Joint Optimization of Server and Network Resource Utilization in Cloud Data Centers

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Outline

- Backgrounds
- Problem
- Solutions
- Evaluation

Backgrounds

- Virtual machine placement
  - A key component of cloud resource management.
  - Improve resource utilization, reduce operational costs.

- Challenges
  - Jointly optimize the server and network resource utilization.
  - Design fast & performance-guaranteed algorithms.

- Our focus
  - Design efficient algorithms to maximize the overall resource utilization in multiple dimensions without violating resource capacity constraints.

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Abstracting the problem

- Problem
  - Given a set of VMs, how to pack VMs into servers such that overall resource utilization is maximized while no constraints on resources are violated.
- Definition of size
  - The size of a VM is the product of the resource demands on all its resource dimensions.
  - Portray the level of load along multiple dimensions in a unified manner.
- Solving the problem is NP-hard.

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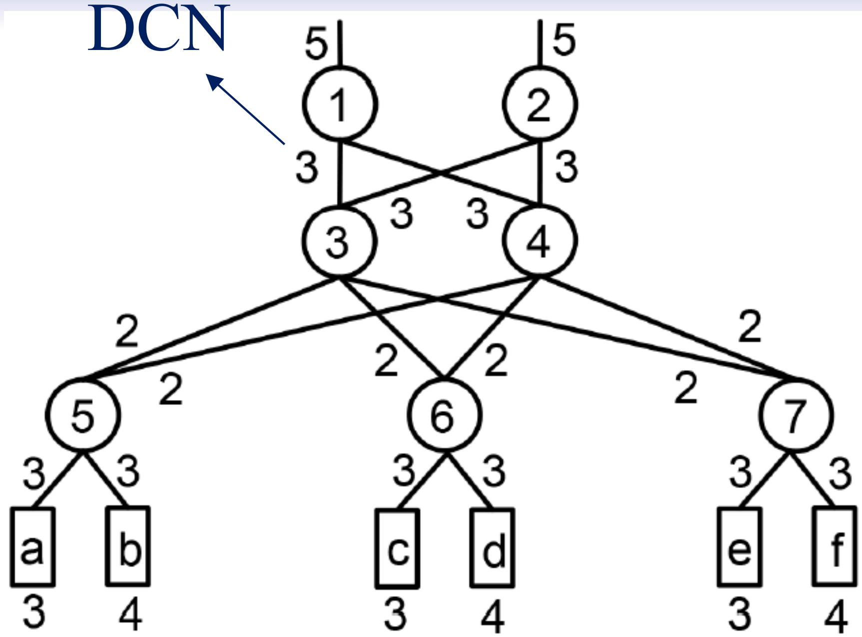
Analysis

- Main difficulty
  - Networks are oversubscribed.
  - Bandwidth is shared among servers.
  - Server & network.

- Total resource capacity
  - The sum of the possible size of all its servers.
  - An upper bound.

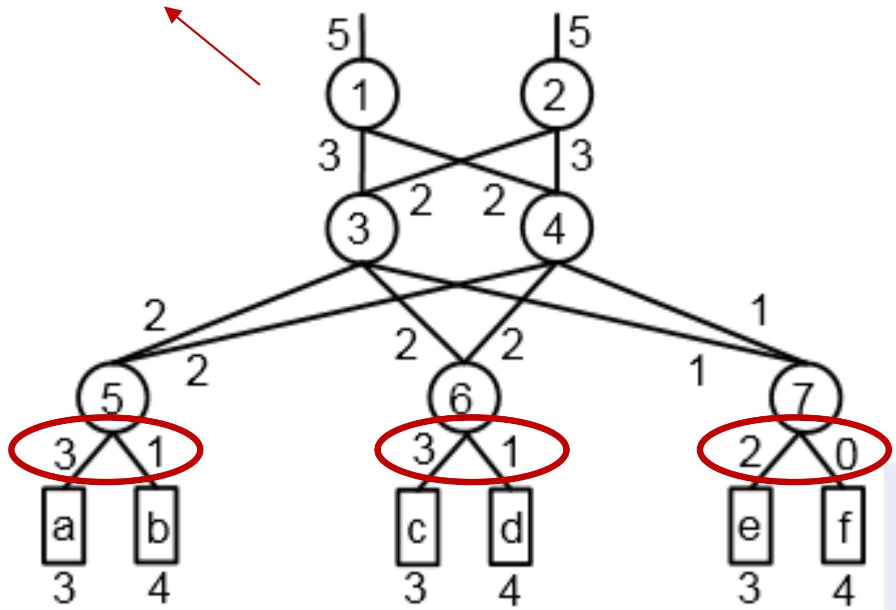
Motivation solutions

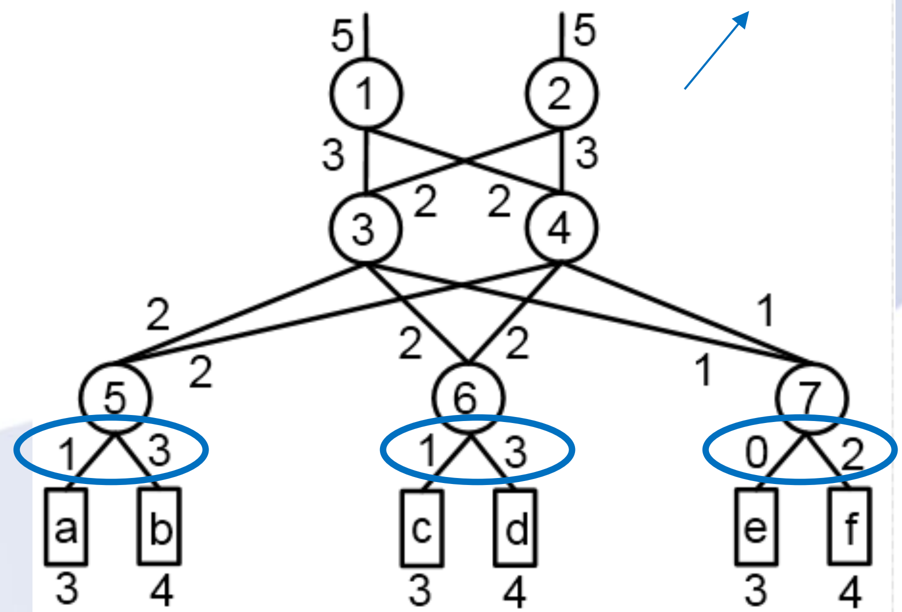
DCN



Solution 1:
(3*3+4*1)*2
+3*2=32

Solution 2:
(3*1+4*3)*2
+4*2=38





Analysis

- Observation
  - An efficient solution will allocate the server that has a larger CPU capacity with a larger bandwidth capacity.

- A two-staged solution
  - Bandwidth allocation using min-cost max-flow algorithm.
  - Two-dimensional item packing.

Solutions

- Offline scenario
  - For m identical servers, and an accommodating input, there exists an offline algorithm that achieves ¼ approximation in linear time.
  - For an accommodating input, there exists an offline algorithm that achieves 1/4r approximation in linear time.

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Solutions

- Online scenario
  - SortFirstFit: always places the arriving VM into the server with maximum CPU capacity which has enough residual CPU capacity and bandwidth
  - SortWorstFit: always places the arriving VM into the server with maximum residual size.
  - The maximum possible bandwidth in both algorithms are computed by solving a min-cost max-flow problem.

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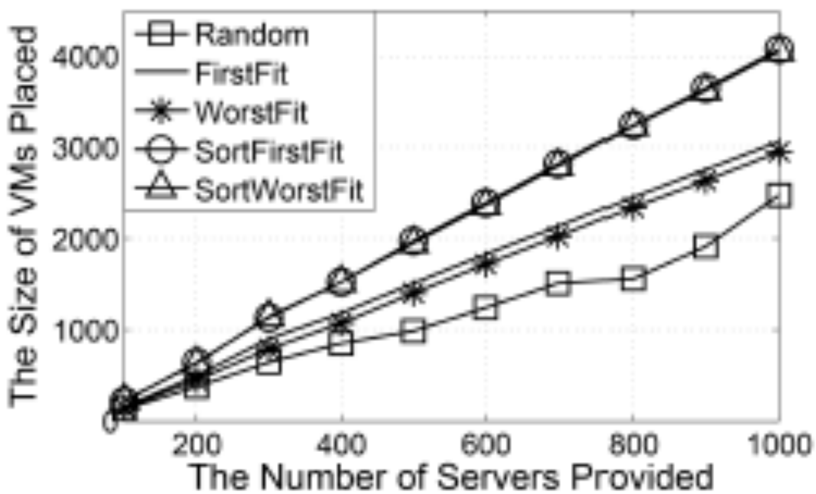
The evaluation setting

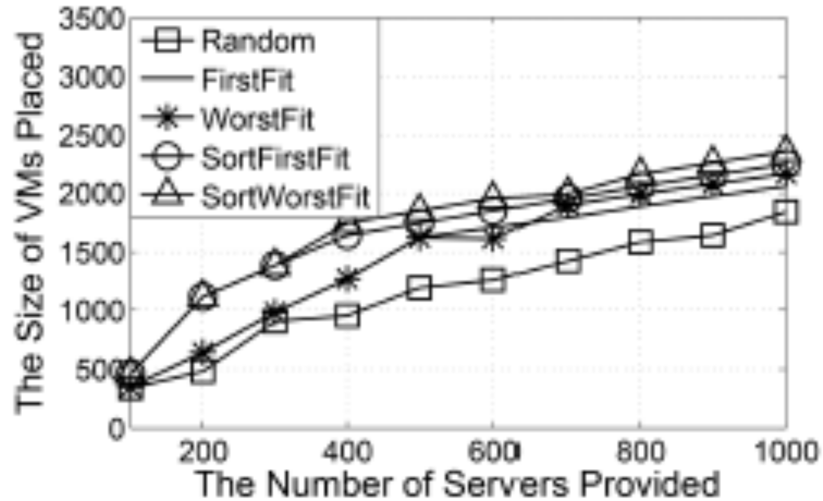
- Benchmarks
  - FirstFit (as less server as possible)
  - WorstFit (as balance as possible)
  - Random

- Metric
  - The size of VMs placed.

The impact of arriving VM sequence



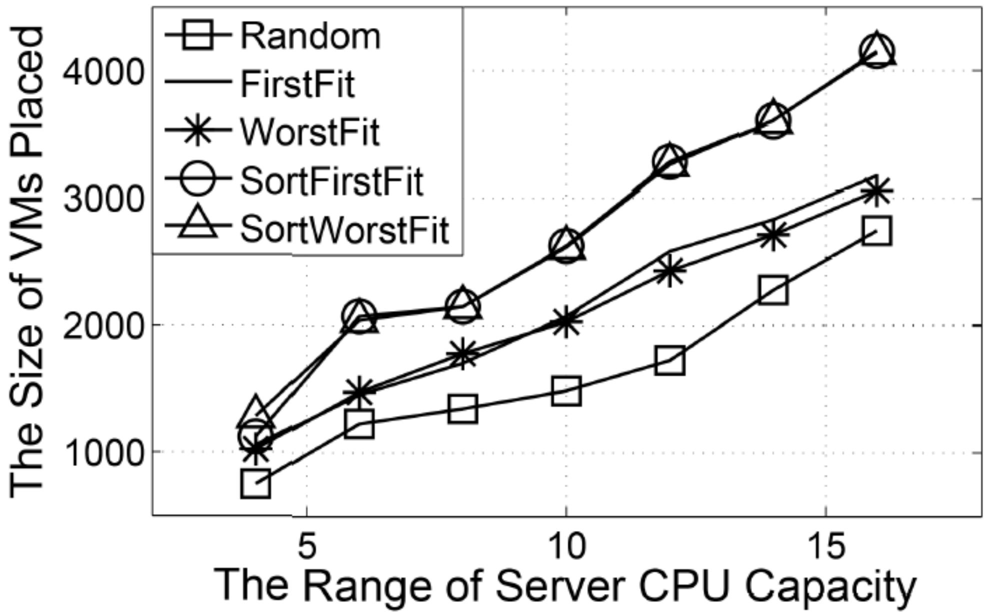
(a)



(b)

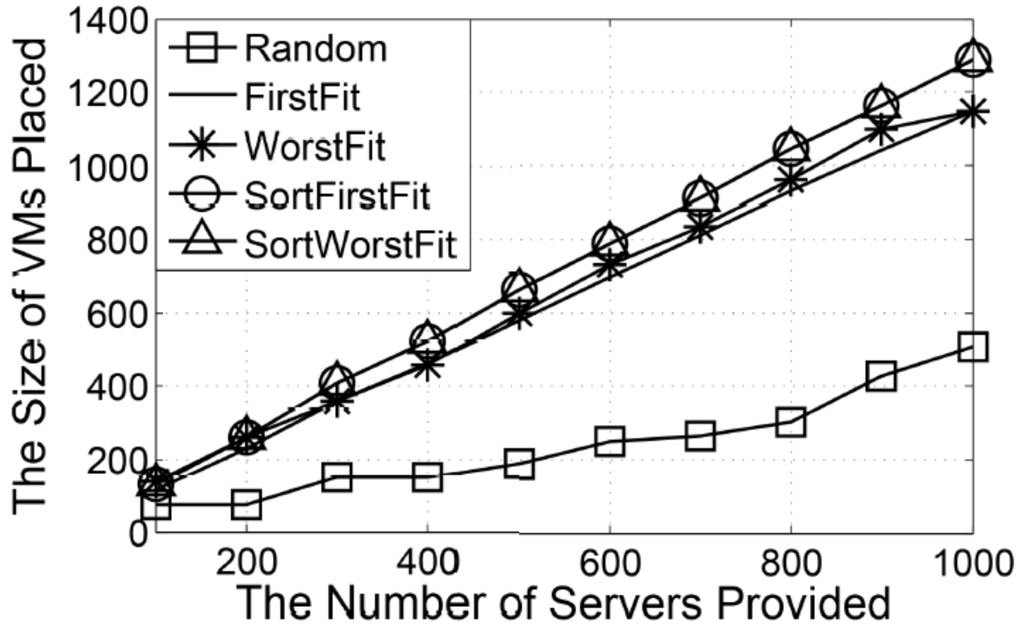
- (a) our heuristics works much better than other heuristics under both the arriving VM sequence that consists of a sequence of small VMs followed by a sequence of large VMs and the arriving VM sequence that consists of a sequence of large VMs followed by a sequence of small VMs.
- (b) we can conclude that processing sorting before placement may make the placement more efficient.

The impact of hardware heterogeneity



- (a) the advantages of sorting will be more significant when the difference of resources of servers in the network are larger.

Testing with real traces



- The results in this situation verify that the performances of the five heuristics using trace-driven data sets are in line with those using the above three generated data sets.

Thanks for your attention!