

An Open-Source, Comprehensive and Modular Simulation Framework for Virtual Memory Research

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Improving Virtual Memory

- Virtual memory causes high **performance overheads**
- Various solutions have been proposed to reduce these overheads

Improving TLB subsystem	Hash-based mapping
Efficient page table structures	Employing large pages
Contiguity-aware schemes to enable offset-based translation	Reducing page fault latency

Lack of Simulation Framework

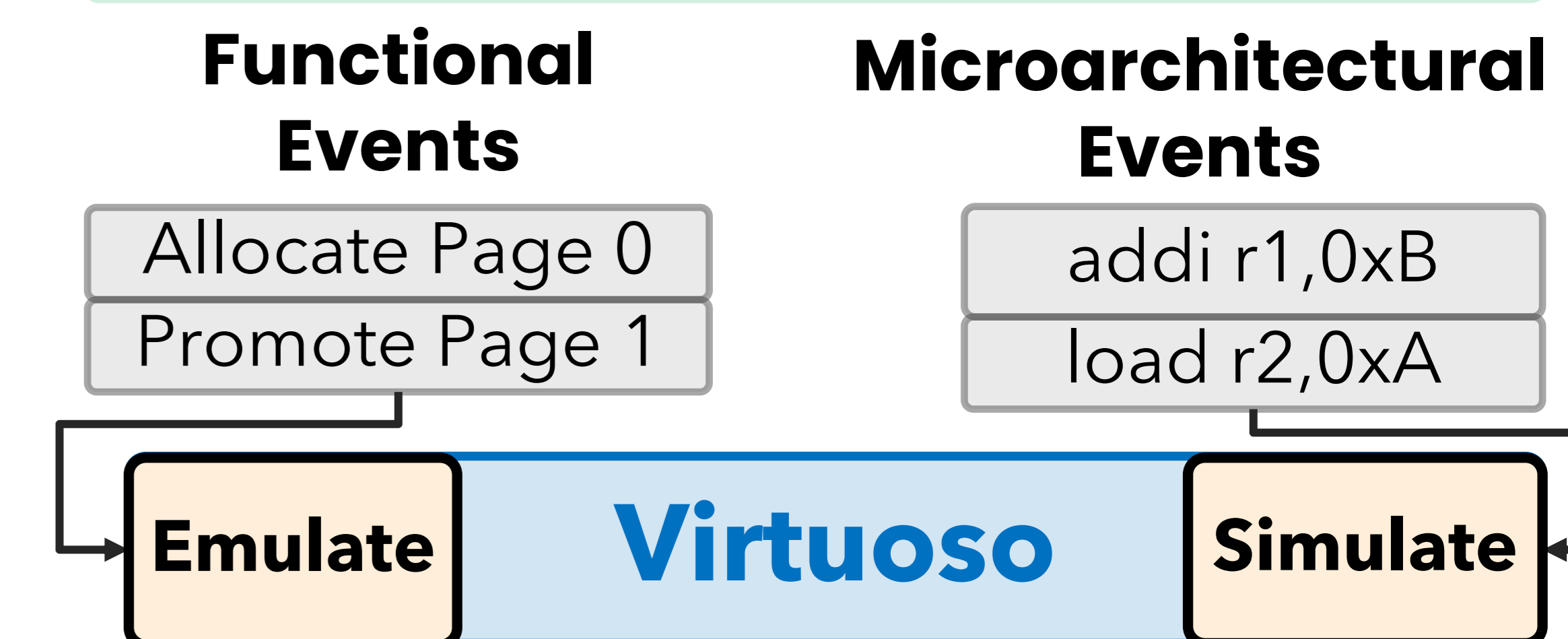
- Evaluating the efficiency of VM solutions is crucial** and heavily depends on the interplay between several system components
- For example: **memory management affects TLB performance** while page table design affects main memory and cache interference
- No existing simulation framework comprehensively supports virtual memory**

Virtuoso

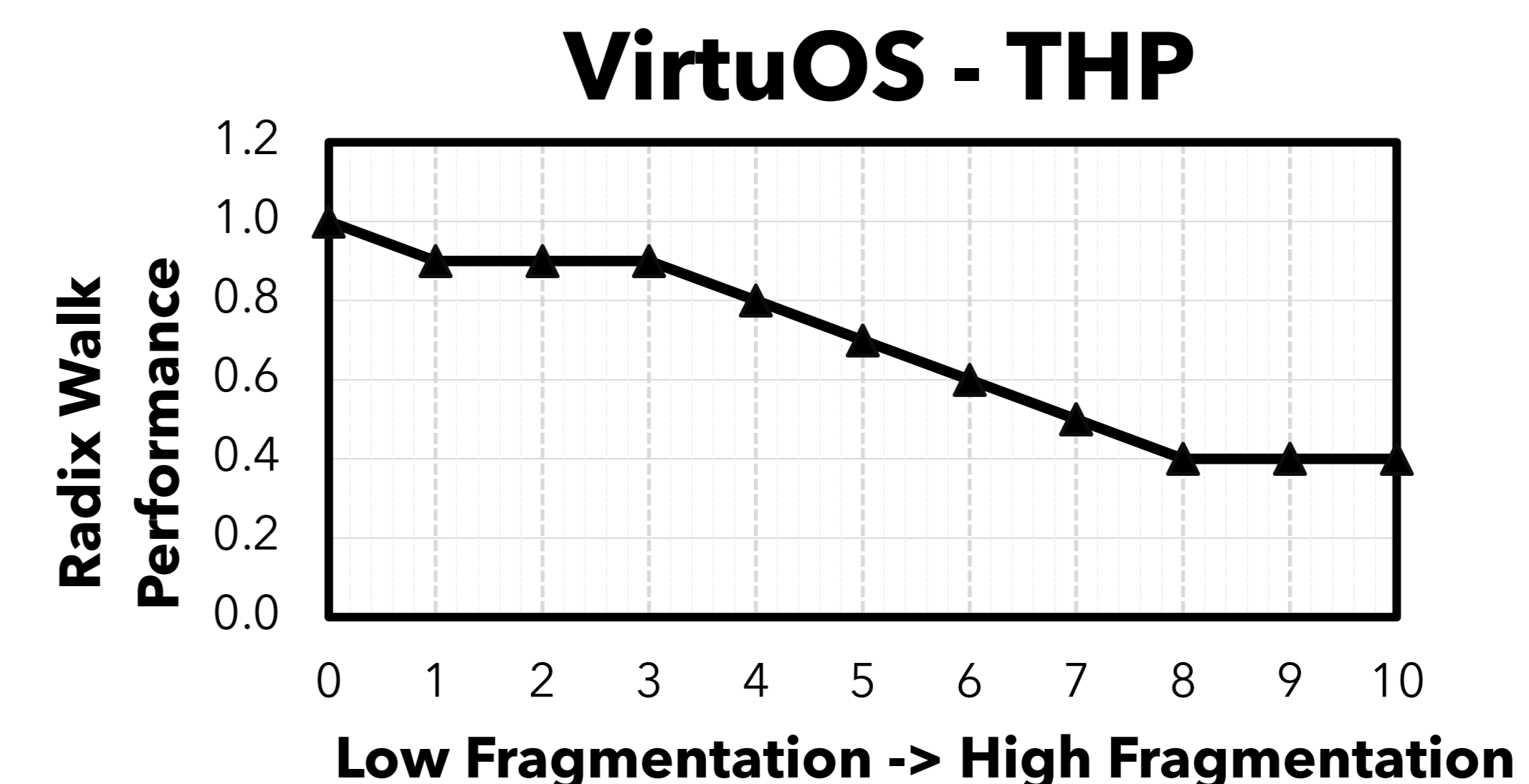
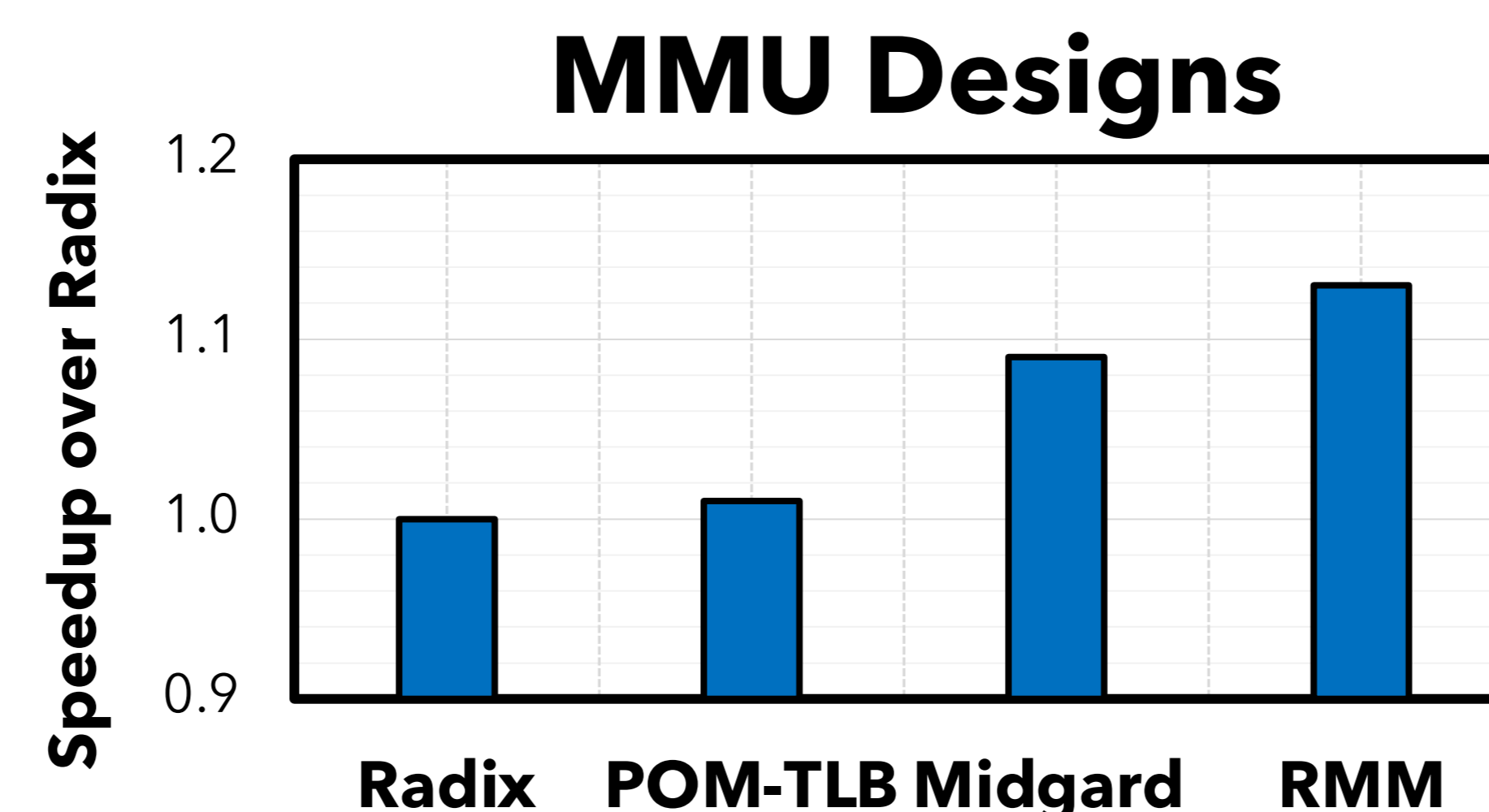
- Open-source, comprehensive** and **modular** simulation framework that models various VM designs to establish a common ground for virtual memory research
- Enables new use cases by accurately simulating the interplay between different VM components
- Avoids simulation-specific primitives and can be easily integrated in various simulators by attaching it to the memory subsystem

VirtuOS: Mini-OS for Memory Management

Example Routine: Page fault handler



New case studies



Open-Source



Github

Virtuoso's New Components

TLB Subsystem	Page Table Design	Contiguity	Intermediate Spaces	Metadata	Memory Management
Configurable TLB hierarchy	Configurable Radix Table with PWCs	Offset-based translation with Redundant Memory Mappings	Virtual Block Interface with configurable post-LLC miss translation	Memory tagging for performance optimizations using XMem	Buddy allocator
Multi-page Size TLBs	Hash-table with open-addressing and PTE clustering				Eager paging
Page-size Prediction	Elastic Cuckoo Hash-based Page Table				Memory Management Emulation
TLB Prefetching	Support for Nested MMUs (Nested MMU, Nested Walks etc.)	Direct Segments	Midgard-based address translation with trace-based VMA tracking	Mondriaan Data Protection	Reservation-based THP
Software-managed TLBs					Artificial Fragmentation Generator