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Increasing Virtual Machine Density With KSM

Introduction to KSM

KSM is linux kernel module that aim to save
memory by searching and merging identical pages
inside one or more memory areas in a way invisible
to the user.

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The Need For KSM

As an hypervisor one of the more critical missions
kvm have is sharing resources among guests,
the two most critical resources are:

Cpu resources sharing:
handled by the linux scheduler very effectivly,
when one guest idle its cpu time go into another guest.

Physical memory resources sharing:
handled by the linux swapping mechanism,
when a page is not used frequently by the guest it move into
the disk and another page replace it.

The Problem With Swapping And How KSM Solve It

For some workloads such as desktops, high interactive responsive is needed, swapping is just not an option for such cases.

KSM solve this problem by allow the system to overcommit while still all the memory is stored in the physical ram, this allow fast access to the memory and keep the system interactive.

The Implementation Goals Of KSM

1. Applications using memory that part of it was merged by KSM should have the same behavior as if this pages were never merged. (reading / writing to that pages would result the same as if this pages were not merged)

2. Finding identical pages should be fast.

3. Merged pages should be treated by the VM like any other pages (including the abilaty to swap/migrate this pages)

Keep Applications Behvior The Same

KSM mark all the page tables pointed to merged page as readonly.

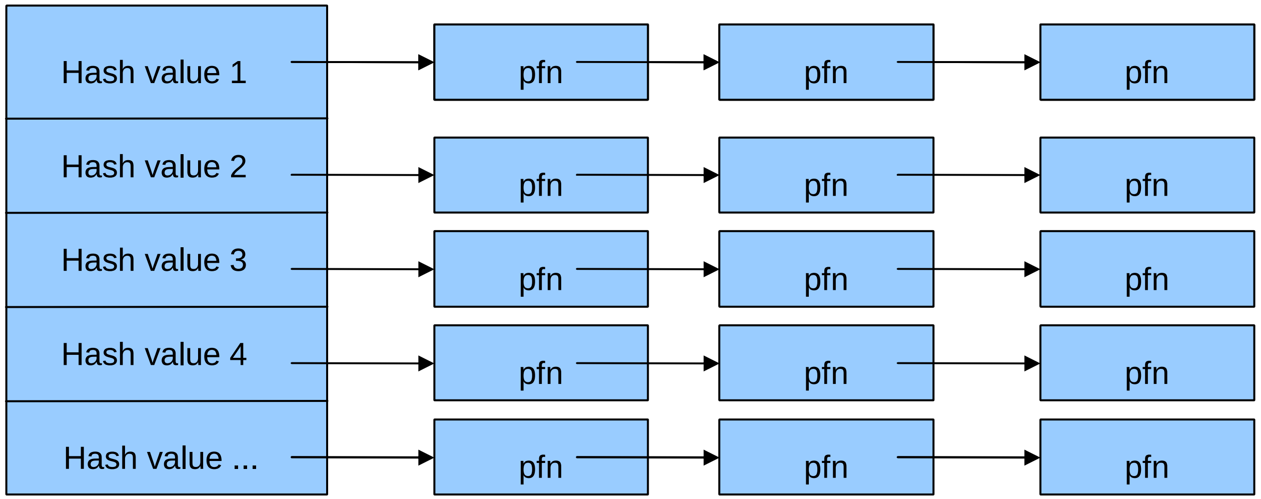
When one application write into merged page
it receive a new private copy of this page.

this is all run in the page fault handler without the application will ever know about it.

Fast Way To Find Identical Pages

KSM use hash table data structure in order to find identical pages in an effective way.

The hash table hold the page frame numbers and is accessed by the hash value of the page.



Fast Way To Find Identical Pages (reverse mapping)

Since pages can changed, KSM need to update its hash table after each iteration.

KSM use another hash table accssed by the page frame number that hold reverse mapping for each page.

using this reverse mapping KSM check if the hash value of the page was changed, and update the hash table if needed

Fast Way To Find Identical Pages (safe compare)

To avoid a race when page is changed after KSM found it identical to another page but before the page was merged:

KSM write protect the two pages and do full compare on both of them again,
then it is safe to merge the two pages.

Adjusted Time

Let The VM Treat The Pages Like Any Other Page.

The VM use reverse mapping in order to do nice tricks such as swapping and page migration.

Unfortunately the VM reverse mapping is desgined to use the fact that ptes pointing to a shared page have the same offset for each vma holding shared page inside linux, the rmap use this in order to find the pte inside given vma that point to a shared page, this is not true for pages that ksm merge, beacuse of this KSM cannot use without modifications the current reverse mapping found in linux. (we dont want to use nonlinear vma)

to solve this, we created what we call:
External Rmaps.

External Rmaps what is it?

What is it?
External Rmaps is a new methods added to the kernel that allow for a driver to mange by itself it rmap.

Drivers using External Rmaps benefit from all the current code of the main VM, and able to use any feature that supprted by the VM just like any other drivers.

External Rmaps
The Goals

In any case not to increase the size of the page data structure!!!

Allow users of External Rmaps, to use all the great features of the main VM.

External Rmaps
The Implementation

External Rmaps main data structure is:

struct ext_rmap_ops {

void (*page_add_rmap) — use to add new pte

void (*page_remove_rmap) - use to remove pte

void (*page_free) — call back to recive when page it release

void (*pte_next) — call back to allow walking on the rmap

swap_entry swp — used when the page is swapped.

};

In addition pointer to the ext_rmap_ops struct is added as a new field to the index and freelist union, this field is used when the page is extrnal rmap page

External Rmaps
The Implementation (identify extrmap page)

External Rmap Page is identified by checking the new

PAGE_MAPPING_EXTRMAP bit,

if this bit is set,

the VM will call the Driver private

External Rmap methods instead of the VM rmap.

(External Rmap page can be file backed or

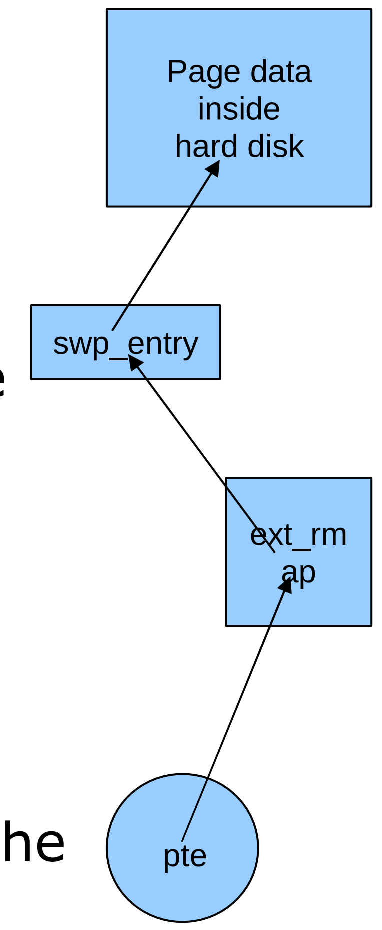
anonymous page)

External Rmaps
The Implementation (swapping)

In order to swap External Rmaps page, the VM use the following logic:

when the pte is unmmaped by try_to_unmap_one() the swp_entry is saved inside the ext_rmap struct and pointer to the ext_rmap structure is saved inside the pte (the pte is marked as pte_file)

when page is swapped in, Linux check if the pte is file_pte and if the vma is not nonlinear,
in case that this two cases are meet, we get the ext_rmap structrue from the pte and in turn we get the swp_entry from there.



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Woof!