USB HID Drivers on OpenSolaris and Linux – By Example

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Topics Covered

- Description of Wacom Tablet
- USB HID Device Driver Overview
- Linux Input Event Subsystem Overview
- HID Driver Framework on OpenSolaris
- Wacom Kernel Module and X Input Extension Library on OpenSolaris

Overview of the Wacom Tablet

- Tablet models come in different sizes and features
- Each tablet comes with a pen with replaceable stylus and side switches
- Tablet can send proximity events, absolute pen coordinates, pressure, height, tilt, pen serial number, and various “expresskey” events and slider(s) events
- Tablet contains HID boot protocol which allows pen to work like a mouse
- More information at www.wacom.com

USB HID Device Overview

- Communication between HID devices and a HID driver are in the form of *Device Descriptors* and/or data
- Device Descriptor
  - Configuration Descriptor
    - Interface Descriptor
      - Endpoint Descriptor
      - HID Descriptor
        - Report Descriptor
        - Physical Descriptor
- Descriptors can be viewed using `mdb(1)`or `prtpicl(1)`
- See Device Class Definition for Human Interface Devices(HID)

Device Descriptors For Wacom Tablet

```
# mdb -k
Loading modules: [ unix genunix specfs dtrace mac cpu.generic
 uppc pcplusmp scsi_vhci zfs sockfs ip hook neti sctp arp usba uhci
 sd fctl md lofs audiosup fcip fcp random cpc crypto logindmux ptm ufs
 nsmb sppp ipc ]
> ::prtusb
INDEX   DRIVER      INST  NODE             VID.PID     PRODUCT
1       ehci        0     pci17aa,200b     0000.0000   No Product String
2       uhci        0     pci17aa,200a     0000.0000   No Product String
3       uhci        1     pci17aa,200a     0000.0000   No Product String
4       uhci        2     pci17aa,200a     0000.0000   No Product String
5       uhci        3     pci17aa,200a     0000.0000   No Product String
6       scsa2usb    1     storage          1058.0704   External HDD
7       hid         0     mouse            056a.0065   MTE-450
8       usb_mid     0     device           0483.2016   Biometric Coprocessor
>
```

Device Descriptors For Wacom Tablet (Continued)

```
> ::prtusb -v -i 7 ← Add "-t" to also show HID Usage Tables
INDEX    DRIVER      INST  NODE             VID.PID     PRODUCT
7        hid         0     mouse            056a.0065   MTE-450

Device Descriptor ← usb_dev_descr_t from uts/common/sys/usb/usbai.h
{
    bLength = 0x12
    bDescriptorType = 0x1
    bcdUSB = 0x200
    BDeviceClass = 0 ← class info in interface descriptor
    bDeviceSubClass = 0
    bDeviceProtocol = 0
    bMaxPacketSize0 = 0x40
    idVendor = 0x56a ← Wacom vendor id
    idProduct = 0x65 ← "Bamboo"
    bcdDevice = 0x108
    iManufacturer = 0x1
    iProduct = 0x2
    iSerialNumber = 0
    bNumConfigurations = 0x1
}
```

Device Descriptors for Wacom Tablet (Continued)

```
-- Active Config Index 0
Configuration Descriptor
{
    bLength = 0x9
    bDescriptorType = 0x2
    wTotalLength = 0x22
    bNumInterfaces = 0x1
    bConfigurationValue = 0x1
    iConfiguration = 0x0
    bmAttributes = 0x80 ← bus powered
    bMaxPower = 0x16 ←44mA
}
    Interface Descriptor
    {
        bLength = 0x9
        bDescriptorType = 0x4
        bInterfaceNumber = 0x0
        bAlternateSetting = 0x0
        bNumEndpoints = 0x1
        bInterfaceClass = 0x3 ←HID Class Device
        bInterfaceSubClass = 0x1 ← Device supports a boot interface
        bInterfaceProtocol = 0x2 ← Boot protocol is mouse
        iInterface = 0x0
    }
```

Device Descriptors For Wacom Tablet (Continued)

```
    HID Descriptor
    {
        bLength = 0x9
        bDescriptorType = 0x21 ← Assigned by USB, mouse
        bcdHID = 0x100
        bCountryCode = 0x0 ←Not localized
        bNumDescriptors = 0x1
        bReportDescriptorType = 0x22 ←mouse
        wReportDescriptorLength = 0x92
    }
Endpoint Descriptor
{
    bLength = 0x7
    bDescriptorType = 0x5 ← mouse
    bEndpointAddress = 0x81 ← input endpoint number 1
    bmAttributes = 0x3 ← interrupt endpoint
    wMaxPacketSize = 0x9
    bInterval = 0x4
}

>
```

Viewing Device Descriptors on Linux

- On Linux, USB device information, including descriptors, is located in `/proc/bus/usb/devices`
- Information is in ascii (so you can `cat` the file)
- See `Documentation/usb/proc_usb_info.txt` in the Linux source code
- `lsusb -vvv` also shows descriptors as well as HID Usage Tables

USB HID Device Drivers on Linux

- Drivers for HID devices on Linux can be implemented via:
  - A kernel driver that communicates with a USB host controller driver via the `usb-core` API
    - See Programming Guide for Linux USB Device Drivers
  - A user level driver that communicates with the `hid_input` kernel module
  - A user level driver that communicates with the `hiddev` kernel module
  - `Hid-input` and `hiddev` communicate with the USB host controller driver via `hid-core`

USB HID Device Drivers on Linux (Continued)

- User level drivers communicate with kernel via `libusb` and/or `libhid`
- Note that the Wacom implementation on Linux consists of a kernel module that communicates directly with the USB host controller via `usb-core`
  - User level communication with Wacom is via Linux generic `input` device (`/dev/input/event#`)

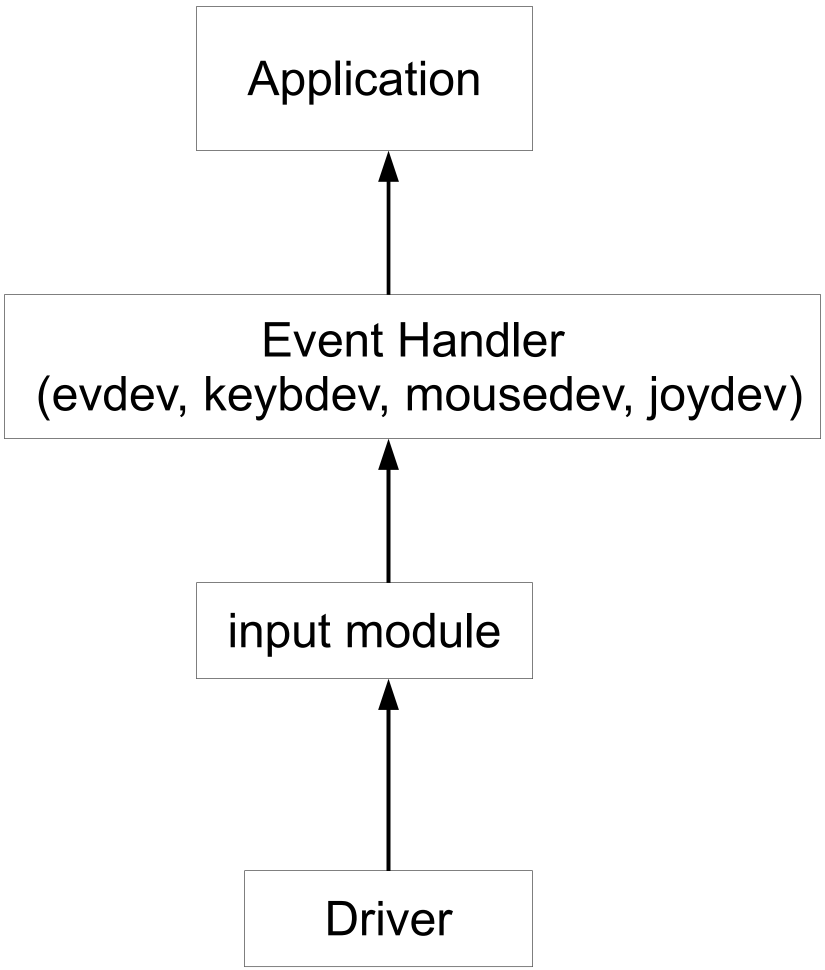
USB HID Device Drivers on OpenSolaris

- For HID devices, OpenSolaris provides the `hid(7d)`driver and `hidparser` kernel module
  - `hid(7d)` handles all communication with the USB host controller via `usba(7d)` (analagous to `usb-core` on Linux)
  - `hid(7d)` is a STREAMS driver
    - Individual HID devices can use a STREAMS module pushed onto the driver to handle the device
    - There is no documentation for writing such a module
  - The `hidparser` module handles HID descriptors

USB HID Device Drivers on OpenSolaris (Continued)

- OpenSolaris also has support for `libusb(3LIB)`
  - Uses the `ugen(7d)` kernel driver to communicate with the USB host controller via `usba(7d)`
- OpenSolaris currently has no support for `libdev` or the Linux `input` device module
- There are currently `hid(7d)` STREAMS modules to support mouse, keyboard, and audio control devices.

Linux Input Device Handling



- Application opens and reads from an input device (/dev/input/event#, for instance)
- Event Handler is a kernel module that gets input events from the input module
- The input module gets events from registered drivers, and passes them to registered handlers
- The driver handles the device. For USB, the driver communicates with the host controller via usb-core, or via hid-core
- Input events include a time stamp, type of event, code for event type, and a value
  - For instance, a type of event might be a button event, the code indicates which button, and the value would indicate press or release.

Linux Input Device Handling – USB Input Driver Example

```
/* note that in this example, many details are omitted */
static int foo_probe(struct usb_interface *intf,
                      Const struct usb_device_id *id)
{
    struct foo *foo;  /* private state data for device */
    foo = kzalloc(sizeof(struct foo), GFP_KERNEL);
    input_dev = input_allocate_device();
    foo->data = usb_buffer_alloc(dev, len, flags, &foo->data_dma);
    foo->irq = usb_alloc_urb(0, flags);
    input_dev->open = foo_open;
    input_dev->close = foo_close;
    /* initialize input_dev capabilities, i.e., */
    /* set input_dev evbits and keybits (buttons, abs vs. rel, etc. */
    /* tell input module about supported and min/max params */
    /* for instance... */
    input_set_abs_params(input_dev, ABS_X, minx, maxx, 0, 0);
    …
    endp = intf->cur_altsetting->endpoint[i].desc;
    usb_fill_int_urb(foo->irq, dev,
        usb_rcvintpipe(dev, endp->bEndpointAddress), foo->data, len,
        foo_irq, foo, endp->bEndpointInterval);
    input_register_device(foo->dev);
    /* send/retrieve reports, as needed  */
    usb_set_report(...);
}
```

Linux Input Device Handling – USB Input Driver Example (Continued)

```
Static void
foo_irq(struct urb urb) /* called when data arrives from device (usb-core)*/
{
    struct foo *foo = (struct foo *)urb->context;
    unsigned char *data = foo->data;  /* the data from the device */
    struct input_dev *input_dev = foo->inputdev;
    switch(urb->status) {
    case 0:
        /* success, first process data, then send keys, abs/rel, events */
        input_report_abs(input_dev, type, code, value);
        /* and/or input_event(), input_report_rel(), input_report_key() */
    default:
        /* handle error */
}
```

Linux Input Device Handling – Input Module

- Each input device module maintains bit field arrays of capabilities of the underlying device
  - Device driver fills in bits for corresponding capabilities supported by the device
    - Events
    - Keys
    - Relative Positions
    - Absolute Positions
    - Miscellaneous Events
    - LEDs
    - Sound Effects
    - Force Feedback Events
    - Switches

- Device drivers tell the input module about events that have occurred
  - Input module checks to make sure the device is capable of generating the event
  - Then the input module passes the event to interested event handler(s), or sent to the device (to turn on/off an LED, for instance)

- The input module is meant for generic input device handling, currently only used with usb

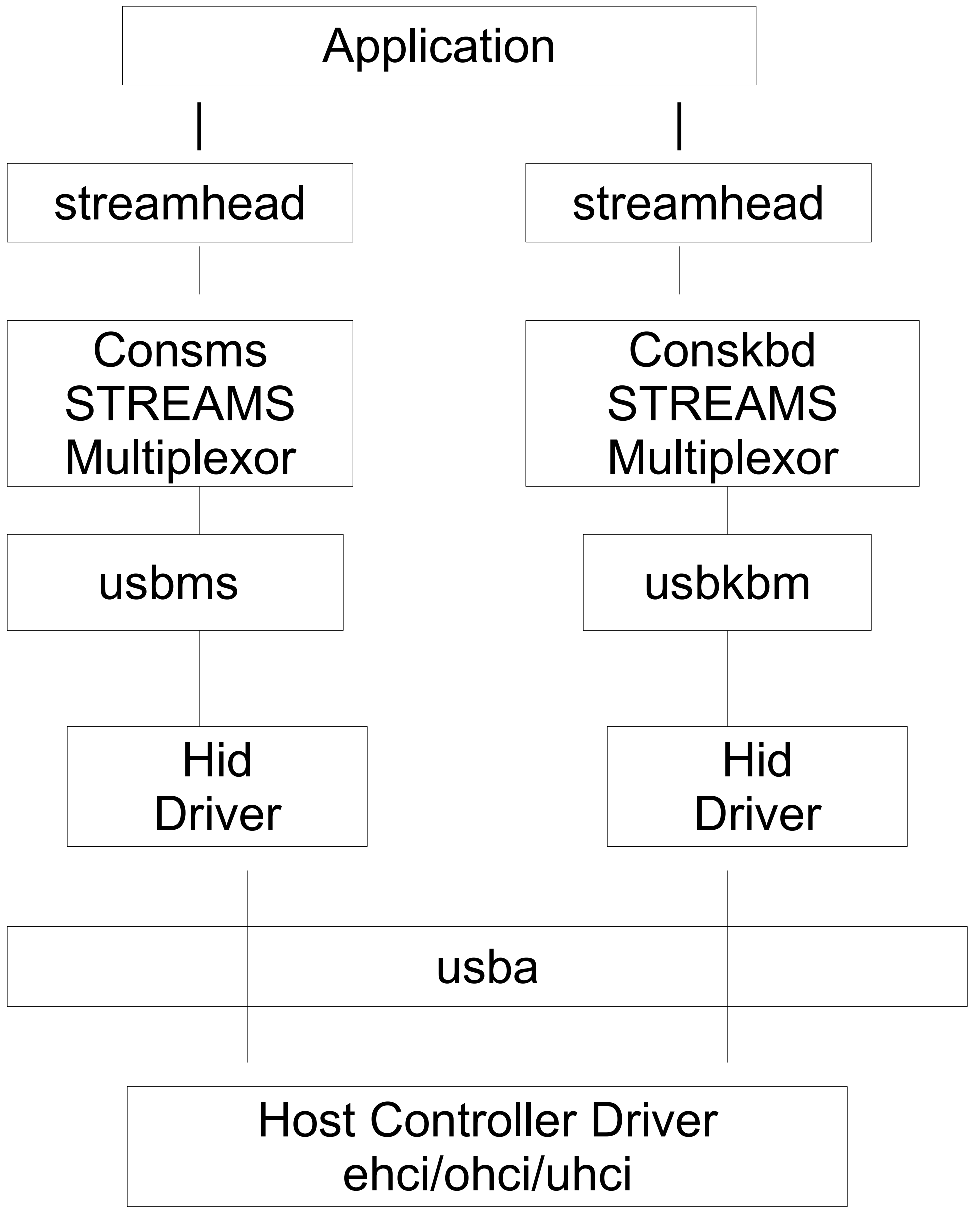
Linux Input Device Handling – Event Handler (evdev)

- The `evdev` module is meant for processing of generic events
  - Other event handlers exist (mouse, keyboard, joystick), and others can be added
- `evdev` places the event in a client buffer and sends a `SIGIO` to waiting application
- Applications using `evdev` will first open an event device (`/dev/input/event#` where `#` is between 0 and 31) corresponding to the device for which the application expects events
  - Handler is added for device during `input_register_device()`
  - Applications must search `/dev/input/event#` devices to find correct corresponding device (open and then get vendor/product id)

Linux Input Device Handling – Application Level

- User level code typically implemented in a library (`foo_drv.so`)
  1. Applications wishing to use the device link with the library
- For the `X` windowing system, the library does the following actions:
  1. The `ModuleSetupProc` function tells X about the new input driver
  2. The `PreInit` function loads the kernel `foo` driver and the event handler module (for instance, `evdev`)
  3. The `device_control` function, on `DEVICE_INIT`, opens each `/dev/input/event#` device until it finds one corresponding to the correct underlying hardware
  4. The `read_input` function is called whenever packets are ready to be read by the server.
     i. For each packet read, `read_input` gathers the packets until it has enough information to send event(s) associated with the packet(s)
     ii. Once all packets have been read, the library calls `xf86Post`*`xxx`*`Event()` to dispatch button press/release, motion, keystrokes, etc. events to the X server.
- A description of the above functions can be found at http://www.x.org/wiki/Development/Documentation/XorgInputHOWTO

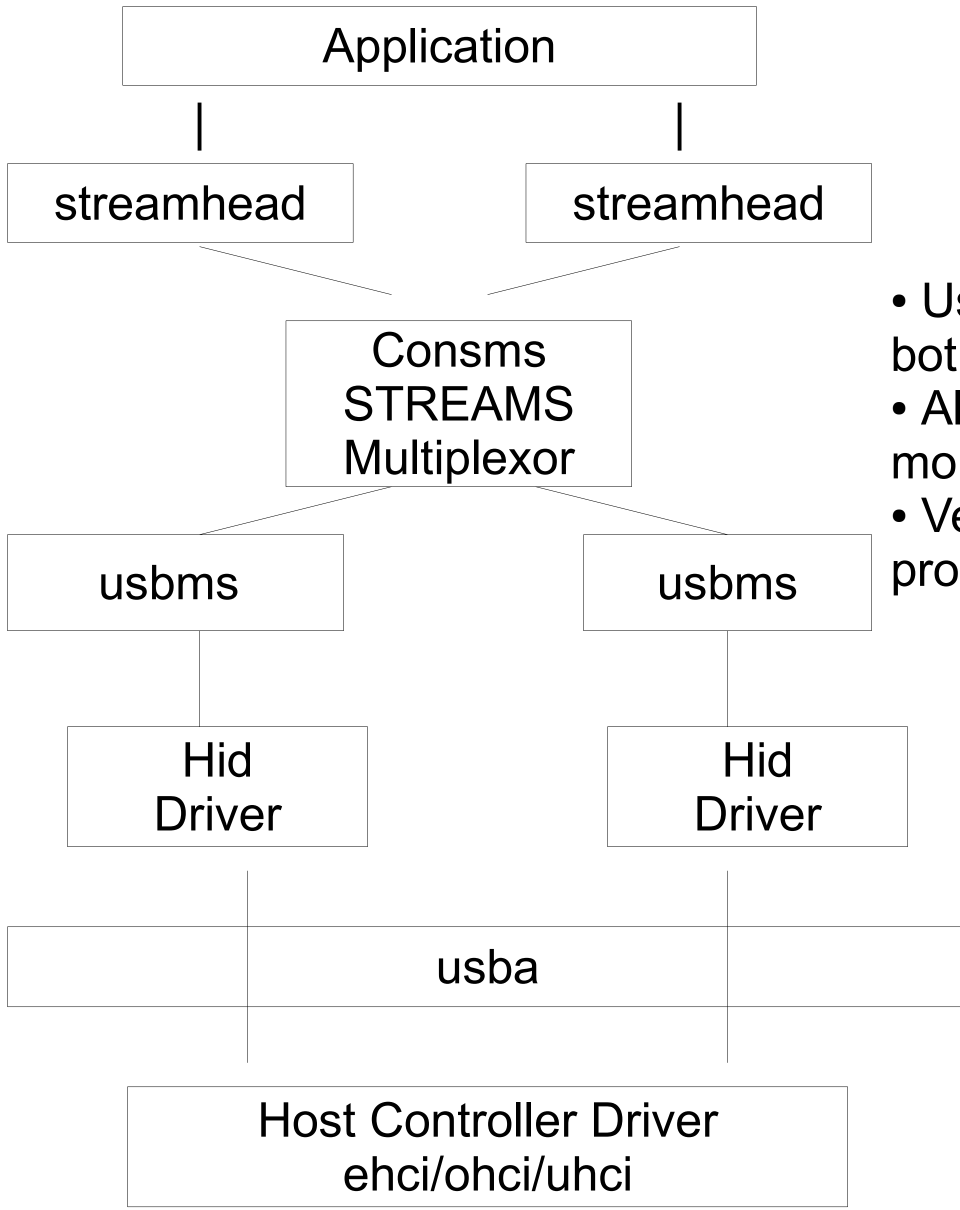
HID Framework on OpenSolaris (Example)



Wacom Tablet on OpenSolaris

- 3 versions
  - Modified usbms module
  - Implement input device handling in kernel module
  - Re-Implement Xinput library module

Wacom Driver as Modified usbms



- Usbms modified to support both mouse and tablet
- All tablet events sent as mouse events
- Version has been in production for 2 years

Problems with First Solution

- The first iteration was implemented because I could not find a way to “pop” the usbms module
  - Plumbing of `usbms` module done by `consconfig_dacf` kernel module based on `dacf.conf(4)`
    - Boot protocol identifies tablet as a mouse
- No tablet key support (pen, erasor, and side switches work)
- On SPARC, hwc module caused problem
- All handling of tablet specific data done by modified `usbms` module

Wacom Module Implementing Linux `input` Events

- Problem of mouse boot protocol goes away by `open(2)` of the underlying device (`usbms` module is popped)
- `wacom` STREAMS module pushed onto `hid` by modified Linux `wacom_drv.so` library
  - Otherwise, `wacom_drv.so` needs no modification
  - `wacom` module converts raw input from tablet into `input_event` structures expected by library module
  - All features of tablet now work

Problems with Second Solution

- The Linux solution does much of the processing twice, once in the kernel module, and again in the library
- Licensing
  - (But we won't talk about this...)

Wacom on OpenSolaris – Yet Another Solution

- `wacom` kernel module puts the tablet into “pen” mode, and sends raw tablet data to consumers
- The X input library, `wacom_drv.so`, accepts raw data, converts into X events, and sends the events.
- Currently, solution is using some Linux library code
  - So, not yet released for OpenSolaris

Wacom Kernel Module – Sending a Report

```
wacom_get_vid_pid(wacom_state_t wacomp) /* called from module open */
{
        struct iocblk mctlmsg;
        mblk_t *mctl_ptr;
        dev_info_t *devinfo;

        queue_t *q = wacomp->wacom_rq_ptr;

        mctlmsg.ioc_cmd = HID_GET_VID_PID;
        mctlmsg.ioc_count = 0;

        mctl_ptr = usba_mk_mctl(mctlmsg, NULL, 0);

        putnext(wacomp->wacom_wq_ptr, mctl_ptr);
        wacomp->wacom_flags |= WACOM_QWAIT;
        while (wacomp->wacom_flags & WACOM_QWAIT) {
                if (qwait_sig(q) == 0) {
                        wacomp->wacom_flags = 0;
                        return (EINTR);
                }
         }
         Return(0);
}
```

Wacom Kernel Module – Reading a Report

- The `hid` module acts on `M_CTL` messages and sends another `M_CTL` message upstream
- The `wacom` module, when it receives the answering `M_CTL` message, takes appropriate action (for instance, waking up code in the open function), and discards the message
- All tablet data is received as `M_DATA` messages, which are passed upstream with no processing

Acknowledgements

- Philip Brown's Wacom driver has been helpful, see http://www.bolthole.com/solaris/drivers/usb-wacom.h
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