IT Systems Engineering | Universität Potsdam

InstantLab – The Cloud as Operating System Teaching Platform

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Operating Systems and Middleware Group

Cloud Futures 2011

Operating Systems and Middleware

IT Systems Engineering
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Agenda

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1. Operating System Experiments – the Windows Case
2. InstantLab
3. Demo
4. Research Questions
5. Conclusions

Windows Research Kernel (WRK)

- Stripped down Windows Server 2003 sources
  - Only kernel itself, no drivers, GUI, user-mode components
  - Missing components: HAL, power management, plug-and-play
- Released in 2006
- Freely available to academic institutions
- Encouraged by license:
  - Modification
  - Publication (of excerpts)

Structuring Experiments: The UMK Approach

- U-phase
  - Concentrate on OS concepts
  - Introduce OS interfaces
  - Systems programming
- M-phase
  - Observe concepts at run-time
  - Introduce monitoring tools
  - System measurements
- K-phase
  - Discuss kernel implementation
  - Introduce kernel source code (WRK/UNIX)
  - Kernel programming

Kernel Programming Experiments

- Debugging/Instrumenting the WRK
  - Boot phase
  - Process creation
  - Single-step debugging the WRK in a virtual machine
- Creating a new system call
  - Hide/Show a specified process from the system
  - Memorize hidden processes
  - Implement a system service DLL
- Memory management

Kernel Programming Experiments – Bottom Line

- Experiments comprise
  - Documentation
  - Source code
  - Workload generators
  - Measurement/visualization tools
- Experiment setup:
  - Install and configure test operating system
  - Build and deploy the sources
  - Configure kernel debugging infrastructure
- Virtualization helps, but
  - Variety of OS platforms, virtualization vendors among students
  - Hardware requirements

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The InstantLab Idea

- Provision of "canned experiments"
  - Virtual machine images (VMI) as foundation
  - Self-contained, pre-configured experiment in one VMI
  - Instantaneous execution of a lab or experiment on Cloud resources

Embrace The Cloud

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- Virtualize laboratory environment
  - No physical machines in university, no maintenance
  - Compute resources in the Cloud
- Migrate exercises and demos into the Cloud
  - Provision of VM template(s) for each exercise
  - Instantiation on demand
- Facilitate experiments through remote display session
  - Run experiments in Web browser
  - Support of various platforms and compute power

InstantLab - Architecture

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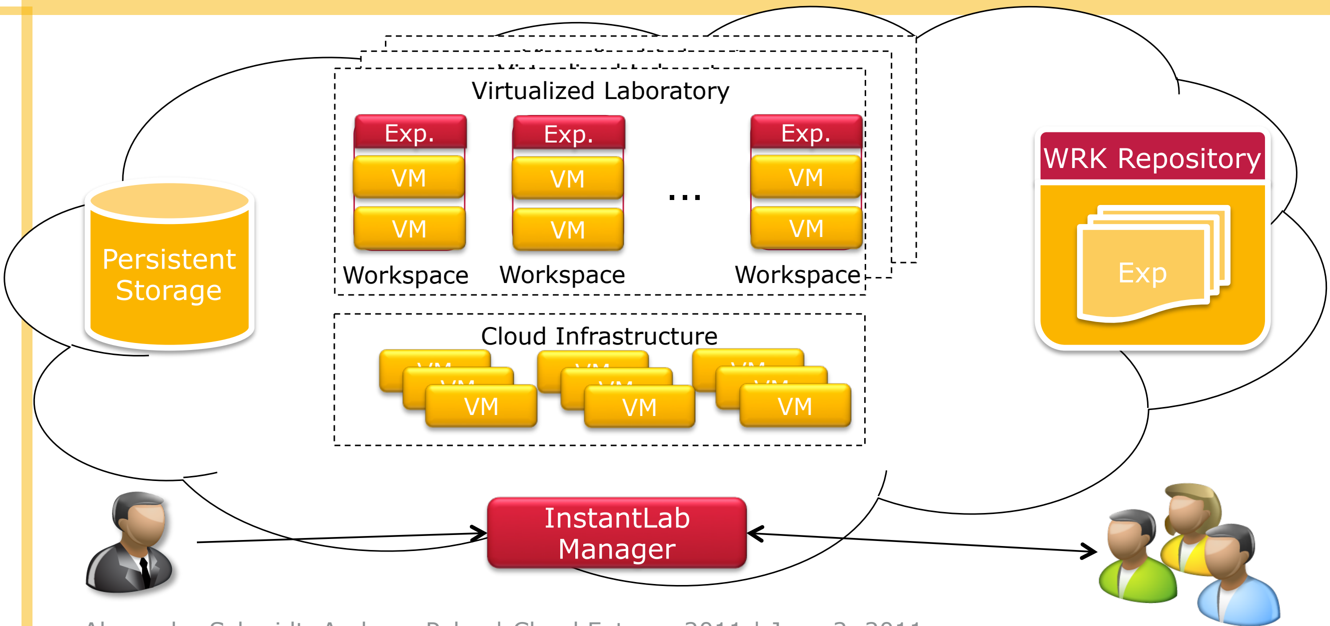

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Facilitating Remote Access

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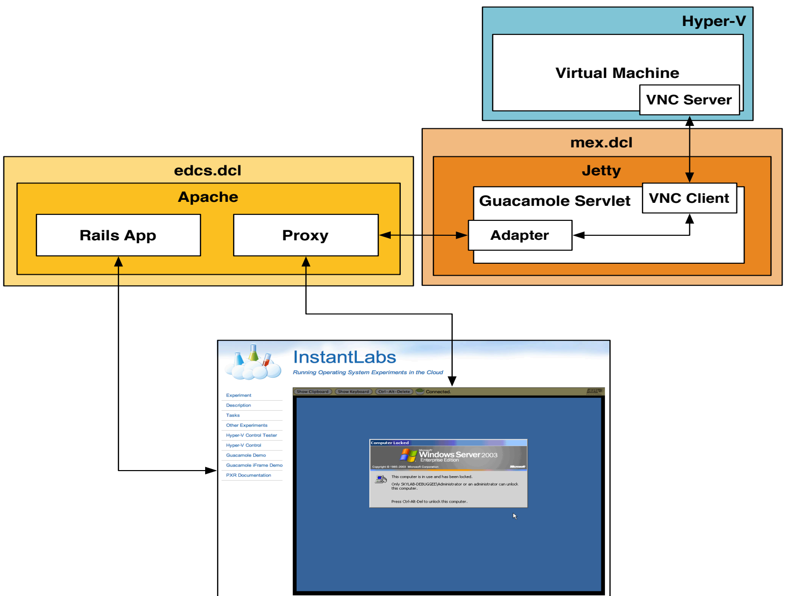

InstantLab Demo – Working Set Replacement Experiment

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InstantLab Demo – Working Set Replacement Experiment

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Lab Management – Architecture

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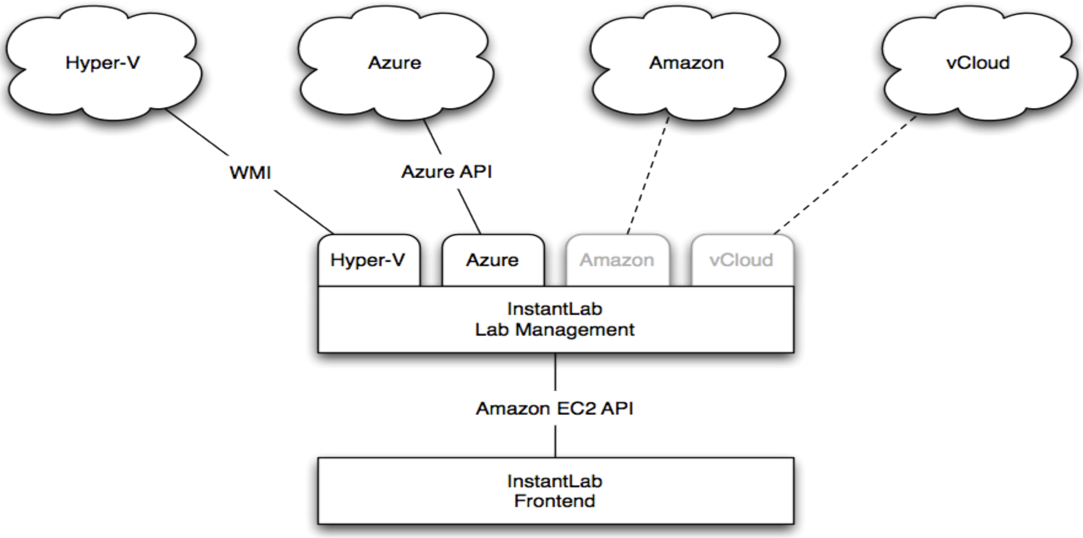

InstantLab Demo – Lab Management

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InstantLab Demo – Lab Management

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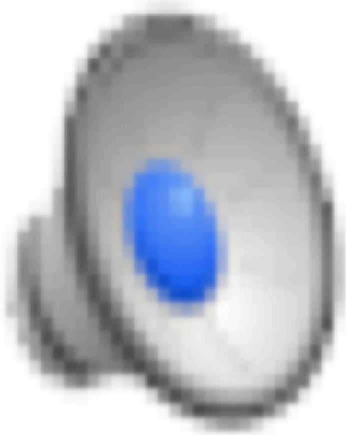

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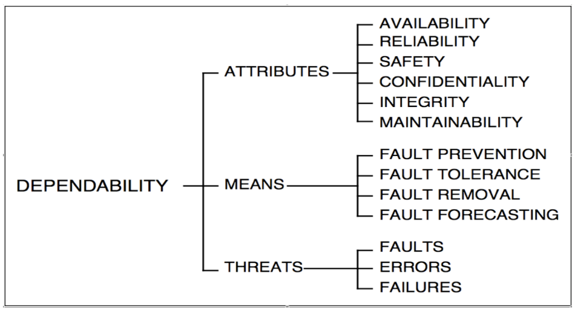
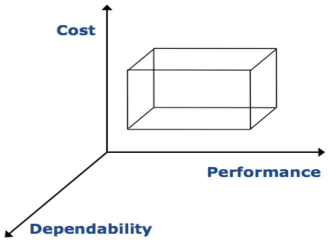
Dependability – does it matter for Cloud?

Umbrella term for operational requirements on a system

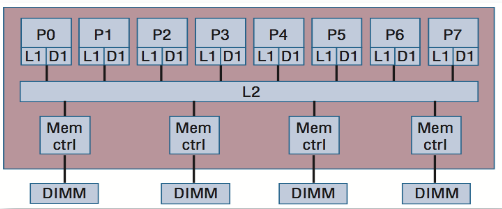
- *„Trustworthiness of a computer system such that reliance can be placed on the service it delivers to the user“* [Laprie]

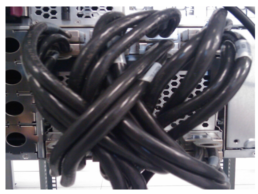
General question: How to deal with unexpected events ?

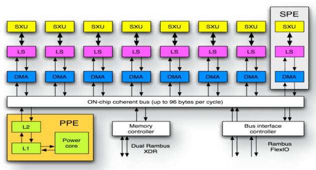


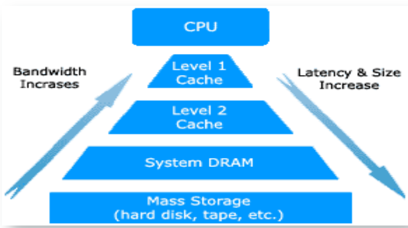


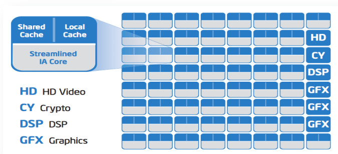
Hardware Revolution in the x86 World





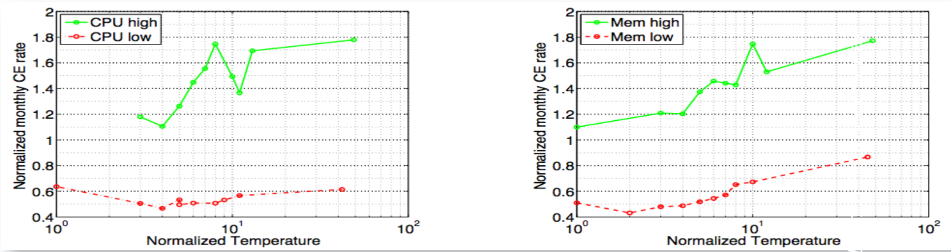






Classical Reliability Wisdoms Get Replaced

- Dramatic shift in single machine reliability aspects
  - SMP becomes heterogeneous tiled on-chip network
  - Decreasing structural sizes + dynamic frequency and voltage
  - Massive memory increase
- **More fault classes, less error containment !**
- Few research results from HPC perspective
  - Type and intensity of workload significantly influences life time
  - Failure rates depend on processor count, not hardware type



Research in the FutureSOC Lab

HPI FutureSOC Lab

- Collaboration with industry for software research on next-generation x86 hardware (32-65 cores, 1-2 TB RAM)

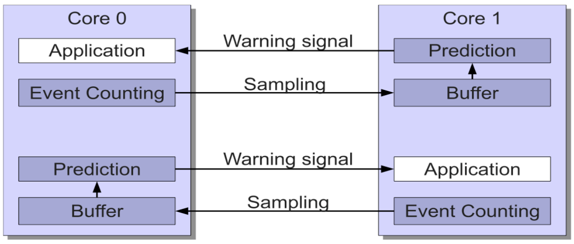
Our research @ FutureSOC Lab

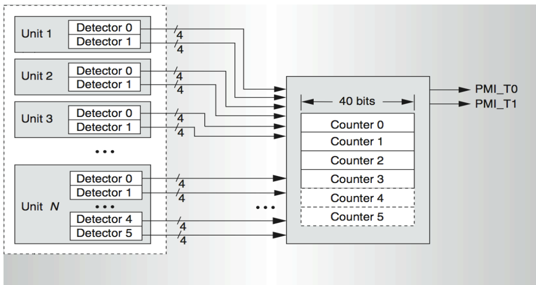
- Failure prediction based on cross-level monitoring data analysis
- Pro-active virtual machine migration
- Fault injection based on UEFI firmware technology

CPU Level:
Online Hardware Failure Prediction

Using X86 hardware performance events

- Instruction retirement, cache miss, branch miss-prediction, ...
  - Limited number of hardware counter units -> exploit event correlations
  - Threshold-triggered, time-triggered
- Applicable to major cellular multiprocessing platforms
  (Intel, AMD, SPARC, IBM Power)





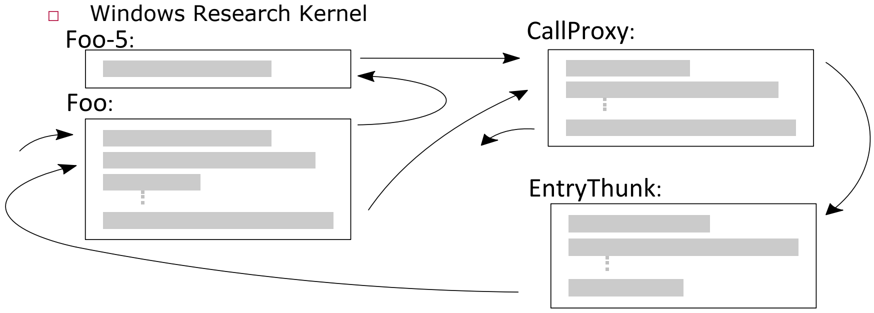
Memory level:
observations from our FutureSOC Lab

Date	Severity	Event	Source	Description
15-Jun-2010 13:47:12	Info	No	BIOS	System boot (POST complete)
15-Jun-2010 13:45:53	Major	No	[0x00:00]	POST - 'MEM4_DIMM-2D' memory training failed
15-Jun-2010 13:45:53	Major	No	[0x00:00]	POST - 'MEM4_DIMM-1D' memory training failed
15-Jun-2010 13:45:53	Major	No	[0x00:00]	POST - 'MEM4_DIMM-2B' memory training failed
15-Jun-2010 13:45:53	Major	No	[0x00:00]	POST - 'MEM4_DIMM-1B' memory training failed
15-Jun-2010 13:45:53	Critical	Yes	SMI	'MEM4_DIMM-1D' Memory: Uncorrectable error (ECC)
15-Jun-2010 13:45:53	Critical	Yes	SMI	'MEM4_DIMM-1C' Memory: Uncorrectable error (ECC)
15-Jun-2010 13:45:53	Critical	Yes	SMI	'MEM4_DIMM-1B' Memory: Uncorrectable error (ECC)
15-Jun-2010 13:45:53	Critical	Yes	SMI	'MEM4_DIMM-1A' Memory: Uncorrectable error (ECC)
15-Jun-2010 13:45:40	Critical	Yes	iRMC S2	'MEM4_DIMM-2D': Memory module failed (disabled)
15-Jun-2010 13:45:40	Critical	Yes	iRMC S2	'MEM4_DIMM-1D': Memory module failed (disabled)
15-Jun-2010 13:45:40	Critical	Yes	iRMC S2	'MEM4_DIMM-2B': Memory module failed (disabled)
15-Jun-2010 13:45:40	Critical	Yes	iRMC S2	'MEM4_DIMM-1B': Memory module failed (disabled)
15-Jun-2010 13:43:43	Info	No	BIOS	System boot (POST complete)
14-Jun-2010 17:41:47	Critical	Yes	iRMC S2	'MEM4_DIMM-1D': Memory module error
14-Jun-2010 17:26:17	Major	Yes	iRMC S2	'MEM4_DIMM-1D': Memory module failure predicted

OS level: our NTrace for Windows

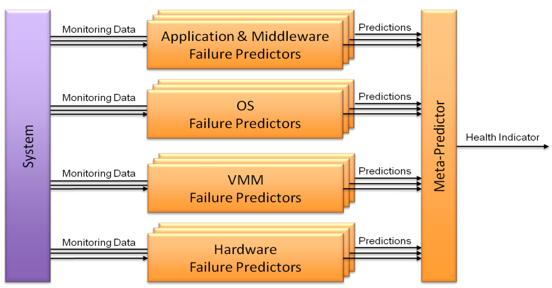
- Compiler/linker switch
  - /hotpatch, /functionpadmin
  - Microsoft C compiler shipped with Windows Server 2003 SP1 and later
- Hotpatchable:
  - Windows Server 2003 SP1,Vista, Server 2008, Windows 7
  - Windows Research Kernel

```
          ...
          retn 10
          nop
          nop
          nop
          nop
          nop
NtfsPinMappedData:
          mov     edi, edi
          push    ebp
          mov     ebp, esp
          mov     ecx, [ebp+18h]
          mov     edx, [ebp+0Ch]
          ...
```



„Ablaufverfolgung in einem laufenden Computersystem"
Pat. pend. **DE-10 1009 038 177.5**

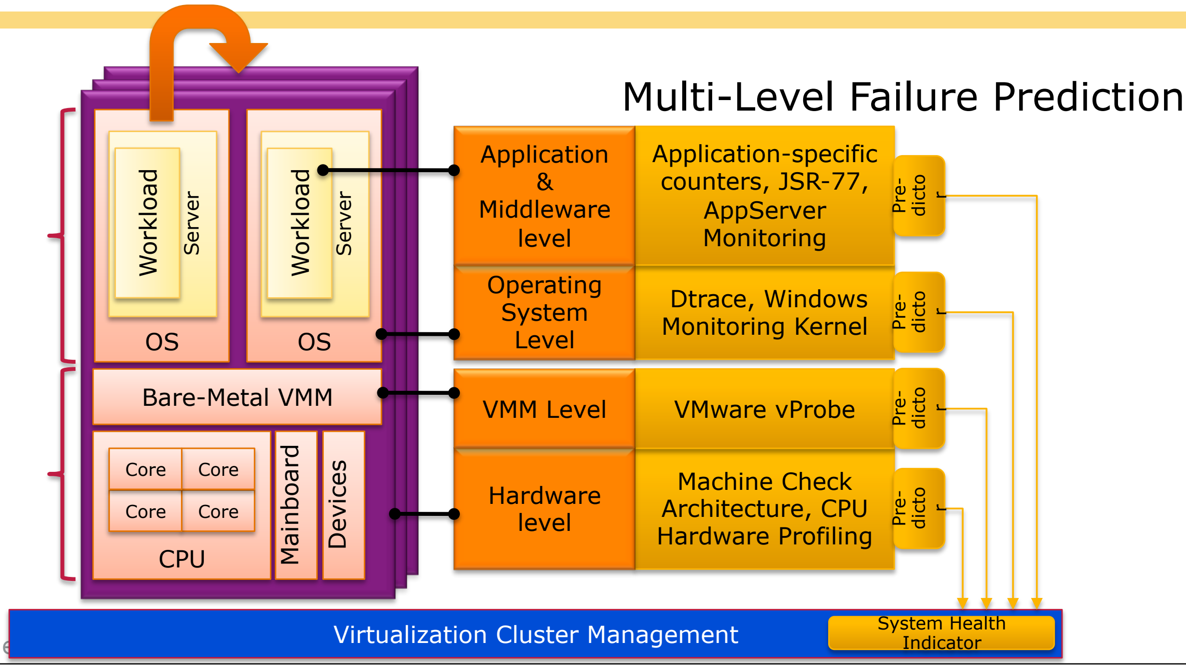
The Meta Predictor – Bringing it all together



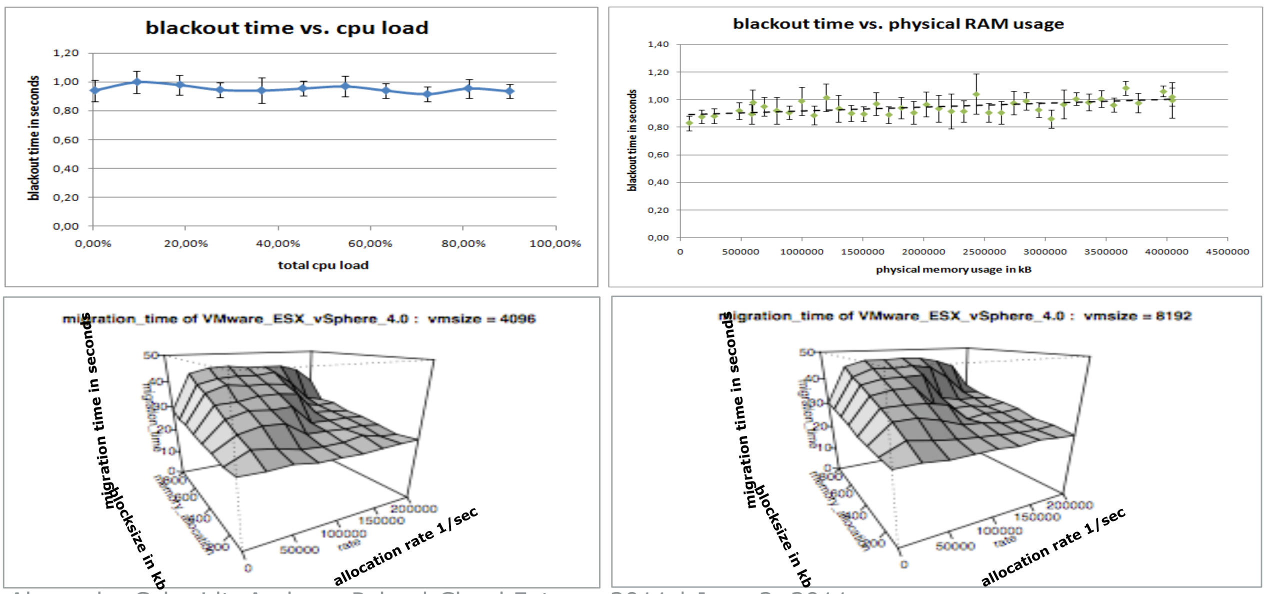
Ensemble learning:

- Boosts accuracy – which failure-prone situations can best be identified by either hardware, OS, VMM failure predictors?
- Domain knowledge – operating system vendors know their system best and can provide the most advanced predictor on OS level
- Pluggable – domain predictors provided by an application vendor can easily be integrated into our anticipatory virtualization architecture
- Ensemble-learning can combine predictions across all system levels

Our Idea: Global System Health Indicator



VM Migration – how long does it take? VMWare ESX 4



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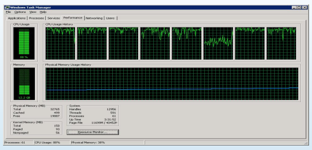
Applying it to the Cloud

- Servers have evolved – cloud will too
  - Ever growing number of CPU cores
  - Tremendous amounts of memory
- Reliability will become the most sought-after feature of future server systems
  - Higher density, integration levels in future CPUs will lead to multi-bit faults
  - Failure prediction and VM migration as promising concept
- Must have fault isolation boundaries (LPARs, blades)
- Cloud will embrace new programming and management models

Computer architecture drives changes in system software

Servers have evolved…

- New form factors
- Higher density
- Standard architectures
- Multicore/multithreaded

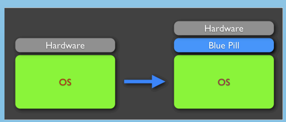


Advances in operating systems

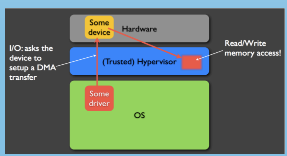
- Virtualization
- Thrustworthiness/security
- Clustering
- Need for new programming models, SW Architectures, Services

Virtualization problems

- Security: extended attack surface
- Virtualization-based malware
- Must trust hypervisor



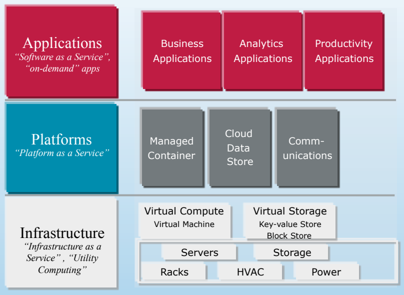
Intel VT-x, AMD Pacifica



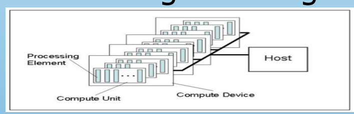
Cloud Computing – the three layers

Challenges:

- Has to abstract underlying hardware
- Be elastic in scaling to demand
- Pay per use basis



Hybrid Computing
OpenCL: New Programming Models



- One Host + one or more Compute Devices
  - Each Compute Device is composed of one or more Compute Units
  - Each Compute Unit is further divided into one or more Processing Elements