The Hierarchical Microkernel: A Flexible and Robust OS Architecture

Stefan Winter, Martin Tsarev, Neeraj Suri
DEEDS Group, TU Darmstadt
moduli-os@deeds.informatik.tu-darmstadt.de

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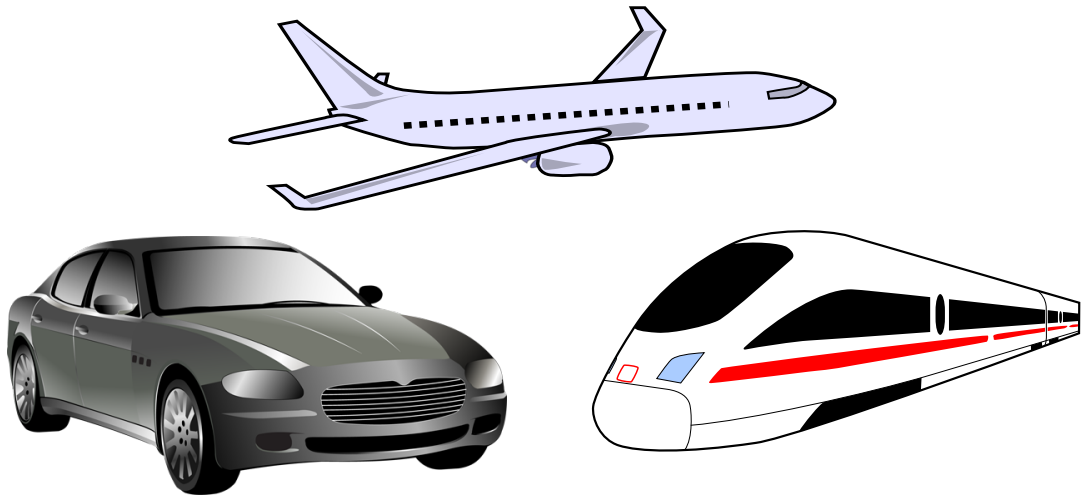
Problem Statement

Existing Approaches

Proposed Solution

Summary

My PhD research focus



Robustness

Correct operation despite

- invalid inputs
- stressful environmental conditions

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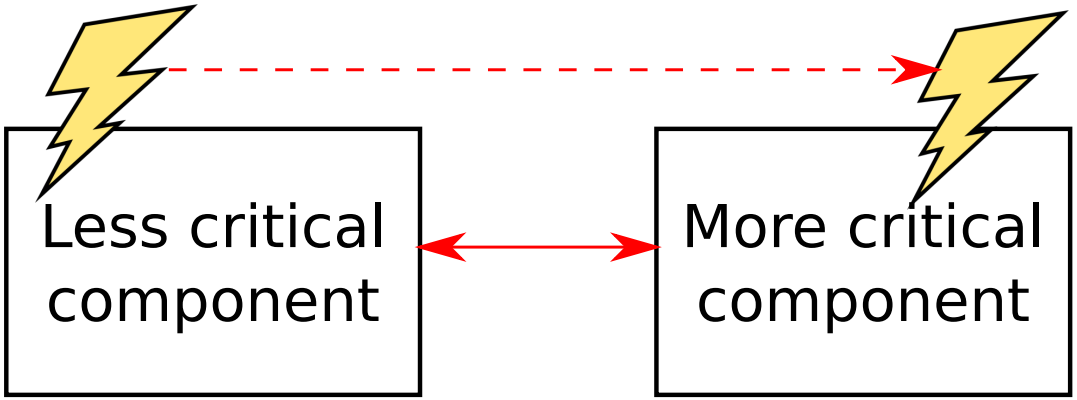

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How (most) software systems evolve

Composition

- static linking
- dynamic linking

Problems

- static: system down time
- dynamic. . . ?

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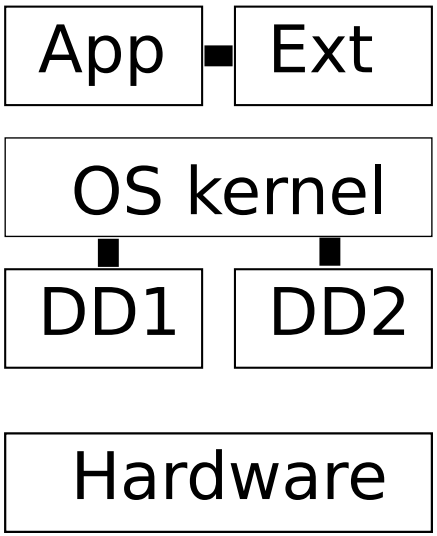
Monolithic compositions do (not) support robust evolution



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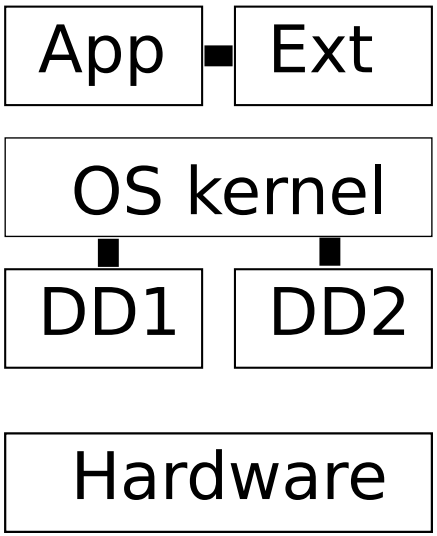

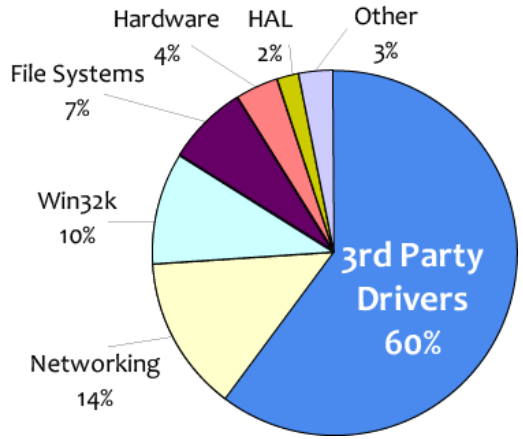

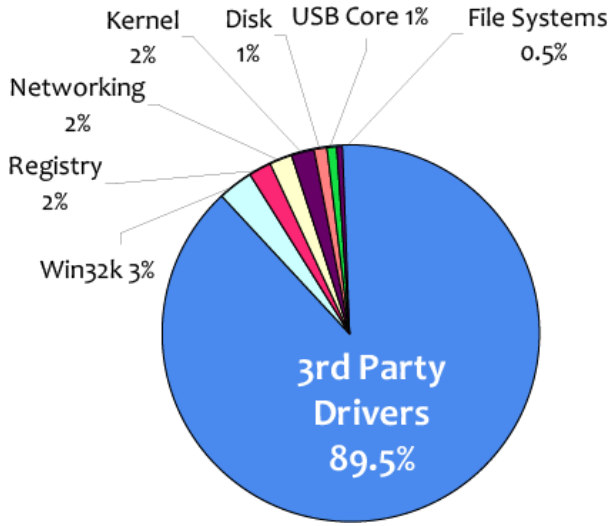

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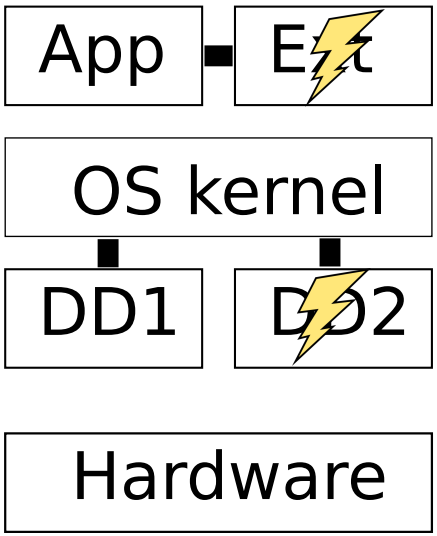

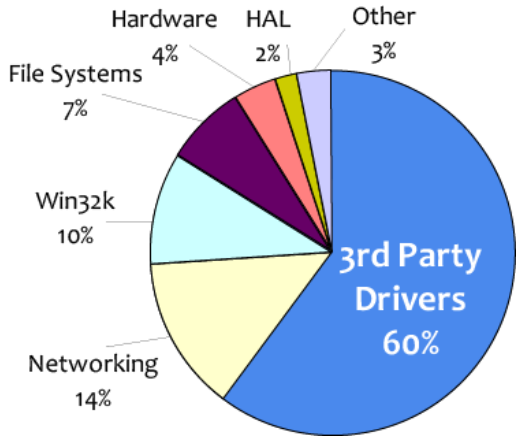

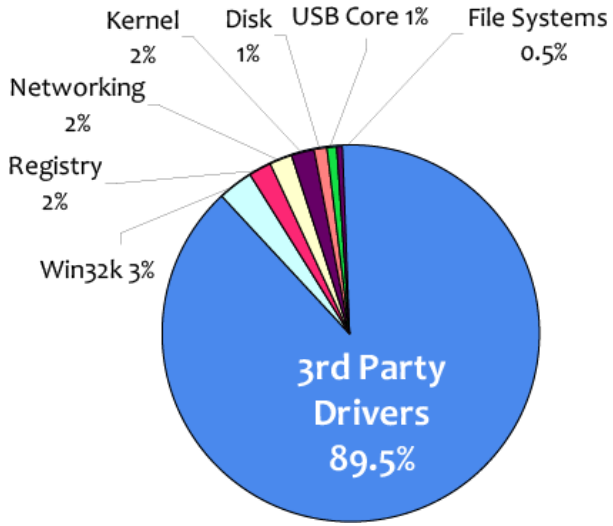

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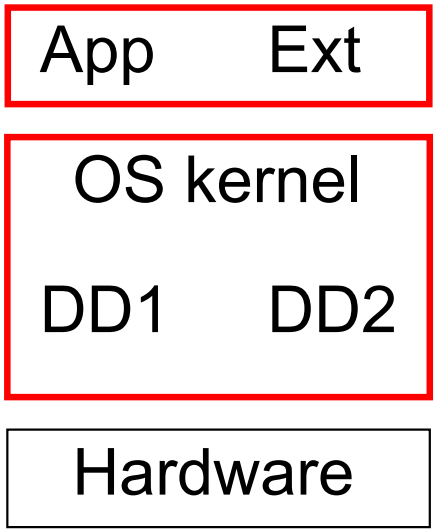
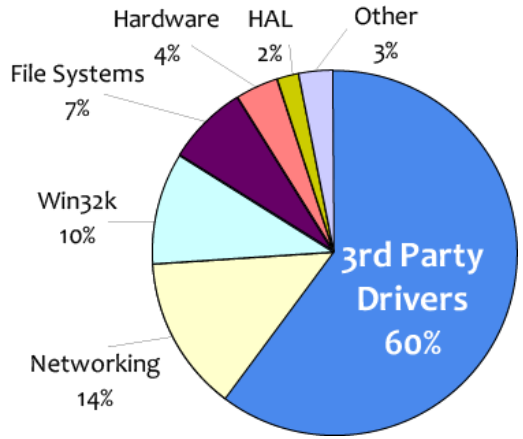
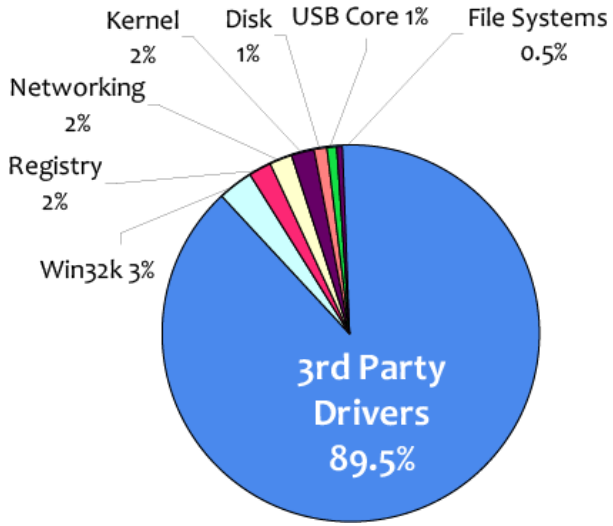
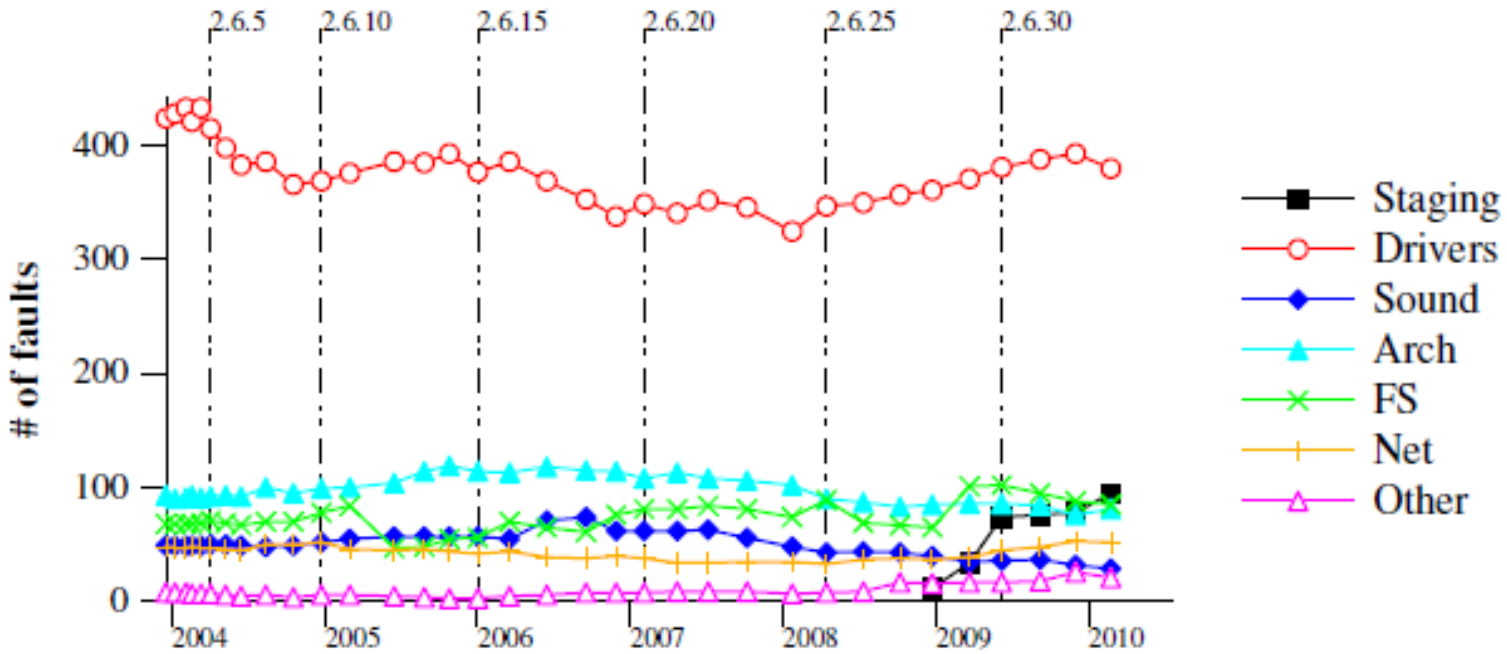






Extensions are difficult to get right



© Palix et al., *Faults in Linux: ten years later*, ASPLOS'11

Problems with software evolution

1. components of different criticality
2. components of different origin (COTS/SOUP)
3. uniform privilege
4. complex and volatile interfaces evolve independently

Solution 1: Sandboxing

- Nooks: Linux driver sandboxing[1]
- Microdrivers[2]: performance-critical code in the kernel
- BGI: Byte-Granularity Isolation[3]
- (L)XFI: Windows/Linux in-kernel fault isolation[4,5]

Sandboxing issues

- available?
- working?
- *co-evolution* with OS required

[1] Swift et al.: *Improving the Reliability of Commodity Operating Systems*, SOSP'03
[2] Ganapathy et al.: *The design and implementation of microdrivers*, ASPLOS'08
[3] Castro et al.: *Fast Byte-Granularity Software Fault Isolation*, SOSP'09
[4] Erlingsson et al.: *XFI: software guards for system address spaces*, OSDI'06
[5] Mao et al.: *Software fault isolation with API integrity and multi-principal modules*, SOSP'11

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Solution 2: Isolation by design

- Virtual Machines[6]: high redundancy
- Singularity[7]: type safety, limited runtime protection
- Microkernels[8]

[6] LeVasseur et al.: *Unmodified device driver reuse and improved system dependability via virtual machines*, OSDI'04

[7] Hunt et al.: *Broad New OS Research: Challenges and Opportunities*, HotOS'05

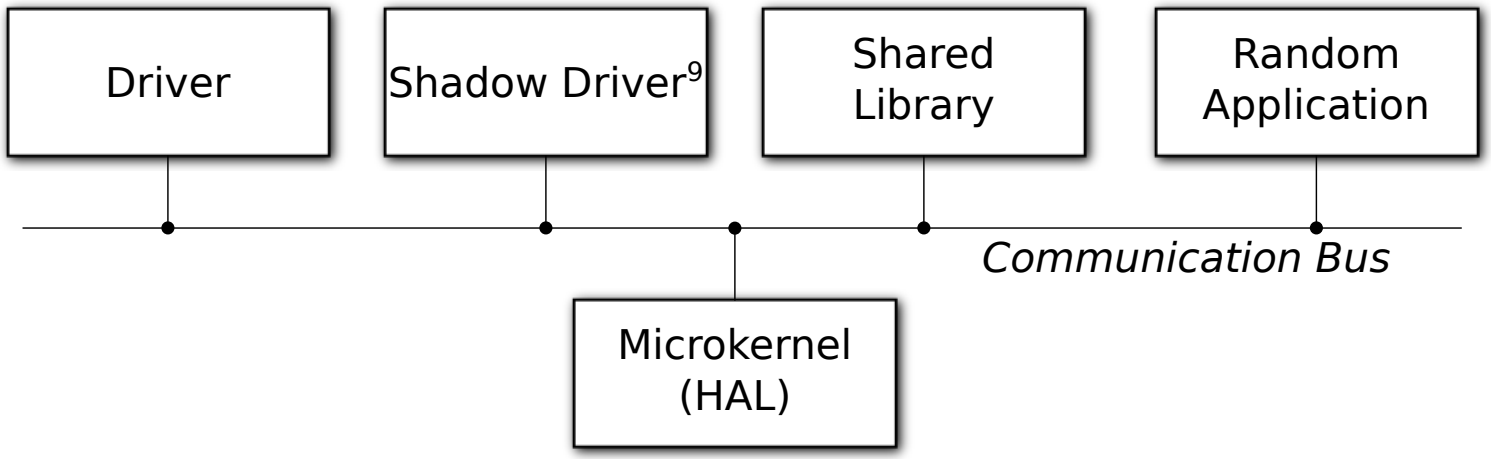
[8] Herder et al.: *Fault isolation for device drivers*, DSN'09

Proposed solution: "Hierarchical" μ-kernel

Two core concepts:

1. broadcast IPC
2. recursive system (de)composition

Broadcast communication and scalability



HM building blocks

- **Modules**: small isolated executable entities
- **Buses**: broadcast message-passing for inter-module communication (in software)

[9] Swift et al.: Recovering device drivers, ACM TOCS 24 4/2006

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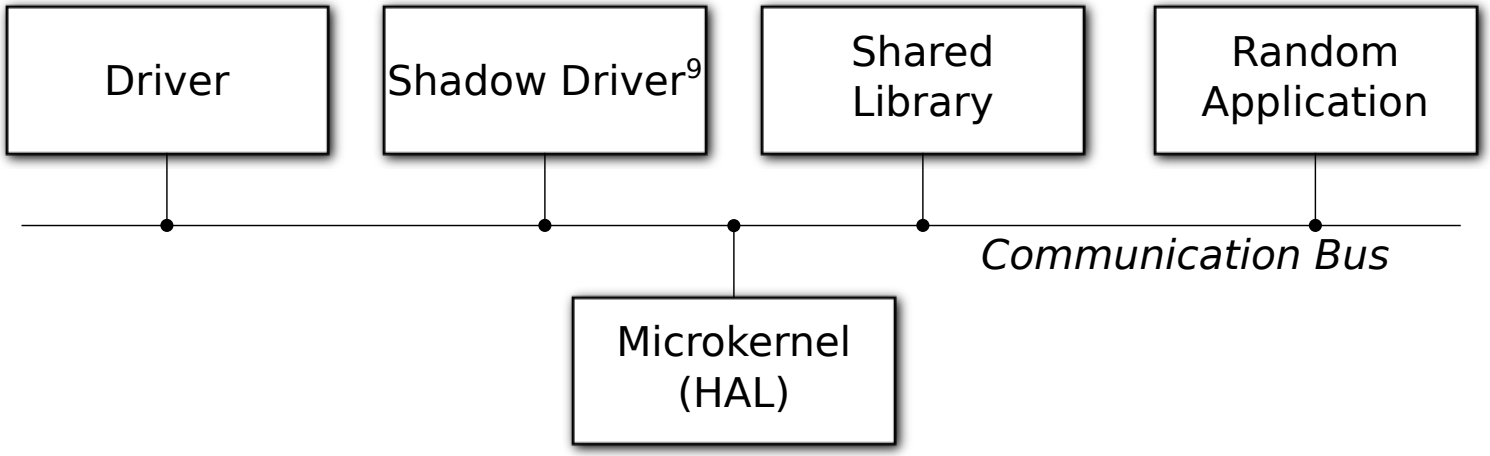


Pros

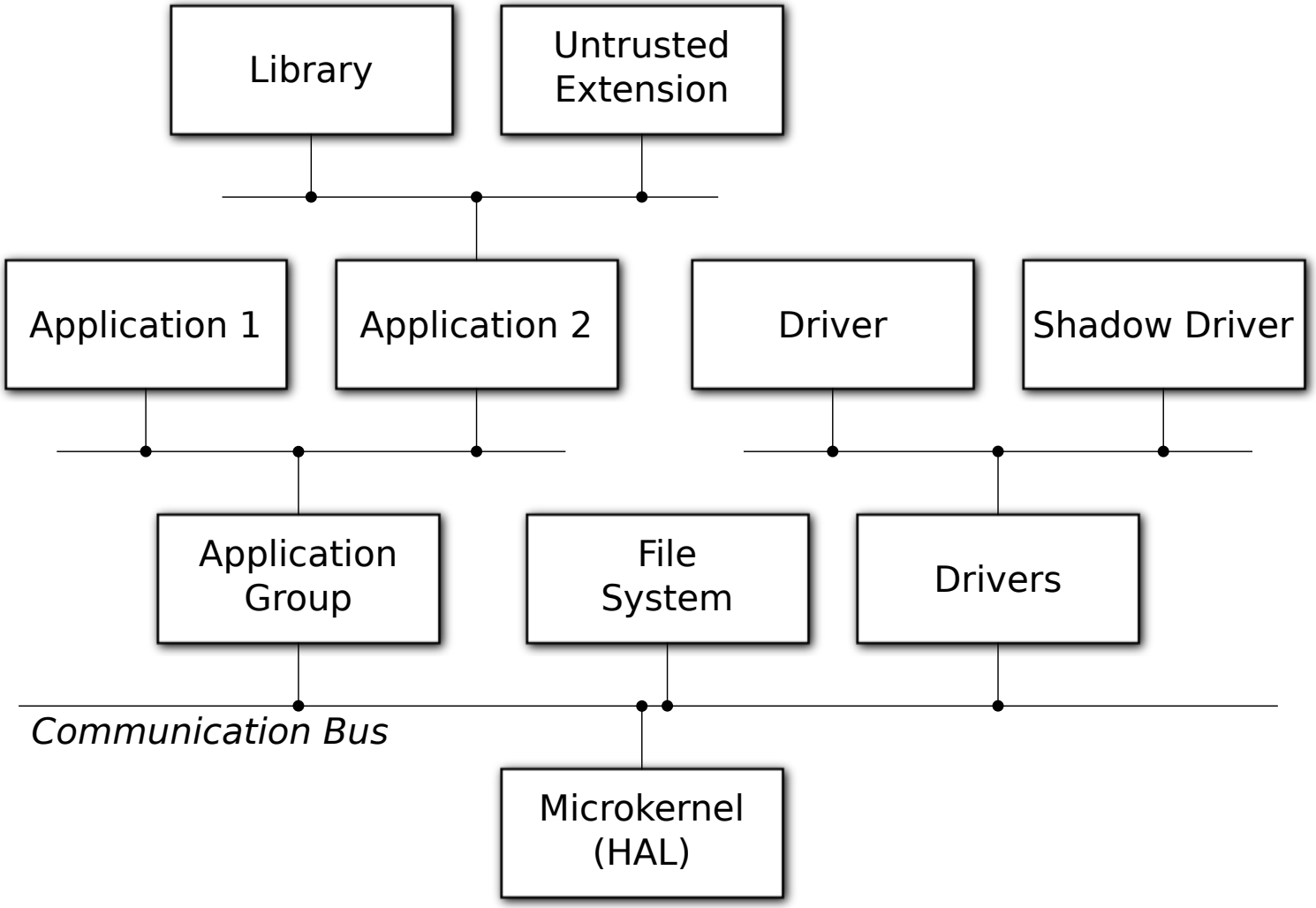
- safe evolution
- no interposition mechanisms required for reconfiguration
- unbounded scalability?

Cons

- Congestion
- Bus as SPOF
- Confidentiality? Availability?

[9] Swift et al.: Recovering device drivers, ACM TOCS 24 4/2006

Mitigating the downsides of broadcast: Hierarchical (de)composition



Hierarchical (de)composition

Hierarchy

Parent/Child relation across modules and buses:

- Manage children
  - multiplex resources provided by lower layer
  - provide "system calls"

→ Trust parents

Pros

- Broadcast scope restriction
- Management load distribution
- Distance from kernel reflects degree of distrust

Cons

- Communication overheads (routing)
- Hierarchy emulation on binary privilege architectures

Wrap-up

Problems

1. components of different criticality
2. components of different origin (COTS/SOUP)
3. uniform privilege
4. complex and volatile interfaces evolve independently

Proposal

- *localized* broadcast communication
- *fair* management overhead distribution
- more fine-grained trust/overhead trade-off