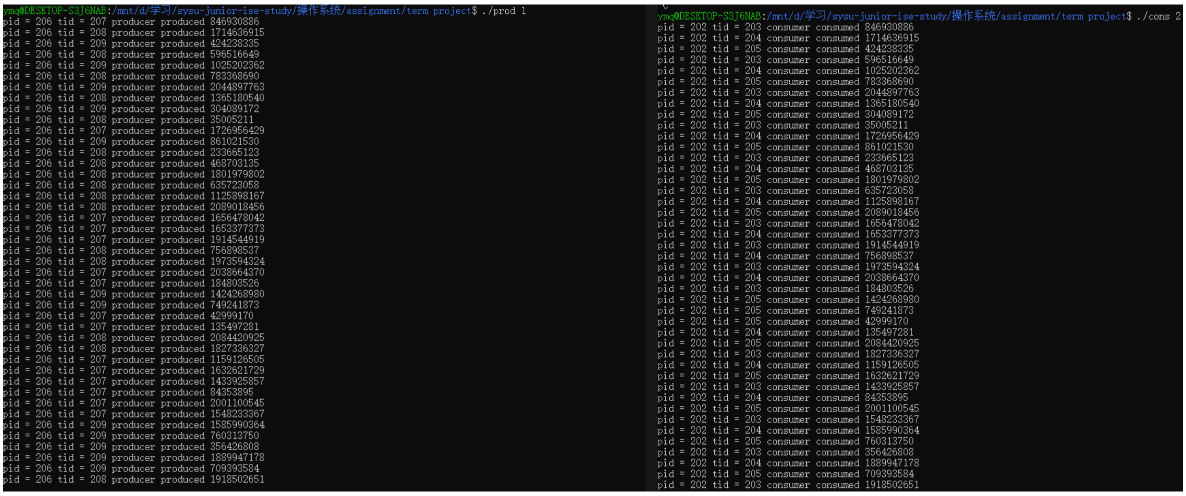
1

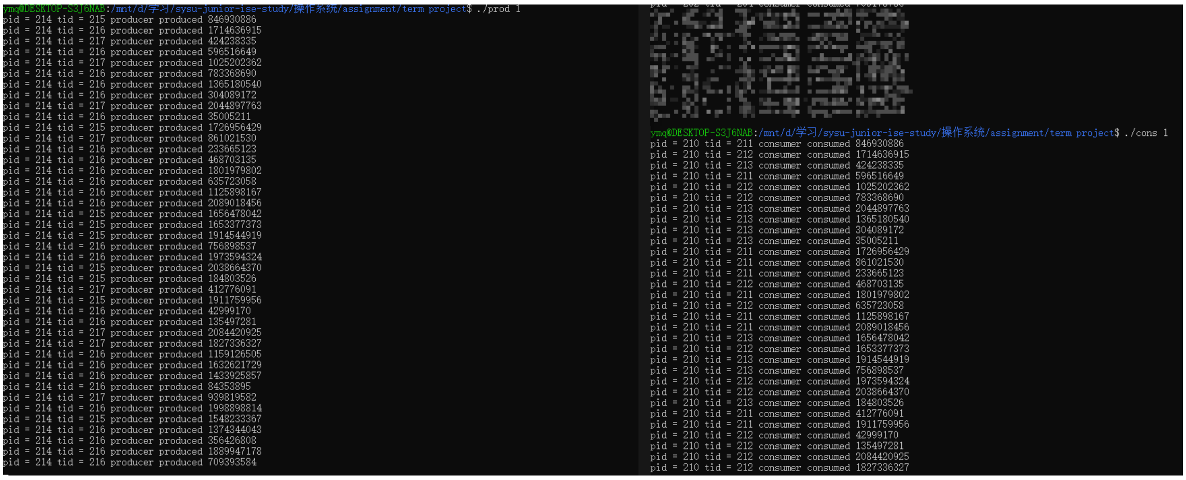
```
ymq@DESKTOP-S3J6NAB:/mnt/d/学习/sysu-junior-ise-study/操作系统/assignment/term project$ ./dph
State:
Philospher 0 is thinking
Philospher 1 is thinking
Philospher 2 is thinking
Philospher 3 is eating
Philospher 4 is thinking

State:
Philospher 0 is thinking
Philospher 1 is thinking
Philospher 2 is thinking
Philospher 3 is thinking
Philospher 4 is thinking

State:
Philospher 0 is eating
Philospher 1 is thinking
Philospher 2 is thinking
Philospher 3 is thinking
Philospher 4 is thinking

State:
Philospher 0 is eating
Philospher 1 is thinking
Philospher 2 is eating
Philospher 3 is thinking
Philospher 4 is hungry

State:
Philospher 0 is thinking
Philospher 1 is hungry
Philospher 2 is eating
Philospher 3 is hungry
Philospher 4 is eating

State:
Philospher 0 is hungry
Philospher 1 is hungry
Philospher 2 is eating
Philospher 3 is hungry
Philospher 4 is eating

State:
Philospher 0 is hungry
Philospher 1 is eating
Philospher 2 is thinking
Philospher 3 is hungry
Philospher 4 is eating

State:
Philospher 0 is hungry
Philospher 1 is eating
Philospher 2 is hungry
Philospher 3 is hungry
Philospher 4 is eating
```

2

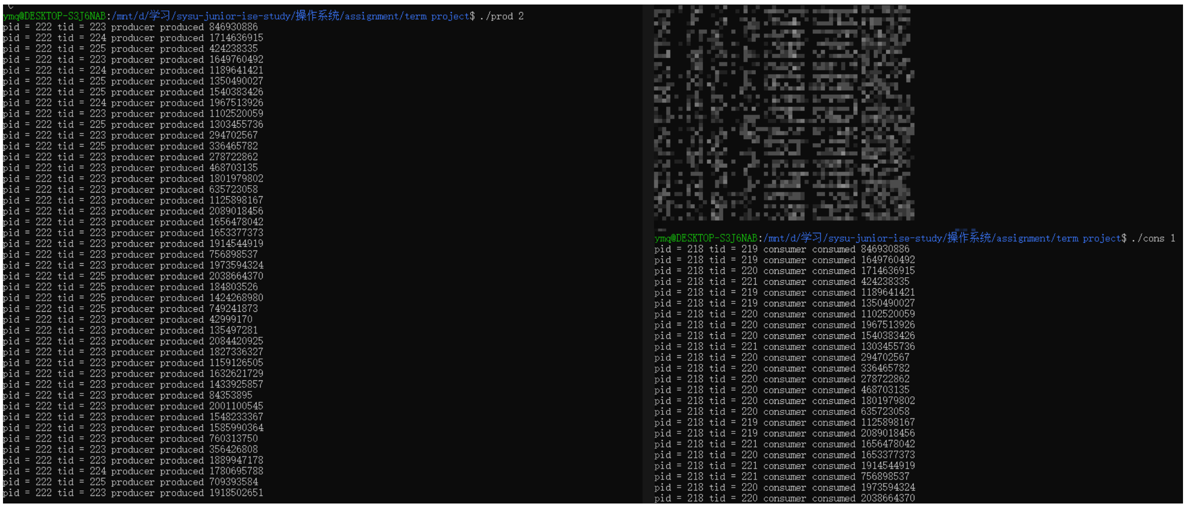
$$\lambda p < \lambda c$$



$$\lambda p = \lambda c$$



$\lambda p > \lambda c$



3

以下分析基于linux内核版本5.3.7

相关的数据结构

task_struct

定义在`/linux/sched.h`中

```c
struct task_struct {
    /* -1 unrunnable, 0 runnable, >0 stopped: */
    volatile long state;

    int on_rq;

    int prio;
    int static_prio;
    int normal_prio;
    unsigned int rt_priority;

    const struct sched_class *sched_class;
    struct sched_entity se;
    struct sched_rt_entity rt;
    ...
}
```

sched_entity

调度器实体，在`task_struct`中以变量`se`存在，`vruntime`存放着进程的虚拟运行时间，以ns为单位

定义在`/linux/sched.h`中

```c
struct sched_entity {
    /* For load-balancing: */
    struct load_weight load;
    unsigned long runnable_weight;
    struct rb_node run_node;
    struct list_head group_node;
    unsigned int on_rq;

    u64 exec_start;
    u64 sum_exec_runtime;
    u64 vruntime;
    u64 prev_sum_exec_runtime;

    u64 nr_migrations;

    struct sched_statistics statistics;
}
```

cfs_rq

定义在`kernel/sched/sched.h`

```c
struct cfs_rq {
    struct load_weight  load;
    unsigned long       runnable_weight;
    unsigned int        nr_running;
    unsigned int        h_nr_running;

    u64         exec_clock;
    u64         min_vruntime;

    struct rb_root_cached   tasks_timeline;

    /*
```

```
	 * 'curr' points to currently running entity on this cfs_rq.
	 * It is set to NULL otherwise (i.e when none are currently running).
	 */
	struct sched_entity *curr;
	struct sched_entity *next;
	struct sched_entity *last;
	struct sched_entity *skip;
};
```

几个数据结构的关系大体总结来说就是，`task_struct`保存了任务信息和调度实体`sched_entity`，`sched_entity`中包含了`run_node`，也就是红黑树中的结点，CFS会在每个CPU上维护一个`cfs_rq`，`cfs_rq`保存有红黑树的根结点，该红黑树以调度实体的`vruntime`为键值。

CFS的实现

创建进程

进程被创建后，会调用`enqueue_entity`函数，更新相应的信息并将进程插入到红黑树中

```
static void
enqueue_entity(struct cfs_rq *cfs_rq, struct sched_entity *se, int flags)
{
	bool renorm = !(flags & ENQUEUE_WAKEUP) || (flags & ENQUEUE_MIGRATED);
	bool curr = cfs_rq->curr == se;

	/*
	 * If we're the current task, we must renormalise before calling
	 * update_curr().
	 */
	if (renorm && curr)
		se->vruntime += cfs_rq->min_vruntime;

	update_curr(cfs_rq);

	/*
	 * Otherwise, renormalise after, such that we're placed at the current
	 * moment in time, instead of some random moment in the past. Being
	 * placed in the past could significantly boost this task to the
	 * fairness detriment of existing tasks.
	 */
	if (renorm && !curr)
		se->vruntime += cfs_rq->min_vruntime;

	/*
	 * When enqueuing a sched_entity, we must:
	 *   - Update loads to have both entity and cfs_rq synced with now.
	 *   - Add its load to cfs_rq->runnable_avg
	 *   - For group_entity, update its weight to reflect the new share of
	 *     its group cfs_rq
	 *   - Add its new weight to cfs_rq->load.weight
	 */
	update_load_avg(cfs_rq, se, UPDATE_TG | DO_ATTACH);
	update_cfs_group(se);
	enqueue_runnable_load_avg(cfs_rq, se);
	account_entity_enqueue(cfs_rq, se);

	if (flags & ENQUEUE_WAKEUP)
```

```
        place_entity(cfs_rq, se, 0);

    check_schedstat_required();
    update_stats_enqueue(cfs_rq, se, flags);
    check_spread(cfs_rq, se);
    if (!curr)
        __enqueue_entity(cfs_rq, se);
    se->on_rq = 1;

    if (cfs_rq->nr_running == 1) {
        list_add_leaf_cfs_rq(cfs_rq);
        check_enqueue_throttle(cfs_rq);
    }
}
```

`__enqueue_entity`负责将调度实体插入到树中

```
/*
 * Enqueue an entity into the rb-tree:
 */
static void __enqueue_entity(struct cfs_rq *cfs_rq, struct sched_entity *se)
{
    struct rb_node **link = &cfs_rq->tasks_timeline.rb_root.rb_node;
    struct rb_node *parent = NULL;
    struct sched_entity *entry;
    bool leftmost = true;

    /*
     * Find the right place in the rbtree:
     */
    while (*link) {
        parent = *link;
        entry = rb_entry(parent, struct sched_entity, run_node);
        /*
         * We dont care about collisions. Nodes with
         * the same key stay together.
         */
        if (entity_before(se, entry)) {
            link = &parent->rb_left;
        } else {
            link = &parent->rb_right;
            leftmost = false;
        }
    }

    rb_link_node(&se->run_node, parent, link);
    rb_insert_color_cached(&se->run_node,
                   &cfs_rq->tasks_timeline, leftmost);
}
```

删除进程

和插入进程类似，调用`dequeue_entity`函数更新信息，并调用`__dequeue_entity`将调度实体移出红黑树

```
static void
```

```c
dequeue_entity(struct cfs_rq *cfs_rq, struct sched_entity *se, int flags)
{
    /*
     * Update run-time statistics of the 'current'.
     */
    update_curr(cfs_rq);

    /*
     * When dequeuing a sched_entity, we must:
     *   - Update loads to have both entity and cfs_rq synced with now.
     *   - Subtract its load from the cfs_rq->runnable_avg.
     *   - Subtract its previous weight from cfs_rq->load.weight.
     *   - For group entity, update its weight to reflect the new share
     *     of its group cfs_rq.
     */
    update_load_avg(cfs_rq, se, UPDATE_TG);
    dequeue_runnable_load_avg(cfs_rq, se);

    update_stats_dequeue(cfs_rq, se, flags);

    clear_buddies(cfs_rq, se);

    if (se != cfs_rq->curr)
        __dequeue_entity(cfs_rq, se);
    se->on_rq = 0;
    account_entity_dequeue(cfs_rq, se);

    /*
     * Normalize after update_curr(); which will also have moved
     * min_vruntime if @se is the one holding it back. But before doing
     * update_min_vruntime() again, which will discount @se's position and
     * can move min_vruntime forward still more.
     */
    if (!(flags & DEQUEUE_SLEEP))
        se->vruntime -= cfs_rq->min_vruntime;

    /* return excess runtime on last dequeue */
    return_cfs_rq_runtime(cfs_rq);

    update_cfs_group(se);

    /*
     * Now advance min_vruntime if @se was the entity holding it back,
     * except when: DEQUEUE_SAVE && !DEQUEUE_MOVE, in this case we'll be
     * put back on, and if we advance min_vruntime, we'll be placed back
     * further than we started -- ie. we'll be penalized.
     */
    if ((flags & (DEQUEUE_SAVE | DEQUEUE_MOVE)) != DEQUEUE_SAVE)
        update_min_vruntime(cfs_rq);
}
```

进程选择

CFS调度算法使用红黑树储存所有的进程，红黑树根据`vruntime`对进程进行排序，CFS调度算法选择`vruntime`最小的进程运行，即红黑树的最左节点，选取最左节点的函数(定义在`fair.c` 600行)如下，最左节点被保存在`cfs_rq.tasks_timeline->leftmost`中

```
struct sched_entity *__pick_first_entity(struct cfs_rq *cfs_rq)
{
    struct rb_node *left = rb_first_cached(&cfs_rq->tasks_timeline);

    if (!left)
        return NULL;

    return rb_entry(left, struct sched_entity, run_node);
}
```

当调度器挑选下一个运行的进程时，会调用`pick_next_task_fair`方法，该方法又会调用`pick_next_entity`方法找出下一个进程，`pick_next_task_fair`方法定义如下，当`CONFIG_FAIR_GROUP_SCHED`被定义时，意味着`sched_entity`有可能是一个进程组，所以需要额外的处理，将这部分代码去掉，核心部分的源码如下

```
static struct task_struct *
pick_next_task_fair(struct rq *rq, struct task_struct *prev, struct rq_flags
*rf)
{
    struct cfs_rq *cfs_rq = &rq->cfs;
    struct sched_entity *se;
    struct task_struct *p;
    int new_tasks;

again:
    // 队列上没有其他可运行的任务
    if (!cfs_rq->nr_running)
        goto idle;

    // 将上一个进程放回队列
    put_prev_task(rq, prev);

    // 选出下一个任务
    do {
        se = pick_next_entity(cfs_rq, NULL);
        set_next_entity(cfs_rq, se);
        cfs_rq = group_cfs_rq(se);
    } while (cfs_rq);

    p = task_of(se);

// curr继续运行直到有新任务出现
idle:
    update_misfit_status(NULL, rq);
    new_tasks = idle_balance(rq, rf);

    /*
     * Because idle_balance() releases (and re-acquires) rq->lock, it is
     * possible for any higher priority task to appear. In that case we
     * must re-start the pick_next_entity() loop.
     */
    if (new_tasks < 0)
```

```
        return RETRY_TASK;

    if (new_tasks > 0)
        goto again;

    /*
     * rq is about to be idle, check if we need to update the
     * lost_idle_time of clock_pelt
     */
    update_idle_rq_clock_pelt(rq);

    return NULL;
}
```

`pick_next_entity`方法定义如下

```
/*
 * Pick the next process, keeping these things in mind, in this order:
 * 1) keep things fair between processes/task groups
 * 2) pick the "next" process, since someone really wants that to run
 * 3) pick the "last" process, for cache locality
 * 4) do not run the "skip" process, if something else is available
 */
static struct sched_entity *
pick_next_entity(struct cfs_rq *cfs_rq, struct sched_entity *curr)
{
    // 选出最左节点
    struct sched_entity *left = __pick_first_entity(cfs_rq);
    struct sched_entity *se;

    /*
     * If curr is set we have to see if its left of the leftmost entity
     * still in the tree, provided there was anything in the tree at all.
     */
    if (!left || (curr && entity_before(curr, left)))
        left = curr;

    se = left; /* ideally we run the leftmost entity */

    /*
     * Avoid running the skip buddy, if running something else can
     * be done without getting too unfair.
     */
    // 如果选出的任务被设为skip，再选一个
    if (cfs_rq->skip == se) {
        struct sched_entity *second;

        if (se == curr) {
            second = __pick_first_entity(cfs_rq);
        } else {
            second = __pick_next_entity(se);
            if (!second || (curr && entity_before(curr, second)))
                second = curr;
        }

        if (second && wakeup_preempt_entity(second, left) < 1)
            se = second;
```

```
    }

    /*
     * Prefer last buddy, try to return the CPU to a preempted task.
     */

    if (cfs_rq->last && wakeup_preempt_entity(cfs_rq->last, left) < 1)
        se = cfs_rq->last;

    /*
     * Someone really wants this to run. If it's not unfair, run it.
     */
    if (cfs_rq->next && wakeup_preempt_entity(cfs_rq->next, left) < 1)
        se = cfs_rq->next;

    clear_buddies(cfs_rq, se);

    return se;
}
```

进程唤醒

在`euqueue_entity`方法中有这样一个分支，用于处理唤醒进程

```
if (flags & ENQUEUE_WAKEUP)
    place_entity(cfs_rq, se, 0);
```

在`place_entity`函数中，对应的代码分支如下，主要作用是以`min_vruntime`为基础，对唤醒进程的`vruntime`重新进行设定，使其可以获得合理的CPU运行时间

```
static void
place_entity(struct cfs_rq *cfs_rq, struct sched_entity *se, int initial)
{
    u64 vruntime = cfs_rq->min_vruntime;

    /* sleeps up to a single latency don't count. */
    if (!initial) {
        unsigned long thresh = sysctl_sched_latency;

        /*
         * Halve their sleep time's effect, to allow
         * for a gentler effect of sleepers:
         */
        if (sched_feat(GENTLE_FAIR_SLEEPERS))
            thresh >>= 1;

        vruntime -= thresh;
    }

    /* ensure we never gain time by being placed backwards. */
    se->vruntime = max_vruntime(se->vruntime, vruntime);
}
```

进程抢占

在`pick_next_entity`中可看到其调用了`wakeup_preempt_entity`，该函数用于判断`se`是否可以抢断`curr`，只有当se的`vruntime`小于`curr`的`vruntime`时才有可能抢断，为了避免频繁的切换，还会调用`wakeup_gran`方法使得权重低的进程不会轻易抢占权重高的进程

```
/*
 * Should 'se' preempt 'curr'.
 *
 *             |s1
 *        |s2
 *   |s3
 *         g
 *      |<--->|c
 *
 *  w(c, s1) = -1
 *  w(c, s2) =  0
 *  w(c, s3) =  1
 *
 */
static int
wakeup_preempt_entity(struct sched_entity *curr, struct sched_entity *se)
{
    s64 gran, vdiff = curr->vruntime - se->vruntime;

    if (vdiff <= 0)
        return -1;

    gran = wakeup_gran(se);
    if (vdiff > gran)
        return 1;

    return 0;
}
```

`wakeup_gran`的定义如下，`calc_delta_fair`在下方的问题回答中有分析到

```
static unsigned long wakeup_gran(struct sched_entity *se)
{
    unsigned long gran = sysctl_sched_wakeup_granularity;

    /*
     * Since its curr running now, convert the gran from real-time
     * to virtual-time in his units.
     *
     * By using 'se' instead of 'curr' we penalize light tasks, so
     * they get preempted easier. That is, if 'se' < 'curr' then
     * the resulting gran will be larger, therefore penalizing the
     * lighter, if otoh 'se' > 'curr' then the resulting gran will
     * be smaller, again penalizing the lighter task.
     *
     * This is especially important for buddies when the leftmost
     * task is higher priority than the buddy.
     */
    return calc_delta_fair(gran, se);
}
```

不知道怎么归类的信息

sched_feat用于检查某个特性是否开启，在features.h中可以查到feature是否开启

简述进程优先级、nice值和权重之间的关系

进程优先级越高，nice值越低，而权重由nice值转化得

进程的权重在sched_entity有所体现，而进程的权重根据nice值变换得，在fair.c中可看到与权重更新相关的函数reweight_task（2908行），其中调用了sched_prio_to_weight，在kernel/sched/core.c中可找到定义（7563行）如下

```
const int sched_prio_to_weight[40] = {
 /* -20 */     88761,     71755,     56483,     46273,     36291,
 /* -15 */     29154,     23254,     18705,     14949,     11916,
 /* -10 */      9548,      7620,      6100,      4904,      3906,
 /*  -5 */      3121,      2501,      1991,      1586,      1277,
 /*   0 */      1024,       820,       655,       526,       423,
 /*   5 */       335,       272,       215,       172,       137,
 /*  10 */       110,        87,        70,        56,        45,
 /*  15 */        36,        29,        23,        18,        15,
};
```

nice值的范围为-20~19，转换关系如上所示，公式为

$$1024 * (1.25)^{(-nice)}$$

nice值每降一个单位，CPU使用时间+10%

CFS调度器中的vruntime的基本思想是什么？是如何计算的？何时得到更新？其中的min_vruntime有什么作用？

基本思想

vruntime是每个进程的虚拟运行时间，CFS根据该信息衡量哪个进程最应该被调度，权重越大的进程，虚拟运行时间越小，这样被调度的机会也就越大

计算

在sched/fair.c中，update_curr计算了实际运行时间并存放在delta_exec中，而vruntime的更新数值经calc_delta_fair计算而来

```
static void update_curr(struct cfs_rq *cfs_rq)
{
    struct sched_entity *curr = cfs_rq->curr; // 获取当前进程
    u64 now = rq_clock_task(rq_of(cfs_rq));
    u64 delta_exec;

    if (unlikely(!curr))
        return;

    delta_exec = now - curr->exec_start; // 计算运行时间
    if (unlikely((s64)delta_exec <= 0))
        return;

    curr->exec_start = now; //更新exec_start

    schedstat_set(curr->statistics.exec_max,
```

```
            max(delta_exec, curr->statistics.exec_max));

    curr->sum_exec_runtime += delta_exec; // 更新运行总时间
    schedstat_add(cfs_rq->exec_clock, delta_exec);

    curr->vruntime += calc_delta_fair(delta_exec, curr);
    update_min_vruntime(cfs_rq);

    if (entity_is_task(curr)) {
        struct task_struct *curtask = task_of(curr);

        trace_sched_stat_runtime(curtask, delta_exec, curr->vruntime);
        cgroup_account_cputime(curtask, delta_exec);
        account_group_exec_runtime(curtask, delta_exec);
    }

    account_cfs_rq_runtime(cfs_rq, delta_exec);
}
```

`calc_delta_fair`定义如下

```
static inline u64 calc_delta_fair(u64 delta, struct sched_entity *se)
{
    if (unlikely(se->load.weight != NICE_0_LOAD))
        delta = __calc_delta(delta, NICE_0_LOAD, &se->load);

    return delta;
}
```

其调用的函数`__calc_delta`定义如下

```
static u64 __calc_delta(u64 delta_exec, unsigned long weight, struct load_weight
*lw)
{
    u64 fact = scale_load_down(weight); // fact = weight
    int shift = WMULT_SHIFT; // shift = 32

    __update_inv_weight(lw);

    if (unlikely(fact >> 32)) {
        while (fact >> 32) {
            fact >>= 1;
            shift--;
        }
    }

    /* hint to use a 32x32->64 mul */
    fact = (u64)(u32)fact * lw->inv_weight;

    while (fact >> 32) {
        fact >>= 1;
        shift--;
    }

    return mul_u64_u32_shr(delta_exec, fact, shift);
}
```

`NICE_0_LOAD`使用宏定义，将相关定义找出为如下三条

```
#define NICE_0_LOAD (1L << NICE_0_LOAD_SHIFT)
#define NICE_0_LOAD_SHIFT (SCHED_FIXEDPOINT_SHIFT)
#define SCHED_FIXEDPOINT_SHIFT 10
```

即`NICE_0_LOAD`的默认值为1024，也是`nice`值为0对应的权重

根据`__cala_delta`函数的注释可知，vruntime更新的数值计算公式如下

$$delta = delta \times \frac{NICE\_0\_LOAD}{curr->se->load.weight}$$

所以权重越高的进程，vruntime越小

更新

由上面的分析可知`vruntime`在`update_curr()`中被更新，所以只要调用了该函数的过程都会更新`vruntime`，所以进程切换，进程的入队与出队的时候都会更新`vruntime`，大体总结来说就是，只要函数在运行时`curr`还在运行，那么就要更新`curr`的`vruntime`

min_vruntime的作用

`min_vruntime`在`init_cfs_rq`中被初始化`-1<<20`

```
void init_cfs_rq(struct cfs_rq *cfs_rq)
{
    cfs_rq->tasks_timeline = RB_ROOT_CACHED;
    cfs_rq->min_vruntime = (u64)(-(1LL << 20));
#ifndef CONFIG_64BIT
    cfs_rq->min_vruntime_copy = cfs_rq->min_vruntime;
#endif
#ifdef CONFIG_SMP
    raw_spin_lock_init(&cfs_rq->removed.lock);
#endif
}
```

在调用`update_curr`和`dequeue_entity`函数时，`min_vruntime`都会被更新

`min_vruntime`的更新代码如下，已做相应的注释

```
static void update_min_vruntime(struct cfs_rq *cfs_rq)
{
    // 设置vruntime的值
    struct sched_entity *curr = cfs_rq->curr;
    struct rb_node *leftmost = rb_first_cached(&cfs_rq->tasks_timeline);

    u64 vruntime = cfs_rq->min_vruntime;

    if (curr) {
        if (curr->on_rq)
            vruntime = curr->vruntime;
        else
            curr = NULL;
    }

    // 找到最左节点，即vruntime最小的节点
```

```
    if (leftmost) { /* non-empty tree */
        struct sched_entity *se;
        se = rb_entry(leftmost, struct sched_entity, run_node);

         // 设置vruntime为curr和最左进程中较小的
        if (!curr)
            vruntime = se->vruntime;
        else
            vruntime = min_vruntime(vruntime, se->vruntime);
    }

    /* ensure we never gain time by being placed backwards. */
    cfs_rq->min_vruntime = max_vruntime(cfs_rq->min_vruntime, vruntime);
#ifndef CONFIG_64BIT
    smp_wmb();
    cfs_rq->min_vruntime_copy = cfs_rq->min_vruntime;
#endif
}
```

更新函数的作用为比较curr进程和红黑树中最左节点的vruntime，若两者中的较小值比当前的 `min_vruntime` 大，则更新该值，即该值是单调递增的，在 `fair.c` 搜索这个值，可看出 `min_vruntime` 的作用主要为

1. 保证新进程或休眠进程的 `vruntime` 为合理的时间

新进程的 `vruntime` 大于等于 `min_vruntime` 小于父进程的 `vruntime`

如果一个进程长时间休眠，此时休眠进程的 `vruntime` 会很小，为了避免休眠进程在被唤醒后长时间抢占CPU，会以 `min_vruntime` 为基础，为休眠进程重新设定 `vruntime`

```
static void
place_entity(struct cfs_rq *cfs_rq, struct sched_entity *se, int initial)
{
    u64 vruntime = cfs_rq->min_vruntime;

    /*
     * The 'current' period is already promised to the current tasks,
     * however the extra weight of the new task will slow them down a
     * little, place the new task so that it fits in the slot that
     * stays open at the end.
     */
    if (initial && sched_feat(START_DEBIT)) // 新进程
        vruntime += sched_vslice(cfs_rq, se);

    /* sleeps up to a single latency don't count. */
    if (!initial) { // 休眠进程
        unsigned long thresh = sysctl_sched_latency;

        /*
         * Halve their sleep time's effect, to allow
         * for a gentler effect of sleepers:
         */
        if (sched_feat(GENTLE_FAIR_SLEEPERS))
            thresh >>= 1;

        vruntime -= thresh;
    }
```

```
    /* ensure we never gain time by being placed backwards. */
    se->vruntime = max_vruntime(se->vruntime, vruntime);
}
```

2. 保证进程从一个CPU转到其他CPU执行的时候`vruntime`值正确

由于不同的CPU运行队列上`min_vruntime`是不同的，对于一个进程在不同CPU上执行的情况，Linux内核的处理是根据`min_vruntime`对进程的`vruntime`进行处理，公式如下

$$vruntime_{A\ to\ B} = vruntime - min\_vruntime_A + min\_vruntime_B$$

所以在

`enqueue_entity`中有

```
se->vruntime += cfs_rq->min_vruntime;
```

`dequeue_entity`中有

```
se->vruntime -= cfs_rq->min_vruntime;
```

添加系统调用

基于内核版本4.15.0更改

`arch/x86/entry/syscalls/syscall_64.tbl`添加

```
333 common mycall sys_mycall
```

`include/linux/syscalls.h`添加

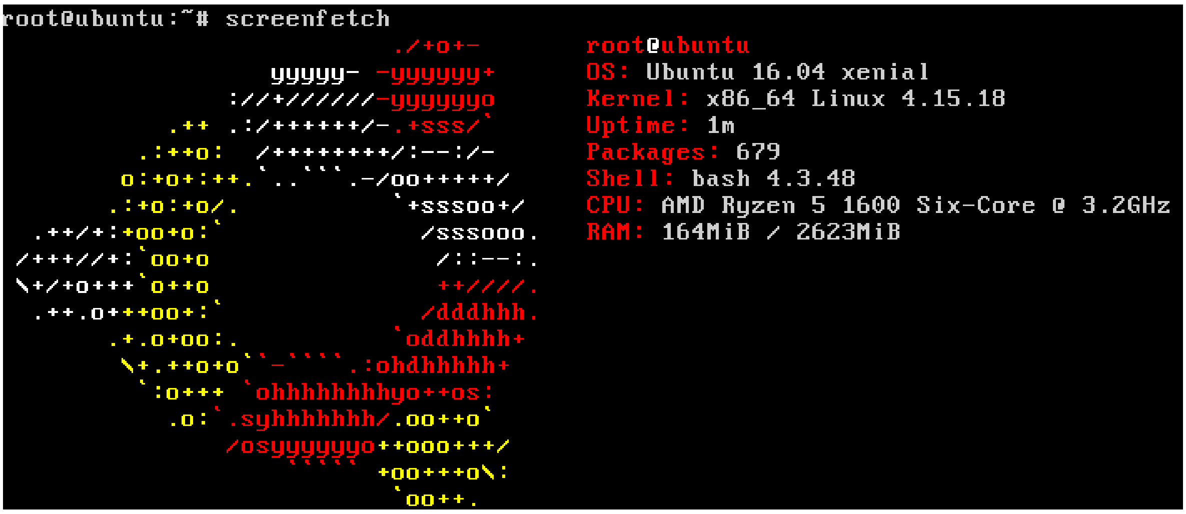
```
asmlinkage long sys_mycall(void);
```

`kernel/sys.c`添加(SPLIT_NS的定义也要移过来)

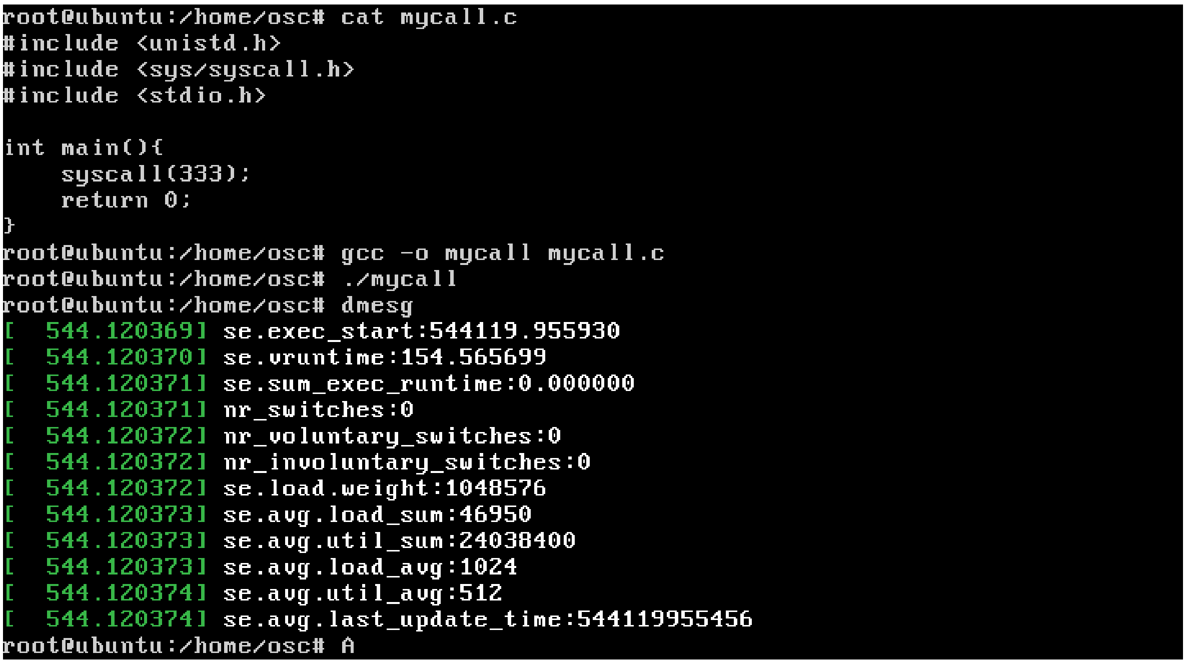
```
SYSCALL_DEFINE0(mycall){
    printk("se.exec_start:%Ld.%06ld\n", SPLIT_NS(current->se.exec_start));
    printk("se.vruntime:%Ld.%06ld\n", SPLIT_NS(current->se.vruntime));
    printk("se.sum_exec_runtime:%Ld.%06ld\n", SPLIT_NS(current->se.sum_exec_runtime));
    printk("nr_switches:%lu\n", current->nvcsw + current->nivcsw);
    printk("nr_voluntary_switches:%lu\n", current->nvcsw);
    printk("nr_involuntary_switches:%lu\n", current->nivcsw);
    printk("se.load.weight:%lu\n", current->se.load.weight);
    printk("se.avg.load_sum:%llu\n", current->se.avg.load_sum);
    printk("se.avg.util_sum:%d\n", current->se.avg.util_sum);
    printk("se.avg.load_avg:%lu\n", current->se.avg.load_avg);
    printk("se.avg.util_avg:%lu\n", current->se.avg.util_avg);
    printk("se.avg.last_update_time:%llu\n", current->se.avg.last_update_time);
    return 0;
}
```

原系统的screenfetch截图

添加系统调用，重新编译内核后的sceenfetch截图



系统调用后的截图



```
root@ubuntu:/home/osc# cat mycall.c
#include <unistd.h>
#include <sys/syscall.h>
#include <stdio.h>

int main(){
    syscall(333);
    return 0;
}
root@ubuntu:/home/osc# gcc -o mycall mycall.c
root@ubuntu:/home/osc# ./mycall
root@ubuntu:/home/osc# dmesg
[  544.120369] se.exec_start:544119.955930
[  544.120370] se.vruntime:154.565699
[  544.120371] se.sum_exec_runtime:0.000000
[  544.120371] nr_switches:0
[  544.120372] nr_voluntary_switches:0
[  544.120372] nr_involuntary_switches:0
[  544.120372] se.load.weight:1048576
[  544.120373] se.avg.load_sum:46950
[  544.120373] se.avg.util_sum:24038400
[  544.120373] se.avg.load_avg:1024
[  544.120374] se.avg.util_avg:512
[  544.120374] se.avg.last_update_time:544119955456
root@ubuntu:/home/osc# A
```