LF Real-Time Operating Systems: Evolution and Trends

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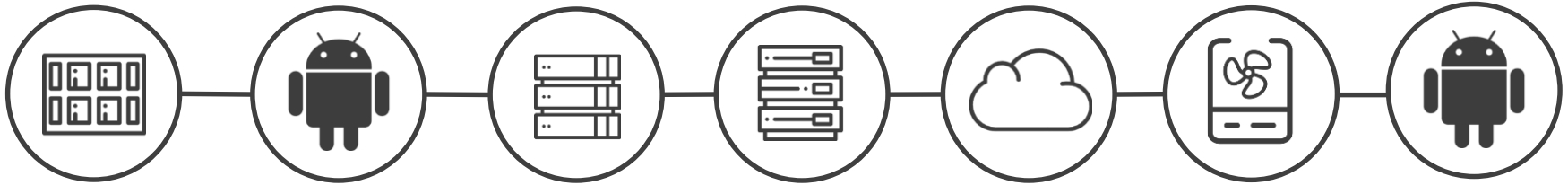
THE LINUX FOUNDATION

Linux Foundation Real-Time OS Projects: Real-Time Linux & Zephyr

Both launched around the same time - 2015Q4/2016Q1

The Linux Operating System Has Grown into the Most Important Software Platform in the World

100%	82%	2nd	90%	90%	62%	#1
Supercomputer Market	Smartphone Market Share	To Windows in Enterprise	Mainframe Customers	Public Cloud Workload	Embedded Systems Market	Internet Client



Every market Linux has entered it eventually dominates

Why do we care about Real-Time?

Real-Time Linux is primarily being used in/by:

- Financial institutions, brokerages, stock exchanges
- Audio/Video devices
- Aviation, flight simulators, medical, military
- Control systems, manufacturing
- Some telecom applications

Emerging use in IoT, automotive and safety-critical products

What is Real-Time Linux?

The standard Linux kernel only meets soft real-time requirements.

- Provides basic POSIX operations for userspace time handling but has no guarantees for hard timing deadlines
- Ingo Molnar's Real-Time Preemption patch and Thomas Gleixner's generic clock event layer with high resolution support (together referred to as the PREEMPT-RT patch), the kernel gains hard Real-Time capabilities.

The PREEMPT-RT patch is in use throughout many industries.

- Its aim towards mainline integration made it an interesting option for hard and firm Real-Time applications from professional audio to industrial control.
- PREEMPT-RT work has been going on for ~15 years and is very comparable to the best Real-Time Operating Systems

Real-Time LINUX

Goals of Real-Time Linux Project

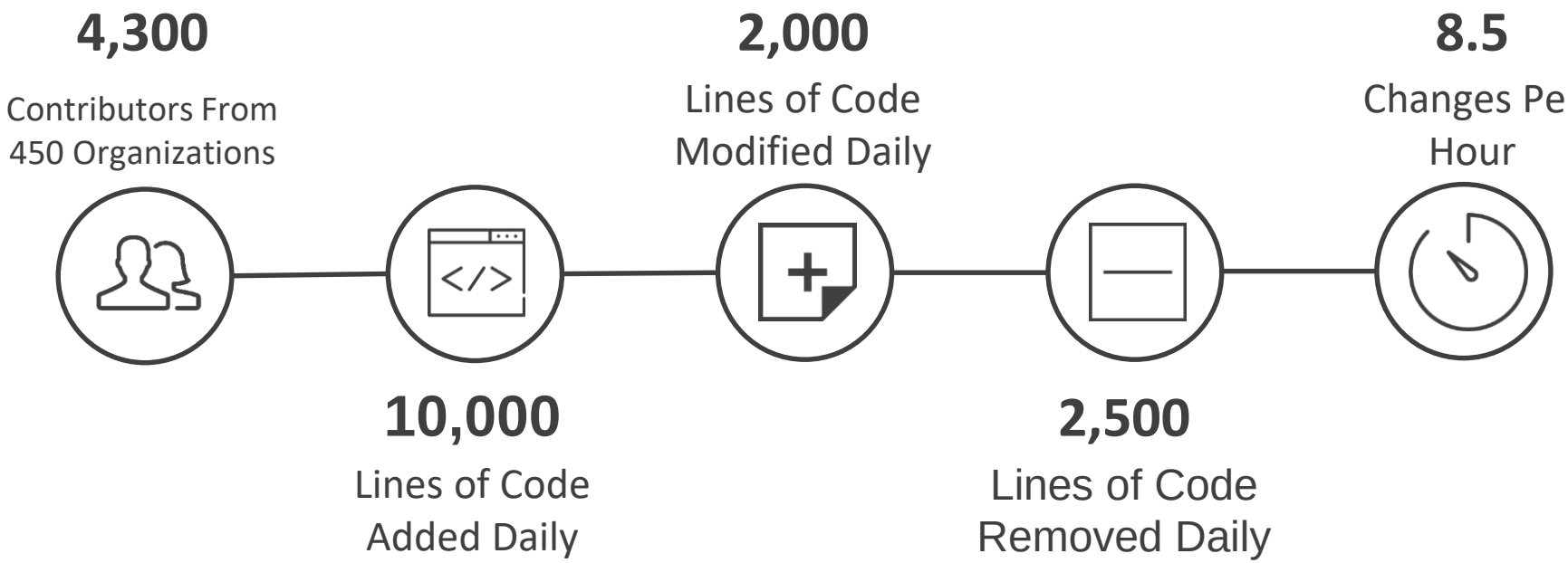
- Announced 2015Q4, development started 2016Q1.
- Full mainline integration of PREEMPT-RT
- Sustaining patch maintenance and development
- Foster the Real-Time developer community
- Improve Testing infrastructure

A bit of history...

- 1991: First version of Linux published
- 1994: Academic discussions on Real-Time Linux start
- 2004: LKML discussions on Real-Time Linux start
- 2006: First production version of PREEMPT-RT released.
- 2012: Sustainability of PREEMPT-RT concerns raised.
- 2014: PREEMPT-RT went into hobbyist mode…
- 2015: OSADL funded basic maintenance… but maintenance was not enough.
- 2016: Real-Time Linux project started to work on upstreaming of PREEMPT-RT.

Real-Time LINUX

2017 Linux Kernel Development Report



Upstreaming: catching the moving target

2016 → 2018Q4: ~1000 patches merged upstream

- Rework of CPU hotplug
- Rework of the timer wheel
- Preparatory work all over the place

2019: finish upstreaming

- Printk series
- FPU rework
- Memory management swap patches
- Soft IRQs
- Bit Spinlocks

Ongoing Patch Development for Maintenance

Initial patches for released kernel version created based on what is accepted upstream. Status today:

4.16: Handed off to stable

- EOL by now

4.19: Version of patches released

- Switched over from working on 4.18

Community Now Supports Stable Versions

Developer	Current Focus Areas
Steven (VMware)	Maintenance: **Linux v4.14-rt** & fixing regressions Working with Julia on a process to coordinate backports among different kernel releases.
Julia (NI)	Maintenance: **Linux v4.9-rt** & fixing regressions
Daniel (Siemens)	Maintenance: **Linux v4.4-rt** & fixing regressions. Come up with more generic tools.
Tom (Intel)	Maintenance: **Linux v3.18-rt** & fixing regressions.
Mark (Linaro)	rt-stable trees are now being tested in kernelci.org

Real-Time LINUX

Testing Infrastructure

Continuous Integration sources for Real-Time publicly available:

- https://github.com/ci-rt/test-description
- https://github.com/ci-rt/jenkins-cirt-libs

And yes, there is documentation:

- overview about all ci-rt repos
- setup documentation

After Upstream? Stability & Sharing Knowledge

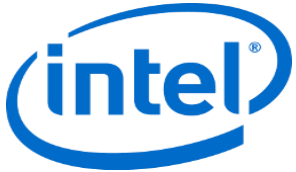
Immediate focus:

- Ensuring the stability of RT in the upstream kernel
- Addressing the side effects of the RT merge and helping upstream developers to understand the limitations and scope
- Addressing documentation gaps
- Enhancing and running the test infrastructure

Additional longer term focus is needed on developing required training so the knowledge is spread out and continuous upstream work can be guaranteed.

Who to thank...

- Thomas and developers working on this effort!
- Members of Real-Time Linux Project who fund the project:



BMW Car IT GmbH

To learn more:

- Real-Time Project Home page: https://wiki.linuxfoundation.org/realtime/start

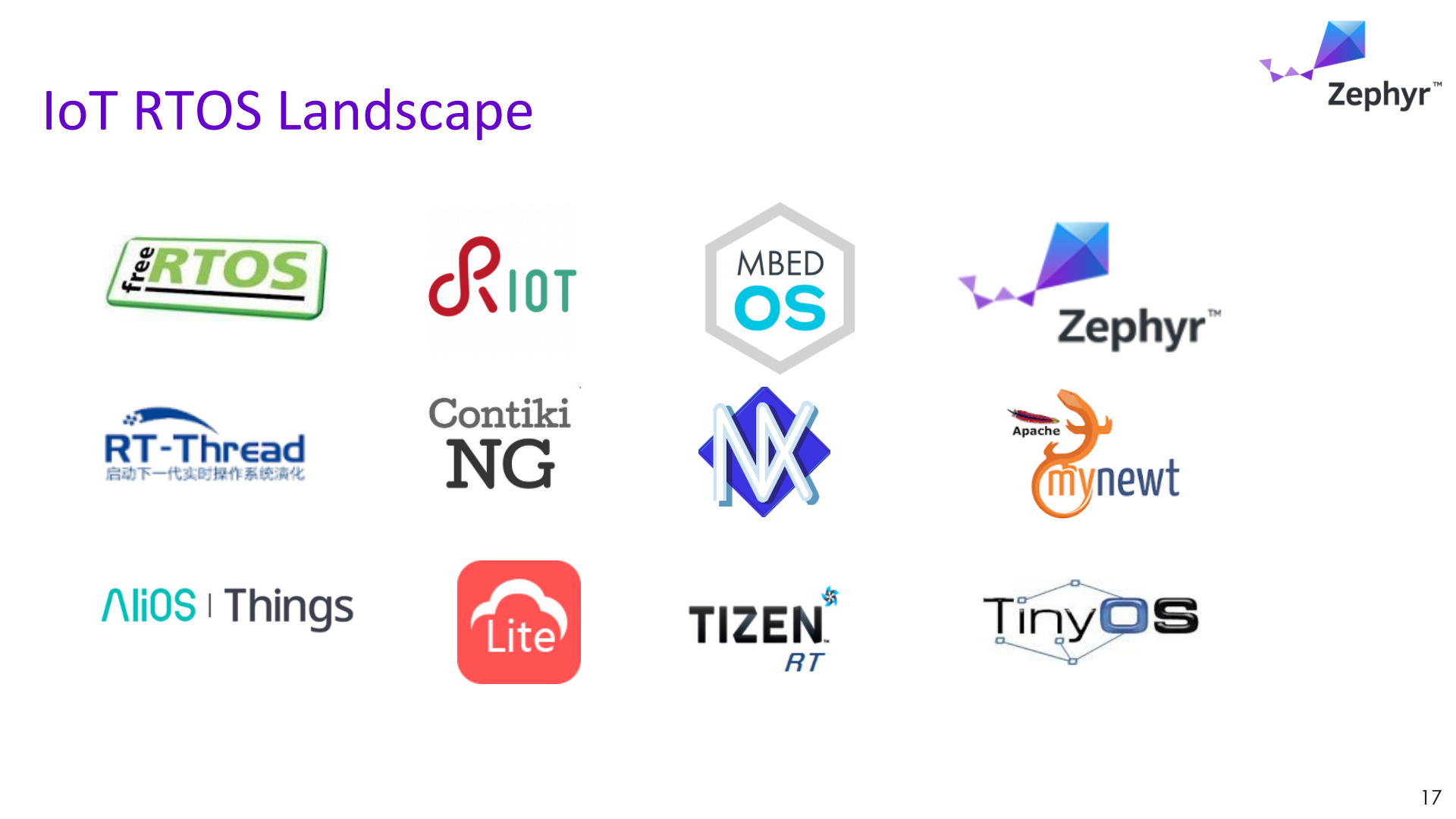
- Real-Time Linux Microconference at LPC (Nov. 2018)
  - etherpad notes from session
  - Videos of discussions

But what happens when Linux is “too big”?

Emerging IoT applications calling for similar hard and firm Real-Time guarantees.

Sensors as well as other power & size constrained devices need Real-Time as well.

IoT RTOS Landscape

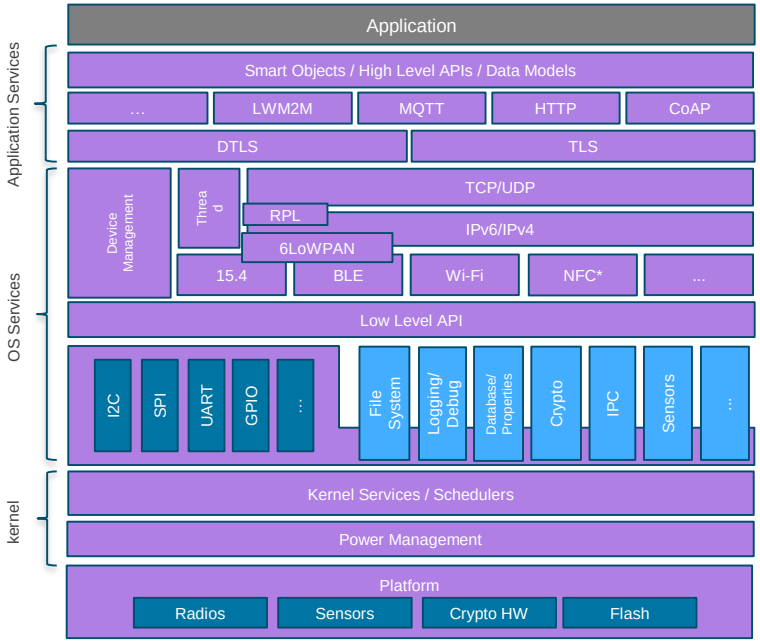


Zephyr Project:

- **Open source** real time operating system
- **Vibrant Community** participation
- Built with **safety and security** in mind
- **Cross-architecture** with growing developer tool support
- **Vendor Neutral** governance
- **Permissively** licensed - Apache 2.0
- **Complete**, fully integrated, highly configurable, **modular** for **flexibility**, better than roll-your-own
- **Product** development ready with LTS
- **Certification** ready with Auditable

THE LINUX FOUNDATION PROJECTS

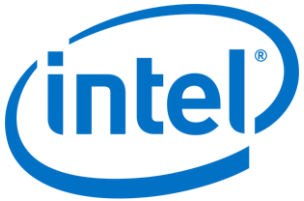
Architecture



- Highly Configurable, Highly Modular
- Cooperative and Pre-emptive Threading
- Memory and Resources are typically statically allocated
- Integrated device driver interface
- Memory Protection: Stack overflow protection, Kernel object and device driver permission tracking, Thread isolation
- Bluetooth® Low Energy (BLE 4.2, 5.0) with both controller and host, BLE Mesh
- Native, fully featured and optimized networking stack

Fully featured OS allows developers to focus on the application

Zephyr Supported Architectures



Sample of Board Support


SiFive HiFive1


Arduino Due


Nucleo 103RB


NRF51


Nucleo64 L476RG


Nucleo F411RE


NRF52 pca10040


Nucleo F334R8


Synopsys EMSK


Arduino 101


Minnowboard


Altera MAX10


Nucleo 401RE


Hexiwear


ARM V2M MPS2


STM3210c


Atmel SAM E70


Adafruit Feather


Galileo


NXP FRDM K64F


NRF52


Seeed Carbon


TI Launchpad Wifi


BBC Microbit


STM32373c


Redbear BLE Nano


96b Neon Key


Quark D2000


STM32 Olimexino


STM Mini A15


Seeed Nitrogen


ARM V2M Beetle


Zedboard Pulpino


NXP FRDM-KW41Z

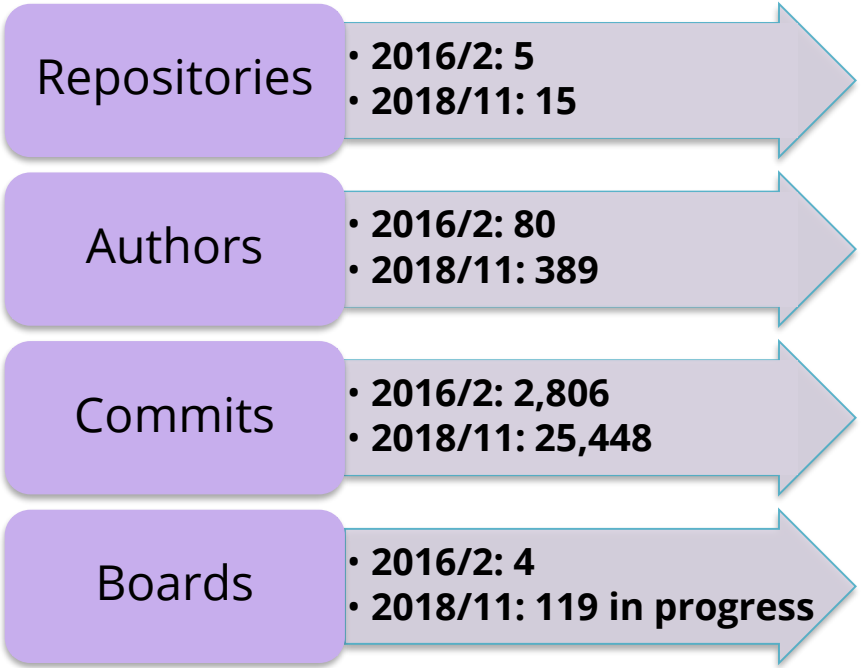

tinyTILE


NXP i.MX RT1050

119 BOARDS TODAY, WITH MORE ON WAY…

http://docs.zephyrproject.org/boards/boards.html

Very Active Diverse Community!



1.13 release statistics:

- **13** weeks cycle, with 2 weeks of merge window
- **1,834** changes (patch commits)
- **140** developers identified
- **25** companies participated
- **20** changes / day (.8/hour)

Zephyr in RTOS Landscape 11/26

Total Contributors

Rank	RTOS	#
1	mbed OS	468
2	**Zephyr**	**382**
3	nuttX	276

Total Commits

Rank	RTOS	#
1	nuttX	37,492
2	**Zephyr**	**25,321**
3	mbed OS	20,387

Commits to Master (last 30 days)

Rank	RTOS	#
1	**Zephyr**	**849**
2	mbed OS	355
3	nuttX	222

Real-Time Characterization Starting...

Comparison and characterization work just starting by Zephyr members who need it for products.

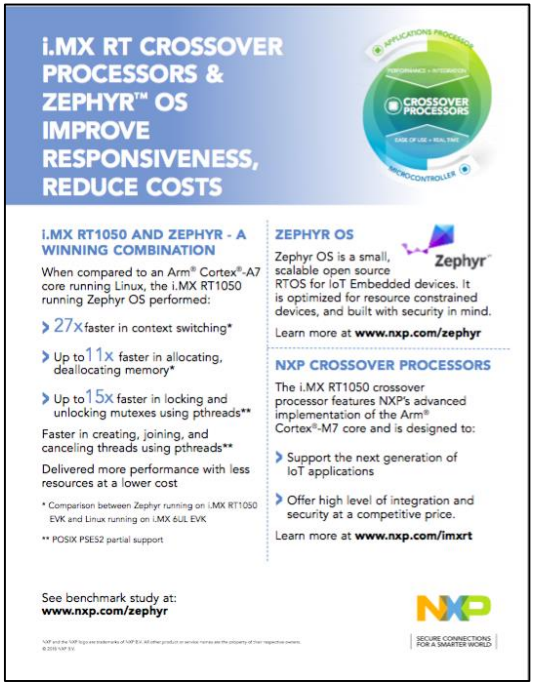
NXP [whitepaper] about some Real-Time benchmarks based on common API's for comparing with Linux

Initial results show performance benefit* in:

- Context Switching
- Locking and unlocking Mutexes

Zephyr is ready for more 3rd party characterization and Real-Time testing.

*Linux used did not have PREEMPT-RT patches applied.



Summary: watch this space in 2019! :-)

Real-Time Linux PREEMPT-RT patch set is almost upstream

- Developers are starting to plan tasks for after merging

Zephyr will be having first LTS release in early 2019

- Members have key applications that need Real-Time
- Already seeing Zephyr used in products, before first LTS

Both projects are setting the foundation for safety critical products

Thank you for your interest.

Questions?