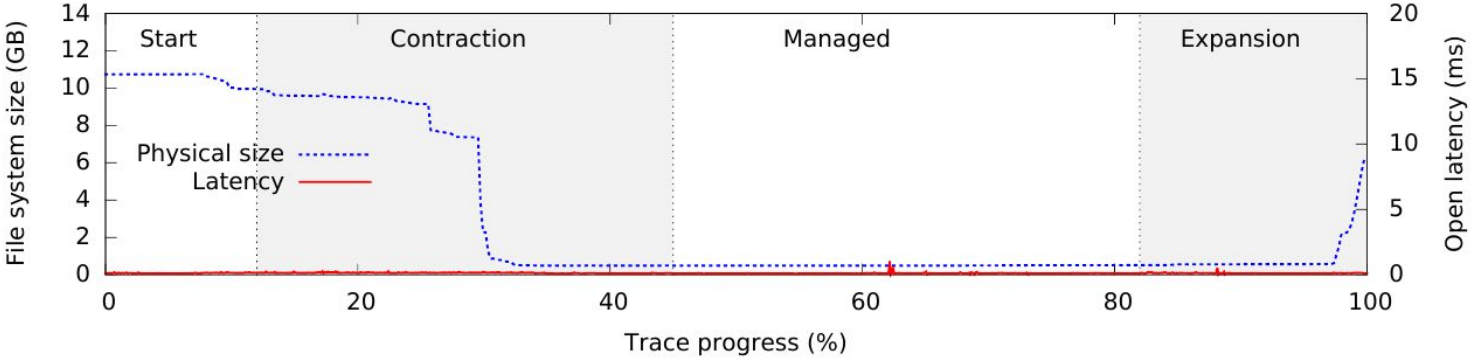
Motif-ize some of it to speed up future runs

Evaluation

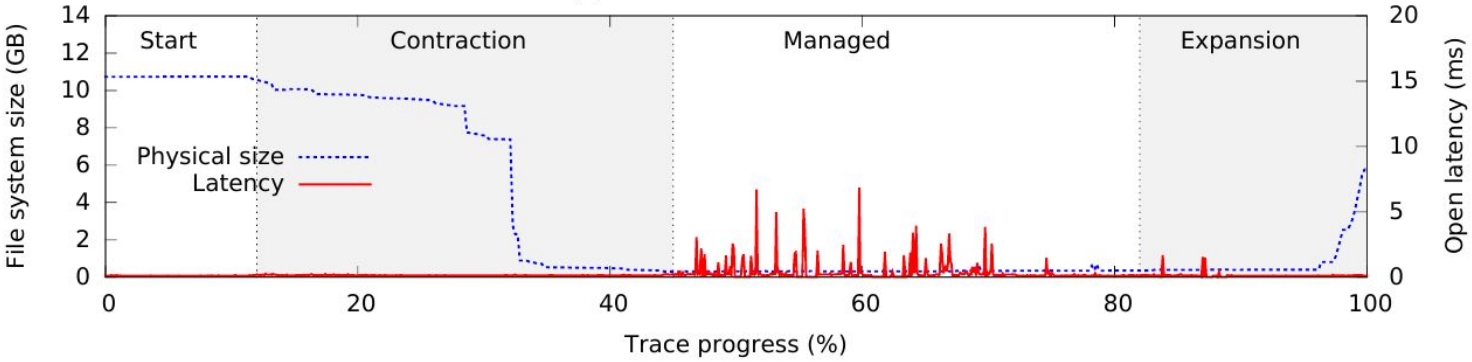
Filebench performance



CarillonFS elasticity

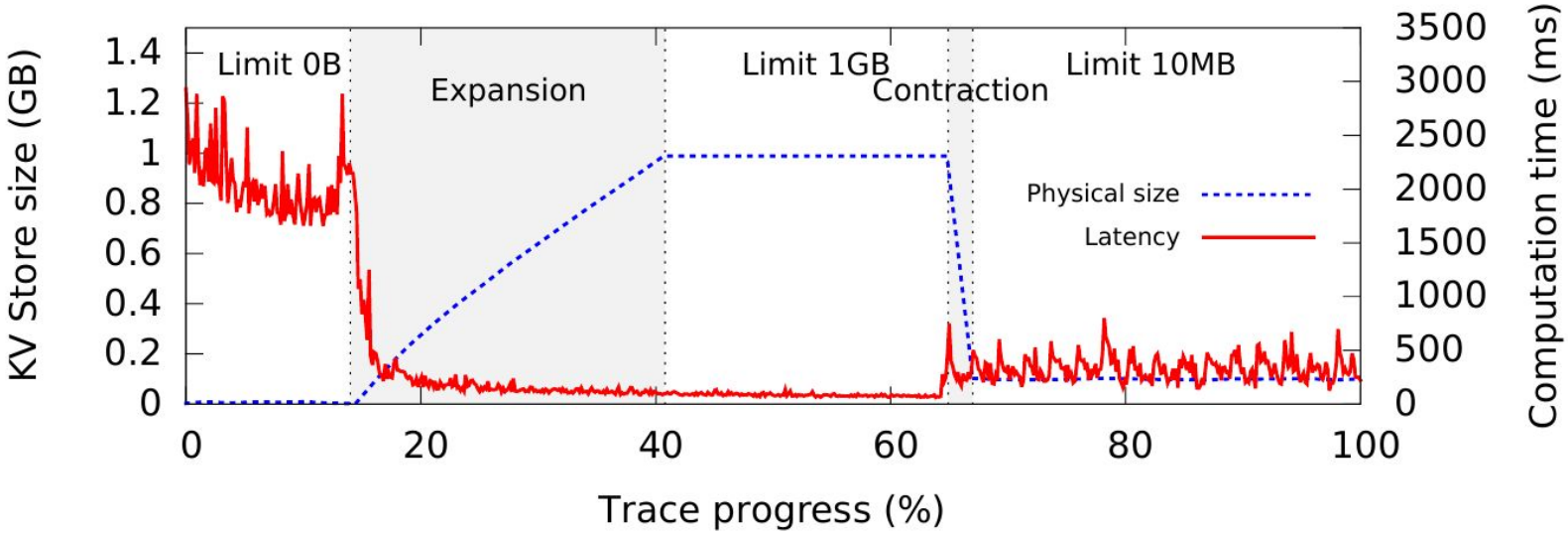


(a) *500MB available to Carillon-FS.*



(b) *No space available to Carillon-FS.*

CarillonKV elasticity

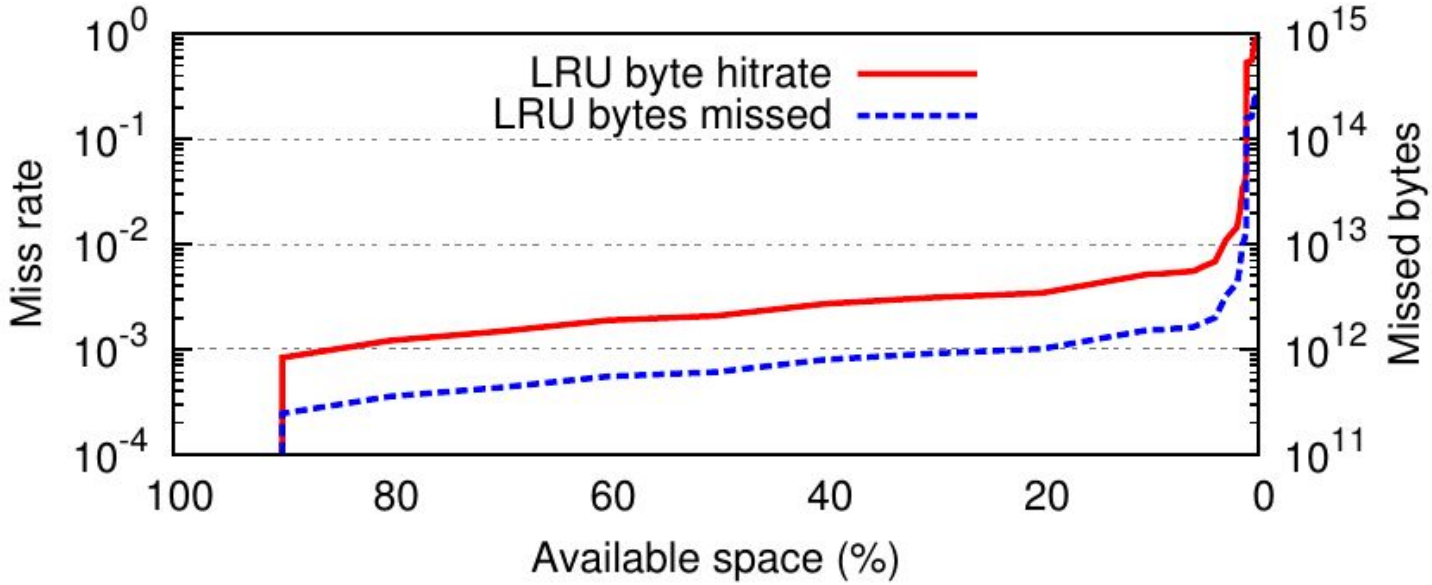


Questions?

Bonus slides!

Highly skewed trace

A vast majority of file accesses happens to a very small subset of files



Example motif

Network storage motif

Contracts a file by copying it to a remote store

Expands by copying back

Very similar to the one used in our evaluations

```
int contract(struct context *ctx) {
 int res = execute(
    "ssh %s \"mkdir -p ''dirname \"%s%s\"''\"",
    IP, PATH, ctx->path);
 if(res == 0)
   res = execute("scp \"%3$s\" '%s:\"%s%s\"'",
                 IP, PATH, ctx->path);
 return res;
}

int expand(struct context *ctx) {
 return execute(
    "scp '%1$s:\"%2$s%3$s\"' \"%3$s\"",
    IP, PATH, ctx->path);
}

static struct motif m = {
    .name     = "compress-motif",
    .contract = contract,
    .expand   = expand,
};

struct motif* init() { return &m; }
void cleanup() { }
motif_init(init);
```