Recovering Device Drivers

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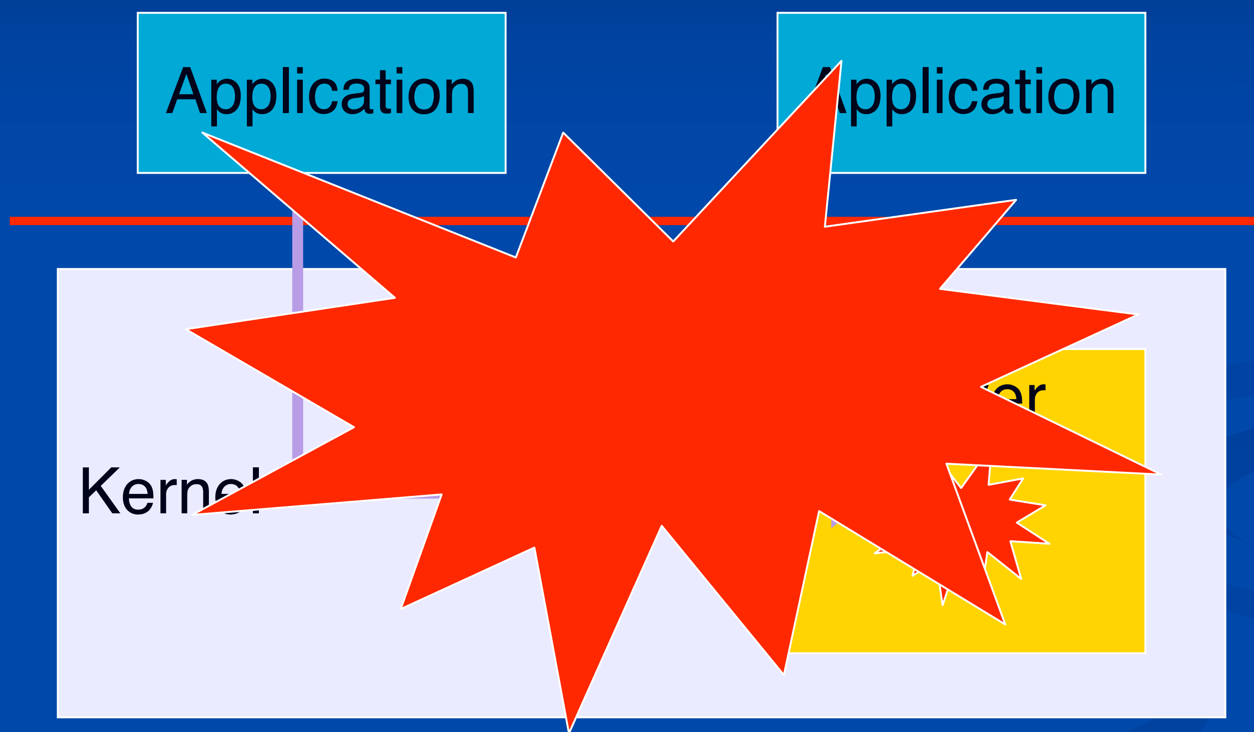
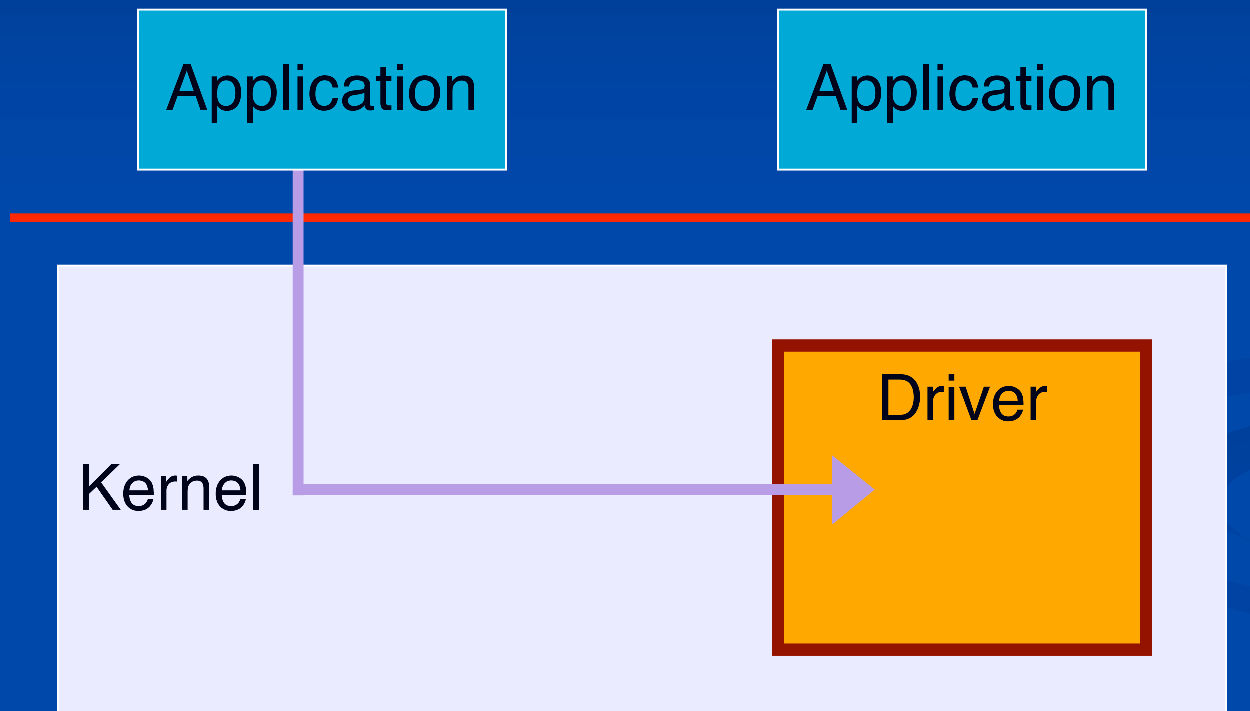
Device Drivers Cause Crashes

- Device drivers are the most common cause of system crashes
  - 85% of Windows XP crashes caused by drivers
  - Linux drivers 7x buggier than other kernel code
- System reliability will not improve until we fix the driver problem

Driver Crashes

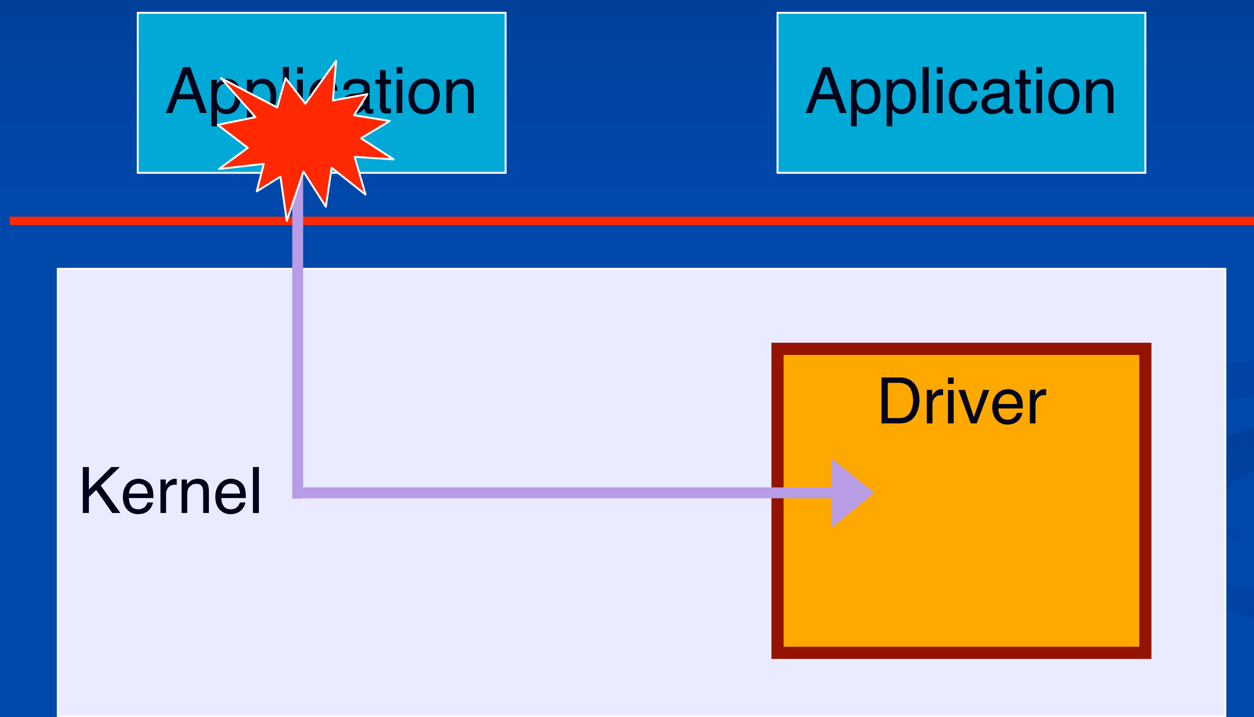


SOSP 2003: Isolating Drivers



Restarting failed drivers prevents system crashes by reinitializing driver & kernel data structures

SOSP 2003: Isolating Drivers



Restarting does not prevent application crashes

- Loses application state in driver
- Exposes application to errors during restart

Preventing Application Crashes

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Preventing Application Crashes

1. Rewrite driver to recover itself
2. Rewrite applications to handle driver failures
3. Conceal driver failures with a generic recovery service

Generalizations About Drivers

1. Rebooting fixes failures
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1. Rebooting fixes failures
   - Focus on transient errors
2. They can be made to fail cleanly
   - Recover by restarting driver
3. Small # of common interfaces
   - Leverage well-known behavior without knowledge of implementation

Outline

- Introduction
- The Shadow Driver System
  - Overview
  - Components
- Evaluation
- Conclusion

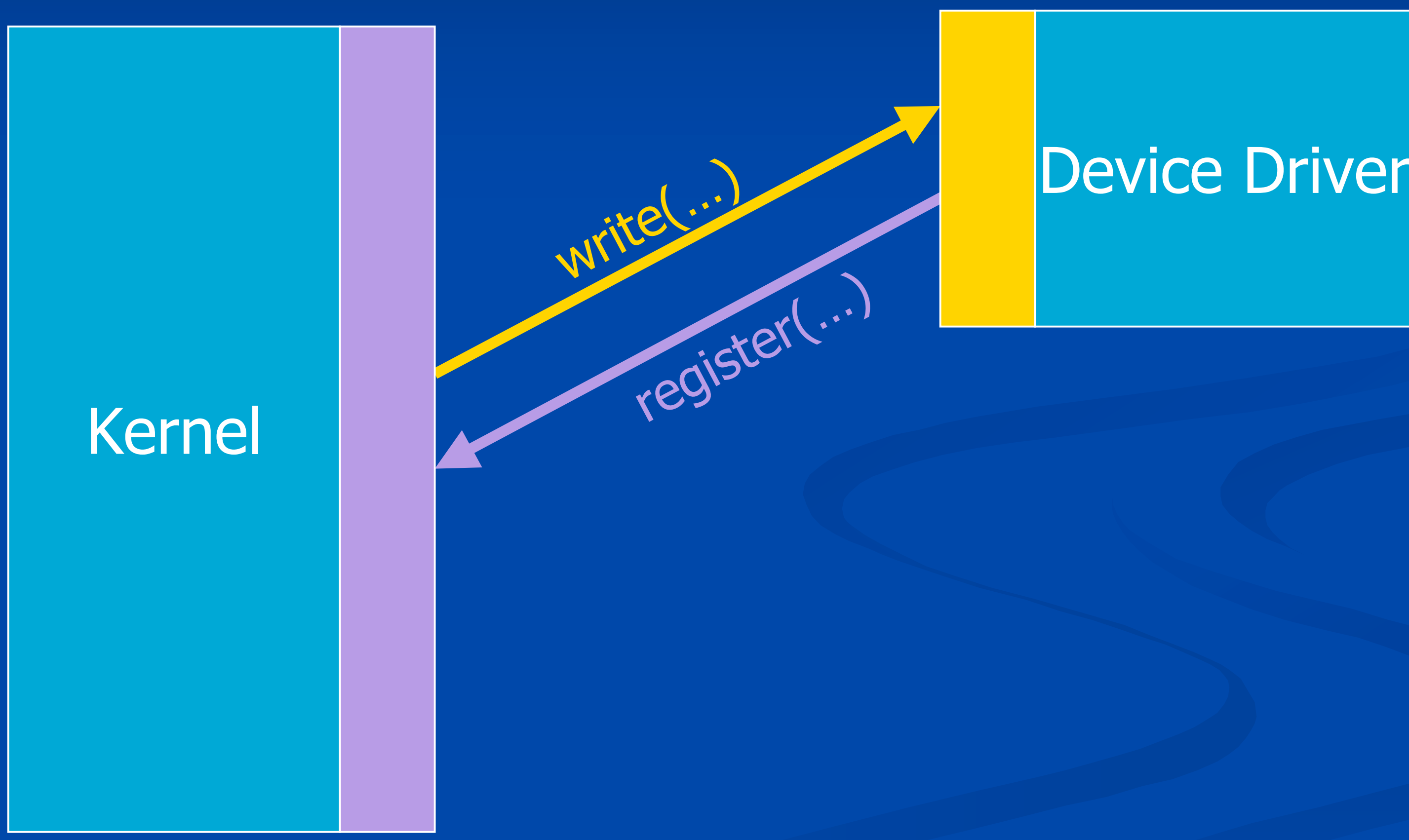
Shadow Driver Overview

- Shadow drivers hide driver failures from applications and the OS
  - Generic service infrastructure
  - Leverages existing driver/kernel interface
  - One shadow driver handles recovery for an entire class of device drivers

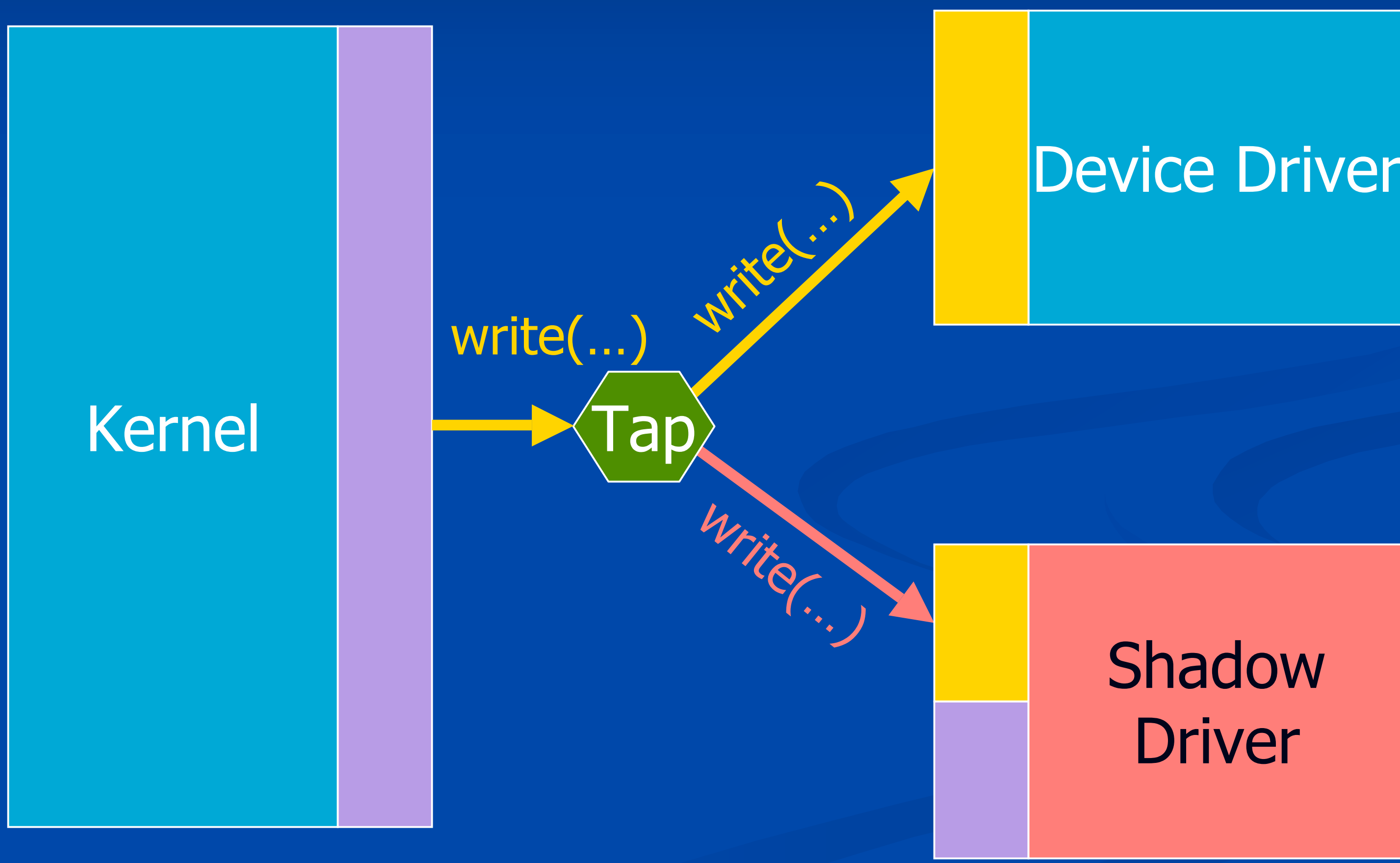
Shadow Driver Overview

- Shadow drivers hide driver failures from applications and the OS
  - Generic service infrastructure
  - Leverages existing driver/kernel interface
  - One shadow driver handles recovery for an entire class of device drivers
- What shadow drivers do:
  - Prepare
  - Recover
  - Conceal

Today's Systems



Shadowing a Working Driver



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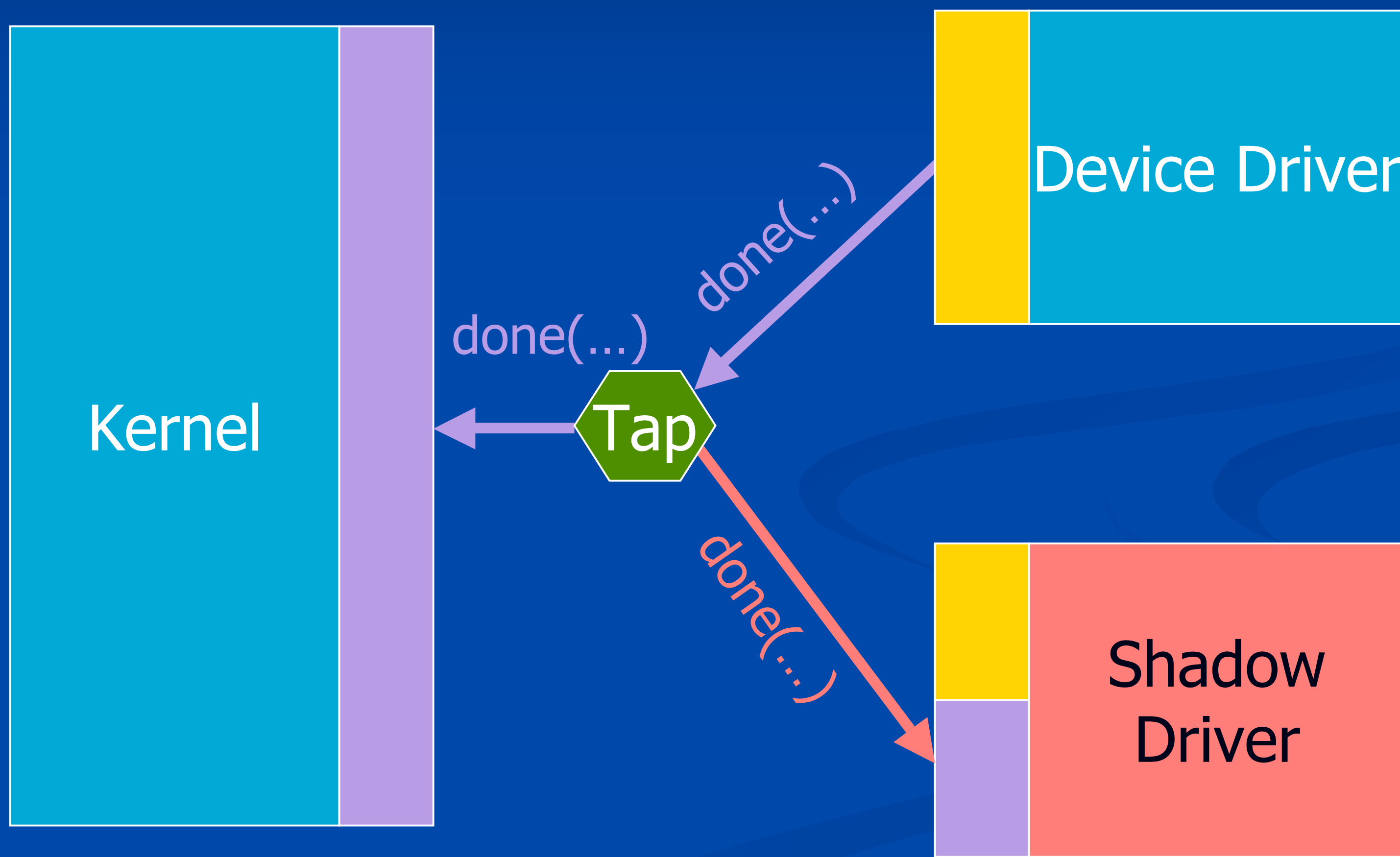
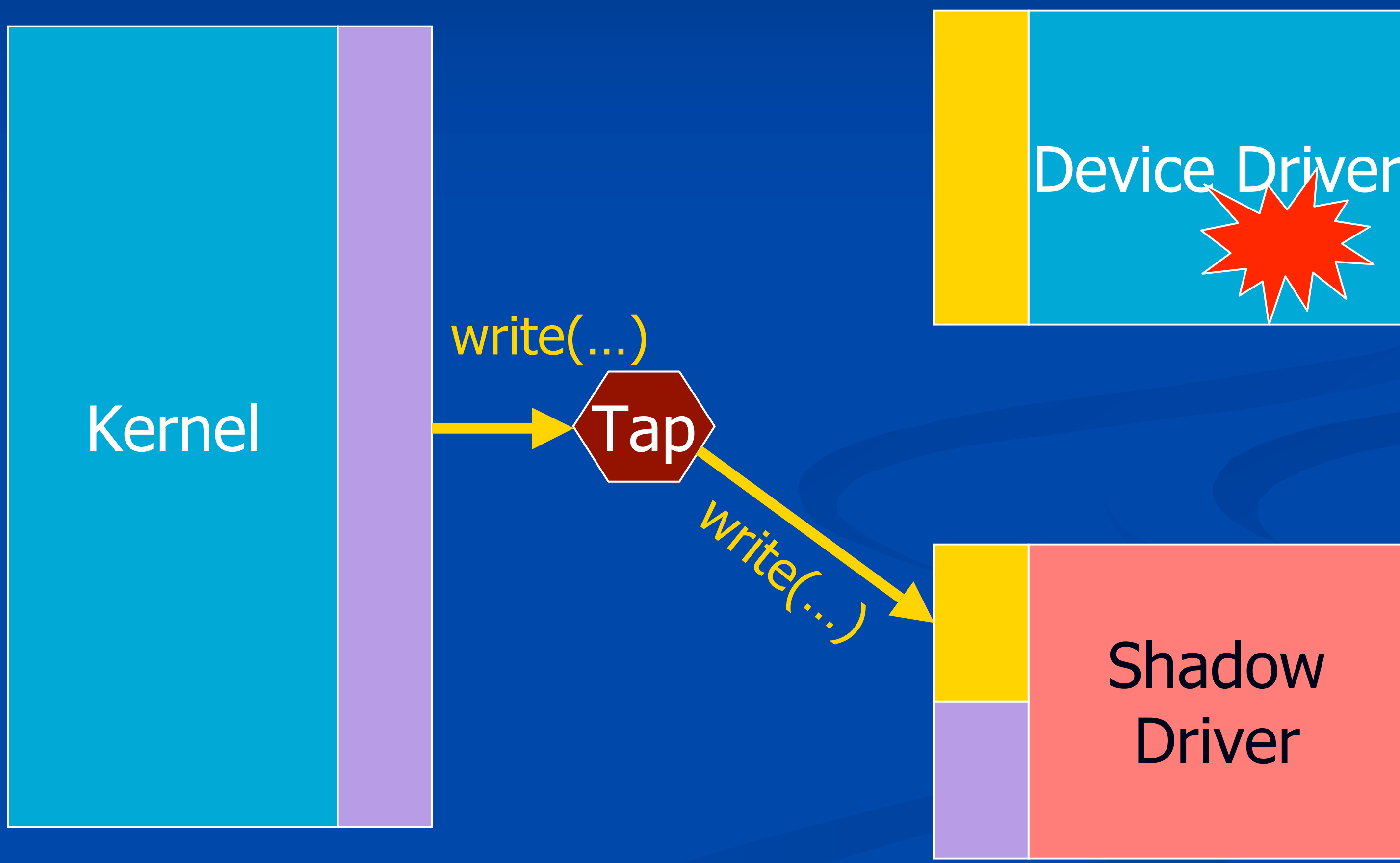
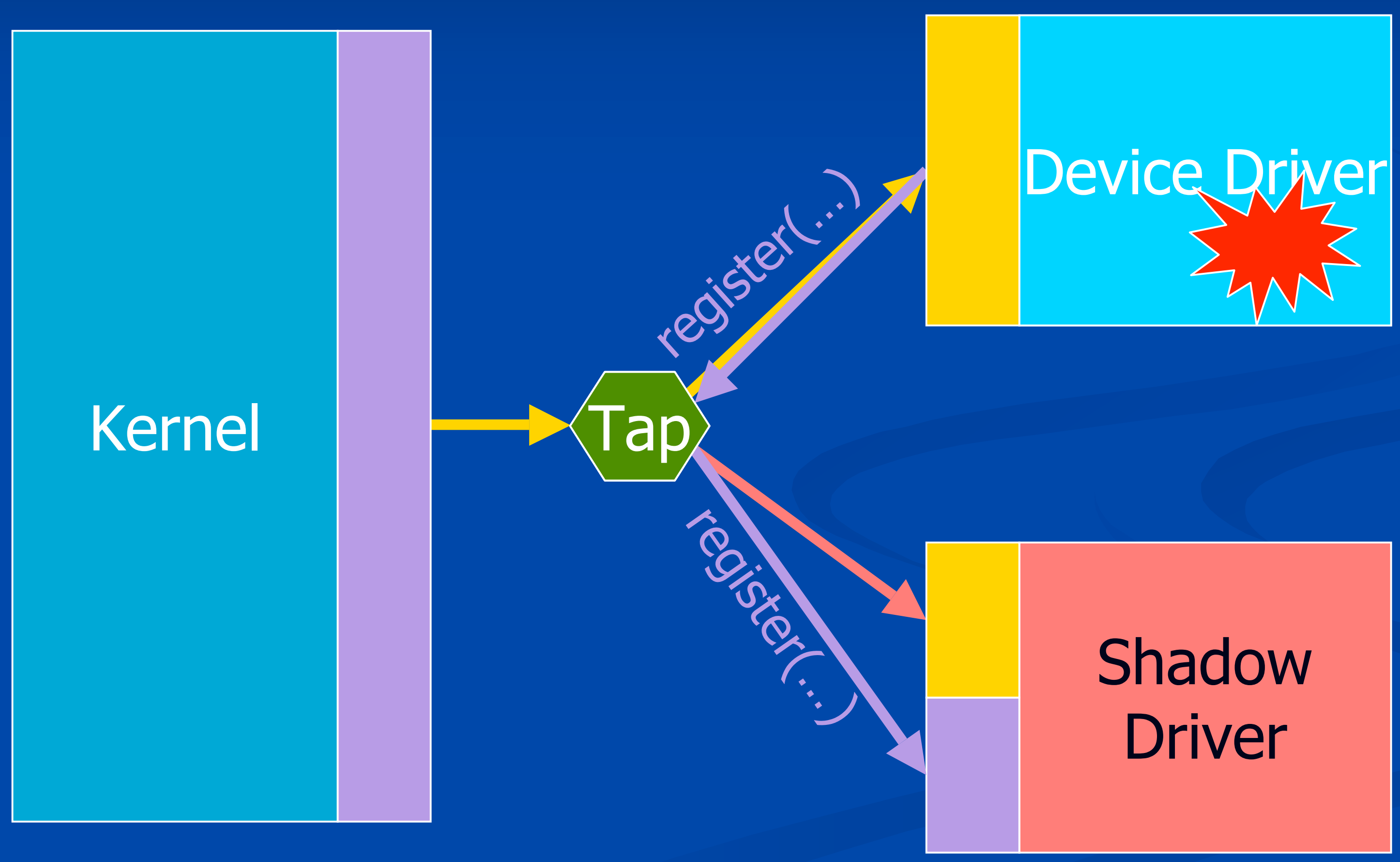


Spoofing a Failed Driver



Recovering a Failed Driver



What Shadow Drivers Do

- Prepare:
  - Monitor kernel-driver communication
- Recover:
  - Restart driver after failure
- Conceal:
  - Act as driver during recovery

Preparing for Recovery

- Monitor kernel-driver communication to capture relevant state
  - Configuration operations
  - Active connections
  - Outstanding requests

Recovering Driver

1. Reset driver
2. Repeat driver initialization calls
3. Transfer in state
   - Reopen active connections
   - Replay configuration requests from log
   - Resubmit active requests

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- Shadow responds to driver's kernel requests
  - Hide restart from kernel and driver
  - Supply driver with existing resources

Concealing Failure

- Shadow acts as driver
  - Applications and OS unaware that driver failed
  - No device control
- General Strategies:
  1. Answer request from log
  2. Act busy
  3. Block caller
  4. Queue request
  5. Drop request

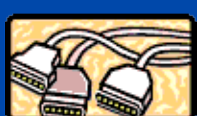
Implementation

- Implemented in Linux 2.4.18 kernel
- Uses Nooks driver fault isolation system
- Supports three driver classes:
  - Sound card
  - Network interface card
  - IDE storage

Outline

- Introduction
- Shadow Driver System
- Evaluation
  - Can shadow drivers conceal failure?
  - At what cost?
    - Performance
    - Complexity
- Conclusion

Drivers Tested



Class	Drivers
Sound	SoundBlaster Audigy, Soundblaster Live!, Intel 810 Audio, Ensoniq 1371, Crystal Sound 4232
Network	Intel Pro/1000 Gigabit Ethernet, Intel Pro/100 10/100, 3Com 3c59x 10/100, AMD PCnet32, SMC Etherpower 100
IDE Storage	ide-disk, ide-cd

Evaluation

- Testing Methodology
  - Add bugs to driver
    - Port real bugs
    - Inject synthetic bugs
  - Run application using driver

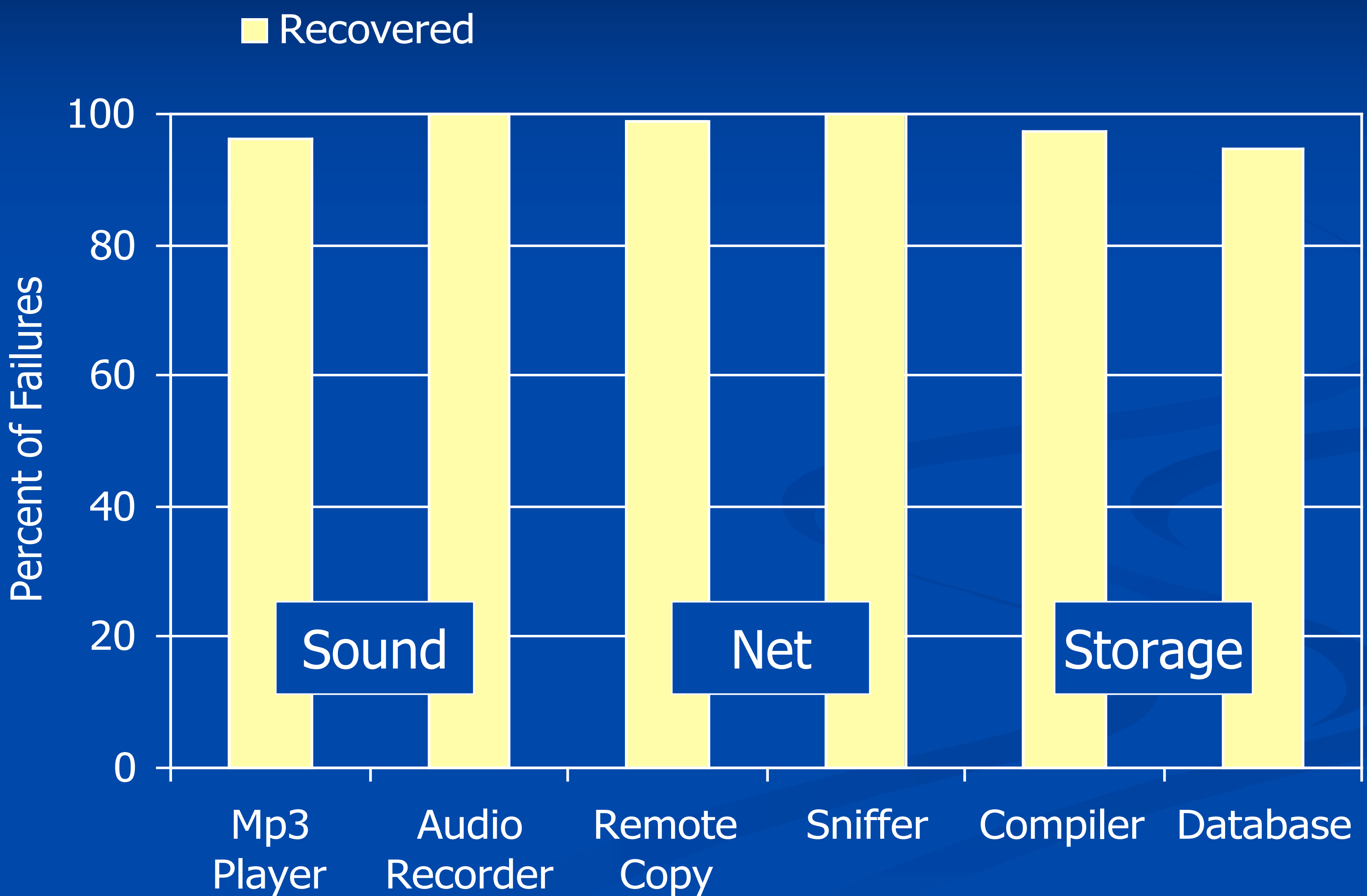
- Platforms:
  - *Native*: standard 2.4.18 kernel
  - *Shadow*: fault isolation + shadow drivers

Possible Outcomes

✔	Everything kept working
X	Application crashed
XX	Total system crash

	App.	Native	Shadow	SOSP
Sound	Mp3 Player	XX	✔	X
	Audio Recorder	XX	✔	X
	Speech Synth.	XX	✔	✔
	Game	XX	✔	X
Network	Remote Copy	XX	✔	✔
	Remote Window	XX	✔	✔
	Packet Sniffer	XX	✔	X
Storage	Compiler	XX	✔	XX
	Encoder	XX	✔	XX
	Database	XX	✔	XX

Large-Scale Fault Injection



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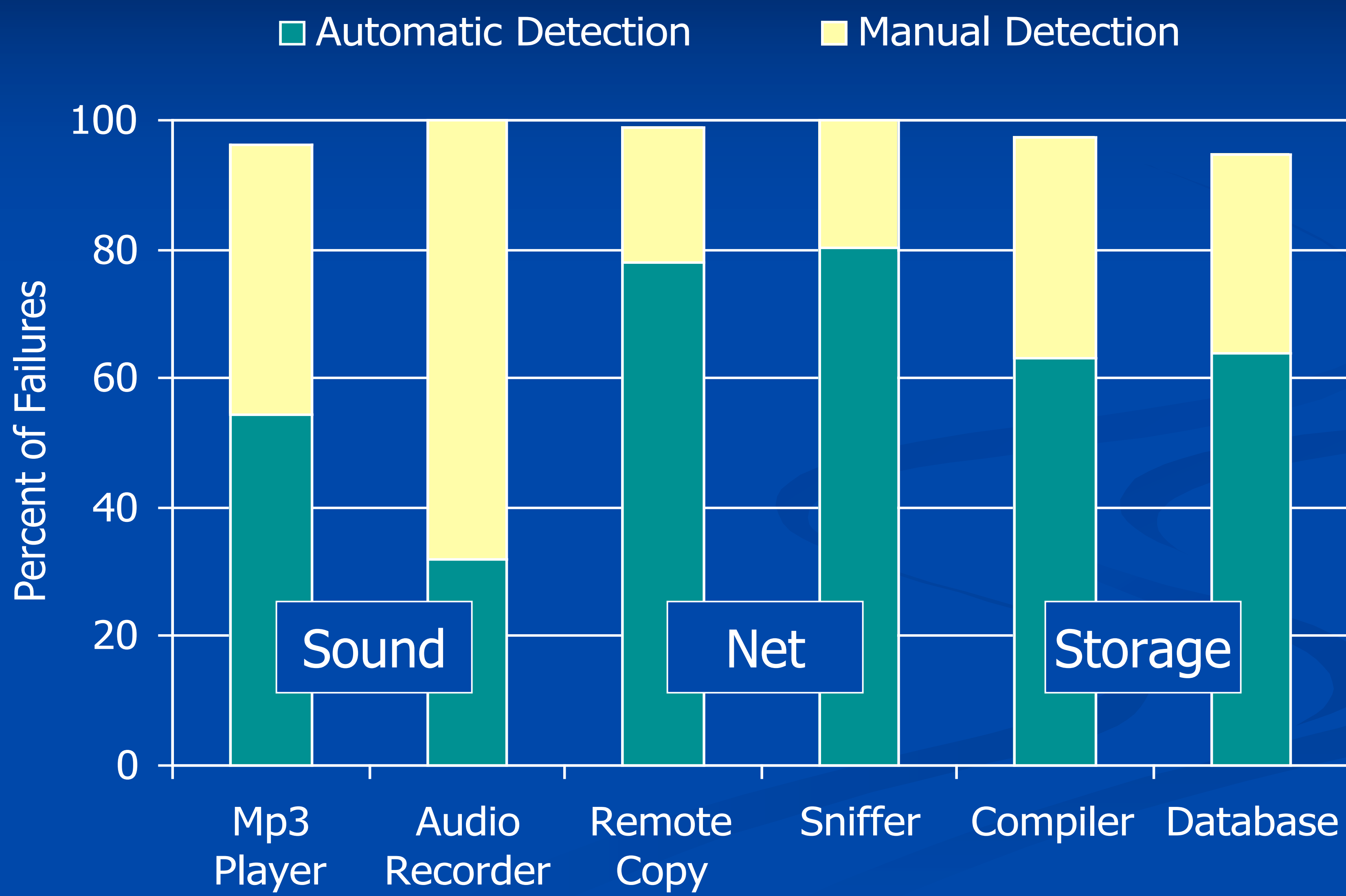

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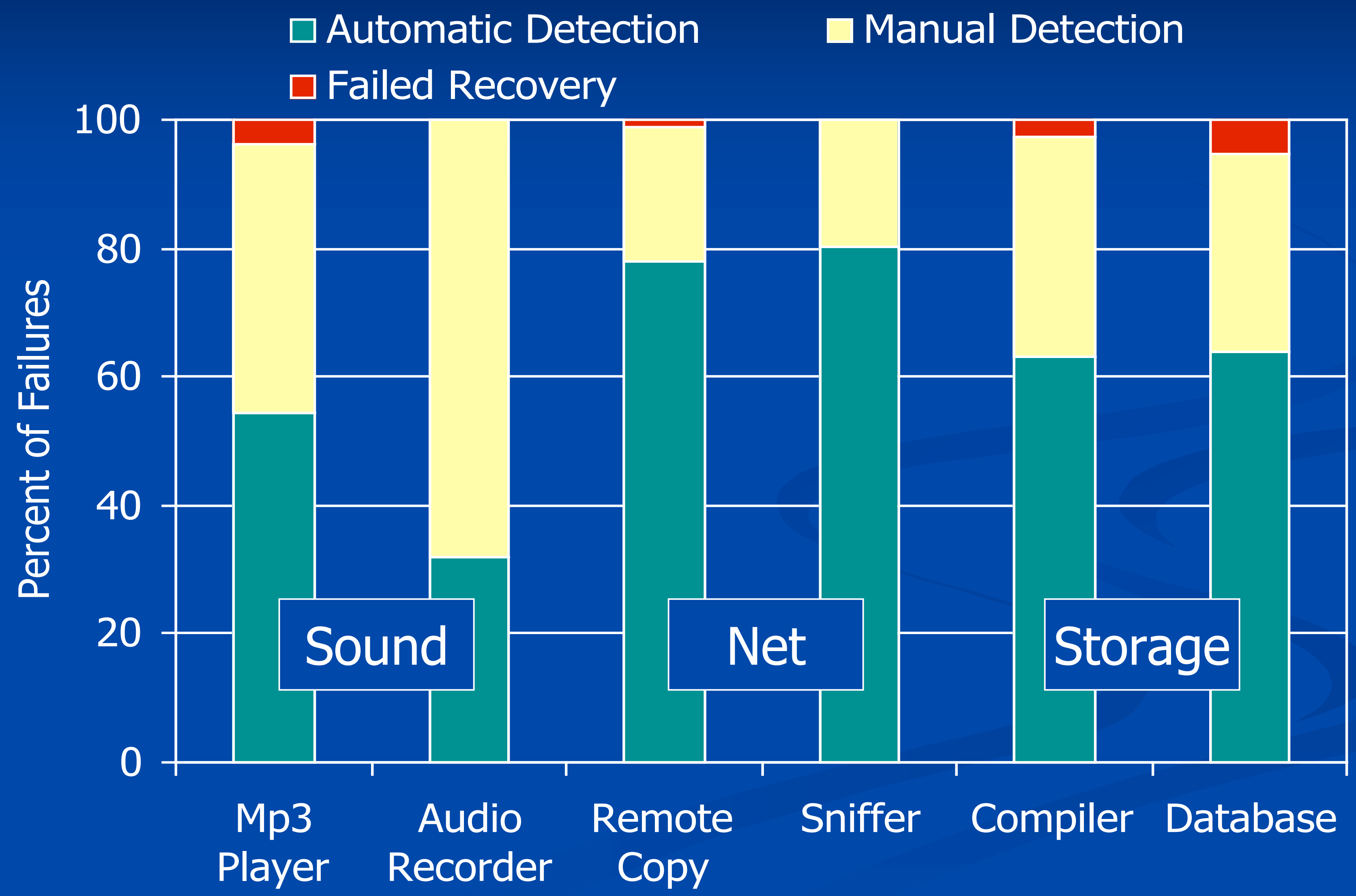
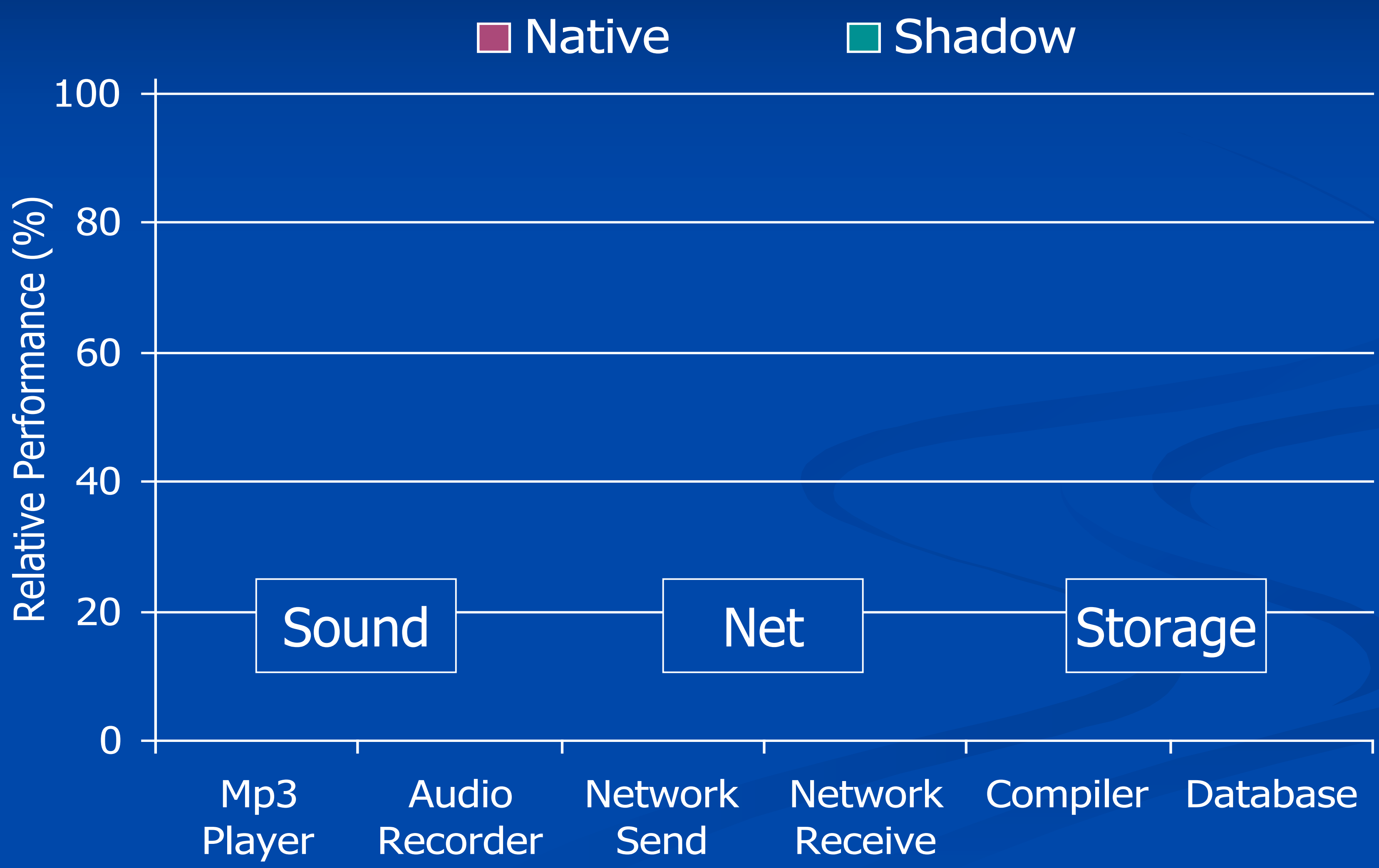


Relative Performance



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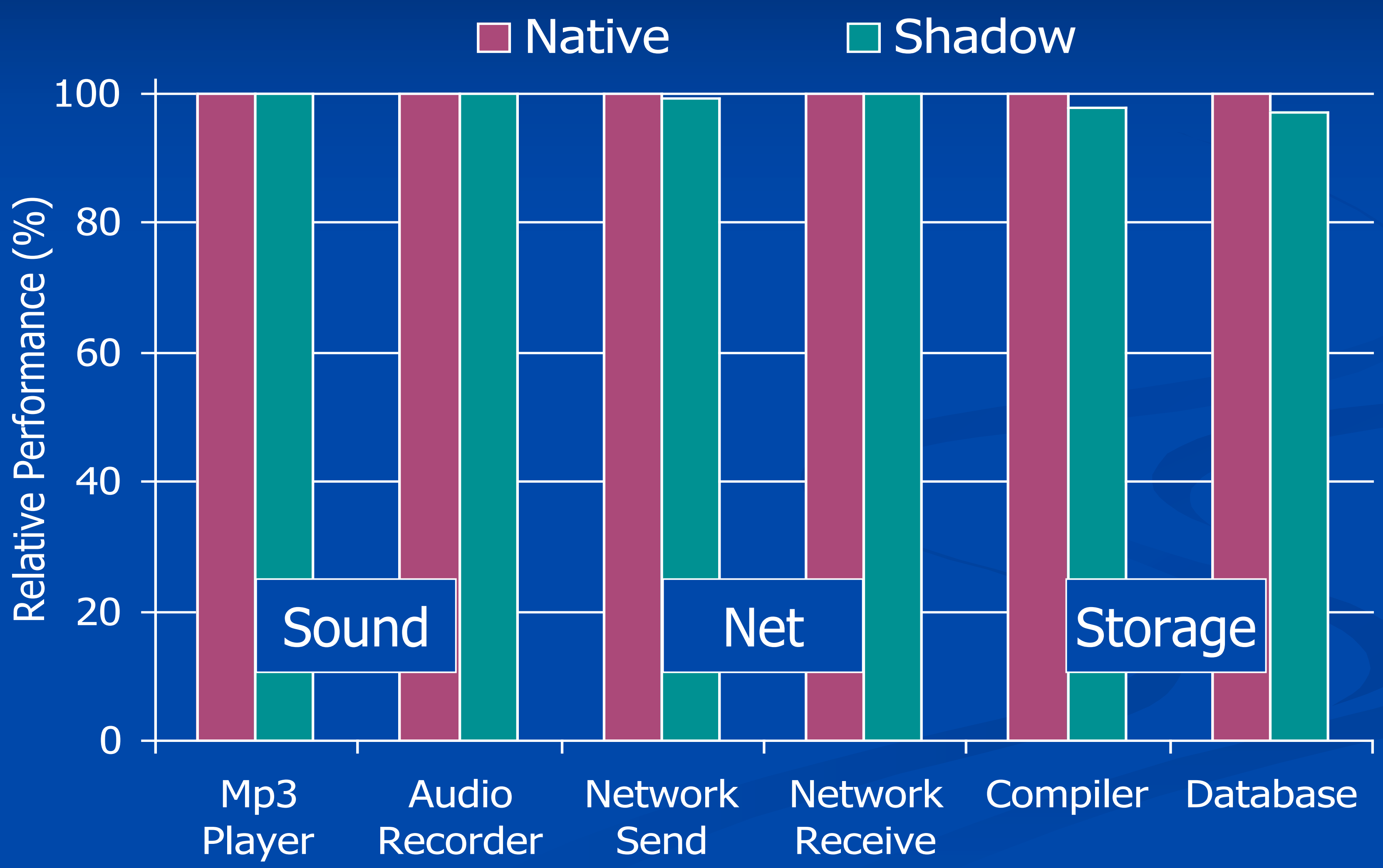

Complexity

Driver Class	Shadow Driver L.O.C.	1 Device Driver L.O.C.	All Drivers Count	All Drivers L.O.C.
Sound	666	7,381	48	118,981
Network	198	13,577	190	264,500
Storage	321	5,358	8	29,000

- Shadow Drivers: 3300 lines
- Nooks Fault Isolation: 23,000 lines
- Linux Kernel: 2.7 million lines

Conclusion

- Shadow drivers protect applications from driver failures
  - Shadow drivers leverage existing driver interfaces for recovery
  - Shadow drivers prevented 98% of application failures in testing
- Shadow drivers have low cost

Want More Information?

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or

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