

## Monitoring and Analyzing Virtual Machine Interference via Host Kernel Tracing

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## Agenda

#### Motivation

- Why tracing virtual machines ?
- What are the challenges in tracing virtual machines?

#### Investigations

- Background
- Analyzing virtual machine interference via host kernel tracing
  - Resource Monitoring for virtual machines by host kernel tracing
    - Demo
  - Monitoring Processes and threads inside virtual machine with host kernel tracing
    - Demo

Conclusion and in-progress

References



## Motivation

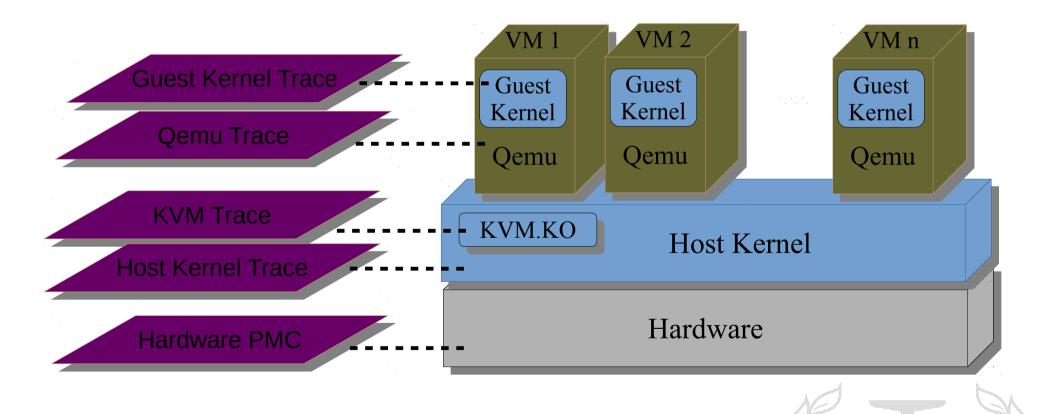
### Why tracing virtual machines?

- Cloud User:
  - Identify performance anomaly
  - Find the root cause and correct it
  - What if the performance degradation is not from a process inside the VM?
- Cloud Administrator:
  - Identify performance degradation of each VM
  - Contention for shared resources
  - Find the root cause and solve the problem



## Motivation

# What are the main challenges in tracing virtual machines?



### Background

- The Paper that uses kernel level Information
  - PerfCompass [1]
    - Global and local anomaly detection tool
- The Papers that uses Hardware level Information
  - Resource contention detection in virtualized Environments [2]
  - DeepDive [3]
    - •Identifies when interference occurs and what resources is causing it
    - •Using Hardware Performance Counters
  - CPI2 [4]
    - •Performance interference detector in shared resources
    - •Using CPI and CPU usage

## Investigatio<u>ns</u>

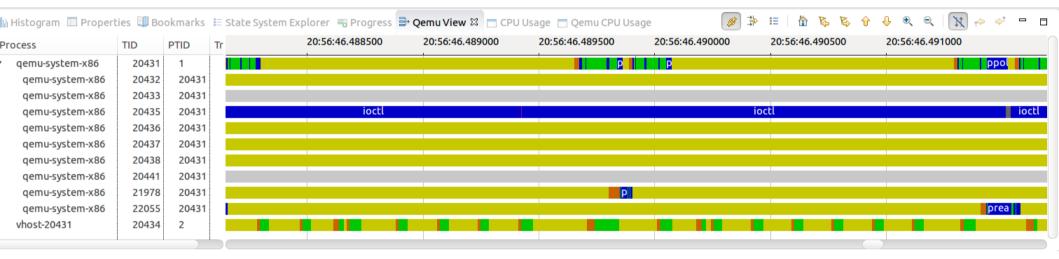
## Analyzing virtual machine interference via host kernel tracing

• Interference is what happens when VMs are concurrently competing for

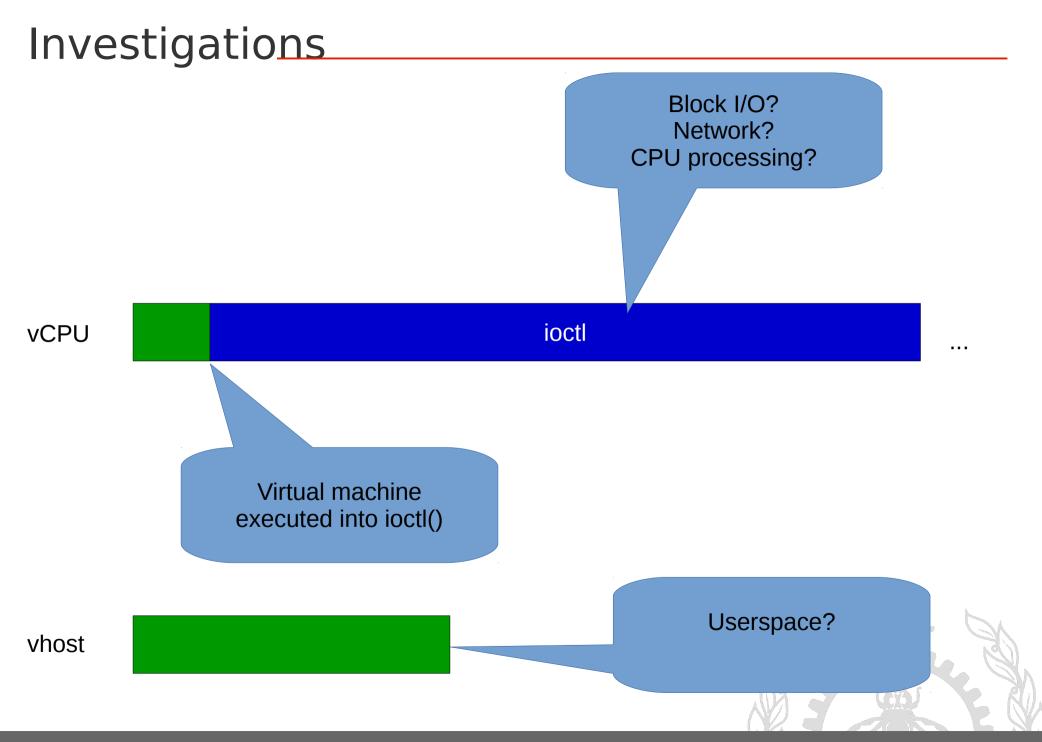
hardware resources

- Increase the latency and reduce the performance
- Goal:
  - Identify the interference
    - By applying Machine Learning
  - Find the root cause of interference
    - By finding most frequent events during the interference period
  - Solve the interference
    - By categorizing VMs based on workload by using Machine Learning
    - Migrate the Vms, limitation on resource usage, add more resources

#### Qemu threads in Control Flow View





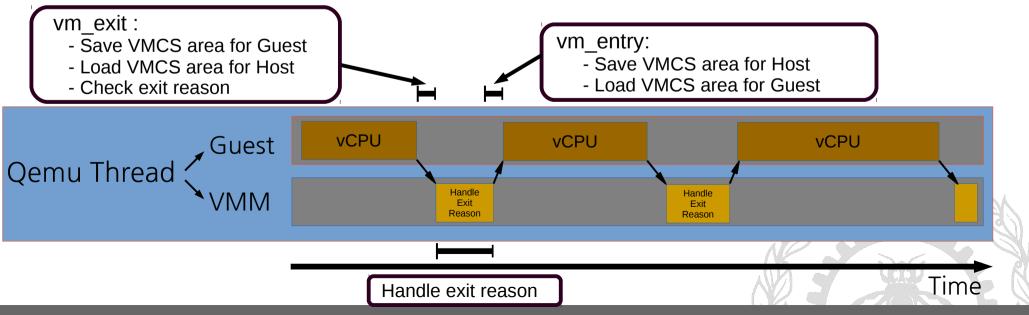


## Resource Monitoring for virtual machine by host kernel tracing

- Disk I/O:
  - Using Qemu trace points
    - qemu:thread\_pool\_submit, qemu:thread\_pool\_complete, qemu:bdrv\_co\_io\_em
- Network:
  - Using Host Kernel Trace
    - net\_if\_rx, net\_dev\_xmit, sched\_switch and sched\_wakup for vhost-\$(VM-main-thread)
- CPU:
  - Using KVM Trace and Host Kernel Trace
    - sched\_switch for qemu-system-x86, vm\_entry, vm\_exit,
    - vcpu\_guest\_entry

## Resource Monitoring for virtual machine by host kernel tracing

- CPU Virtualization with intel-VT-x:
  - VMX transition
    - Between Guest and Virtual Machine Manager (VMM)
      - vm\_entry , vm\_exit
      - Virtual Machine Control Structure (VMCS)



#### Resource Monitoring for virtual machine by host kernel tracing

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Disk testU4					State	READ_IO_QEMU	
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Metrics for Disk I/O:

- Number of submitted disk request(s) (read/write) for each or all VM(s)
- How much read/write is submitted by each or all VM(s)
- Duration of completing a disk request
- Variance of submitting disk requests by each VM
- Variance of completing disk requests by each VM



#### Resource Monitoring for virtual machine by host kernel

#### tracing

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Net testU5				RX 32944	
				TX 66	
				Date 2015-12-07	
				Start Time   09:52:57.720	734191
				Stop Time   09:52:57.720	775713
				Duration 0.000041522	S

- Metrics for Network:
  - Number of bytes received and transmitted
  - Variance of submitting network requests by each VM
  - Waiting time to receive/transmit packets



### Investigations Resource Monitoring for virtual machine by host kernel

#### tracing

Control Flow	🖩 Resources 🛱 🔲 Statisti	cs							ø :		B 0 0	€ ⊖	
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#### Metrics for CPU:

- How many vCPUs are active
- The amount of time gemu thread is in root mode and non-root mode
- Most frequent exit reasons and their frequency
- How much pCPU is used by each VM
- Variance of exiting non-root mode
- The amount of time vCPU is preempted in each or all VM(s)
- Variance of preemption for each VM

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VM\_Running

VMM\_Running

# Demo



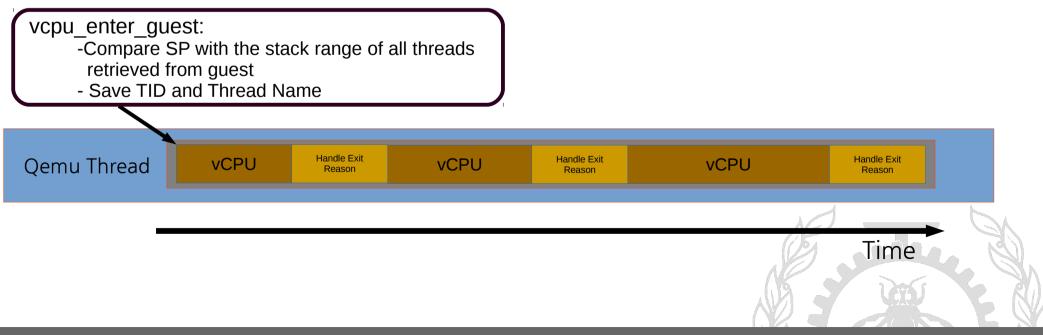
## Monitoring Processes and threads inside virtual machine with host kernel tracing

- Guest Processor State is saved into VMCS [6]
  - Guest Register State
    - Control Register CR0, CR3, and CR4
    - Debug Register DR7
    - SP and IP and FLAGS and …
  - •Guest non-Register State
    - Activity State
    - Interruptibility State and …



#### Investigations Monitoring Processes and threads inside virtual machine with host kernel tracing

- New trace points:
  - vcpu\_enter\_guest to obtain unique tuple (CR3, SP, IP)
  - If you want more information:
    - Ittng\_statedump\_stack to obtain thread stack range, thread ID, thread name, hostname



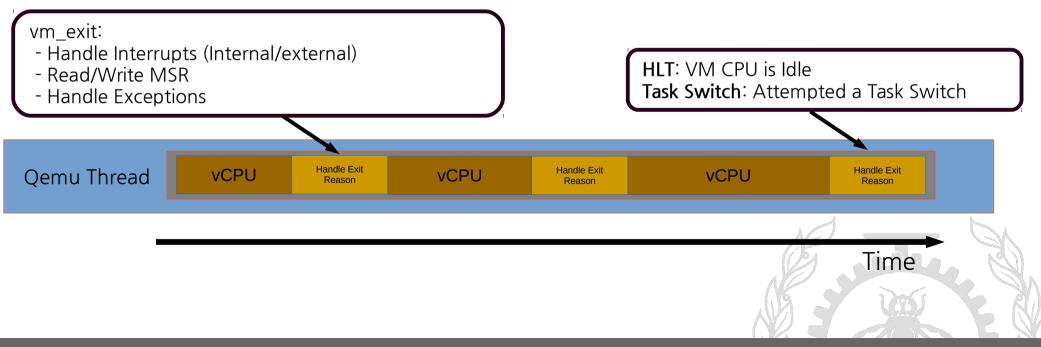


## One More Thing ...



## Monitoring Processes and threads inside virtual machine with host kernel tracing

- What are these exit reasons?
  - Schedule out gemu-system-x86 on Host without sending HLT or Task switch
  - VM assume that the task is still running (Preemption)



# Demo



## Conclusion and in-progress

#### Inferences

- Fine-grained resource monitoring lets the cloud administrator identify the contention for resources.
- Monitoring processes and associated threads lets the cloud administrator find the amount of time a thread in the VM is actually running.
  - Preemption and too many switches between guest and VMM are causing latency in the VM.

#### **Going Further**

- Memory related usage view for each virtual machine by Host Kernel Tracing
- Add some performance indicators from hardware performance counter
- Identifying interference between resources automatically
- Building Control flow view of each virtual machine by Host Kernel Tracing



## References

[1] Dean, D.; Nguyen, H.; Wang, P.; Gu, X.; Sailer, A.; Kochut, A., "PerfCompass: Online Performance Anomaly Fault Localization and Inference in Infrastructure-as-a-Service Clouds," in Parallel and Distributed Systems, IEEE Transactions on , vol.PP, no.99, pp.1-1

[2] Mukherjee, J.; Krishnamurthy, D.; Rolia, J., "Resource Contention Detection in Virtualized Environments," in Network and Service Management, IEEE Transactions on , vol.12, no.2, pp.217-231, June 2015

[3] D. Novakovic, N. Vasic, S. Novakovic, D. Kostic and R. Bianchini "DeepDive: Transparently identifying and managing performance interference in virtualized environments", Proc. Annu. Tech. Conf., pp.219-230 2013

[4] X. Zhang, E. Tune, R. Hagmann, R. Jnagal, V. Gokhale, and J. Wilkes, "CPI2: CPU performance isolation for shared compute clusters," in Proceedings of the 8th ACM European Conference on Computer Systems, ser. EuroSys '13. New York, NY, USA: ACM, 2013, pp. 379-391.

[5] Intel 64 and IA-32 Architectures Software Develope's Manual, Volume 3B, System Programming Guide, Part 2



## Questions?

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https://github.com/Nemati/Trace-Compass



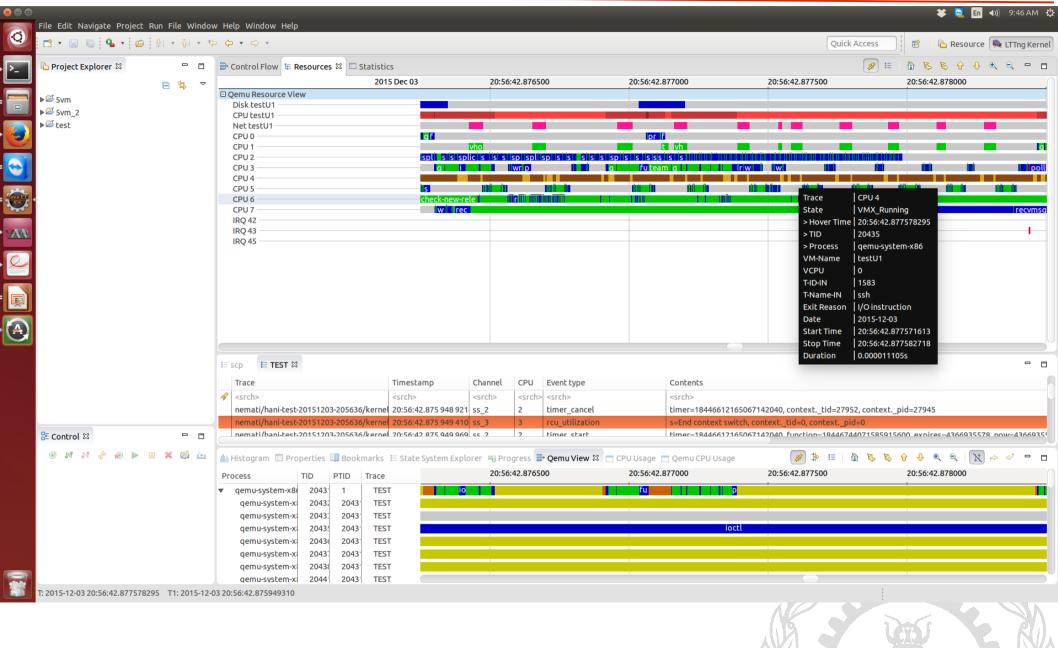
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### Demo



## Questions?

Hani.nemati@polymtl.ca

https://github.com/Nemati/Trace-Compass

