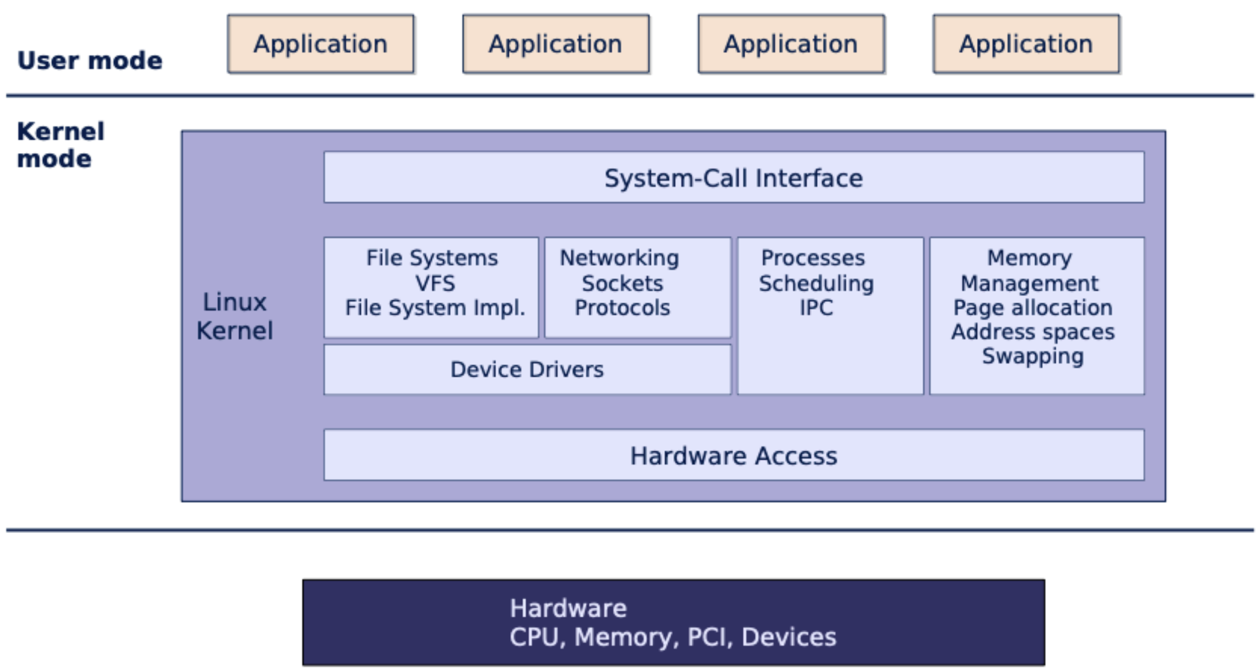
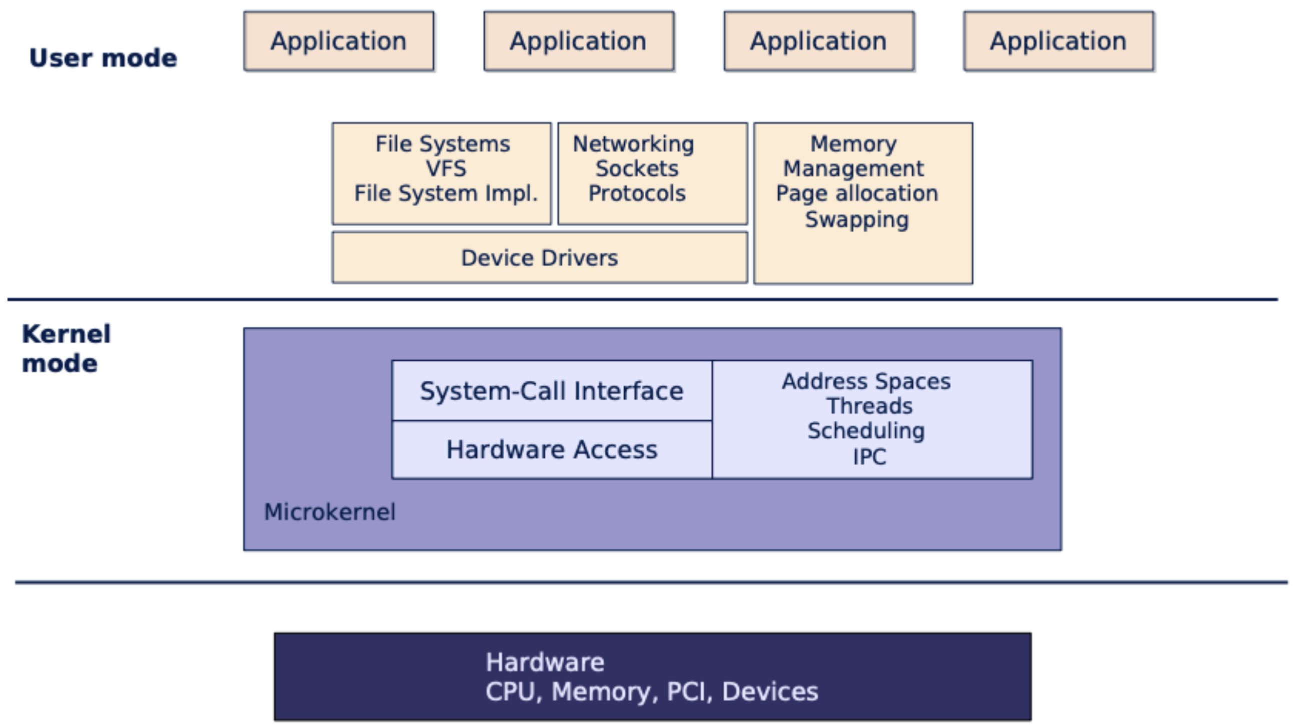
Scalable Operating System Design

Sebastian Ertel

Monolithic vs Micro Kernel Design





TU Dresden, Operating Systems Groups, Slides from Microkernel Lecture

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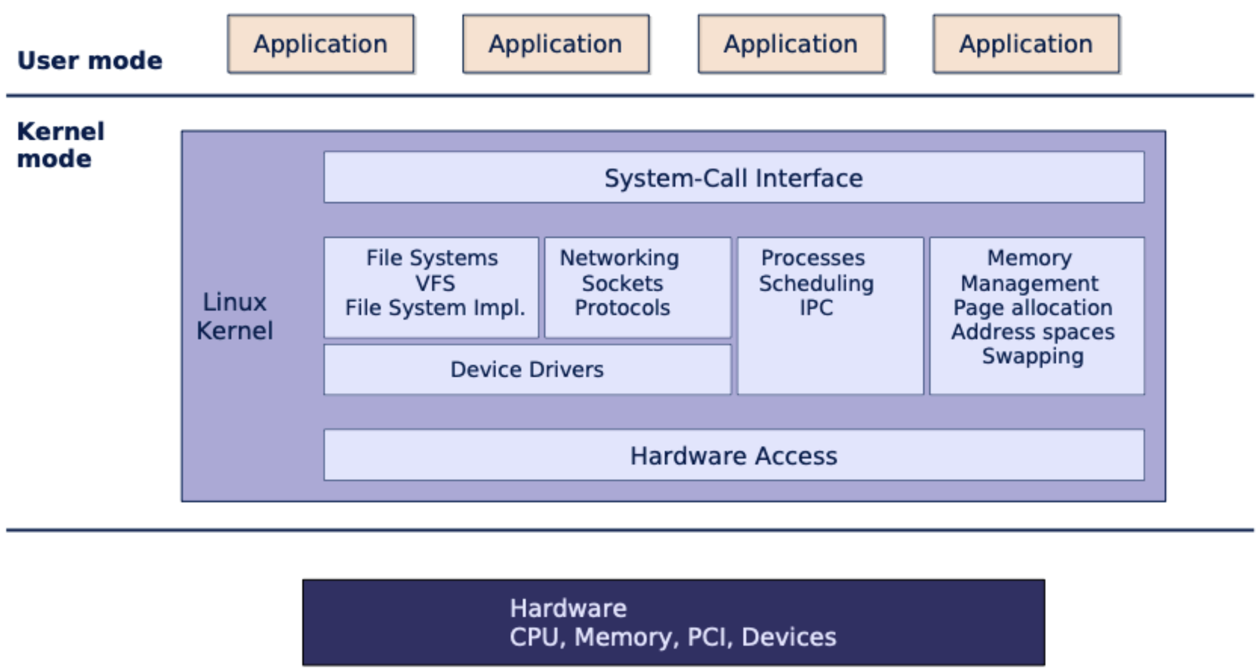

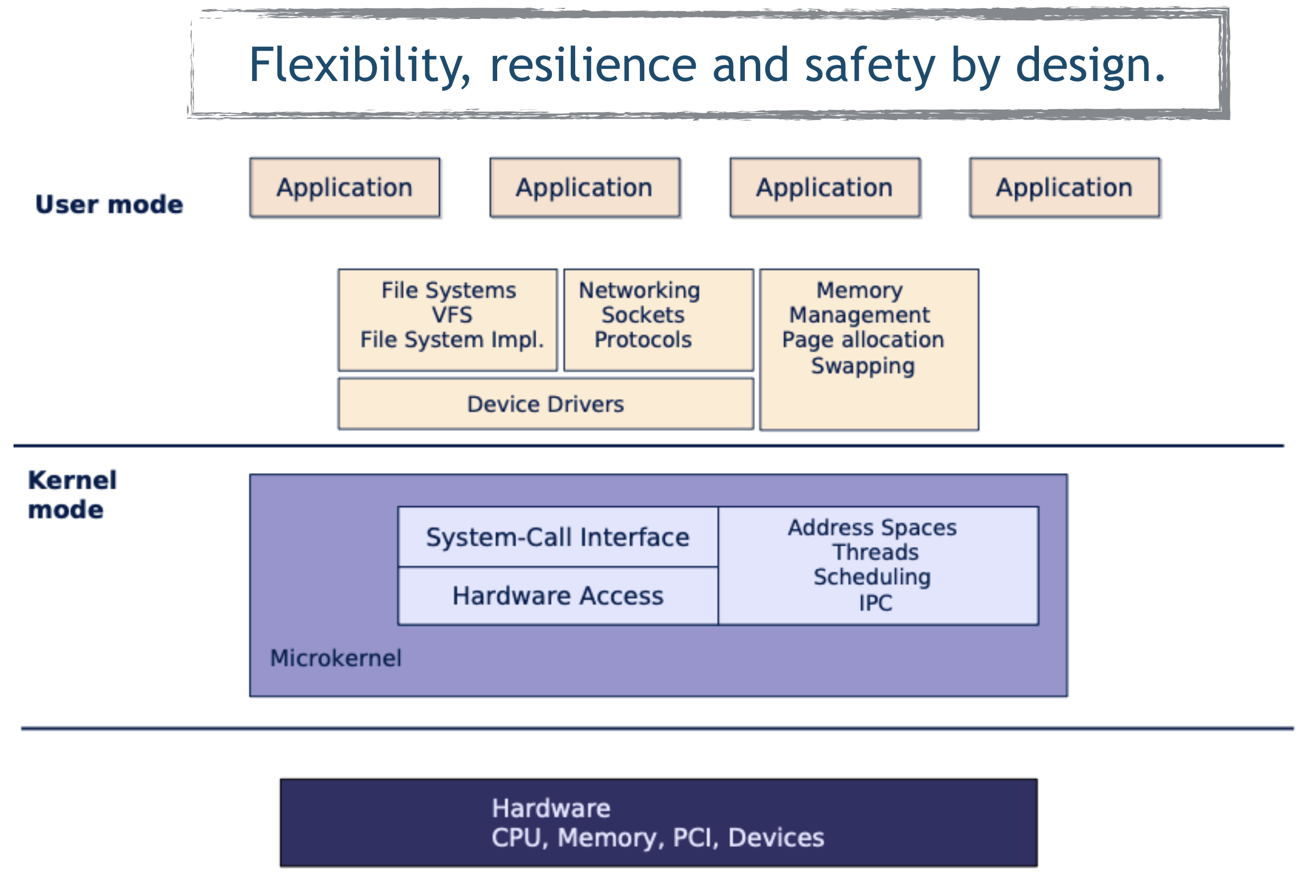

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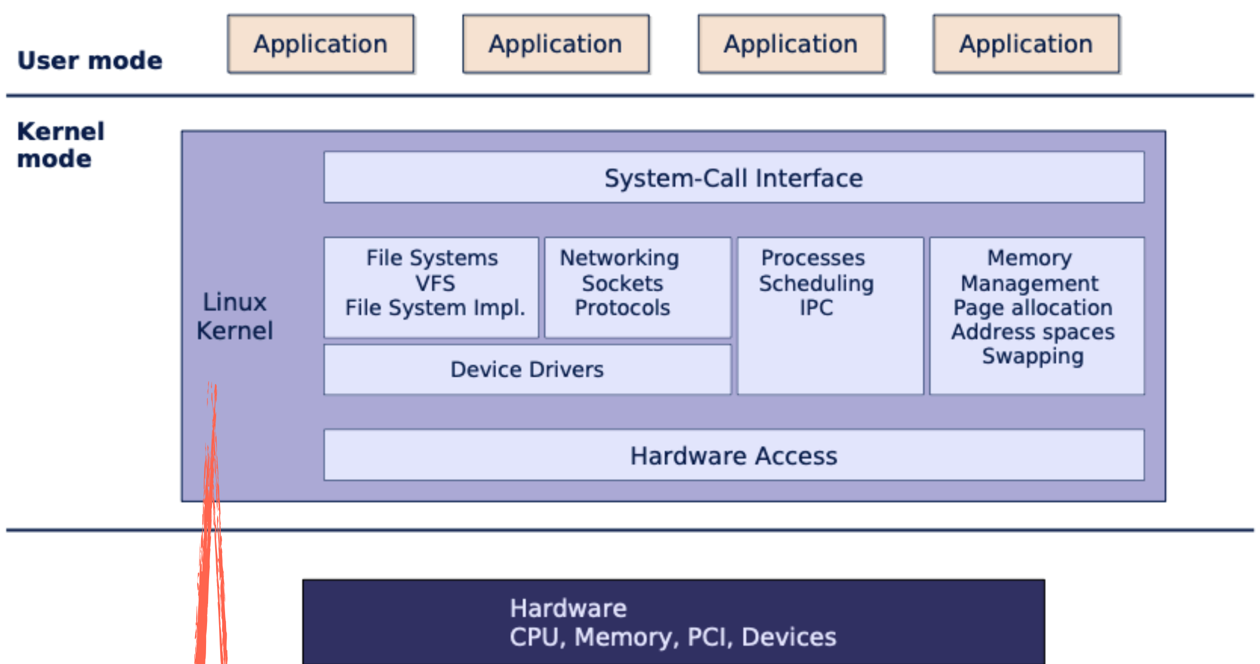
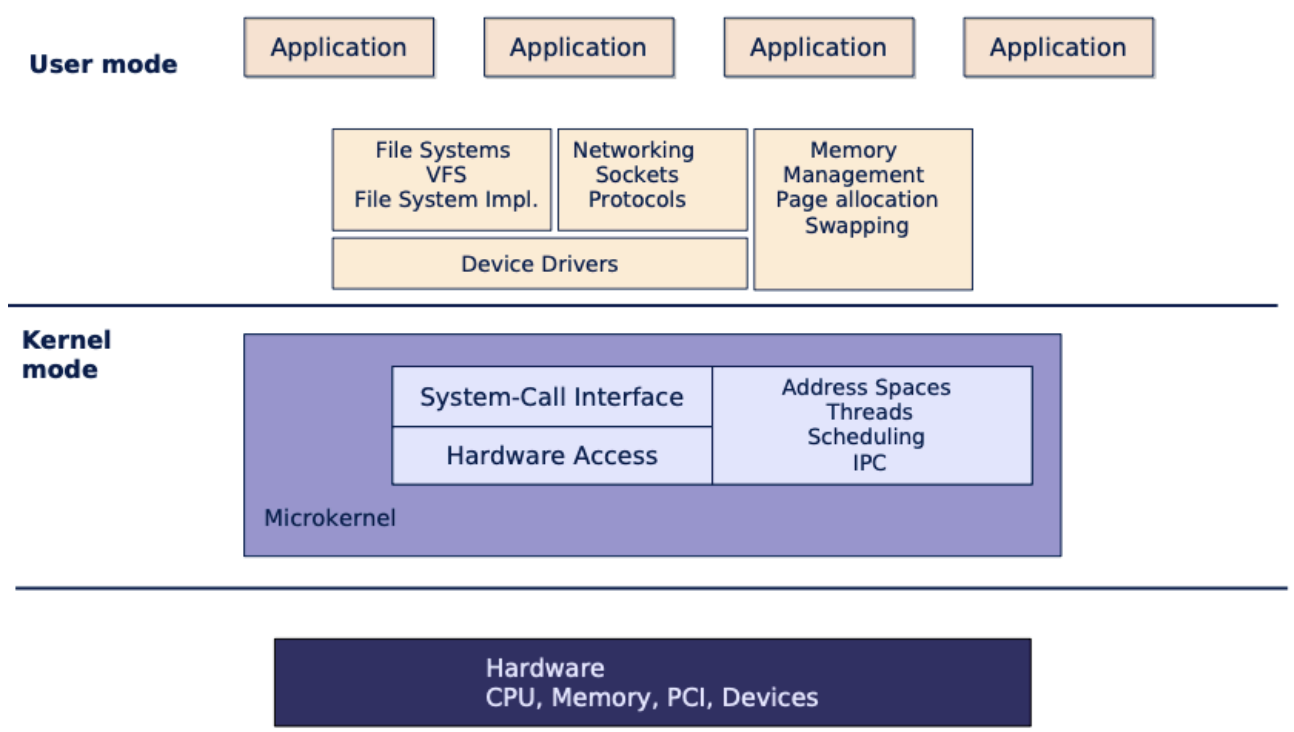
Monolithic vs Micro Kernel Design

Flexibility, resilience and safety by design.





Complex kernel design:
- ➪ High prob. of bugs
- ➪ Very hard to verify properties

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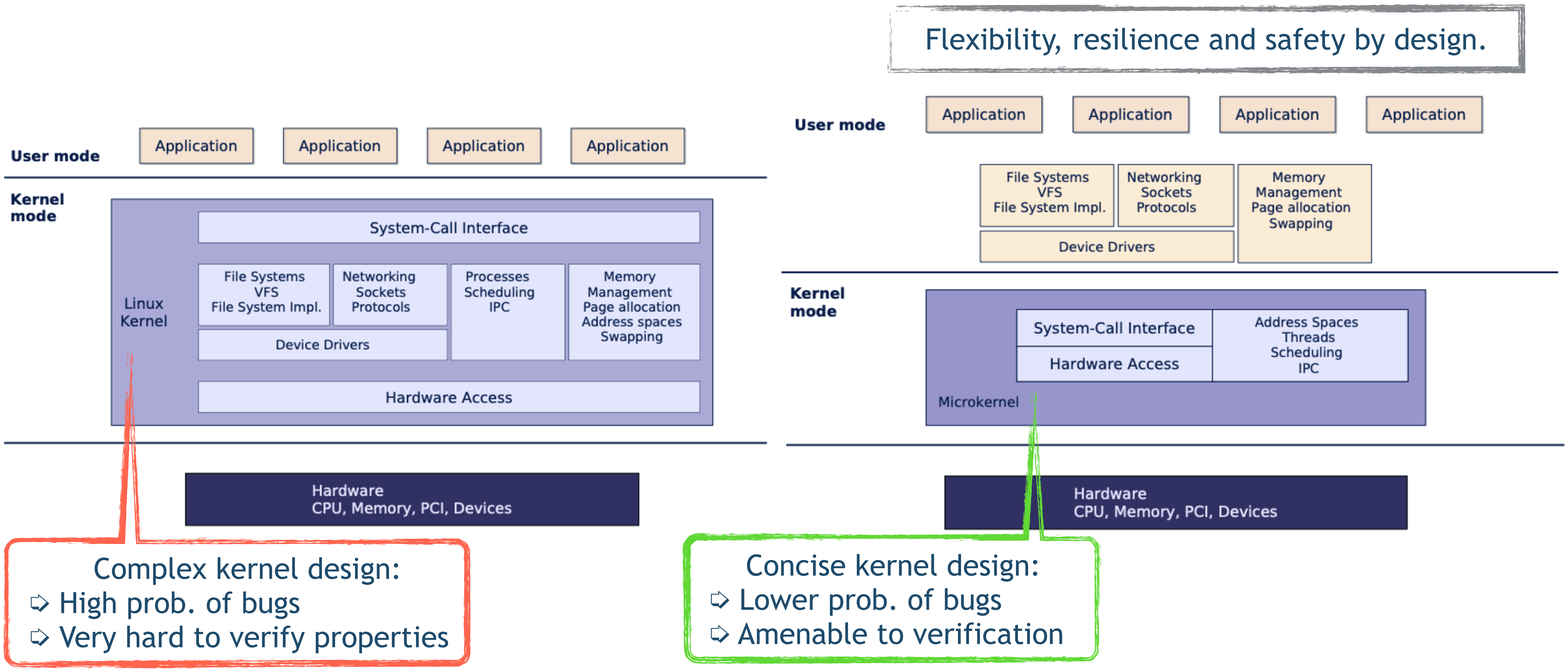

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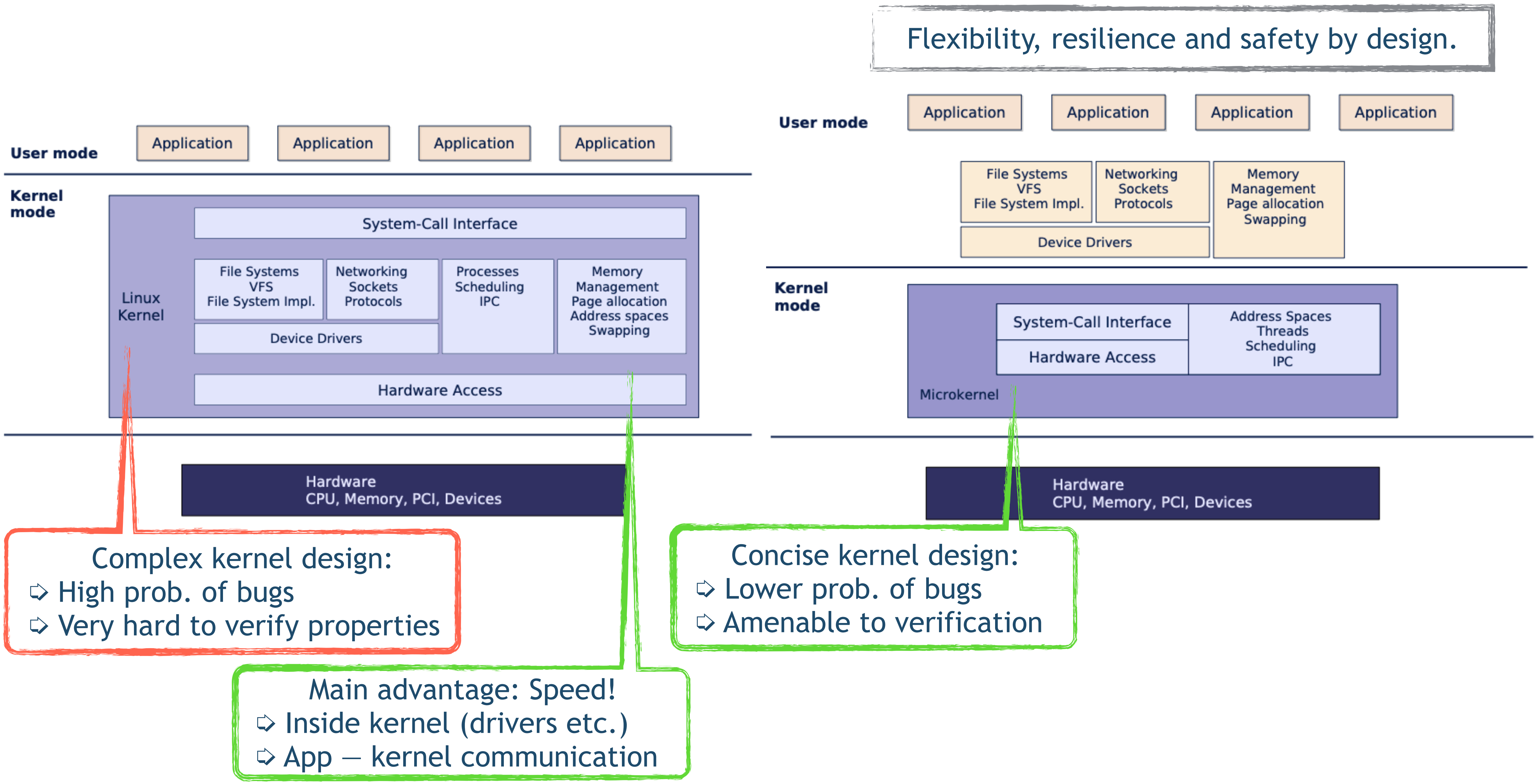

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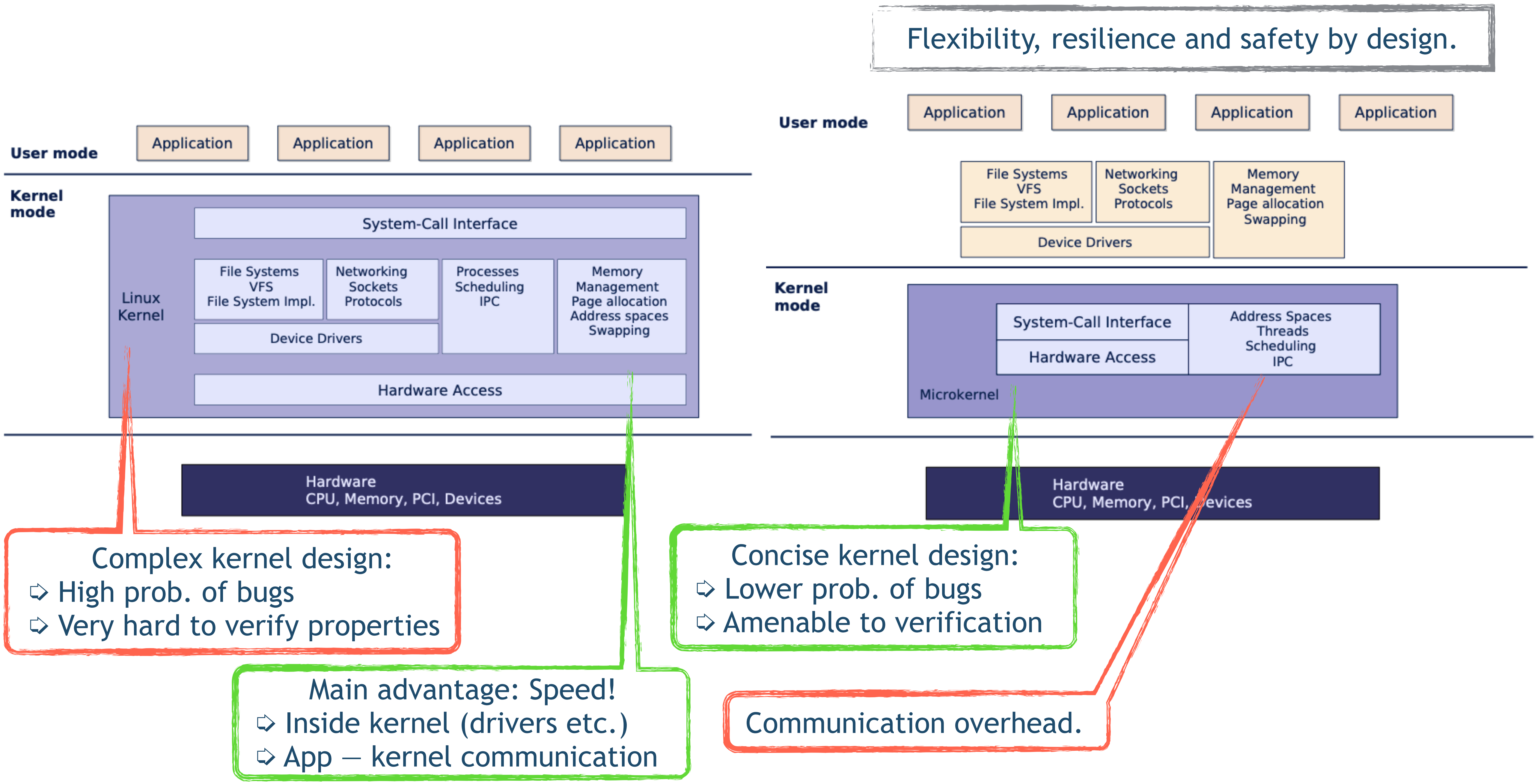

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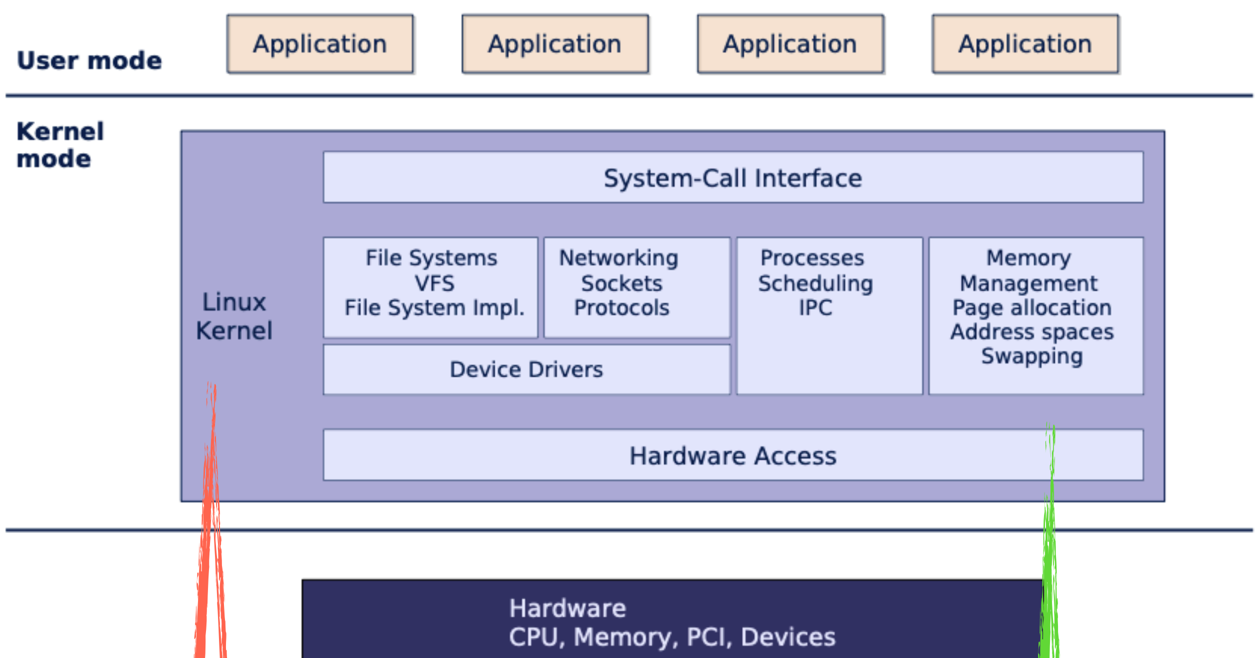
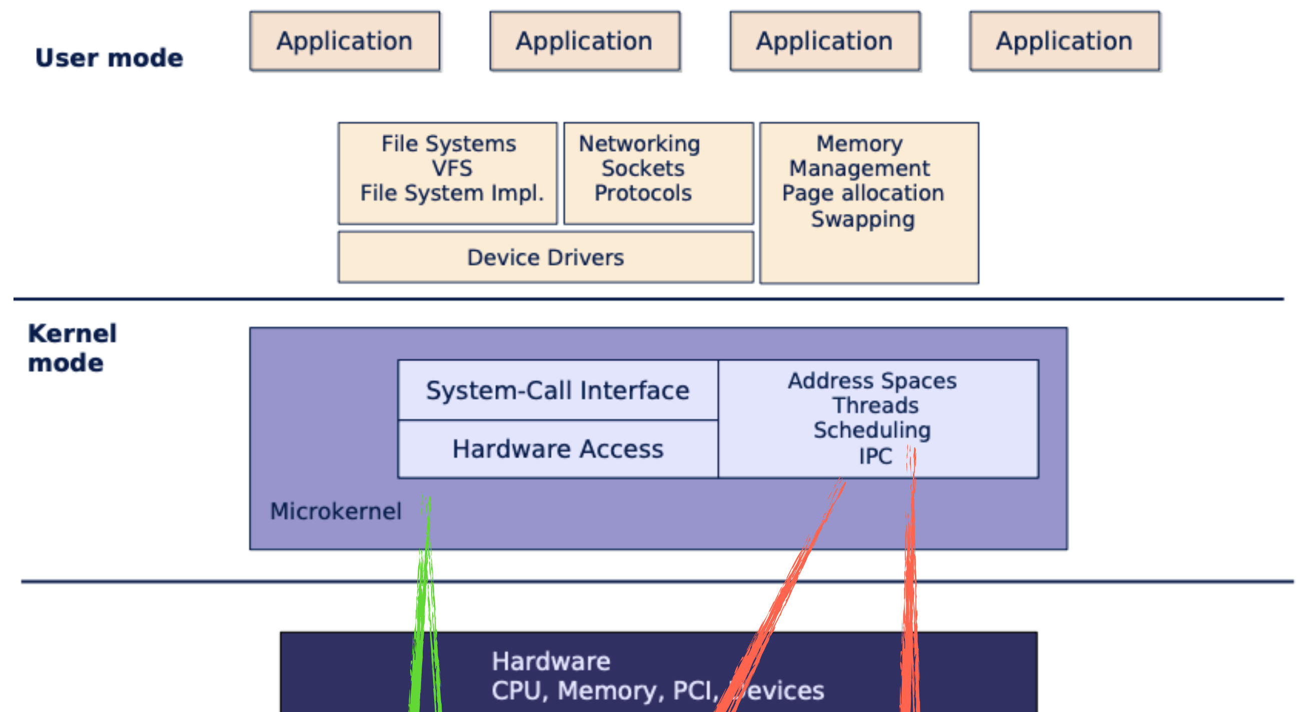




Complex kernel design:
- ➪ High prob. of bugs
- ➪ Very hard to verify properties

Main advantage: Speed!
- ➪ Inside kernel (drivers etc.)
- ➪ App – kernel communication

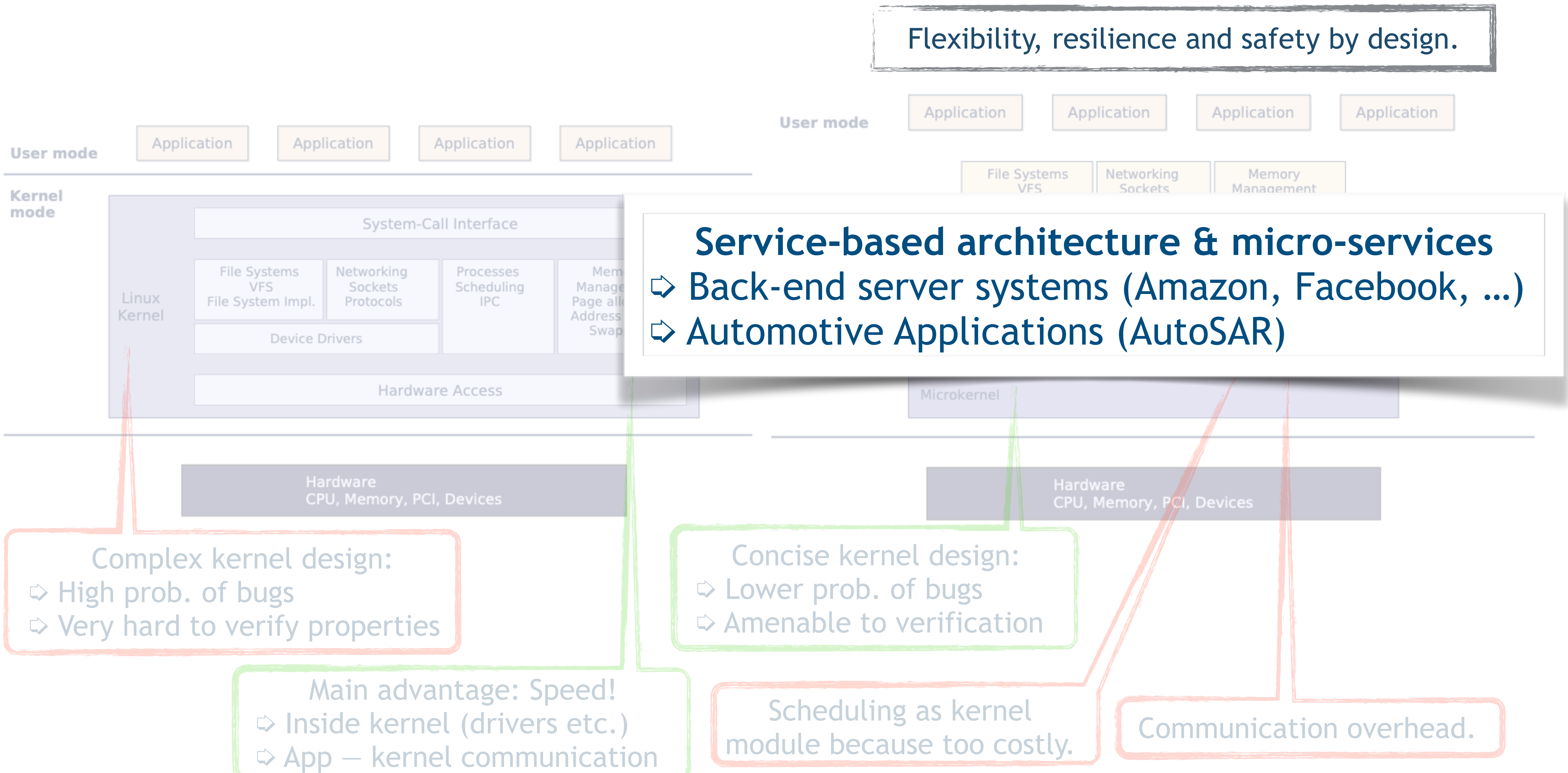
Concise kernel design:
- ➪ Lower prob. of bugs
- ➪ Amenable to verification

Communication overhead.

Scheduling as kernel module because too costly.

TU Dresden, Operating Systems Groups, Slides from Microkernel Lecture

Monolithic vs Micro Kernel Design



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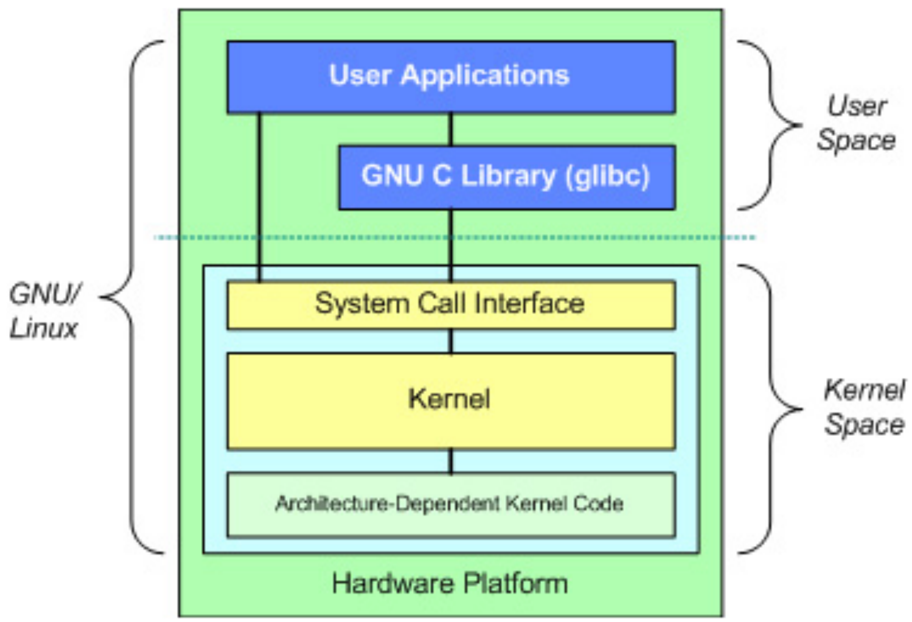
Linux Kernel



https://www.engineersgarage.com/tutorials/introduction-linux-part-715

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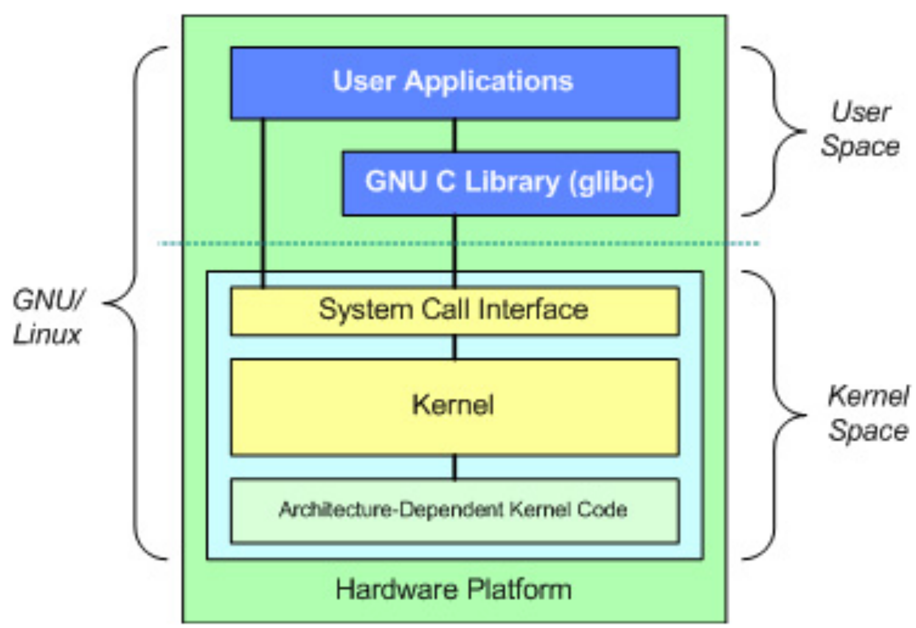

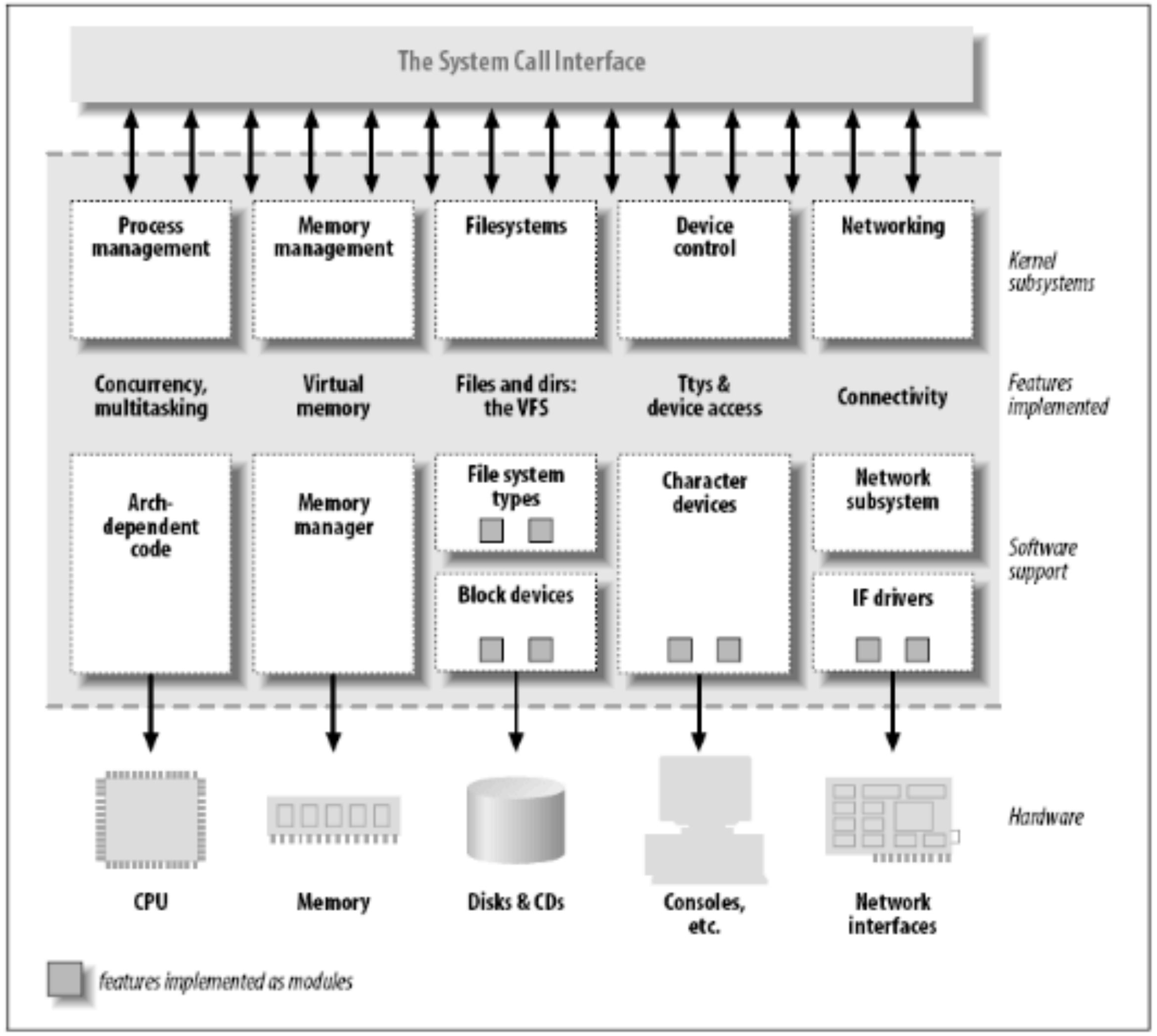

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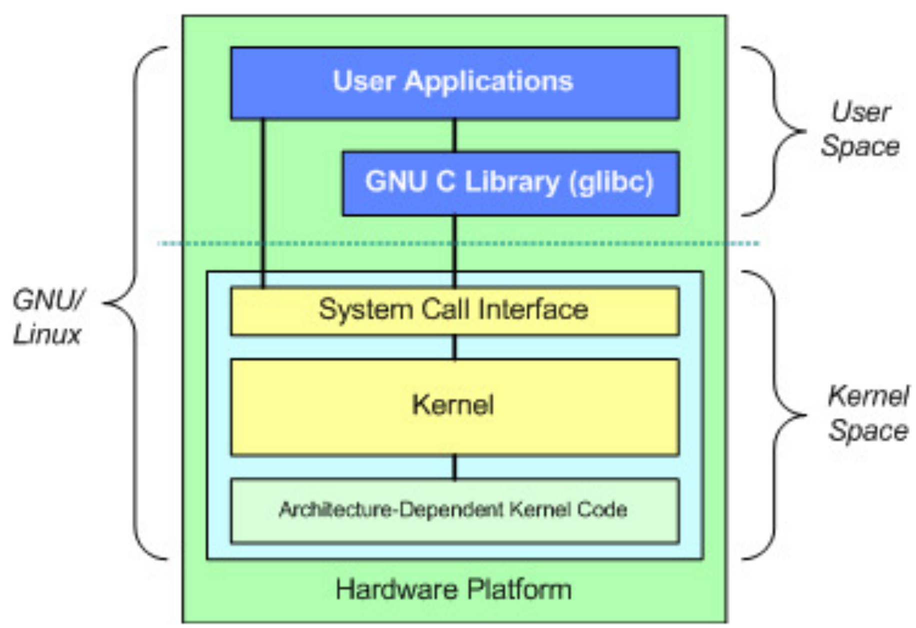

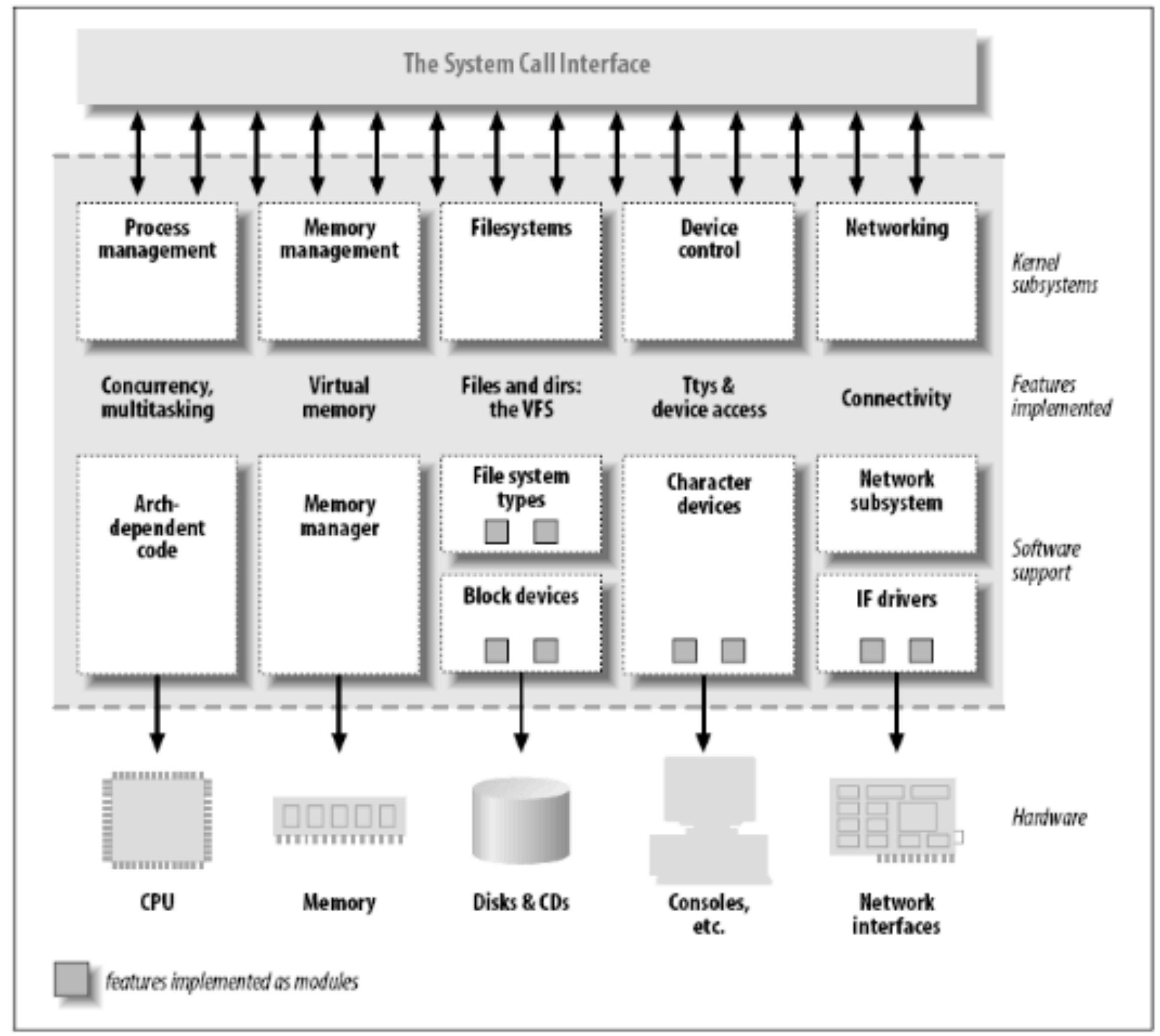

An OS kernel is inherently stateful!

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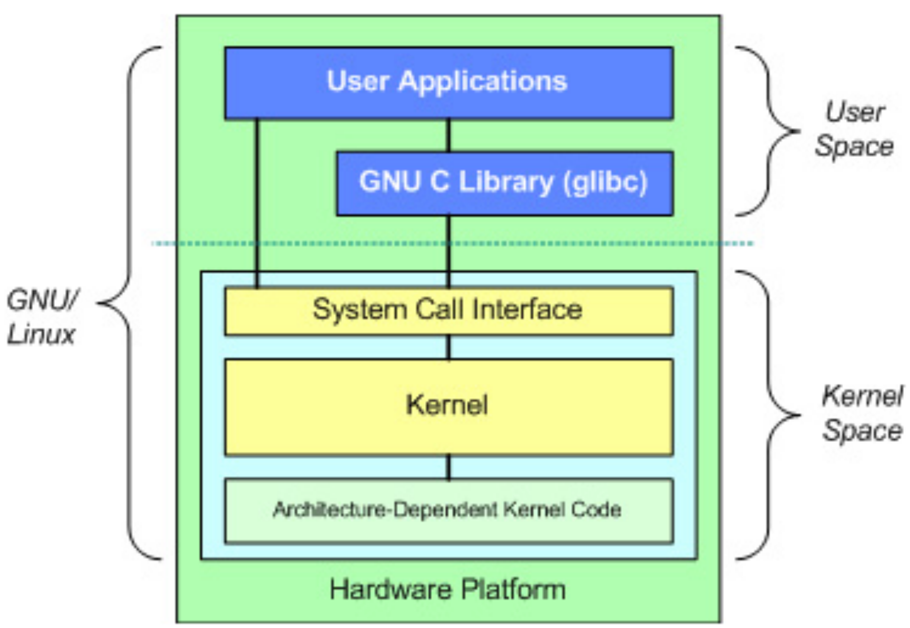
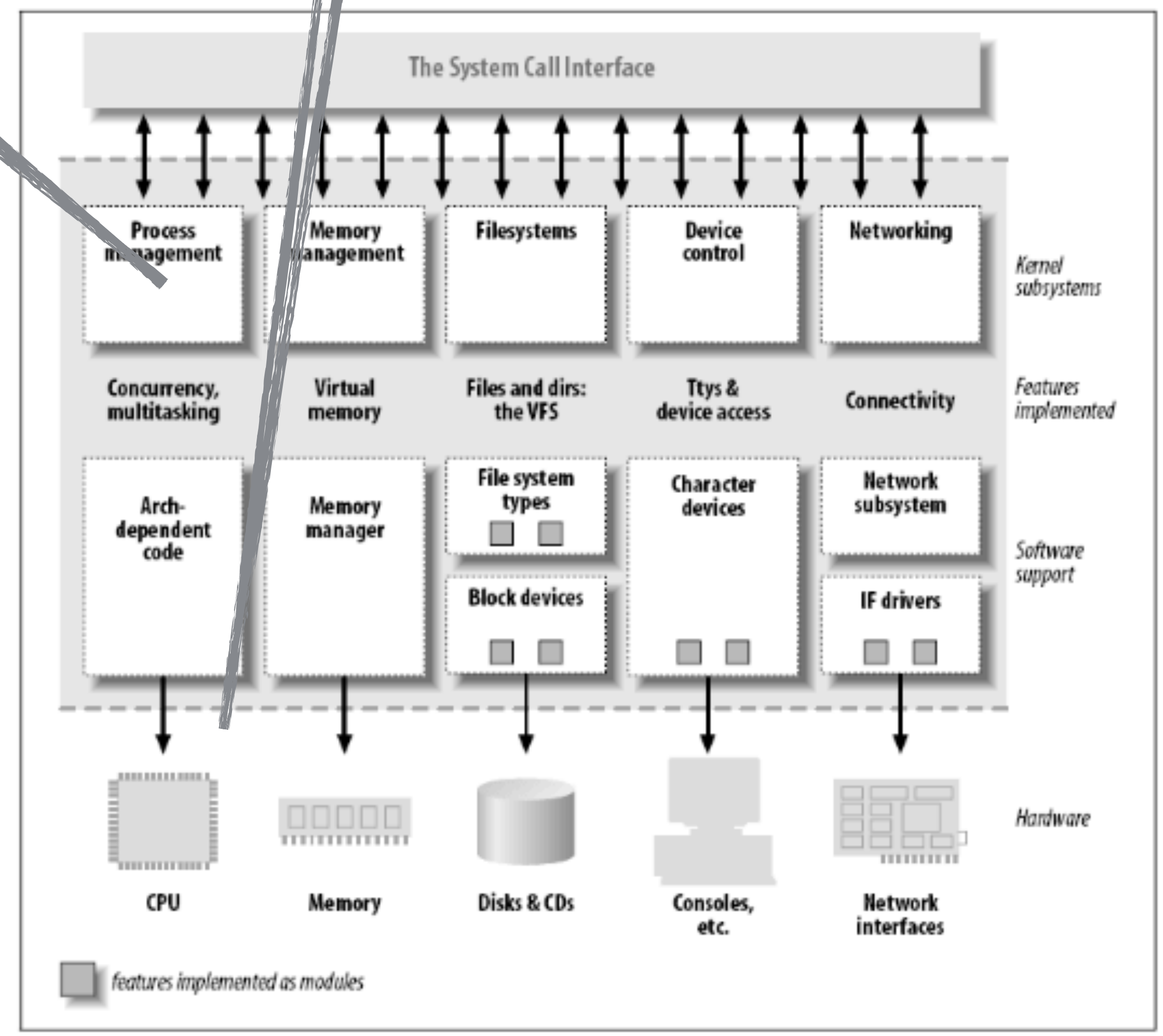
Linux Kernel

Completely Fair Scheduler

Process Isolation





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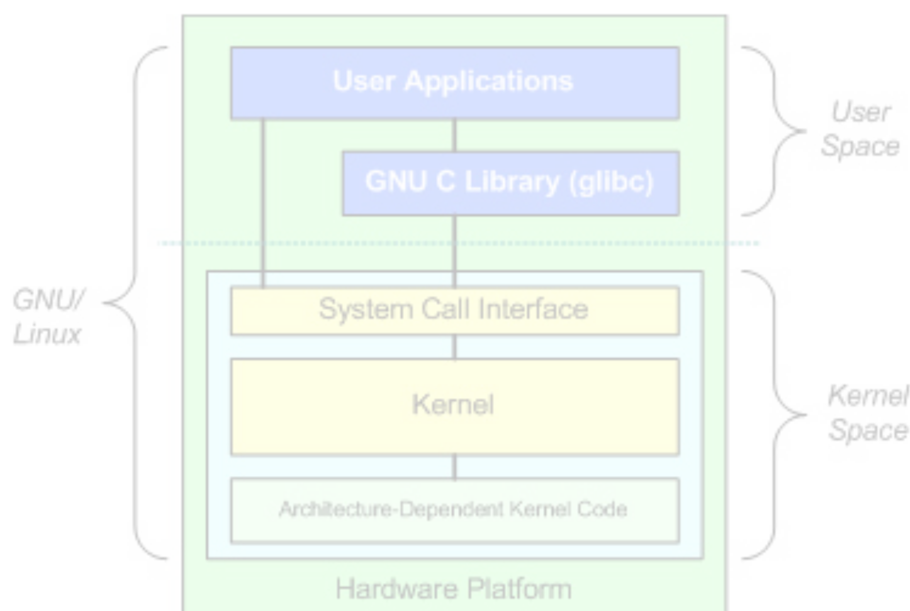

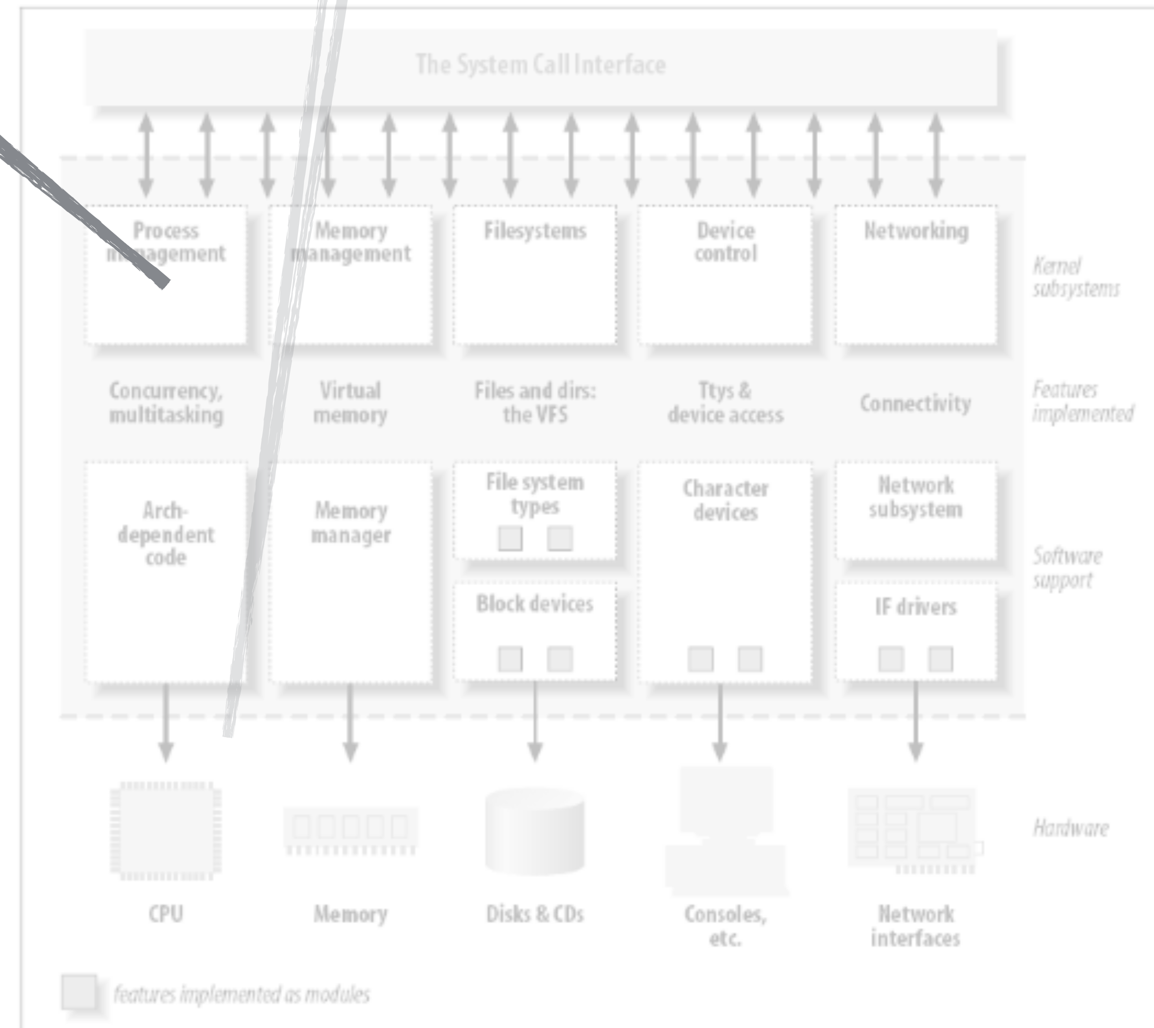

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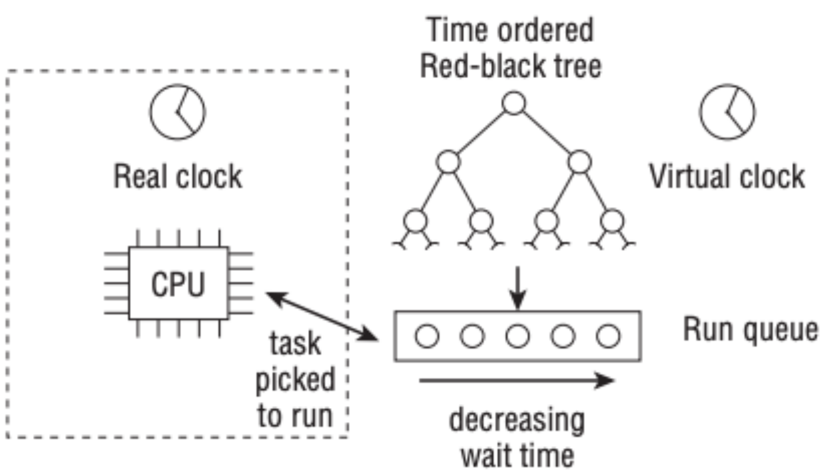
Linux Kernel
— Multi-core Architecture —



CPU 1

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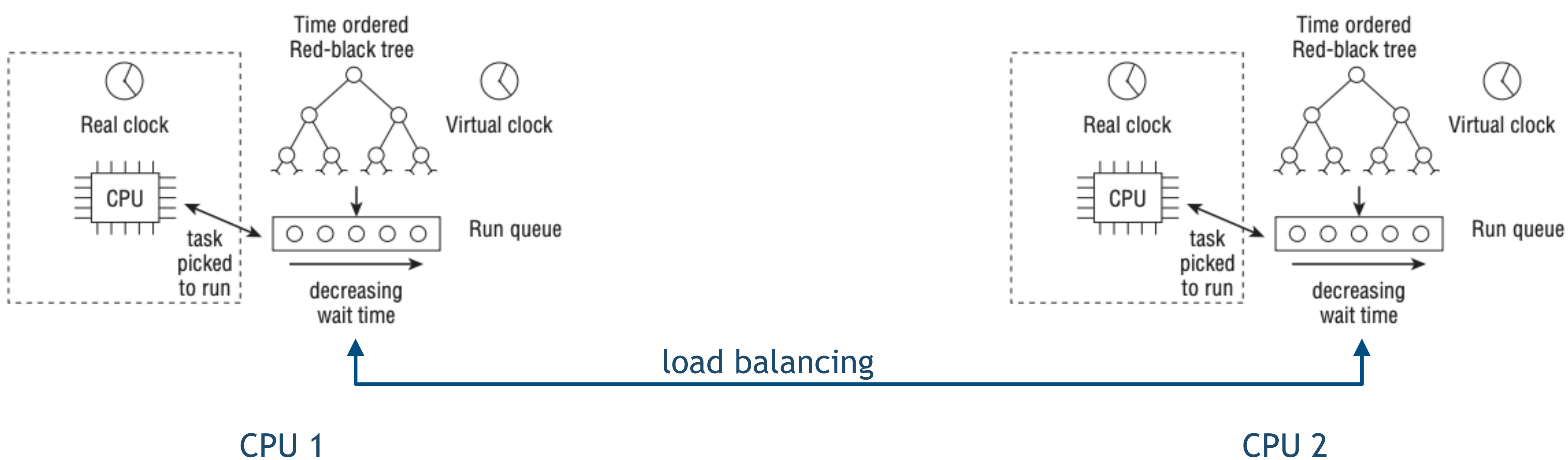

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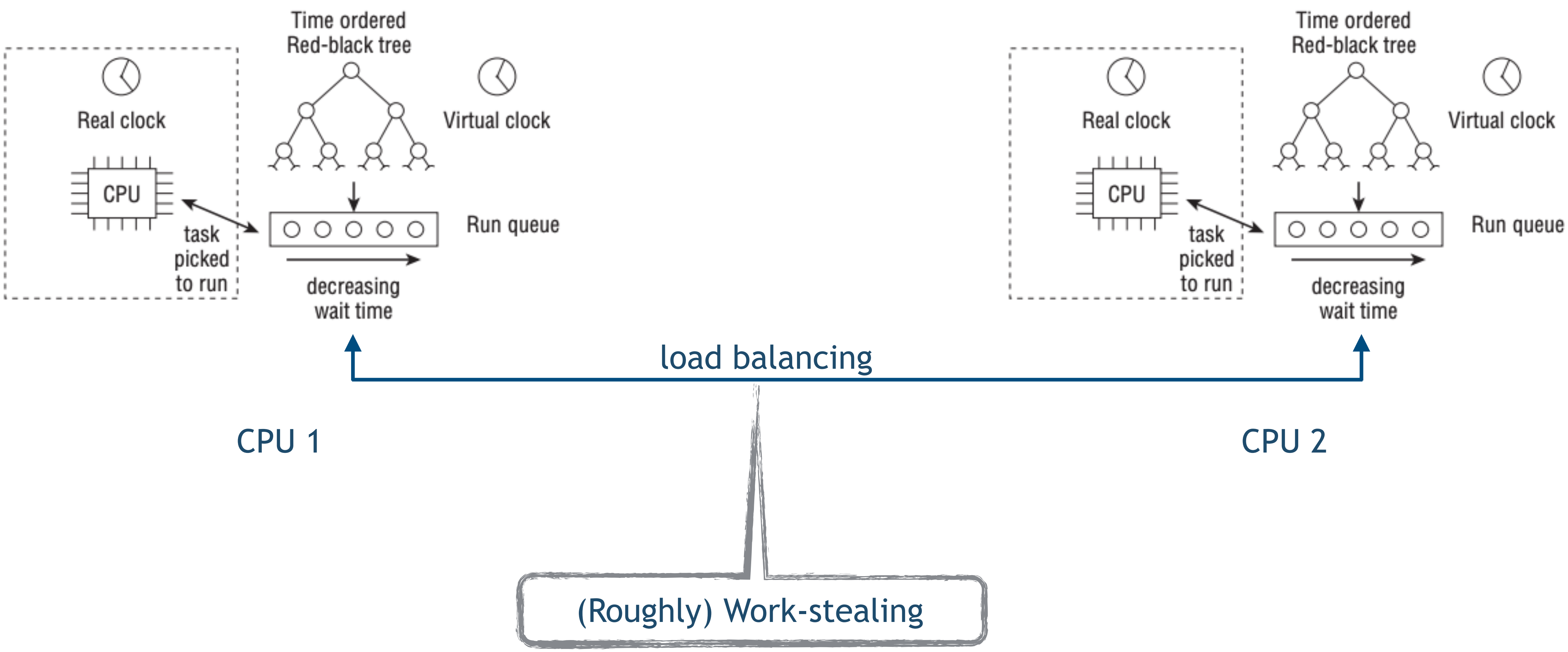

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Multikernel — Barrelfish

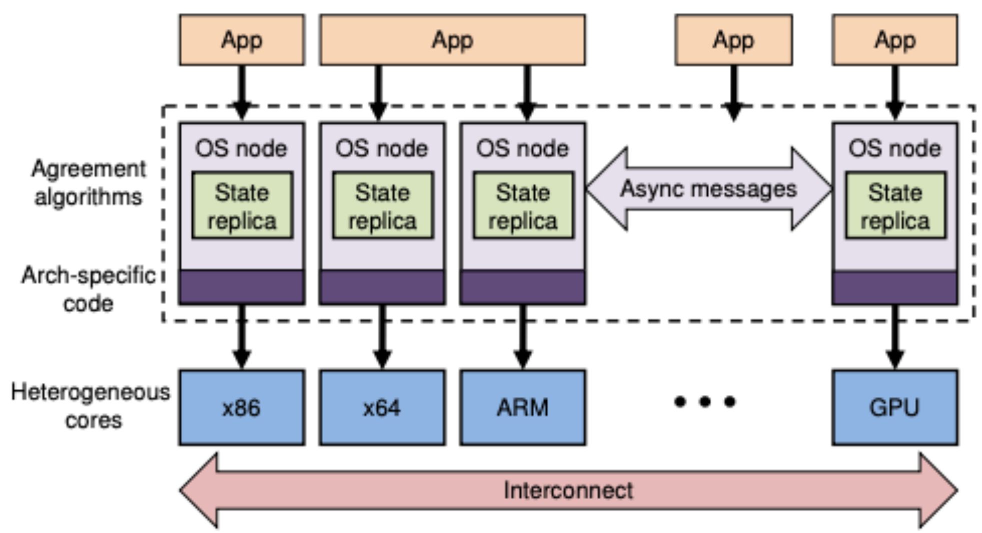

Figure 1: The multikernel model.

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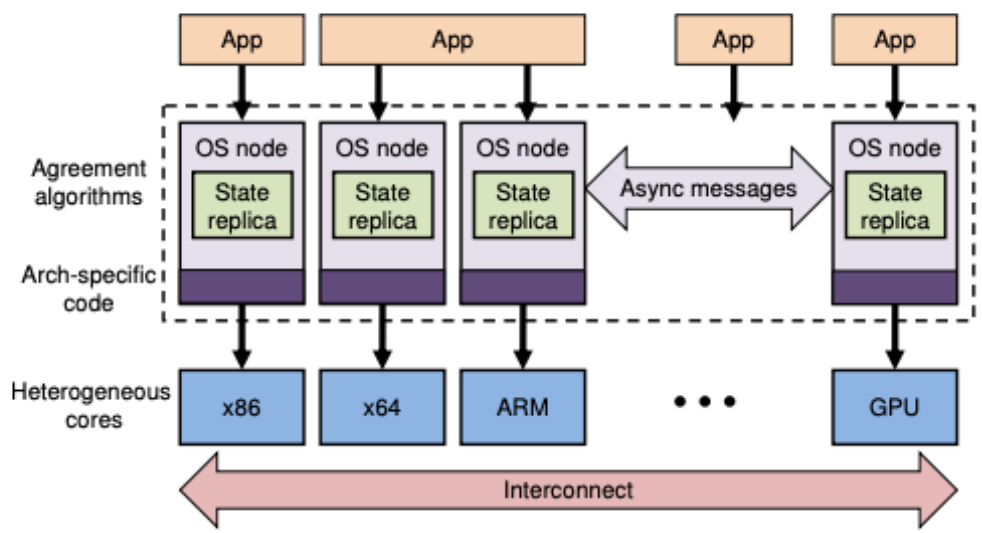

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Highlights:

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- replicated state with 2-phase commit coordination

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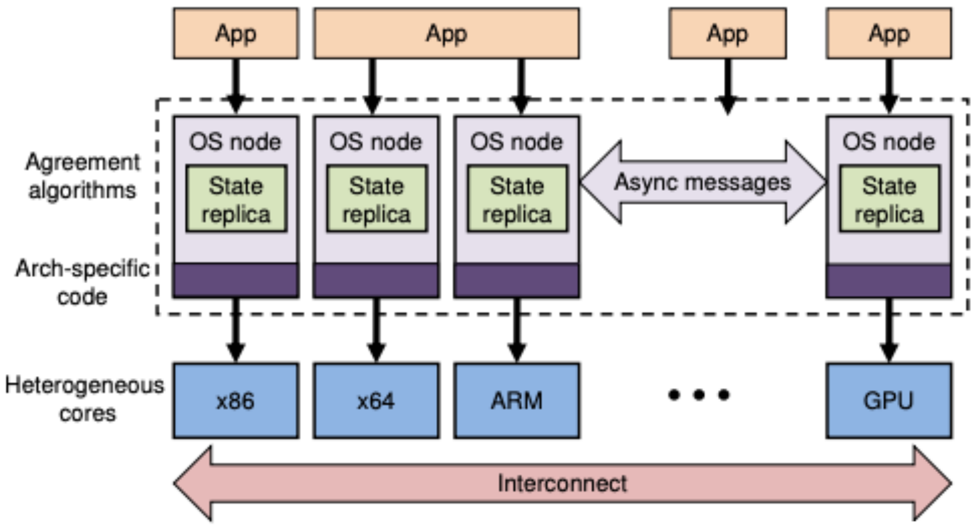

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Figure 4: Spectrum of sharing and locking disciplines.

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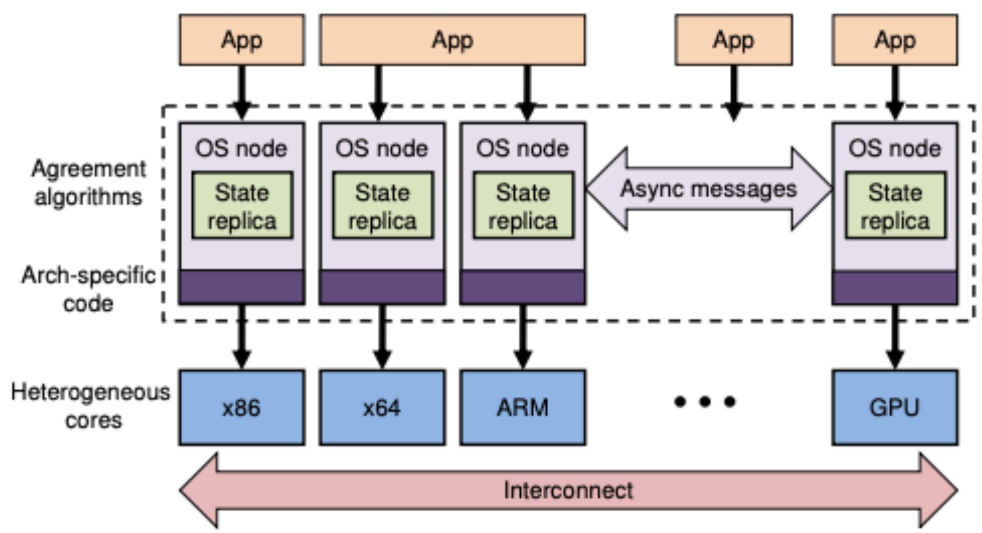

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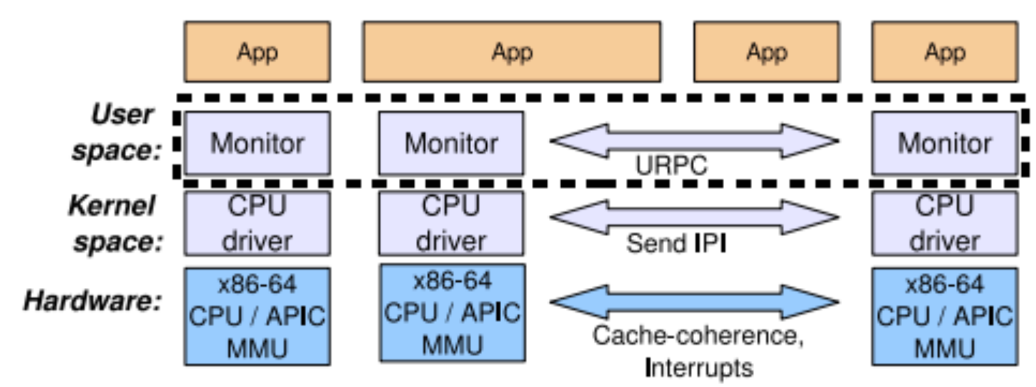

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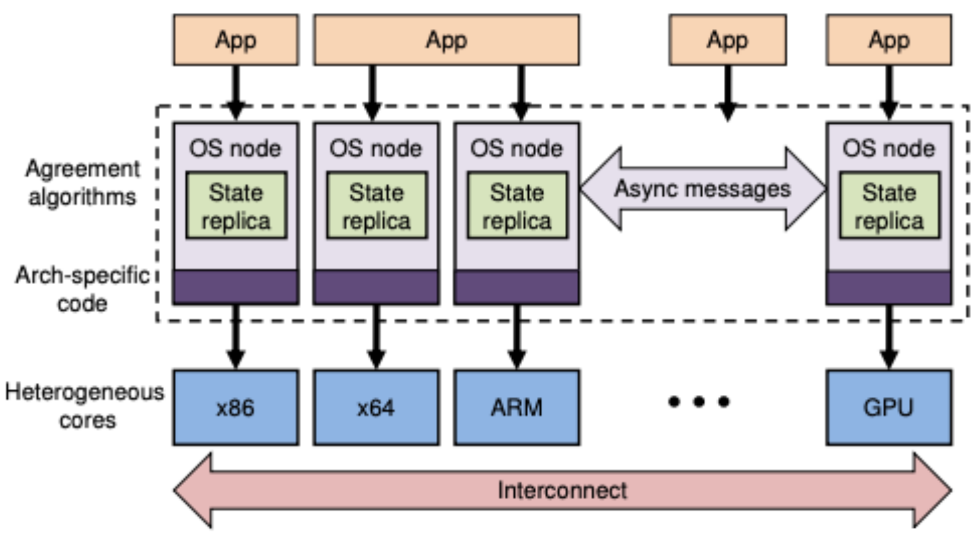

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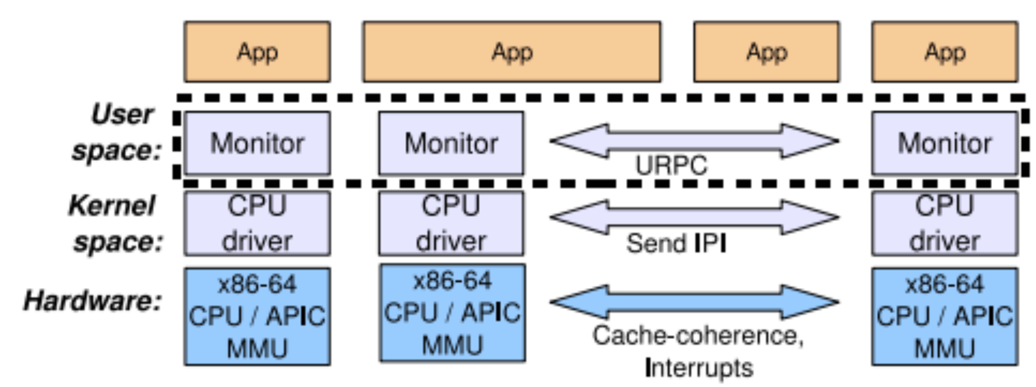
Analysis:

- great modular design for heterogeinity
- replicated state == replicated cache
- 2-phase commit vs. HW cache coherency



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Linux on Multi-/Many-core

Monolithic kernels can scale:

- "Just" pick the right locks!
- Make side-effects local whenever possible!
- Use "new" optimizations (sloppy counters)!

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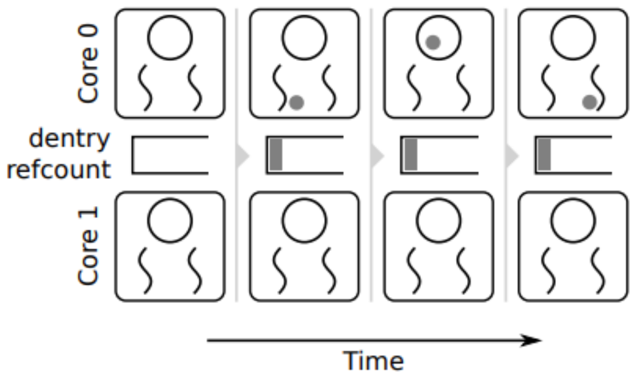

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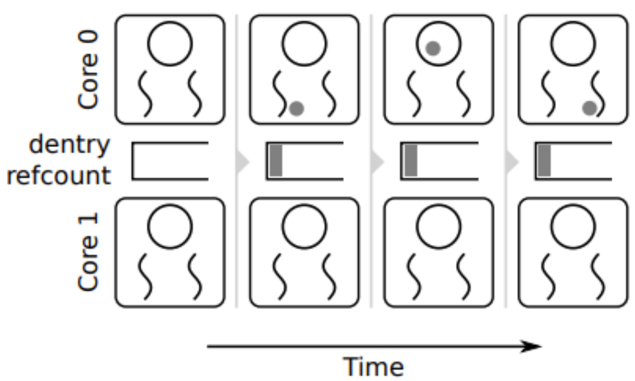

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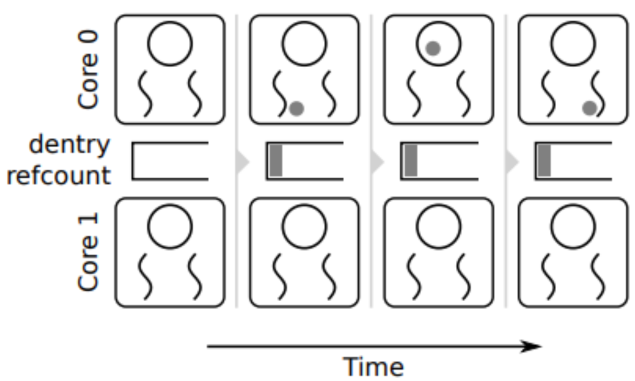

Architecture-dependent optimizations:

- often spread across various routines in the kernel/scheduler and
- result in semantic composability problems of functions.

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Take-away Points

Support for heterogeneity:

- Good separation of architectural aspects results in simpler and more concise kernels
- Optimize messaging interactions via well-known techniques (batching)

Scheduling:

- Implementing a correct scheduler for heterogeneous architectures is a big challenge!
- Even more so for micro-kernels.

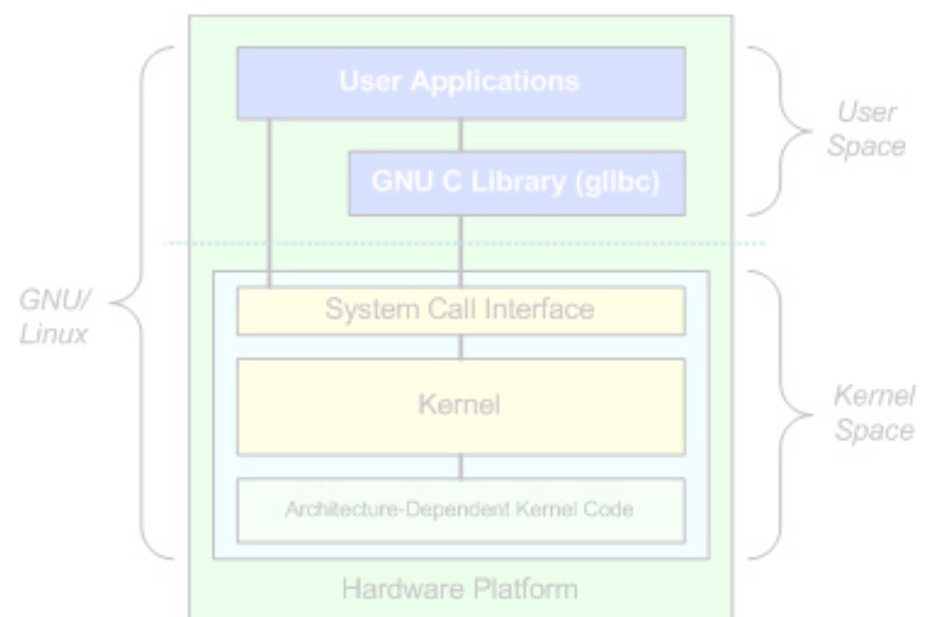
Cache-coherence vs Message-passing:

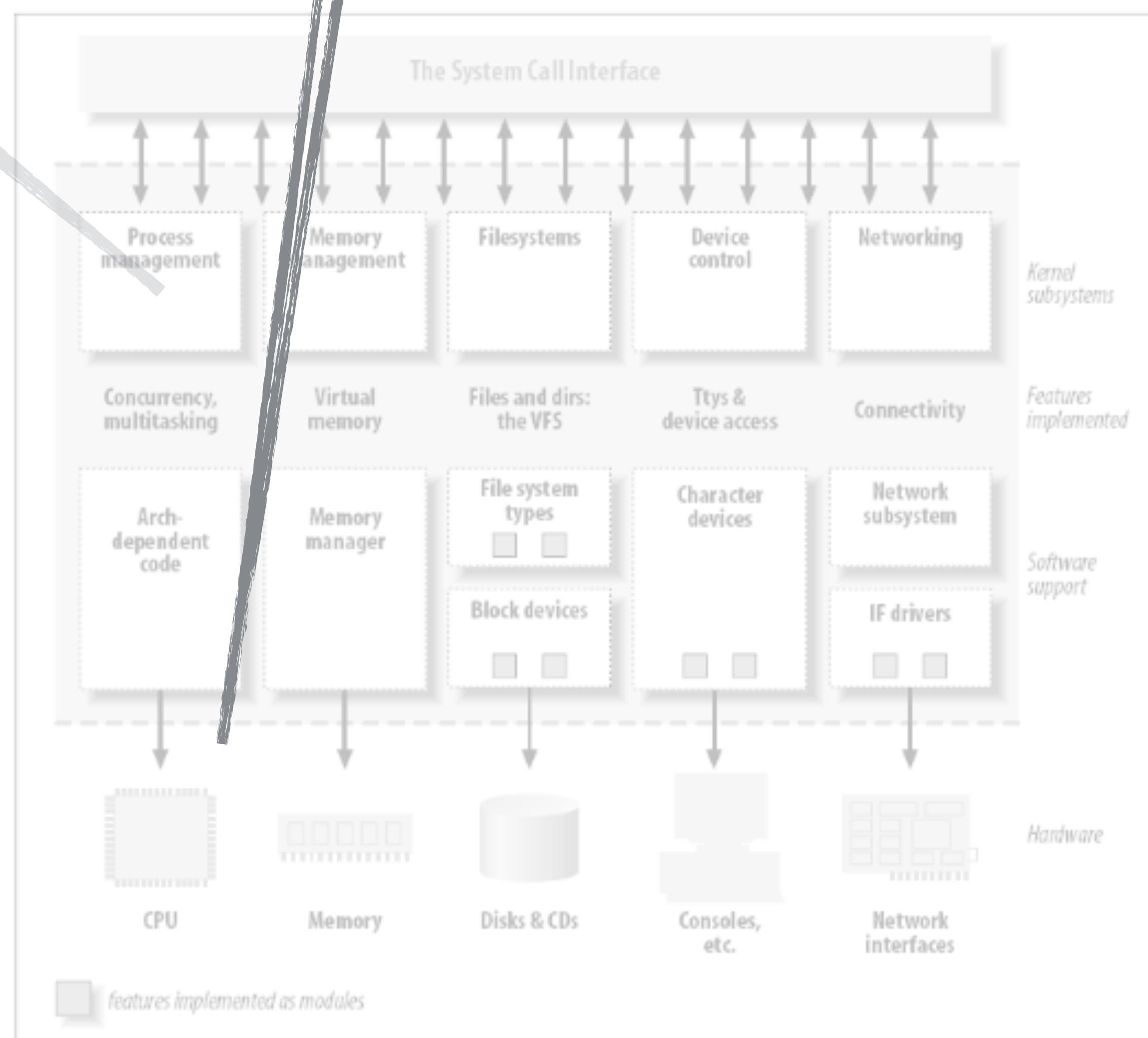
- Abstract and optimize for the fastest approach provided by HW.
- The programming model of the kernel matters!
- Treat them not only as alternatives but things that can be used in parallel!

Linux Kernel

Completely Fair Scheduler

Process Isolation





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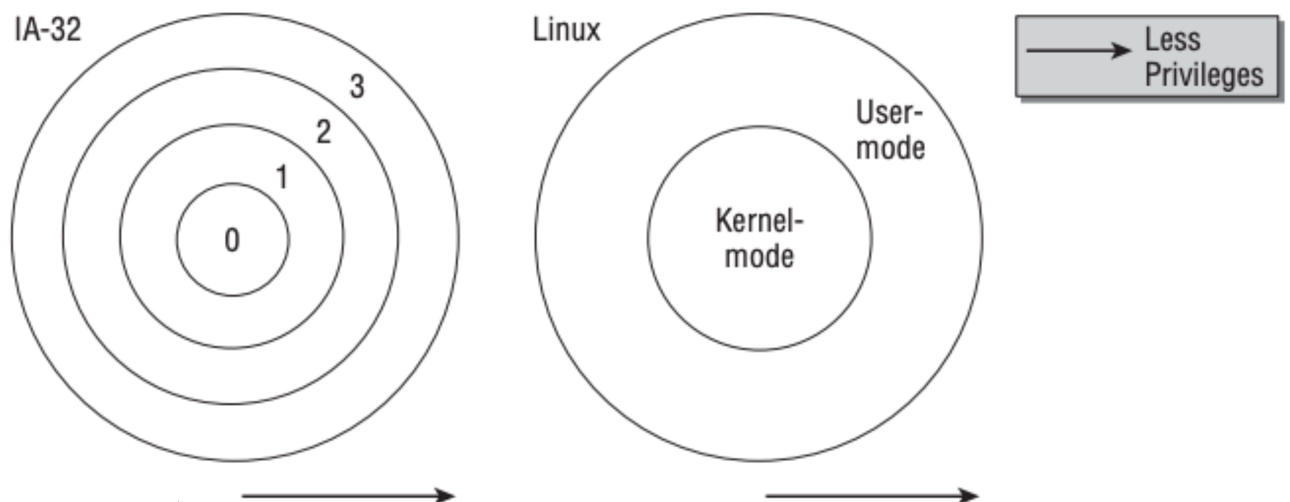

Hardware-based Protection overhead.
MMU ➪ Control Register 0 (x86)

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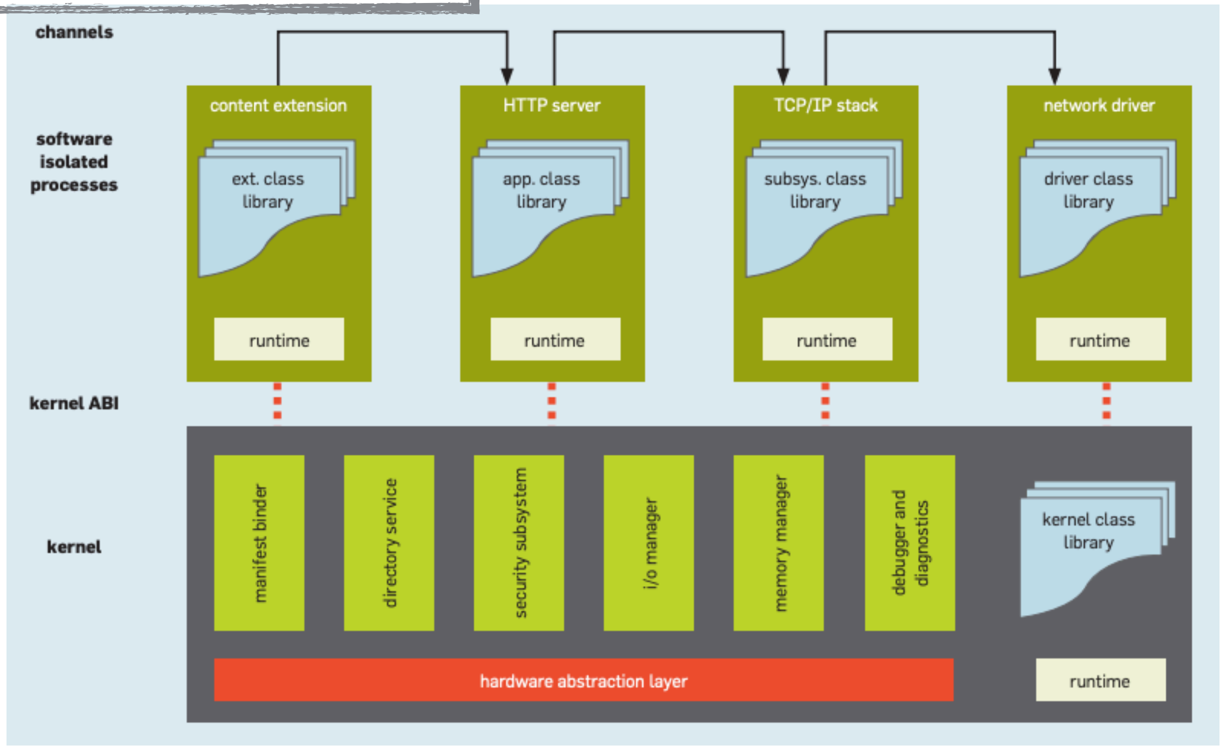
Singularity

Microkernel design.



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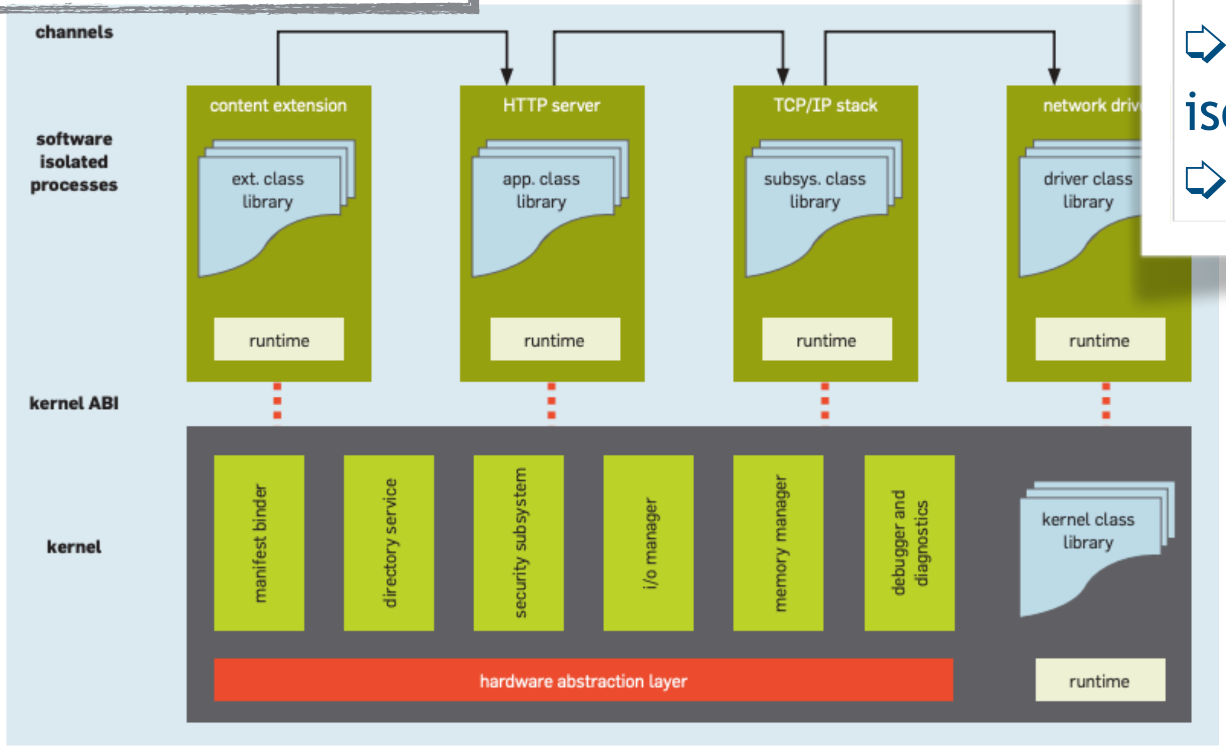

Highlights:

- ownership/linear types to construct software isolated processes
- contracts (session types) to verify across processes

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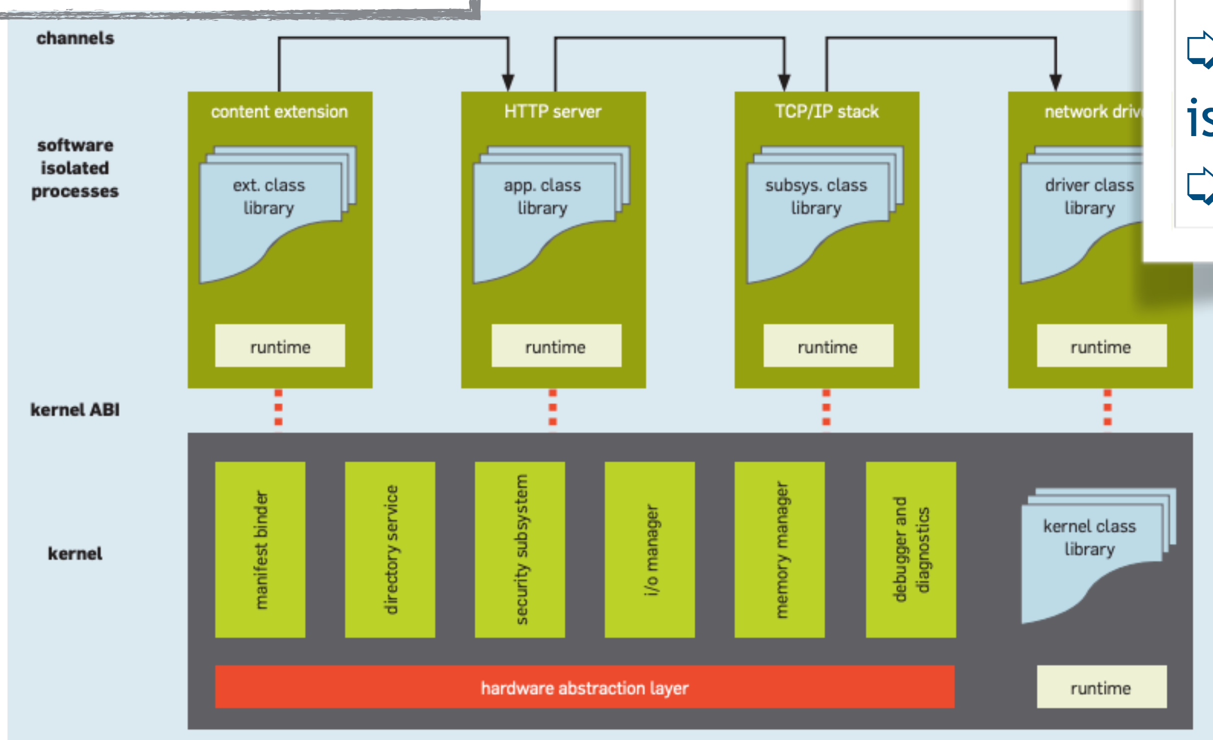

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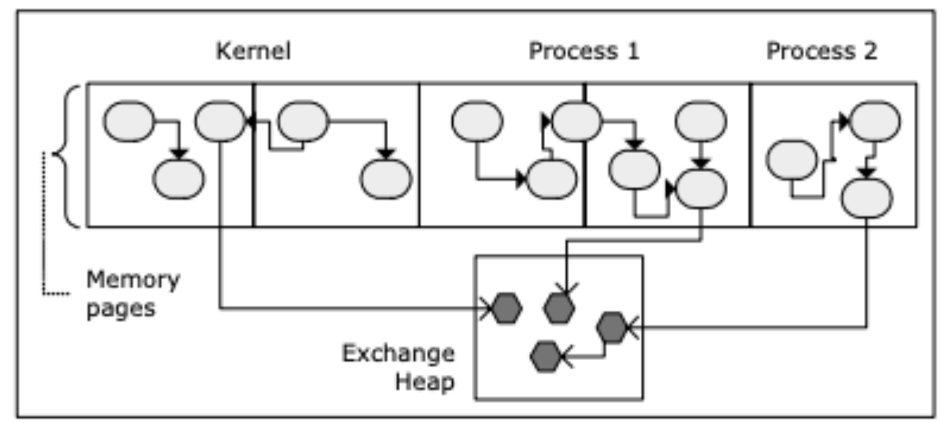

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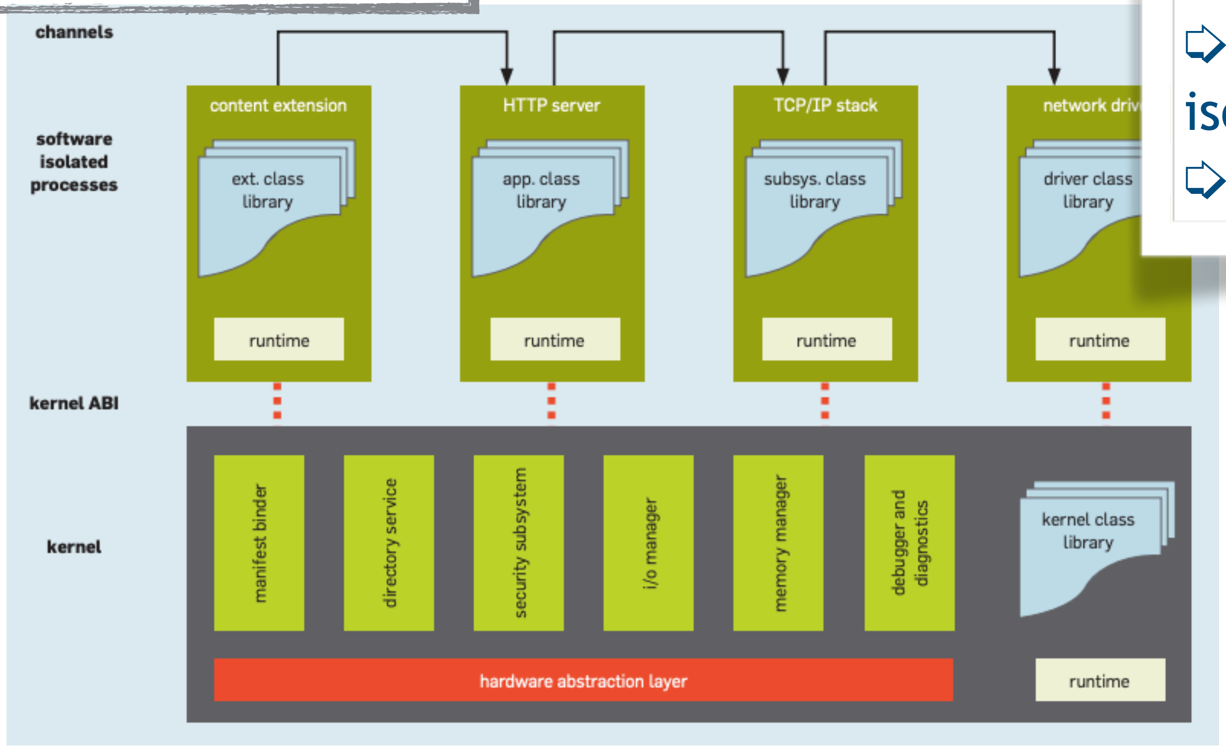

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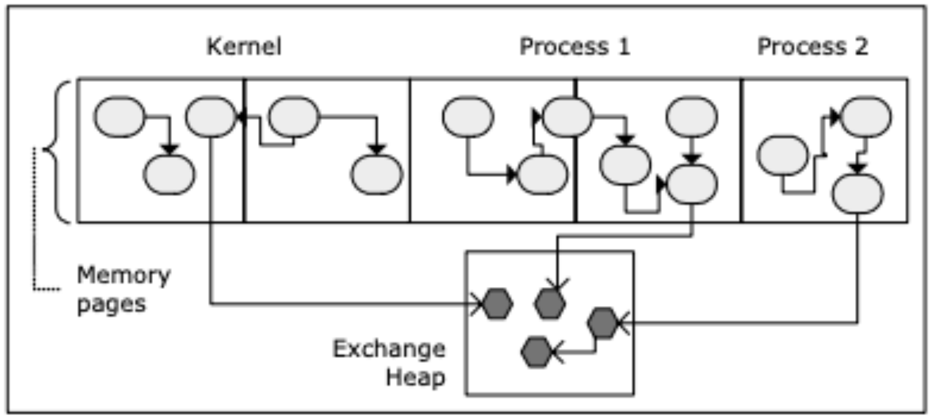

Analysis:

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- zero-copy messaging!
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Singularity

Comparison possible!

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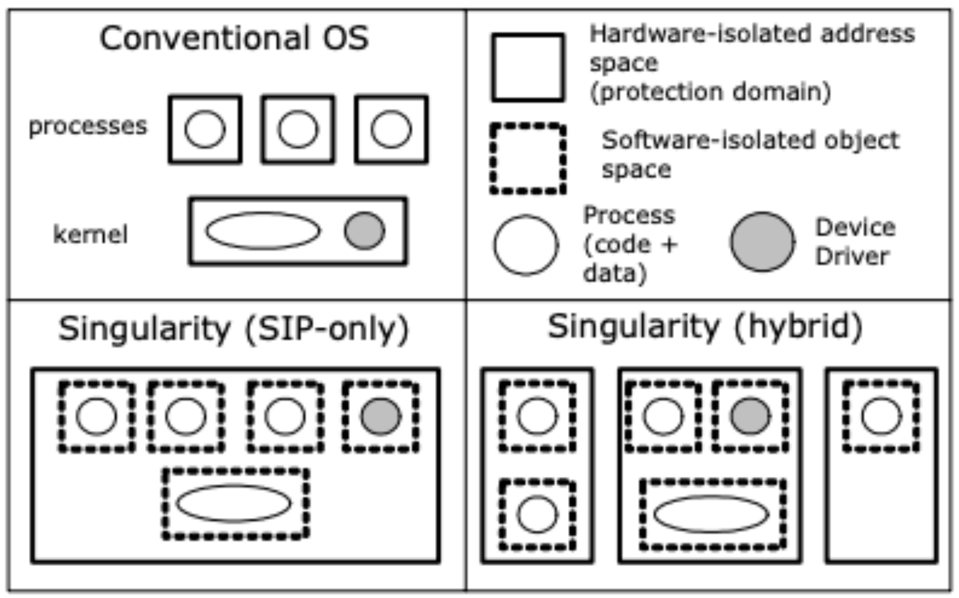
Singularity

Comparison possible!



Analysis:

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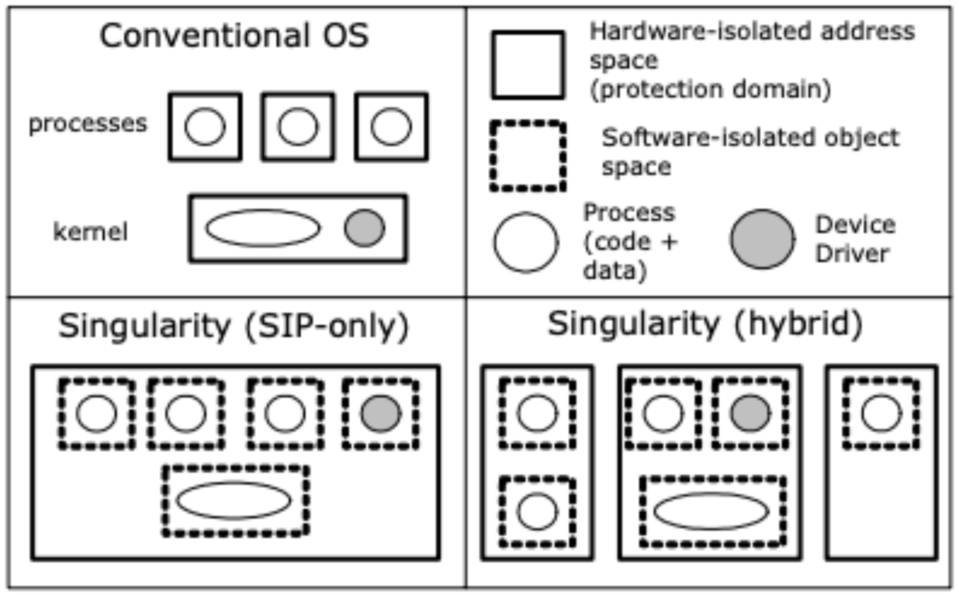

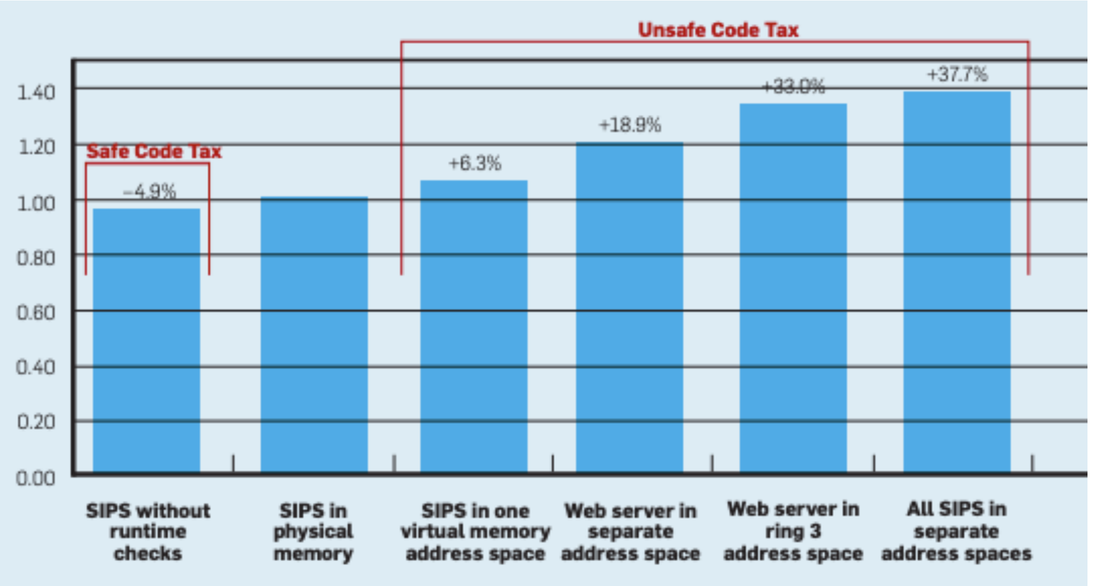

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Take-away Points

Efficient communication and process isolation:

➪ Ownership types and Linear types are your friends!

Cross-application verification:

➪ Check out Session Types!

Open challenges:

➪ Trusted code verification.

➪ Support for applications written in other languages.

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