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CLASS: Linux Driver Primer
ASSIGNMENT: Free-Style Device Driver
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1.0 Project Objectives

A 2001 article from the Linux Journal ("How to Write a Linux Device Driver") provided an overview of how to write a USB Device Driver, along with compilable source code for a "usb skeleton driver." The source code was compatible with Linux version 2.4

This project has the following objectives:

OBJ-1: Make changes necessary to the "usb skeleton driver" so that it compiles with a modern Linux version (3.16.0)

OBJ-2: Modify the source code and write shell scripts so that the usb_skeleton driver so that it will bind to a Logitech mouse device.

OBJ-3: Demonstrate that the usb_skeleton driver is binding to the Logitech mouse device, and update the USB skeleton driver so it reports more data about the device

~~**OBJ-4: Investigate steps that would be needed to get the usb_skeleton driver to respond to the Logitech mouse movement**~~

~~**OBJ-4a: Compare the USB packet activities present with the Logitech device driver vs. usb_skeleton driver**~~

~~**OBJ-4b: Research/identify changes that would be necessary to make to the usb_skeleton driver to cause it to respond to Logitech mouse movement**~~

OBJ-4 Add code to USB driver to receive Logitech mouse packets and display their contents so they are viewable with the dmesg command. Demonstrate that this code works.

2.0 Changes needed to usb_skeleton driver to compile with Linux 3.16.0 (OBJ-1)

A number of changes to the device driver interface were made between 2001 and 2016. The changes that needed to be made to usb_skeleton are listed below:

#	Change to kernel	Change to source code
1	config.h no longer used	Comment out #include /* #include <linux/config.h> */
2	dbg and err macros removed	Added macros as follows #define dbg(fmt, ...) printk(KERN_DEBUG fmt, __VA_ARGS__); #define err(fmt, ...) printk(KERN_ERR fmt, __VA_ARGS__); #define dbg1(msg) printk(KERN_DEBUG msg);

3	smp_lock functionality removed	Commented out #include /* #include <linux/smp_lock.h> */ Also commented out lock_kernel(); This makes driver less robust, but we'll assume that only 1 instance of the driver is running here
4	Write callback function no longer uses pt_regs	Remove pt_regs from write call back function (function body did not use pt_regs) static void skel_write_bulk_callback(struct urb *urb)
5	struct usb_class_driver no longer includes mode	Commented out //.mode = S_IFCHR | S_IRUSR | S_IWUSR | S_IRGRP | S_IWGRP | S_IROTH,
6	struct usb_driver no longer includes field owner	Commeted out // commented out KFB .owner = THIS_MODULE,

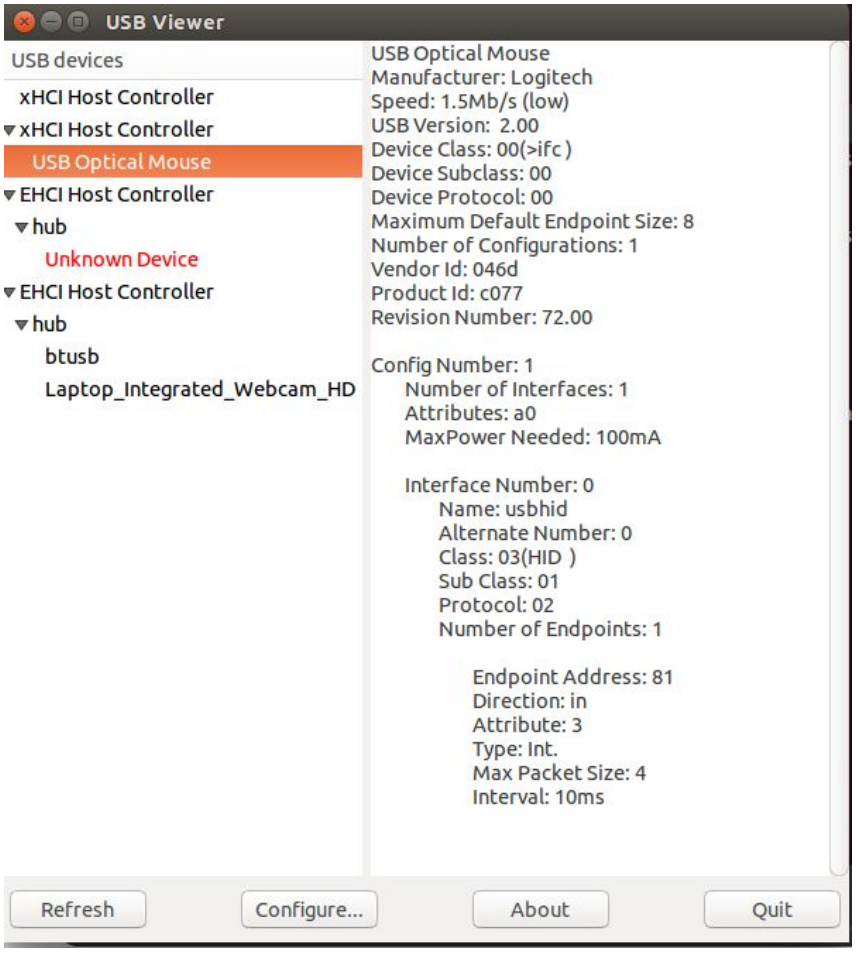
3.0 Modify skeleton source code and write shell script to bind to Logitech mouse (OBJ-2)

The first source code modification involved changing the Vendor ID and Product ID fields:

```
#define USB_SKEL_VENDOR_ID    0x046d
#define USB_SKEL_PRODUCT_ID    0xc077
```

The vendor ID and Product ID fields were obtained by using the "usbview" program.

The USB Skeleton program was setup to work with a USB device that has a bulk input and bulk output endpoint. Once it is connected to a Logitech mouse, the skeleton program will fail, because the mouse only has one endpoint, mainly an interrupt endpoint. This can be seen with the "usbview" program:



As such, the lines in the probing function that check for the bulk endpoints were commented out:

```
    /*
     if (!dev->bulk_in_endpointAddr &&
            (endpoint->bEndpointAddress & USB_DIR_IN) &&
            ((endpoint->bmAttributes & USB_ENDPOINT_XFERTYPE_MASK)
                        == USB_ENDPOINT_XFER_BULK)) {
             buffer_size = endpoint->wMaxPacketSize;
             dev->bulk_in_size = buffer_size;
             dev->bulk_in_endpointAddr = endpoint->bEndpointAddress;
             dev->bulk_in_buffer = kmalloc(buffer_size, GFP_KERNEL);
             if (!dev->bulk_in_buffer) {
                    printk(KERN_ERR "Could not allocate bulk_in_buffer");
                    goto error;
             }
     }

     if (!dev->bulk_out_endpointAddr &&
            !(endpoint->bEndpointAddress & USB_DIR_IN) &&
            ((endpoint->bmAttributes & USB_ENDPOINT_XFERTYPE_MASK)
                        == USB_ENDPOINT_XFER_BULK)) {
             dev->bulk_out_endpointAddr = endpoint->bEndpointAddress;
     }
     */

}

/*
if (!(dev->bulk_in_endpointAddr)) {
     printk(KERN_ERR "Could not find bulk-in endpoint");
     goto error;
}
```

```
if (!(dev->bulk_out_endpointAddr)) {
     printk(KERN_ERR "Could not find bulk-out endpoint");
     goto error;
}
    */
```

The following shell script was used to remove the existing Logitech USB HID driver, and then install the USB Skeleton driver in its place

> (NOTE - It is necessary to use a laptop computer for this, as removing the USB HID driver on a desktop computer may render it non-functional!)

```
#!/bin/bash
# First, remove any existing old copy of the USB skeleton driver
rmmod usb_skeleton

# Save old messages off to a file, then clear the message list for simplicity
dmesg -c >old_messages_$$

# Unbind the mouse (endpoint was found to be constant thru USB tree cmd)
# tree /sys/bus/usb/drivers
echo "3-1:1.0" >/sys/bus/usb/drivers/usbhid/unbind

# Remove the USB HID driver
rmmod usbhid

# Install the USB skeleton driver
insmod usb_skeleton.ko

# Show messages from this operation
dmesg
```

An additional script was written to re-install the HID driver:

```
insmod  /lib/modules/$(uname -r)/kernel/drivers/hid/usbhid/usbhid.ko
```

This script locates the USB HID driver within the Linux hierarchy and re-installs it.

4.0 Demonstrate that the driver is attaching to the Logitech mouse, and extend the USB skeleton code to report more information about the device (OBJ-3)

The following code was added to the USB skeleton driver to report additional information about the device:

```
struct usb_device *my_usb_dev;


my_usb_dev = dev->udev;
// Print out information about the device
printk(KERN_INFO "USB-SKEL: Probe activated \n");
printk(KERN_INFO "Device Number = %d\n", my_usb_dev->devnum);
printk(KERN_INFO "Device Path=%s\n", my_usb_dev->devpath);
printk(KERN_INFO "Bus mA=%d", my_usb_dev->bus_mA);
    printk(KERN_INFO "Speed is %d\n", my_usb_dev->speed);
printk(KERN_INFO "Can submit URBs %d\n", my_usb_dev->can_submit);
```

```
    if (my_usb_dev->product != NULL)
        printk(KERN_INFO "Product String=%s\n", my_usb_dev->product);
    else
      printk(KERN_INFO "Product String=NULL\n");

    if (my_usb_dev->manufacturer != NULL)
      printk(KERN_INFO "Manufacturer=%s\n", my_usb_dev->manufacturer);
    else
      printk(KERN_INFO "Manufacturer=NULL\n");

    if (my_usb_dev->serial != NULL)
      printk(KERN_INFO "Serial=%s\n", my_usb_dev->serial);
    else
      printk(KERN_INFO "Serial=NULL\n");
```

The following shows the messages associated with plugging in the Logitech mouse. Lines in RED originate from the USB skeleton code.

```
[28295.907872] usb 3-1: new low-speed USB device number 32 using xhci_hcd
[28296.070187] usb 3-1: New USB device found, idVendor=046d, idProduct=c077
[28296.070198] usb 3-1: New USB device strings: Mfr=1, Product=2, SerialNumber=0
[28296.070205] usb 3-1: Product: USB Optical Mouse
[28296.070210] usb 3-1: Manufacturer: Logitech
[28296.070518] usb 3-1: ep 0x81 - rounding interval to 64 microframes, ep desc says 80
microframes
[28296.080289] USB-SKEL: Probe activated
[28296.080300] Device Number = 32
[28296.080305] Device Path=1
[28296.080310] Bus mA=500
[28296.080315] Speed is 1
[28296.080319] Can submit URBs 1
[28296.080324] Product String=USB Optical Mouse
[28296.080328] Manufacturer=Logitech
[28296.080332] Serial=NULL
[28296.080337] Found endpoint 0, type is 3
[28296.080340] Packetsize is 4
[28296.080344] Endpoint address is 129This is an interrupt endpoint
[28296.080632] USB Skeleton device now attached to USBSkel-0
```

5.0 Add code to the USB driver to receive Logitech mouse packets and display them to the dmesg interface. Demonstrate that the code works (OBJECTIVE #4)

The Wireshark program can be installed and configured to allow USB packets to be observed:

```
# (Credit: Stackoverflow.com)
sudo aptget install wireshark libpcap0.8
sudo dpkgreconfigure wiresharkcommon
sudo usermod a G wireshark <your_username>
sudo modprobe usbmon
sudo chmod 644 /dev/usbmon*
```

Connecting the USB Mouse with my USB Skeleton driver active generates 45 USB packets as shown below:

```
No.     Time           Source                Destination           Protocol Length Info
```

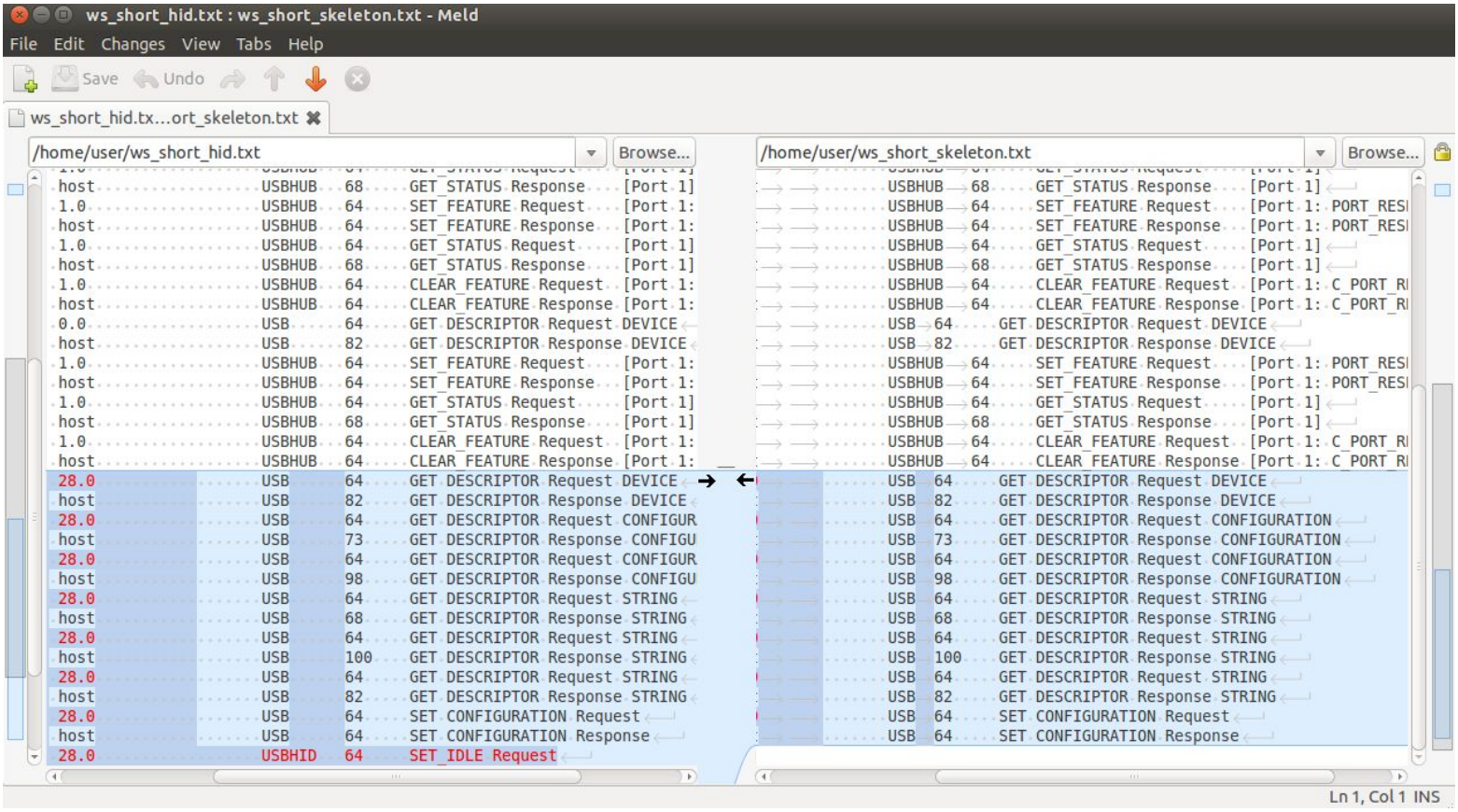
```
1 0.000000000       host                1.0                 USBHUB   64         GET_STATUS Request  [Port 1]
2 0.000013000       1.0                 host                USBHUB   68         GET_STATUS Response [Port 1]
3 0.000017000       host                1.0                 USBHUB   64         GET_STATUS Request  [Port 2]
4 0.000024000       1.0                 host                USBHUB   68         GET_STATUS Response [Port 2]
5 0.000027000       host                1.1                 USB       64        URB_INTERRUPT in
6 0.000037000       host                1.0                 USB       64        GET DESCRIPTOR Request DEVICE
7 0.000040000       1.0                 host                USB       82        GET DESCRIPTOR Response DEVICE
8 0.000051000       1.1                 host                USB       64        URB_INTERRUPT in
9 22.250827000   host                   1.0                 USBHUB   64         GET_STATUS Request  [Port 1]
10 22.250866000   1.0                   host                USBHUB   68         GET_STATUS Response [Port 1]
11 22.250877000   host                  1.0                 USBHUB   64         CLEAR_FEATURE Request  [Port 1: C_PORT_CONNECTION]
12 22.250893000   1.0                   host                USBHUB   64         CLEAR_FEATURE Response [Port 1: C_PORT_CONNECTION]
13 22.250900000   host                  1.0                 USBHUB   64         GET_STATUS Request  [Port 2]
14 22.250911000   1.0                   host                USBHUB   68         GET_STATUS Response [Port 2]
15 22.351353000   host                  1.1                 USB       64        URB_INTERRUPT in
16 22.351397000   host                  1.0                 USBHUB   64         GET_STATUS Request  [Port 1]
17 22.351442000   1.0                   host                USBHUB   68         GET_STATUS Response [Port 1]
18 22.351547000   host                  1.0                 USBHUB   64         SET_FEATURE Request [Port 1: PORT_RESET]
19 22.351570000   1.0                   host                USBHUB   64         SET_FEATURE Response   [Port 1: PORT_RESET]
20 22.407340000   host                  1.0                 USBHUB   64         GET_STATUS Request  [Port 1]
21 22.407378000   1.0                   host                USBHUB   68         GET_STATUS Response [Port 1]
22 22.407416000   host                  1.0                 USBHUB   64         CLEAR_FEATURE Request  [Port 1: C_PORT_RESET]
23 22.407444000   1.0                   host                USBHUB   64         CLEAR_FEATURE Response [Port 1: C_PORT_RESET]
24 22.463445000   host                  0.0                 USB       64        GET DESCRIPTOR Request DEVICE
25 22.466944000   0.0                   host                USB       82        GET DESCRIPTOR Response DEVICE
26 22.466998000   host                  1.0                 USBHUB   64         SET_FEATURE Request [Port 1: PORT_RESET]
27 22.467040000   1.0                   host                USBHUB   64         SET_FEATURE Response   [Port 1: PORT_RESET]
28 22.519348000   host                  1.0                 USBHUB   64         GET_STATUS Request  [Port 1]
29 22.519384000   1.0                   host                USBHUB   68         GET_STATUS Response [Port 1]
30 22.519432000   host                  1.0                 USBHUB   64         CLEAR_FEATURE Request  [Port 1: C_PORT_RESET]
31 22.519457000   1.0                   host                USBHUB   64         CLEAR_FEATURE Response [Port 1: C_PORT_RESET]
32 22.591379000   host                  21.0                USB       64        GET DESCRIPTOR Request DEVICE
33 22.594829000   21.0                  host                USB       82        GET DESCRIPTOR Response DEVICE
34 22.594879000   host                  21.0                USB       64        GET DESCRIPTOR Request CONFIGURATION
35 22.598817000   21.0                  host                USB       73        GET DESCRIPTOR Response CONFIGURATION
36 22.598849000   host                  21.0                USB       64        GET DESCRIPTOR Request CONFIGURATION
37 22.605818000   21.0                  host                USB       98        GET DESCRIPTOR Response CONFIGURATION
38 22.605855000   host                  21.0                USB       64        GET DESCRIPTOR Request STRING
39 22.608813000   21.0                  host                USB       68        GET DESCRIPTOR Response STRING
40 22.608840000   host                  21.0                USB       64        GET DESCRIPTOR Request STRING
41 22.615814000   21.0                  host                USB      100        GET DESCRIPTOR Response STRING
42 22.615844000   host                  21.0                USB       64        GET DESCRIPTOR Request STRING
43 22.620812000   21.0                  host                USB       82        GET DESCRIPTOR Response STRING
44 22.626779000   host                  21.0                USB       64        SET CONFIGURATION Request
45 22.627814000   21.0                  host                USB       64        SET CONFIGURATION Response
```

To simplify the process of comparing packet activity with the Logitech USB driver vs. the USB Skeleton driver, I used the "print to ascii file" command of Wireshark to save the USB activity under two configurations:

File ws_short_hid = Activity when Logitech HID driver is connected
File ws_short_skeleton = Activity when USB Skeleton driver is connected

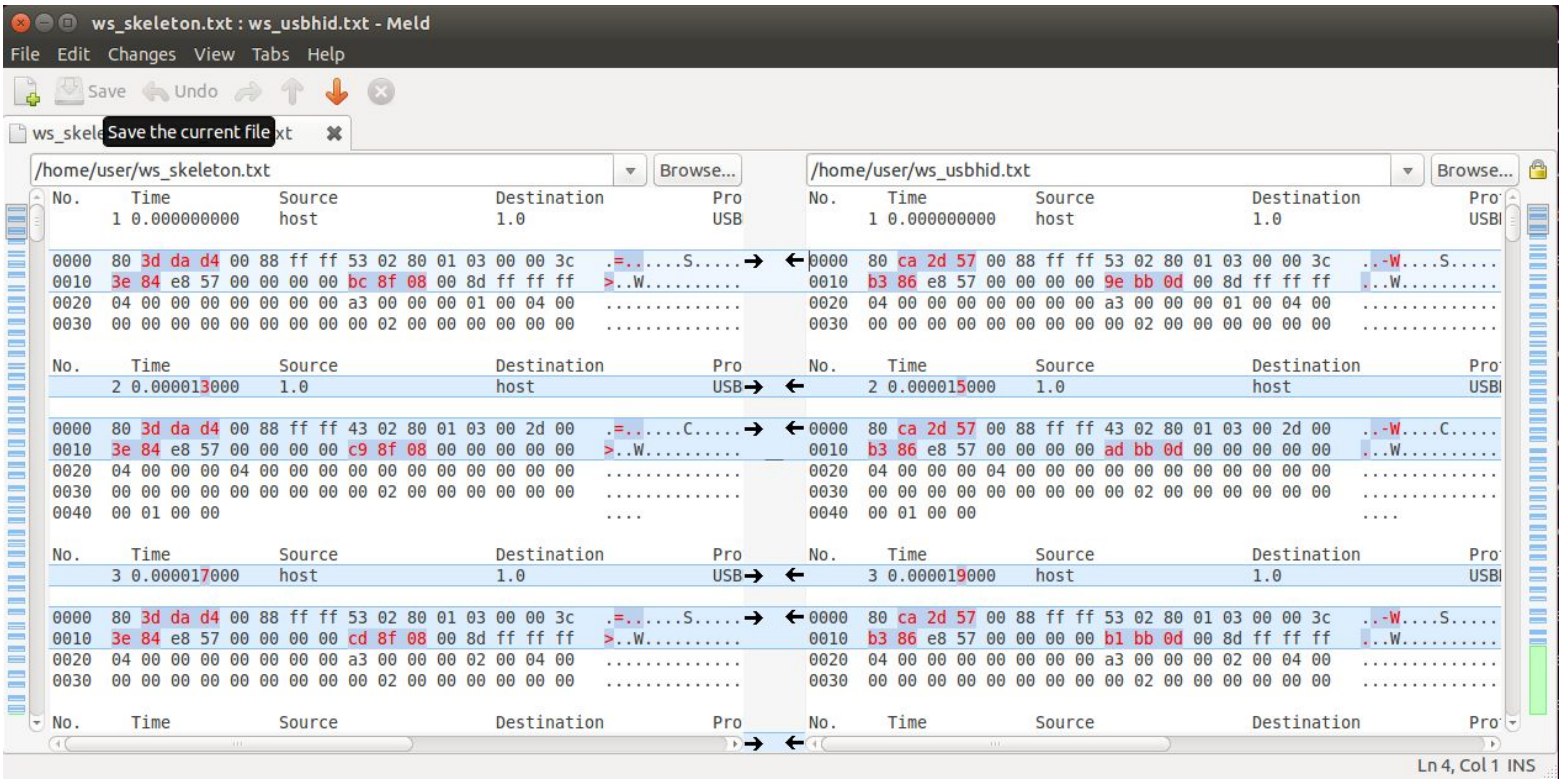
The source code for the Logitech HID driver is available online here.

The below program shows the graphical output from the "meld" program, which provides side-by-side comparison of text files in Ubuntu with highlights for differences:



Interestingly, the number, direction, and characteristics of the packets is virtually identical between the Logitech driver.

However, when the USB skeleton driver is operating with the Logitech mouse, the interrupt packets are not seen, so there is a difference in the configuration. By outputting more detailed information from Wireshark, differences in the packets can be observed as follows:



The following references were helpful in creating the code to receive interrupt packets:

#	Author	Description	URL
1	USB Kernel Reference	usb_fill_int_urb	Link
2	USB Kernel Reference	What is a URB?	Link
3	Max Bruning, 2009	USB HID Drivers on Solaris	Link
4	Corbet/Rubini/et al	Linux Device Drivers	Link
5	Kroa-Hartman	How to write a driver	Link
6	Free Electrons	Description of GET_STATUS Packet	Link
7	Free Electrons	Description of GET_DESCRIPTION packet	Link
8	Free Electrons	Description of SET CONFIGURATION packet	Link
9	Free Electrons	Filling a URB	Link
10	USB Kernel Ref	USB Kernel Helper Functions	Link
11	Stack Overflow	Project to implement I2C driver in Linux	Link

The following code was added to the usb_skeleton driver to receive interrupt packets:

```
static void urb_complete_callback(struct urb *my_urb)
{   int retval;
    unsigned char *my_point = my_urb->transfer_buffer;
    int horizontal, vertical;
    char direction[20] = "";

    horizontal = *(my_point + 1);
    vertical = *(my_point + 2);

    if (vertical > 128)
      strcat(direction, "UP ");
    else if (vertical > 0)
      strcat(direction, "DOWN ");

    if (horizontal > 128)
      strcat(direction, "LEFT ");
    else if (horizontal > 0)
      strcat(direction, "RIGHT ");


    printk(KERN_INFO "MOUSE moved %s....%d bytes in. Vertical=%d, Horizontal=%d \n", direction,
my_urb->actual_length,
       vertical, horizontal);

    retval = usb_submit_urb(my_urb, GFP_KERNEL);
    if (retval)
        printk(KERN_ERR "%s - failed submitting write urb, error %d", __FUNCTION__, retval);
}
```

(BELOW CODE ADDED TO skel_probe)

```
if (the_end == USB_ENDPOINT_XFER_INT)
 {
        printk(KERN_INFO  "This is my interrupt endpoint, setting up URB to receive information\n");
        buffer_size = endpoint->wMaxPacketSize;
        dev->int_in_size = buffer_size;
        dev->int_in_endpointAddr = endpoint->bEndpointAddress;
        dev->int_in_buffer = kmalloc(buffer_size, GFP_KERNEL);
        if (!dev->int_in_buffer) {
               printk(KERN_ERR "Could not allocate int_in_buffer");
```

```
                goto error;
        }
        printk(KERN_INFO  "Allocated buffer of size %ld address %p\n", dev->int_in_size, dev->int_in_buffer);

        dev->my_urb = usb_alloc_urb(0, GFP_KERNEL);

        usb_fill_int_urb(dev->my_urb,
               dev->udev,
               usb_rcvintpipe(dev->udev, endpoint->bEndpointAddress),
               dev->int_in_buffer,
               dev->int_in_size,
               urb_complete_callback,
               NULL,
               endpoint->bInterval);

retval = usb_submit_urb(dev->my_urb, GFP_KERNEL);
printk(KERN_INFO "Return value from usb_submit was %d \n", retval);

}
```

The output from the dmesg command is shown below

```
[ 1041.484059] SKELETON: Initializing function
[ 1041.484105] USB-SKEL: Probe activated
[ 1041.484108] Device Number = 4
[ 1041.484110] Device Path=1
[ 1041.484112] Bus mA=500
[ 1041.484114] Speed is 1
[ 1041.484116] Can submit URBs 1
[ 1041.484118] Product String=USB Optical Mouse
[ 1041.484120] Manufacturer=Logitech
[ 1041.484121] Serial=NULL
[ 1041.484123] Found endpoint 0, type is 3
[ 1041.484125] Packetsize is 4
[ 1041.484127] Endpoint address is 129
[ 1041.484129] This is my interrupt endpoint, setting up URB to receive information
[ 1041.484132] Allocated buffer of size 4 address ffff880036b95fa0
[ 1041.484142] Return value from usb_submit was 0
[ 1041.484251] USB Skeleton device now attached to USBSkel-0
[ 1041.484298] usbcore: registered new interface driver skeleton
[ 1044.347073] MOUSE moved UP LEFT ....4 bytes in. Vertical=253, Horizontal=255
[ 1044.355085] MOUSE moved UP RIGHT ....4 bytes in. Vertical=252, Horizontal=1
[ 1044.363096] MOUSE moved UP RIGHT ....4 bytes in. Vertical=255, Horizontal=3
[ 1044.371101] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=2
[ 1044.379052] MOUSE moved UP RIGHT ....4 bytes in. Vertical=255, Horizontal=4
[ 1044.387008] MOUSE moved UP RIGHT ....4 bytes in. Vertical=255, Horizontal=2
[ 1044.395128] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=2
[ 1044.403137] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=3
[ 1044.411088] MOUSE moved UP RIGHT ....4 bytes in. Vertical=254, Horizontal=4
[ 1044.419154] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=1
[ 1044.427165] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=5
[ 1044.435175] MOUSE moved UP RIGHT ....4 bytes in. Vertical=255, Horizontal=5
[ 1044.443066] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=5
[ 1044.451079] MOUSE moved UP RIGHT ....4 bytes in. Vertical=255, Horizontal=8
[ 1044.459101] MOUSE moved UP RIGHT ....4 bytes in. Vertical=255, Horizontal=5
[ 1044.467210] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=6
[ 1044.475219] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=6
[ 1044.483232] MOUSE moved UP RIGHT ....4 bytes in. Vertical=254, Horizontal=5
[ 1044.491239] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=4
[ 1044.499130] MOUSE moved UP RIGHT ....4 bytes in. Vertical=255, Horizontal=2
[ 1044.507138] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=2
[ 1044.515158] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=1
[ 1044.523285] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=3
[ 1044.531294] MOUSE moved UP RIGHT ....4 bytes in. Vertical=255, Horizontal=2
[ 1044.539304] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=1
```

```
[ 1044.547307] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=2
[ 1044.555320] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=1
[ 1049.456885] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=255
[ 1049.464951] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=249
[ 1049.472965] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=248
[ 1049.480973] MOUSE moved UP LEFT ....4 bytes in. Vertical=255, Horizontal=249
[ 1049.488923] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=249
[ 1049.496988] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=249
[ 1049.504999] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=251
[ 1049.513006] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=251
[ 1049.521021] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=252
[ 1049.529026] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=252
[ 1049.536979] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=254
[ 1049.545047] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=253
[ 1049.552997] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=254
[ 1049.561066] MOUSE moved UP LEFT ....4 bytes in. Vertical=254, Horizontal=253
[ 1049.569075] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=255
[ 1049.577081] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=255
[ 1049.585093] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=253
[ 1049.593099] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=255
[ 1049.601052] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=253
[ 1049.609059] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=254
[ 1049.617034] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=253
[ 1049.625138] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=254
[ 1049.633088] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=255
[ 1049.641157] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=253
[ 1049.649166] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=254
[ 1049.657174] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=254
[ 1049.665187] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=255
[ 1049.673196] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=255
[ 1049.681205] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=255
[ 1053.453479] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=3
[ 1053.461545] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=4
[ 1053.469554] MOUSE moved RIGHT ....4 bytes in. Vertical=0, Horizontal=1
[ 1053.477565] MOUSE moved UP RIGHT ....4 bytes in. Vertical=255, Horizontal=1
[ 1053.685806] MOUSE moved UP RIGHT ....4 bytes in. Vertical=252, Horizontal=1
[ 1053.693818] MOUSE moved UP ....4 bytes in. Vertical=254, Horizontal=0
[ 1053.701825] MOUSE moved UP ....4 bytes in. Vertical=253, Horizontal=0
[ 1053.709834] MOUSE moved UP LEFT ....4 bytes in. Vertical=251, Horizontal=255
[ 1053.717844] MOUSE moved UP LEFT ....4 bytes in. Vertical=253, Horizontal=254
[ 1053.725851] MOUSE moved UP ....4 bytes in. Vertical=254, Horizontal=0
[ 1053.733861] MOUSE moved UP LEFT ....4 bytes in. Vertical=252, Horizontal=255
[ 1053.741871] MOUSE moved UP ....4 bytes in. Vertical=254, Horizontal=0
[ 1053.749876] MOUSE moved UP LEFT ....4 bytes in. Vertical=254, Horizontal=255
[ 1053.757888] MOUSE moved UP ....4 bytes in. Vertical=254, Horizontal=0
[ 1053.765897] MOUSE moved UP LEFT ....4 bytes in. Vertical=252, Horizontal=255
[ 1053.773848] MOUSE moved UP ....4 bytes in. Vertical=254, Horizontal=0
[ 1053.781919] MOUSE moved UP ....4 bytes in. Vertical=252, Horizontal=0
[ 1053.789924] MOUSE moved UP ....4 bytes in. Vertical=252, Horizontal=0
[ 1053.797934] MOUSE moved UP LEFT ....4 bytes in. Vertical=252, Horizontal=253
[ 1053.805885] MOUSE moved UP LEFT ....4 bytes in. Vertical=253, Horizontal=255
[ 1053.813953] MOUSE moved UP ....4 bytes in. Vertical=252, Horizontal=0
[ 1053.821962] MOUSE moved UP LEFT ....4 bytes in. Vertical=254, Horizontal=255
[ 1053.829972] MOUSE moved UP LEFT ....4 bytes in. Vertical=253, Horizontal=255
[ 1053.837980] MOUSE moved UP LEFT ....4 bytes in. Vertical=255, Horizontal=255
[ 1053.853999] MOUSE moved UP LEFT ....4 bytes in. Vertical=255, Horizontal=255
[ 1053.862009] MOUSE moved UP LEFT ....4 bytes in. Vertical=255, Horizontal=255
[ 1053.870018] MOUSE moved UP LEFT ....4 bytes in. Vertical=254, Horizontal=252
[ 1053.878030] MOUSE moved UP LEFT ....4 bytes in. Vertical=254, Horizontal=253
[ 1053.885972] MOUSE moved UP LEFT ....4 bytes in. Vertical=255, Horizontal=254
[ 1053.894044] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=253
[ 1058.915814] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=255
[ 1058.923737] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=254
[ 1058.931772] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=252
[ 1058.939843] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=252
[ 1058.947793] MOUSE moved DOWN LEFT ....4 bytes in. Vertical=1, Horizontal=254
[ 1058.955802] MOUSE moved DOWN LEFT ....4 bytes in. Vertical=2, Horizontal=251
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[ 1058.963773] MOUSE moved DOWN LEFT ....4 bytes in. Vertical=1, Horizontal=254
[ 1058.971879] MOUSE moved DOWN LEFT ....4 bytes in. Vertical=1, Horizontal=254
[ 1058.979738] MOUSE moved DOWN LEFT ....4 bytes in. Vertical=1, Horizontal=254
[ 1058.987897] MOUSE moved LEFT ....4 bytes in. Vertical=0, Horizontal=253
[ 1058.995848] MOUSE moved DOWN LEFT ....4 bytes in. Vertical=1, Horizontal=255
[ 1059.100026] MOUSE moved DOWN ....4 bytes in. Vertical=2, Horizontal=0
[ 1059.107918] MOUSE moved DOWN ....4 bytes in. Vertical=3, Horizontal=0
[ 1059.116040] MOUSE moved DOWN ....4 bytes in. Vertical=5, Horizontal=0
[ 1059.124052] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=5, Horizontal=2
[ 1059.132062] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=6, Horizontal=1
[ 1059.140071] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=4, Horizontal=1
[ 1059.148077] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=5, Horizontal=3
[ 1059.156030] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=5, Horizontal=2
[ 1059.164099] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=6, Horizontal=3
[ 1059.172048] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=5, Horizontal=1
[ 1059.180057] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=4, Horizontal=2
[ 1059.188125] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=6, Horizontal=3
[ 1059.196138] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=5, Horizontal=2
[ 1059.204142] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=7, Horizontal=3
[ 1059.212155] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=10, Horizontal=4
[ 1059.220162] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=8, Horizontal=3
[ 1059.228055] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=7, Horizontal=2
[ 1059.236182] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=8, Horizontal=2
[ 1059.244192] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=7, Horizontal=1
[ 1059.252197] MOUSE moved DOWN RIGHT ....4 bytes in. Vertical=6, Horizontal=2
[ 1059.260106] MOUSE moved DOWN ....4 bytes in. Vertical=3, Horizontal=0
[ 1059.268219] MOUSE moved DOWN ....4 bytes in. Vertical=3, Horizontal=0
[ 1059.276228] MOUSE moved DOWN LEFT ....4 bytes in. Vertical=2, Horizontal=255
[ 1059.284237] MOUSE moved DOWN LEFT ....4 bytes in. Vertical=1, Horizontal=255
```