Controlling EIB/KNX Devices from Linux using USB

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Introduction

Why USB?
Why Linux?
About the authors

Introduction

- About the authors
  - Jens Neumann & Vladimir Vinarski
    - Authors of the Open Source tool „Linux EIB Home Server“
      - See http://sourceforge.net/projects/eibcontrol
    - Participation in EMBASSI project
    - Affiliation: Loewe Opta Competence Center Hannover

  - Heinz Werntges
    - Teaches computer science at FH Wiesbaden since 2003
    - Background: Physics + commercial IT
    - New to EIB/KNX: First contact about 1 year ago
    - Motivation: Make EIB/KNX more popular and accessible, especially for the Linux community

Introduction

Konnex Association

KNX access via	Windows	Linux
RS.232	Available	Available
IP	Available	Available
USB	Available	Missing

Task:
Fill this gap!

Introduction

- Why USB instead of RS.232 ?
  - PC view:
    - RS.232 is „legacy hardware“, gets replaced
    - Notebook PCs: Rarely equipped with RS.232 anymore
  - EIB/KNX view:
    - RS.232 transmissions are slower than USB and are sometimes riddled with timing issues
    - Special FT1.2 protocol required
    - USB downside: USB adds complexity
  - Why not skip USB and go right for IP?
    - Cost issues

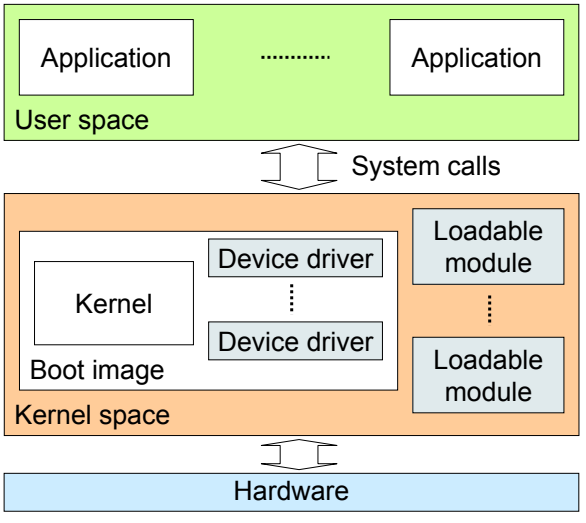
Introduction

- Why use Linux instead of Windows?
  - It is **Open Source**
    - Adapt it to your particular project‘s / product‘s needs
    - Well-established for (not-too-small) embedded systems
    - Royalty-free!
  - It is **powerful**
    - Suffices for most practical purposes
    - Real-time options available, strong on networks (IP !), …
    - Very reliable, good success record on servers
  - Because **it‘s there**…
    - Don‘t miss the Linux community and its many technology „addicts“
    - Well-established in academia, and …
    - … it is always good to have an alternative.

Background on Linux and USB

Background

- Linux: Kernel, device drivers, and modules



E.g., the **Linux EIB Home Server**

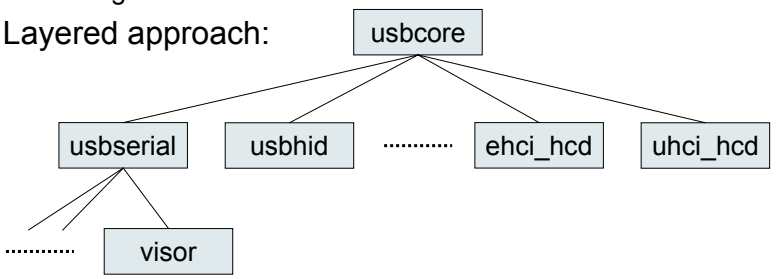
Q: How do we „talk“ to KNX devices?

Q: New module needed?

E.g., the **KNX USB Interface**

Background

- Linux: The USB module family
  - USB devices
    - Broad variety, both block and character devices
    - Kernel 2.6.12.1: **70** USB modules available
    - „Families“: **`atm, class, core, host, image, input, media, misc, mon, net, serial, storage`**
    - Plug-and-play option requires dynamic driver and device management
  - Layered approach:



The KNX USB Interface

The KNX USB Interface

- Specifications
  - AN037: KNX on USB
    - Protocol Specification & KNX USB Interface Device Requirements (2003.07.07)
  - AN070: USB adaptations (2005.03.17)
- Key features
  - **HID** class (HID = human interface device)
  - Interrupt transfer mode for data exchange, both in & out
  - Max. 64 octets of data per transfer
  - Reserved usage page ID: Non-standard control page
    - The multitude of KNX controls is not modelled with USB means; instead, KNX frames are tunneled through HID reports
  - New protocol for tunneling, different from FT1.2

The KNX USB Interface

- USB HID support by Linux
  - Based on **`usbcore`** module
  - Part of **`input`** module family
  - Specialized modules (e.g. for keyboard, mouse) available for popular usage page IDs
  - Generic module **`hiddev`** available for other page IDs
- **Result 1:**

  `hiddev` is the appropriate driver for KNX USB interfaces

  ➔ Modern Linux kernels already support KNX USB devices

  ➔ KNX USB programming may be restricted to user space

  (no new „KNX/USB“ kernel module needed!)

  Well – so far for the theory…

Device discovery

Device discovery

- What happens when you plug in a KNX USB device?
  - The USB core system exchanges control information
  - It adds the device to the list of connected USB devices
  - It assigns the appropriate driver (major device number)
  - It loads the required module(s) into the kernel
  - It issues an available minor device number

  ➔ **Device path determined!**

Device discovery

- Example for KNX USB interfaces
  - **`usbcore`** detects a generic HID → **`hiddev`** needed
  - Major device no = 180, minor device no = 96+x
  - x=0 if this is the first generic HID (x=1 if second, …)

  → Resulting device path is **`/dev/usb/hiddev0`**

- Alternative approach: **`usbdevfs`**
  - Ex: Second device on bus of first USB controller:
    `/proc/bus/usb/001/002`

  (Not used here)

Device discovery

- Information about USB devices
  - Selection by vendor ID and product ID
    - All devices on the USB bus can also be searched automatically
    - Device selection can be based on vendor & product ID when those are known *a priori*.
  - Tools
    - **`lsusb`** Lists device descriptors + bus topology
    - **`usbview`** X front-end, similar
    - **`lsmod`** Lists loaded modules, incl. USB modules

Device discovery

- **`lsusb`** output for a KNX USB device:

First 16 of 106 lines

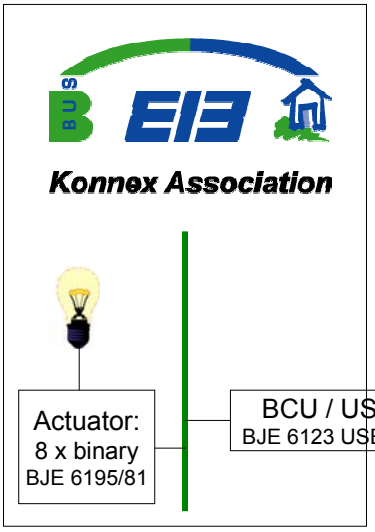
```
Bus 003 Device 002: ID 145c:1330
Device Descriptor:
  bLength                18
  bDescriptorType         1
  bcdUSB               1.01
  bDeviceClass            0 (Defined at Interface level)
  bDeviceSubClass         0
  bDeviceProtocol         0
  bMaxPacketSize0         8
  idVendor           0x145c
  idProduct          0x1330
  bcdDevice            1.01
  iManufacturer           1  Busch-Jaeger Elektro GmbH
  iProduct                2  KNX-USB Interface (Flush mounted)
  iSerial                 0
  bNumConfigurations      1
```

Use these parameters for device selection

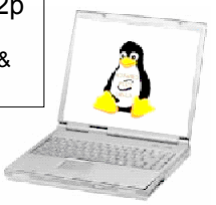
Test setup

Test setup

- Test equipment and procedure



IBM Thinkpad T42p
SuSE Linux 9.2
Kernels 2.6.8.14-24 &
2.6.12.1



Test sequences / reports:

1) ← **Device feature „get“ frame**
(Query supported EMI types)
2) → **Device feature „response“ frame**
3) ← **Device feature „set“ frame**
(Set active EMI type to EMI1)
4) ← **PC_SET_VAL.req**, tunnelled
(Activate Link Layer)
5) ← **L_DATA.req**, tunnelled
(Switch light on, group addr.=1/0/0)

Writing reports

Now that we know which device to open:
<u>How</u> do we write data to it?

<u>Three approaches:</u>

1) Windows (for comparison)
2) Linux, „libhid“
3) **Linux, standard** (system calls)

Writing reports

1) On Windows (for comparison)

- Device discovery
  - Complicated, based on vendor & product ID, well-documented, fixed procedure) → device handle
- Writing reports: Very simple – a single line!

```
WriteFile(handle, report_buffer,
                  64, &n_written, NULL);
```

Derived from Endpoint Descriptor (out):

```
wMaxPacketSize     0x0040  bytes 64 once
```


Writing reports

2) Linux, „libhid“ approach

- **Libhid**:
  - An Open Source library for accessing HIDs on Linux systems
  - Bypasses **`usbhid`** module by directly calling into **`usbcore`**
- Device discovery
  - By vendor ID and product ID + „path“ into the HID usage tree
- Writing reports
  - Convenient report exchange, similar to the Windows API

```
unsigned char const PATHLEN = 3;
int const PATH_OUT[] =
{ 0xffa00001, 0xffa00001, 0xffa10005 };
```

Usage page

Usage data

```
hid_set_output_report(
       handle, PATH_OUT, PATHLEN,
       report_buffer, 64);
```

Writing reports

3) Linux, standard approach

- Device discovery
  - Currently: Determine the device path manually
  - Obtain device handle from path:

```
hnd = open(device_path, O_RDWR );
```

- Expectation:
  - Initially, some special system calls **`ioctl()`**
  - Then, system call **`write()`** should suffice to send a report.
- Surprises:
  - System call **`write()`** *not* available
  - Hardly any documentation found!
  - Instead, rather obscure **`ioctl()`** system calls to transfer all report octets into a kernel buffer before sending the report

Writing reports

3) Linux, standard approach: Writing reports
a) KNX USB report data structure

```
struct HidReport{                          // 12 Byte header
   unsigned char  reportId;
   unsigned char  packetInfo;
   unsigned char  dataLength;
   unsigned char  protocolVersion;
   unsigned char  headerLength;
   unsigned char  bodyLengthHi;
   unsigned char  bodyLengthLo;
   unsigned char  protocolId;
   unsigned char  emiId;
   unsigned char  manufactureCodeHi;
   unsigned char  manufactureCodeLo;
   unsigned char  emiMessageCode;
   unsigned char  frame[52];           // max 52 octets remaining
} __attribute__((__packed__));
```

Item(Global): Report ID, data= [0x01]
1

Watch out for big-endian vs. little-endian processors!

See AN037!

Writing reports

3) Linux, standard approach: Writing reports
b) Transmission loop

```
int hidReportSend( HidReport *hidr, int hnd ) {
   signed char *report = (signed char *)hidr;
   struct hiddev_usage_ref   uref;
   struct hiddev_report_info rinfo;

   uref.report_type = HID_REPORT_TYPE_OUTPUT;
   uref.report_id   = *report++;
   uref.field_index = 0; uref.usage_code = 0xFFA10005;

   for( int uindex = 0; uindex < 63; uindex++ ) {
     uref.usage_index = uindex;
     uref.value = *report++;
     ioctl( hnd, HIDIOCSUSAGE, &uref );
   }
   rinfo.report_type = HID_REPORT_TYPE_OUTPUT;
   rinfo.report_id =  0x01;   rinfo.num_fields = 1;
   ioctl( hnd, HIDIOCSREPORT, &rinfo ); return 0;
}
```

Item(Global): Logical Minimum, data= [0x80] 128
Item(Global): Logical Maximum, data= [0x7f] 127

Special treatment of initial report_ID byte!

Item(Global): **Usage**, data= [0x05] 5 (null)

Item(Global): **Usage Page**, data= [0xa1 0xff] 65441 (null)

Item(Global): Report Count, data= [0x3f] 63

Reading reports

How do we receive data
from Konnex devices?

Reading reports

1) Windows (for comparison)
   - Single call („ReadFile“), similar to sending. Convenient

2) Linux, „libhid“ approach
   - Convenient report exchange, similar to the Windows API
   - Two alternatives (control transfers, interrupt transfers)

3) Linux, standard approach
   - Control transfers: Reports received bytewise, similar to sending
   - Interrupt transfers: Reports received through system call **`read()`**
     - Array of data structures which contain the desired report bytes
     - Three different data structures available, selectable through flags
     - Use e.g. separate thread to prevent blocking I/O

   Note: Some work left to be done here.

Results

Results

1) Windows (for comparison)
   - Worked as expected

Results	Call ok	Call error
Effect ok	++	-
No effect	-	-

2) Linux, „libhid“ approach
   - Kernel 2.6.8.14:
     - Non-reproducible results!

New:
     - Kernel reported timeout problems
     - Discussion with libhid authors:
       - Device timing ok?
       - Libhid: No outbound interrupt transfers

Results	Call ok	Call error
Effect ok	+	+
No effect	++	++

The libhid approach is currently NOT an option!

   - Kernel 2.6.12.1:
     - Calls always return ok, but without effect. Kernel: Timeouts!

Results	Call ok	Call error
Effect ok	--	--
No effect	++	--

Results

3) Linux, standard approach
   - Status of conference proceedings, end of July 2005:

Results	Call ok	Call error
Effect ok	-	-
No effect	++	-

→ Kernel debugging required!

   - **Breakthrough** on last Sunday:

Results	Call ok	Call error
Effect ok	++	-
No effect	-	-

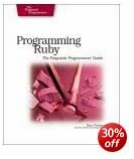
A user space driver is indeed all it takes to make Linux applications talk to KNX devices through a KNX USB interface!

Outlook

Outlook

- Upgrade of Linux/Windows **EIB Homeserver**
  - Will support also USB, both on Linux and Windows
  - Needs adaptation from FT1.2 to „AN037“ protocol
  - Current hardware requires downgrade from EMI2 to EMI1 format
    Note: Authors expected upgrade to cEMI format.

- Support for high-level programming languages like **Ruby**
  - API to KNX USB through extension modules (.dll, .so)
  - Foundation for efficient, high-level programming projects
    - User interfaces
    - Automation tasks



- Open Source **user space driver,** to be supplied on the Web
  - Some work left to be done for the **`read()`** system calls
  - See http://www.informatik.fh-wiesbaden.de/~werntges/proj

Outlook

- A personal vision
  - Low-cost, ubiquitous USB access to KNX systems
    - Maybe integrated into power supplies?
  - An open source „supplement“ to ETS3
    - Near-term goal: Change KNX installation parameters just with a PC and free software – no electrician or high-end panel involved.
    - Far-term goal: An Open Source, platform-independent tool for programming EIB/KNX systems in non-commercial environments
      - Skill requirements: High
      - Price: Low (free tool)
      - Convenience: Low
      - Productivity: Low

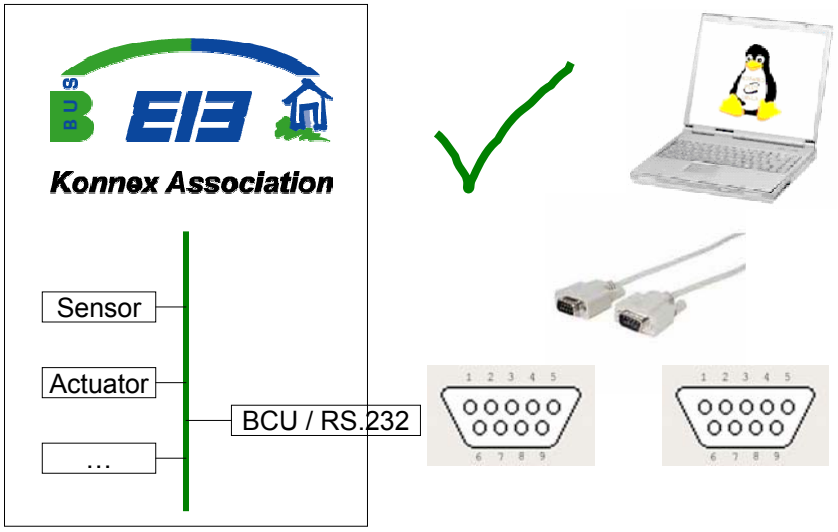
Let‘s offer something to the technical enthusiasts with good skills but low budget. We need those early adopters as „multiplies“!

Appendix

(Optional slides)

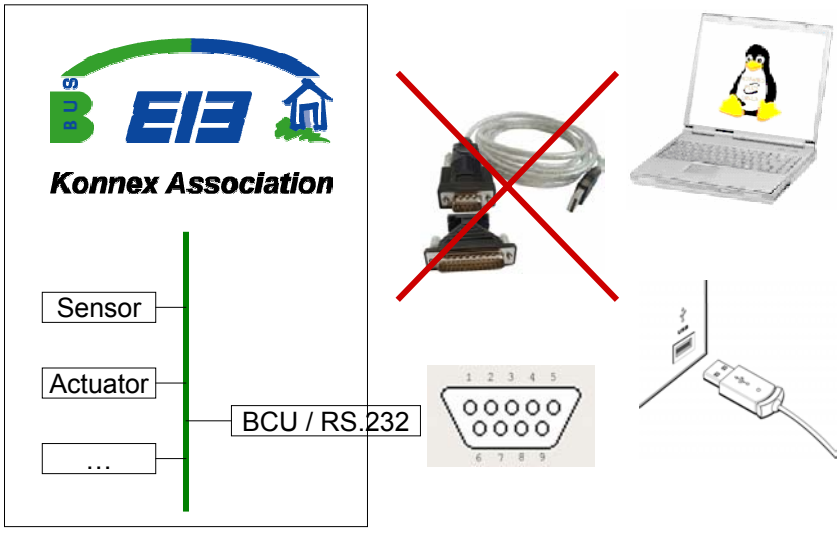
Introduction

- Situation before USB



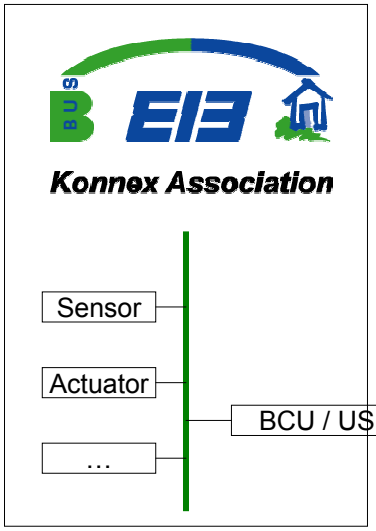
Introduction

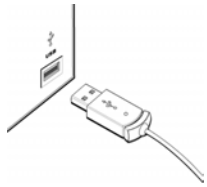
- Situation with USB (only at PC end)

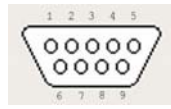


Introduction

- Situation with USB (only at KNX end)

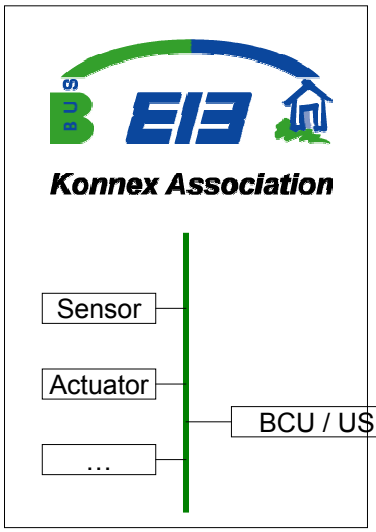


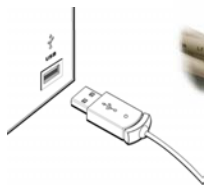




Introduction

- Situation with USB





Background

- Linux: Drivers, modules and devices
  - Kernel 2.6.12.1:
    - 1270 (!) modules in total
    - Most drivers may be either statically linked or dynamically loaded
  - Devices: Special files
    - Accessed as special files in the filesystem („everything is a file“)
    - Two types:
    - **Block devices**
      - Block is smallest access unit, random access
      - Ex: First IDE disk **`/dev/hda`**
    - **Char. devices**
      - Octet is smallest access unit; typically serial access
      - Ex: „COM1“ **`/dev/ttyS0`**
  - Note: One driver may serve multiple devices.

Background

- Linux: Drivers, modules and devices
  - Basic drivers are enumbered by the kernel
    - See „Major device no“ and **`/proc/devices`**
    - Ex: „180 usb“, „188 ttyUSB“
  - One driver/module can control multiple devices
    - See „Minor device no“ and `/proc/devices`
  - File system entries in **`/dev`** map filenames to device no‘s: