Exokernel, IX, Arrakis

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Overview

1. Exokernel
2. IX
3. Arrakis
4. Discussion

OS: All about abstractions

- Traditional OS provides:
  - Protection + resource management + HW abstractions
- Generally there is more than one way to abstract
  - OS needs to pick one
  - Different abstractions have different performance

Abstractions considered harmful

Not all applications want the same abstractions

- Performance differences
- Hiding too much information
  - can make it difficult for the application to implement functionality (e.g. databases, user space threads)
- Changing “the one” abstraction can be difficult to impossible

Exokernel

- Kernel only implements protection
- Abstraction is implemented in user space
- Expose:
  - Hardware (securely)
  - Physical Names
  - Allocation
  - Revocation

Library Operating Systems

- Implement abstractions in user space
- Application can choose which library to use
  - Abstractions can be tailored to application
  - No need for general purpose implementations
- Can avoid many kernel crossings: function calls instead of system calls

Secure Bindings

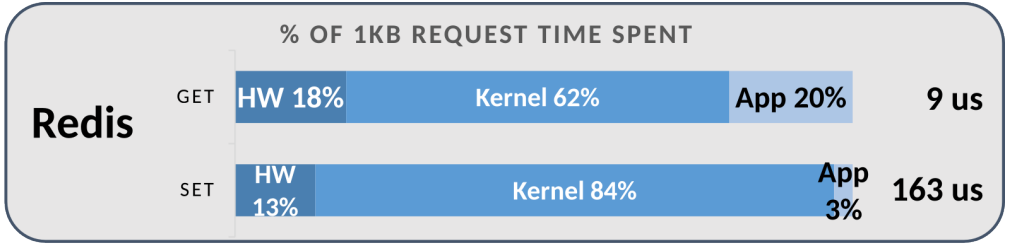
- Separate authorization from use
- Only perform authorization check at bind time
- At access time only simple access check required
- Implement using: hardware, caching, and downloading code

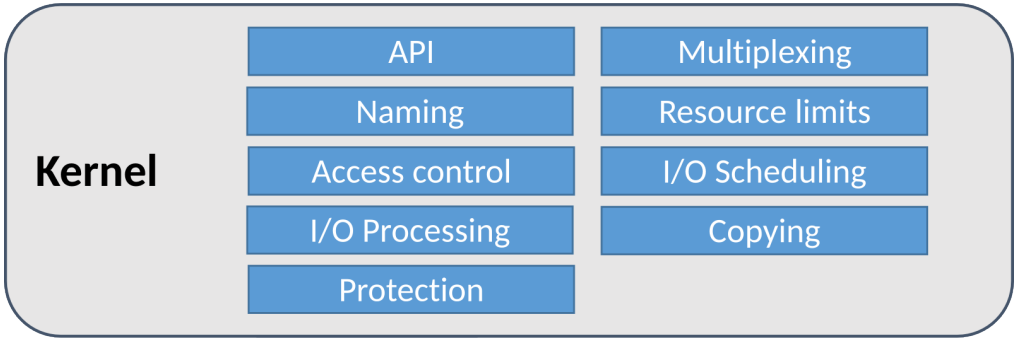
“Downloading” code into kernel

- Allows pieces of code to be pushed into kernel
- Not specific to an application
- Helpful for things that need to go fast like packet filters

c.f. Berkeley Packet Filter in Linux

Linux I/O Performance





10G NIC
2 us / 1KB packet

RAID Storage
25 us / 1KB write

Stolen IX slides

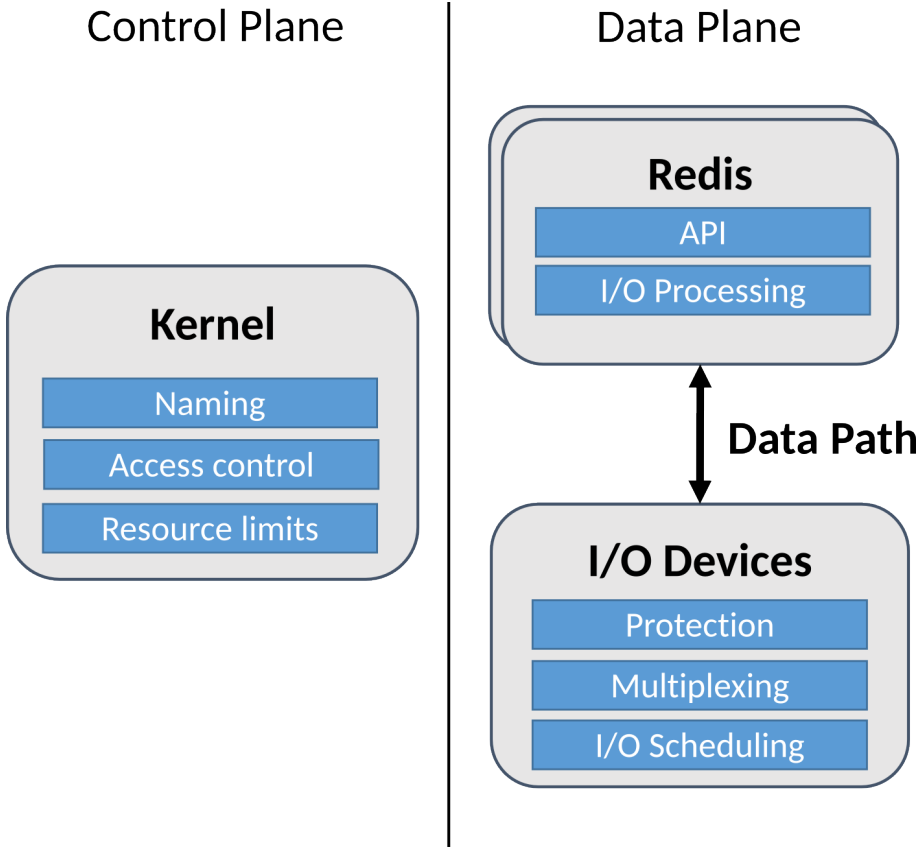
Arrakis

- Directly map vNIC into applications
- Implement network stack as a library
- Use hardware features for protection and demultiplexing to multiple applications:
  - Hardware I/O virtualization: SR-IOV, IOMMU
  - NIC: packet filters, rate-limiting

Arrakis: Control/Data plane split

- Kernel is control plane, data plane is fully in user space
- Control plane not on the critical path
  - Packets sent/received directly from user space
- Invoke control plane only infrequently
  - Changing packet filters/rate limits
  - Analogous to Exokernel’s secure bindings

Arrakis I/O Architecture

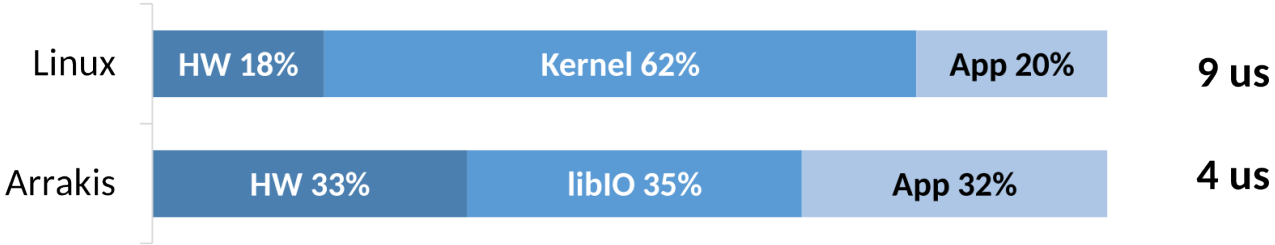


Arrakis: Storage stack

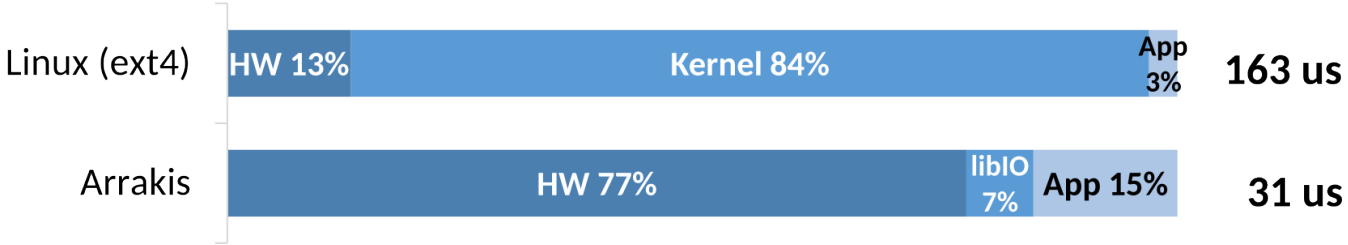
- Same idea can be applied to storage
- Direct access to storage controller for applications
- Application-specific persistent data structures instead of general purpose FS
- IPC interface to allow indirect access through VFS.

Arrakis Performance

- Reduced (in-memory) GET latency by **65%**



- Reduced (persistent) SET latency by **81%**



IX vs Arrakis

- Do we need to protect the network stack from the application?
  - To what degree is the OS responsible for correct protocol implementation?
  - Possible problems: congestion control, others?
  - How does this differ from the cloud setting?
  - Would more hardware support help?

IX, Arrakis applicability

- Both are primarily targeted at data centers
- Are there other settings where they could be useful?
  - Mobile? Desktops?

Exokernel

- Interesting ideas for applications?
- VMMs vs Exokernel?
- What challenges prevent this from being the standard kernel structure today?
  - What are possible solutions to those challenges?

Specialization

- Both IX and Arrakis provide POSIX-compatible interfaces that come with some performance cost
  - -> Inherent complexity vs performance trade-off