Introducing kernel-agnostic Genode executables

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Outline

1. Kernel diversity - What's the appeal?

2. Bridging the gap between kernels
   - Notion of components
   - Raising the level of abstraction of IPC
   - Virtual-memory management
   - Custom tooling

3. From a uniform API to binary compatibility

4. Future prospects

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How to build a user land for a non-existing kernel?

- Planning in terms of interim solutions
- Weak assumptions about the kernel

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Approach: Target two existing kernels at once

- Opposite ends of a spectrum: Linux and L4/Fiasco
- If it works on those, it should be portable to NOVA

Reassuring experiences

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- Cross-correlating bugs and performance problems

- Getting clarity of application-level requirements

Benefiting from a high diversity of kernels

Kernels differ in many respects:

- Hardware-platform support
- Leveraged hardware features
  Virtualization, IOMMU, SMP, TrustZone
- Performance, security, scheduling
- Implementation, License
- Community

Maintenance burden

Surprisingly little kernel-specific code!

Repository	Source lines of code
repos/	254,367
repos/base/	23,282
repos/base-fiasco/	1,563
repos/base-foc/	3,264
repos/base-linux/	3,582
repos/base-nova/	5,711
repos/base-okl4/	1,958
repos/base-pistachio/	1,869
repos/base-sel4/	3,300
repos/base-hw/	14,751

$\rightarrow$ *manageable*

Emergence of a vision

What POSIX is for monolithic OSes,
Genode may become for microkernel-based OSes.

$\rightarrow$ *Deliberate cultivation of cross-kernel interoperability*

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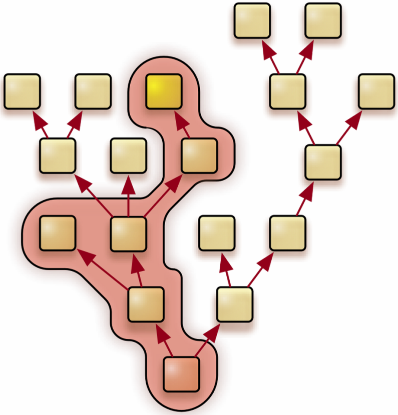
...to be considered later.

Holistic architecture



Clean-slate design

Hiding the construction of components

Traditional: Tight user-kernel interplay

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Interesting at application level:

- Defining the executable to load
  $\rightarrow$ *ROM dataspace*
- Exercising control over the new protection domain
  $\rightarrow$ *Parent-child RPC interface*

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Approach: Satisfy those requirements, hide “loading” mechanics

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Microkernel IPC ridden with technicalities and jargon

thread IDs, task IDs, portals, message registers, message tags, message dopes, message-buffer layouts, UTCBs, MTDs, hot spots, CRDs, receive windows, badges, reply capabilities, flex pages, string items, timeouts, short IPC vs. long IPC

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IDL compilers supposedly hide those details. But they don't.

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Genode's API level:

- Consistent and simple nomenclature
  (client, server, session, RPC object, capability)
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→ no bit fiddling, "optimizations"

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Dataspace: Memory object referred by a capability

- Owner = creator
- Created via the root of the component tree
- Can be attached to a component's local address space
- Can be shared with others by delegating the capability
  $\rightarrow$ *shared memory*

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$\rightarrow$ *Exploration/education costs*

Relieving the user from those technicalities

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Custom tooling

- Bullet-proof integration of 3rd-party code
  → *ports mechanism*
- Kernel-agnostic system-scenario descriptions
  → *run scripts*
- Unified tool chain
  → *blessed bare-metal C++ runtime*

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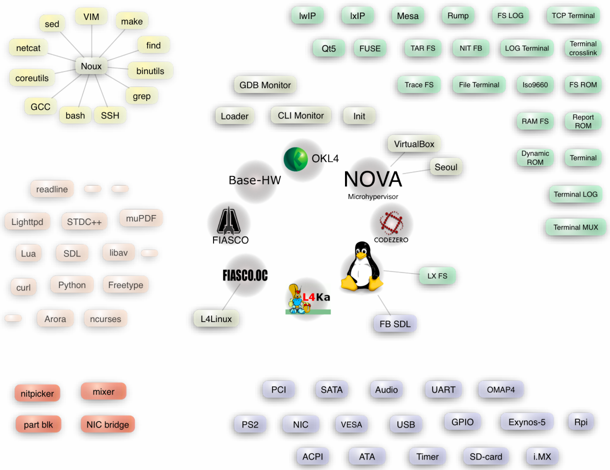

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    - Utilities
2. Component code that issues system calls
    - IPC
    - Multi-threading, synchronization
    - Virtual memory management
    - Hardware access
    - Kernel-object creation/destruction

Decoupling the user land from the kernel

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2. Galvanic separation of kernel-specific from application code
   $\rightarrow$ *distinct ELF objects*

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- Runtime: static binary
  - Lives inside the component
  - Obtains and bootstraps the kernel-agnostic executable
  - Resolves references to the Genode API with itself
  - Exposes the Genode API as its library interface
  - Loads and initializes shared libraries

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free-standing Genode API $\rightarrow$ *generic ABI of the dynamic linker*

Genode's application binary interface (ABI)

ABI definition:

- Symbol names, types, and meta data
- Extracted from the concrete dynamic linker instance
- Cleaned from redundancies
  - Undefined symbols
  - Weak C++ symbols
    (template instances, inline functions, vtables, type infos)
- Cross-checked with all kernels
  - No inner-framework global symbols
  - A few kernel-specific parts remain

$\rightarrow$ *Genode ABI definition: 22 KiB*

Crossing CPU-architecture boundaries

Goal: The same ABI across all supported architectures

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Shudder: Huge differences between x86_32 and x86_64

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Mangled C++ symbols encode entire function signatures

Example: `void Connection::upgrade_ram(size_t)`

x86_32: `_ZN10Connection11upgrade_ramEj`
x86_64: `_ZN10Connection11upgrade_ramEm`

Life is (almost) good without `size_t`

No use of `__SIZE_TYPE__` by Genode API:

- `Genode::size_t` defined as `unsigned long`
  → *Genode ABI is architecture agnostic*
- Remaining problem: libc uses compiler-defined `size_t`
- Fine for C code (symbol == function name w/o arguments)
- Problem with libc-depending C++ code *(like Qt5)*

→ *Solution 1: architecture-dependent ABIs*
→ *Solution 2: tweak the compiler*

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→ *Targets can be built without the libraries they depend on.*

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- Kernel-specific targets are named after the kernel
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  $\rightarrow$ *build results can peacefully coexist*

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- Choice of kernel not before running a scenario:
  `make run/demo KERNEL=nova`

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Two orthogonal directions

1. Successive hardening of the foundation, transparent to users
2. Scaling the software stack with a fixed target

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Shaping the entire vertical software stack:

- Tool chain $\leftrightarrow$ Work-flow automation $\leftrightarrow$ Quality assurance
- Build system $\leftrightarrow$ Source-code management $\leftrightarrow$ Package management
- Dynamic linker *(cross-kernel binary compatibility)*
- C runtime, C++ runtime *(encapsulating legacies)*
- VFS infrastructure *(component-level customiztions)*
- Init and system configuration *(session routing)*
- Genode ABI and API *(enforcing a safe C++ dialect)*
- Kernel *(base-hw, scheduling, kernel-resource management)*
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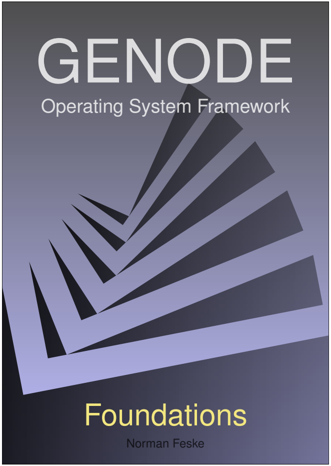
$\rightarrow$ **Simple and holistic solutions!**

The Book “Genode Foundations”



https://genode.org/documentation/genode-foundations-16-05.pdf

Thank you

Genode OS Framework

https://genode.org

Genode Labs GmbH

https://www.genode-labs.com

Source code at GitHub

https://github.com/genodelabs/genode