拒绝造轮子！如何移植并使用Linux内核的通用链表（附完整代码实现）

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以下文章来源于嵌入式与Linux那些事 ，作者仲一

嵌入式与Linux那些事
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> 在实际的工作中，我们可能会经常使用链表结构来存储数据，特别是嵌入式开发，经常会使用linux内核最经典的双向链表 list_head。
>
> 本篇文章详细介绍了Linux内核的通用链表是如何实现的，对于经常使用的函数都给出了详细的说明和测试用例，并且移植了Linux内核的链表结构，在任意平台都可以方便的调用内核已经写好的函数。建议收藏，以备不时之需！

1. 链表简介

链表是一种常用的组织**有序数据**的数据结构，它通过指针将一系列数据节点连接成一条数据链，是线性表的一种重要实现方式。

相对于数组，链表具有更好的**动态性**，建立链表时无需预先知道数据总量，可以**随机分配空间**，可以**高效**地在链表中的任意位置实时插入或删除数据。

通常链表数据结构至少应包含两个域：数据域和指针域，**数据域**用于存储数据，**指针域**用于建立与下一个节点的联系。按照指针域的组织以及各个节点之间的联系形式，链表又可以分为**单链表、双链表、循环链表**等多种类型。

下面分别给出这几类常见链表类型的示意图：

1.1 单链表

单链表是最简单的一类链表，它的特点是**仅有一个指针域**指向后继节点（next）。因此，对单链表的遍历**只能从头至尾（通常是NULL空指针）顺序进行**。

1.2 双链表

通过设计前驱和后继两个指针域，双链表可以从**两个方向**遍历，这是它区别于单链表的地方。

如果打乱前驱、后继的依赖关系，就可以构成"**二叉树**"；如果再让首节点的前驱指向链表尾节点、尾节点的后继指向首节点，就构成了**循环链表**；如果设计更多的指针域，就可以构成各种复杂的**树状**数据结构。

双链表

1.3 循环链表

循环链表的特点是**尾节点的后继指向首节点**。前面已经给出了双链表的示意图，它的特点是从任意一个节点出发，沿两个方向的任何一个，都能找到链表中的任意一个数据。如果去掉前驱指针，就是单循环链表。

循环链表

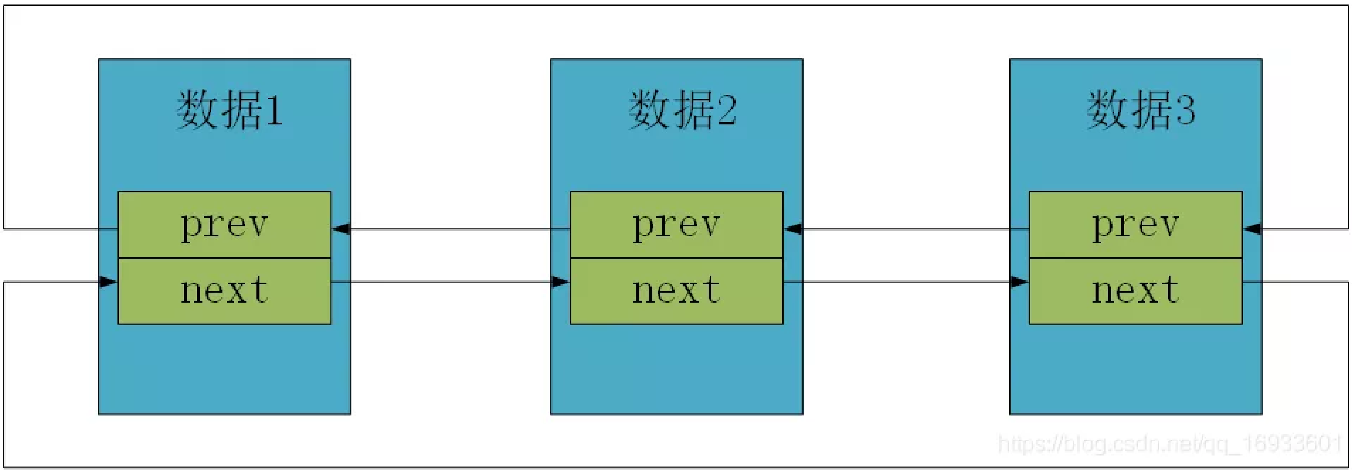
2. Linux内核中的链表

上面介绍了普通链表的实现方式，可以看到**数据域都是包裹在节点指针中的**，通过节点指针访问下一组数据。

但是 Linux内核的链表实现可以说比较特殊，**只有前驱和后继指针，而没有数据域**。链表的头文件是在include/list.h（Linux2.6内核）下。在实际工作中，也可以将内核中的链表拷贝出来供我们使用，就需不要造轮子了。

2.1 链表的定义

内核链表**只有前驱和后继指针**，并不包含数据域，这个链表具备通用性，使用非常方便。因此可以很容易的将内核链表结构体包含在任意数据的结构体中，非常容易扩展。我们只需要**将链表结构体包括在数据结构体中**就可以。下面看具体的代码。



内核中的链表

内核链表的结构

```
//链表结构
struct list_head
{
    struct list_head *prev;
    struct list_head *next;
};
```

当需要用内核的链表结构时，只需要在**数据结构体中**定义一个 `struct list_head{}` 类型的结构体成员对象就可以。这样，我们就可以很方便地使用内核提供给我们的一组**标准接口**来对链表进行各种操作。我们定义一个学生结构体，里面包含学号和数学成绩。结构体如下：

```
 struct student
{
    struct list_head list;//暂且将链表放在结构体的第一位
    int ID;
    int math;
};
```

2.2 链表的初始化

2.2.1 内核实现

```
#define LIST_HEAD_INIT(name) { &(name), &(name) }

#define LIST_HEAD(name) \
 struct list_head name = LIST_HEAD_INIT(name)

static inline void INIT_LIST_HEAD(struct list_head *list)
{
 list->next = list;
 list->prev = list;
}
```

2.2.2 说明

`INIT_LIST_HEAD` 和 `LIST_HEAD` 都可以初始化链表，二者的区别如下： `LIST_HEAD(stu_list)` 初始化链表时会**顺便创建链表对象**。

```
//LIST_HEAD(stu_list) 展开如下
struct list_head stu_list= { &(stu_list), &(stu_list) };
```

`INIT_LIST_HEAD(&stu1.stu_list)` 初始化链表时需要我们**已经有了一个链表对象** `stu1_list` 。

我们可以看到链表的初始化其实非常简单，就是让**链表的前驱和后继都指向了自己。**

2.2.3 举例

```
INIT_LIST_HEAD(&stu1.stu_list);
```

2.3 链表增加节点

2.3.1 内核实现

```
/*
 * Insert a new entry between two known consecutive entries.
 *
 * This is only for internal list manipulation where we know
 * the prev/next entries already!
 */
#ifndef CONFIG_DEBUG_LIST
static inline void __list_add(struct list_head *new,
         struct list_head *prev,
         struct list_head *next)
{
 next->prev = new;
 new->next = next;
 new->prev = prev;
 prev->next = new;
}
#else
extern void __list_add(struct list_head *new,
         struct list_head *prev,
         struct list_head *next);
#endif

/**
 * list_add - add a new entry
 * @new: new entry to be added
```

```
 * @head: list head to add it after
 *
 * Insert a new entry after the specified head.
 * This is good for implementing stacks.
 */
#ifndef CONFIG_DEBUG_LIST
static inline void list_add(struct list_head *new, struct list_head *head)
{
 __list_add(new, head, head->next);
}
#else
extern void list_add(struct list_head *new, struct list_head *head);
#endif


/**
 * list_add_tail - add a new entry
 * @new: new entry to be added
 * @head: list head to add it before
 *
 * Insert a new entry before the specified head.
 * This is useful for implementing queues.
 */
static inline void list_add_tail(struct list_head *new, struct list_head *head)
{
 __list_add(new, head->prev, head);
}
```

2.3.2 说明

`list_add` 为头插法，即在**链表头部（head节点）前插入节点**。最后打印的时候，先插入的先打印，后插入的后打印。

例如原链表为1->2->3,使用 `list_add` 插入4后变为，4->1->2->3。因为链表时循环的，而且通常没有首尾节点的概念，所以可以把**任何一个节点当成head**。

同理， `list_add_tail` 为尾插法，即在**链表尾部（head节点）插入节点**。最后打印的时候，先插入的后打印，后插入的先打印。

例如原链表为1->2->3,使用 `list_add_tail` 插入4后变为，1->2->3->4。

2.3.3 举例

```
#include "mylist.h"
#include <stdio.h>
#include <stdlib.h>
struct student
{
    struct list_head stu_list;
    int ID;
    int math;
};

int main()
{
    struct student *p;
    struct student *q;
    struct student stu1;
    struct student stu2;
    struct list_head *pos;
    //链表的初始化
    INIT_LIST_HEAD(&stu1.stu_list);
    INIT_LIST_HEAD(&stu2.stu_list);
    //头插法创建stu stu1链表
     for (int i = 0;i < 6;i++) {
         p = (struct student *)malloc(sizeof(struct student));
         p->ID=i;
         p->math = i+80;
         //头插法
         list_add(&p->stu_list,&stu1.stu_list);
         //尾插法
         //list_add_tail(&p->list,&stu.list);
     }

    printf("list_add: \r\n");
    list_for_each(pos, &stu1.stu_list) {
        printf("ID = %d,math = %d\n",((struct student*)pos)->ID,((struct student*)pos)-
    }

    //尾插法创建stu stu1链表
     for (int i = 0;i < 6;i++) {
         p = (struct student *)malloc(sizeof(struct student));
         p->ID=i;
```

```
            p->math = i+80;
            //头插法
            //list_add(&p->stu_list,&stu1.stu_list);
            //尾插法
            list_add_tail(&p->stu_list,&stu2.stu_list);
        }

    printf("list_add_tail: \r\n");
    list_for_each(pos, &stu2.stu_list) {
        printf("ID = %d,math = %d\n",((struct student*)pos)->ID,((struct student*)pos)
    }
    return 0;
}
```

```
book@www.100ask.org:~/work/C_Test$ gcc Kernel_LinkList.c -o Kernel_LinkList.out
book@www.100ask.org:~/work/C_Test$ ./Kernel_LinkList.out
list_add:
ID = 5,math = 85
ID = 4,math = 84
ID = 3,math = 83
ID = 2,math = 82
ID = 1,math = 81
ID = 0,math = 80
list_add_tail:
ID = 0,math = 80
ID = 1,math = 81
ID = 2,math = 82
ID = 3,math = 83
ID = 4,math = 84
ID = 5,math = 85
```


测试结果

2.4 链表删除节点

2.4.1 内核实现

```
//原来内核设置的删除链表后的指向位置
// # define POISON_POINTER_DELTA 0
// #define LIST_POISON1  ((void *) 0x00100100 + POISON_POINTER_DELTA)
// #define LIST_POISON2  ((void *) 0x00200200 + POISON_POINTER_DELTA)

//这里我们设置为NULL 内核中定义NULL 为0
#define NULL ((void *)0)
#define LIST_POISON1  NULL
#define LIST_POISON2  NULL
/*
 * Delete a list entry by making the prev/next entries
 * point to each other.
 *
```

```
 * This is only for internal list manipulation where we know
 * the prev/next entries already!
 */
static inline void __list_del(struct list_head * prev, struct list_head * next)
{
 next->prev = prev;
 prev->next = next;
}

/**
 * list_del - deletes entry from list.
 * @entry: the element to delete from the list.
 * Note: list_empty() on entry does not return true after this, the entry is
 * in an undefined state.
 */
#ifndef CONFIG_DEBUG_LIST
static inline void list_del(struct list_head *entry)
{
 __list_del(entry->prev, entry->next);
 entry->next = LIST_POISON1;
 entry->prev = LIST_POISON2;
}
#else
extern void list_del(struct list_head *entry);
#endif
```

2.4.2 说明

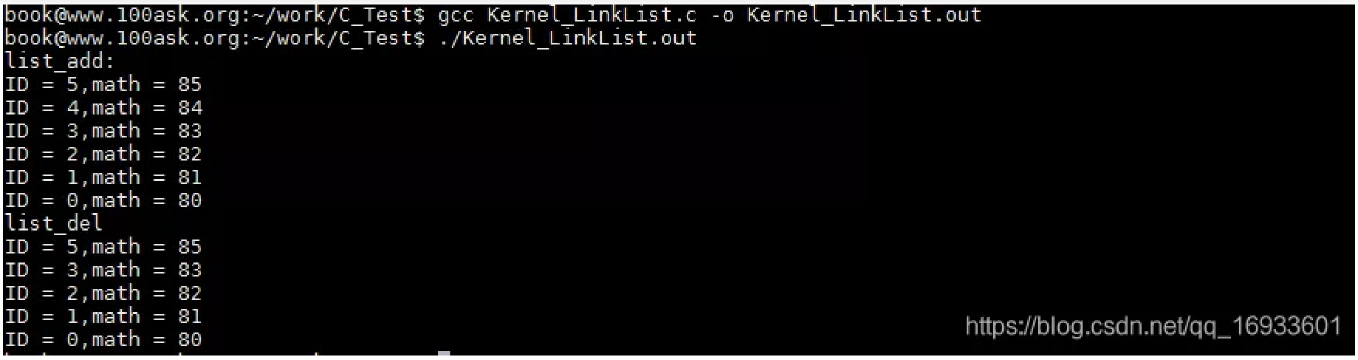
链表删除之后，entry的前驱和后继会分别指向 `LIST_POISON1` 和 `LIST_POISON2` ，这个是内核设置的一个区域，但是在本例中将其置为了 `NULL` 。

2.4.3 举例

```
#include "mylist.h"
#include <stdio.h>
#include <stdlib.h>
struct student
{
    struct list_head stu_list;
```

```
    int ID;
    int math;
};
int main()
{
    struct student *p;
    struct student *q;
    struct student stu1;
    struct student stu2;
    struct list_head *pos1;
    //注意这里的pos2，后面会解释为什么定义为
    struct student *pos2;
    //stu = (struct student*)malloc(sizeof(struct student));
    //链表的初始化
    INIT_LIST_HEAD(&stu1.stu_list);
    INIT_LIST_HEAD(&stu2.stu_list);
    LIST_HEAD(stu);
    //头插法创建stu stu1链表
     for (int i = 0;i < 6;i++) {
         p = (struct student *)malloc(sizeof(struct student));
         p->ID=i;
         p->math = i+80;
         //头插法
         list_add(&p->stu_list,&stu1.stu_list);
         //尾插法
         //list_add_tail(&p->list,&stu.list);
     }

    printf("list_add: \r\n");
    list_for_each(pos1, &stu1.stu_list) {
        printf("ID = %d,math = %d\n",((struct student*)pos1)->ID,((struct student*)pos1
    }

    //删除
    list_for_each_entry(pos2,&stu1.stu_list,stu_list) {
        if (pos2->ID == 4) {
            list_del(&pos2->stu_list);
            break;
        }
    }

    printf("list_del\r\n");
    list_for_each_entry(pos2,&stu1.stu_list,stu_list) {
        printf("ID = %d,math = %d\n",pos2->ID,pos2->math);
    }
```

```
    return 0;

}
```



```
book@www.100ask.org:~/work/C_Tests$ gcc Kernel_LinkList.c -o Kernel_LinkList.out
book@www.100ask.org:~/work/C_Tests$ ./Kernel_LinkList.out
list_add:
ID = 5,math = 85
ID = 4,math = 84
ID = 3,math = 83
ID = 2,math = 82
ID = 1,math = 81
ID = 0,math = 80
list_del
ID = 5,math = 85
ID = 3,math = 83
ID = 2,math = 82
ID = 1,math = 81
ID = 0,math = 80
```


测试结果

2.5 链表替换节点

2.5.1 内核实现

```
/**
 * list_replace - replace old entry by new one
 * @old : the element to be replaced
 * @new : the new element to insert
 *
 * If @old was empty, it will be overwritten.
 */
static inline void list_replace(struct list_head *old,
    struct list_head *new)
{
 new->next = old->next;
 new->next->prev = new;
 new->prev = old->prev;
 new->prev->next = new;
}

static inline void list_replace_init(struct list_head *old,
     struct list_head *new)
{
 list_replace(old, new);
 INIT_LIST_HEAD(old);//重新初始化
}
```

2.5.2 说明

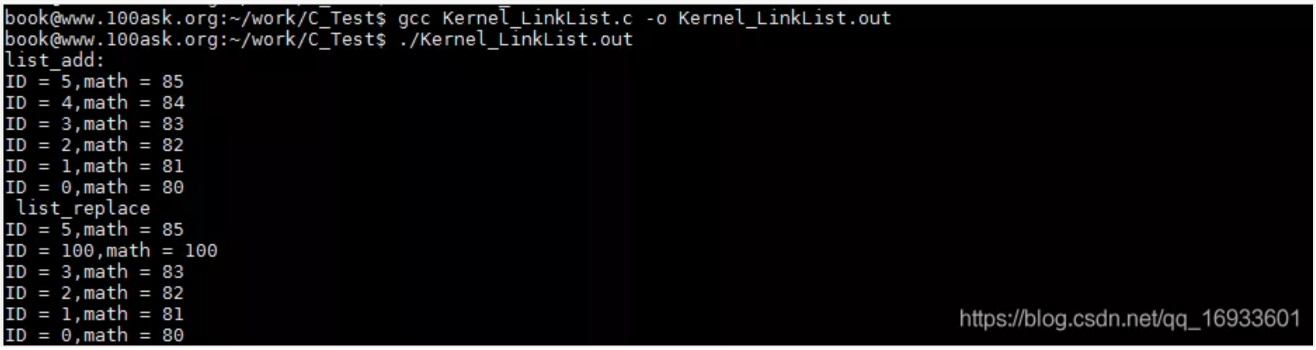
`list_replace` 使用新的节点替换旧的节点。

`list_replace_init` 与 `list_replace` 不同之处在于， `list_replace_init` 会将旧的节点**重新初始化**，让前驱和后继指向自己。

2.5.3 举例

```
#include "mylist.h"
#include <stdio.h>
#include <stdlib.h>
struct student
{
    struct list_head stu_list;
    int ID;
    int math;
};
int main()
{
    struct student *p;
    struct student *q;
    struct student stu1;
    struct student stu2;
    struct list_head *pos1;
    struct student *pos2;
    struct student new_obj={.ID=100,.math=100};
    //stu = (struct student*)malloc(sizeof(struct student));
    //链表的初始化
    INIT_LIST_HEAD(&stu1.stu_list);
    INIT_LIST_HEAD(&stu2.stu_list);
    LIST_HEAD(stu);
    //头插法创建stu stu1链表
     for (int i = 0;i < 6;i++) {
         p = (struct student *)malloc(sizeof(struct student));
         p->ID=i;
         p->math = i+80;
         //头插法
         list_add(&p->stu_list,&stu1.stu_list);
         //尾插法
```

```
            //list_add_tail(&p->list,&stu.list);
        }
    printf("list_add: \r\n");
    list_for_each(pos1, &stu1.stu_list) {
        printf("ID = %d,math = %d\n",((struct student*)pos1)->ID,((struct student*)pos1
    }

    //替换
    list_for_each_entry(pos2,&stu1.stu_list,stu_list) {
        if (pos2->ID == 4) {
            list_replace(&pos2->stu_list,&new_obj.stu_list);
            break;
        }
    }
    printf("list_replace\r\n");
    list_for_each_entry(pos2,&stu1.stu_list,stu_list) {
        printf("ID = %d,math = %d\n",pos2->ID,pos2->math);
    }
    return 0;
}
```



测试结果

2.6 链表删除并插入节点

2.6.1 内核实现

```
/**
 * list_move - delete from one list and add as another's head
 * @list: the entry to move
 * @head: the head that will precede our entry
 */
static inline void list_move(struct list_head *list, struct list_head *head)
{
    list_del(list->prev, list->next);
```

```
 __list_del(list->prev, list->next);
 list_add(list, head);
}

/**
 * list_move_tail - delete from one list and add as another's tail
 * @list: the entry to move
 * @head: the head that will follow our entry
 */
static inline void list_move_tail(struct list_head *list,
      struct list_head *head)
{
 __list_del(list->prev, list->next);
 list_add_tail(list, head);
}
```

2.6.2 说明

`list_move` 函数实现的功能是**删除list指向的节点**，同时将其以**头插法插入到head中**。`list_move_tail` 和 `list_move` 功能类似，只不过是将list节点插入到了**head的尾部**。

2.6.3 举例

```
#include "mylist.h"
#include <stdio.h>
#include <stdlib.h>
struct student
{
    struct list_head stu_list;
    int ID;
    int math;
};
int main()
{
    struct student *p;
    struct student *q;
    struct student stu1;
    struct student stu2;
    struct list_head *pos1;
```

```
    struct student *pos2;
    struct student new_obj={.ID=100,.math=100};
    //stu = (struct student*)malloc(sizeof(struct student));
    //链表的初始化
    INIT_LIST_HEAD(&stu1.stu_list);
    INIT_LIST_HEAD(&stu2.stu_list);
    LIST_HEAD(stu);
    //头插法创建stu stu1链表
     for (int i = 0;i < 6;i++) {
         p = (struct student *)malloc(sizeof(struct student));
         p->ID=i;
         p->math = i+80;
         //头插法
         list_add(&p->stu_list,&stu1.stu_list);
         //尾插法
         //list_add_tail(&p->list,&stu.list);
     }
    printf("list_add: \r\n");
    list_for_each(pos1, &stu1.stu_list) {
        printf("ID = %d,math = %d\n",((struct student*)pos1)->ID,((struct student*)pos1
    }

    //移位替换
    list_for_each_entry(pos2,&stu1.stu_list,stu_list) {
        if (pos2->ID == 0) {
            list_move(&pos2->stu_list,&stu1.stu_list);
            break;
        }
    }
    printf("list_move\r\n");
    list_for_each_entry(pos2,&stu1.stu_list,stu_list) {
        printf("ID = %d,math = %d\n",pos2->ID,pos2->math);
    }
    return 0;
}
```

```
book@www.100ask.org:~/work/C_Tests$ gcc Kernel_LinkList.c -o Kernel_LinkList.out
book@www.100ask.org:~/work/C_Tests$ ./Kernel_LinkList.out
list_add:
ID = 5,math = 85
ID = 4,math = 84
ID = 3,math = 83
ID = 2,math = 82
ID = 1,math = 81
ID = 0,math = 80
 list_move
ID = 0,math = 80
ID = 5,math = 85
ID = 4,math = 84
ID = 3,math = 83
ID = 2,math = 82
ID = 1,math = 81
```


测试结果

2.7 链表的合并

2.7.1 内核实现

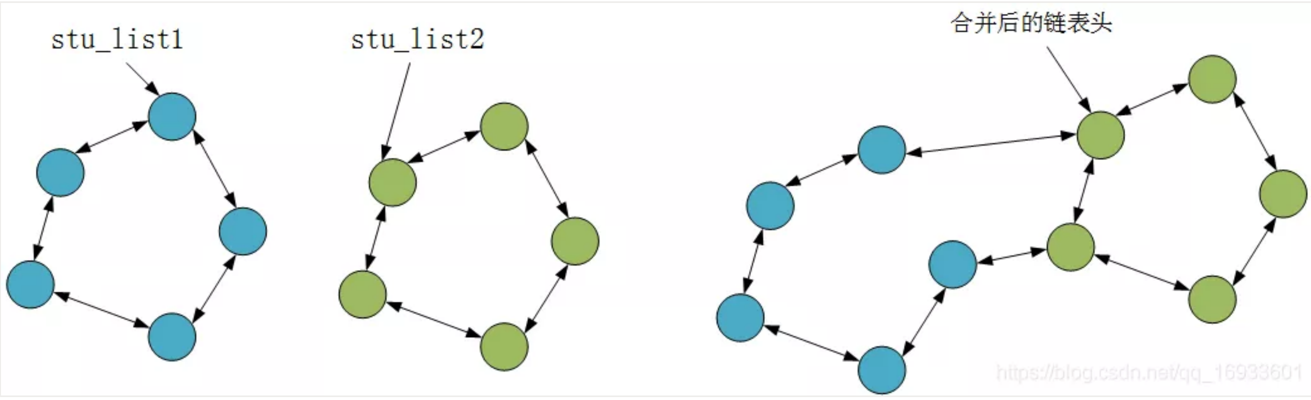
```
static inline void __list_splice(struct list_head *list,
     struct list_head *head)
{
 struct list_head *first = list->next;
 struct list_head *last = list->prev;
 struct list_head *at = head->next;

 first->prev = head;
 head->next = first;

 last->next = at;
 at->prev = last;
}

/**
 * list_splice - join two lists
 * @list: the new list to add.
 * @head: the place to add it in the first list.
 */
static inline void list_splice(struct list_head *list, struct list_head *head)
{
 if (!list_empty(list))
  __list_splice(list, head);
}

/**
 * list_splice_init - join two lists and reinitialise the emptied list.
 * @list: the new list to add.
 * @head: the place to add it in the first list.
 *
 * The list at @list is reinitialised
 */
static inline void list_splice_init(struct list_head *list,
        struct list_head *head)
{
 if (!list_empty(list)) {
  __list_splice(list, head);
  INIT_LIST_HEAD(list);//置空
```

```
  }
}
```

2.7.2 说明

list_splice 完成的功能是合并两个链表。

假设当前有两个链表，表头分别是 stu_list1 和 stu_list2 （都是 struct list_head 变量），当调用 list_splice(&stu_list1,&stu_list2) 时，只要 stu_list1 非空， stu_list1 链表的内容将被挂接在 stu_list2 链表上，位于 stu_list2 和 stu_list2.next （原 stu_list2 表的第一个节点）之间。新 stu_list2 链表将以原 stu_list1 表的第一个节点为首节点，而尾节点不变。



合并两个链表

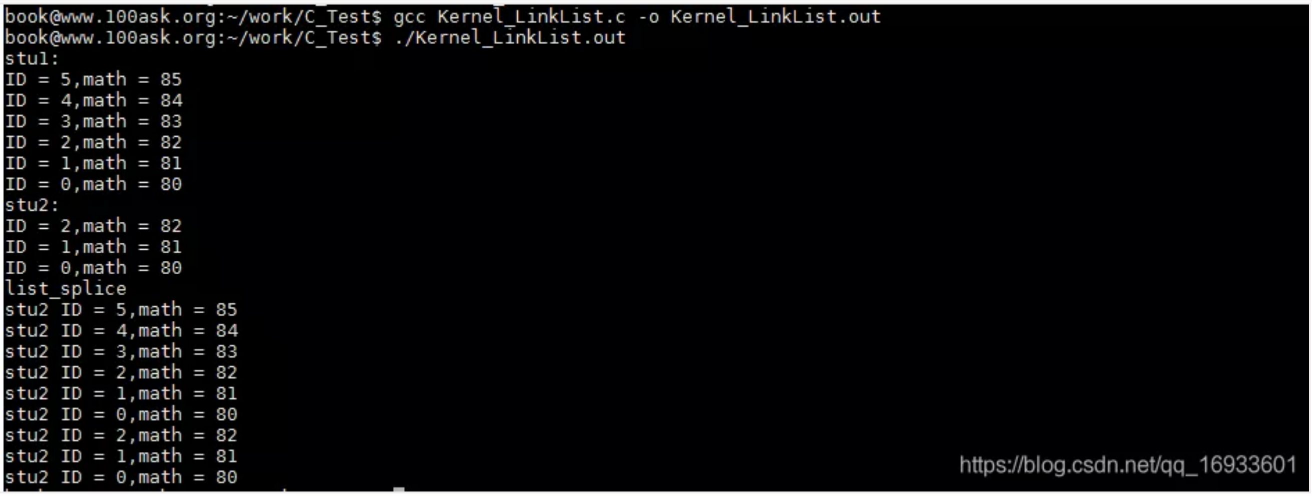
list_splice_init 和 list_splice 类似，只不过在合并完之后，调用 INIT_LIST_HEAD(list) 将list设置为空链。

2.7.3 用例

```
#include "mylist.h"
#include <stdio.h>
#include <stdlib.h>
struct student
{
    struct list_head stu_list;
    int ID;
    int math;
};
int main()
{
```

```
struct student *p;
struct student *q;
struct student stu1;
struct student stu2;
struct list_head *pos1;
struct student *pos2;
struct student new_obj={.ID=100,.math=100};
//stu = (struct student*)malloc(sizeof(struct student));
//链表的初始化
INIT_LIST_HEAD(&stu1.stu_list);
INIT_LIST_HEAD(&stu2.stu_list);
LIST_HEAD(stu);
//头插法创建stu1 list链表
 for (int i = 0;i < 6;i++) {
     p = (struct student *)malloc(sizeof(struct student));
     p->ID=i;
     p->math = i+80;
     //头插法
     list_add(&p->stu_list,&stu1.stu_list);
     //尾插法
     //list_add_tail(&p->list,&stu.list);
 }
printf("stu1: \r\n");
list_for_each(pos1, &stu1.stu_list) {
    printf("ID = %d,math = %d\n",((struct student*)pos1)->ID,((struct student*)pos1
}
//头插法创建stu2 list 链表
 for (int i = 0;i < 3;i++) {
     q = (struct student *)malloc(sizeof(struct student));
     q->ID=i;
     q->math = i+80;
     //头插法
     list_add(&q->stu_list,&stu2.stu_list);
     //尾插法
     //list_add_tail(&p->list,&stu.list);
 }
printf("stu2: \r\n");
list_for_each(pos1, &stu2.stu_list) {
    printf("ID = %d,math = %d\n",((struct student*)pos1)->ID,((struct student*)pos1
}

//合并
list_splice(&stu1.stu_list,&stu2.stu_list);
printf("list_splice\r\n");
```

```
    list_for_each(pos1, &stu2.stu_list) {
        printf("stu2 ID = %d,math = %d\n",((struct student*)pos1)->ID,((struct student*
    }


    return 0;
}
```



测试结果

2.8 链表的遍历

2.8.1 内核实现

```
//计算member在type中的位置
#define offsetof(type, member)  (size_t)(&((type*)0)->member)
//根据member的地址获取type的起始地址

#define container_of(ptr, type, member) ({          \
        const typeof(((type *)0)->member)*__mptr = (ptr);    \
    (type *)((char *)__mptr - offsetof(type, member)); })

/**
 * list_entry - get the struct for this entry
 * @ptr: the &struct list_head pointer.
 * @type: the type of the struct this is embedded in.
 * @member: the name of the list_struct within the struct.
 */
#define list_entry(ptr, type, member) \
 container_of(ptr, type, member)
```

```
/**
 * list_first_entry - get the first element from a list
 * @ptr: the list head to take the element from.
 * @type: the type of the struct this is embedded in.
 * @member: the name of the list_struct within the struct.
 *
 * Note, that list is expected to be not empty.
 */
#define list_first_entry(ptr, type, member) \
 list_entry((ptr)->next, type, member)

/**
 * list_for_each - iterate over a list
 * @pos: the &struct list_head to use as a loop cursor.
 * @head: the head for your list.
 */
#define list_for_each(pos, head) \
 for (pos = (head)->next; prefetch(pos->next), pos != (head); \
         pos = pos->next)

/**
 * __list_for_each - iterate over a list
 * @pos: the &struct list_head to use as a loop cursor.
 * @head: the head for your list.
 *
 * This variant differs from list_for_each() in that it's the
 * simplest possible list iteration code, no prefetching is done.
 * Use this for code that knows the list to be very short (empty
 * or 1 entry) most of the time.
 */
#define __list_for_each(pos, head) \
 for (pos = (head)->next; pos != (head); pos = pos->next)

/**
 * list_for_each_prev - iterate over a list backwards
 * @pos: the &struct list_head to use as a loop cursor.
 * @head: the head for your list.
 */
#define list_for_each_prev(pos, head) \
 for (pos = (head)->prev; prefetch(pos->prev), pos != (head); \
```

```
         pos = pos->prev)

/**
 * list_for_each_safe - iterate over a list safe against removal of list entry
 * @pos: the &struct list_head to use as a loop cursor.
 * @n:  another &struct list_head to use as temporary storage
 * @head: the head for your list.
 */
#define list_for_each_safe(pos, n, head) \
 for (pos = (head)->next, n = pos->next; pos != (head); \
  pos = n, n = pos->next)

/**
 * list_for_each_entry - iterate over list of given type
 * @pos: the type * to use as a loop cursor.
 * @head: the head for your list.
 * @member: the name of the list_struct within the struct.
 */
#define list_for_each_entry(pos, head, member)    \
 for (pos = list_entry((head)->next, typeof(*pos), member); \
      prefetch(pos->member.next), &pos->member != (head);  \
      pos = list_entry(pos->member.next, typeof(*pos), member))

/**
 * list_for_each_entry_reverse - iterate backwards over list of given type.
 * @pos: the type * to use as a loop cursor.
 * @head: the head for your list.
 * @member: the name of the list_struct within the struct.
 */
#define list_for_each_entry_reverse(pos, head, member)   \
 for (pos = list_entry((head)->prev, typeof(*pos), member); \
      prefetch(pos->member.prev), &pos->member != (head);  \
      pos = list_entry(pos->member.prev, typeof(*pos), member))

/**
 * list_prepare_entry - prepare a pos entry for use in list_for_each_entry_continue()
 * @pos: the type * to use as a start point
 * @head: the head of the list
 * @member: the name of the list_struct within the struct.
 *
 * Prepares a pos entry for use as a start point in list_for_each_entry_continue().
```

```
 */
#define list_prepare_entry(pos, head, member) \
 ((pos) ? : list_entry(head, typeof(*pos), member))

/**
 * list_for_each_entry_continue - continue iteration over list of given type
 * @pos: the type * to use as a loop cursor.
 * @head: the head for your list.
 * @member: the name of the list_struct within the struct.
 *
 * Continue to iterate over list of given type, continuing after
 * the current position.
 */
#define list_for_each_entry_continue(pos, head, member)   \
 for (pos = list_entry(pos->member.next, typeof(*pos), member); \
      prefetch(pos->member.next), &pos->member != (head); \
      pos = list_entry(pos->member.next, typeof(*pos), member))

/**
 * list_for_each_entry_from - iterate over list of given type from the current point
 * @pos: the type * to use as a loop cursor.
 * @head: the head for your list.
 * @member: the name of the list_struct within the struct.
 *
 * Iterate over list of given type, continuing from current position.
 */
#define list_for_each_entry_from(pos, head, member)    \
 for (; prefetch(pos->member.next), &pos->member != (head); \
      pos = list_entry(pos->member.next, typeof(*pos), member))

/**
 * list_for_each_entry_safe - iterate over list of given type safe against removal of .
 * @pos: the type * to use as a loop cursor.
 * @n:  another type * to use as temporary storage
 * @head: the head for your list.
 * @member: the name of the list_struct within the struct.
 */
#define list_for_each_entry_safe(pos, n, head, member)   \
 for (pos = list_entry((head)->next, typeof(*pos), member), \
  n = list_entry(pos->member.next, typeof(*pos), member); \
      &pos->member != (head);      \
```

```
      pos = n, n = list_entry(n->member.next, typeof(*n), member))

/**
 * list_for_each_entry_safe_continue
 * @pos: the type * to use as a loop cursor.
 * @n:  another type * to use as temporary storage
 * @head: the head for your list.
 * @member: the name of the list_struct within the struct.
 *
 * Iterate over list of given type, continuing after current point,
 * safe against removal of list entry.
 */
#define list_for_each_entry_safe_continue(pos, n, head, member)   \
 for (pos = list_entry(pos->member.next, typeof(*pos), member),   \
  n = list_entry(pos->member.next, typeof(*pos), member);  \
      &pos->member != (head);      \
      pos = n, n = list_entry(n->member.next, typeof(*n), member))

/**
 * list_for_each_entry_safe_from
 * @pos: the type * to use as a loop cursor.
 * @n:  another type * to use as temporary storage
 * @head: the head for your list.
 * @member: the name of the list_struct within the struct.
 *
 * Iterate over list of given type from current point, safe against
 * removal of list entry.
 */
#define list_for_each_entry_safe_from(pos, n, head, member)    \
 for (n = list_entry(pos->member.next, typeof(*pos), member);  \
      &pos->member != (head);      \
      pos = n, n = list_entry(n->member.next, typeof(*n), member))

/**
 * list_for_each_entry_safe_reverse
 * @pos: the type * to use as a loop cursor.
 * @n:  another type * to use as temporary storage
 * @head: the head for your list.
 * @member: the name of the list_struct within the struct.
 *
 * Iterate backwards over list of given type, safe against removal
```

```
  * of list entry.
  */
 #define list_for_each_entry_safe_reverse(pos, n, head, member)  \
  for (pos = list_entry((head)->prev, typeof(*pos), member), \
   n = list_entry(pos->member.prev, typeof(*pos), member); \
       &pos->member != (head);       \
       pos = n, n = list_entry(n->member.prev, typeof(*n), member))
```

2.8.2 说明

`list_entry(ptr, type, member)` 可以得到**节点结构体的地址**，得到地址后就可以对结构体中的元素进行操作了。依靠 `list_entry(ptr, type, member)` 函数，内核链表的增删查改都不需要知道 `list_head` 结构体所嵌入式的对象，就可以完成各种操作。

为什么这里使用 `container_of` 来定义 `list_entry(ptr, type, member)` 结构体呢，下面会详细解释。

`list_first_entry(ptr, type, member)` 得到的是结构体中**第一个元素的地址**。

`list_for_each(pos, head)` 是用来**正向遍历链表**的，pos相当于一个临时的节点，用来不断指向下一个节点。

`list_for_each_prev(pos, head)` 和 `list_for_each_entry_reverse(pos, head, member)` 是用来**倒着遍历链表**的。

`list_for_each_safe(pos, n, head)` 和 `list_for_each_entry_safe(pos, n, head, member)` ，这两个函数是为了避免在遍历链表的过程中**因pos节点被释放而造成的断链**。这个时候就要求我们另外提供一个与pos同类型的指针n，在for循环中暂存pos下一个节点的地址。（内核的设计者考虑的真是全面！）

`list_prepare_entry(pos, head, member)` 用于准备一个结构体的首地址，用在 `list_for_each_entry_contine()` 中。

`list_for_each_entry_continue(pos, head, member)` **从当前pos的下一个节点开始继续遍历剩余的链表**，不包括pos.如果我们将pos、head、member传入 `list_for_each_entry` ，此宏将会从链表的头节点开始遍历。

`list_for_each_entry_continue_reverse(pos, head, member)` **从当前的pos的前一个节点开始继续反向遍历剩余的链表**，不包括pos。

`list_for_each_entry_from(pos, head, member)` 从pos开始遍历剩余的链表。

`list_for_each_entry_safe_continue(pos, n, head, member)` **从pos节点的下一个节点开始遍历剩余的链表**，并防止因删除链表节点而导致的遍历出错。

`list_for_each_entry_safe_from(pos, n, head, member)` **从pos节点开始继续遍历剩余的链表**，并防止因删除链表节点而导致的遍历出错。其与 `list_for_each_entry_safe_continue(pos, n, head, member)` 的不同在于在第一次遍历时，pos没有指向它的下一个节点，而是从pos开始遍历。

`list_for_each_entry_safe_reverse(pos, n, head, member)` **从pos的前一个节点开始反向遍历一个链表**，并防止因删除链表节点而导致的遍历出错。

`list_safe_reset_next(pos, n, member)` 返回当前pos节点的下一个节点的type结构体首地址。

2.8.3 举例

```
#include "mylist.h"
#include <stdio.h>
#include <stdlib.h>
struct student
{
    struct list_head stu_list;
    int ID;
    int math;
};
int main()
{
    struct student *p;
    struct student *q;
    struct student stu1;
    struct student stu2;
    struct list_head *pos1;
    struct student *pos2;
    struct student new_obj={.ID=100,.math=100};
    //stu = (struct student*)malloc(sizeof(struct student));
    //链表的初始化
    INIT_LIST_HEAD(&stu1.stu_list);
    INIT_LIST_HEAD(&stu2.stu_list);
    LIST_HEAD(stu);
    //头插法创建stu stu1链表
```

```
        for (int i = 0;i < 6;i++) {
            p = (struct student *)malloc(sizeof(struct student));
            p->ID=i;
            p->math = i+80;
            //头插法
            list_add(&p->stu_list,&stu1.stu_list);
            //尾插法
            //list_add_tail(&p->list,&stu.list);
        }
    printf("stu1: \r\n");
    list_for_each(pos1, &stu1.stu_list) {
        printf("ID = %d,math = %d\n",((struct student*)pos1)->ID,((struct student*)pos1
    }

    printf("list_for_each_prev\r\n");
    list_for_each_prev(pos1, &stu1.stu_list){
        printf("stu2 ID = %d,math = %d\n",((struct student*)pos1)->ID,((struct student*
    }

    return 0;
}
```

```
book@www.100ask.org:~/work/C_Test$ gcc Kernel_LinkList.c -o Kernel_LinkList.out
book@www.100ask.org:~/work/C_Test$ ./Kernel_LinkList.out
stu1:
ID = 5,math = 85
ID = 4,math = 84
ID = 3,math = 83
ID = 2,math = 82
ID = 1,math = 81
ID = 0,math = 80
list_for_each_prev
stu2 ID = 0,math = 80
stu2 ID = 1,math = 81
stu2 ID = 2,math = 82
stu2 ID = 3,math = 83
stu2 ID = 4,math = 84
stu2 ID = 5,math = 85
```


测试结果

例子就不都写出来了，感兴趣的可以自己试试。

3. 疑惑解答

之前我们定义结构体的时候是把 `struct list_head` 放在首位的，当使用 `list_for_each` 遍历的时候，pos获取的位置就是结构体的位置，也就是链表的位置。如下所示。

```
struct student
{
    struct list_head list;//暂且将链表放在结构体的第一位
```

```
    struct list_head list;//暂且将链表放在结构体的第一位
    int ID;
    int math;
};
```

```
    list_for_each(pos, &stu1.stu_list) {
        printf("ID = %d,math = %d\n",((struct student*)pos)->ID,((struct student*)pos)-
    }
```

但是当我们把 `struct list_head list;` 放在最后时，pos获取的显然就已经不是链表的位置了，那么当我们再次调用 `list_for_each` 时就会出错。

```
struct student
{
    int ID;
    int math;
    struct list_head list;//暂且将链表放在结构体的第一位
};
```

`list_for_each_entry` 这个函数表示在遍历的时候获取entry，该宏中的pos类型为容器结构类型的指针，这与前面 `list_for_each` 中的使用的类型不再相同（这也就是为什么我们上面会分别定义pos1和pos2的原因了）。

不过这也是情理之中的事，毕竟现在的pos，我要使用该指针去访问数据域的成员age了；head是你使用 `INIT_LIST_HEAD` 初始化的那个对象，即头指针，**注意，不是头结点**；member就是容器结构中的链表元素对象。使用该宏替代前面的方法。这个时候就要用到 `container_of` 这个宏了。（再一次感叹内核设计者的伟大）。

关于 `container_of` **宏将在下一篇文章详细介绍**，这里先知道如何使用就可以。

4. list.h移植源码

这里需要注意一点，如果是在GNU中使用GCC进行程序开发，可以不做更改，直接使用上面的函数即可；但如果你想把其**移植到Windows环境中进行使用**，可以直接将prefetch语句删除即可，因为prefetch函数它通过对数据手工预取的方法，减少了读取延迟，从而提高了性能，也就是**prefetch是GCC用来提高效率的函数**，如果要移植到非GNU环境，可以换成相应环境的预取函数或者直接删除也可，它并不影响链表的功能。

```
#ifndef _MYLIST_H
#define _MYLIST_H
 //原来链表删除后指向的位置，这里我们修改成 0
// # define POISON_POINTER_DELTA 0
// #define LIST_POISON1  ((void *) 0x00100100 + POISON_POINTER_DELTA)
// #define LIST_POISON2  ((void *) 0x00200200 + POISON_POINTER_DELTA)
#define NULL ((void *)0)
#define LIST_POISON1  NULL
#define LIST_POISON2  NULL

//计算member在type中的位置
#define offsetof(type, member)  (size_t)(&((type*)0)->member)
//根据member的地址获取type的起始地址
#define container_of(ptr, type, member) ({          \
        const typeof(((type *)0)->member)*__mptr = (ptr);    \
    (type *)((char *)__mptr - offsetof(type, member)); })

//链表结构
struct list_head
{
    struct list_head *prev;
    struct list_head *next;
};
#define LIST_HEAD_INIT(name) { &(name), &(name) }

#define LIST_HEAD(name) \
 struct list_head name = LIST_HEAD_INIT(name)

static inline void INIT_LIST_HEAD(struct list_head *list)
{
 list->next = list;
 list->prev = list;
}

static inline void init_list_head(struct list_head *list)
{
    list->prev = list;
    list->next = list;
}

#ifndef CONFIG_DEBUG_LIST
static inline void __list_add(struct list_head *new,
```

```
         struct list_head *prev,
         struct list_head *next)
{
 next->prev = new;
 new->next = next;
 new->prev = prev;
 prev->next = new;
}
#else
extern void __list_add(struct list_head *new,
         struct list_head *prev,
         struct list_head *next);
#endif

//从头部添加
/**
 * list_add - add a new entry
 * @new: new entry to be added
 * @head: list head to add it after
 *
 * Insert a new entry after the specified head.
 * This is good for implementing stacks.
 */
#ifndef CONFIG_DEBUG_LIST
static inline void list_add(struct list_head *new, struct list_head *head)
{
 __list_add(new, head, head->next);
}
#else
extern void list_add(struct list_head *new, struct list_head *head);
#endif
//从尾部添加
static inline void list_add_tail(struct list_head *new, struct list_head *head)
{
    __list_add(new, head->prev, head);
}

static inline  void __list_del(struct list_head *prev, struct list_head *next)
{
    prev->next = next;
    next->prev = prev;
}

static inline void list_del(struct list_head *entry)
{
```

```
{
    __list_del(entry->prev, entry->next);
    entry->next = LIST_POISON1;
    entry->prev = LIST_POISON2;
}


static inline void __list_splice(struct list_head *list,
     struct list_head *head)
{
 struct list_head *first = list->next;
 struct list_head *last = list->prev;
 struct list_head *at = head->next;

 first->prev = head;
 head->next = first;

 last->next = at;
 at->prev = last;
}
/**
 * list_empty - tests whether a list is empty
 * @head: the list to test.
 */
static inline int list_empty(const struct list_head *head)
{
 return head->next == head;
}
/**
 * list_splice - join two lists
 * @list: the new list to add.
 * @head: the place to add it in the first list.
 */
static inline void list_splice(struct list_head *list, struct list_head *head)
{
 if (!list_empty(list))
  __list_splice(list, head);
}
/**
 * list_replace - replace old entry by new one
 * @old : the element to be replaced
 * @new : the new element to insert
 *
 * If @old was empty, it will be overwritten.
 */
static inline void list_replace(struct list_head *old,
```

```
    struct list_head *new)
{
 new->next = old->next;
 new->next->prev = new;
 new->prev = old->prev;
 new->prev->next = new;
}

static inline void list_replace_init(struct list_head *old,
     struct list_head *new)
{
 list_replace(old, new);
 INIT_LIST_HEAD(old);
}
/**
 * list_move - delete from one list and add as another's head
 * @list: the entry to move
 * @head: the head that will precede our entry
 */
static inline void list_move(struct list_head *list, struct list_head *head)
{
 __list_del(list->prev, list->next);
 list_add(list, head);
}

/**
 * list_move_tail - delete from one list and add as another's tail
 * @list: the entry to move
 * @head: the head that will follow our entry
 */
static inline void list_move_tail(struct list_head *list,
      struct list_head *head)
{
 __list_del(list->prev, list->next);
 list_add_tail(list, head);
}
#define list_entry(ptr, type, member) \
    container_of(ptr, type, member)

#define list_first_entry(ptr, type, member) \
    list_entry((ptr)->next, type, member)

#define list_for_each(pos, head) \
```

```
    for (pos = (head)->next; pos != (head); pos = pos->next)
/**
 * list_for_each_entry - iterate over list of given type
 * @pos: the type * to use as a loop cursor.
 * @head: the head for your list.
 * @member: the name of the list_struct within the struct.
 */
#define list_for_each_entry(pos, head, member)      \
 for (pos = list_entry((head)->next, typeof(*pos), member); \
      &pos->member != (head);  \
      pos = list_entry(pos->member.next, typeof(*pos), member))
/**
 * list_for_each_prev - iterate over a list backwards
 * @pos: the &struct list_head to use as a loop cursor.
 * @head: the head for your list.
 */
#define list_for_each_prev(pos, head) \
 for (pos = (head)->prev;  pos != (head); \
         pos = pos->prev)
```

- EOF -

公众号

点赞和在看就是最大的支持❤