



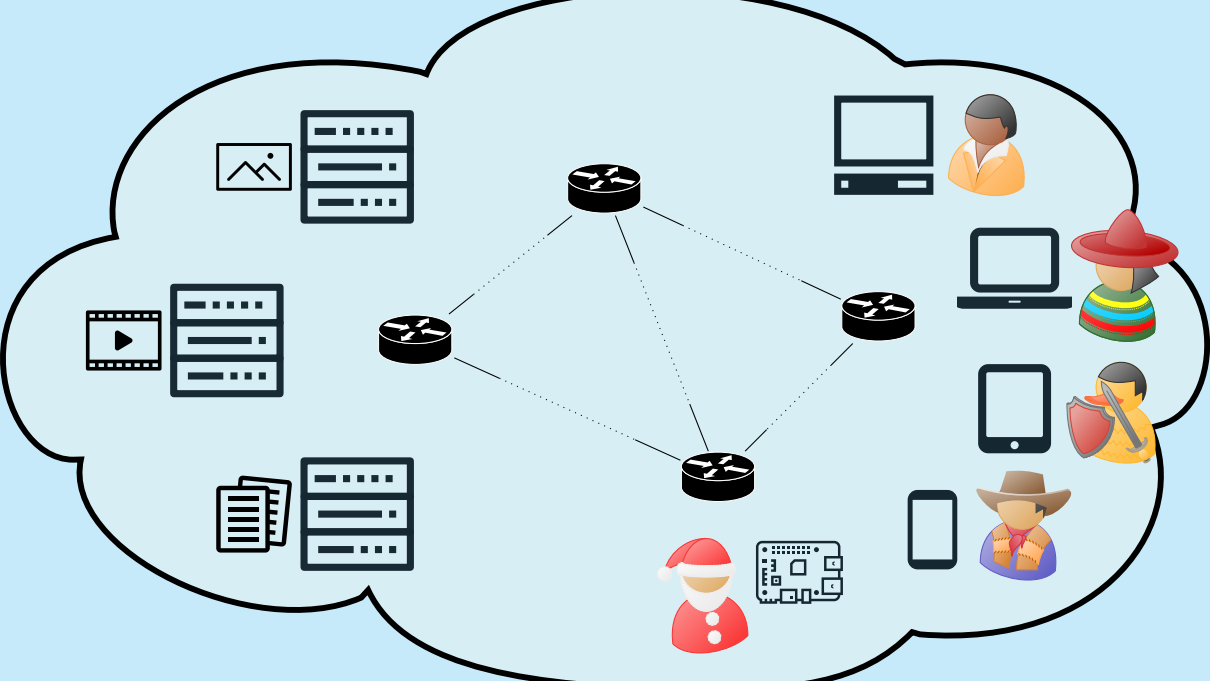
Interconnecting the IoT

IEEE World Forum on IoT
Limerick, Ireland

Cenk Gündoğan
cenk.guendogan@haw-hamburg.de

On Behalf of the RIOT Community

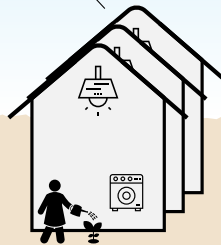
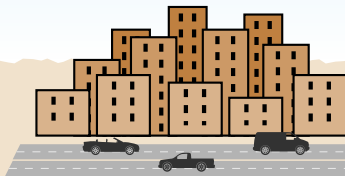
April 17, 2019





The Internet

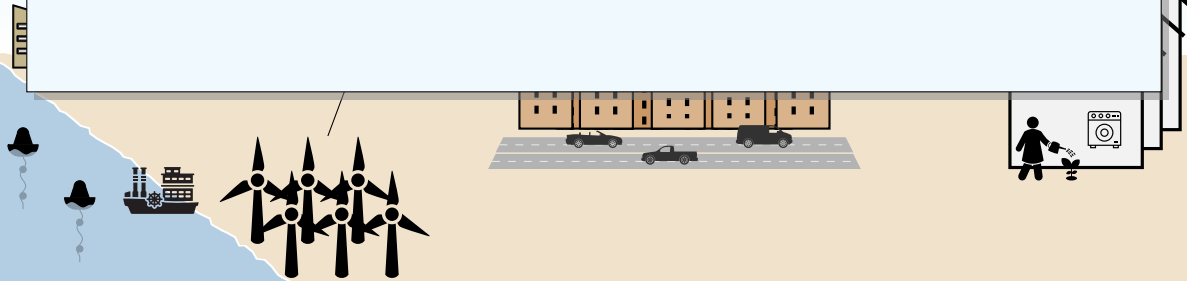
10 billion devices by 2020, 22 billion devices by 2025



The Internet

10 billion devices by 2020 22 billion devices by 2025

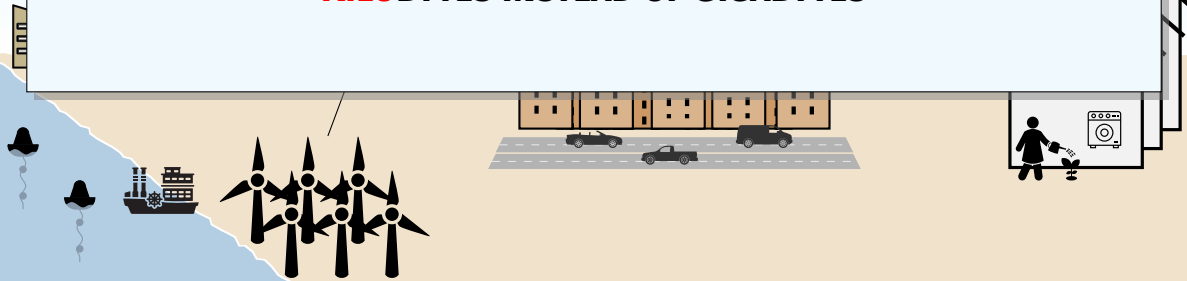
**FOSTER A TRANSPARENT, ROBUST, SECURE IOT:
SOFTWARE BIG BANG & REUSABLE COMPONENTS**



The Internet

10 billion devices by 2020 22 billion devices by 2025

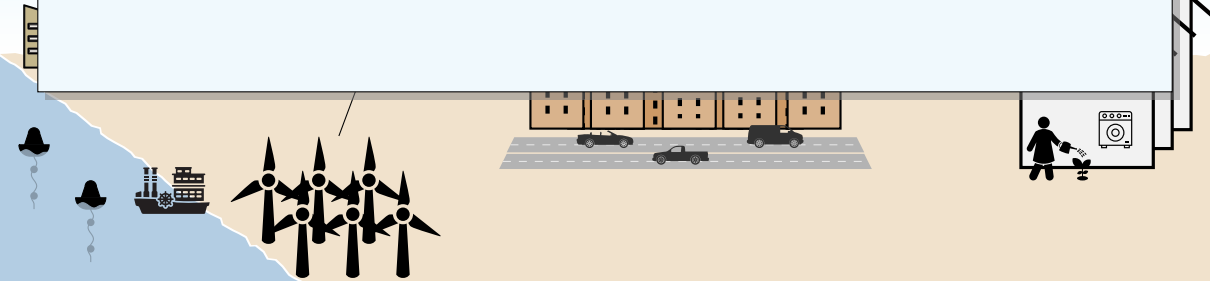
MILLIWATT INSTEAD OF WATT
MEGAHERTZ INSTEAD OF GIGAHERTZ
KILOBYTES INSTEAD OF GIGABYTES



The Internet

10 billion devices by 2020 22 billion devices by 2025

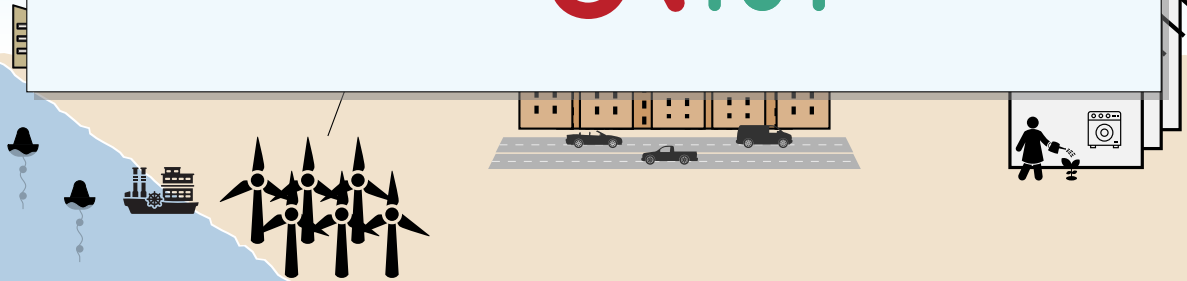
IF YOU CAN'T RUN LINUX ...



The Internet

10 billion devices by 2020 22 billion devices by 2025

...RUN RIOT



RIOT—The Friendly Operating System for the IoT

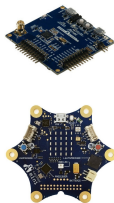
- ▶ Free, open source operating system for the IoT
- ▶ Small memory footprint (≈ 1.5 kB RAM, ≈ 5 kB ROM)
- ▶ Hardware abstraction
- ▶ Full featured, expendable network stacks

Design Principles

- ▶ **Adaptive:** High modularity and easy tailoring
- ▶ **Robust:** Module-level error handling
- ▶ **Energy efficient:** Tickless scheduler
- ▶ **Instinctive:** Preemptive multi-threading & powerful IPC
- ▶ **Real-time capable:** Deterministic $\mathcal{O}(1)$ scheduling
- ▶ **Reactive:** Low latency interrupt handling

Supported Platforms

- ▶ Vendor independent support: TI, NXP, STM, Nordic, Atmel, Silicon Labs, ESP
- ▶ Runs on various 8-bit, 16-bit, 32-bit platforms
- ▶ 8-bit: AVR8
- ▶ 16-bit: MSP430
- ▶ 32-bit: MIPS, PIC32, ARM7, x86, Cortex-M, RISC-V, ESP
- ▶ Over 130 boards supported

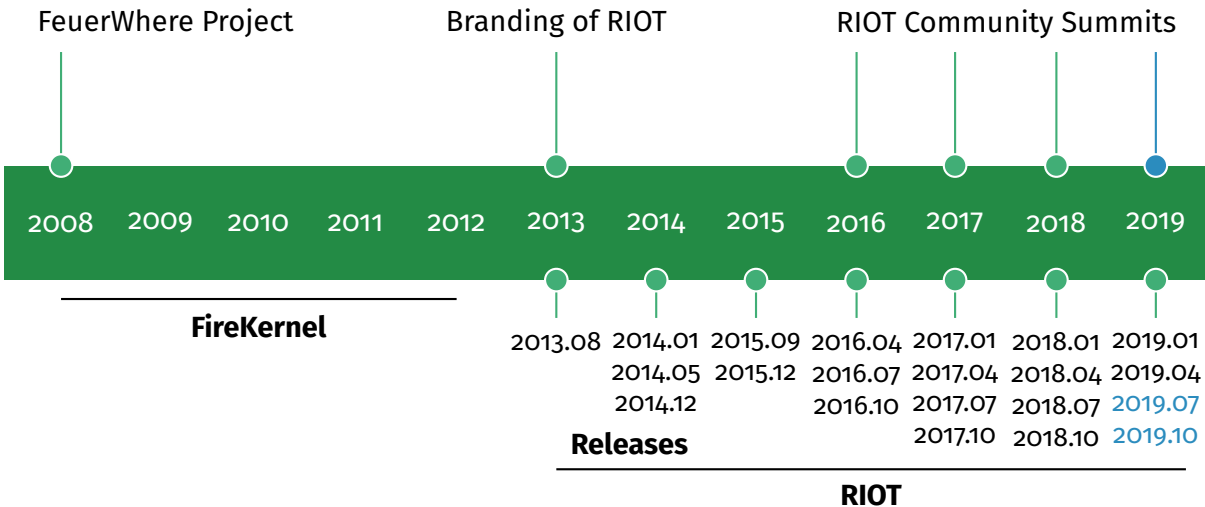


Supported Connectivity Technologies

- ▶ Wireless Personal Area Networks (WPANs)
 - ▶ IEEE 802.15.4(e)
 - ▶ Bluetooth Low Energy (BLE)
 - ▶ Near Field Communication (NFC)
- ▶ Local Area Networks (LANs)
 - ▶ Ethernet
 - ▶ Wi-Fi
 - ▶ CAN Bus
- ▶ Cellular Technologies (ongoing)
 - ▶ 2G, 3G, 4G
 - ▶ NB-IoT & LTE-M
- ▶ Long-range Technologies
 - ▶ LoRa
 - ▶ SigFox



History of RIOT



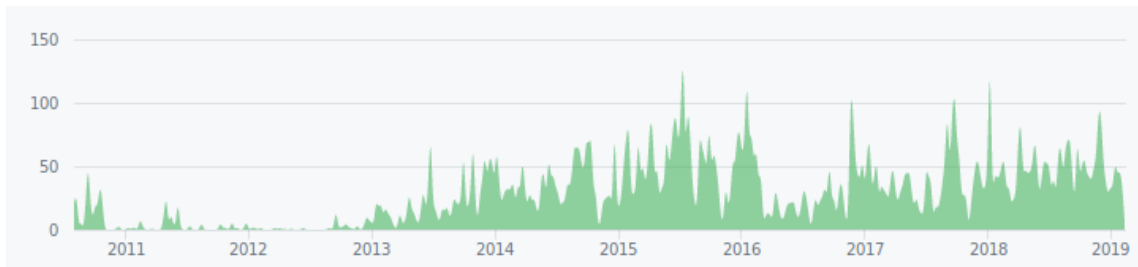
Open Source Community

- ▶ RIOT core distributed with non-viral copyleft license (LGPLv2.1)
- ▶ Source code and community maintenance on GitHub
- ▶ Maintainer team of ≈ 30 people, larger number of contributors
- ▶ 210 contributors worldwide from academia, industry, hobbyist background
- ▶ More than 1200 forks & over 20000 commits in code base
- ▶ ≈ 170 new pull requests per month
- ▶ Self-organizing community with rough consensus decision-making (c.f. IETF)
- ▶ *Bazaar*¹ model: development and discussions in public

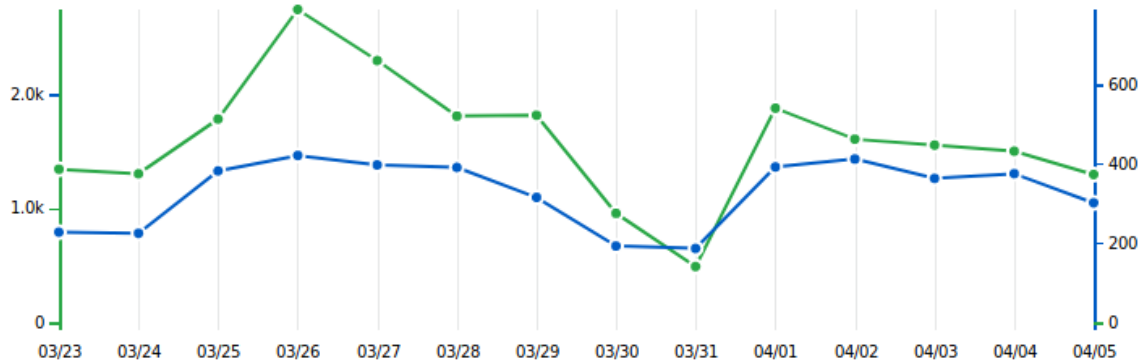
¹The Cathedral and the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary, Eric S. Raymond

Github Statistics—Contributions Activity

- ▶ Increased contributions activity since 2013
- ▶ Fast-paced progression for 6 years without interruptions



Github Statistics—Views & Unique Visitors



22,374

Views

3,751

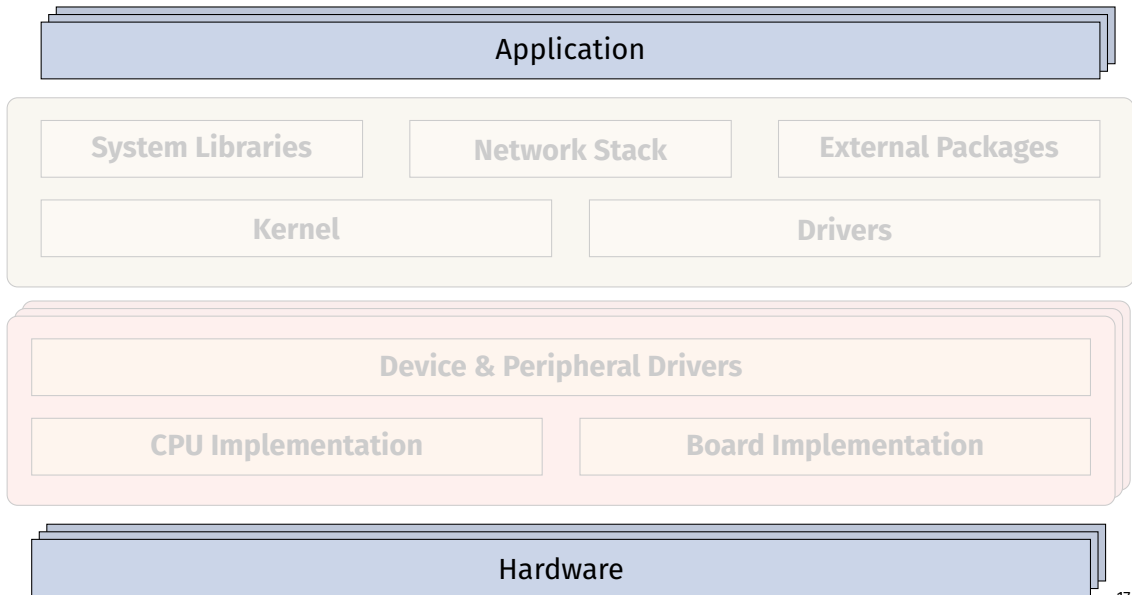
Unique visitors

Easy Development & Code Portability

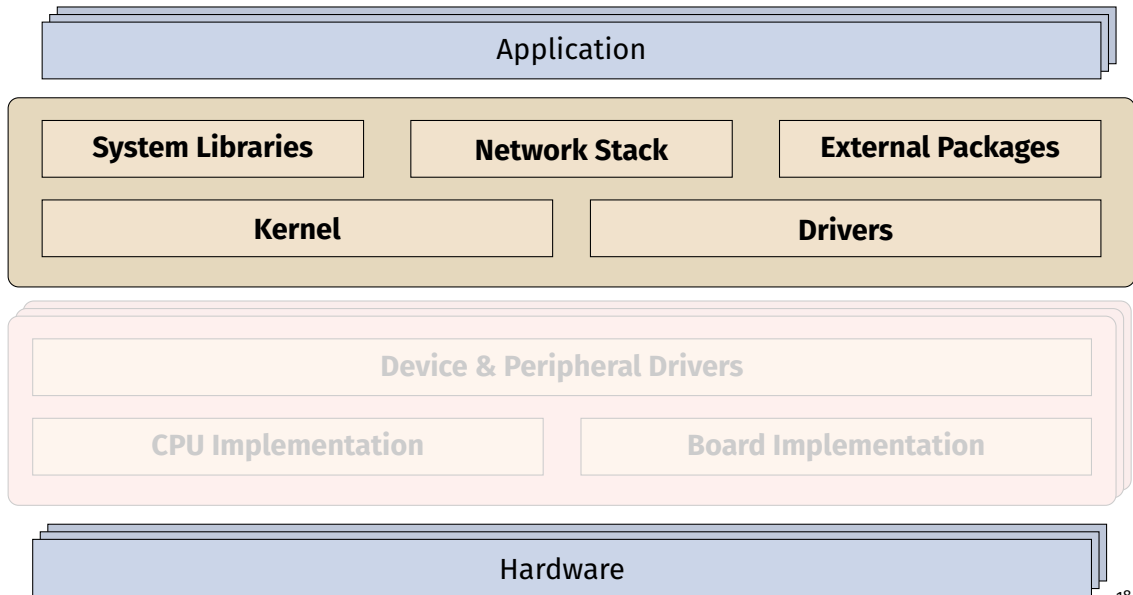
- ▶ Compliant to widely used POSIX features, such as pthread and sockets
- ▶ Standard development & debugging tools, such as gcc, clang, gdb, valgrind
- ▶ Fast feedback & rapid iteration: deploy RIOT as a Linux process
- ▶ Recommended programming language: ANSI-C
- ▶ Support for C++, Arduino Sketches, partial support for scripting languages

```
1  struct sockaddr_in6 dst = { .sin6_family = AF_INET6 };
2  uint16_t port = 8888;
3  int s;
4  ...
5  s = socket(AF_INET6, SOCK_DGRAM, IPPROTO_UDP);
6  sendto(s, data, data_len, 0, (struct sockaddr *)&dst, sizeof(dst))
7  ...
```

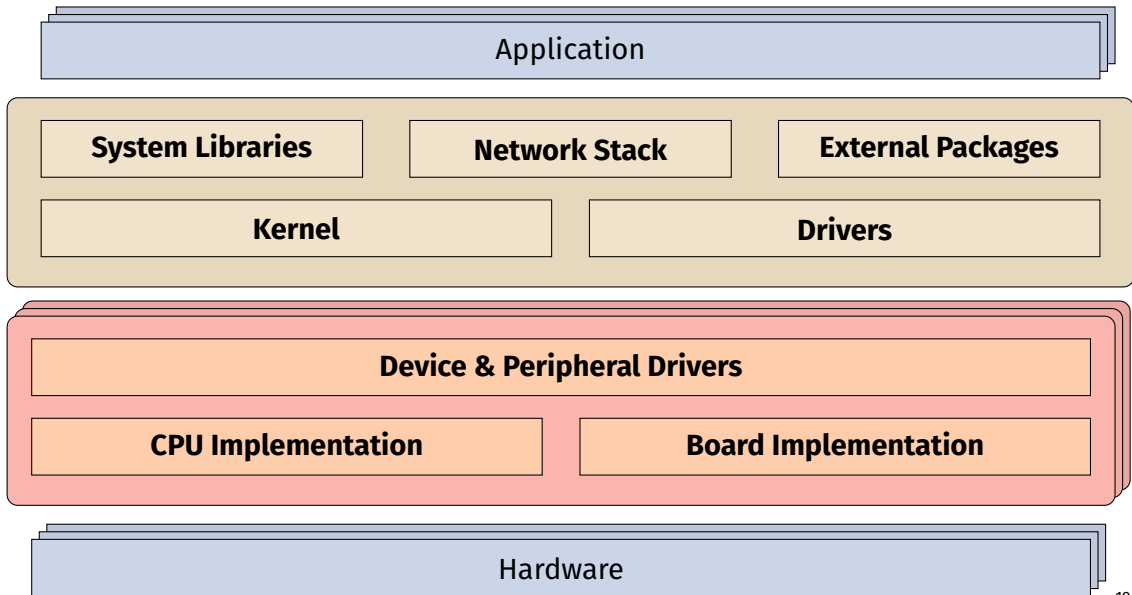
Hardware & Software Abstraction



Hardware & Software Abstraction

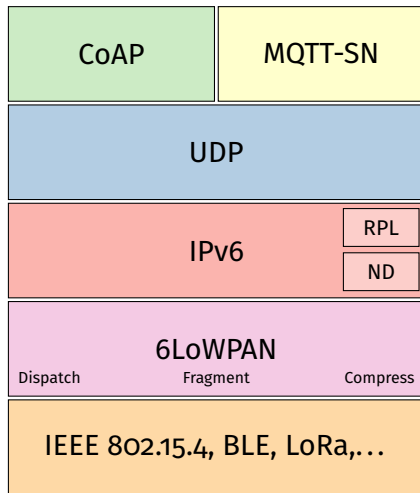


Hardware & Software Abstraction

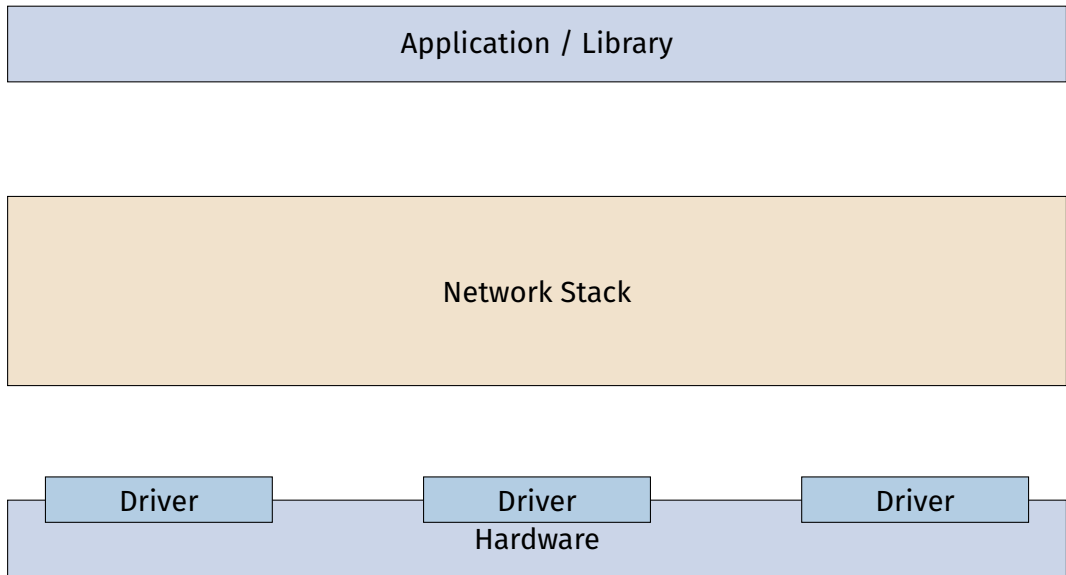


IoT Network Stack

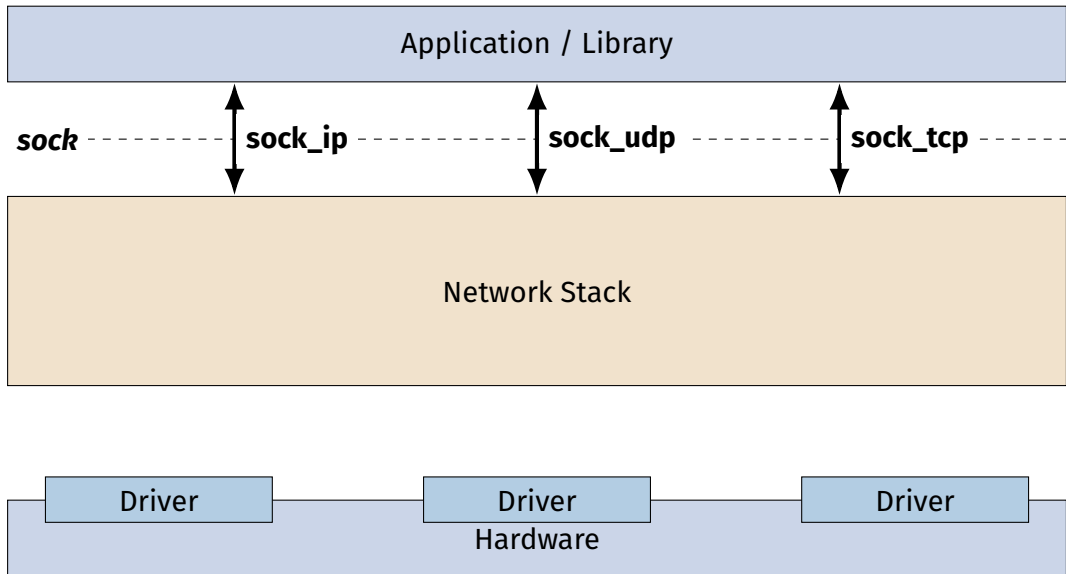
- ▶ Open-access protocols
- ▶ Support for IETF network stacks
 - ▶ **GNRC** for IPv6/6LoWPAN (default)
 - ▶ **lwIP** for IPv4 & IPv6/6LoWPAN
 - ▶ **emb6** for 6LoWPAN
 - ▶ **OpenWSN** for 6LoWPAN & 802.15.4e
- ▶ Support for non-IETF network stacks
 - ▶ **OpenThread** for Thread
 - ▶ **LoRaWAN** for LoRa deployments
 - ▶ **CCN-lite & NDN-lite** for Information-centric Networking



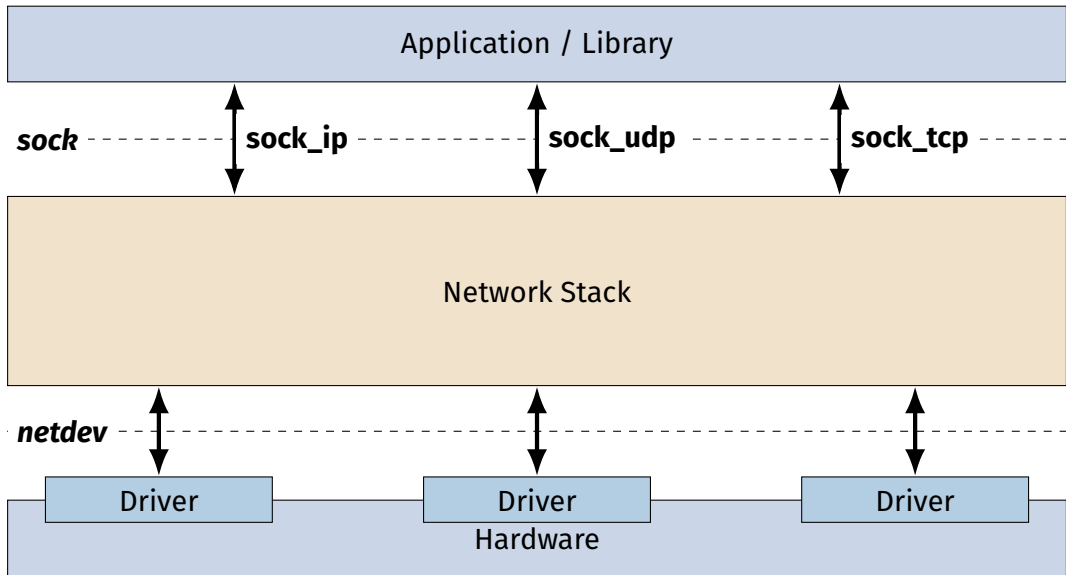
Loosely Coupled Network Stack Architecture



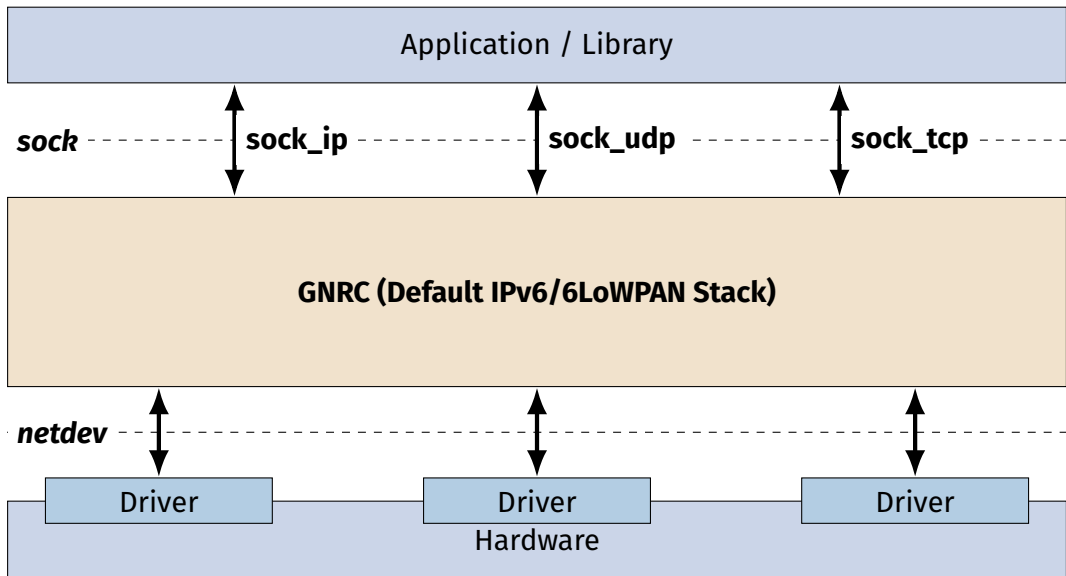
Loosely Coupled Network Stack Architecture



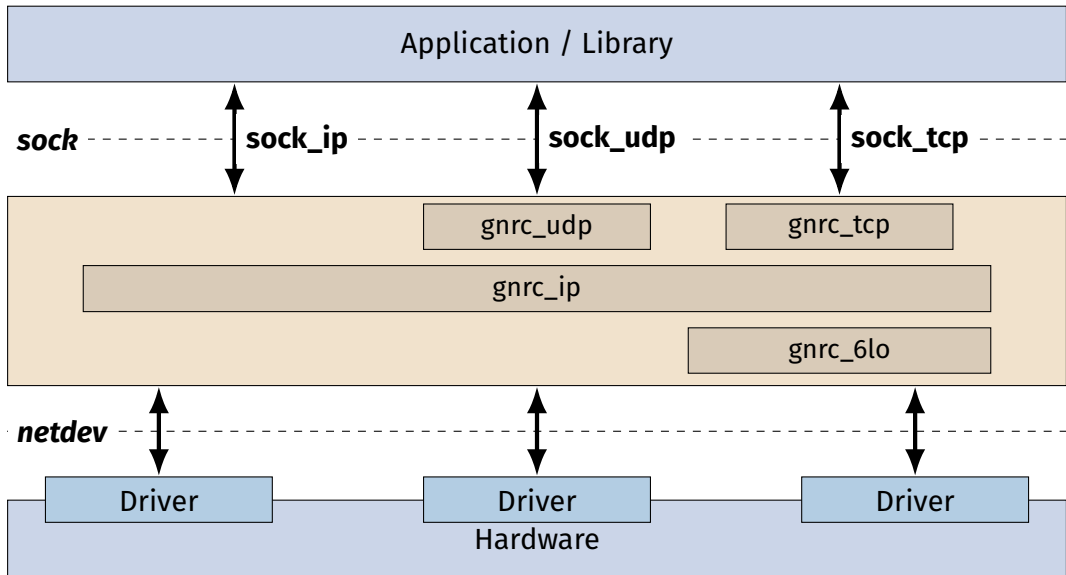
Loosely Coupled Network Stack Architecture



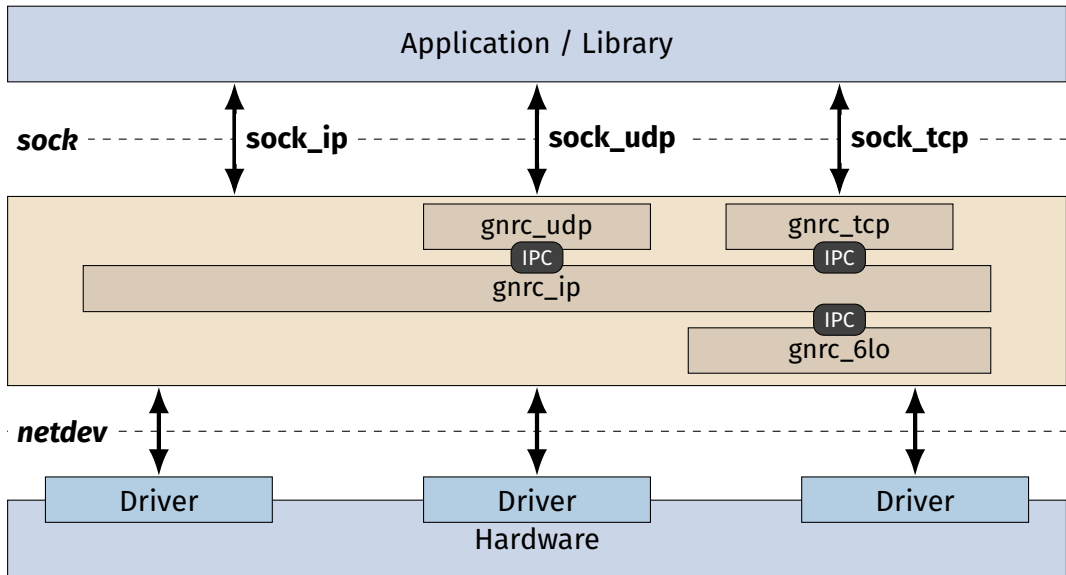
Loosely Coupled Network Stack Architecture



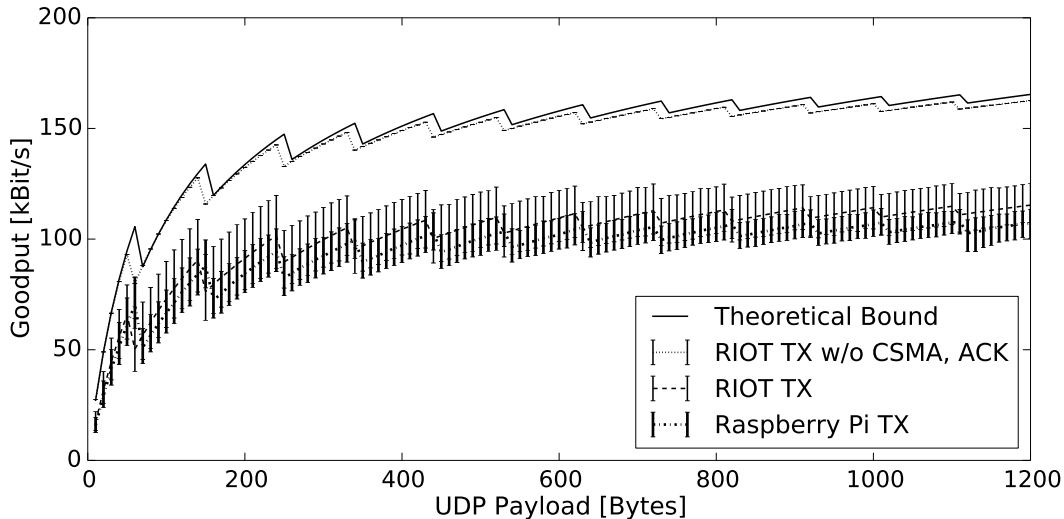
Loosely Coupled Network Stack Architecture



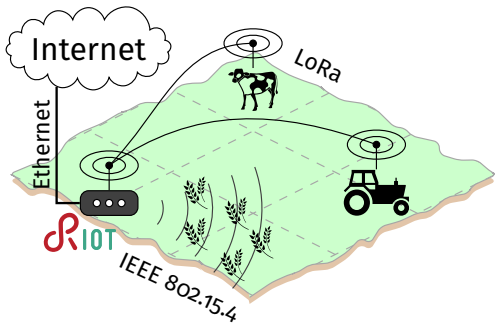
Loosely Coupled Network Stack Architecture



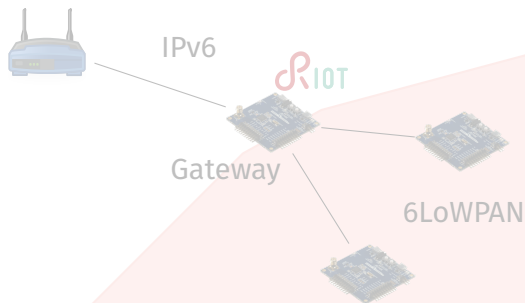
Goodput Comparison for RIOT vs Linux in a IEEE 802.15.4 Network



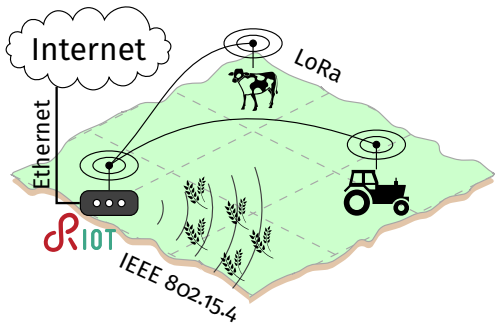
Multi-Interface & IoT Gateway Setups



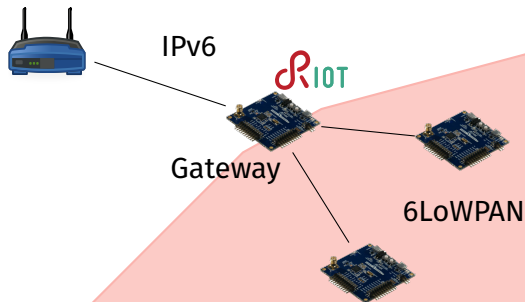
- ▶ Allows multiple interfaces simultaneously
- ▶ Supports gateway functionalities



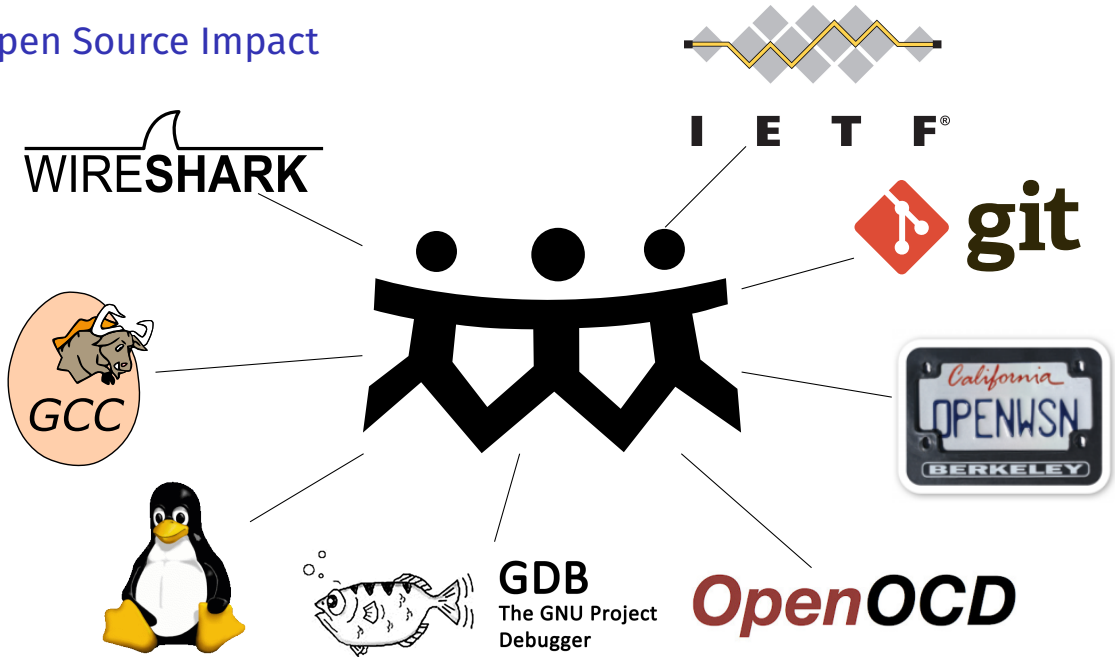
Multi-Interface & IoT Gateway Setups



- ▶ Allows multiple interfaces simultaneously
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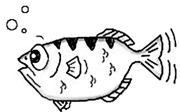


Open Source Impact





WIRESHARK: CONTRIBUTION OF P2P-RPL DISSECTOR



GDB
The GNU Project
Debugger

OpenOCD



LINUX: INTEROP. TESTING, CONTRIBUTE DISCUSSIONS AND FIXES



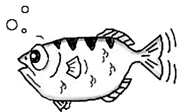
GDB
The GNU Project
Debugger

OpenOCD

WIRESHARK



OPENOCD: THREADING SUPPORT FOR RIOT IN GDB



GDB
The GNU Project
Debugger

OpenOCD



**IETF: PARTICIPATION IN DISCUSSIONS
AUTHORING OF IOT RELATED DOCUMENTS**



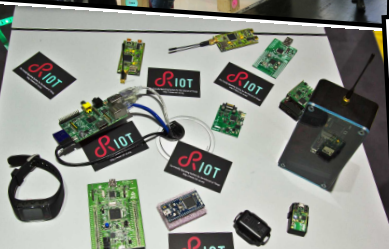
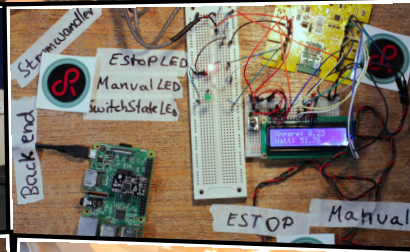
GDB
The GNU Project
Debugger

OpenOCD

Current Hot Topics of Interest

- ▶ Hardware-in-the-loop (HIL) testing infrastructure
 - ▶ Automated network tests, including interoperability & regression
- ▶ LoRa PHY & MAC layer integration
- ▶ NB-IoT & LTE-M transceiver integration
- ▶ IoT semantic & hypermedia interop. (T2TRG/IETF)
- ▶ Exploration of secure firmware update mechanisms for the IoT (SUIT/IETF)

WE CARE ABOUT OUR COMMUNITY



THANK YOU!

RIOT Summit
September 5 - 6, 2019
Meet in Helsinki!

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