Industrial I/O subsystem of the Linux kernel

Practical examples from the OSADL QA Farm

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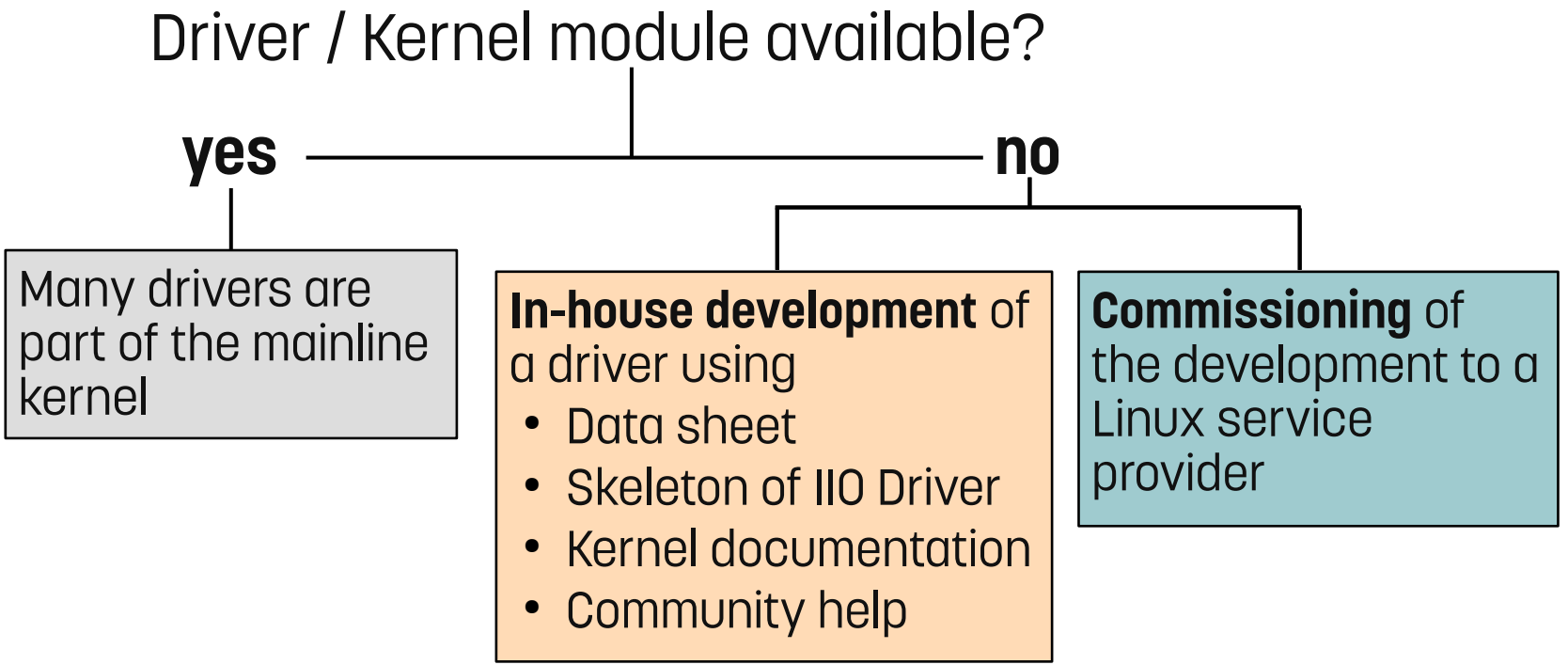
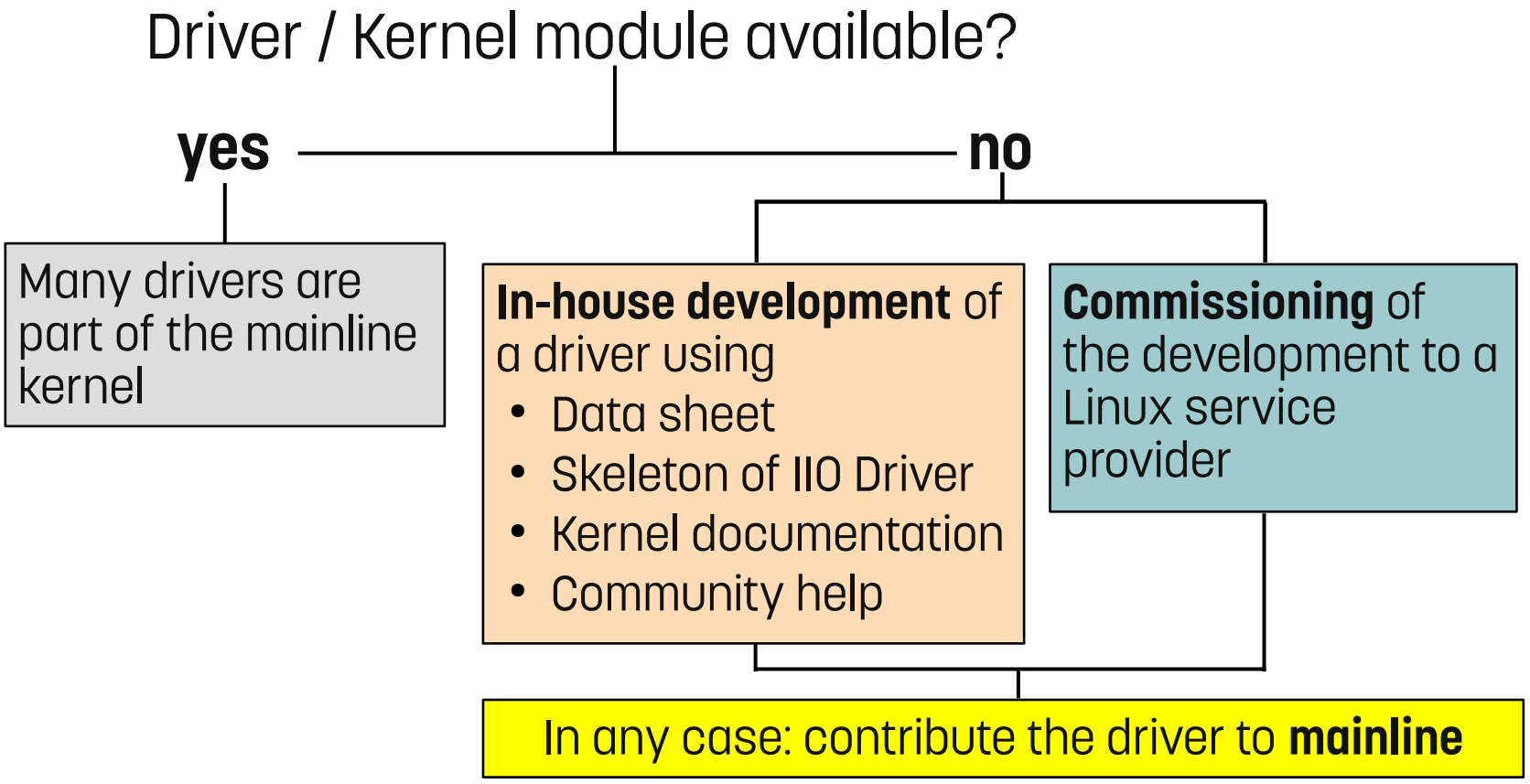
Integration of IIO-Devices



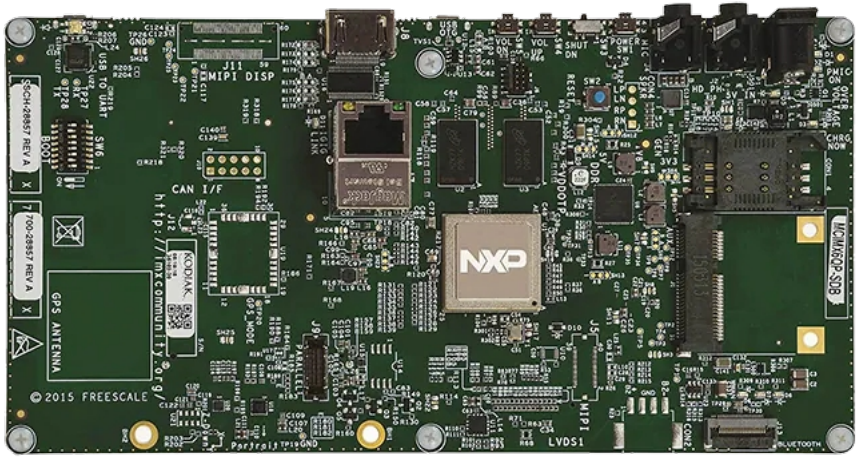
Integration of IIO-Devices



Integration of IIO-Devices

Hardware integration of the module/sensor to the system:

System: NXP imx6q



Sensor: MAG3110, (Three-Axis, Digital Magnetometer)

Integration of IIO-Devices

Software integration:

```
root@i2c:~# i2cdetect -y 2
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:                         -- -- -- -- -- -- 0e --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

Integration of IIO-Devices

Software integration:

```
root@i2c:~# i2cdetect -y 2
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:                         -- -- -- -- -- -- 0e --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
50: -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

Information on detected devices from

https://i2cdevices.org/addresses

here: 0x0e -> AK8975 - IST-8310 - MAG3110

Integration of IIO-Devices

Software integration:

```
root@i2c:~# i2cdetect -y 2
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:                         -- -- -- -- -- -- 0e --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
root@i2c:~# modprobe mag3110
```

Integration of IIO-Devices

Software integration:

```
root@i2c:~# i2cdetect -y 2
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:                         -- -- -- -- -- -- UU --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
50: -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
root@i2c:~# modprobe mag3110
root@i2c:~#
```

Device driver in use

Integration of IIO-Devices

Software integration:

```
root@i2c:~# lsiio -v
Device 001: mag3110
   in_magn_z_raw
   in_magn_x_raw
   in_temp_raw
   in_magn_y_raw

Device 000: mma8451
   in_accel_y_raw
   in_accel_z_raw
   in_accel_x_raw

Trigger 000: mma8451-dev0
```

Additional tools for integrating / testing

Name	Tool	Source
i2c-tools	i2cdetect i2cget i2cset i2cdump	Distro-package (i2c-tools, git)
Kernel tools	lsiio iio_event_monitor iio_generic_buffer	Kernel-Sources (tools/iio)
libiio	C/C++ library that provides generic access to Industrial Input Output (IIO) devices and built in bindings for Python, C#	Distro-packages (libiio, libiio-utils)
libiio-utils	iio_info iio_attr iio_reg iio_readdev iio_writedev	

Kernel config items for IIO

Recommendations (depending on the use case):

```
CONFIG_IIO=y
CONFIG_IIO_BUFFER=y
CONFIG_IIO_KFIFO_BUF=y
CONFIG_IIO_TRIGGERED_BUFFER=y
CONFIG_IIO_CONFIGFS=y
CONFIG_IIO_TRIGGER=y
CONFIG_IIO_SW_TRIGGER=y
CONFIG_IIO_TRIGGERED_EVENT=y
CONFIG_IIO_HRTIMER_TRIGGER=y
CONFIG_IIO_INTERRUPT_TRIGGER=y
CONFIG_IIO_SYSFS_TRIGGER=y
```

PREEMPT_RT and IIO – How they play together?

Verification of the real-time capability of the IIO subsystem in the Linux kernel:

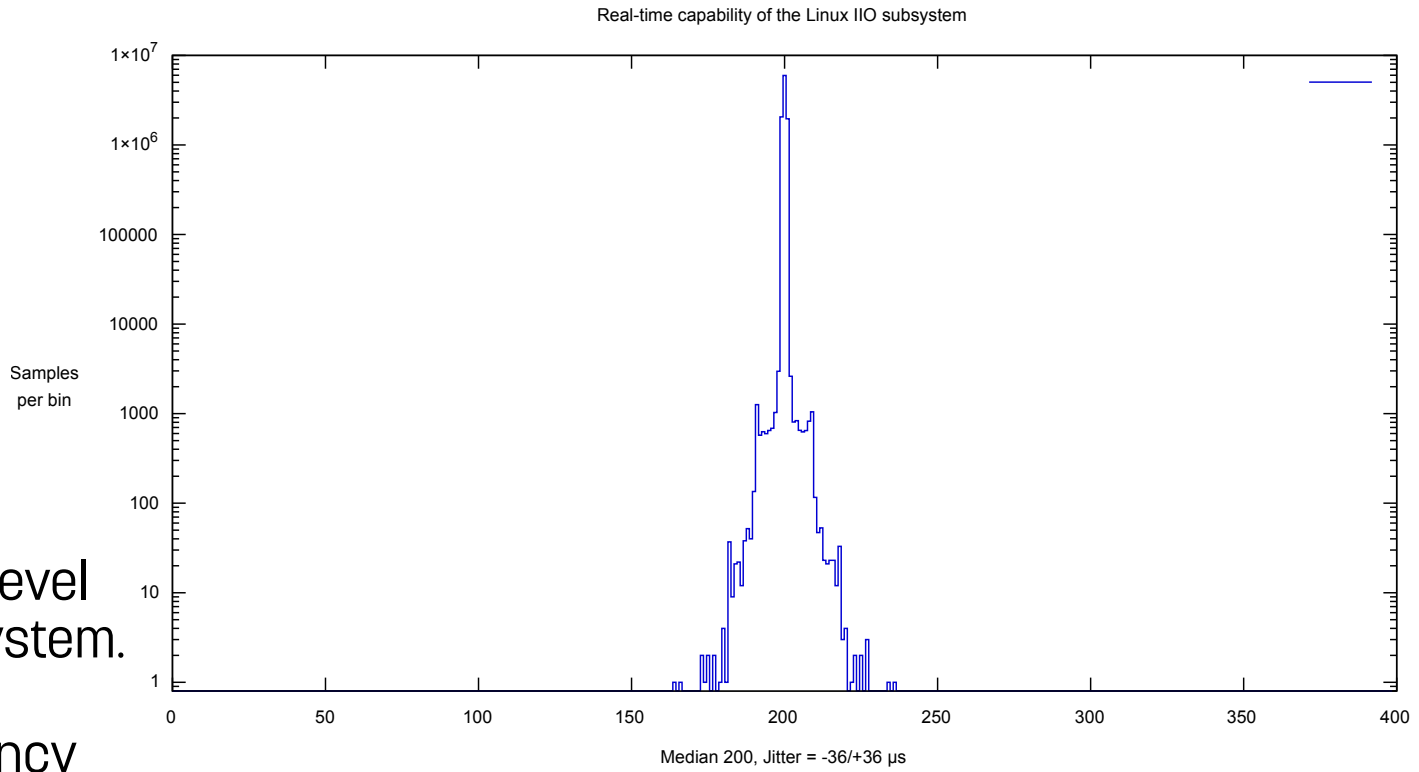
Setup and implementation:

- Use of the dummy-iio driver (to exclude the influence of external hardware)
- Use of hrtimer as trigger with 5 kHz (200 µs)
- Prioritization of the IRQ and the readout process
- Transfer data from the ringbuffer
- Recording the jitter at 10,000,000 readings/cycles
- Statistical analysis of the data and graphical representation with gnuplot

PREEMPT_RT and IIO – How they play together?

Statistical plot:

- Median 200
- Jitter +36/-36 µs



The jitter is of the same level as in cyclictest of this system. It is caused by the over-lapping of hardware latency and wakeup latency of the IRQ handler, verified by examining the latency histograms.

Conclusion

- For real-time data acquisition using the iio, it is necessary to determine the latencies from the sensor to the kernel- / userspace.
- IIO's clear and modular interface makes it an ideal framework for industrial sensors.
- Sensors can be easily integrated with the existing tooling.
- Buffer, Trigger, Event abstraction simplifies driver model.
- zLarge number of drivers are part of the mainline kernel.