Copilot - a Coprocessor-based Kernel Runtime Integrity Monitor

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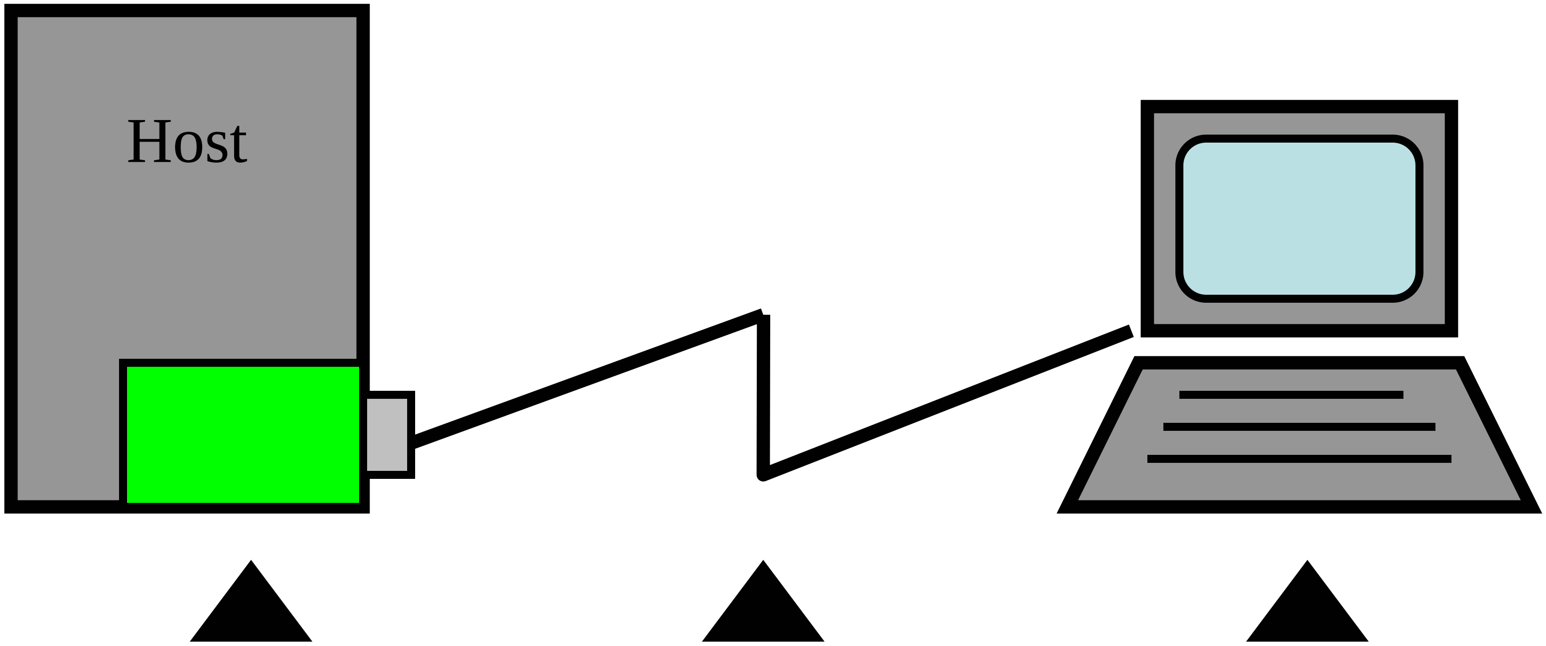
Copilot Overview

- Protects commodity operating systems
  - Detects malicious modifications to running system
- Minimal effect on monitored system
  - Requires no change to existing host software
  - Less than 1% performance penalty
- Effective and robust
  - Has detected 12 real-world rootkits for GNU/Linux
  - Detection window of under 30 seconds
  - Operates even if host kernel is fully compromised

State of commodity OS security

- Complexity abounds
  - Commodity OS's are already complex (and growing)
  - Placing assurance on the many parts is difficult
- Existing security tools rely on system correctness
  - All host software relies on some aspect of kernel integrity
  - This assumption is invalid: attackers modify the kernel
- Copilot provides independence from the host OS
  - Utilize direct access to system resources
  - Perform complex checks without host intervention

Copilot Monitor Experiment



Host

Monitor
(PCI card)

independent
communications link

Admin
Station

What is a Rootkit?

Software used after system compromise to:

- Hide the attacker’s presence
- Provide backdoors for easy reentry

Simple rootkits:

- Modify user programs (ls, ps)
- Detectable by tools like tripwire

Sophisticated rootkits:

- Modify the kernel itself
- Hard to detect from userland

Rootkit Features

Typical rootkit implementation:

- An LKM that interposes on the system call vector:
- Adore, rial, rkit, synapsis, modhide1, phide,kbd, linspy…

More sophisticated, more stealthy:

- SucKIT - loads via /dev/kmem instead of LKM
- Phantasmagoria - modifies kernel text, not syscall vector

Insecurity by Obscurity:

- Taskigt - adds a hook to /proc filesystem
- Knark - adds inet protocol handler

Limitations of Host-based Tools

Userland tools: chkrootkit, checkps, Rkscan, RootCheck…

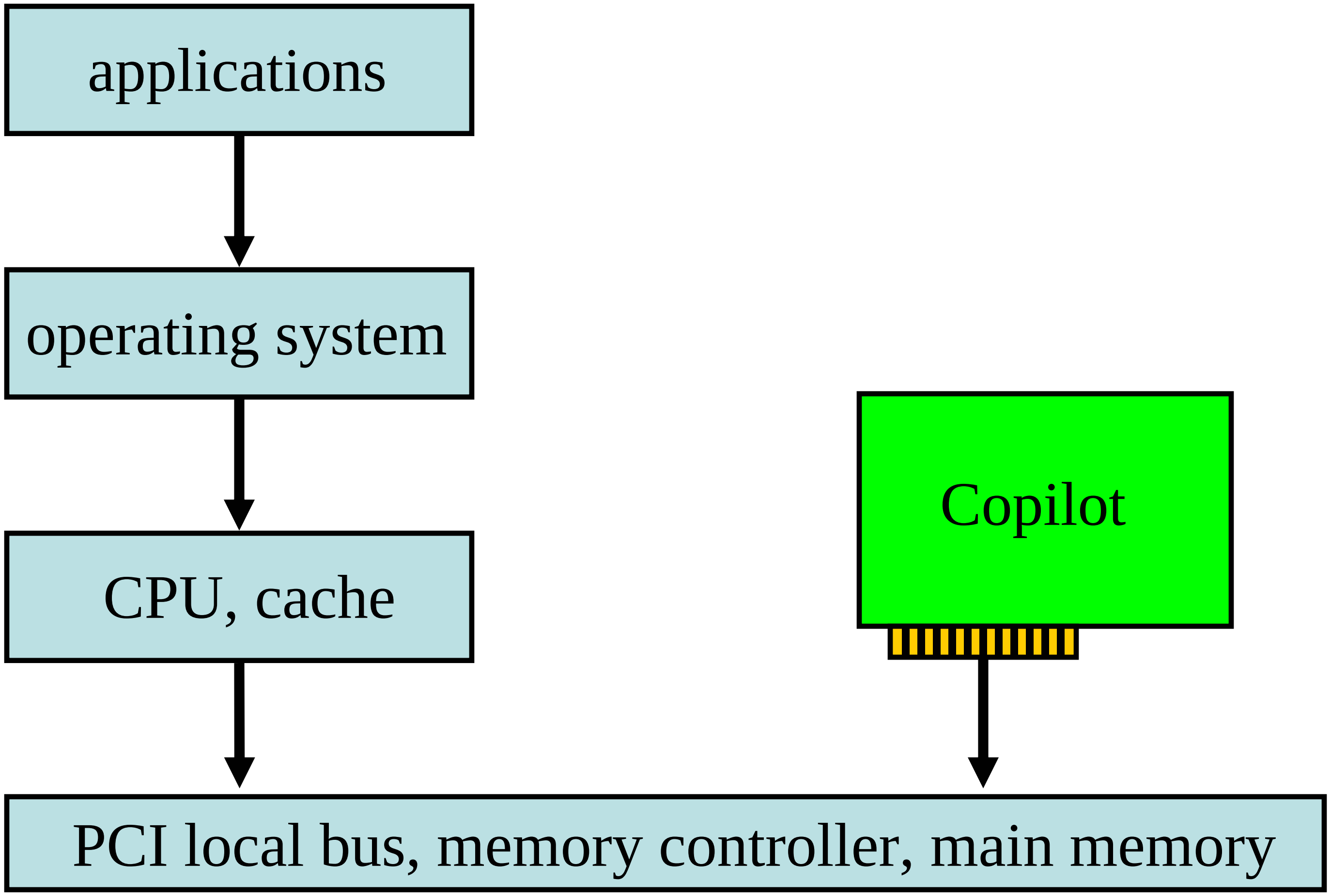
+ Compare ps and /proc, directory link and entry counts
- When the kernel lies, all will seem well in userland
- Some are designed to detect only known rootkits

Kernelspace tools: KSTAT, St. Michael, Carbonite, Samhain

+ Examine kernel data structures via /dev/kmem or an LKM
- Rootkits can make /dev/kmem and LKMs lie, too

“Arms Race”

Correctness Dependencies



applications

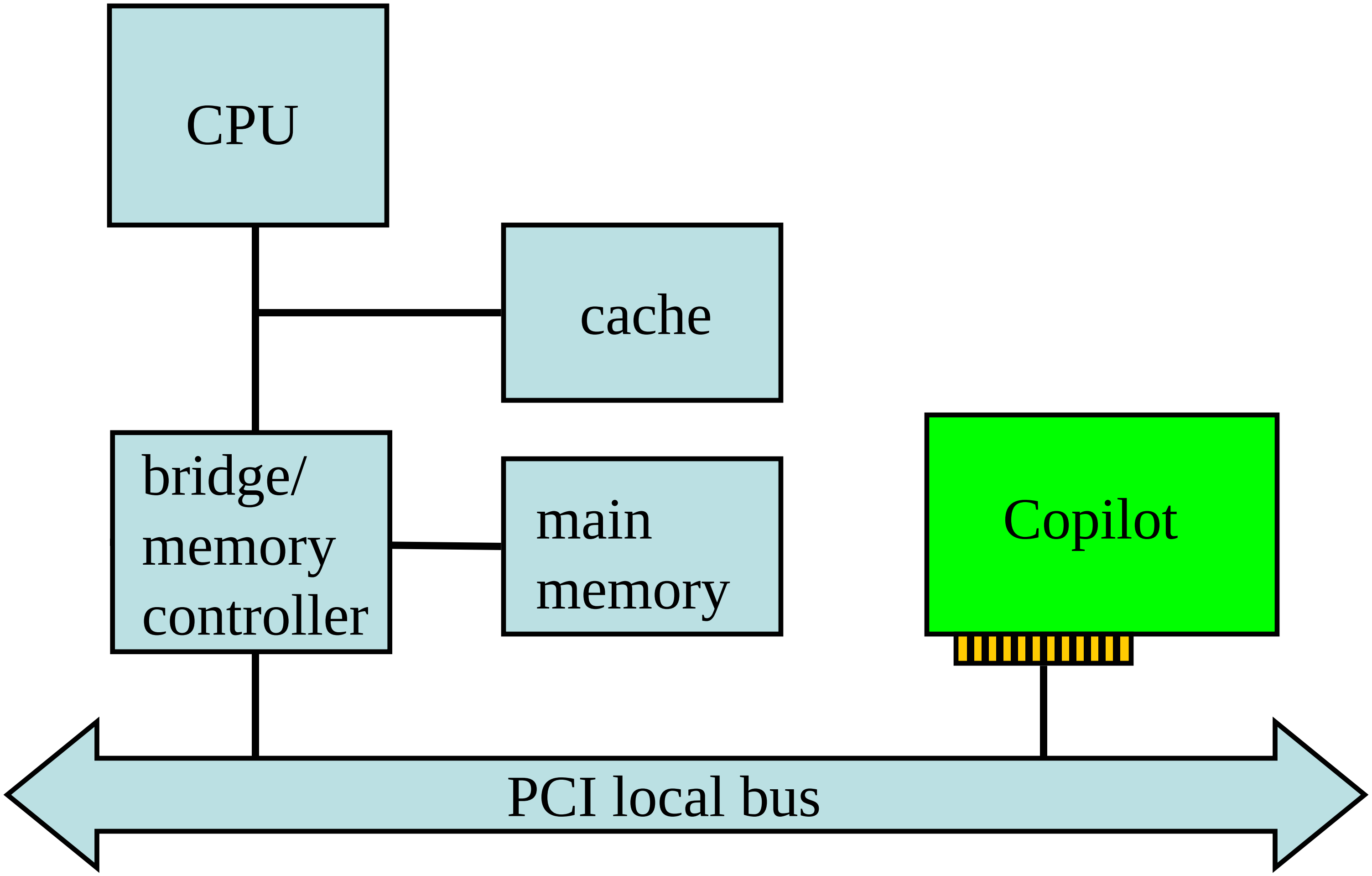
operating system

CPU, cache

Copilot

PCI local bus, memory controller, main memory

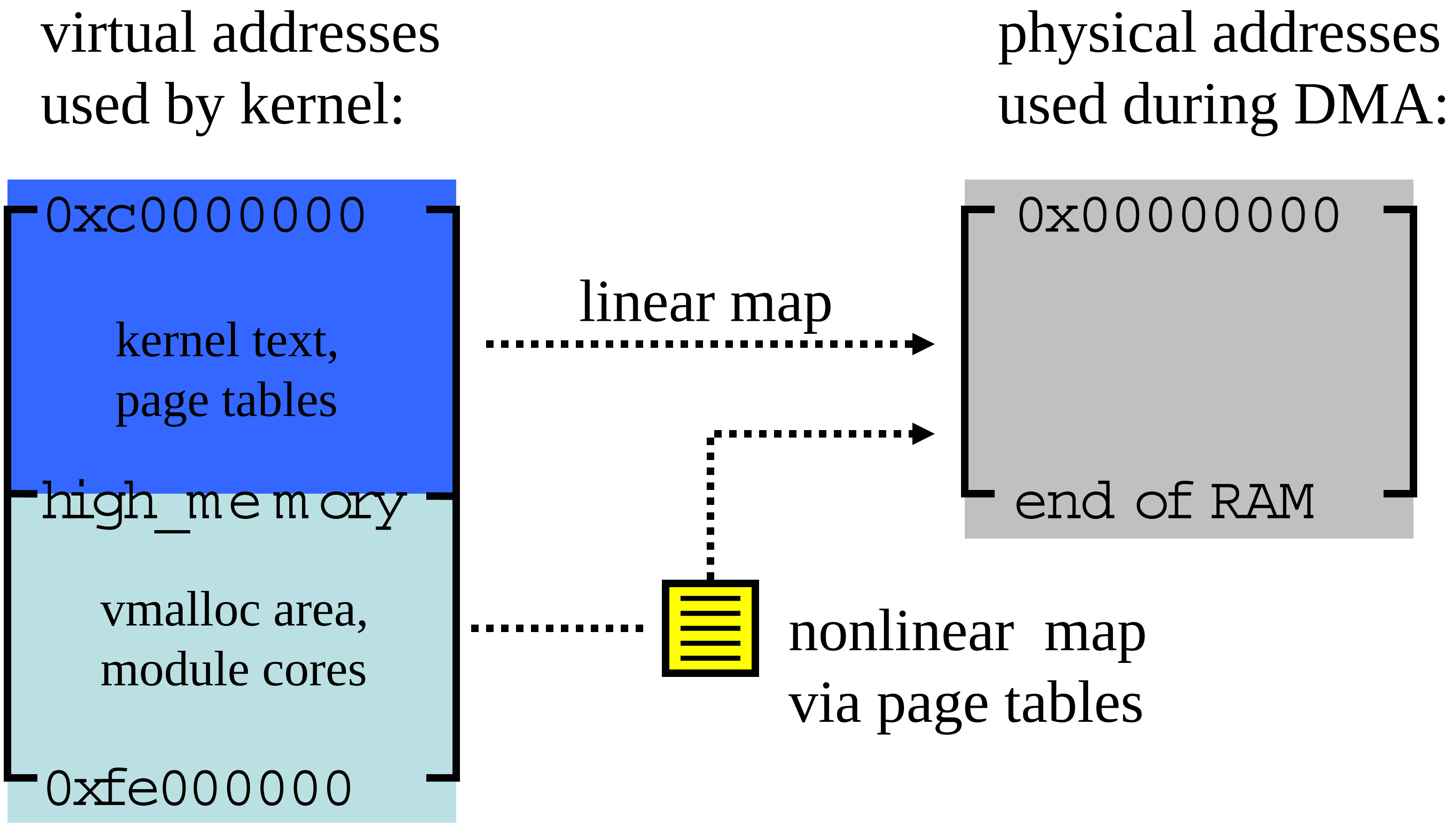
PCI Local Bus



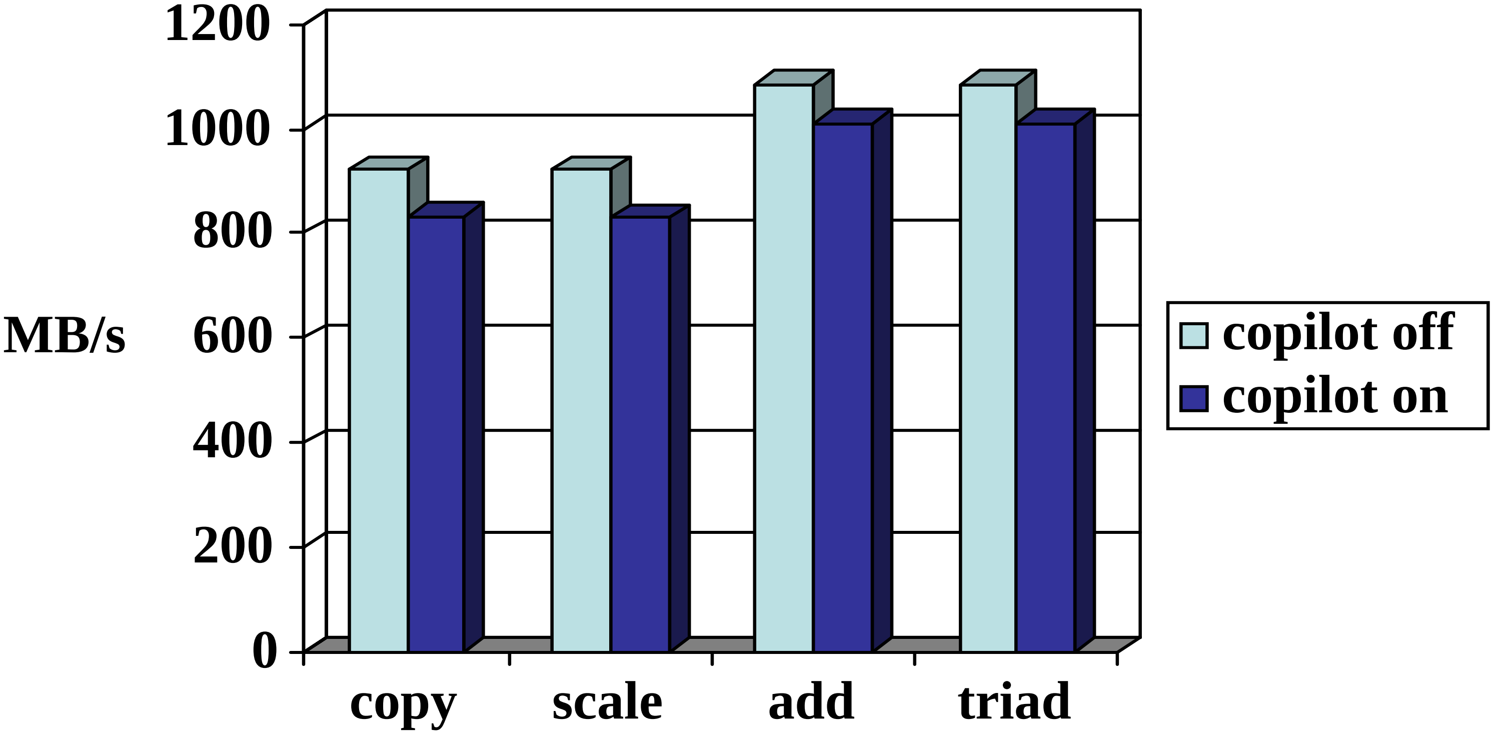
PCI add-in card requirements

- Unrestricted access to memory
  - EBSA-285 has bus mastering capability
- Independence from host
  - EBSA-285 has a mode that ignores host commands
- Sufficient processing power, memory
  - StrongARM SA-110 CPU, 16MB RAM
- Independent communication channel for reporting
  - RS-232 serial port

Linux Virtual memory translation

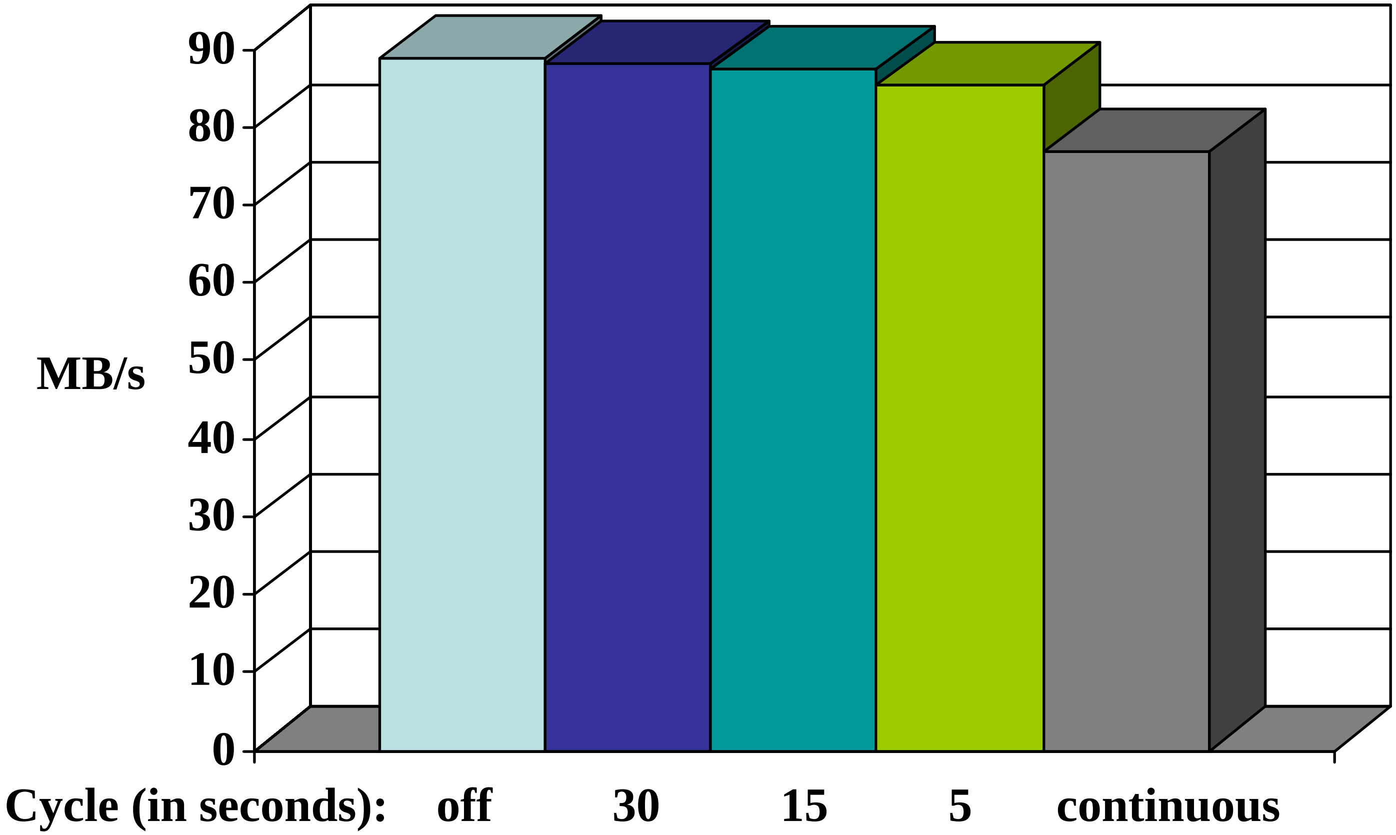


STREAM memory throughput benchmarks



Penalty: 10% 10% 7% 7%

WebStone HTTP throughput benchmark



Penalty: 0% 1% 2% 4% 14%

Copilot Summary

- Proven effective in lab tests:
  - Detected the 12 rootkits listed on earlier slide.
  - 30-second detection window
  - Less than 1% application performance penalty

- Clear advantage over existing technologies:
  - No reliance on host software for correctness
  - Plugs into unmodified commodity host

Future

- New boards with NIC for out-of-band communications
- Integrate previous work (FS integrity monitoring)
- Privilege escalation detection
- Remote configuration, reconstitution, and forensic analysis

END

Rootkit Taxonomy

Rootkit:	Unusual methods:
adore 0.42	
knark 2.4.3	adds /proc, inet hooks
phantasmagoria	mods text, not syscall vector
rial	
rkit 1.01	
SucKIT 1.3b	loads via kmem, not LKM
synapsis 0.4	
taskigt	adds /proc hook

But wait there’s more

Ported to a new board

- Supports *out of band* command and control, *i.e.* it has a dedicated ethernet interface.
- Supports booting from a virtual floppy, remote power cycle and reset.
- Also remote virtual terminal.

Windows Protection

- Windows 2000
  - SDT - Service Desriptor Tables
  - IDT - Interrupt Descriptor Table
  - GDT - Global Descriptor Table
  - Kernel Text
- Windows XP doable (just not finished yet)

Demo

- Windows 2000 SP4 machine with co-pilot add-in board.
  - Show how co-pilot detects the presence of SoftIce
  - Show how co-pilot detects the basic_8 rootkit

Future work

- Dynamic reconstitution and forensic reporting, *e.g. transmit malicious code to central monitoring station and rebuild system.*
- Deepen the monitoring capability into the process level, *e.g. determine when a process has gained root level priviledges without authorization.*