MEMORY FRAGMENTATION AND BLOAT IN RUBY

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SPEEDSHOP.CO


AW, I CAN'T FIT open source INTO MY SCHEDULE.
OSS maintainer
SLEEP
WORK
FOOD
OSS maintainer
SLEEP
WORK
FOOD
OSS maintainer
SLEEP
WORK
FOOD
OR CAN I?...
OSS maintainer
SLEEP
WORK

speedshop

Speedshop is a Ruby on Rails performance consultancy that optimizes the full stack - frontend, backend and environment - to generate revenue and cut scaling costs for businesses on Rails. It's not uncommon for Speedshop clients to halve their server costs and improve perceived load times by 300%. Fast sites are profitable sites. Speed is a feature.

Products and Services

- **The Complete Guide to Rails Performance**, an in-depth 370 page book and 17 hours of HD screencasts and interviews with top experts, including DHH himself.
- **Speedshop Blog**, the number one Ruby on Rails performance blog on the 'net.

Who is Speedshop?

Who would win

popular web framework

512MB of RAM

MEMORY CONSTRAINED ENVIRONMENTS

* EMBEDDED
* 512 MB DYNOS
* 50% (?) OF RAILS APPS ARE MEMORY-CONSTRAINED

MEMORY BEHAVIOR IS DIFFICULT FOR RUBYISTS TO UNDERSTAND

LAYERS OF ABSTRACTION

1. Your Ruby code itself
2. Ruby runtime
3. Allocator
4. MMU (virtual/real memory)
5. Actual memory location (swap/RAM)

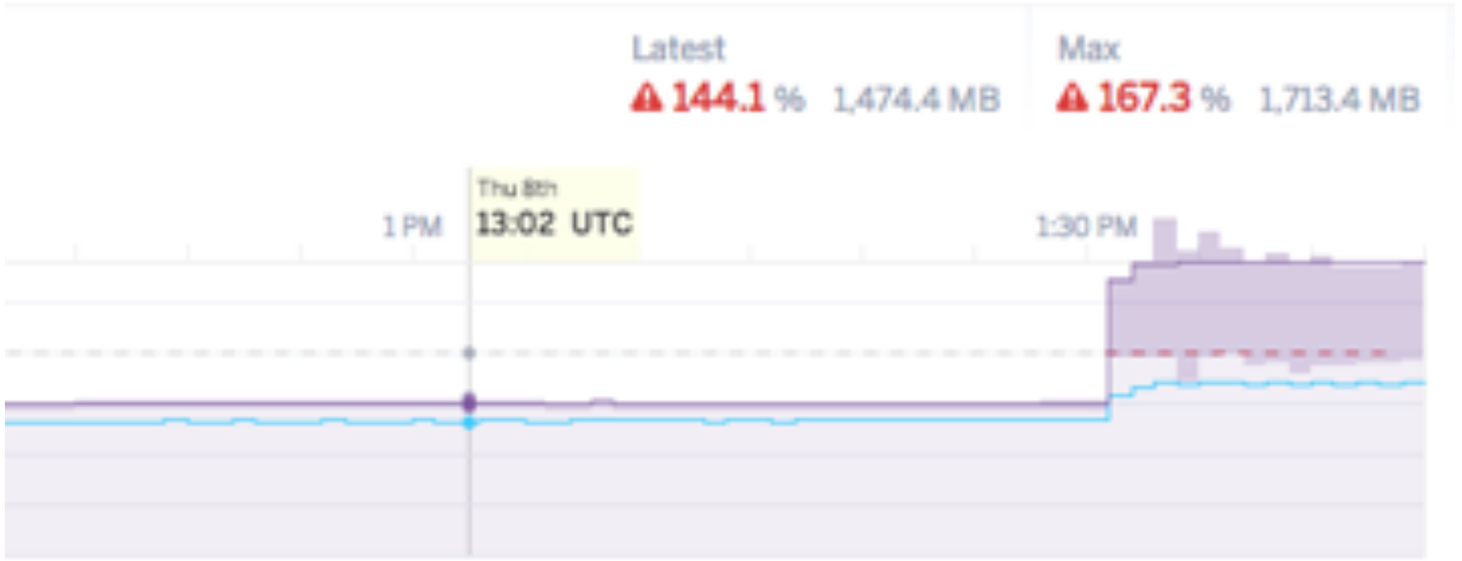
WE SHOULD PREVENT MEMORY OVERUSE OR MAKE IT EASIER TO DEBUG AND FIX

BLOAT

PATTERN

SUDDEN SPIKES

IN MEMORY, SLOW/NO FALLOFF


Latest
144.1 %
1,474.4 MB
Max
167.3 %
1,713.4 MB
Thu 8th
13:02 UTC
1 PM
1:30 PM

MEMORY USAGE THAT'S NECESSARY, BUT EXCESSIVE

PRIMARILY A FUNCTION OF THE RUNTIME AND YOUR USER CODE

CONTRIBUTES TO RAILS PROCESSES THAT NEED ~1GB EACH

User.all.each

API::V1::ADMIN::EXPORTSCONTROLLER

```
def index
  @every_single_user.to_csv
end
```

“Note that, in general, "freeing" memory does not actually return it to the operating system for other applications to use.
However, if the top chunk in a heap - the portion adjacent to unmapped memory - becomes large enough, some of that memory may be unmapped and returned to the operating system.”

» MallocInternals

“Closing as NOTABUG based on comment 3. malloc/free indeed cannot give address space back to the kernel when main arena is discontinuous and that is expected behaviour.”

» Malloc bug 15321


SOLUTION(?):
PAIN
IN INTERFACES


WANTED
MANIAC

MINITEST: PAINFUL STUBS

```
Time.stub :now, Time.at(0) do
  assert obj_under_test.stale?
end
```

RAILS "STRICT MODE"

```
SomeModel.all.each # *always* batches
SomeModel.select(:some_attribute) # *always* select
```

ENUMERABLE

```
raise CollectionTooLargeError # dev only, WARN in prod
some_huge_collection.map # raise
```

BUT THIS CAN BE ABUSED: WE DON'T WANT TO "THINK LIKE A COMPUTER"

“No user-level memory management
Ruby has automatic memory management.”

» Ruby manpage

SOLUTION(?):

JUST ALLOCATE LESS

SINATRA VS RAILS

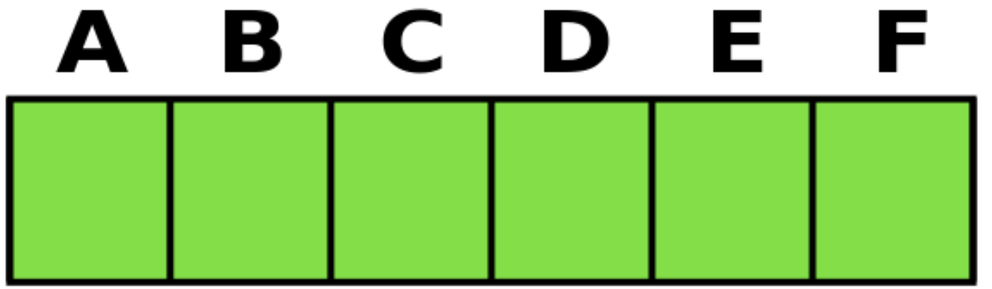
SOLUTION(?): AGGRESSIVE DE-ALLOCATION

FRAGMENTATION

PATTERN:

SLOW, ENDLESS "LOGARITHMIC" GROWTH IN LONG-RUNNING RUBY PROGRAMS

External fragmentation



Total free memory available for allocation.

Dynamically allocated
three blocks of memory (**A**, **B**, **C**).

Out of these three continuous blocks of allocated memory, consider that the middle block B is released. It is not possible to use the freed block B, if the memory to be allocated is larger than the size of block B.

SWISS CHEESE

WEB REQUEST ALLOCATION PATTERN

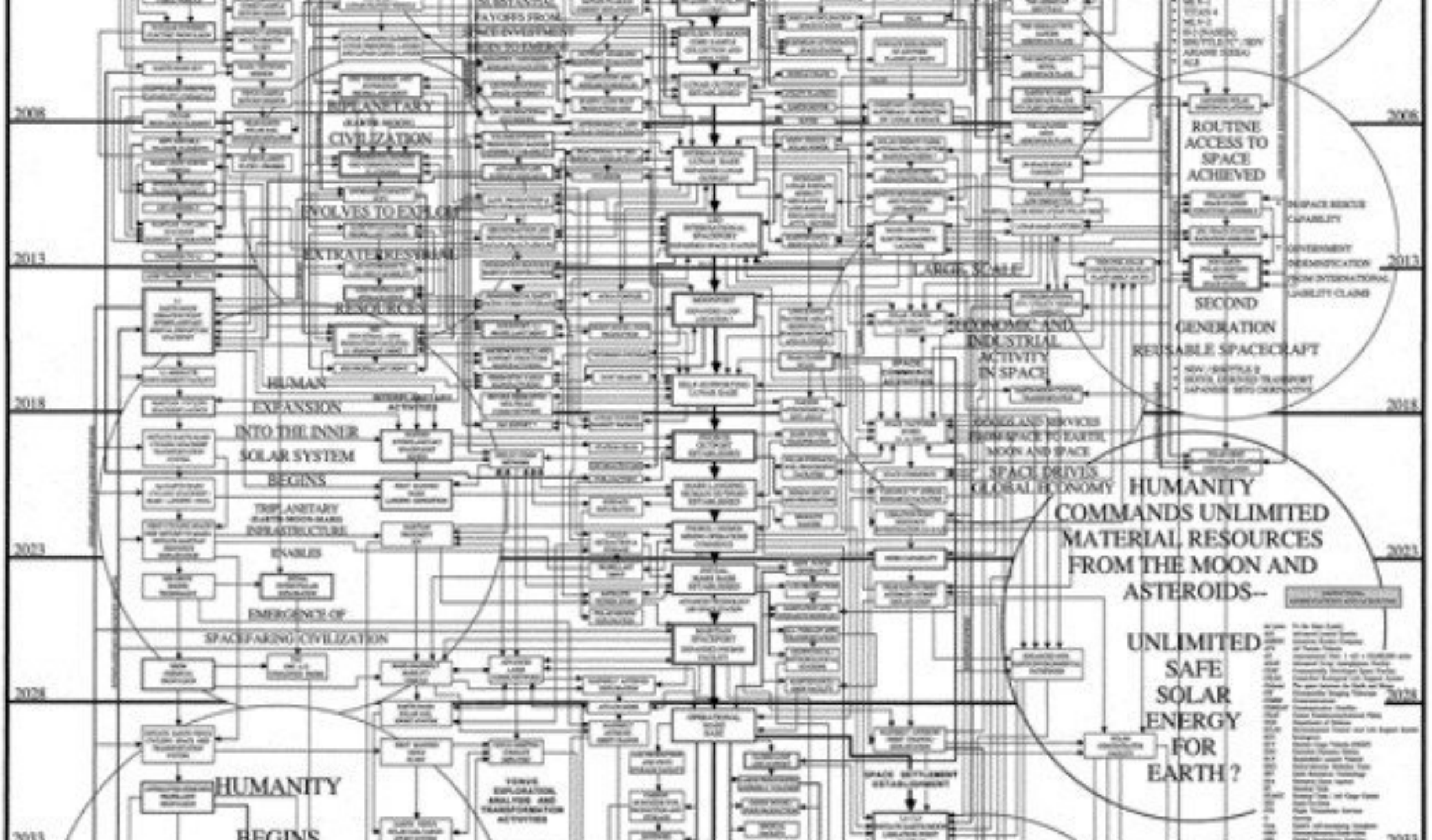
PRIMARILY

RUNTIME AND ALLOCATOR

OFTEN MISTAKEN FOR LEAKS (LINEAR V LOG GROWTH)

GC.STAT

RUBY GC INTERNALS IN 60 SECONDS


2008
2013
2018
2023
2028
2033
TRIPLANETARY
CIVILIZATION
EVOLVES TO EXPLOIT
EXTRATERRESTRIAL
RESOURCES
HUMAN
EXPANSION
INTO THE INNER
SOLAR SYSTEM
BEGINS
TRIPLANETARY
INFRASTRUCTURE
ENABLES
EMERGENCE OF
SPACEFARING CIVILIZATION
HUMANITY
BEGINS
VENUS
EXPLORATION,
ANALYSIS AND
TRANSFORMATION
ACTIVITIES
LARGE SCALE
ECONOMIC AND
INDUSTRIAL
ACTIVITY
IN SPACE
GOODS AND SERVICES
FROM SPACE TO EARTH,
MOON AND SPACE
SPACE DRIVES
GLOBAL ECONOMY
SPACE SETTLEMENT
ESTABLISHMENT
ROUTINE
ACCESS TO
SPACE
ACHIEVED
SECOND
GENERATION
REUSABLE SPACECRAFT
HUMANITY
COMMANDS UNLIMITED
MATERIAL RESOURCES
FROM THE MOON AND
ASTEROIDS--
UNLIMITED
SAFE
SOLAR
ENERGY
FOR
EARTH?

EVERY OBJECT IS GIVEN A 40-BYTE

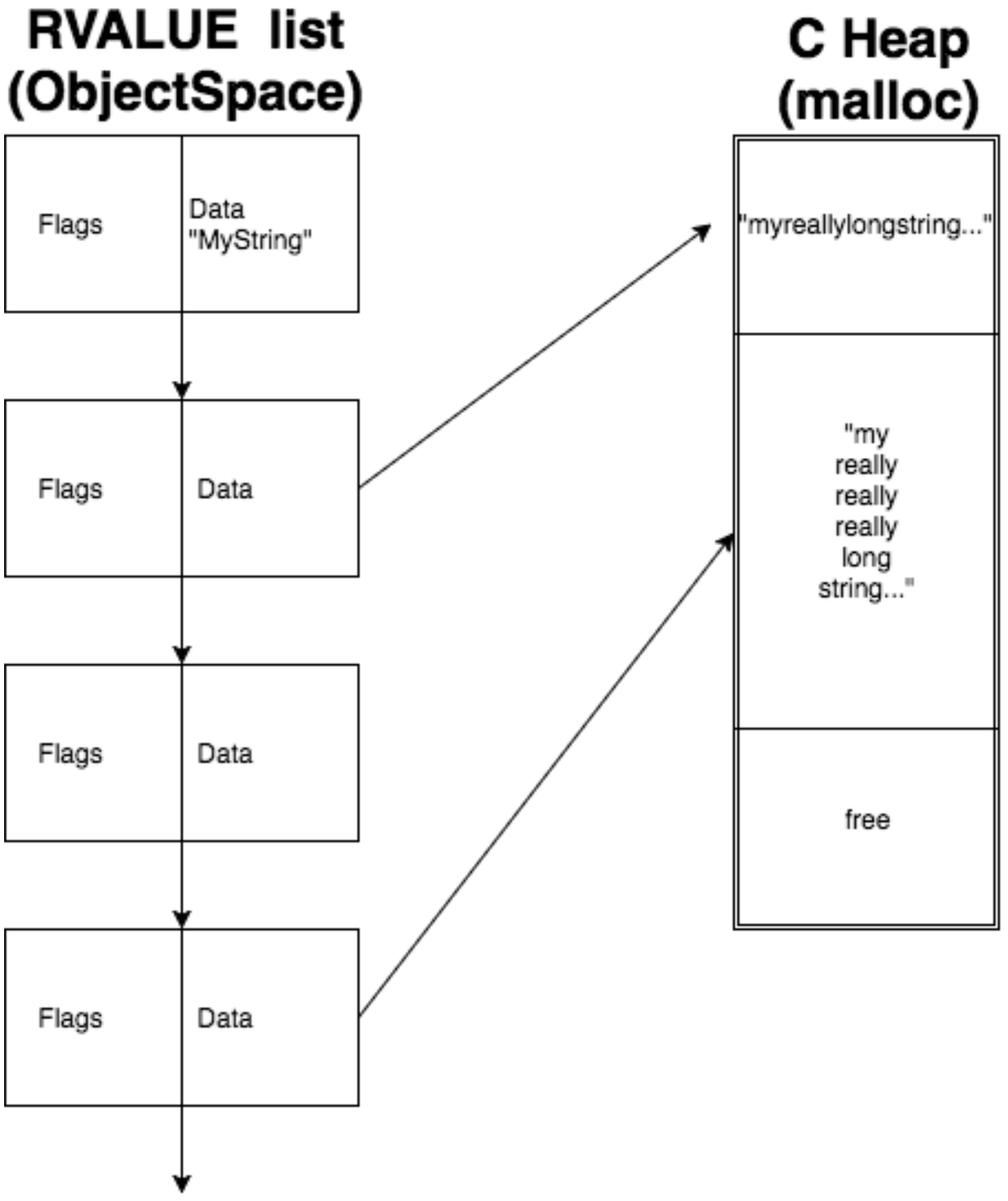
RVALUE

ORGANIZED INTO

408-SLOT

"HEAP PAGES"

SOME (MOST?) OBJECTS CONTAIN A POINTER TO `malloc`ED MEMORY WHERE ACTUAL OBJECT DATA IS STORED


RVALUE list
(ObjectSpace)
C Heap
(malloc)
Flags
Data
"MyString"
Flags
Data
Flags
Data
Flags
Data
"myreallylongstring..."
"my
really
really
really
long
string..."
free

```ruby
5.times { GC.start }
GC.stat[:heap_live_slots] # 24508
GC.stat[:heap_eden_pages] # 83
GC::INTERNAL_CONSTANTS[:HEAP_PAGE_OBJ_LIMIT] # 408

# live_slots / (eden_pages * slots_per_page)
# 24508 / (83 * 408) = 72.3%
```

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Page 1

Page 3

```ruby
GC.stat[:heap_sorted_length] # 83

# sorted_length / eden_pages
# 1
```

ALLOCATOR

PROBLEM:

PER-THREAD ARENAS IN GLIBC

"PUMA USES MORE MEMORY THAN UNICORN"

"SIDEKIQ IS LEAKING"

PER-THREAD MEMORY ARENAS REDUCE CONTENTION FOR THE MAIN ARENA

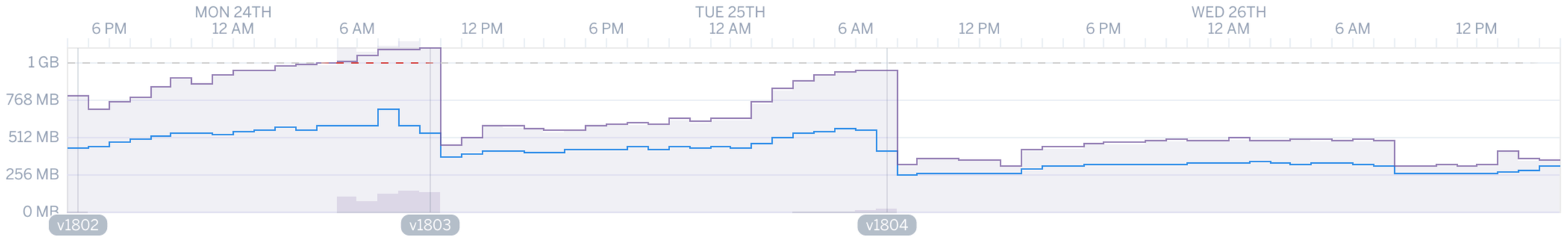
“As pressure from thread collisions increases, additional arenas are created via mmap to relieve the pressure. The number of arenas is capped at eight times the number of CPUs in the system [...], but the trade-off is that there will be less fragmentation.”

» MallocInternals

MALLOC_ARENA_MAX

Memory Usage

Latest	Max	Average
35.1 % 363.4 MB	⚠ 115.2 % 1,179.8 MB	40.2 % 411.6 MB



MAJOR SOURCE OF RUBY FRAGMENTATION?

SOLUTION(?):
REDUCE ALLOCATIONS

SOLUTION(?): MANAGED MALLOC

» Memory pools or slabs in the runtime

» Memcached does this

» Multiple heaps

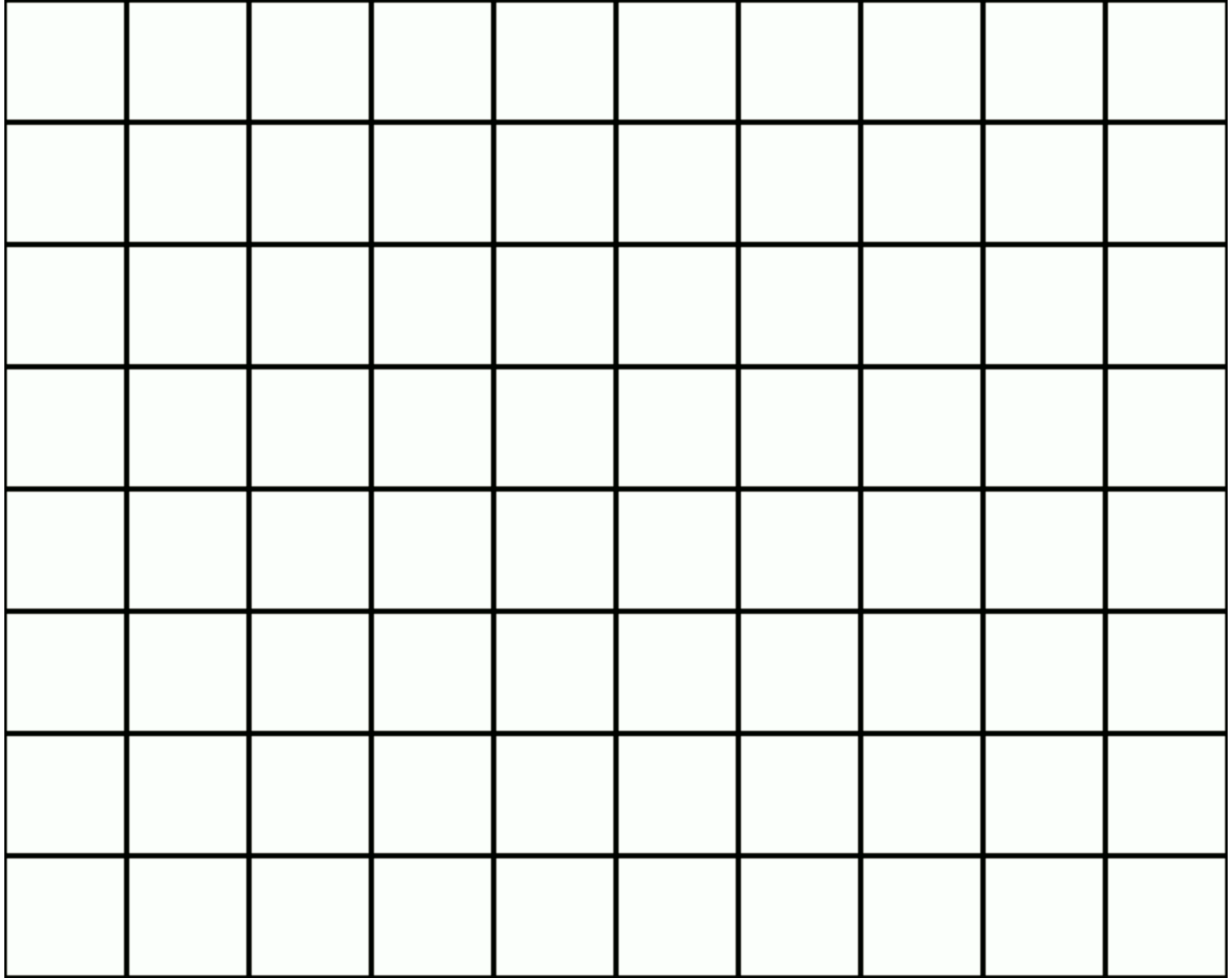
» "Buddy blocks"

» Eliminates the allocator

SOLUTION(?): JUST USE JEMALLOC

» Memory contiguity is unspecified!

» Rust: use jemalloc-specfic features



SOLUTION(?): HARD DEFAULTS

» Disable memory arenas

» JEMalloc, etc

» Disable THP


TRADEOFFS

THANK YOU!

@NATEBERKOPEC

MORE TACTICS AT:

RAILSSPEED.COM