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linux设备模型之uart驱动架构分析

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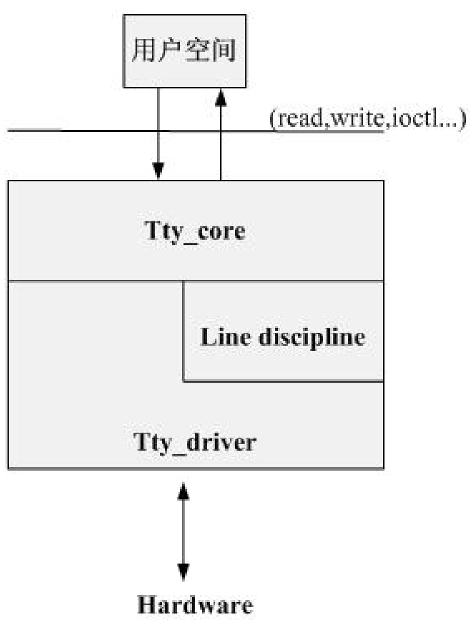
一:前言

接着前面的终端控制台分析,接下来分析serial的驱动.在linux中,serial也对应着终端,通常被称为串口终端.在shell上,我们看到的/dev/ttyS*就是串口终端所对应的设备节点.

在分析具体的serial驱动之前.有必要先分析uart驱动架构.uart是Universal Asynchronous Receiver and Transmitter的缩写.翻译成中文即为"通用异步收发器".它是串口设备驱动的封装层.

二:uart驱动架构概貌

如下图所示:



上图中红色部份标识即为uart部份的操作.

从上图可以看到,uart设备是继tty_driver的又一层封装.实际上uart_driver就是对应tty_driver.在它的操作函数中,将操作转入uart_port.

在写操作的时候,先将数据放入一个叫做circ_buf的环形缓存区.然后uart_port从缓存区中取数据,将其写入到串口设备中.

当uart_port从serial设备接收到数据时,会将设备放入对应line discipline的缓存区中.

这样.用户在编写串口驱动的时候,只先要注册一个uart_driver.它的主要作用是定义设备节点号.然后将对设备的各项操作封装在uart_port.驱动工程师没必要关心上层的流程,只需按硬件规范将uart_port中的接

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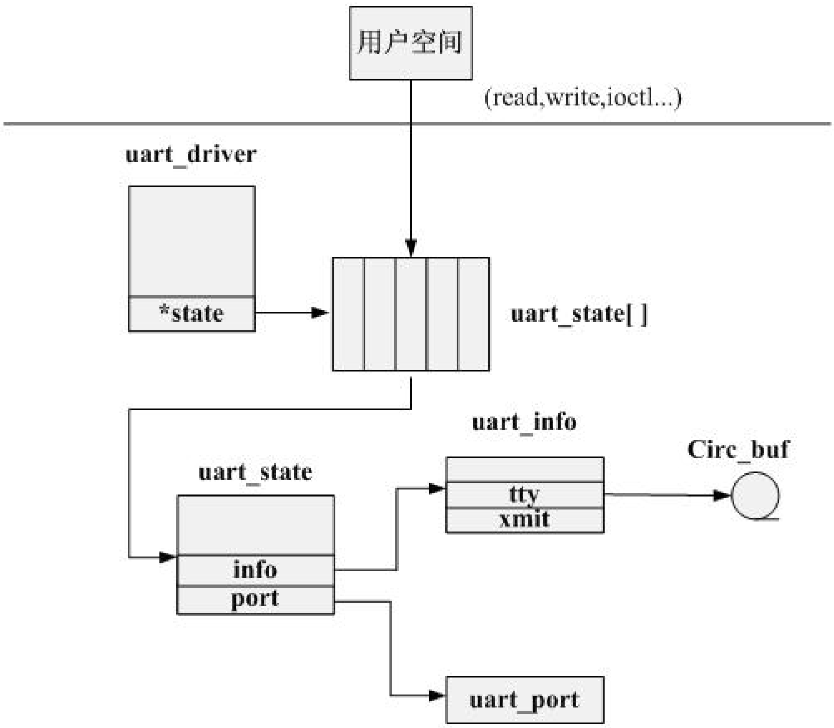
口函数完成就可以了.

三:uart驱动中重要的数据结构及其关联
我们可以自己考虑下,基于上面的架构代码应该要怎么写.首先考虑以下几点:
1: 一个uart_driver通常会注册一段设备号.即在用户空间会看到uart_driver对应有多个设备节点.例如:
/dev/ttyS0 /dev/ttyS1
每个设备节点是对应一个具体硬件的,从上面的架构来看,每个设备文件应该对应一个uart_port.
也就是说:uart_device怎么同多个uart_port关系起来?怎么去区分操作的是哪一个设备文件?

2:每个uart_port对应一个circ_buf,所以uart_port必须要和这个缓存区关系起来

回忆tty驱动架构中.tty_driver有一个叫成员指向一个数组,即tty->ttys.每个设备文件对应设数组中的一项.而这个数组所代码的数据结构为tty_struct. 相应的tty_struct会将tty_driver和ldisc关联起来.
那在uart驱动中,是否也可用相同的方式来处理呢?
将uart驱动常用的数据结构表示如下:



结合上面提出的疑问.可以很清楚的看懂这些结构的设计.

四:uart_driver的注册操作
Uart_driver注册对应的函数为: uart_register_driver()代码如下:

```
int uart_register_driver(struct uart_driver *drv)
{
    struct tty_driver *normal = NULL;
    int i, retval;

    BUG_ON(drv->state);

    /*
     * Maybe we should be using a slab cache for this, especially if
     * we have a large number of ports to handle.
     */
    drv->state = kzalloc(sizeof(struct uart_state) * drv->nr, GFP_KERNEL);
    retval = -ENOMEM;
    if (!drv->state)
```

```
        goto out;

    normal  = alloc_tty_driver(drv->nr);
    if (!normal)
        goto out;

    drv->tty_driver = normal;

    normal->owner      = drv->owner;
    normal->driver_name    = drv->driver_name;
    normal->name       = drv->dev_name;
    normal->major      = drv->major;
    normal->minor_start    = drv->minor;
    normal->type       = TTY_DRIVER_TYPE_SERIAL;
    normal->subtype        = SERIAL_TYPE_NORMAL;
    normal->init_termios   = tty_std_termios;
    normal->init_termios.c_cflag = B9600 | CS8 | CREAD | HUPCL | CLOCAL;
    normal->init_termios.c_ispeed = normal->init_termios.c_ospeed = 9600;
    normal->flags      = TTY_DRIVER_REAL_RAW | TTY_DRIVER_DYNAMIC_DEV;
    normal->driver_state    = drv;
    tty_set_operations(normal, &uart_ops);

    /*
     * Initialise the UART state(s).
     */
    for (i = 0; i nr; i++) {
        struct uart_state *state = drv->state + i;

        state->close_delay     = 500;    /* .5 seconds */
        state->closing_wait    = 30000;  /* 30 seconds */

        mutex_init(&state->mutex);
    }

    retval = tty_register_driver(normal);
out:
    if (retval
        put_tty_driver(normal);
        kfree(drv->state);
    }
    return retval;
}
```

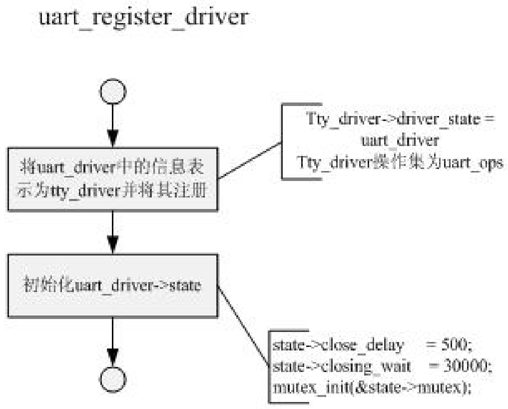
从上面代码可以看出.uart_driver中很多数据结构其实就是tty_driver中的.将数据转换为tty_driver之后,注册tty_driver.然后初始化uart_driver->state的存储空间.

这样,就会注册uart_driver->nr个设备节点.主设备号为uart_driver-> major. 开始的次设备号为uart_driver-> minor.

值得注意的是.在这里将tty_driver的操作集统一设为了uart_ops.其次,在tty_driver-> driver_state保存了这个uart_driver.这样做是为了在用户空间对设备文件的操作时,很容易转到对应的uart_driver.

另外:tty_driver的flags成员值为: TTY_DRIVER_REAL_RAW | TTY_DRIVER_DYNAMIC_DEV.里面包含有TTY_DRIVER_DYNAMIC_DEV标志.结合之前对tty的分析.如果包含有这个标志,是不会在初始化的时候去注册device.也就是说在/dev/下没有动态生成结点(如果是/dev下静态创建了这个结点就另当别论了^_^).

流程图如下:



五: uart_add_one_port()操作

在前面提到.在对uart设备文件过程中.会将操作转换到对应的port上,这个port跟uart_driver是怎么关联起来的呢?这就是uart_add_ont_port()的主要工作了.

顾名思义,这个函数是在uart_driver增加一个port.代码如下:

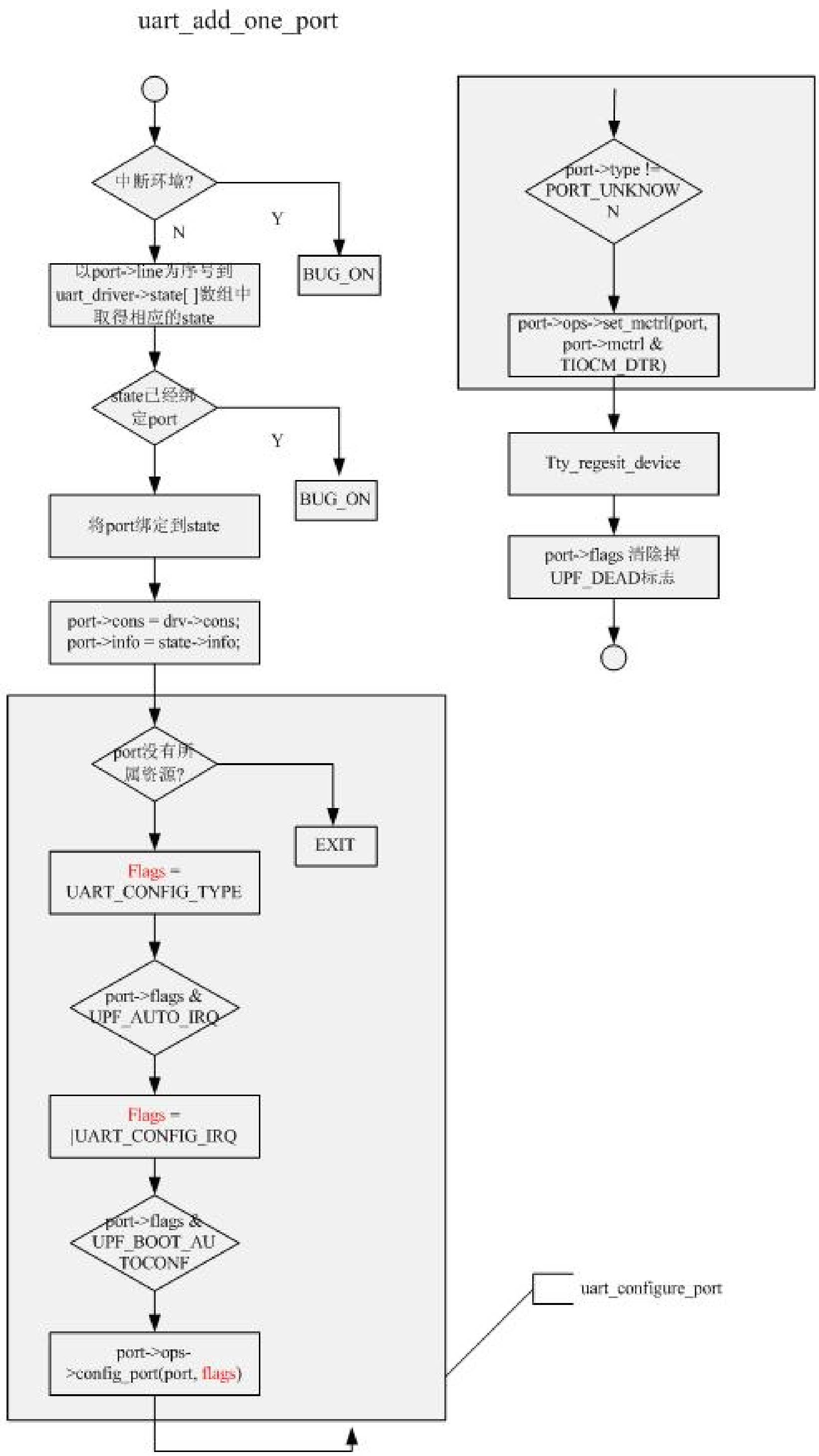
```
int uart_add_one_port(struct uart_driver *drv, struct uart_port *port)
{
    struct uart_state *state;
    int ret = 0;
    struct device *tty_dev;

    BUG_ON(in_interrupt());

    if (port->line >= drv->nr)
       return -EINVAL;

    state = drv->state + port->line;

    mutex_lock(&port_mutex);
    mutex_lock(&state->mutex);
    if (state->port) {
       ret = -EINVAL;
       goto out;
    }

    state->port = port;
    state->pm_state = -1;

    port->cons = drv->cons;
    port->info = state->info;

    /*
     * If this port is a console, then the spinlock is already
     * initialised.
     */
    if (!(uart_console(port) && (port->cons->flags & CON_ENABLED))) {
       spin_lock_init(&port->lock);
       lockdep_set_class(&port->lock, &port_lock_key);
    }

    uart_configure_port(drv, state, port);

    /*
     * Register the port whether it's detected or not.  This allows
     * setserial to be used to alter this ports parameters.
```

```
     */
    tty_dev = tty_register_device(drv->tty_driver, port->line, port->dev);
    if (likely(!IS_ERR(tty_dev))) {
        device_can_wakeup(tty_dev) = 1;
        device_set_wakeup_enable(tty_dev, 0);
    } else
        printk(KERN_ERR "Cannot register tty device on line %d\n",
               port->line);

    /*
     * Ensure UPF_DEAD is not set.
     */
    port->flags &= ~UPF_DEAD;

out:
    mutex_unlock(&state->mutex);
    mutex_unlock(&port_mutex);

    return ret;
}
```

首先这个函数不能在中断环境中使用. Uart_port->line就是对uart设备文件序号.它对应的也就是uart_driver->state数组中的uart_port->line项.

它主要初始化对应uart_driver->state项.接着调用uart_configure_port()进行port的自动配置.然后注册tty_device.如果用户空间运行了udev或者已经配置好了hotplug.就会在/dev下自动生成设备文件了.

操作流程图如下所示:



六:设备节点的open操作

在用户空间执行open操作的时候,就会执行uart_ops->open. Uart_ops的定义如下:

```
static const struct tty_operations uart_ops = {
    .open          = uart_open,
    .close         = uart_close,
    .write         = uart_write,
    .put_char  = uart_put_char,
    .flush_chars  = uart_flush_chars,
    .write_room    = uart_write_room,
    .chars_in_buffer= uart_chars_in_buffer,
    .flush_buffer  = uart_flush_buffer,
    .ioctl         = uart_ioctl,
```

```
    .throttle = uart_throttle,
    .unthrottle   = uart_unthrottle,
    .send_xchar    = uart_send_xchar,
    .set_termios  = uart_set_termios,
    .stop         = uart_stop,
    .start        = uart_start,
    .hangup       = uart_hangup,
    .break_ctl    = uart_break_ctl,
    .wait_until_sent= uart_wait_until_sent,
#ifdef CONFIG_PROC_FS
    .read_proc    = uart_read_proc,
#endif
    .tiocmget = uart_tiocmget,
    .tiocmset = uart_tiocmset,
};
```

对应open的操作接口为uart_open.代码如下:

```
static int uart_open(struct tty_struct *tty, struct file *filp)
{
    struct uart_driver *drv = (struct uart_driver *)tty->driver->driver_state;
    struct uart_state *state;
    int retval, line = tty->index;

    BUG_ON(!kernel_locked());
    pr_debug("uart_open(%d) called\n", line);

    /*
     * tty->driver->num won't change, so we won't fail here with
     * tty->driver_data set to something non-NULL (and therefore
     * we won't get caught by uart_close()).
     */
    retval = -ENODEV;
    if (line >= tty->driver->num)
       goto fail;

    /*
     * We take the semaphore inside uart_get to guarantee that we won't
     * be re-entered while allocating the info structure, or while we
     * request any IRQs that the driver may need.  This also has the nice
     * side-effect that it delays the action of uart_hangup, so we can
     * guarantee that info->tty will always contain something reasonable.
     */
    state = uart_get(drv, line);
    if (IS_ERR(state)) {
       retval = PTR_ERR(state);
       goto fail;
    }

    /*
     * Once we set tty->driver_data here, we are guaranteed that
     * uart_close() will decrement the driver module use count.
     * Any failures from here onwards should not touch the count.
     */
    tty->driver_data = state;
    tty->low_latency = (state->port->flags & UPF_LOW_LATENCY) ? 1 : 0;
    tty->alt_speed = 0;
    state->info->tty = tty;

    /*
```

```
     * If the port is in the middle of closing, bail out now.
     */
    if (tty_hung_up_p(filp)) {
        retval = -EAGAIN;
        state->count--;
        mutex_unlock(&state->mutex);
        goto fail;
    }

    /*
     * Make sure the device is in D0 state.
     */
    if (state->count == 1)
        uart_change_pm(state, 0);

    /*
     * Start up the serial port.
     */
    retval = uart_startup(state, 0);

    /*
     * If we succeeded, wait until the port is ready.
     */
    if (retval == 0)
        retval = uart_block_til_ready(filp, state);
    mutex_unlock(&state->mutex);

    /*
     * If this is the first open to succeed, adjust things to suit.
     */
    if (retval == 0 && !(state->info->flags & UIF_NORMAL_ACTIVE)) {
        state->info->flags |= UIF_NORMAL_ACTIVE;

        uart_update_termios(state);
    }

fail:
    return retval;
}
```

在这里函数里,继续完成操作的设备文件所对应state初始化.现在用户空间open这个设备了.即要对这个文件进行操作了.那uart_port也要开始工作了.即调用uart_startup()使其进入工作状态.当然,也需要初始化uart_port所对应的环形缓冲区circ_buf.即state->info-> xmit.

特别要注意,在这里将tty->driver_data = state;这是因为以后的操作只有port相关了,不需要去了解uart_driver的相关信息.

跟踪看一下里面调用的两个重要的子函数. uart_get()和uart_startup().先分析uart_get().代码如下:

```
static struct uart_state *uart_get(struct uart_driver *drv, int line)
{
    struct uart_state *state;
    int ret = 0;

    state = drv->state + line;
    if (mutex_lock_interruptible(&state->mutex)) {
        ret = -ERESTARTSYS;
        goto err;
    }

    state->count++;
    if (!state->port || state->port->flags & UPF_DEAD) {
```

```
        ret = -ENXIO;
        goto err_unlock;
    }

    if (!state->info) {
        state->info = kzalloc(sizeof(struct uart_info), GFP_KERNEL);
        if (state->info) {
            init_waitqueue_head(&state->info->open_wait);
            init_waitqueue_head(&state->info->delta_msr_wait);

            /*
             * Link the info into the other structures.
             */
            state->port->info = state->info;

            tasklet_init(&state->info->tlet, uart_tasklet_action,
                    (unsigned long)state);
        } else {
            ret = -ENOMEM;
            goto err_unlock;
        }
    }
    return state;

err_unlock:
    state->count--;
    mutex_unlock(&state->mutex);
err:
    return ERR_PTR(ret);
}
```

从代码中可以看出.这里注要是操作是初始化state->info.注意port->info就是state->info的一个副本.即port直接通过port->info可以找到它要操作的缓存区.

uart_startup()代码如下:

```
static int uart_startup(struct uart_state *state, int init_hw)
{
    struct uart_info *info = state->info;
    struct uart_port *port = state->port;
    unsigned long page;
    int retval = 0;

    if (info->flags & UIF_INITIALIZED)
        return 0;

    /*
     * Set the TTY IO error marker - we will only clear this
     * once we have successfully opened the port.  Also set
     * up the tty->alt_speed kludge
     */
    set_bit(TTY_IO_ERROR, &info->tty->flags);

    if (port->type == PORT_UNKNOWN)
        return 0;

    /*
     * Initialise and allocate the transmit and temporary
     * buffer.
     */
```

```
    if (!info->xmit.buf) {
        page = get_zeroed_page(GFP_KERNEL);
        if (!page)
            return -ENOMEM;

        info->xmit.buf = (unsigned char *) page;
        uart_circ_clear(&info->xmit);
    }

    retval = port->ops->startup(port);
    if (retval == 0) {
        if (init_hw) {
            /*
             * Initialise the hardware port settings.
             */
            uart_change_speed(state, NULL);

            /*
             * Setup the RTS and DTR signals once the
             * port is open and ready to respond.
             */
            if (info->tty->termios->c_cflag & CBAUD)
                uart_set_mctrl(port, TIOCM_RTS | TIOCM_DTR);
        }

        if (info->flags & UIF_CTS_FLOW) {
            spin_lock_irq(&port->lock);
            if (!(port->ops->get_mctrl(port) & TIOCM_CTS))
                info->tty->hw_stopped = 1;
            spin_unlock_irq(&port->lock);
        }

        info->flags |= UIF_INITIALIZED;

        clear_bit(TTY_IO_ERROR, &info->tty->flags);
    }

    if (retval && capable(CAP_SYS_ADMIN))
        retval = 0;

    return retval;
}
```

在这里,注要完成对环形缓冲,即info->xmit的初始化.然后调用port->ops->startup( )将这个port带入到工作状态.其它的是一个可调参数的设置,就不详细讲解了.

七:设备节点的write操作

Write操作对应的操作接口为uart_write( ).代码如下:

```
static int
uart_write(struct tty_struct *tty, const unsigned char *buf, int count)
{
    struct uart_state *state = tty->driver_data;
    struct uart_port *port;
    struct circ_buf *circ;
    unsigned long flags;
    int c, ret = 0;

    /*
     * This means you called this function _after_ the port was
```

```
     * closed.  No cookie for you.
     */
    if (!state || !state->info) {
        WARN_ON(1);
        return -EL3HLT;
    }

    port = state->port;
    circ = &state->info->xmit;

    if (!circ->buf)
        return 0;

    spin_lock_irqsave(&port->lock, flags);
    while (1) {
        c = CIRC_SPACE_TO_END(circ->head, circ->tail, UART_XMIT_SIZE);
        if (count
            c = count;
        if (c
            break;
        memcpy(circ->buf + circ->head, buf, c);
        circ->head = (circ->head + c) & (UART_XMIT_SIZE - 1);
        buf += c;
        count -= c;
        ret += c;
    }
    spin_unlock_irqrestore(&port->lock, flags);

    uart_start(tty);
    return ret;
}
```

Uart_start()代码如下:

```
static void uart_start(struct tty_struct *tty)
{
    struct uart_state *state = tty->driver_data;
    struct uart_port *port = state->port;
    unsigned long flags;

    spin_lock_irqsave(&port->lock, flags);
    __uart_start(tty);
    spin_unlock_irqrestore(&port->lock, flags);
}
static void __uart_start(struct tty_struct *tty)
{
    struct uart_state *state = tty->driver_data;
    struct uart_port *port = state->port;

    if (!uart_circ_empty(&state->info->xmit) && state->info->xmit.buf &&
        !tty->stopped && !tty->hw_stopped)
        port->ops->start_tx(port);
}
```

显然,对于write操作而言,它就是将数据copy到环形缓存区.然后调用port->ops->start_tx()将数据写到硬件寄存器.

八:Read操作

Uart的read操作同Tty的read操作相同,即都是调用ldsic->read()读取read_buf中的内容.有对这部份内

容不太清楚的,参阅>.

九:小结
本小节是分析serial驱动的基础.在理解了tty驱动架构之后,再来理解uart驱动架构应该不是很难.随着我们在linux设备驱动分析的深入,越来越深刻的体会到,linux的设备驱动架构很多都是相通的.只要深刻理解了一种驱动架构.举一反三.也就很容易分析出其它架构的驱动了.

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