Peripheral-side USB support for NetBSD

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What is this?

- With this framework, Platforms that run NetBSD kernel can act as USB devices, such as USB serials, mass storage, printers, Ethernet adapters, etc.
This side of USB have been supported for many years.

Now we support this side of USB.
USB Bus

- Host
  - USB Host Controller
    - Root Hub
      - USB Device Address=2
      - USB Device Address=4
      - USB Device Address=3
      - Hub Address=3
      - USB Device Address=5
      - USB Device Address=6
      - USB Device Address=7
Physical Connection

Host (or Hub)

VBus (+5V)

D+

D-

(ID)

Type-B receptacle

GND
USB device

Interface

Host side

Peripheral side

USB device driver

Pipes

USB System Software (USB driver)

Load drivers

Control pipe

Endpoint #7

Endpoint #12

Interface

Endpoint

Endpoint

Endpoint #0
USB device

Host side

USB device driver

Peripheral side

USB device

Endpoint

Interface

Endpoint

Interface

Endpoint

Interface

Endpoint

Pipes

Load drivers

USB System Software (USB driver)

Control pipe

Endpoint #0
USB descriptors

Device Descriptor
- Device ID,
- Vendor ID,
- Device Class, ...

Configuration Descriptor

String Descriptor

Configuration Descriptor

Configuration Descriptor

Configuration Descriptor

Configuration Descriptor

Configuration Descriptor

Configuration Descriptor

Configuration Descriptor

Configuration Descriptor

Interface Descriptor
- Interface Class Id, ...

Endpoint Descriptor

Endpoint Descriptor

Interface Descriptor

Interface Descriptor

Interface Descriptor
### Standard Device Descriptor

From USB 2.0 specification.

<table>
<thead>
<tr>
<th>Offset</th>
<th>Field</th>
<th>Size</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>bLength</td>
<td>1</td>
<td>Number</td>
<td>Size of this descriptor in bytes</td>
</tr>
<tr>
<td>1</td>
<td>bDescriptorType</td>
<td>1</td>
<td>Constant</td>
<td>DEVICE Descriptor Type</td>
</tr>
<tr>
<td>2</td>
<td>bcdUSB</td>
<td>2</td>
<td>BCD</td>
<td>USB Specification Release Number in Binary-Coded Decimal (i.e., 2.10 is 210H). This field identifies the release of the USB Specification with which the device and its descriptors are compliant.</td>
</tr>
<tr>
<td>4</td>
<td>bDeviceClass</td>
<td>1</td>
<td>Class</td>
<td>Class code (assigned by the USB-IF). If this field is reset to zero, each interface within a configuration specifies its own class information and the various interfaces operate independently. If this field is set to a value between 1 and FFH, the device supports different class specifications on different interfaces and the interfaces may not operate independently. This value identifies the class definition used for the aggregate interfaces. If this field is set to FFH, the device class is vendor-specific.</td>
</tr>
<tr>
<td>5</td>
<td>bDeviceSubClass</td>
<td>1</td>
<td>SubClass</td>
<td>Subclass code (assigned by the USB-IF). These codes are qualified by the value of the bDeviceClass field. If the bDeviceClass field is reset to zero, this field must also be reset to zero. If the bDeviceClass field is not set to FFH, all values are reserved for assignment by the USB-IF.</td>
</tr>
</tbody>
</table>
Composite device and host-side drivers (1)

Determined by Device ID, Device Class ID, etc.

USB device driver for the device as-a-whole

Load drivers

USB System Software (USB driver)

Control pipe

Composite device and host-side drivers (1)
Composite device and host-side drivers (2)

Determined by Interface ID, Interface Class ID, etc.

USB device driver for the interface A

USB device driver for the interface B

USB System Software (USB driver)

Load drivers

Control pipe

Host side

Peripheral side

USB device

Pipes

Endpoint #0

Interface A

Endpoint

Endpoint

Interface B

Endpoint

Endpoint
Design Goal of our Framework

• Common tasks among many USB devices are done in the framework.
  – Let framework users to focus on codes for functionality of interfaces they want to implement.

• The framework and interface implementation should be independent of the characteristic of USB client controllers.
Design Goal of our Framework

- Interfaces can be implemented either as
  - in-kernel device drivers, or
  - userland programs
Design Goal of our Framework

- A USB device implemented using this framework can “transform” into a different USB device without rebooting into another kernel binary.
  - Interfaces can be attached to/detached from the USB device on-the-fly.
Design Goal of our Framework

- USB Interface implementation can be used to make a simple USB device, or to form a composite device combined with other interface implementations.
components in the framework

- USBP
- Client controller drivers
- USB interface drivers
- Userland interface to USBP.
- Userland programs for USB interfaces.
components in the framework

Kernel space

USBP

I/F to USBP

Userland

USB interface implemented as a userland program.

read/write/ioctl

USB interface implemented as an in-kernel device driver

USB client controller driver

USB client controller

USBP
components in the framework

- **USBP**
  - logical driver for peripheral-side USB support.
  - handles USB protocol on control pipe, such as enumeration and configuration.
  - implements functionality of the USB devices
- **Client controller drivers**
  - there are many kind of client controllers
  - control send/receive of USB packets.
  - USBP and interface drivers access to the controller through a common interface.
components in the framework

- USB interface drivers
  - USB serial, communication device class, mass storage, human interface device, audio, video, etc.
- Userland interface to USBP.
  - in order to implement USB interface functionality as userland programs.
- Userland programs for USB interfaces.
Kernel configuration for peripheral-side support

in config(5)

pxaudc0 at obio0   # Client controller driver
usbp0 at pxaudc0   # USB Peripheral-side support
cdcef0 at usbp0    # CDC Ethernet model
upftdi0 at usbp0   # FTDI USB serial emulation
ucom* at upftdi?   # Userland gateway for USBP
usbpusr* at usbp?  # Userland gateway for USBP
Multiple interfaces and a composite device

Device tree in kernel

Implemented USB composite device
API for USB interface drivers

Note: the API is now being debugged and may be modified in the future. It is already modified from the version in my paper.

```c
usbd_status usbp_add_interface(
    struct usbp_device *device,
    const struct usbp_add_iface_request *request,
    const struct usbp_interface_methods *iface_methods,
    struct usbp_interface **interface);
```
struct usbp_add_iface_request

struct usbp_add_iface_request {
    struct usbp_device_info devinfo;
    struct usbp_interface_spec ispec;
    struct usbp_endpoint_request endpoints[];
};

- used to build the device descriptor
- characteristic of the interface
- type and directions of required endpoints
struct usbp_device_info

```c
struct usbp_device_info {
    int16_t class_id;  /* can be USBP_ID_UNSPECIFIED */
    uint8_t subclass_id;
    uint8_t protocol;
    int vendor_id;  /* can be USBP_ID_UNSPECIFIED */
    uint16_t product_id;
    uint16_t bcd_device;  /* device release number in BCD */
    const char *manufacturer_name;
    const char *product_name;
    const char *serial;  /* device's serial number */
};
```

- Used to build a device descriptor.
- If class_id is USBP_ID_UNSPECIFIED, the value from other interface or the default value is used.
struct usbp_interface_spec

• Used to build a interface descriptor, and to request endpoints to be used for the interface.
struct usbp_endpoint_request

struct usbp_endpoint_request {
    uint8_t dir;  /* UE_DIR_IN or UE_DIR_OUT*/
    uint8_t attributes; /* Transfer type: UE_ISOCHROMOUS,
                         UE_BULK,
                         UE_INTERRUPT */
    uint8_t epnum; /* endpoint number. recommended to set 0 */
    bool optional;
    u_int packetsize;
    /* need more for isochronous */
};

- request an endpoint for a interface.
- if the client controller can not provide the non-optional endpoint, the interface is not used.
- when epnum is 0, platform choose a suitable endpoint. You can explicitly specify endpoint number here, but it is not recommended.
struct usbp_interface_methods

{
 usbd_status (* configured)(
     struct usbp_interface *);
 usbd_status (* unconfigured)(
     struct usbp_interface *);
 usbd_status (* handle_device_request)(
     struct usbp_interface *,
     usb_device_request_t *,
     void **);
 usbd_status (* fixup_idesc)(
     struct usbp_interface *,
     usb_interface_descriptor_t *);
};

• callback methods from USBP to interface drivers.
• “configured” method is called when the interface is actually put in the device. In this method, the interface driver starts real task.
example sequence

Interface #1

Interface #2

USBP

kernel

attach

config_search, and
config_attach

attach

attach

usbp_add_interface

build a USB device

classified

open pipes, etc.
Other APIs

- usbp_delete_interface
- usbp_get_endpoint
- usbp_open_pipe
- usbd_alloc_xfer
- usbd_alloc_buffer
- usbd_free_xfer
- usbd_setup_xfer
- usbd_get_xfer_status
- usbd_transfer
- usbd_abort_pipe
- ....
Userland gateway

- /dev/usbp0/ctl
- /dev/usbp0/0, /dev/usbp0/1 … for endpoints.
- ioctl(USBP_IOC_ADDIFACE)
- ioctl(USBP_GETEP)
  - blocks until the interface is selected in the device.
- read/write on endpoint nodes.
Current implementation

https://github.com/bsh-git/netbsd-usb-peripheral.git
Comparison

• OpenBD
  – usbf(4)

• Linux
  – Gadget
  – http://www.linux-usb.org/gadget/
Demonstration

- FTDI USB serial adapter
- CDC Ethernet emulation (port of cdcef(4) of O)
- Umass in the userland (not working yet)
Future development

- Clean up the code, get reviewed, commit it into the codebase.
- More client controllers
- More interface drivers
- DMA support
- USB 2.0, 3.0
Questions?
Acknowledgement

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