A Fine-grained Performance-based Decision Model for Virtualization Application Solution

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Outline

- Introduction
- Architecture of VirtDM
- Metrics choosing
- VirtDM modeling
  - VirtDM formulation
  - VirtDM implementation
- Case study
- Conclusion

1.Introduction

- Datacenter virtualization problem
  - Virtualization Application Solution(VAS)
  - Decision of VAS for special virtualization application scenarios

- Systematic Decision method——VirtDM
  - Virtualization performance evaluation
  - MCDM: Multi-Criteria Decision-Making
  - Human preference
  - Comparable results

Datacenter virtualization problem

- Application Virtualization
- Presentation Virtualization
- Desktop Virtualization
- Storage Virtualization
- Network Virtualization

Vmware

Xen

KVM

Hyper-V

VirtualBox

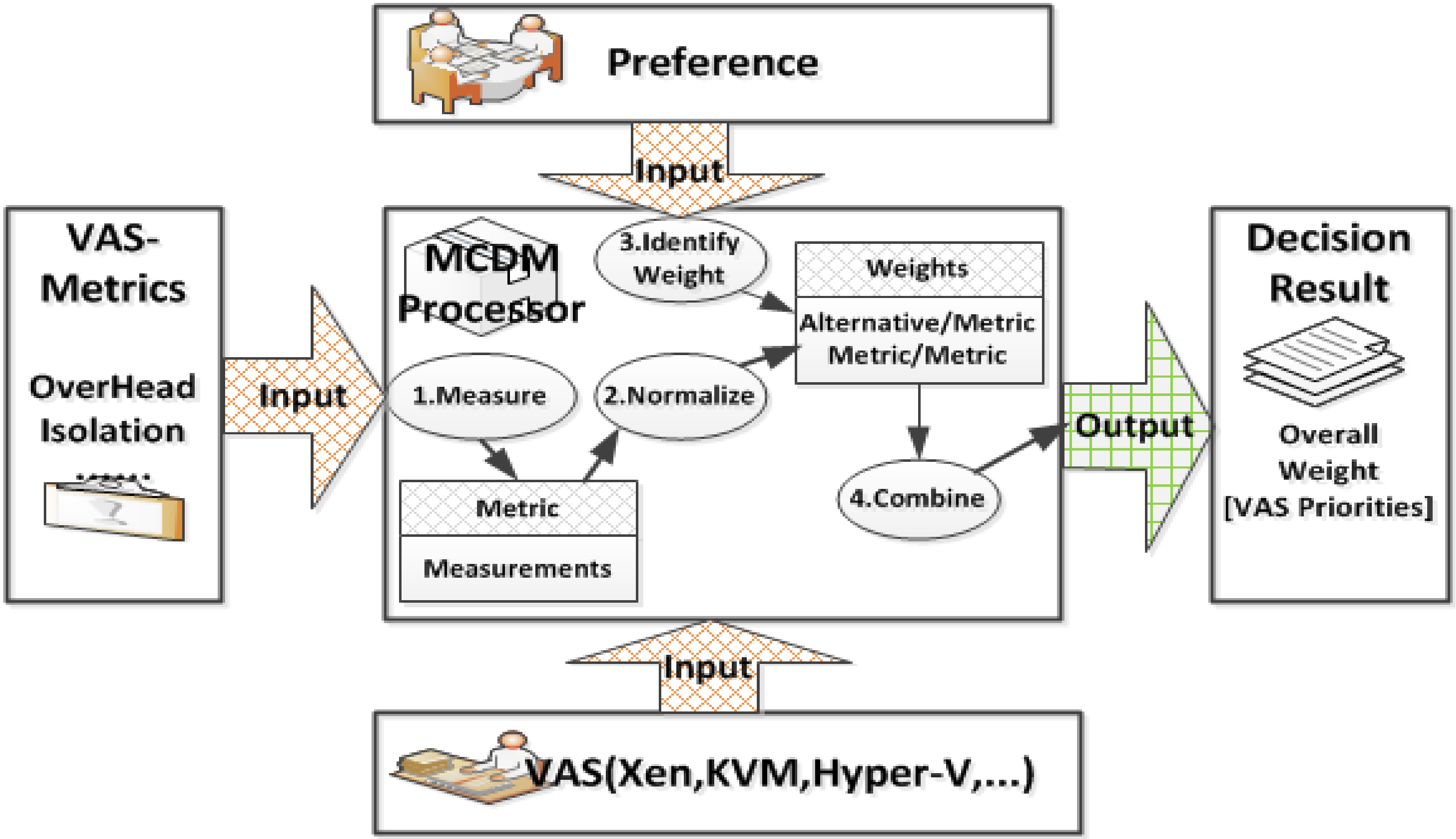
……

Problems of VirtDM

- What metrics should be taken into account to measured a VAS?

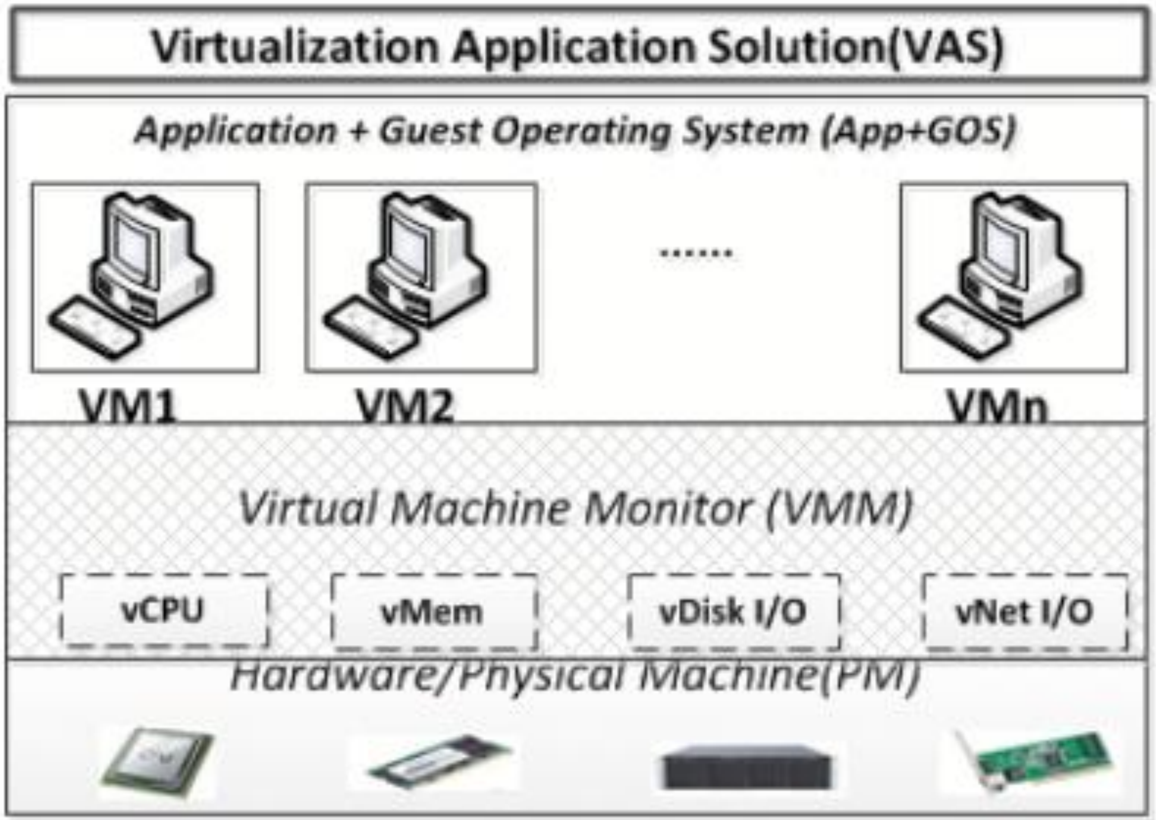
- How to quantify a datacenter architect’s preference on these metrics?
- How to achieve an overall decision from different metrics’ results and architects’ preference?

2. Architecture of VirtDM



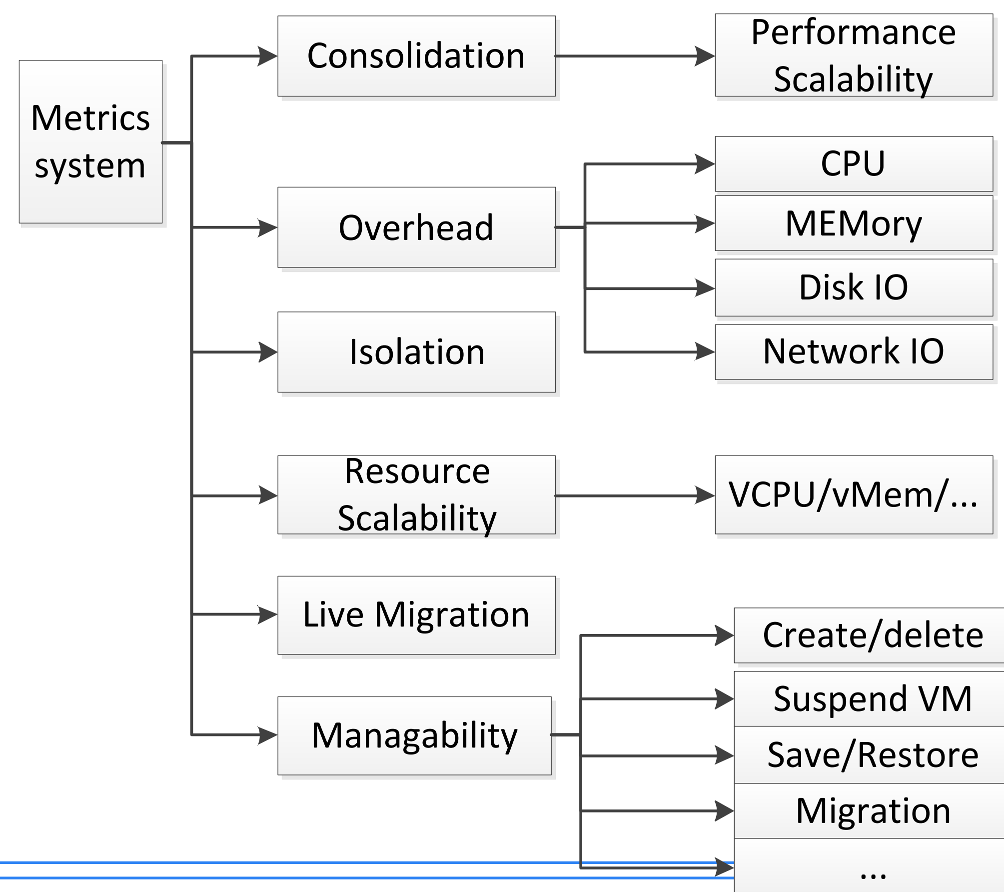
What is VAS

- Refers to a specific software and hardware implementation of virtualization technologies.
- Para-virtualization & Full virtualization
- Hardware with Intel VT or ADM SVM



3. Metrics Choosing

- Virtualization application solution
  - Virtualization Overhead
  - Manageability
  - Isolation
  - Consolidation
  - Live migration
  - ......



Virtualization Overhead

- Four workloads used to measure
  - CPU task, memory task, I/O task and Context Switch task.
- Performance degradation percentage is used to express the quantities of overhead

Manageability

- Include 5 metrics
- immeasurable metrics
  - VM resource scalability
  - Migration function
  - Consolidation functional scalability
- Measure with response time
  - VM snapshot save/resume efficiency
  - VM start/shutdown efficiency

Isolation

- run different stress tests - CPU bomb, memory bomb, I/O bomb
- cause extreme resource consumption and refer their VMs as bad VMs
- measure the performance degradation of the normal workloads on a well-behaving VM.

Consolidation

- Uneasy to measure
- A good method is to use benchmark tool: SPECvirt sc2010.
- Scales the workloads on the System Under Test (SUT) until the SUT reaches its peak performance.

Migration

- Use Virt-LM benchmark
- It provides the results of four metrics
  - downtime
  - total migration time
  - the amount of migrated data
  - migration overhead

4. VirtDM Modeling

- VirtDM Formulation
  - Is a formulation for the VAS Multi-Criteria Decision-Making problem
  - Main parts include: VAS candidates，Metrics, Decision-making Matrix
- VirtDM Implementation
  - Metrics quantification
  - Metrics normalization with dimensionless method
  - Weight identification \& pairwise comparison method
  - AHP

Hierarchical structure of VirtDM

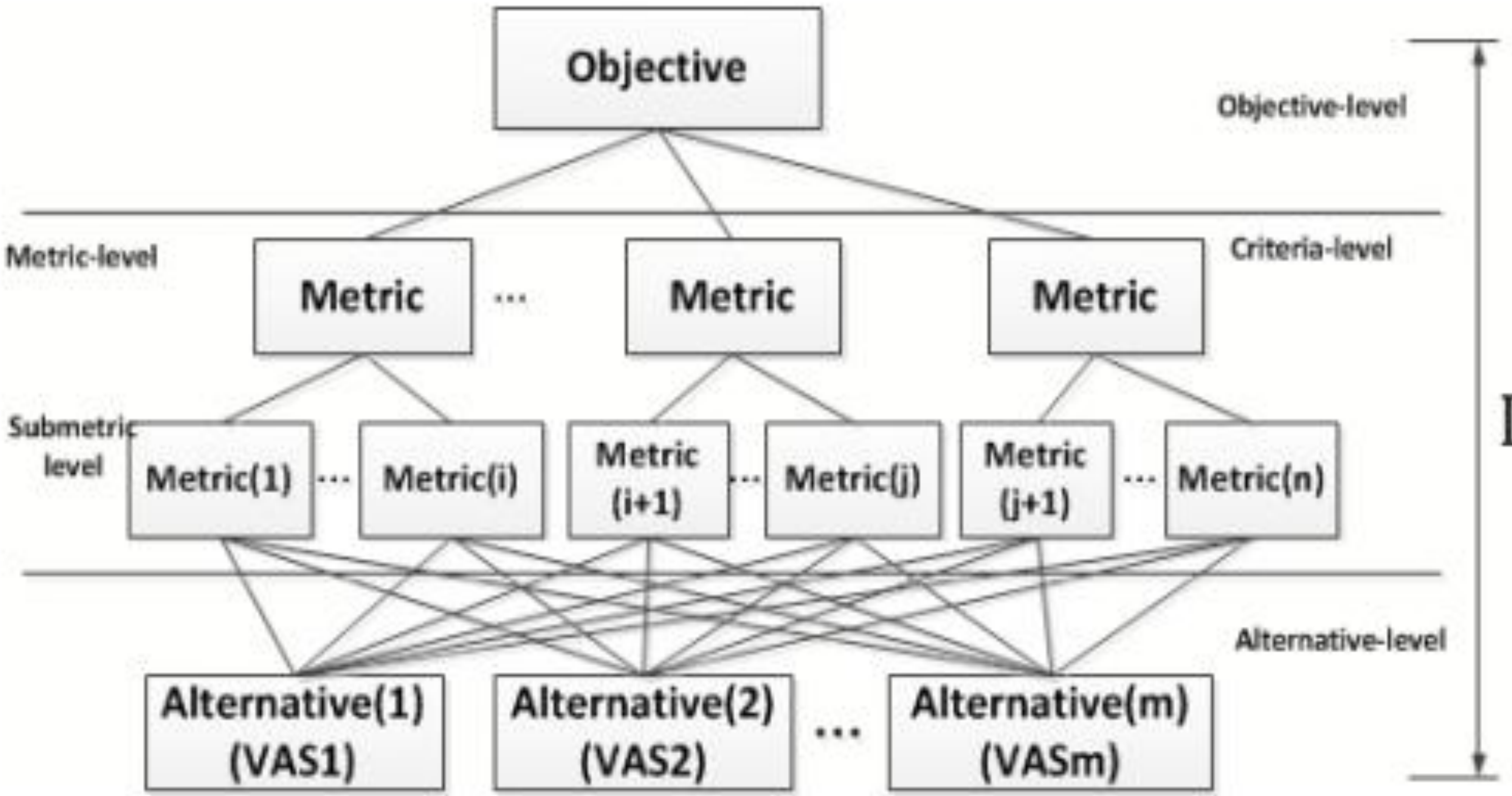


Fig. 3: The formulation of VirtDM with hierarchical structure

Problems

Problem 1. (**Generalization problem**). The MCDM problem of the VirtDM is provided with a hierarchy structure and must be decomposed into levels as shown in Fig. 3. It comprises L-levels ($L >= 3$): alternative(VAS candidate, one fixed level), criteria (one or more of metric levels, apparently equal to $L - 2$ levels) as well as objective (decision objective level, one fixed level).

Problem 2. (**Special case**). Let $L = 4$ in problem 1, then we have a new hierarchy MCDM problem with four levels. In this way, in addition to the alternative-level and objective-level, the metric-level of general problem is divided into two levels: ML(metric-level) and SML(sub-metric level) as illustrated in Fig. 3. Each metric of the metric-level can be composed of several sub-metrics of the sub-metric level.

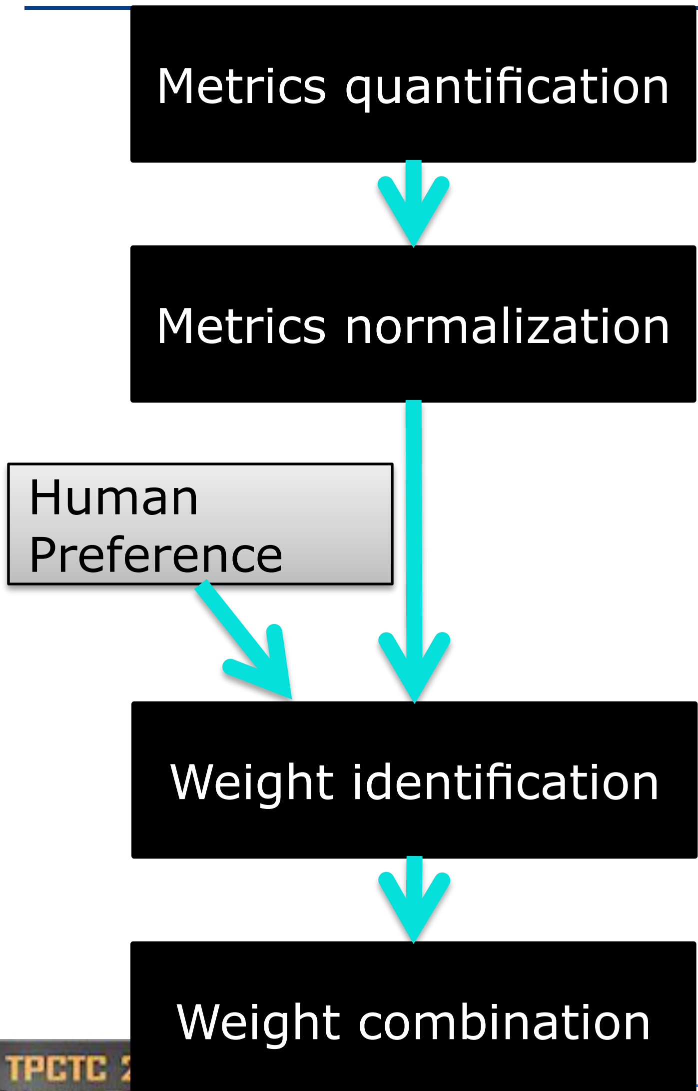
Definitions

Definition 1. *(**Size of the hierarchy structure**). Assume problem 2 contain m alternatives(VASes), n sub-metrics and s metrics in the criteria level as well as 1 objective at the top level. Two adjacent levels are directly related.*

If the i_{th} given metric of the metric-level contains n_i sub-metrics, it will satisfy the equation: $\sum_{i=1}^{s} n_i = n$.

Definition 2. *(**Decision Attribute Matrix**). For each alternative, we can obtain a numerical value, called an attribute, for each metric of sub-metrics. Then, in problem 2 we have $m \times n$ attributes which comprise the decision basis of VirtDM. To store the decision attributes, we give a matrix: $D = (d_{ij})_{m \times n}, (i = 1, ..., m, j = 1, ..., n)$, where the element d_{ij} represents the j^{th} sub-metric value of the i^{th} VAS alternative. This matrix is called Decision attribute matrix (DAM).*

VirtDM implementation



- Metrics: quantitative and qualitative
- Normalization means:
  - vector normalization
  - linear scale transformation
  - (0-1) interval conversion

$$Score(A_i) = \sum_{j=1}^{n} r_{ij} * w_j. \qquad (2)$$

$$V = R * W3 * W2 * W1 \qquad (6)$$

Algorithm 1 Algorithm WIA : weight identification of pairwise comparison method.

Require:

The amount of metrics for pairwise comparison, N;
The random index corresponding to N dimension, RI;
The pairwise comparison matrix, $P = (x_{ij})_{N\times N}$;

Ensure:

The weight vector of metrics, $W = (w_i)^T, i = 1..N$;

1: Determining and input the elements of P according to decision maker's preference by Satty's scale method [13].

2: Use geometric mean method as Formula (3): an approximate method to calculate the weight $W = (w_i)^T, i = 1..N$.

$$m_i = \prod_{j=1}^{N} x_{ij}, \qquad \overline{w_i} = \sqrt[n]{m_i}, \qquad w_i = \overline{w_i} / \sum_{i=1}^{n} \overline{w_i}. \tag{3}$$

3: Using Formula (4): an approximate method to calculate the maximum eigenvalue of P.

$$\lambda_{max} = \sum_{i=1}^{n} (\sum x_{ij} W)_i / n \cdot w_i. \tag{4}$$

4: Using Formula (5) to carry out CI and CR.

$$CI = (\lambda_{max} - n)/(n-1), \qquad CR = CI/RI. \tag{5}$$

5: If $CR < 0.5$ then goto step (6) to output the result weight vector: W; else goto step (1);

6: **return** W.

5. Case Study

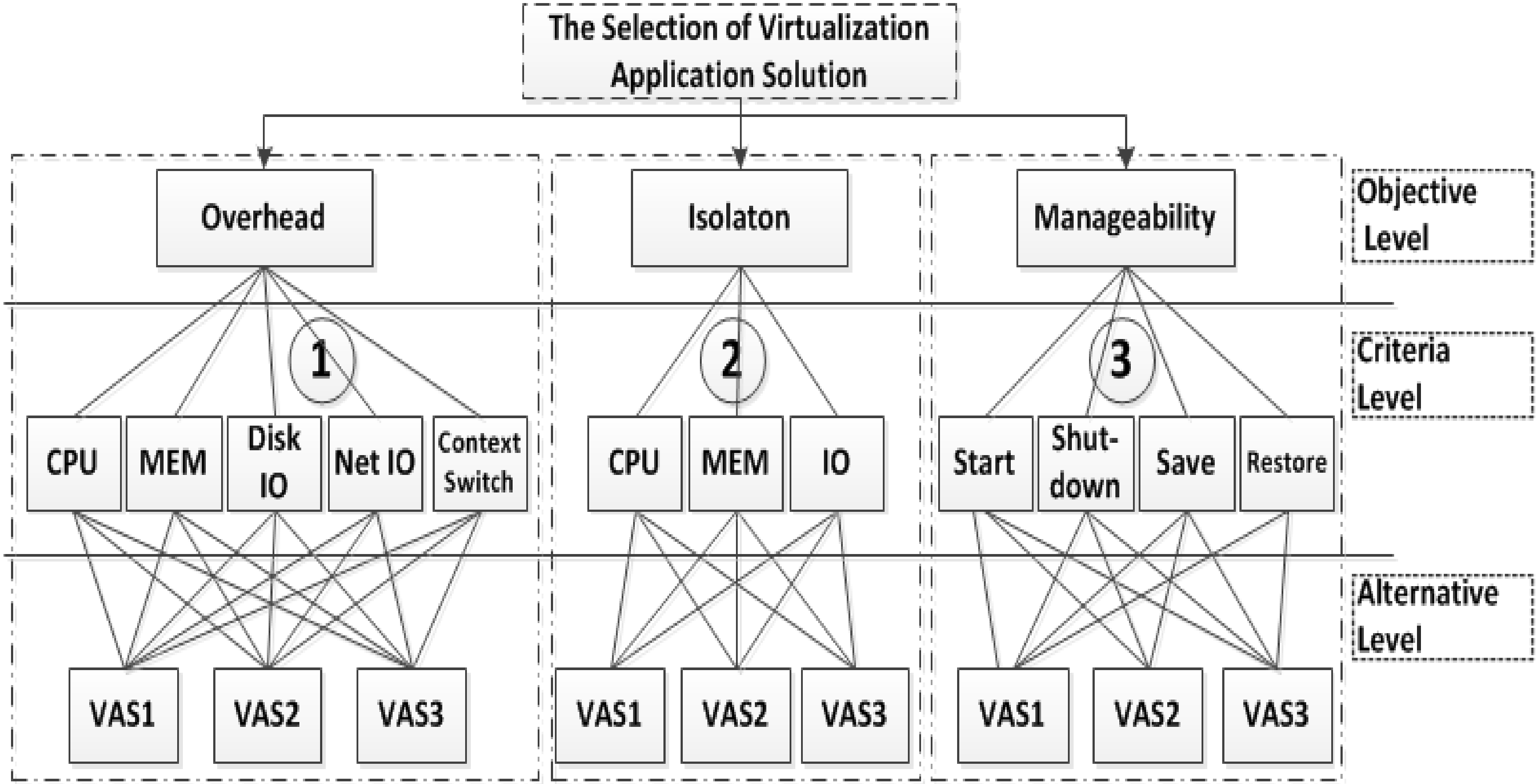
- Suppose a virtualized datacenter deployed preferring I/O performance
- Given and setup three VAS platforms environment for VirtDM implementation
- The purpose is to make decision the best VAS candidate

- Measuring the performance
- Overall decision process

Experimental Environment Setup

- 1)VAS-XEN-HV
  - Physical host is a Dell PowerEdge T710, with dual quadcore Intel Xeon processor E5620 at 2.4GHZ and 24GB of memory.
  - VMM is Xen-3.3.1 with Linux Kernel 2.6.18.8-xen
- 2)VAS-XEN-PV
  - Using the same host and VMM as VAS-XEN-HV but with a para-virtualized VM.
- 3)VAS-KVM
  - Using the same host and VM as VAS-XEN-HV but with a different VMM — KVM.

Hierarchical Metrics for decsion



Performance Measurement

Table 1: Performance measurements from three VASes: XEN-HV, XEN-PV, KVM.

	Overhead[%]					Isolation[%]			Manageability[sec]			
	CPU	Mem	Disk I/O	Net I/O	C.S.	CPU	Mem	I/O	start	shut.	save	rest.
XEN-HV	8.1	15.5	51.1	7.7	41	0.6	35.7	42.4	21	2.4	17.9	16.2
XEN-PV	11.13	4.8	7.9	4.8	98	23.8	21.8	20.1	18.5	3.5	17.2	16.9
KVM	9.13	14.5	56.3	7.0	50	0.4	33.5	55.0	20	2.5	18	16.5

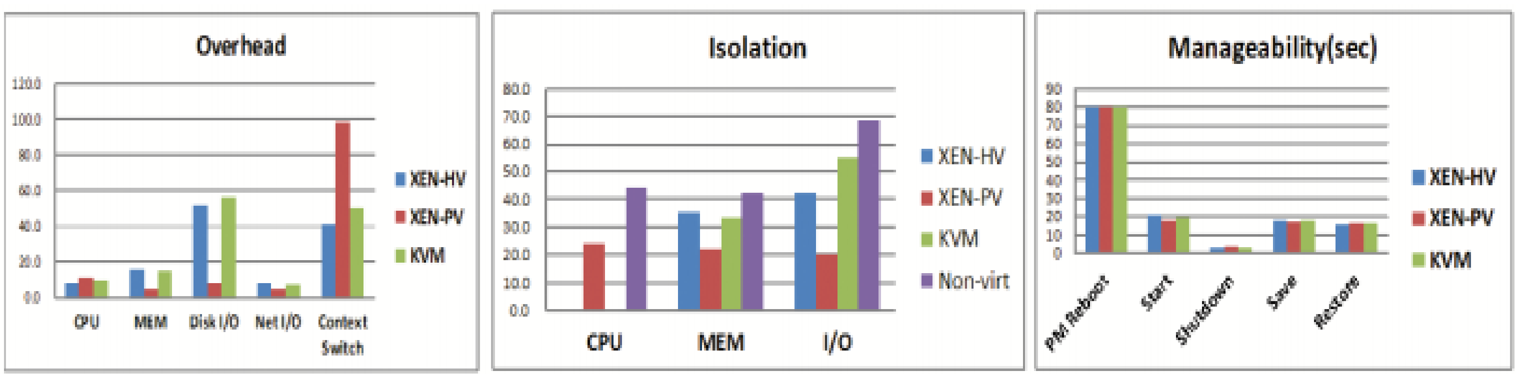


Fig. 5: The metrics results of three VASes

Overall Decision Process

Table 2: The normalized data

	Overhead[%]					Isolation[%]			Manageability[sec.]			
	CPU	Mem	DiskIO	NetIO	C.S.	CPU	Mem	IO	Start	Shut.	Save	Rest.
XEN-HV	0.38	0.18	0.12	0.27	0.31	0.38	0.19	0.26	0.28	0.30	0.28	0.31
XEN-PV	0.28	0.58	0.77	0.43	0.13	0.01	0.31	0.54	0.32	0.21	0.29	0.30
Hyper-V	0.34	0.25	0.11	0.30	0.56	0.61	0.50	0.20	0.40	0.49	0.42	0.39

- Give examples to demonstrate the usefulness of VirtDM
  - Performance data comes from measurement
  - Data is standardized and normalized
  - MCDM of VirtDM is used to get score for each VAS

Constructing the decision-making matrix

- Normalize the metrics

Table 2: The normalized data

	Overhead[%]					Isolation[%]			Manageability[sec.]			
	CPU	Mem	Disk I/O	Net I/O	C.S.	CPU	Mem	I/O	Start	Shut.	Save	Rest.
XEN-HV	0.38	0.19	0.12	0.27	0.45	0.38	0.27	0.26	0.31	0.38	0.33	0.34
XEN-PV	0.28	0.61	0.77	0.43	0.19	0.01	0.44	0.54	0.36	0.26	0.34	0.33
KVM	0.34	0.20	0.11	0.30	0.36	0.61	0.29	0.20	0.33	0.36	0.33	0.33

- Construct decision-making matrix

$$O = \begin{bmatrix} 0.38 & 0.19 & 0.12 & 0.27 & 0.45 \\ 0.28 & 0.61 & 0.77 & 0.43 & 0.19 \\ 0.34 & 0.20 & 0.11 & 0.30 & 0.36 \end{bmatrix}, I = \begin{bmatrix} 0.38 & 0.27 & 0.26 \\ 0.01 & 0.44 & 0.54 \\ 0.61 & 0.29 & 0.20 \end{bmatrix}, M = \begin{bmatrix} 0.31 & 0.38 & 0.33 & 0.34 \\ 0.36 & 0.26 & 0.34 & 0.33 \\ 0.33 & 0.36 & 0.33 & 0.33 \end{bmatrix}$$

Identifying weights based on preference

- AHP method is applied
  Pairwise comparison matrix

$$PO = \begin{array}{c} \\ CPU \\ Mem \\ DiskI/O \\ NetI/O \\ Cont.S \end{array} \begin{array}{c} \begin{array}{ccccc} CPU & Mem & DiskI/O & NetI/O & Cont.S \end{array} \\ \begin{bmatrix} 1 & 1 & 0.111 & 0.14 & 0.333 \\ 1 & 1 & 0.143 & 0.125 & 0.2 \\ 9 & 7 & 1 & 0.5 & 2 \\ 7 & 8 & 2 & 1 & 3 \\ 3 & 5 & 0.5 & 0.333 & 1 \end{bmatrix} \end{array}, PI = \begin{array}{c} \\ CPU \\ Mem \\ I/O \end{array} \begin{array}{c} \begin{array}{ccc} CPU & Mem & I/O \end{array} \\ \begin{bmatrix} 1 & 3 & 5 \\ 0.33 & 1 & 3 \\ 0.2 & 0.33 & 1 \end{bmatrix} \end{array},$$

$$PM = \begin{array}{c} \\ start \\ shut. \\ save \\ res. \end{array} \begin{array}{c} \begin{array}{cccc} start & shut. & save & res. \end{array} \\ \begin{bmatrix} 1 & 1 & 0.17 & 0.17 \\ 1 & 1 & 0.2 & 0.2 \\ 6 & 5 & 1 & 1 \\ 6 & 5 & 1 & 1 \end{bmatrix} \end{array}, PP = \begin{array}{c} PCM1 \\ ove. \\ iso. \\ man. \end{array} \begin{array}{c} \begin{array}{ccc} ove. & iso. & man. \end{array} \\ \begin{bmatrix} 1 & 3 & 9 \\ 0.33 & 1 & 4 \\ 0.11 & 0.25 & 1 \end{bmatrix} \end{array}$$

Combining weights

$$(1) W_1 = O \cdot Wo = \begin{bmatrix} 0.38 & 0.19 & 0.12 & 0.27 & 0.45 \\ 0.28 & 0.61 & 0.77 & 0.43 & 0.19 \\ 0.34 & 0.20 & 0.11 & 0.30 & 0.30 \end{bmatrix} \cdot \begin{bmatrix} 0.048 \\ 0.044 \\ 0.311 \\ 0.435 \\ 0.163 \end{bmatrix} = (0.254, 0.499, 0.248)^T$$

$$(2) W_2 = I \cdot Wi = \begin{bmatrix} 0.38 & 0.27 & 0.26 \\ 0.01 & 0.44 & 0.54 \\ 0.61 & 0.29 & 0.20 \end{bmatrix} \cdot \begin{bmatrix} 0.634 \\ 0.260 \\ 0.106 \end{bmatrix} = (0.338, 0.178, 0.484)^T,$$

$$(3) W_3 = M \cdot Wm = \begin{bmatrix} 0.31 & 0.38 & 0.33 & 0.34 \\ 0.36 & 0.26 & 0.34 & 0.33 \\ 0.33 & 0.36 & 0.33 & 0.33 \end{bmatrix} \cdot \begin{bmatrix} 0.075 \\ 0.081 \\ 0.422 \\ 0.422 \end{bmatrix} = (0.337, 0.330, 0.333)^T.$$

$$V = (W_1, W_2, W_3) \cdot Wp = \begin{bmatrix} 0.254 & 0.499 & 0.248 \\ 0.338 & 0.178 & 0.484 \\ 0.337 & 0.330 & 0.0.333 \end{bmatrix} \cdot \begin{bmatrix} 0.681 \\ 0.250 \\ 0.069 \end{bmatrix} = (0.281, 0.407, 0.313)^T.$$

7. CONCLUSIONS AND FUTURE WORK

- Design and implement the VirtDM model to serve the VAS decision making in a datacenter
- Provide a fine-grained, in-depth, and human friendly metrics system to cover essential performance characteristics of a VAS
- Many aspects of VirtDM are far from satisfying:
  - metrics system are to be improved
  - other MCDM methods excludes AHP method

Thank You!