Non-intrusive, Out-of-band and Out-of-the-Box Systems Monitoring in the Cloud

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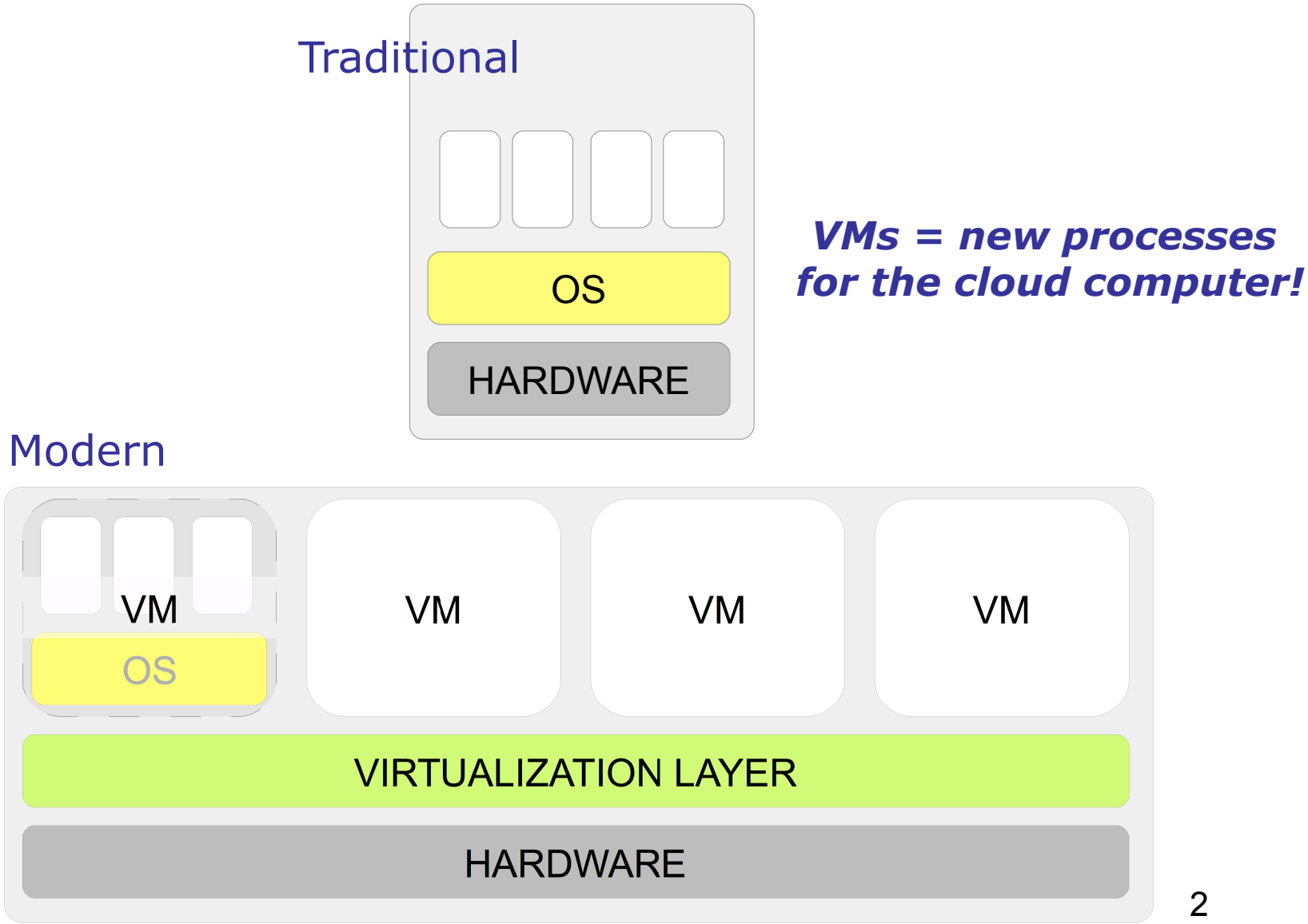
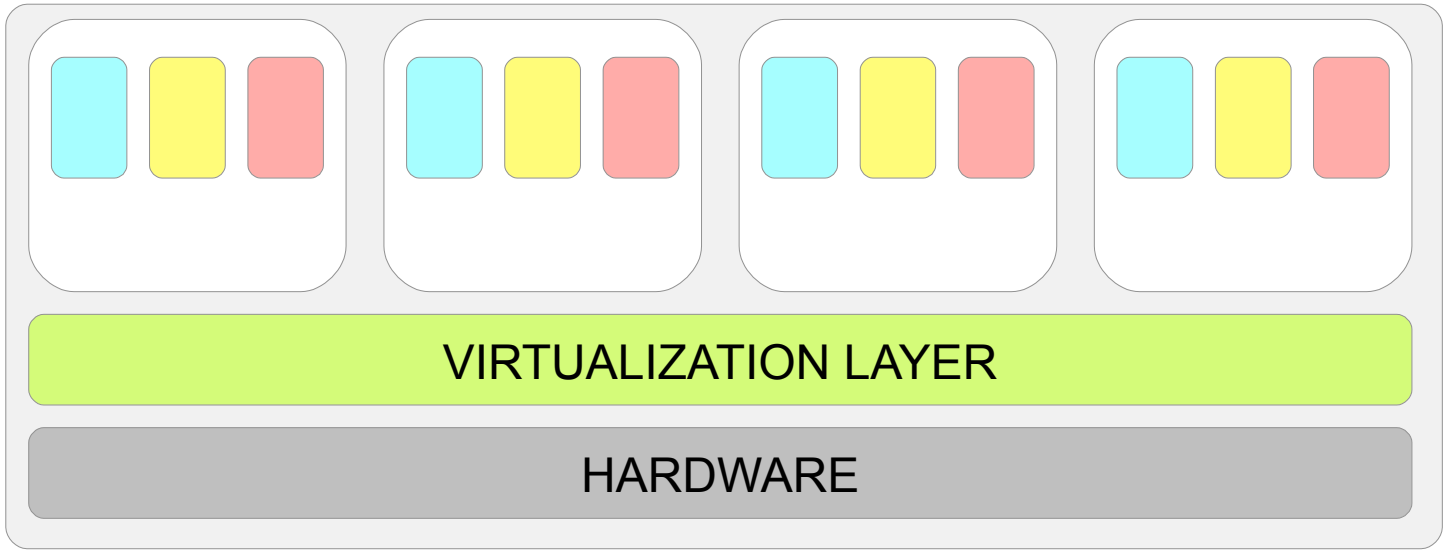
Data Center Machines



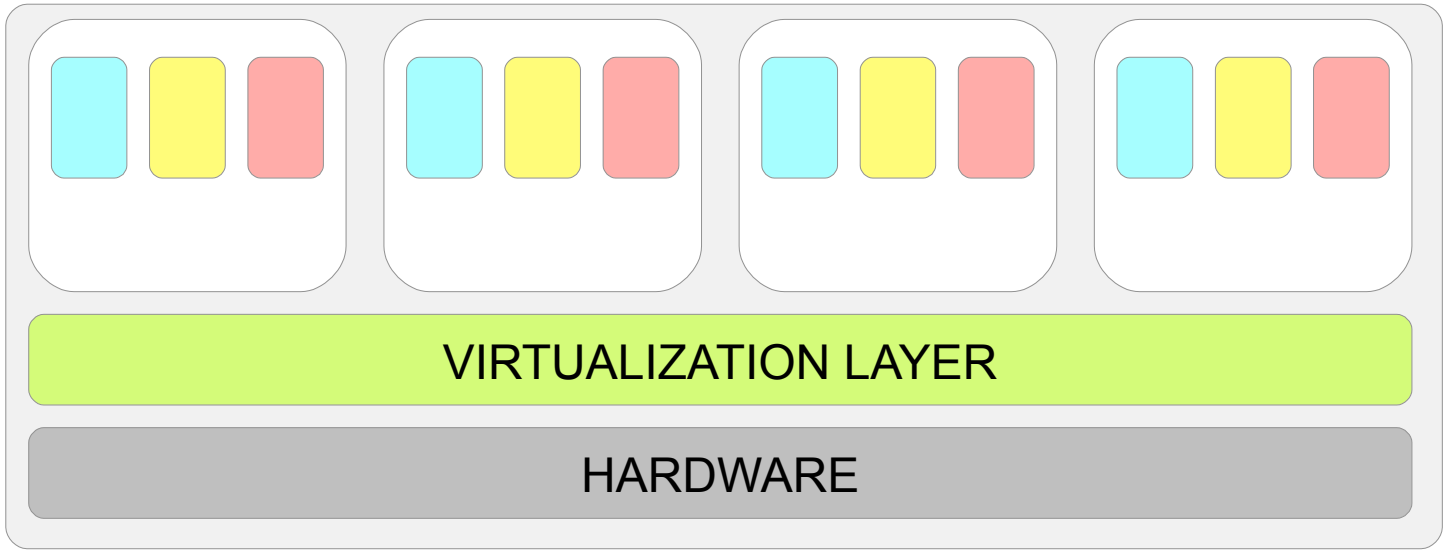
VMs = new processes for the cloud computer!

Traditional Systems Monitoring

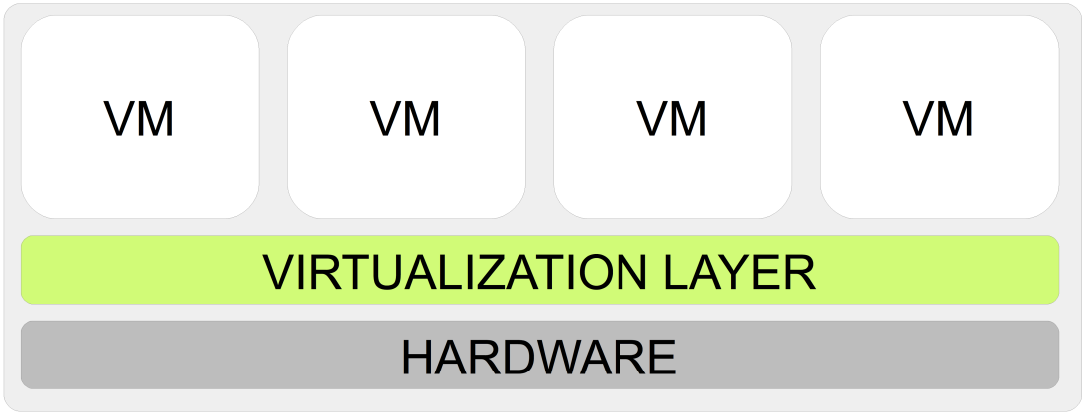
Traditional Systems Monitoring



Introducing- *Near Field Monitoring*



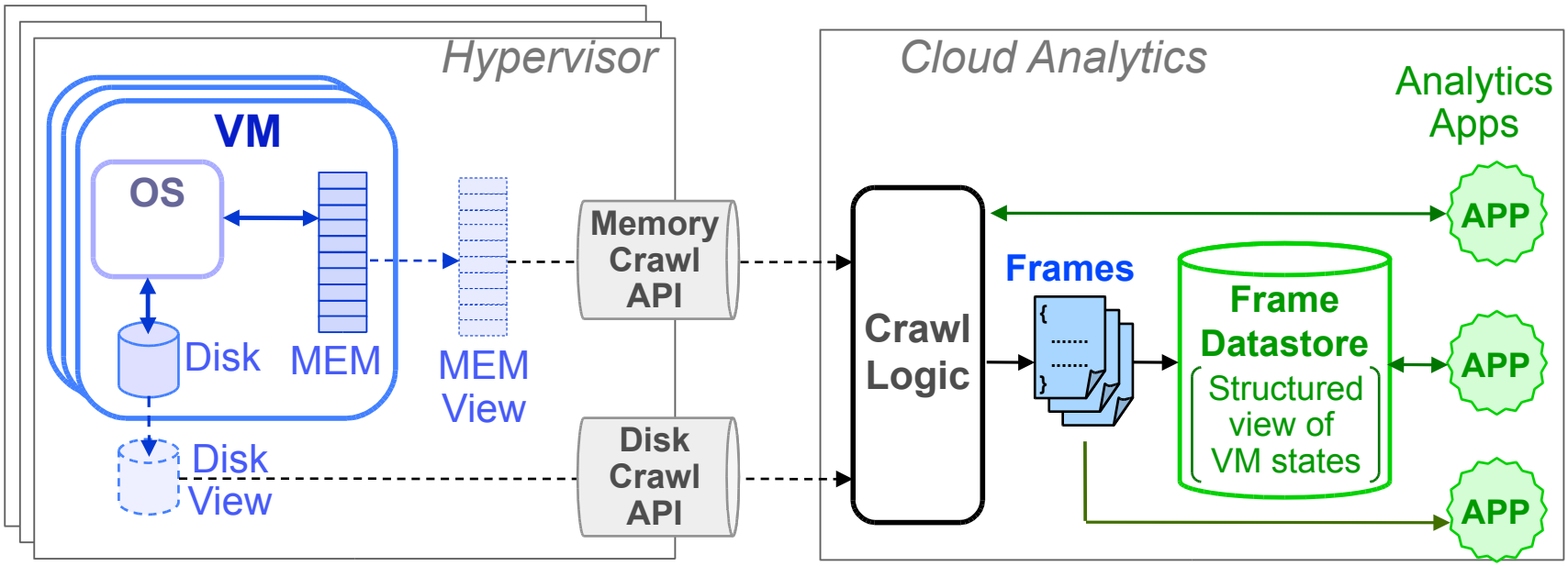
Near Field Monitoring (NFM)



NFM's Advantages

- Always-on: Works for unresponsive or compromised systems
- Out-of-the-box: Unmodified guest
  No agent or hook installation
- Non-intrusive: No guest cooperation
  No interference with guest operation
- Out-of-band: Outside guest's context
  Decouple execution and monitoring
- Virtualization-aware: Holistic knowledge
  Accurate and efficient monitoring

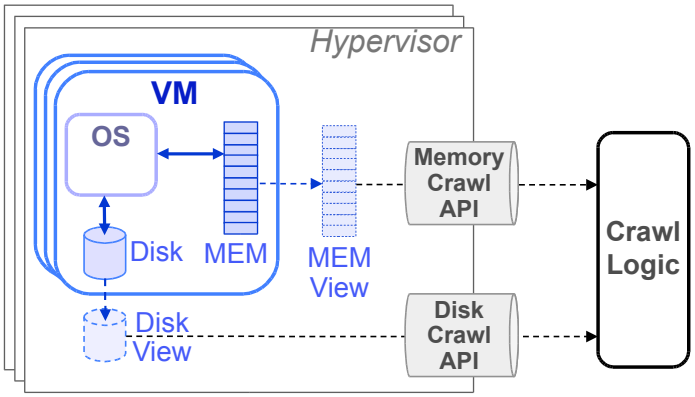
NFM's Architecture



Frontend

Backend

Approach: VM Memory Introspection



1. Exposing VM Memory State
   - Gain access to VM's memory image from outside
     - Unmodified VM
     - Unmodified hypervisor
2. Exploit VM Memory State
   - Reconstruct VM's runtime state from the memory image
   - In-memory kernel data structure traversal

Approach | Exposing VM Mem State

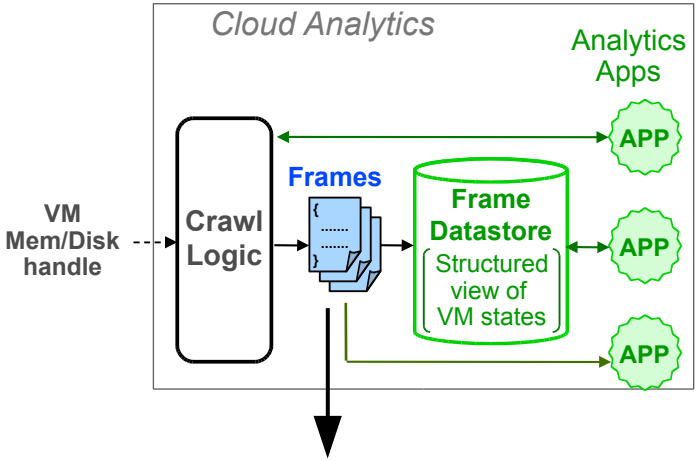
- Memory dump
  - Dump / migrate guest memory to file
  - KVM-QEMU *pmemsave* or *migrate*-to-file
  - High overhead: VM paused for dump duration
- Live R/O memory handle
  - Xen
    - Map guest memory into crawler process- *xc_map_foreign_range()*
  - KVM
    - No default support
    - New live handle, read VM mem directly via
      - QEMU process' /proc/<pid>/mem + /proc/<pid>/maps
  - Negligible impact on VM

Approach | Exploiting VM Mem State

- Extract system information by traversing linux kernel's *C structs* in exposed memory image
  - Different structs for different kinds of information
    - *task_struct, mm_struct, files_struct, net_device etc.*

- Requirements:
  - Starting addresses for structs
    - /boot/System.map
  - Offsets for particular struct fields
    - Linux source or *vmlinux*
    - /boot/<Build.config>

Backend | Crawl Output



CPU	NumCores, Hz, CacheSize, ...
OS	Nodename, Release, Arch, ...
N/W device	HWaddr, Ipaddr, TX/RX bytes, ...
Modules	Name, State, ...
Process	PID, Command, RSS, ...
Open files	FD → filename, ...
Memory Mapping	MappedFiles, VA → PA mappings, ...
N/W connections	SocketState, {Src, Dst, Ports}, ...

Backend | Prototype Apps

1. *CTop*: Cloud-wide consolidated resource monitoring

2. *PaVScan*: Hypervisor paging aware virus scanner

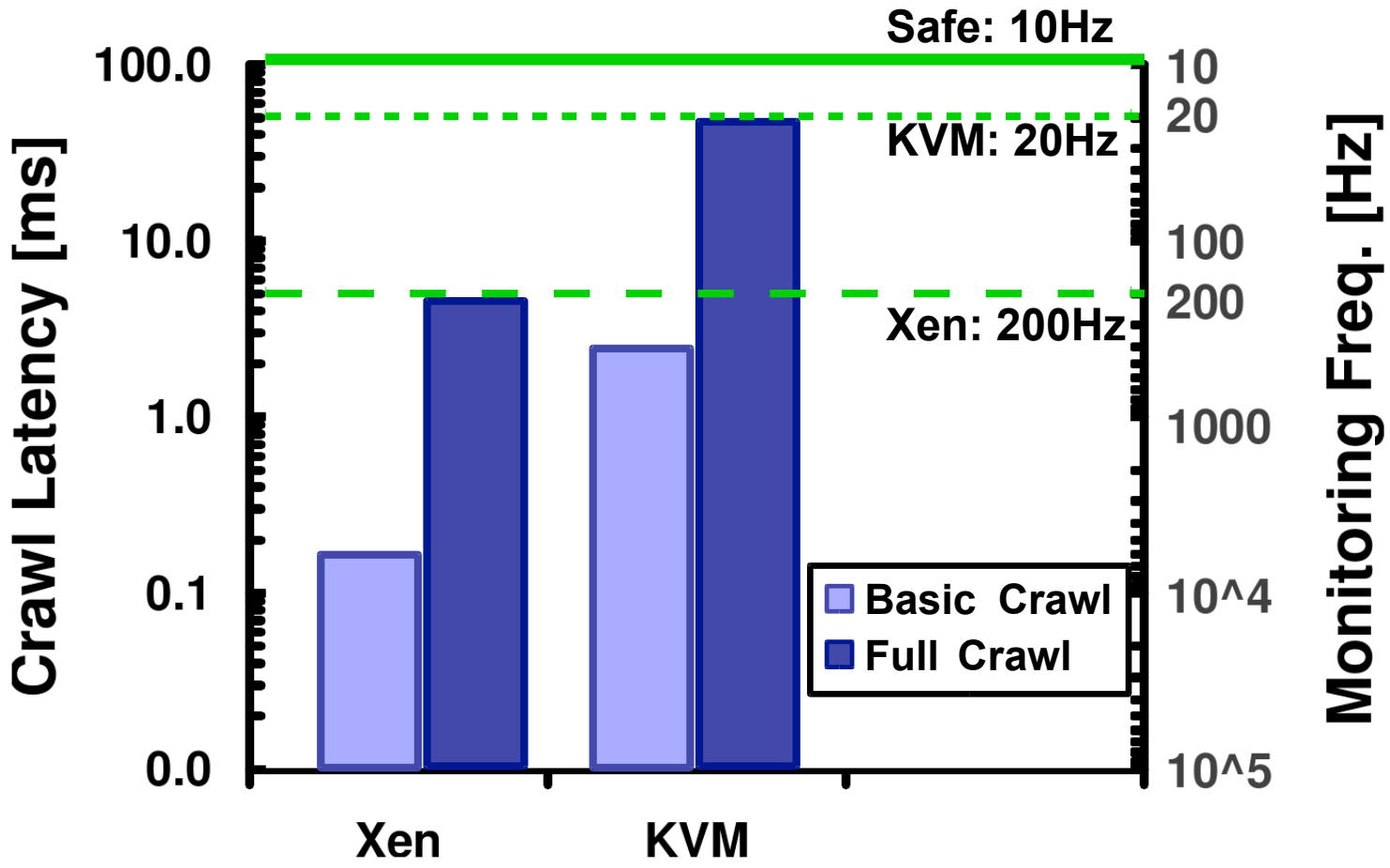
3. *RConsole*: Remote console

4. *TopoLog*: Network topology discovery

Evaluating NFM

- Latency / monitoring frequency?
- Accuracy?
- Overhead?
- Advantages?

NFM's High Monitoring Frequency



NFM's Accuracy: Cloud Top vs. *top*

```
top - 11:58:42 up 1 day, 22:19,  1 user, load average: 0.90, 0.22, 0.11
Tasks: 57 total,   3 running,    54 sleeping,  0 stopped,    0 zombie
Cpu(s): 99.0%us, 0.0%sy, 0.0%ni, 0.0%id, 0.0%wa, 0.7%hi, 0.0%si, 0.3%st
Mem:  2052104k total, 1976340k used,   75764k free,     3996k buffers
Swap: 6160380k total,  304068k used, 5856312k free,     1868k cached
```

top

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
1942	root	20	0	1028m	1.0g	188	R	49.9	51.0	0:08.98	malloc
1940	root	20	0	1028m	780m	136	R	49.5	38.9	0:11:91	malloc
1	root	20	0	56220	1164	408	S	0.0	0.1	0:00.71	systemd
2	root	20	0	0	0	0	S	0.0	0.0	0:00.00	kthreadd

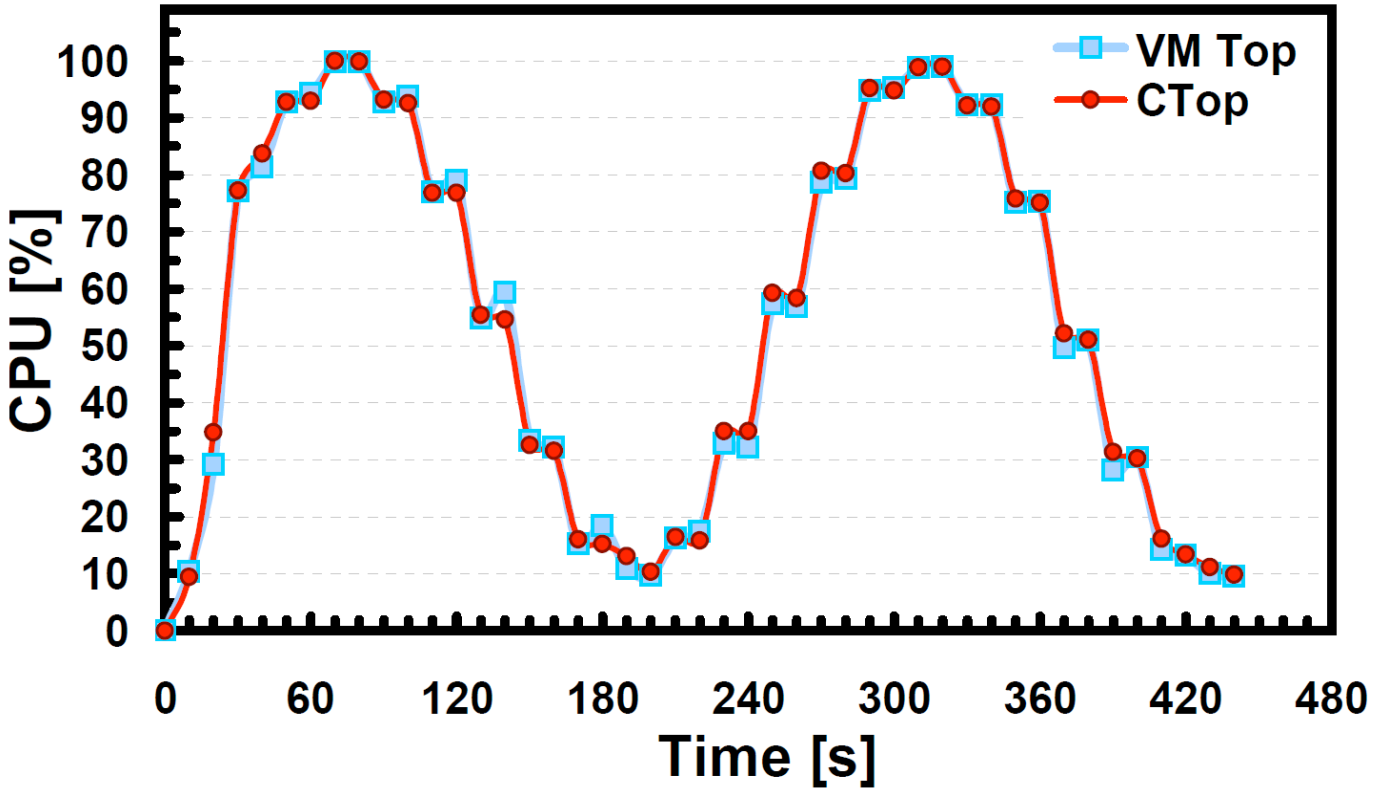
```
Every 0.5s: ./topUpdate.sh

CPU up time: 4461430125 jiffies
```

cTop

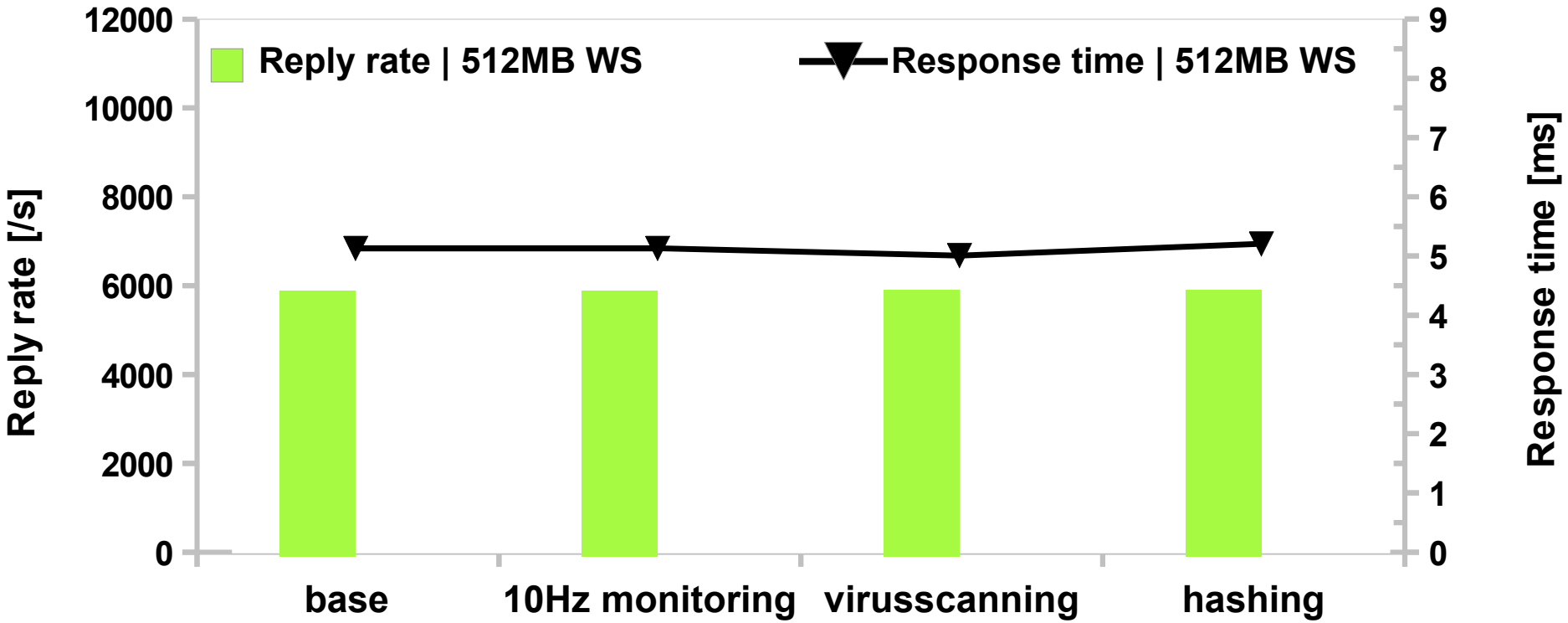
PID	VIRT	RES	%CPU	%MEM	TIME+	COMMAND
1942	1052704KB	1047368KB	45.8	51.0	0:08:33	malloc
1940	1052704KB	798816KB	45.8	38.9	0:11.92	malloc
1	56220KB	1164KB	0.0	0.1	0:00.70	systemd
2	0	0	0.0	0.0	0:00.00	kthreadd
:						

NFM's High Accuracy



<4% variation

NFM's Low VM Overhead



+ 256MB WS in paper

NFM's Advantages: Analyze Dysfunctional Systems

- Via *RConsole* - Out-of-band console-like R/O interface
- Supported functions: *ls, lsmod, ps, netstat, ifconfig, ...*
- Time travel: *sync* and *seed* APIs
- *Analyzes unresponsive systems*: kernel panic, misconfigured n/w
- Detects (some) rootkits:

In-VM Console:

```
Active Internet connections (servers and established)
Proto Local Address        Foreign Address    State
tcp   127.0.0.1:25         0.0.0.0:*          LISTEN
tcp   9.XX.XXX.110:52019   9.XX.XXX.109:22    ESTABLISHED
:
tcp   9.XX.XXX.110:22      9.XX.XXX.15:49845 ESTABLISHED
```

RConsole:

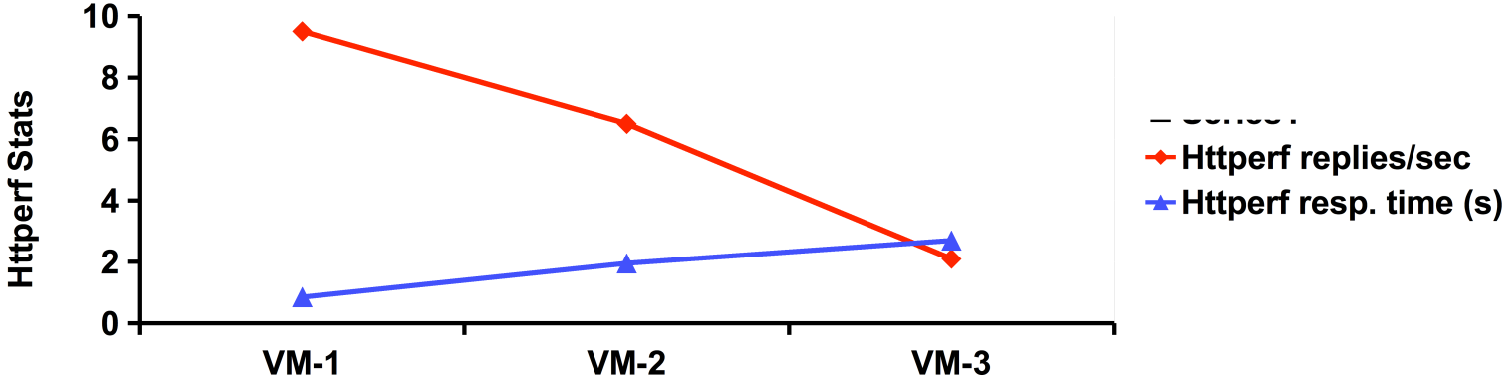
```
Active Internet connections
Proto   Local Address       Foreign Address    State             PID Process
tcp     127.0.0.1:25        0.0.0.0:0          SS_UNCONNECTED    741 [sendmail]
tcp     9.XX.XXX.110:52019  9.XX.XXX.109:22    SS_CONNECTED     6177 [ssh]
:
tcp     9.XX.XXX.110:22     9.XX.XXX.15:49845  SS_CONNECTED    14894 [sshd]
tcp     0.0.0.0:2476        0.0.0.0:0          SS_UNCONNECTED  23304 [datacpy]
```

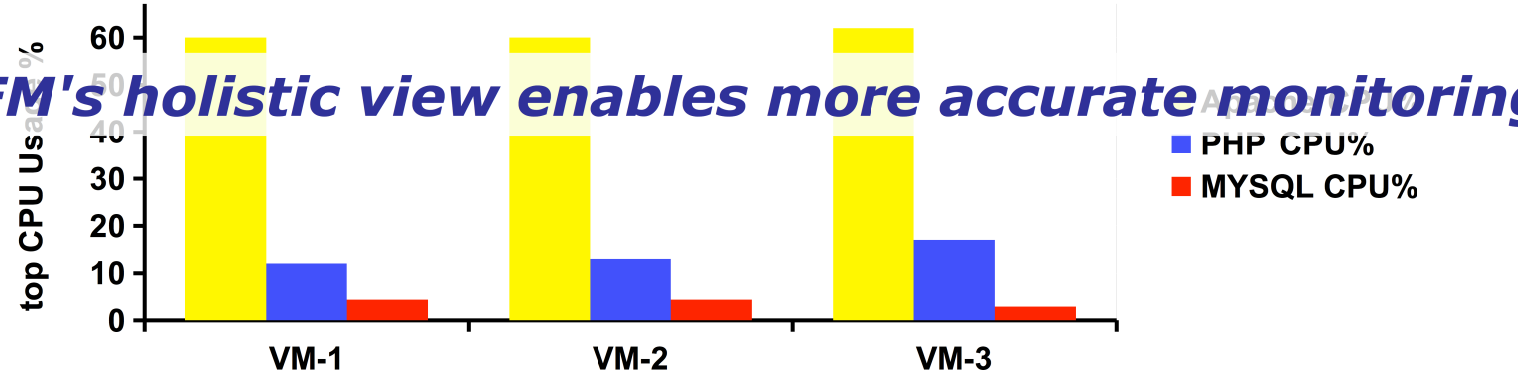
NFM's Advantages: Better Accuracy

- Distributed Application
  - 3 LAMP instances

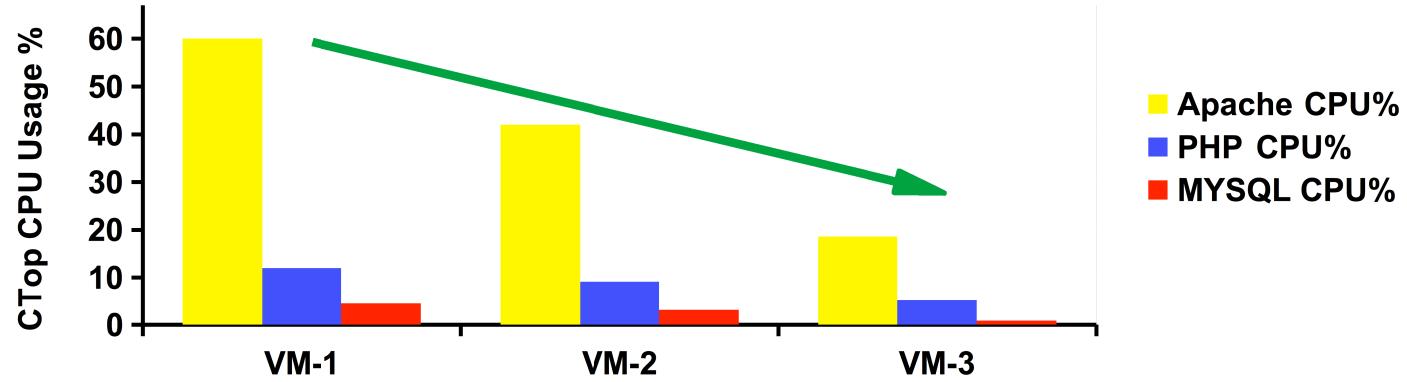
	VM1	VM2	VM3
Reservation	30%	30%	30%
Allocation	100%	70%	30%

NFM's Advantages: Better Accuracy





NFM's holistic view enables more accurate monitoring



Conclusion

- Current monitoring techniques unfit for modern virtualized Cloud
- Introducing Near Field Monitoring- Leverage virtualization for a fundamentally different VM monitoring approach
  - Eliminates in-VM hooks, provides same fidelity monitoring out-of-band
  - Decoupled VM monitoring - execution architecture
  - Alleviates concerns with existing techniques
    - Always-on, non-intrusive, holistic view, ...
- Evaluation:
  - High frequency
  - Low overhead
  - Better accuracy
  - Higher efficiency