

# WrtVMM: A Virtual Machine Monitor for Embedded Devices

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# Motivation

- Increasingly powerful embedded devices
- Few VMMs direct to embedded devices
- Virtual machine benefits
  - **Isolation** between routing and applications
  - Move and **clone services** between routers
  - **Elimination of additional hardware**

# WRT54GL & OpenWrt (Host)

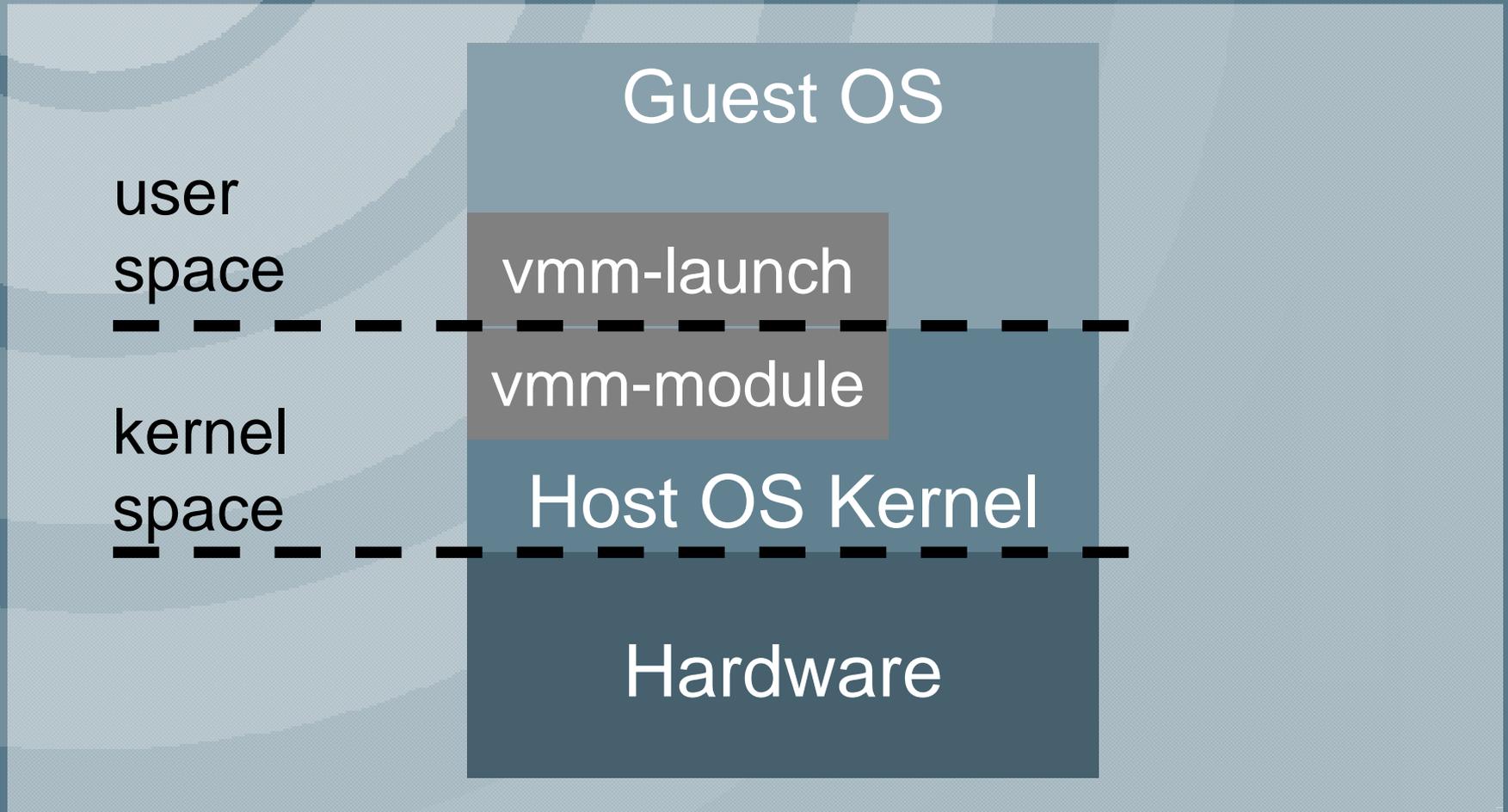
- Linksys WRT54GL Wireless Router
  - 200 MHz MIPS Processor
  - 16 MB RAM / 4 MB Flash
  - Added serial ports
- **OpenWrt** (Host)  
Wireless Freedom
  - 2.6.30 Linux kernel
  - Designed for small networking hardware



# Embedded Xinu (Guest)

- OS designed for education and research
- Provides
  - Process management
  - Memory management
  - Serial I/O
- Disabled
  - Network stack
  - Memory protection (new feature)

# Architecture

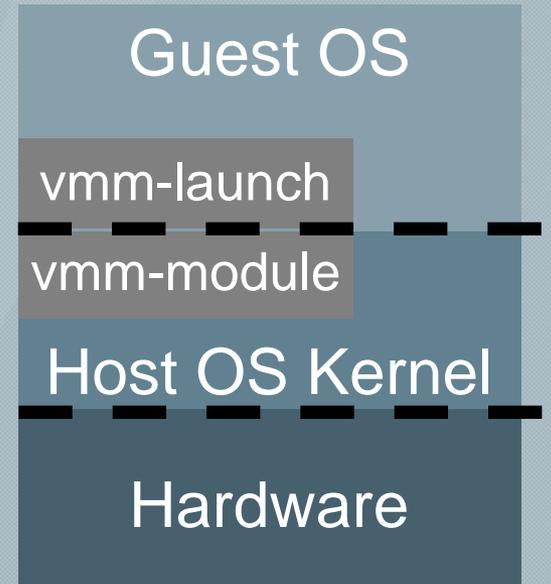


# Memory Virtualization

- VMM Module Supports Memory Allocation
  - executable memory for **running guest OS**
  - special memory for guest OS **registering interrupt handler (VCPU)**

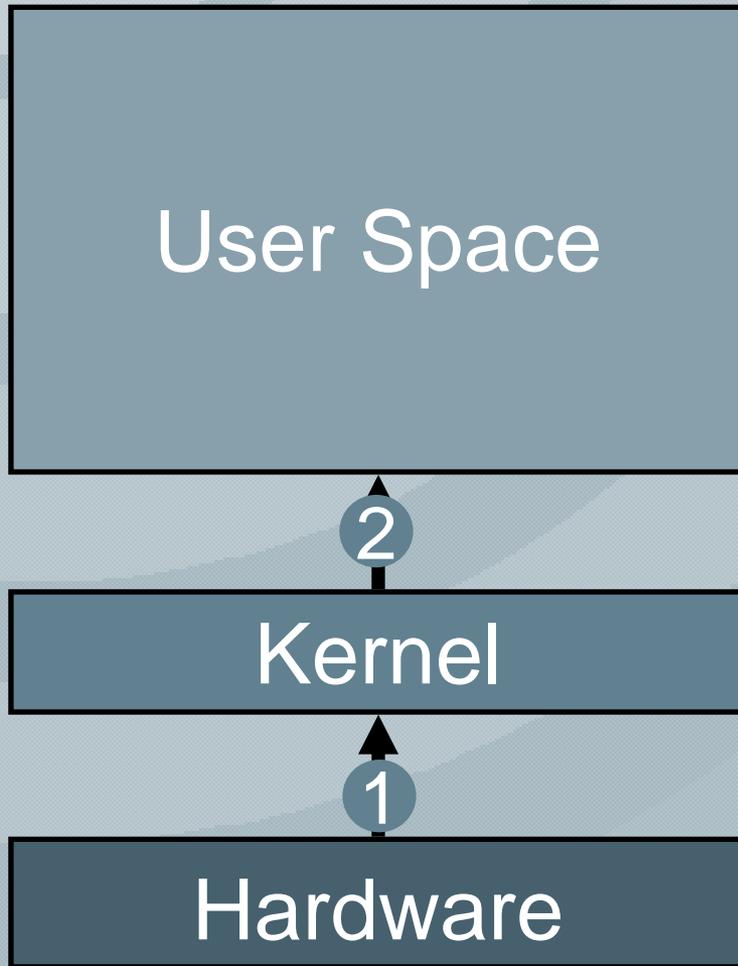
user  
space

kernel  
space

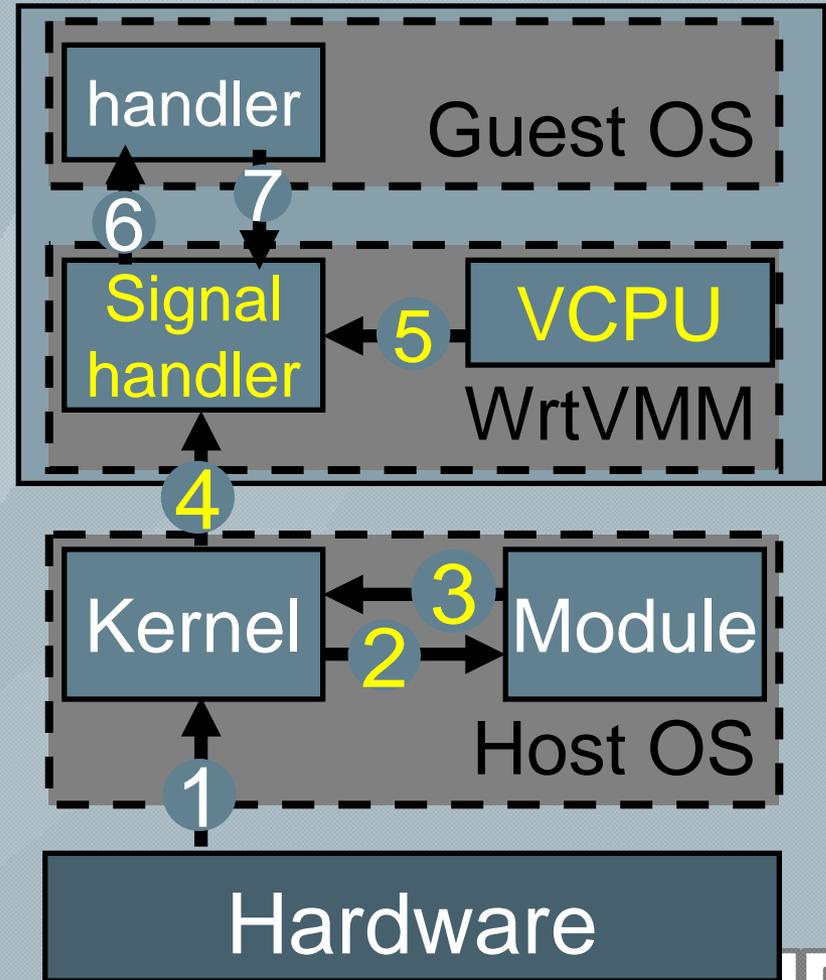


# Interrupt Handling

- Conventional Interrupt

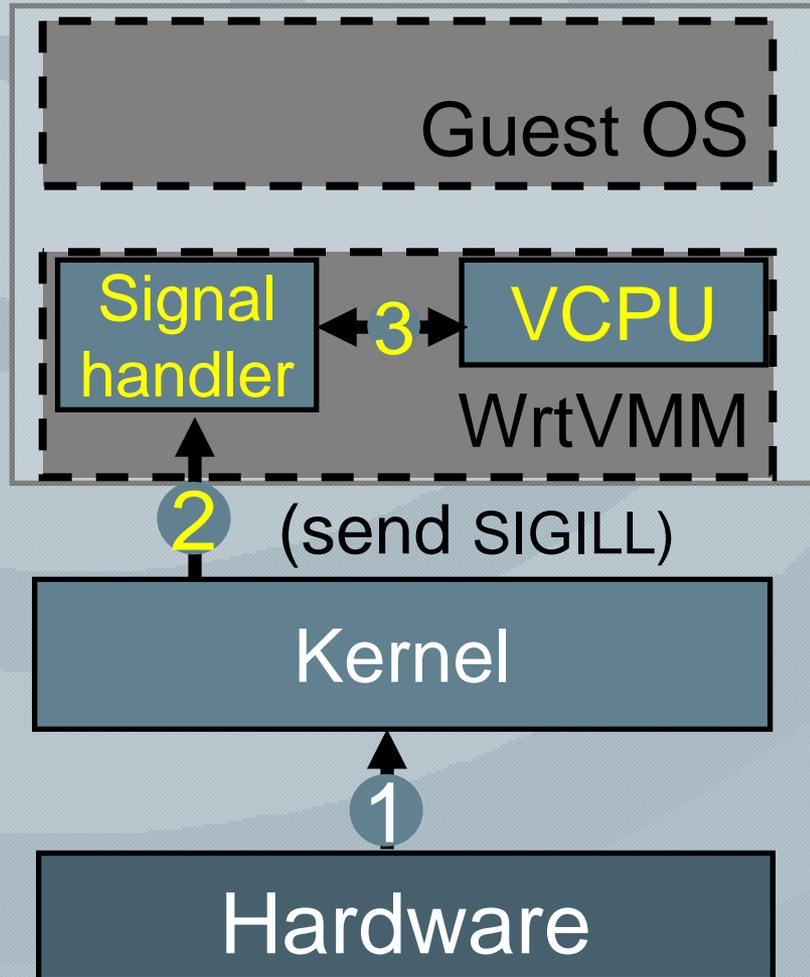


- with Virtualization



# Privileged Instructions

- Use Built-in SIGILL



## Examples

- **mtc0 t0, \$12**
  - move t0 to coprocessor 0 status register
  - emulate it by move to VCPU
- **mfc0 t0, \$12**
  - Correctly move from VCPU

**WrtVMM**

# Proc/Mem Benchmarking

- CPU Intensive – N Queens Problem

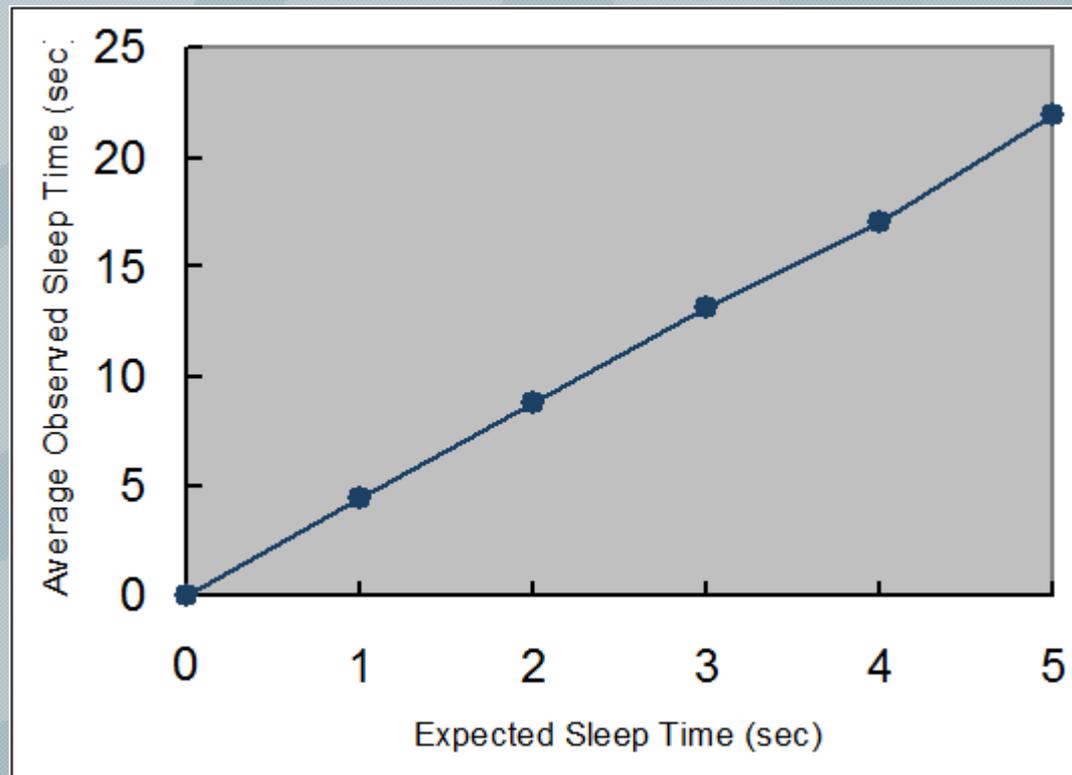
Config	OpenWRT only	Xinu only	Xinu as Guest OS	Host & Guest at the Same time
Time (ms)	5.39	13.74	13.93	27.91

- Memory Intensive – Array Summing

Config	OpenWRT only	Xinu only	Xinu as Guest OS	Host & Guest at the same time
Time (ms)	0.014	0.033	0.034	0.066

# Timer Interrupt Benchmarking

- Sleep Time: Expected vs. Observed



# Summary

- Built VMM for an embedded device
- Mechanisms for **providing memory** and **handling interrupts** and **privileged instructions**
- Minimal processor and memory overhead
- Future work: network device virtualization