Sculpt OS - a dynamic general-purpose OS powered by Genode on seL4

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About

Alexander Böttcher

2005 member of TU-Dresden OS group
2009 internship at Microsoft XCG group
2012 joining Genode Labs

- Maintaining Genode's NOVA version
- x86 VMM Seoul and VBox 4/5
- Involved in seL4 support
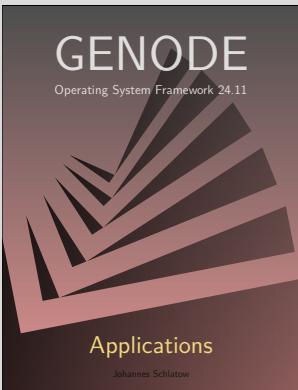- Intel display driver port
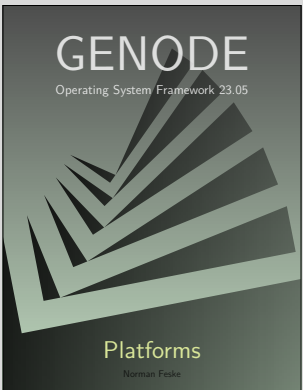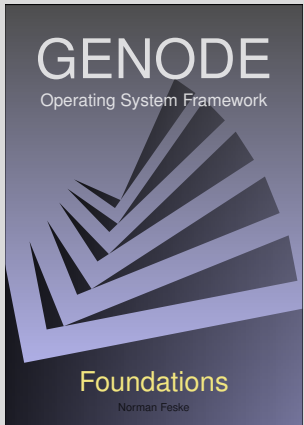- ...

living in Dresden / Germany

Genode OS framework

- Vision of a truly trustworthy operating system

  least privilege ★ *capability-based* ★ *microkernel* ★ *virtualization*

- Open-source tool kit to craft own operating systems
  - ► Prototype 2006, company founded 2008, first release in 2009
  - ► Language: C++, License: AGPLv3, optional commercial

- Over 100 ready to use components
  - ► Sandboxed drivers, multiplexer and applications
  - ► Several microkernels and one monolithic kernel
  - ► Kernel-agnostic application binary interface
  - ► Package management
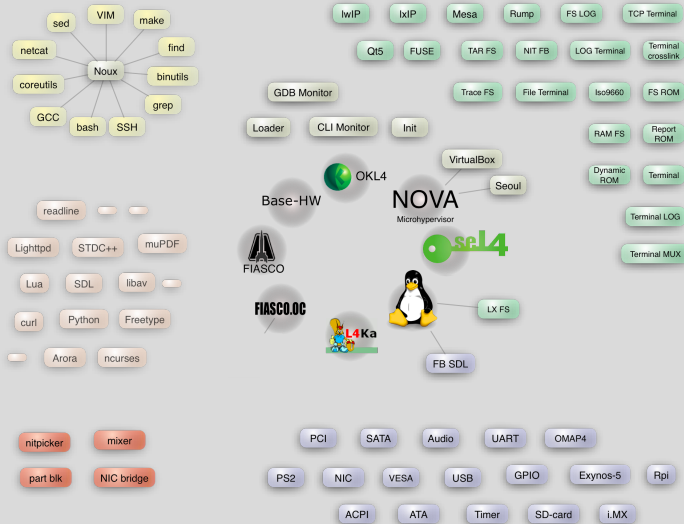
- Quarterly releases & documentation

GENODE
Operating System Framework

Foundations

Norman Feske

GENODE
Operating System Framework 23.05

Platforms

Norman Feske

GENODE
Operating System Framework 24.11

Applications

Johannes Schlatow

sed · VIM · make
netcat · find
coreutils · Noux · binutils
GCC · grep
bash · SSH

readline
Lighttpd · STDC++ · muPDF
Lua · SDL · libav
curl · Python · Freetype
Arora · ncurses

nitpicker · mixer
part blk · NIC bridge

lwIP · lxIP · Mesa · Rump · FS LOG · TCP Terminal
Qt5 · FUSE · TAR FS · NIT FB · LOG Terminal · Terminal crosslink
GDB Monitor · Trace FS · File Terminal · Iso9660 · FS ROM
Loader · CLI Monitor · Init · RAM FS · Report ROM
VirtualBox · Dynamic ROM · Terminal
OKL4 · NOVA · Seoul
Base-HW · Microhypervisor · Terminal LOG
FIASCO · seL4 · Terminal MUX
FIASCO.OC · L4Ka · LX FS
FB SDL

PCI · SATA · Audio · UART · OMAP4
PS2 · NIC · VESA · USB · GPIO · Exynos-5 · Rpi
ACPI · ATA · Timer · SD-card · i.MX

Sculpt OS - dynamic usage of Genode

- **Day to day OS** used by community and developers on consumer devices

- Combining Genode's microkernel architecture, capability-based security, sandboxed device drivers, and virtual machines in a novel OS
  - ▶ **Tiny** base OS with automatic device detection and configuration
  - ▶ **Tight** GUI as control interface
  - ▶ GUI for package manager & **federated** package provisioning
  - ▶ Release cycle: 2x time per year since 2017

- Dynamic configurable at runtime - **sculpt your own OS**
  - ▶ All federated packages to be downloaded
  - ▶ Window manager
  - ▶ Native browsers
  - ▶ Various VMMs to run VMs
  - ▶ Native applications, PDF viewer, GPU applications, ...
  - ▶ **Optional**: POSIX runtime, e.g. to run GNU tools
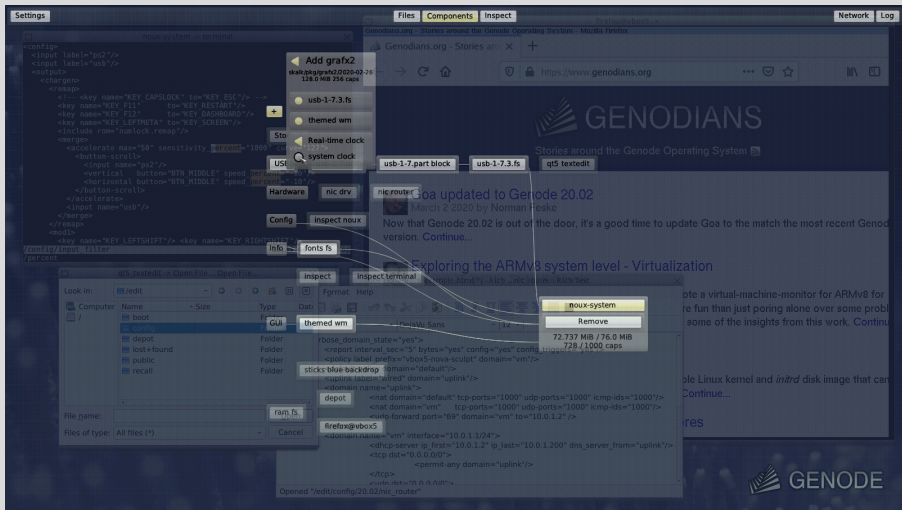
≈60 sandboxes right after boot

- MNT Reform i.MX8MQ, PinePhone (ARMv8) and x86 notebooks

- MNT Pocket Reform, i.MX8MP (ARMv8)
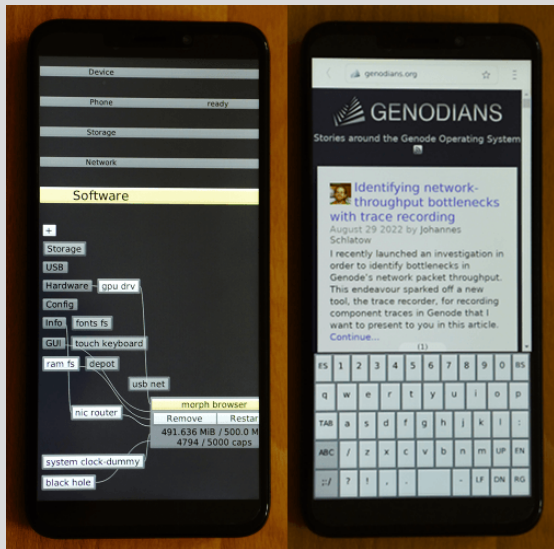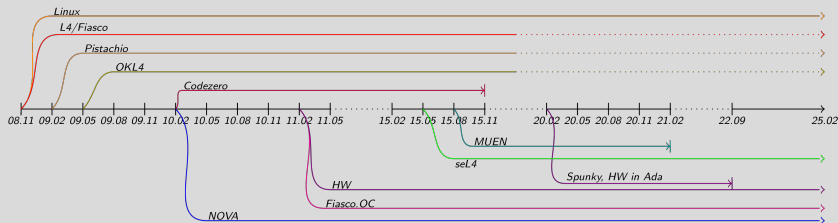
2015 - seL4 2.0 - initial support, x86_32, static scenarios

2016 - seL4 3.2 - enabling device drivers, interactive UI scenarios

2017 - seL4 6.0 - x86_64 & ARM 32bit support

2017 - seL4 7.0 - MBI2/UEFI contribution to seL4 upstream

2018 - seL4 9.0 - update, external contribution

2019 - kernel-agnostic x86 VM interface, e.g. also for seL4

2023 - seL4 12.1 - update, removal of x86_32

Sculpt OS @ seL4

- Up to now: Genode@seL4 support only for static scenarios
  - ▶ various loose, unfinished, ends for dynamic usage
  - → Insufficient to run Sculpt OS with seL4

- Side project since end of 2024:
 - ▶ Extend support to run Sculpt OS on seL4

Sculpt OS @ seL4 - work items, x86 64bit

- Complete release of resources
  - ▶ In core and base-sel4 allocators

- MSI support enabled $\rightarrow$ most drivers working instantly

- Replace PIT timer $\rightarrow$ add new HPET timer
  - ▶ Reduces overhead visible with Sculpt

- Memory and CSpace management adjustments for Genode/seL4
  - ▶ Usable physical & virtual memory increased

- Unlock Genode's pluggable driver support
  - ▶ Driver (re-)start at runtime

- Re-using Genode's user-mode IO-MMU driver
  - ▶ Developed for Genode @ hw primarily

Drivers | Leitzentrale | Runtime

Init

static system

Init

Microkernel / Core
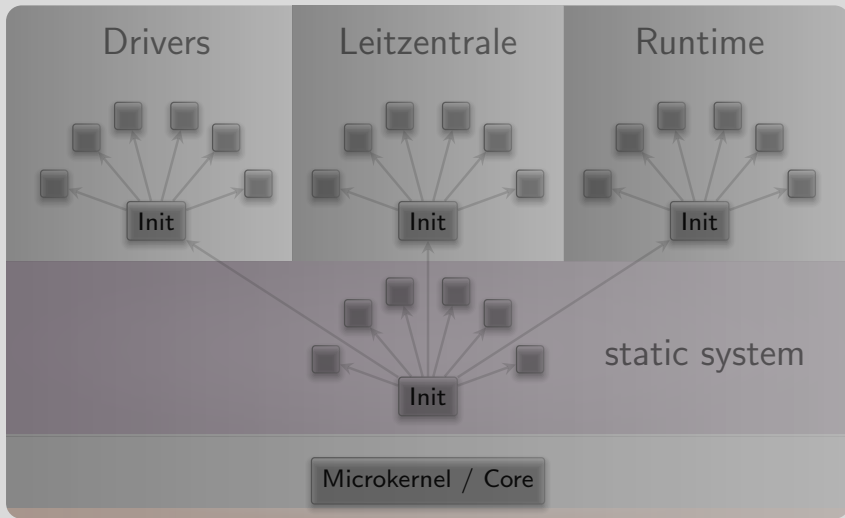
Device driver environments

Various sources for device drivers

Repository	Source	Drivers/Stacks
various	Genode Labs	nvme, ahci, Intel GPU, ...
dde_ipxe	IPXE project	Ethernet
dde_bsd	OpenBSD	Audio
dde_rump	NetBSD RUMP	File systems
dde_zircon	Google Fuchsia	(18.08 - 20.08)
dde_linux	Linux kernel	Ethernet, USB, WIFI, Audio, TCP/IP stack, Intel display i915, ARM GPUs, WireGuard

Linux Device-Driver Environment
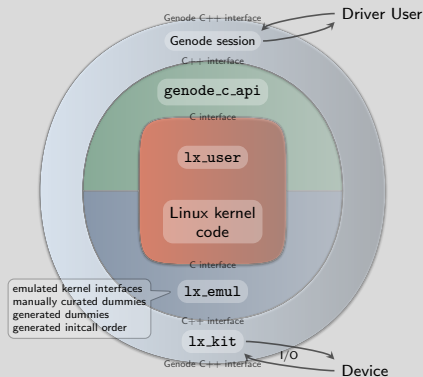
Improved DDE approach with 21.05 release

- 21.05 → initial Linux 5.7, 5.11, ARM
- 22.05 → update to Linux 5.14, PC
- 23.05 → update to Linux 6.1 LTS
- 24.08 → update to Linux 6.6 LTS
- 25.08 → update to Linux 6.12 LTS

→ up-to-date Linux drivers on Genode

Live Demo

Sculpt OS on seL4

- Kernel: seL4 12.1, x86 64bit
- Basics: Intel GPU + display, WIFI, USB, storage
- Federated package management, on-target OS image update support
- Native web-browser Falkon, based on Chrome engine & QT
  - ▶ Audio & USB Webcam
- GPU applications
- Seoul VMM: Firefox & Thunderbird VM (32bit)

State

- Preliminary result of Sculpt OS on seL4
  - ▶ Up and running on PC notebook (Lenovo T460p, T490)
  - ▶ Not optimized

- Missing features compared to other Sculpt OS/kernel variants
  - ▶ x86 64bit VMs, e.g Windows VM support
  - ▶ ACPI suspend/resume
  - ▶ CPU power steering
  - ▶ ARMv8 support

- Directions
  - ▶ Update to seL4 13.x $\rightarrow$ 64bit VMs
  - ▶ Enable ARMv8 support

Thank you

Genode OS Framework
> https://genode.org

Sculpt OS download and manual
> https://genode.org/download/sculpt

Genodians.org community blog
> https://genodians.org

Community-moderated user forum
> https://genode.discourse.group

Genode Labs GmbH
> https://www.genode-labs.com