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Hardware Enforcement of Application Security Policies Using Tagged Memory

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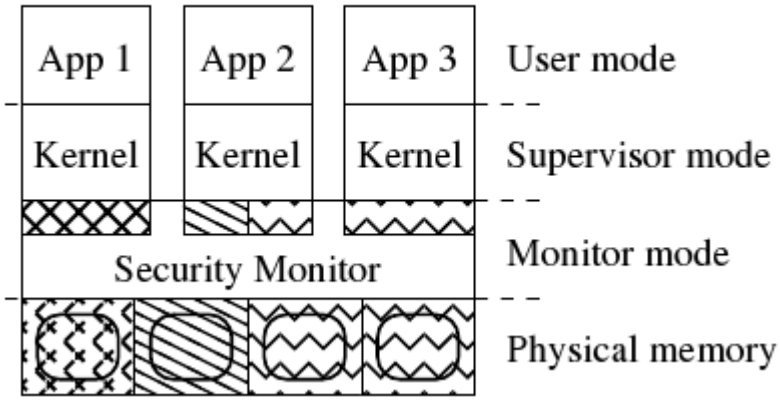
Motivation

- Gap between security mechanisms and different abstraction layers
  - Facebook example: only friends can see profile
- Reflect upon data vs. individual operations
  - Take primitive mechanism that fits all
- Need for small TCB, that ensures certain security policies at runtime, as verification is hard (example: Anti-Virus scanner)

Solution: tagged memory

- Additional memory protection mechanism in hardware
- Word-granular security tags for memory, enforced by the CPU
- Hardware extensions are used in new mode



Starting Point: HiStar

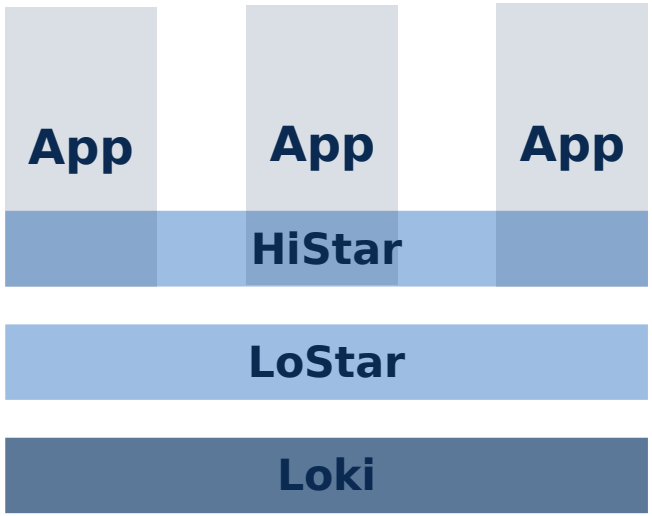
- HiStar is a kind of micro-kernel
  - Inspired by AsbestOS's labels
  - Decentraliced information flow control
  - In contrast to AsbestOS labels are altered explicitly
  - Provides Unix environment that translates Unix implicit policies to HiStar's labeling mechanism (remember Flume: Linux enhanced by DIFC)

HiStar labeling mechanism

- Each kernel object has a *label*:
  - threads, address spaces, segments, gates, containers, devices
- Label is a set of *categories* (61-Bit ID) and taint levels
- Thread's label:
  - Shows degree of information contamination, regarding specific categories
  - Can be extended explicitly up to specified *clearance*
- Gates have an associated label and clearance

Tagged memory and LoStar

- Using hardware memory tags to divide kernel into thread domains
- New super-supervisor mode running small kernel subset, that drives tagging hardware



LoStar's protection

- Twofold memory tags page-wide or word-wide
- Integrity protection of all kernel object's labels and reference counters and the global object hash table by word-tags
- Monitor call API:
  - Thread switch (changes permissions)
  - Allocate or free kernel object (set or free label)
  - IPC by invoking a Gate (label check)
  - Increment or decrement object's refcounter
  - Adjusting the thread's label
  - ...

Cruel thing: Devices

- Interrupts don't change (non-)monitor mode
- Interrupt handling code and most device handling code resides in security monitor
- Interrupts received by non-monitor world need to be delivered to monitor!
- Device driver code that deals with various tags (like disk driver) will remain in trusted code part

Loki

- Associates 32-bit tag for each 32-bit word in physical memory
- Page-tag array indexed by frame address contains tags, is cached by TLB like tag-cache
- Page-tag array entries have a special indirection-bit to indicate word-granular tags for that page
- Additional P-cache contains tag-values and permissions of running thread
- P-cache misses are handled by monitor

Loki prototype

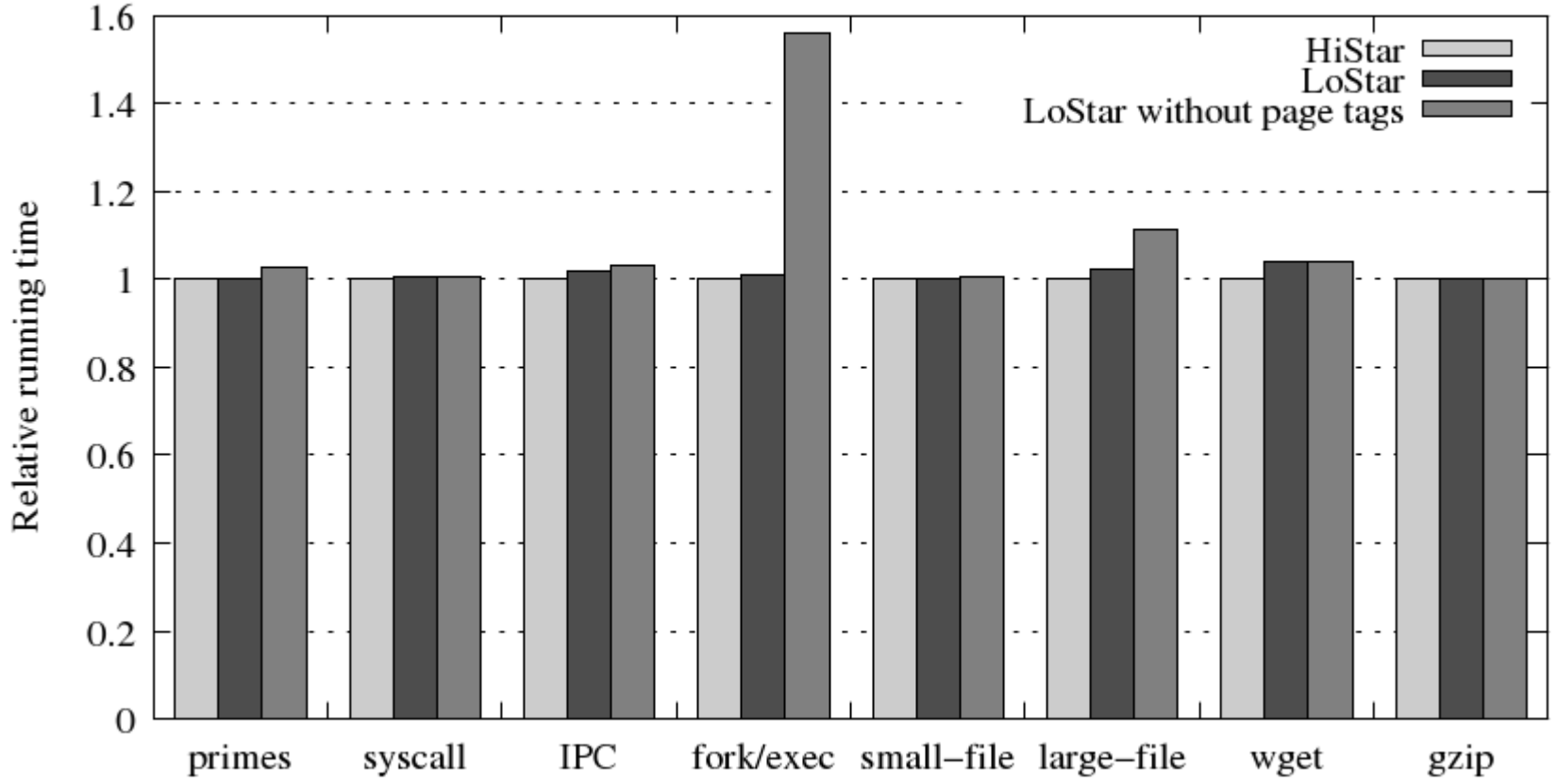
- Leon SPARC V8 (FPGA core) 65 MHz
- Added:
  - 6 instructions (e.g.: P-cache handling)
  - 7 registers (e.g.: faulting tag value)
  - 32 entry 2-way associative P-cache
  - 8 entry full-associative tag-TLB
- P-cache gets accessed at least once by each instruction !!!

Evaluation: TCB

- Trusted code base shrinks?
- They didn't state exactly what is meant by trusted
- To be sure that my applictions policy is enforced by the monitor + Loki I need to trust the whole kernel

Lines of code	HiStar	LoStar
Kernel code	11,600 (trusted)	12,700 (untrusted)
Bootstrapping code	1,300	1,300
Security monitor code	N/A	5,200 (trusted)
TCB size: *trusted code*	**11,600**	**5,200**

Performance



Conclusion / Discussion

- What do they won? TCB size reduction?
- What about 'more realistic hardware and the supposable greater overhead?
- Singularity went in the opposite direction and left out hardware memory protection at all, who is right?
- Is there one security mechanism (like labels) that fits all, or do we need the different layers (example: timing issues, resource accounting ...)

Loki pipeline