Embedded Linux Conference Europe

OpenIoTSummit Europe

# A Sockets API For LoRa

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THE LINUX FOUNDATION

# About The Presenter

- Project Manager for arm64 architecture at SUSE Labs
- Involved in arm port of openSUSE Linux distribution
- Kernel maintainer for Realtek and Actions Semi arm SoCs
- Other kernel projects you might know:
  - Odroid-XU, Parallella, Spring Chromebook, GeekBox, …
  - STM32F4, FM4, XMC4500; S905, IAP140, MB86S71, RDA8810PL
- Background in virtualization technologies – QEMU

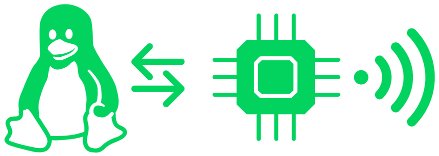
# Why LoRa Technology?

- LoRa = **Long Range** – radio modulation by Semtech
  - https://archive.fosdem.org/2018/schedule/event/sdr_lora_aes/
- Low-Power Wide Area Network (**LPWAN**) with low throughput
- Unlicensed **sub-GHz** and 2.4 GHz ISM/SRD bands (U-LPWA)
- No dependency on network infrastructure providers
- Wide availability of HW – https://en.opensuse.org/HCL:LoRa
- … and just because it’s possible!

# Getting Started With LoRa Chipsets

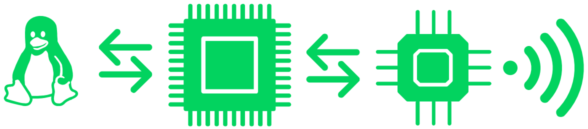
… and down the rabbithole it goes!

# Types Of LoRa Radio Modules



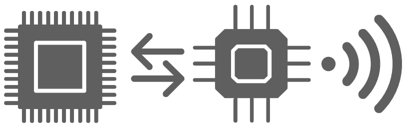
**Plain transceiver**

- SPI / UART / USB
- Volatile register settings
- Software MAC needed



**MCU w/firmware + transceiver**

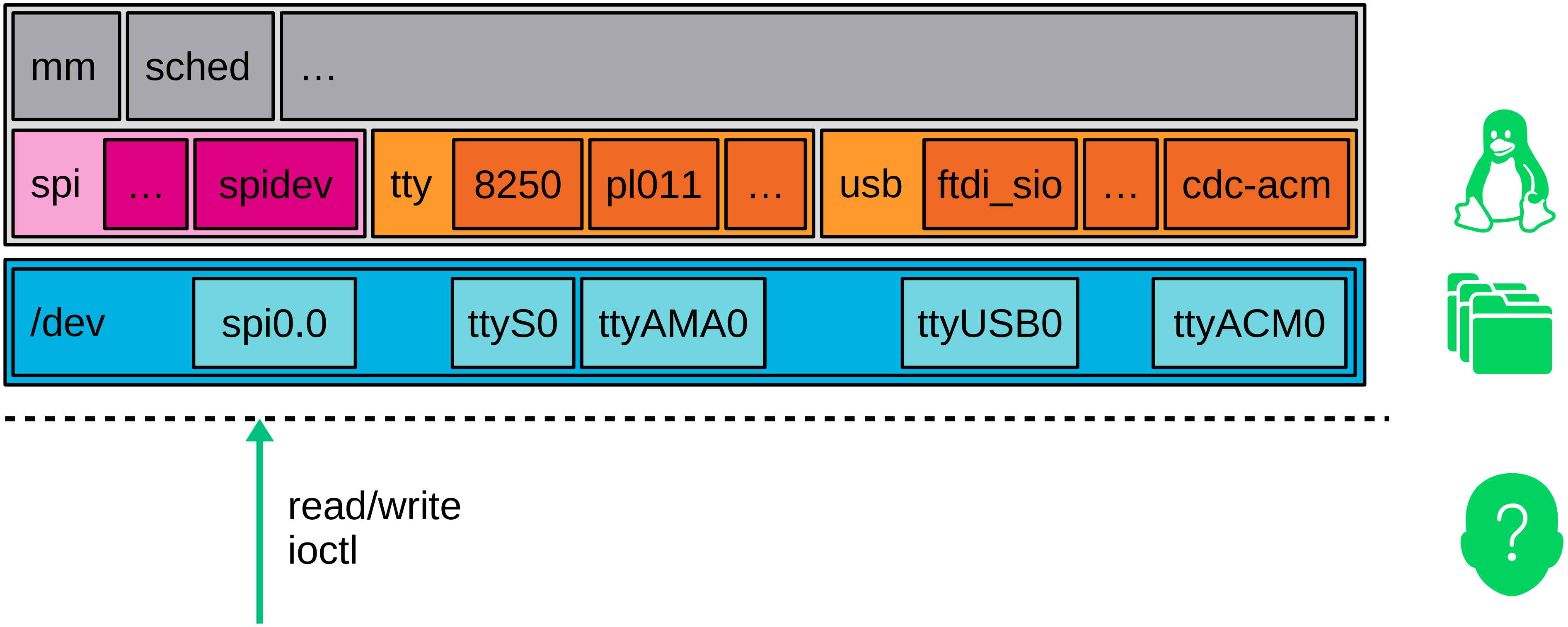
- UART / USB Serial
- Firmware determines chip features exposed
- Optional certified MAC



**Plain MCU + transceiver**

- n/a – no fixed API
- Custom MCU code for sending / receiving
- Optional MAC

# Accessing LoRa Hardware Today



# Issues With LoRa Open Source Software Today

- No upstream community – per-vendor application forks
- Software license incompatibilities
- Use of spidev kernel module gets ugly in distros
- Hardware detection duplicated into applications

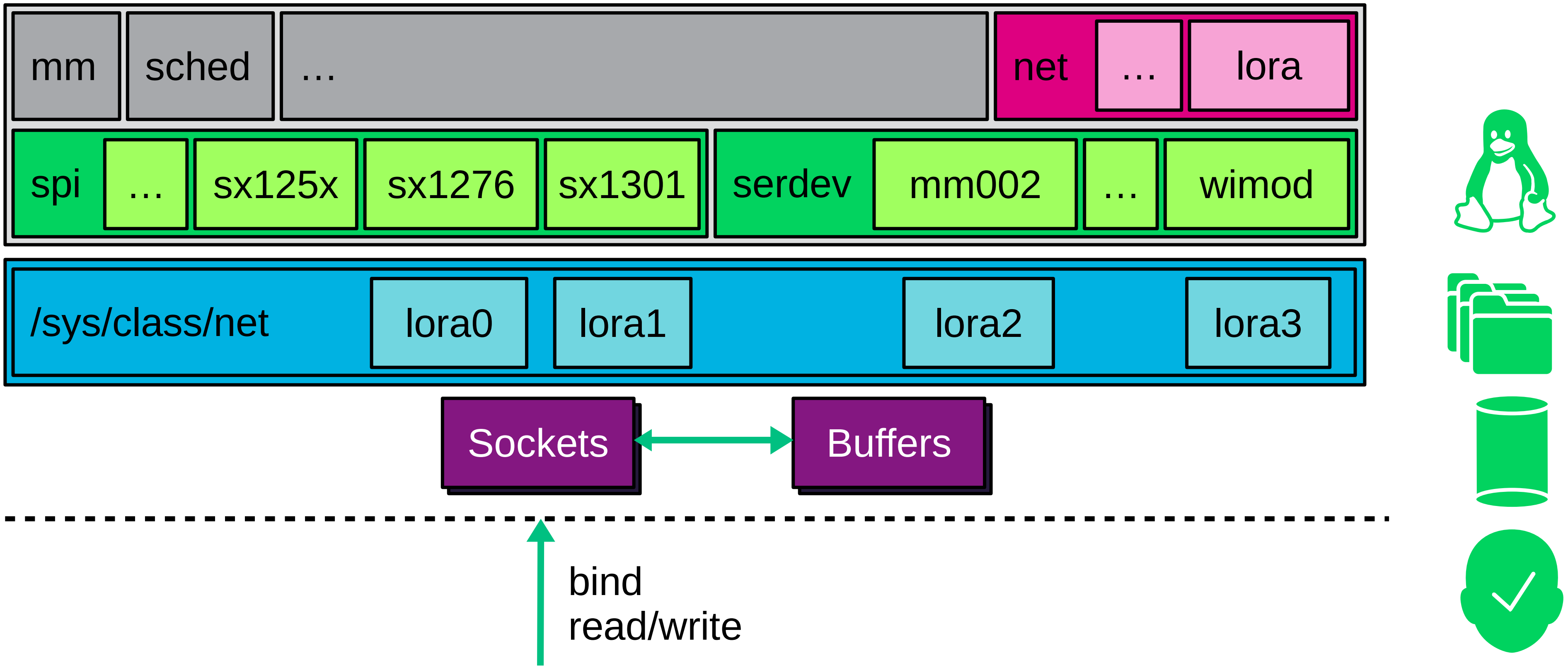
**Idea:** Move chipset drivers into mainline Linux kernel.
Encourage generic, community-maintained packet forwarders.

# Collecting Requirements

- Shall expose equivalent chipset features as before
- Shall allow implementation of proprietary protocols
- Shall allow reuse of protocols layered on top
- Shall fit all Semtech chipsets and many third-party modules

**Idea:** Sockets seem an intriguing approach for LoRaWAN.
Similarities to Wifi and IEEE 802.15.4 may help users.

# Andreas In Wonderland – Sockets (Proposed)



# Semtech SX1272 f. / SX1276 ff. Transceivers

- Single channel
- Two modes: FSK/OOK and LoRa (switchable via Sleep mode)
- State machine for RX vs. TX (switchable via Standby)
- SPI register interface
- 256 byte RAM data buffer (LoRa) / 64 byte FIFO (FSK)

# Semtech SX1261 f. / SX1268 Transceivers

- Single channel
- Two modes: LoRa and FSK
- State machine for RX vs. TX (switchable via Standby RC/XOSC)
- SPI command interface, indirect register interface
- 256 byte RAM data buffer

# Semtech SX1280 f. Transceivers

- Single channel
- Multiple modes: LoRa, FLRC, FSK, BLE and Ranging
- State machine for RX vs. TX (switchable via Standby RC/XOSC)
- UART and SPI command interface, indirect register interface
- 256 byte RAM data buffer

# Semtech SX1301 / SX1308 Concentrators

- Multi-channel
- IF0-7 LoRa channels, IF8 LoRa uplink channel, IF9 FSK channel
- Two radio transceivers (SPI/ADC) – SX1255 / SX1257 f.
- SPI register interface – no documentation, only reference code
- 1024 byte data buffer
- Firmware blobs for calibration and operation

# LoRa Modules With UART Interface

- The serial device bus allows to attach drivers to tty device
  - Child node of UART in Device Tree
- Callback for reception – might be individual bytes or chunks
- API for sending available
- “AT command” interfaces are not standardized
- Binary interfaces encountered, too
- Interrupts plus active reception, or asynchronous notifications

# Unsolved: USB Based Serial Protocols

- Problem: usb-serial devices don't have an of_node associated
  - Proposal by Johan Hovold disliked by Rob Herring
- Problem: How to tell a USB device which serdev driver to use?
  - DT: via usb<vid>,<pid>?
  - ACPI: overload tables via command line?
- Problem: How to deal with hot-plug and changing ports?
  - Derive USB drivers? Use line discipline?

# Socket Addressing For Radios

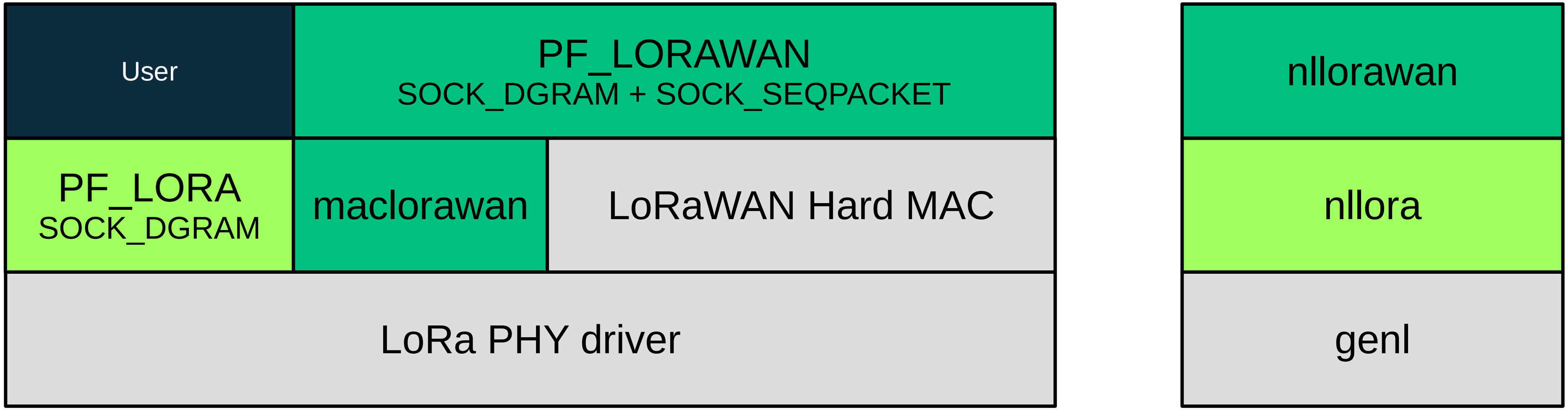
- Transmission is broadcast
  - Addressing only at MAC layer
- Preamble may serve to recognize frame start, not “metadata”
- Optional filtering by Sync Word

**Idea:** Define address as radio properties that allow reception.
(An alternative following later.)

# LoRa Socket Address (Proposed)

- Network interface index
- Radio frequency
- Spreading Factor
- Bandwidth
- Sync Word (1 Byte)

# LoRa Socket Layers (Proposed)



# LoRaWAN Socket Address (Proposed)

- Network interface index
- Data Rate
  - LoRa: channel frequency, SF, bandwidth
  - FSK: channel frequency, bandwidth
- Port

Data Rate implies a fixed LoRa / FSK Sync Word respectively.

# PHY Management Via Generic Netlink (Proposed)

- Socket based command protocol (genl)
- Example: querying frequency of (channel on) device
  - Needs to work for all chipsets and modules
  - Attributes can be added to refine, e.g. channel for SX130x
- TBD: Don’t rely on loraX interface, think of SDR
- Distinction between Device Tree (physical) and NL (config)

# LoRaWAN Management Via Netlink (Proposed)

- Similar, but one level higher
  - Implementation might delegate to PHY netlink interface or translate to AT commands directly, depending on device
- Examples: Data Rate, Join

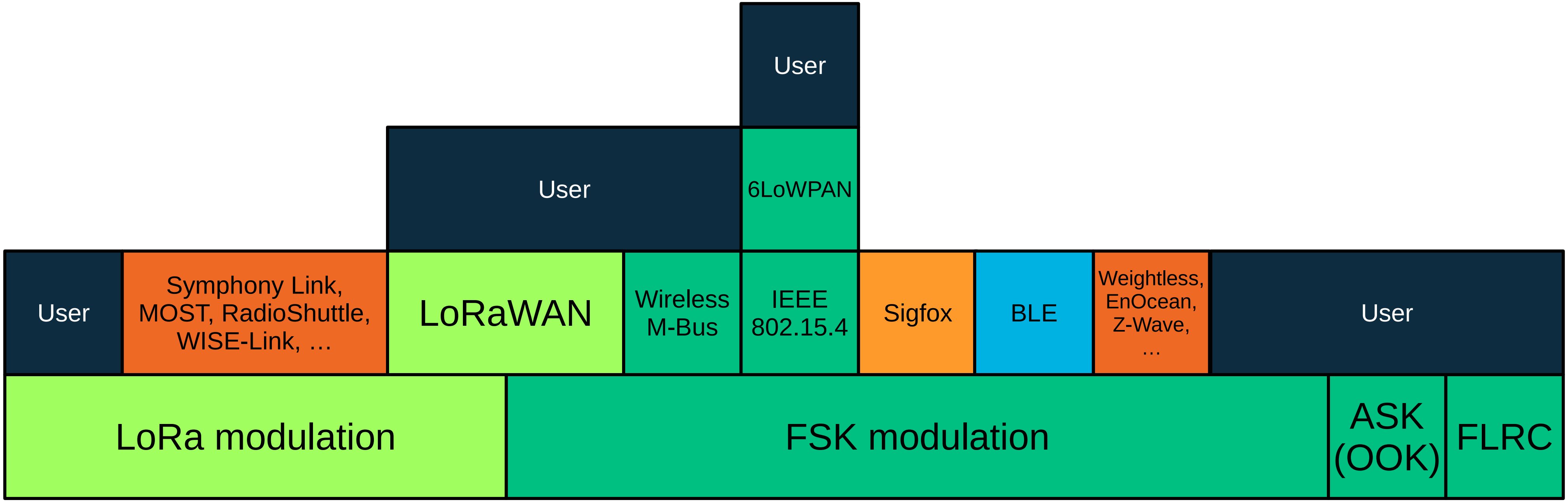
# Regulatory Compliance

- wireless-regdb does not cover sub-GHz frequency bands yet
- With SX128x entering 2.4 GHz realm, reuse seems sensible
- Examples: Transmit power limitation in EU, duty-cycle limit
- Plan: Provide configuration commands in nllora that userspace tools could use to change individual settings

# Listening Can Be Hard

- Packets can be **transmitted** with different modes and settings
- Sockets require to **receive** whenever we’re not transmitting
  - How to detect and handle conflicting settings for reception?
  - When socket is opened, all settings need to have been initialized
- There’s no unified frame format field to **detect** MAC protocols
  - Need to try to parse incoming frames for each protocol

# Protocol Layers Around LoRa



# Frequency-Shift Keying (FSK)

- Address: frequency, sync word (multi-byte), Gauss …

- Also found in: nRF24L01+, CC1120, MRF89XAM8A, SP1ML

# On/Off-Keying (Amplitude-Shift Keying)

- Address: frequency, …
- Also found in: CC1120, MRF89XAM8A

# Fighting Pollution: Unified Radio Sockets?

- Can we avoid a socket address for each modulation?
- Use generic **PF_PACKET** + SOCK_DGRAM + htons(ETH_P_…)?
  - Would not allow radio configuration via socket address
  - Would still allow SOCK_RAW for Software Defined Radio
  - How could we switch modes or detect conflicts? Socket options?

# Related: Bluetooth LE Support

- Semtech SX128x: alternative mode
- AppconWireless RF1276TS, Laird RM1xx: separate antenna
- Kernel appears to rely on **HCI** – what to do about raw PDUs?

# Test Setup For LoRa Kernel Drivers (1/2)

- arm, arm64 and mips Single Board Computers
- Shield / HAT / Click / XBee expansion boards or flying wires
- Relevant chipsets being tested before pushing to linux-lora.git
  - Limitations: 868 MHz and 433 MHz (EU), donated hardware
- Idea: interoperability and co-existence testing
  - Not fully automated Continuous Integration (yet)

# Test Setup For LoRa Kernel Drivers (2/2)

- mips: lora-next branch (based on linux-next)
  - .dts modified
- arm(64): openSUSE Tumbleweed + Kernel:HEAD repo (-rcX)
  - Build modules against host kernels, with tricks for new defines
  - DT Overlays via U-Boot where possible
- https://github.com/afaerber/lora-modules

# Action Plan

- Working towards RFC v2 – need to complete regmap adoption
  - Staging branch to be archived and squashed into series
- On top: LoRaWAN soft MAC patch series by Jian-Hong Pan
  - Cf. https://www.slideshare.net/chienhungpan/lorawan-class-module-and-subsystem
- Validate / evolve **ABI** design – needs testing and feedback
- Merge into mainline kernel, enable in openSUSE Tumbleweed

# Credits

# Industry Contributors – Code

Laird™

# Industry Supporters – Hardware

AppconWireless

DRAGINO

Embedded
MICRO TECHNOLOGY

Gimasi

HELTEC™
AUTOMATION

IMST

Laird™

MIPOT
HI-TECH COMPANY

NEMEUS

n|fuse

# Competing LPWAN Technologies

# Other U-LPWAN: Sigfox

- Frequency: Unlicensed sub-GHz SRD/ISM bands
- MTU: 12 bytes uplink, 8 bytes downlink

- Why care? Found in Nemeus MM002-L**S** modules
  - How to expose? Device? PF_SIGFOX? lora0 + sigfox0?
  - How to interact with LoRa sockets?

# Other LPWAN: NB-IoT

- Frequency: Licensed 3GPP bands
- MTU: 1500 bytes
- Two modes: UDP and non-IP
- SIM card needed

How to handle in Linux?

# Conclusions

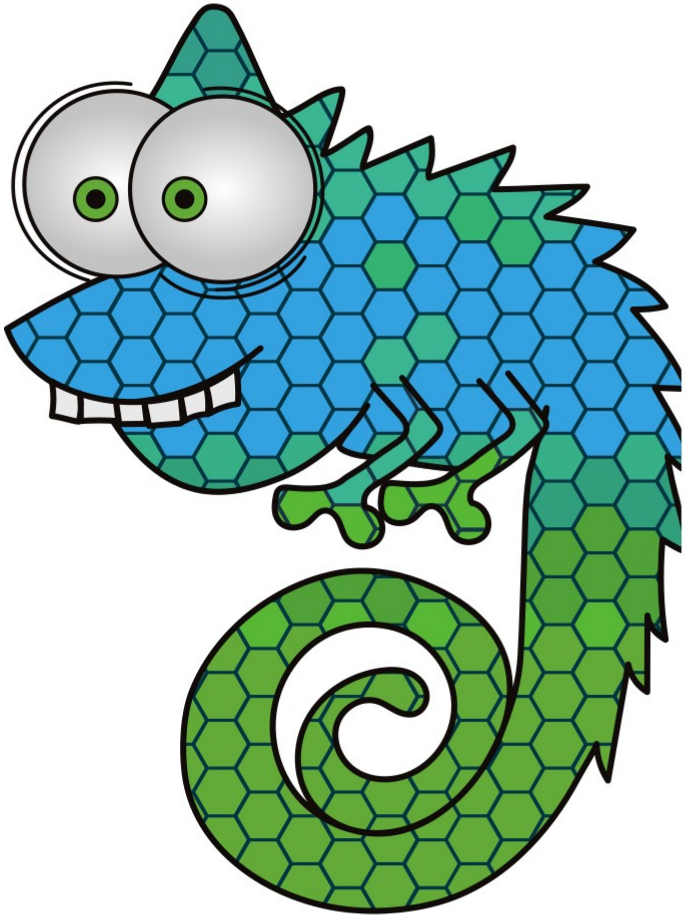
# Summary

- PoC for LoRa sockets & SX1276 Tx has been implemented
- No clear solution for USB adapters / mPCIe cards found yet
- Not a technology endorsement by openSUSE or SUSE

# Resources

- RFC patch series: https://patchwork.ozlabs.org/cover/937545/
- Staging tree with lora-next branch: https://git.kernel.org/pub/scm/linux/kernel/git/afaerber/linux-lora.git/
- Testing hints: https://github.com/afaerber/lora-modules
- Chipset overview and links to SBC expansion boards: https://en.opensuse.org/HCL:LoRa

# Questions? Feedback?



# Join Us at www.opensuse.org

# Backup

# Radio Modulation Types Of Other Technologies

- MIOTY: Lfour: BPSK; TS-UNB: GMSK; DD-UNB: BFSK
- Sigfox: D-BPSK and GFSK
- Weightless-P: GMSK BT=0.3 or OQPSK
- Wireless M-Bus: 4GFSK

- Bluetooth LE: GFSK (2.4 GHz)

## General Disclaimer



## Credits

**Template**
Richard Brown
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**Design & Inspiration**
openSUSE Design Team
http://opensuse.github.io/branding-guidelines/

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