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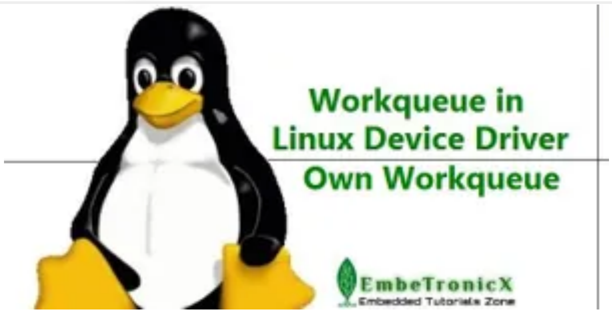

Linux Device Driver Tutorial Part 16 – Workqueue in Linux Kernel Part 3

This is the Series on Linux Device Driver. The aim of this series is to provide easy and practical examples that anyone can understand. In our previous tutorials, we have used global workqueue. But in this tutorial, we are going to use our own workqueue in the Linux device driver.

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Workqueue in Linux Device Driver

In our previous (Part 1, Part 2) tutorials we haven't created any of the workqueue. We were just creating work and scheduling that work to the global workqueue. Now we are going to create our own workqueue. Let's get into the tutorial.

The core workqueue is represented by structure struct workqueue_struct, which is the structure onto which work is placed. This work is added to the queue in the top half (Interrupt context) and the execution of this work happened in the bottom half (Kernel context).
The work is represented by structure struct work_struct, which identifies the work and the deferral function.

Create and destroy workqueue structure

Workqueues are created through a macro called **create_workqueue**, which returns a **workqueue_struct** reference. You can remote this workqueue later (if needed) through a call to the **destroy_workqueue** function.

struct workqueue_struct *create_workqueue(name);

void destroy_workqueue(struct workqueue_struct *);

You should use **create_singlethread_workqueue()** for creating workqueue when you want to create only a single thread for all the processors.

Since **create_workqueue** and **create_singlethread_workqueue()** are macros. Both are using the **alloc_workqueue** function in the background.

```
#define create_workqueue(name)
        alloc_workqueue("%s", WQ_MEM_RECLAIM, 1, (name))
#define create_singlethread_workqueue(name)
        alloc_workqueue("%s", WQ_UNBOUND | WQ_MEM_RECLAIM, 1, (name))
```

alloc_workqueue

Allocate a workqueue with the specified parameters.

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alloc_workqueue (fmt, flags, max_active);

fmt– printf format for the name of the workqueue

flags – WQ_* flags

max_active – max in-flight work items, 0 for default

This will return Pointer to the allocated workqueue on success, NULL on failure.

WQ_* flags

This is the second argument of `alloc_workqueue`.

WQ_UNBOUND

Work items queued to an unbound `wq` are served by the special worker-pools which host workers who are not bound to any specific CPU. This makes the `wq` behave like a simple execution context provider without concurrency management. The unbound worker-pools try to start the execution of work items as soon as possible. Unbound `wq` sacrifices locality but is useful for the following cases.

- Wide fluctuation in the concurrency level requirement is expected and using bound `wq` may end up creating a large number of mostly unused workers across different CPUs as the issuer hops through different CPUs.
- Long-running CPU intensive workloads which can be better managed by the system scheduler.

WQ_FREEZABLE

A freezable `wq` participates in the freeze phase of the system suspend operations. Work items on the `wq` are drained and no new work item starts execution until thawed.

WQ_MEM_RECLAIM

All `wq` which might be used in the memory reclaim paths **MUST** have this flag set. The `wq` is guaranteed to have at least one execution context regardless of memory pressure.

WQ_HIGHPRI

Work items of a highpri wq are queued to the highpri worker-pool of the target CPU. Highpri worker-pools are served by worker threads with elevated nice levels.

Note that normal and highpri worker-pools don't interact with each other. Each maintains its separate pool of workers and implements concurrency management among its workers.

WQ_CPU_INTENSIVE

Work items of a CPU intensive `wq` do not contribute to the concurrency level. In other words, runnable CPU intensive work items will not prevent other work items in the same worker-pool from starting execution. This is useful for bound work items that are expected to hog CPU cycles so that their execution is regulated by the system scheduler.

Although CPU intensive work items don't contribute to the concurrency level, the start of their executions is still regulated by the concurrency management and runnable non-CPU-intensive work items can delay execution of CPU intensive work items.

This flag is meaningless for unbound `wq`.

Queuing Work to workqueue

With the work structure initialized, the next step is enqueuing the work on a workqueue. You can do this in a few ways.

queue_work

This will queue the work to the CPU on which it was submitted, but if the CPU dies it can be processed by another CPU.

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```
int queue_work( struct workqueue_struct *wq, struct
                work_struct *work );
```

Where,

`wq` – workqueue to use

work – work to queue

It returns **false** if ***work*** was already on a queue, **true** otherwise.

queue_work_on

This puts work on a specific CPU.

```
int queue_work_on( int cpu, struct workqueue_struct *wq,
                   struct work_struct *work );
```

Where,

cpu– cpu to put the work task on

wq – workqueue to use

work– job to be done

queue_delayed_work

After waiting for a given time this function puts work in the workqueue.

```
int queue_delayed_work( struct workqueue_struct *wq,
         struct delayed_work *dwork, unsigned long delay );
```

Where,
wq – workqueue to use

dwork – work to queue

delay – number of jiffies to wait before queueing or 0 for immediate execution

queue_delayed_work_on

After waiting for a given time this puts a job in the workqueue on the specified CPU.

```
int queue_delayed_work_on( int cpu, struct workqueue_struct
```

```
                              *wq,
            struct delayed_work *dwork, unsigned long delay );
```

Where,

cpu– CPU to put the work task on

wq – workqueue to use

dwork – work to queue

delay – number of jiffies to wait before queueing or 0 for immediate execution

Programming

Driver Source Code

In that source code, When we read the **/dev/etx_device,** interrupt will hit (To understand interrupts in Linux go to this tutorial). Whenever interrupt hits, I'm scheduling the work to the workqueue. I'm not going to do any job in both interrupt handler and workqueue function since it is a tutorial post. But in real workqueue, this function can be used to carry out any operations that need to be scheduled.

We have created workqueue "own_wq" in init function.

Let's go through the code.

```
#include <linux/kernel.h>
#include <linux/init.h>
#include <linux/module.h>
#include <linux/kdev_t.h>
#include <linux/fs.h>
#include <linux/cdev.h>
#include <linux/device.h>
#include<linux/slab.h>                 //kmalloc()
#include<linux/uaccess.h>              //copy_to/from_user()
#include<linux/sysfs.h>
#include<linux/kobject.h>
#include <linux/interrupt.h>
#include <asm/io.h>
#include <linux/workqueue.h>            // Required for workqueues


#define IRQ_NO 11

static struct workqueue_struct *own_workqueue;

```

```
static void workqueue_fn(struct work_struct *work);

static DECLARE_WORK(work, workqueue_fn);


/*Workqueue Function*/
static void workqueue_fn(struct work_struct *work)
{
    printk(KERN_INFO "Executing Workqueue Function\n");
    return;

}


//Interrupt handler for IRQ 11.
static irqreturn_t irq_handler(int irq,void *dev_id) {
        printk(KERN_INFO "Shared IRQ: Interrupt Occurred\n");
        /*Allocating work to queue*/
        queue_work(own_workqueue, &work);

        return IRQ_HANDLED;
}


volatile int etx_value = 0;


dev_t dev = 0;
static struct class *dev_class;
static struct cdev etx_cdev;
struct kobject *kobj_ref;

static int __init etx_driver_init(void);
static void __exit etx_driver_exit(void);

/*************** Driver Fuctions **********************/
static int etx_open(struct inode *inode, struct file *file);
static int etx_release(struct inode *inode, struct file *file);
static ssize_t etx_read(struct file *filp,
                char __user *buf, size_t len,loff_t * off);
static ssize_t etx_write(struct file *filp,
                const char *buf, size_t len, loff_t * off);

/*************** Sysfs Fuctions **********************/
static ssize_t sysfs_show(struct kobject *kobj,
                struct kobj_attribute *attr, char *buf);
static ssize_t sysfs_store(struct kobject *kobj,
                struct kobj_attribute *attr,const char *buf, size_t count);

struct kobj_attribute etx_attr = __ATTR(etx_value, 0660, sysfs_show, sysfs_store);

static struct file_operations fops =
{
        .owner          = THIS_MODULE,
        .read           = etx_read,
        .write          = etx_write,
        .open           = etx_open,
        .release        = etx_release,
};

static ssize_t sysfs_show(struct kobject *kobj,
                struct kobj_attribute *attr, char *buf)
{
```

```
        printk(KERN_INFO "Sysfs - Read!!!\n");
        return sprintf(buf, "%d", etx_value);
}

static ssize_t sysfs_store(struct kobject *kobj,
                struct kobj_attribute *attr,const char *buf, size_t count)
{
        printk(KERN_INFO "Sysfs - Write!!!\n");
        sscanf(buf,"%d",&etx_value);
        return count;
}

static int etx_open(struct inode *inode, struct file *file)
{
        printk(KERN_INFO "Device File Opened...!!!\n");
        return 0;
}

static int etx_release(struct inode *inode, struct file *file)
{
        printk(KERN_INFO "Device File Closed...!!!\n");
        return 0;
}

static ssize_t etx_read(struct file *filp,
                char __user *buf, size_t len, loff_t *off)
{
        printk(KERN_INFO "Read function\n");
        asm("int $0x3B");  // Corresponding to irq 11
        return 0;
}
static ssize_t etx_write(struct file *filp,
                const char __user *buf, size_t len, loff_t *off)
{
        printk(KERN_INFO "Write Function\n");
        return 0;
}


static int __init etx_driver_init(void)
{
        /*Allocating Major number*/
        if((alloc_chrdev_region(&dev, 0, 1, "etx_Dev")) <0){
                printk(KERN_INFO "Cannot allocate major number\n");
                return -1;
        }
        printk(KERN_INFO "Major = %d Minor = %d \n",MAJOR(dev), MINOR(dev));

        /*Creating cdev structure*/
        cdev_init(&etx_cdev,&fops);

        /*Adding character device to the system*/
        if((cdev_add(&etx_cdev,dev,1)) < 0){
            printk(KERN_INFO "Cannot add the device to the system\n");
            goto r_class;
        }

        /*Creating struct class*/
        if((dev_class = class_create(THIS_MODULE,"etx_class")) == NULL){
            printk(KERN_INFO "Cannot create the struct class\n");
            goto r_class;
        }

```

```
        /*Creating device*/
        if((device_create(dev_class,NULL,dev,NULL,"etx_device")) == NULL){
            printk(KERN_INFO "Cannot create the Device 1\n");
            goto r_device;
        }

        /*Creating a directory in /sys/kernel/ */
        kobj_ref = kobject_create_and_add("etx_sysfs",kernel_kobj);

        /*Creating sysfs file for etx_value*/
        if(sysfs_create_file(kobj_ref,&etx_attr.attr)){
                printk(KERN_INFO"Cannot create sysfs file......\n");
                goto r_sysfs;
        }
        if (request_irq(IRQ_NO, irq_handler, IRQF_SHARED, "etx_device", (void *)(ir
            printk(KERN_INFO "my_device: cannot register IRQ \n");
                    goto irq;
        }

        /*Creating workqueue */
        own_workqueue = create_workqueue("own_wq");

        printk(KERN_INFO "Device Driver Insert...Done!!!\n");
    return 0;

irq:
        free_irq(IRQ_NO,(void *)(irq_handler));

r_sysfs:
        kobject_put(kobj_ref);
        sysfs_remove_file(kernel_kobj, &etx_attr.attr);

r_device:
        class_destroy(dev_class);
r_class:
        unregister_chrdev_region(dev,1);
        cdev_del(&etx_cdev);
        return -1;
}

void __exit etx_driver_exit(void)
{
        /* Delete workqueue */
        destroy_workqueue(own_workqueue);
        free_irq(IRQ_NO,(void *)(irq_handler));
        kobject_put(kobj_ref);
        sysfs_remove_file(kernel_kobj, &etx_attr.attr);
        device_destroy(dev_class,dev);
        class_destroy(dev_class);
        cdev_del(&etx_cdev);
        unregister_chrdev_region(dev, 1);
        printk(KERN_INFO "Device Driver Remove...Done!!!\n");
}

module_init(etx_driver_init);
module_exit(etx_driver_exit);

MODULE_LICENSE("GPL");
MODULE_AUTHOR("EmbeTronicX <embetronicx@gmail.com>");
MODULE_DESCRIPTION("A simple device driver - Workqueue part 3");
MODULE_VERSION("1.12");
```

MakeFile

```
obj-m += driver.o

KDIR = /lib/modules/$(shell uname -r)/build


all:
    make -C $(KDIR)  M=$(shell pwd) modules

clean:
    make -C $(KDIR)  M=$(shell pwd) clean
```

Building and Testing Driver

- Build the driver by using Makefile (***sudo make***)
- Load the driver using **sudo insmod driver.ko**
- To trigger the interrupt read device file (**sudo cat /dev/etx_device**)
- Now see the Dmesg (**dmesg**)

```
[ 2562.609446] Major = 246 Minor = 0
[ 2562.649362] Device Driver Insert...Done!!!
[ 2565.133204] Device File Opened...!!!
[ 2565.133225] Read function
[ 2565.133248] Shared IRQ: Interrupt Occurred
[ 2565.133267] Executing Workqueue Function
[ 2565.140284] Device File Closed...!!!
```

- We can able to see the print "**Shared IRQ: Interrupt Occurred**" and "**Executing Workqueue Function**"
- Use "**ps -aef**" command to see our workqueue. You can able to see our workqueue which is "**own_wq**"

```
UID     PID    PPID      C      STIME      TTY        TIME              CMD

root    3516      2           0        21:35          ?          00:00:00    [own_wq]
```

- Unload the module using **sudo rmmod driver**

Difference between Schedule_work and queue_work

- If you want to use your own dedicated workqueue you should create workqueue using `create_workqueue`. In that time you need to put work on your workqueue by using `queue_work` function.
- If you don't want to create any own workqueue, you can use kernel global workqueue. In that condition, you can use `schedule_work` function to put your work to global workqueue.

In our next tutorial, we will discuss linked list in the Linux device driver.

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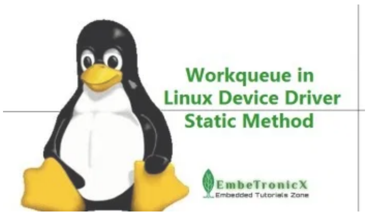

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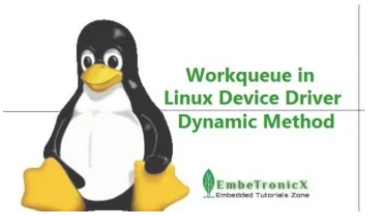

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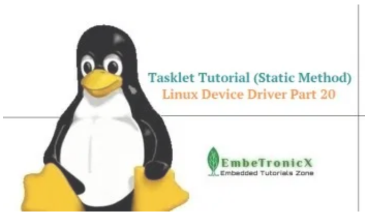

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this error is occurred plz help on this

initialization from incompatible pointer type
[-Werror=incompatible-pointer-types]
.func = (f),
^
./include/linux/workqueue.h:184:25: note: in expansion of macro
'__WORK_INITIALIZER'
struct work_struct n = __WORK_INITIALIZER(n, f)
^

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