
Subject: [-mm PATCH 6/8] Memory controller add per container LRU and reclaim (v2)

Posted by [Balbir Singh](#) on Fri, 06 Jul 2007 05:22:12 GMT

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Add the meta_page to the per container LRU. The reclaim algorithm has been modified to make the isolate_lru_pages() as a pluggable component. The scan_control data structure now accepts the container on behalf of which reclaims are carried out. try_to_free_pages() has been extended to become container aware.

Signed-off-by: Balbir Singh <balbir@linux.vnet.ibm.com>

```
include/linux/memcontrol.h | 11 +++
include/linux/res_counter.h | 23 ++++++++
include/linux/swap.h       | 3 +
mm/memcontrol.c            | 121 ++++++++++++++++++++++++++++++++++++++
mm/swap.c                  | 2
mm/vmscan.c                | 125 ++++++++++++++++++++++++++++++++++++++-----
6 files changed, 259 insertions(+), 26 deletions(-)
```

diff -puN include/linux/memcontrol.h~mem-control-lru-and-reclaim include/linux/memcontrol.h

--- linux-2.6.22-rc6/include/linux/memcontrol.h~mem-control-lru-and-reclaim 2007-07-05

18:28:12.000000000 -0700

+++ linux-2.6.22-rc6-balbir/include/linux/memcontrol.h 2007-07-05 18:45:57.000000000 -0700

```
@@ -26,6 +26,13 @@ extern void page_assign_meta_page(struct
extern struct meta_page *page_get_meta_page(struct page *page);
extern int mem_container_charge(struct page *page, struct mm_struct *mm);
extern void mem_container_uncharge(struct meta_page *mp);
+extern void mem_container_move_lists(struct meta_page *mp, bool active);
+extern unsigned long mem_container_isolate_pages(unsigned long nr_to_scan,
+ struct list_head *dst,
+ unsigned long *scanned, int order,
+ int mode, struct zone *z,
+ struct mem_container *mem_cont,
+ int active);
```

```
#else /* CONFIG_CONTAINER_MEM_CONT */
static inline void mm_init_container(struct mm_struct *mm,
@@ -56,6 +63,10 @@ static inline void mem_container_uncharg
{
}
```

```
+static inline void mem_container_move_lists(struct meta_page *mp, bool active)
+{
+}
+
```

```

#endif /* CONFIG_CONTAINER_MEM_CONT */

#endif /* _LINUX_MEMCONTROL_H */
diff -puN include/linux/swap.h~mem-control-lru-and-reclaim include/linux/swap.h
--- linux-2.6.22-rc6/include/linux/swap.h~mem-control-lru-and-reclaim 2007-07-05
18:28:12.000000000 -0700
+++ linux-2.6.22-rc6-balbir/include/linux/swap.h 2007-07-05 18:28:12.000000000 -0700
@@ -6,6 +6,7 @@
#include <linux/mmzone.h>
#include <linux/list.h>
#include <linux/sched.h>
+#include <linux/memcontrol.h>

#include <asm/atomic.h>
#include <asm/page.h>
@@ -191,6 +192,8 @@ extern void swap_setup(void);
/* linux/mm/vmscan.c */
extern unsigned long try_to_free_pages(struct zone **zones, int order,
    gfp_t gfp_mask);
+extern unsigned long try_to_free_mem_container_pages(struct mem_container *mem);
+extern int __isolate_lru_page(struct page *page, int mode);
extern unsigned long shrink_all_memory(unsigned long nr_pages);
extern int vm_swappiness;
extern int remove_mapping(struct address_space *mapping, struct page *page);
diff -puN mm/memcontrol.c~mem-control-lru-and-reclaim mm/memcontrol.c
--- linux-2.6.22-rc6/mm/memcontrol.c~mem-control-lru-and-reclaim 2007-07-05
18:28:12.000000000 -0700
+++ linux-2.6.22-rc6-balbir/mm/memcontrol.c 2007-07-05 18:49:32.000000000 -0700
@@ -19,6 +19,8 @@
#include <linux/page-flags.h>
#include <linux/bit_spinlock.h>
#include <linux/rcupdate.h>
+#include <linux/swap.h>
+#include <linux/spinlock.h>

struct container_subsys mem_container_subsys;

@@ -46,6 +48,10 @@ struct mem_container {
    */
    struct list_head active_list;
    struct list_head inactive_list;
+ /*
+  * spin_lock to protect the per container LRU
+  */
+ spinlock_t lru_lock;
};

/*

```

```

@@ -103,6 +109,92 @@ void __always_inline unlock_meta_page(st
    bit_spin_unlock(PG_metapage, &page->flags);
}

```

```

+unsigned long mem_container_isolate_pages(unsigned long nr_to_scan,
+    struct list_head *dst,
+    unsigned long *scanned, int order,
+    int mode, struct zone *z,
+    struct mem_container *mem_cont,
+    int active)
+{
+    unsigned long nr_taken = 0;
+    struct page *page;
+    unsigned long scan;
+    LIST_HEAD(mp_list);
+    struct list_head *src;
+    struct meta_page *mp;
+
+    if (active)
+        src = &mem_cont->active_list;
+    else
+        src = &mem_cont->inactive_list;
+
+    for (scan = 0; scan < nr_to_scan && !list_empty(src); scan++) {
+        mp = list_entry(src->prev, struct meta_page, list);
+        page = mp->page;
+
+        if (PageActive(page) && !active) {
+            mem_container_move_lists(mp, true);
+            scan--;
+            continue;
+        }
+        if (!PageActive(page) && active) {
+            mem_container_move_lists(mp, false);
+            scan--;
+            continue;
+        }
+
+        /*
+         * Reclaim, per zone
+         * TODO: make the active/inactive lists per zone
+         */
+        if (page_zone(page) != z)
+            continue;
+
+        spin_lock(&mem_cont->lru_lock);
+        /*
+         * Check if the meta page went away from under us

```

```

+ */
+ if (!list_empty(&mp->list)
+ list_move(&mp->list, &mp_list);
+ else {
+ spin_unlock(&mem_cont->lru_lock);
+ continue;
+ }
+ spin_unlock(&mem_cont->lru_lock);
+
+ if (__isolate_lru_page(page, mode) == 0) {
+ list_move(&page->lru, dst);
+ nr_taken++;
+ }
+ }
+
+ spin_lock(&mem_cont->lru_lock);
+ list_splice(&mp_list, src);
+ spin_unlock(&mem_cont->lru_lock);
+
+ *scanned = scan;
+ return nr_taken;
+}
+
+/*
+ * This routine assumes that the appropriate zone's lru lock is already held
+ */
+void mem_container_move_lists(struct meta_page *mp, bool active)
+{
+ struct mem_container *mem;
+ if (!mp)
+ return;
+
+ mem = mp->mem_container;
+
+ spin_lock(&mem->lru_lock);
+ if (active)
+ list_move(&mp->list, &mem->mem_container->active_list);
+ else
+ list_move(&mp->list, &mem->mem_container->inactive_list);
+ spin_unlock(&mem->lru_lock);
+}
+
+/*
+ * Charge the memory controller for page usage.
+ * Return
+@@ -113,6 +205,7 @@ int mem_container_charge(struct page *pa
+ {
+ struct mem_container *mem;

```

```

    struct meta_page *mp;
+ unsigned long flags;

/*
 * Should meta_page's go to their own slab?
@@ -159,8 +252,22 @@ int mem_container_charge(struct page *pa
 * If we created the meta_page, we should free it on exceeding
 * the container limit.
 */
- if (res_counter_charge(&mem->res, 1))
+ while (res_counter_charge(&mem->res, 1)) {
+ if (try_to_free_mem_container_pages(mem))
+ continue;
+
+ /*
+  * try_to_free_mem_container_pages() might not give us a full
+  * picture of reclaim. Some pages are reclaimed and might be
+  * moved to swap cache or just unmapped from the container.
+  * Check the limit again to see if the reclaim reduced the
+  * current usage of the container before giving up
+  */
+ if (res_counter_check_under_limit(&mem->res))
+ continue;
+
    goto free_mp;
+ }

    lock_meta_page(page);
/*
@@ -177,6 +284,10 @@ int mem_container_charge(struct page *pa
    mp->page = page;
    page_assign_meta_page(page, mp);

+ spin_lock_irqsave(&mem->lru_lock, flags);
+ list_add(&mp->list, &mem->active_list);
+ spin_unlock_irqrestore(&mem->lru_lock, flags);
+
done:
    unlock_meta_page(page);
    return 0;
@@ -196,6 +307,7 @@ void mem_container_uncharge(struct meta_
{
    struct mem_container *mem;
    struct page *page;
+ unsigned long flags;

/*
 * This can happen for PAGE_ZERO

```

```
@@ -205,12 +317,18 @@ void mem_container_uncharge(struct meta_
```

```
    if (atomic_dec_and_test(&mp->ref_cnt)) {  
        page = mp->page;  
+  
        lock_meta_page(page);  
        mem = mp->mem_container;  
        css_put(&mem->css);  
        page_assign_meta_page(page, NULL);  
        unlock_meta_page(page);  
+  
        res_counter_uncharge(&mem->res, 1);  
+  
+ spin_lock_irqsave(&mem->lru_lock, flags);  
+ list_del_init(&mp->list);  
+ spin_unlock_irqrestore(&mem->lru_lock, flags);  
        kfree(mp);  
    }  
}
```

```
@@ -272,6 +390,7 @@ static int mem_container_create(struct c  
    mem->css.container = cont;  
    INIT_LIST_HEAD(&mem->active_list);  
    INIT_LIST_HEAD(&mem->inactive_list);  
+ spin_lock_init(&mem->lru_lock);  
    return 0;  
}
```

```
diff -puN mm/swap.c~mem-control-lru-and-reclaim mm/swap.c
```

```
--- linux-2.6.22-rc6/mm/swap.c~mem-control-lru-and-reclaim 2007-07-05 18:28:12.000000000  
-0700
```

```
+++ linux-2.6.22-rc6-balbir/mm/swap.c 2007-07-05 18:28:12.000000000 -0700
```

```
@@ -31,6 +31,7 @@  
#include <linux/cpu.h>  
#include <linux/notifier.h>  
#include <linux/init.h>  
+#include <linux/memcontrol.h>
```

```
/* How many pages do we try to swap or page in/out together? */
```

```
int page_cluster;  
@@ -148,6 +149,7 @@ void fastcall activate_page(struct page  
    SetPageActive(page);  
    add_page_to_active_list(zone, page);  
    __count_vm_event(PGACTIVATE);  
+ mem_container_move_lists(page_get_meta_page(page), true);  
    }  
    spin_unlock_irq(&zone->lru_lock);  
}
```

```
diff -puN mm/vmscan.c~mem-control-lru-and-reclaim mm/vmscan.c
```

```

--- linux-2.6.22-rc6/mm/vmscan.c~mem-control-lru-and-reclaim 2007-07-05 18:28:12.000000000
-0700
+++ linux-2.6.22-rc6-balbir/mm/vmscan.c 2007-07-05 18:28:12.000000000 -0700
@@ -39,6 +39,7 @@
#include <linux/delay.h>
#include <linux/kthread.h>
#include <linux/freezer.h>
+#include <linux/memcontrol.h>

#include <asm/tlbflush.h>
#include <asm/div64.h>
@@ -70,6 +71,15 @@ struct scan_control {
    int all_unreclaimable;

    int order;
+
+ /* Which container do we reclaim from */
+ struct mem_container *mem_container;
+
+ /* Pluggable isolate pages callback */
+ unsigned long (*isolate_pages)(unsigned long nr, struct list_head *dst,
+ unsigned long *scanned, int order, int mode,
+ struct zone *z, struct mem_container *mem_cont,
+ int active);
};

#define lru_to_page(_head) (list_entry((_head)->prev, struct page, lru))
@@ -604,7 +614,7 @@ keep:
*
* returns 0 on success, -ve errno on failure.
*/
-static int __isolate_lru_page(struct page *page, int mode)
+int __isolate_lru_page(struct page *page, int mode)
{
    int ret = -EINVAL;

@@ -738,6 +748,21 @@ static unsigned long isolate_lru_pages(u
    return nr_taken;
}

+static unsigned long isolate_pages_global(unsigned long nr,
+ struct list_head *dst,
+ unsigned long *scanned, int order,
+ int mode, struct zone *z,
+ struct mem_container *mem_cont,
+ int active)
+{
+ if (active)

```

```

+ return isolate_lru_pages(nr, &z->active_list, dst,
+   scanned, order, mode);
+ else
+ return isolate_lru_pages(nr, &z->inactive_list, dst,
+   scanned, order, mode);
+}
+
+/*
+ * clear_active_flags() is a helper for shrink_active_list(), clearing
+ * any active bits from the pages in the list.
@@ -779,11 +804,11 @@ static unsigned long shrink_inactive_lis
unsigned long nr_freed;
unsigned long nr_active;

- nr_taken = isolate_lru_pages(sc->swap_cluster_max,
-   &zone->inactive_list,
+ nr_taken = sc->isolate_pages(sc->swap_cluster_max,
+   &page_list, &nr_scan, sc->order,
+   (sc->order > PAGE_ALLOC_COSTLY_ORDER)?
-   ISOLATE_BOTH : ISOLATE_INACTIVE);
+   ISOLATE_BOTH : ISOLATE_INACTIVE,
+   zone, sc->mem_container, 0);
nr_active = clear_active_flags(&page_list);

__mod_zone_page_state(zone, NR_ACTIVE, -nr_active);
@@ -932,8 +957,9 @@ force_reclaim_mapped:

lru_add_drain();
spin_lock_irq(&zone->lru_lock);
- pgmoved = isolate_lru_pages(nr_pages, &zone->active_list,
-   &l_hold, &pgscanned, sc->order, ISOLATE_ACTIVE);
+ pgmoved = sc->isolate_pages(nr_pages, &l_hold, &pgscanned, sc->order,
+   ISOLATE_ACTIVE, zone,
+   sc->mem_container, 1);
zone->pages_scanned += pgscanned;
__mod_zone_page_state(zone, NR_ACTIVE, -pgmoved);
spin_unlock_irq(&zone->lru_lock);
@@ -968,6 +994,7 @@ force_reclaim_mapped:
ClearPageActive(page);

list_move(&page->lru, &zone->inactive_list);
+ mem_container_move_lists(page_get_meta_page(page), false);
pgmoved++;
if (!pagevec_add(&pvec, page)) {
__mod_zone_page_state(zone, NR_INACTIVE, pgmoved);
@@ -996,6 +1023,7 @@ force_reclaim_mapped:
SetPageLRU(page);
VM_BUG_ON(!PageActive(page));

```



```

list_move(&page->lru, &zone->active_list);
+ mem_container_move_lists(page_get_meta_page(page), true);
pgmoved++;
if (!pagevec_add(&pvec, page)) {
    __mod_zone_page_state(zone, NR_ACTIVE, pgmoved);
@@ -1127,7 +1155,8 @@ static unsigned long shrink_zones(int pr
    * holds filesystem locks which prevent writeout this might not work, and the
    * allocation attempt will fail.
    */
-unsigned long try_to_free_pages(struct zone **zones, int order, gfp_t gfp_mask)
+unsigned long do_try_to_free_pages(struct zone **zones, gfp_t gfp_mask,
+    struct scan_control *sc)
{
    int priority;
    int ret = 0;
@@ -1136,14 +1165,6 @@ unsigned long try_to_free_pages(struct z
    struct reclaim_state *reclaim_state = current->reclaim_state;
    unsigned long lru_pages = 0;
    int i;
- struct scan_control sc = {
-     .gfp_mask = gfp_mask,
-     .may_writpage = !laptop_mode,
-     .swap_cluster_max = SWAP_CLUSTER_MAX,
-     .may_swap = 1,
-     .swappiness = vm_swappiness,
-     .order = order,
- };

    delay_swap_prefetch();
    count_vm_event(ALLOCSTALL);
@@ -1159,17 +1180,22 @@ unsigned long try_to_free_pages(struct z
    }

    for (priority = DEF_PRIORITY; priority >= 0; priority--) {
-     sc.nr_scanned = 0;
+     sc->nr_scanned = 0;
        if (!priority)
            disable_swap_token();
-     nr_reclaimed += shrink_zones(priority, zones, &sc);
-     shrink_slab(sc.nr_scanned, gfp_mask, lru_pages);
+     nr_reclaimed += shrink_zones(priority, zones, sc);
+     /*
+      * Don't shrink slabs when reclaiming memory from
+      * over limit containers
+      */
+     if (sc->mem_container == NULL)
+     shrink_slab(sc->nr_scanned, gfp_mask, lru_pages);
        if (reclaim_state) {

```

```

    nr_reclaimed += reclaim_state->reclaimed_slab;
    reclaim_state->reclaimed_slab = 0;
}
- total_scanned += sc.nr_scanned;
- if (nr_reclaimed >= sc.swap_cluster_max) {
+ total_scanned += sc->nr_scanned;
+ if (nr_reclaimed >= sc->swap_cluster_max) {
    ret = 1;
    goto out;
}
@@ -1181,18 +1207,18 @@ unsigned long try_to_free_pages(struct z
    * that's undesirable in laptop mode, where we *want* lumpy
    * writeout. So in laptop mode, write out the whole world.
    */
- if (total_scanned > sc.swap_cluster_max +
-     sc.swap_cluster_max / 2) {
+ if (total_scanned > sc->swap_cluster_max +
+     sc->swap_cluster_max / 2) {
    wakeup_pdflush(laptop_mode ? 0 : total_scanned);
- sc.may_writepage = 1;
+ sc->may_writepage = 1;
}

/* Take a nap, wait for some writeback to complete */
- if (sc.nr_scanned && priority < DEF_PRIORITY - 2)
+ if (sc->nr_scanned && priority < DEF_PRIORITY - 2)
    congestion_wait(WRITE, HZ/10);
}
/* top priority shrink_caches still had more to do? don't OOM, then */
- if (!sc.all_unreclaimable)
+ if (!sc->all_unreclaimable && sc->mem_container == NULL)
    ret = 1;
out:
/*
@@ -1215,6 +1241,53 @@ out:
    return ret;
}

+unsigned long try_to_free_pages(struct zone **zones, int order, gfp_t gfp_mask)
+{
+ struct scan_control sc = {
+   .gfp_mask = gfp_mask,
+   .may_writepage = !laptop_mode,
+   .swap_cluster_max = SWAP_CLUSTER_MAX,
+   .may_swap = 1,
+   .swappiness = vm_swappiness,
+   .order = order,
+   .mem_container = NULL,

```

```

+ .isolate_pages = isolate_pages_global,
+ };
+
+ return do_try_to_free_pages(zones, gfp_mask, &sc);
+}
+
+#ifdef CONFIG_CONTAINER_MEM_CONT
+
+#ifdef CONFIG_HIGHMEM
+#define ZONE_USERPAGES ZONE_HIGHMEM
+#else
+#define ZONE_USERPAGES ZONE_NORMAL
+#endif
+
+unsigned long try_to_free_mem_container_pages(struct mem_container *mem_cont)
+{
+ struct scan_control sc = {
+  .gfp_mask = GFP_KERNEL,
+  .may_swap = 1,
+  .swap_cluster_max = SWAP_CLUSTER_MAX,
+  .swappiness = vm_swappiness,
+  .order = 1,
+  .mem_container = mem_cont,
+  .isolate_pages = mem_container_isolate_pages,
+ };
+ int node;
+ struct zone **zones;
+
+ for_each_online_node(node) {
+  zones = NODE_DATA(node)->node_zonelist[ZONE_USERPAGES].zones;
+  if (do_try_to_free_pages(zones, sc.gfp_mask, &sc))
+   return 1;
+ }
+ return 0;
+}
+#endif
+
+/*
+ * For kswapd, balance_pgdat() will work across all this node's zones until
+ * they are all at pages_high.
+ */
+static unsigned long balance_pgdat(pg_data_t *pg_data, int order)
+{
+  .swap_cluster_max = SWAP_CLUSTER_MAX,
+  .swappiness = vm_swappiness,
+  .order = order,
+  .mem_container = NULL,
+  .isolate_pages = isolate_pages_global,
+ };
+}
+/*

```

```

* temp_priority is used to remember the scanning priority at which
diff -puN include/linux/res_counter.h~mem-control-lru-and-reclaim include/linux/res_counter.h
--- linux-2.6.22-rc6/include/linux/res_counter.h~mem-control-lru-and-reclaim 2007-07-05
18:28:12.000000000 -0700
+++ linux-2.6.22-rc6-balbir/include/linux/res_counter.h 2007-07-05 18:28:12.000000000 -0700
@@ -99,4 +99,27 @@ int res_counter_charge(struct res_counte
void res_counter_uncharge_locked(struct res_counter *cnt, unsigned long val);
void res_counter_uncharge(struct res_counter *cnt, unsigned long val);

+static inline bool res_counter_limit_check_locked(struct res_counter *cnt)
+{
+ if (cnt->usage < cnt->limit)
+ return true;
+
+ return false;
+}
+
+/*
+ * Helper function to detect if the container is within it's limit or
+ * not. It's currently called from container_rss_prepare()
+ */
+static inline bool res_counter_check_under_limit(struct res_counter *cnt)
+{
+ bool ret;
+ unsigned long flags;
+
+ spin_lock_irqsave(&cnt->lock, flags);
+ ret = res_counter_limit_check_locked(cnt);
+ spin_unlock_irqrestore(&cnt->lock, flags);
+ return ret;
+}
+
+ #endif

```

--
Warm Regards,
Balbir Singh
Linux Technology Center
IBM, ISTL

Containers mailing list
Containers@lists.linux-foundation.org
<https://lists.linux-foundation.org/mailman/listinfo/containers>
