# On Maximum Elastic Scheduling of Virtual Machines for Cloud-based Data Center Networks

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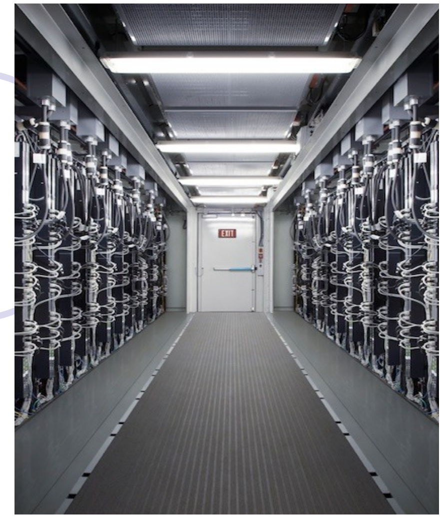
# Outline

1. Background
2. Model and Formulation
3. Simple and Optimal Solutions
4. Properties
5. Simulation Comparisons
6. Conclusions

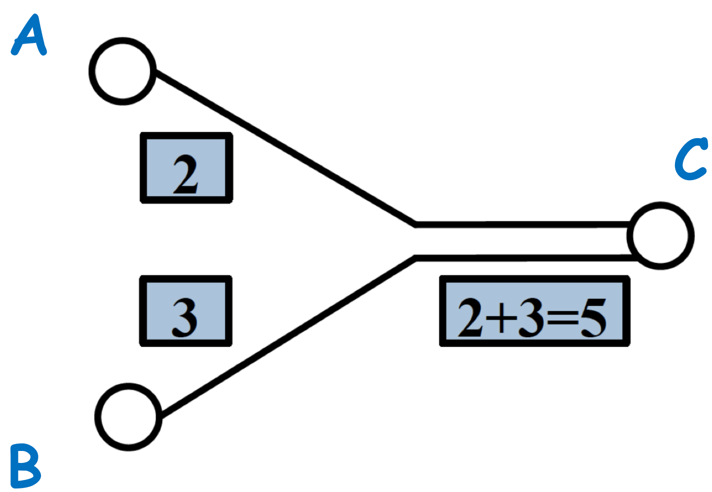
# 1. Background



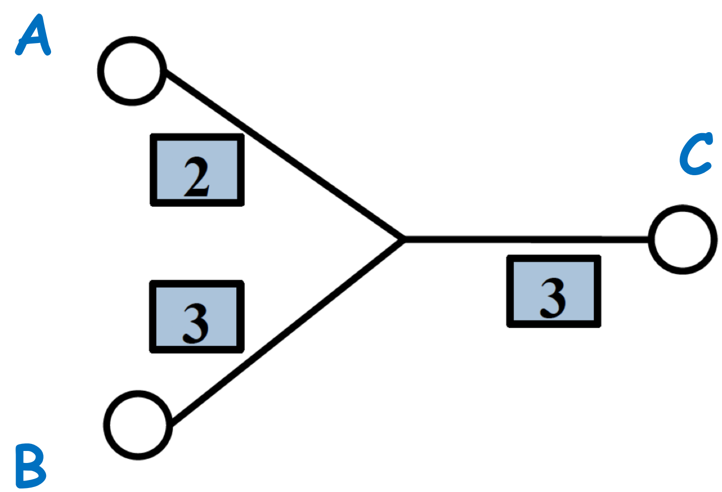
- **Cloud Data Center Networks (DCNs)**
  - Supporting cloud-based applications for large enterprises
- **Virtual Machine Placement**
  - Solving the resource utilization problem in a cloud DCN
- **Motivation**
  - Allocating physical machines (PMs) to virtual machines (VMs)
  - Meeting computation and communication demands
  - Avoiding load redistribution during a run time

# Hose Model

Each hose has aggregated performance guarantees instead of pairwise performance guarantees[1].




pairwise




hose

[1]. Duffield, Nick G., et al. "A flexible model for resource management in virtual private networks." ACM SIGCOMM Computer Communication Review. Vol. 29. No. 4. ACM, 1999.

# 2. Model and Formulation

## Problem

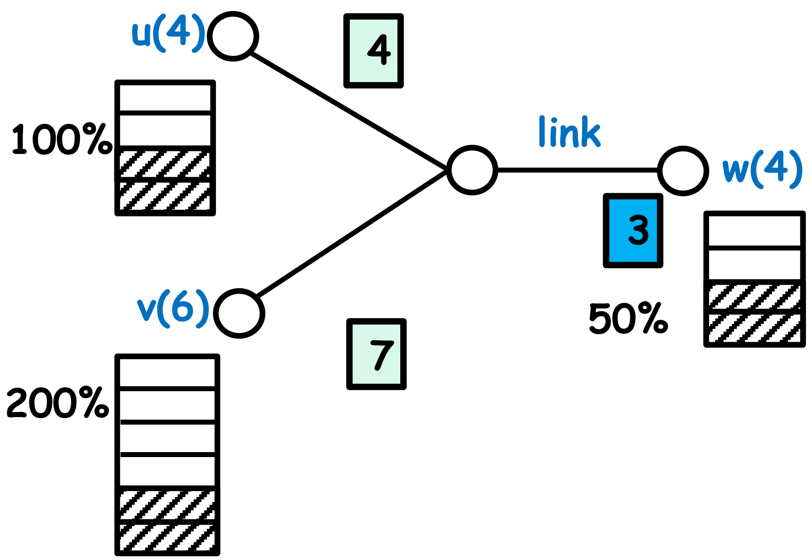
- Provisioning the maximum admissible load (MAL) of VMs in PMs with tree-structured DCNs using the hose model.

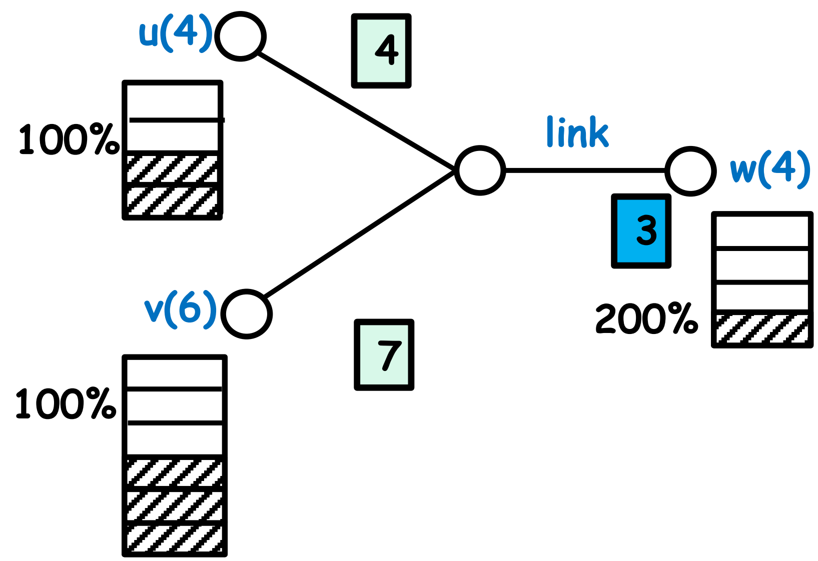
## Maximum Elastic Scheduling

- A task assignment scheme that supports maximum uniform growth in both computation and communication without resorting to task reassignment.

# Hose-based Elastic Scheduling

**Schedule 6 VMs**



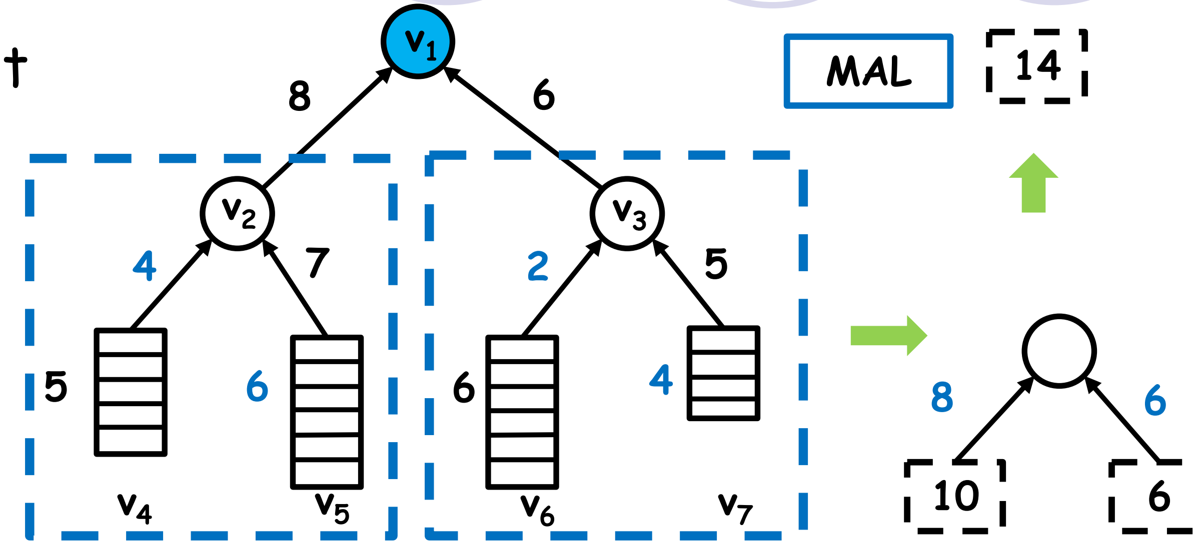




overall: 50% < overall: 100%

# 3. A Simple Up-Down Solution

**Up:** 3-node block as a unit

$min\{N_l, L_l\}$

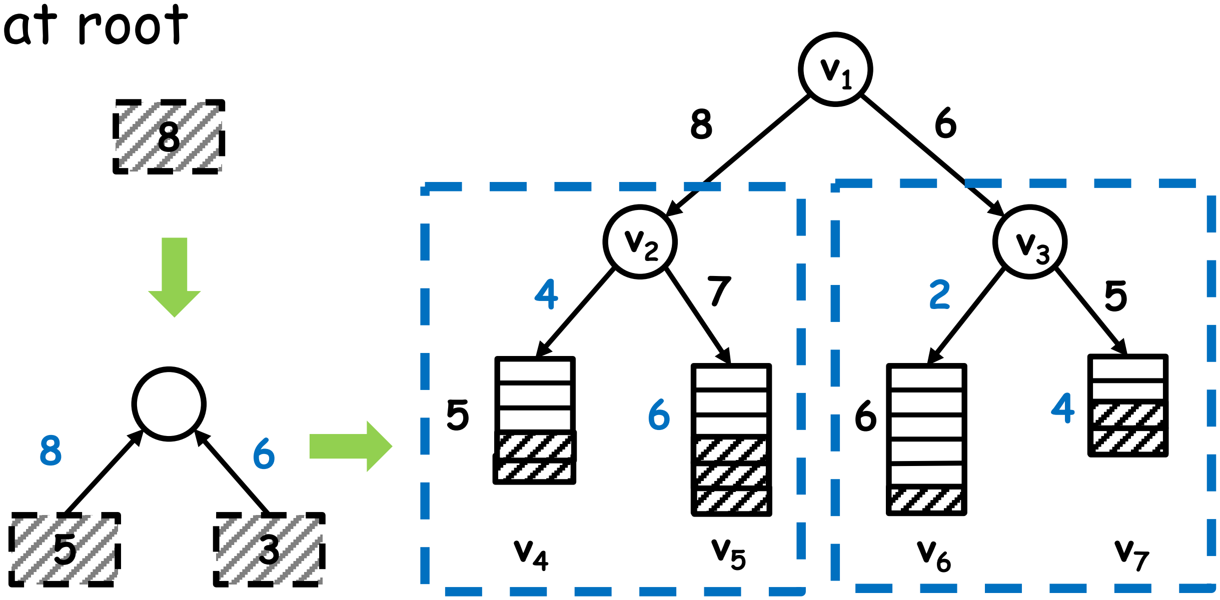



**Down:** Given a load < MAL at root

Left $min\{N_l, L_l\}/N$

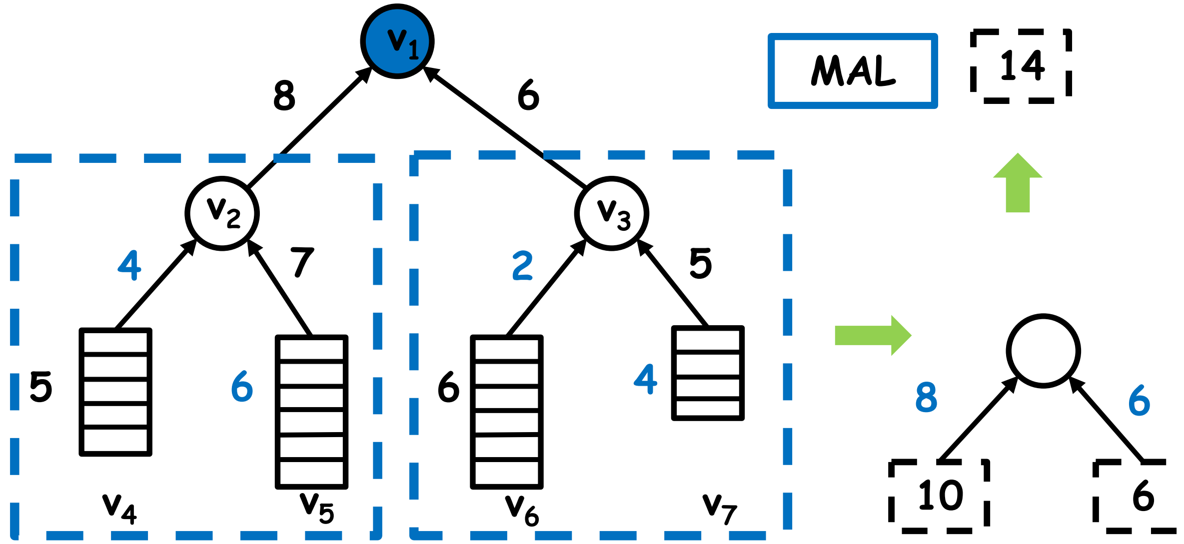
Right $min\{N_r, L_r\}/N$

The simple solution uses n steps, where n is the number of leaf nodes.



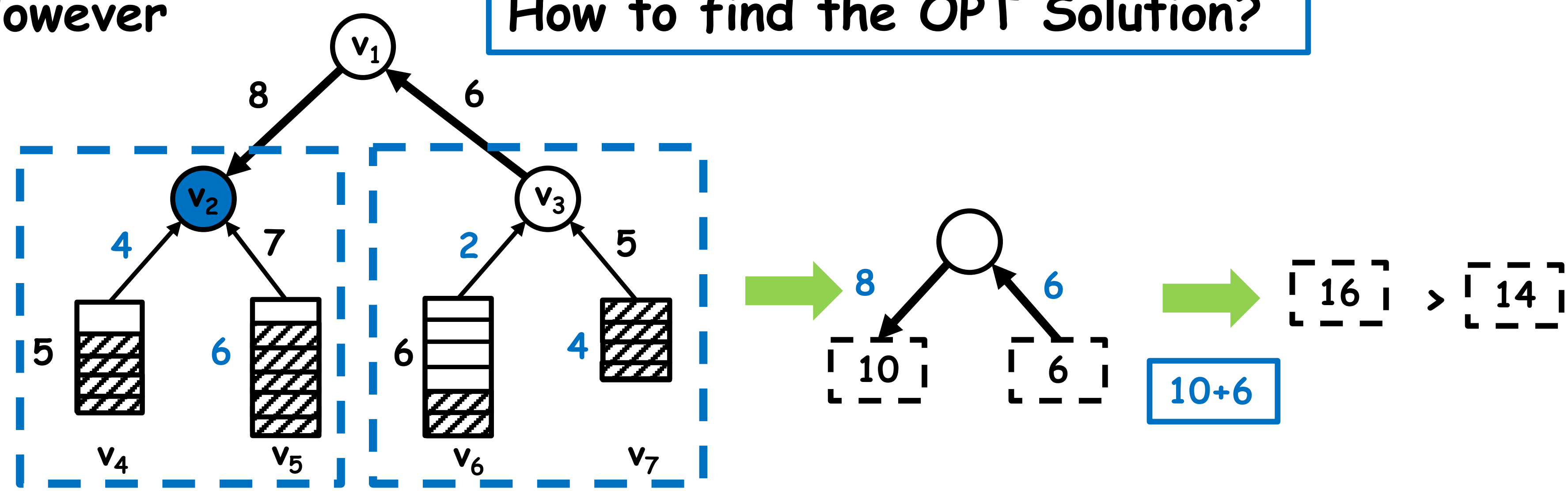
# Why Simple Solution may Fail?

**A Simple Solution**




**However**

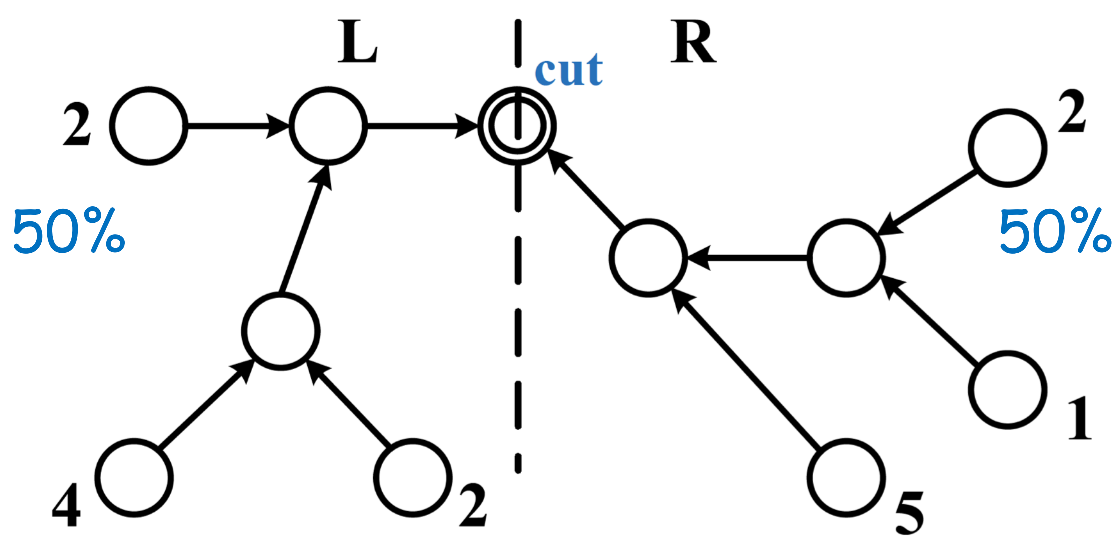
How to find the OPT Solution?



# How to Calculate?

Hose-model-based orientation

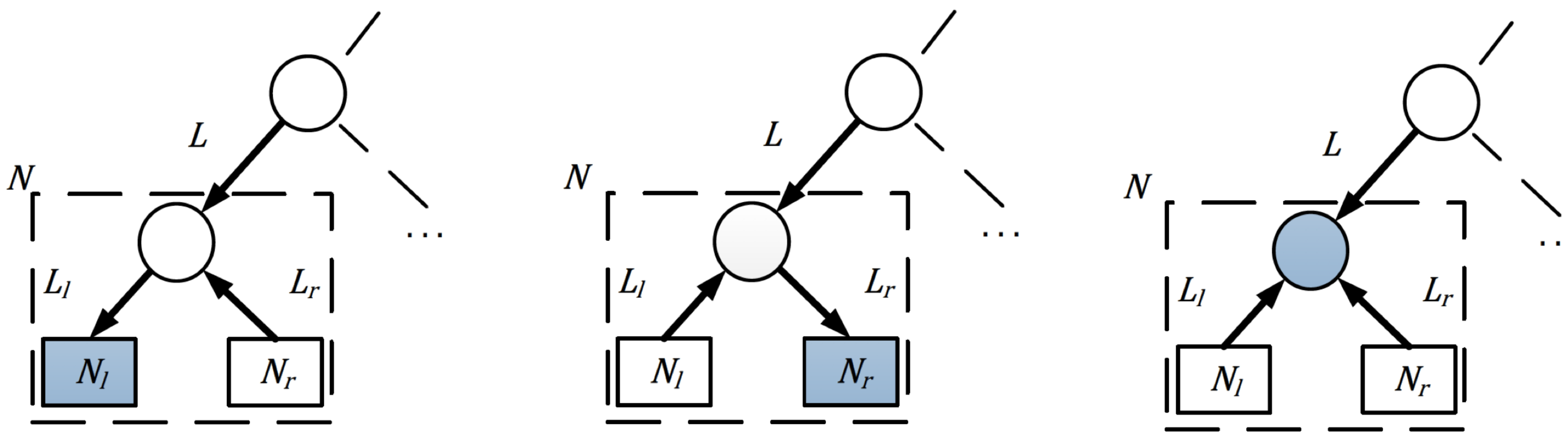
- Link orientation is important
- min{L,R} where L + R is a constant



# An Optimal Distributed Solution

Insights

- Apply the simple solution to different orientations
- Select the best orientation



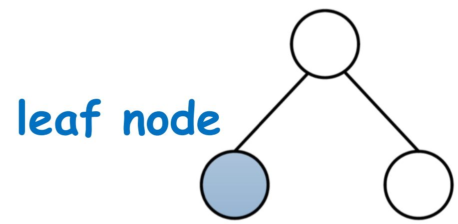

(a) MAL at the **left leaf node**

(b) MAL at the **right leaf node**

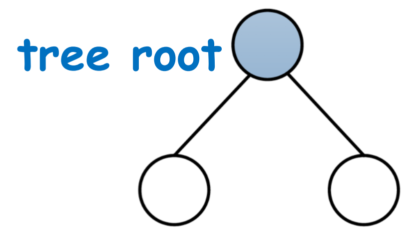
(c) MAL at the **center node**

# Optimal Solution: Details

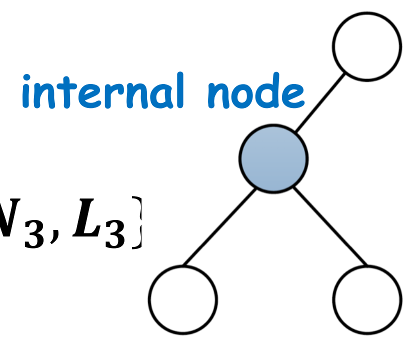
- **Step 1 (leaf node)**
  - Send its load to the connected internal node
  - Calculate its MAL: $\boldsymbol{min\{N,\infty\}+min\{N_1,L_1\}}$




- **Step 2 (internal node with two branches)**
  - Send virtual load $\boldsymbol{min\{N_i,L_i\}}$ to the other branch
  - Calculate its MAL: $\boldsymbol{min\{N_1,L_1\}+min\{N_2,L_2\}}$

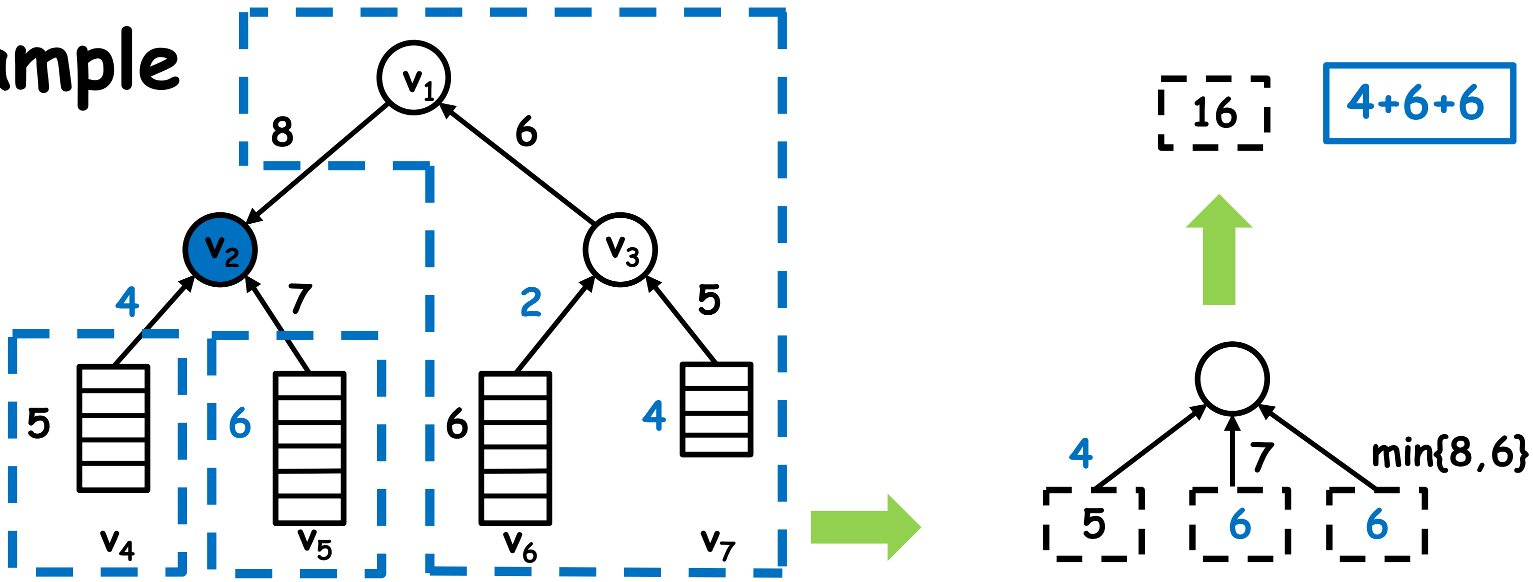



- **Step 3 (internal node with three branches)**
  - Send $\boldsymbol{min\{N_i,L_i\}+min\{N_j,L_j\}}$ to the third branch
  - Calculate its MAL: $\boldsymbol{min\{N_1,L_1\}+min\{N_2,L_2\}+min\{N_3,L_3\}}$



# Optimal Solution: Example

## An example




| | $v_1$ | $v_2$ | $v_3$ | $v_4$ | $v_5$ | $v_6$ | $v_7$ |
|---|---|---|---|---|---|---|---|
| Step 1 | - | - | - | **send** 5 **to** $v_2$ | **send** 6 **to** $v_2$ | **send** 6 **to** $v_3$ | **send** 4 **to** $v_3$ |
| Step 2 | - | **send** $\min\{5,4\}+\min\{6,7\}=10$ **to** $v_1$ | **send** $\min\{6,2\}+\min\{4,5\}=6$ **to** $v_1$ | - | - | - | - |
| Step 3 | **send** $\min\{6,6\}=6$ **to** $v_2$ **send** $\min\{10,8\}=8$ **to** $v_3$ | - | - | - | - | - | - |
| Step 4 | | **send** $\min\{6,8\}+\min\{6,7\}=12$ **to** $v_4$ **send** $\min\{6,8\}+\min\{5,4\}=10$ **to** $v_5$ | **send** $\min\{8,6\}+\min\{4,5\}=10$ **to** $v_6$ **send** $\min\{8,6\}+\min\{6,2\}=8$ **to** $v_7$ | - | - | - | - |
| MAL | $\min\{10,8\}+\min\{6,6\}=14$ | $\min\{5,4\}+\min\{6,7\}+\min\{8,6\}=$**16** | $\min\{6,2\}+\min\{4,5\}+\min\{8,6\}=12$ | $\min\{12,4\}+\min\{5,\infty\}=9$ | $\min\{10,7\}+\min\{6,\infty\}=13$ | $\min\{10,2\}+\min\{6,\infty\}=8$ | $\min\{8,5\}+\min\{4,\infty\}=9$ |

# 4. Properties

**Theorem 1:** The optimal solution determines the MAL.

**Theorem 2:** Hierarchical load distribution generates a schedule with maximum elasticity.

**Theorem 3:** The optimal solution uses $2\log n+1$ steps. The computation complexity is $5(n-1)$, and the communication complexity is $4(n-1)$ .

**Theorem 4:** Simple solution is optimal for a fat-tree.

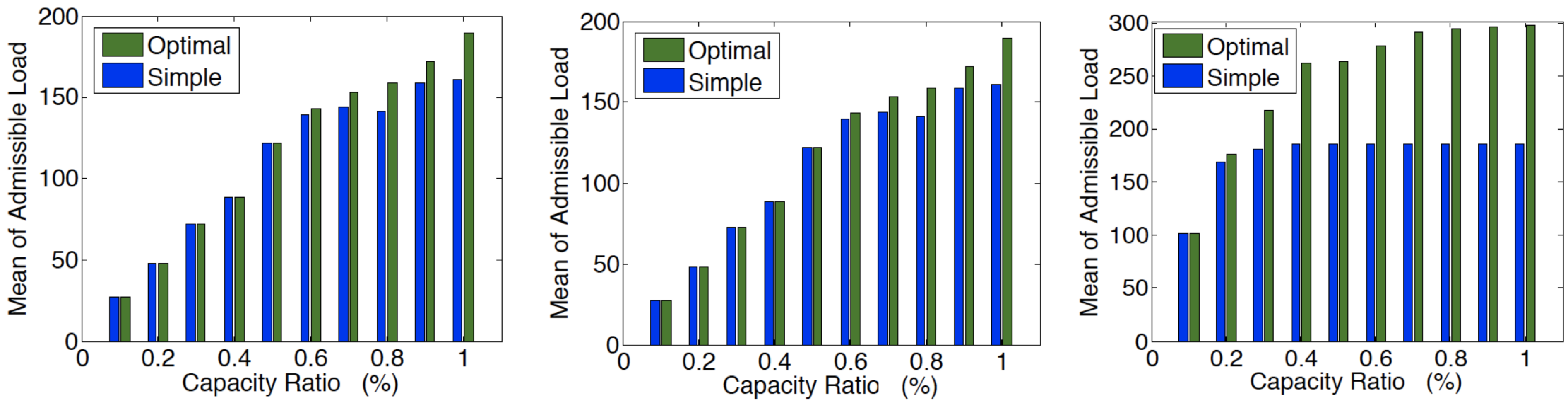
# 5. Simulation Comparisons

- Basic Setting
  - A strict binary tree with levels k = 4 , 5 , and 6
  - Heterogeneous node space from 0 to 100 units
  - Bandwidth demand per-pair of VMs is 1 Gbps
- Three Comparison algorithms
  - Equally Distributed Placement (EDP)
  - Proportion with PM Capacities (PPMC)
  - Proportion with Physical Link (PL) Capacities (PPLC)
  - Proportion with Physical Combinational Capacities (PPCC)

# Experiments

Comparison of the elasticities

- simple and optimal solutions

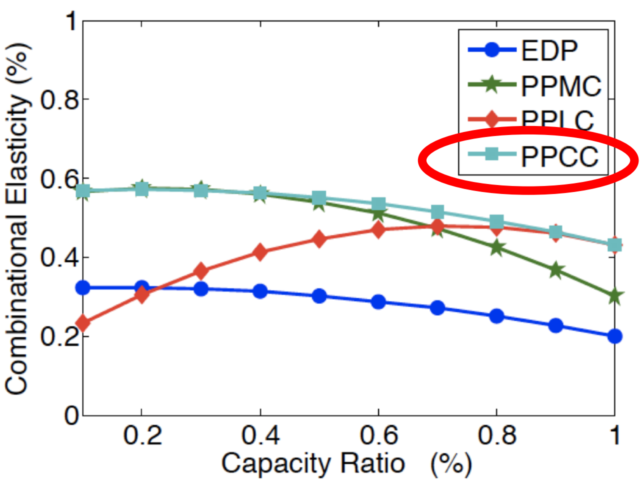



(a) k = 4 (b) k = 5 (c) k = 6

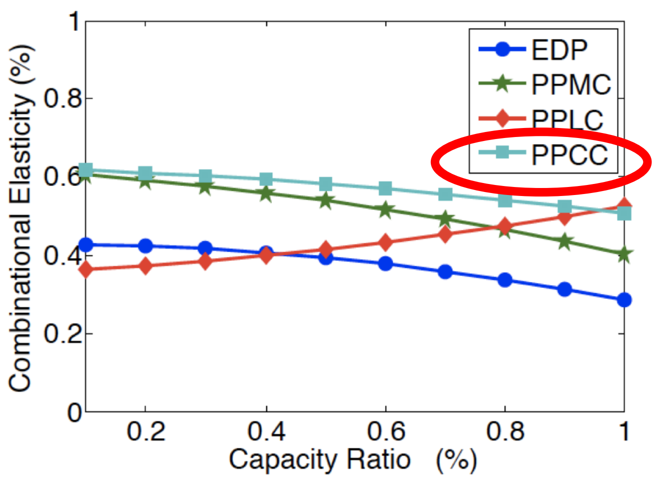
# Experiments (cont'd)

## Comparison of the elasticities

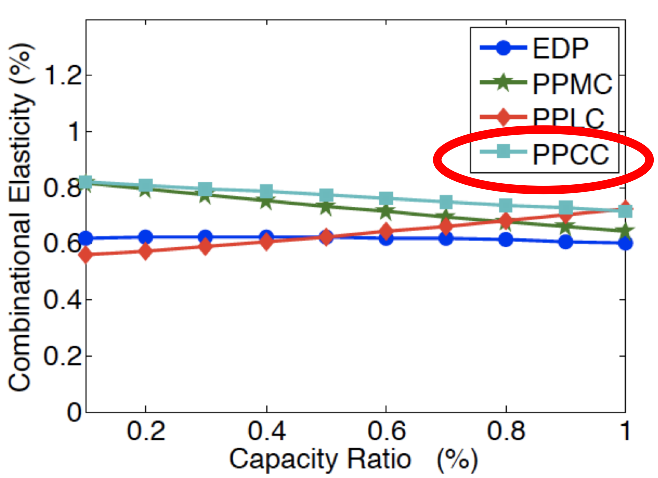
- Three comparison algorithms and PPCC




(a) k = 4




(b) k = 5




(c) k = 6

# 6. Conclusions

- Objective of maximum communication elasticity
  - Hose model
- Maximum elastic scheduling (distributed, optimal solution)
  - Maximum admissible load (MAL)
  - Maximum elastic scheduling of admissible load
- Experiments
  - Efficiency and effectiveness

# Q&A

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