Application-Specific Configuration Selection in the Cloud: Impact of Provider Policy and Potential of Systematic Testing

Mohammad Hajjat[+], **Ruiqi Liu***, Yiyang Chang[+], T.S. Eugene Ng*, Sanjay Rao[+]

[+] Purdue University, * Rice University

Overview

Cloud users face many choices when deploying applications in the cloud
- VM size
- CPU heterogeneity

Cloud providers employ complex policies
- Bandwidth rate limit
- VM packing
- CPU scheduling

Goal
- Understand how policies can impact performance
- Select good configurations for applications

Related work

- "Trial and error" strategies replace bad VMs with good VMs
- Heavy weight testing strategy profiles cost-performance of different VM sizes and migrates applications
- Our systematic testing techniques
  - Consider both VM size and CPU type
  - Advantageous for stateful applications that are hard to migrate

Contributions

- Conducted large scale 19-month measurement study of Amazon EC2
- Found that provider policy impacts configuration choices in surprising ways
  - Larger VM sizes do not necessarily see higher bandwidth
- Proposed and evaluated configuration selection techniques systematically
  - Iprune reduces the number of tests by 40% - 70%
  - Nearest Neighbor selects the configuration within 6% of best for 80% cases with no testing overhead

Amazon EC2 VMs

- General purpose EC2 VMs (M1) have four sizes: small (S), medium (M), large (L), extra-large (X)
- VMs of the same size may be hosted with different types of CPUs

Abbreviation	CPU (Intel Xeon)	Speed (GHz)	Release	Cores
A	E5430	2.66	Q4 2007	4
B	E5645	2.40	Q1 2010	6
C	E5507	2.26	Q1 2010	4
D	E5-2650	2.00	Q1 2012	8

Detailed provider policies

- Rate limit
  - Different policies for different VM sizes
  - Different across hardware generations
- VM packing
  - 8 M on C, 6 L on B, 4 L on C, 8 L on D
- vCPU scheduling: when and how often a VM runs
  - Scheduling delay is different across CPU types

Impact of VM packing

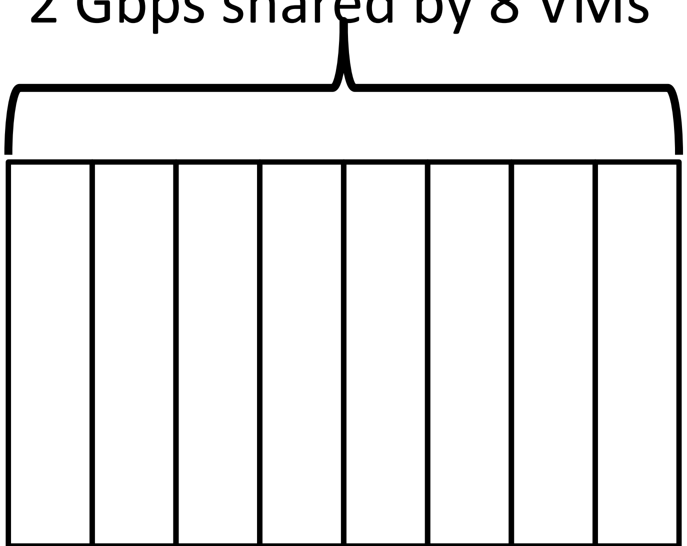
8 MC VMs on a physical machine

4 LC VMs on a physical machine

Impact of VM packing

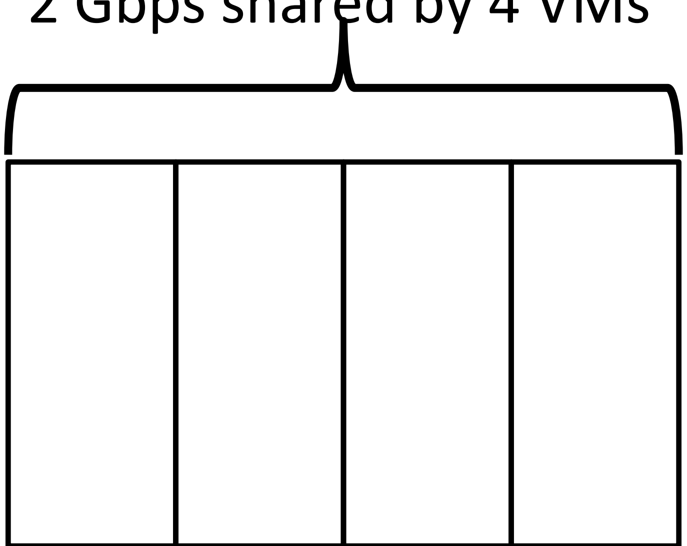
8 MC VMs on a physical machine

2 Gbps shared by 8 VMs



4 LC VMs on a physical machine

2 Gbps shared by 4 VMs



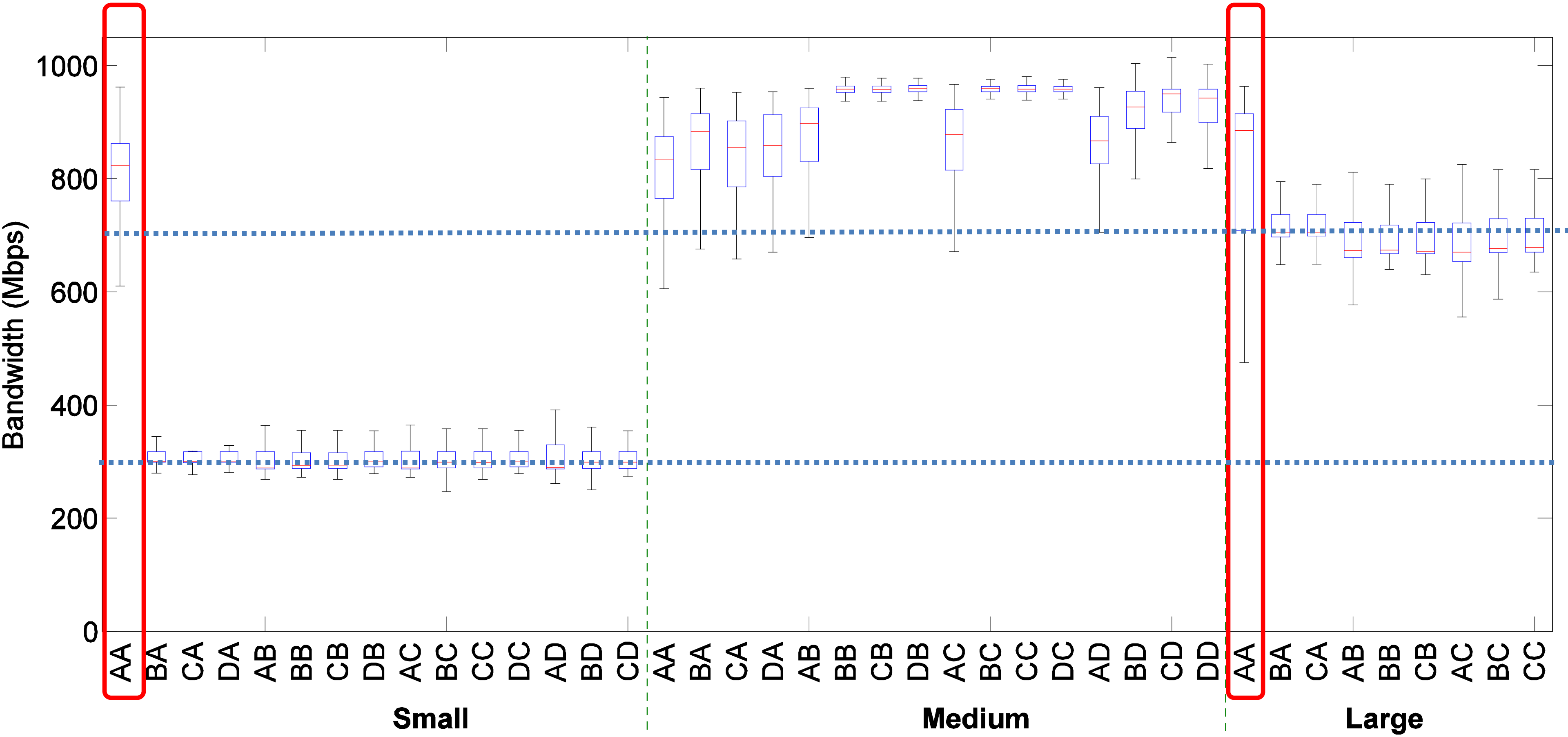
Measurement methodology

- Conducted measurements on general purpose Amazon EC2 VMs from 2012 to 2014
- Used ***iperf*** to measure TCP throughput between two VMs
- Used 29 ***compute intensive applications*** to measure computation performance
- Measured on all available configurations with multiple <u>deployments</u> per configuration and multiple <u>measurements</u> per deployment

Configuration Notations

- A configuration is the combination of VM size and CPU type
  - MC is a medium VM with CPU type C
  - For bandwidth measurement, two VMs are used. Small AC means ***source*** is SA and ***destination*** is SC.

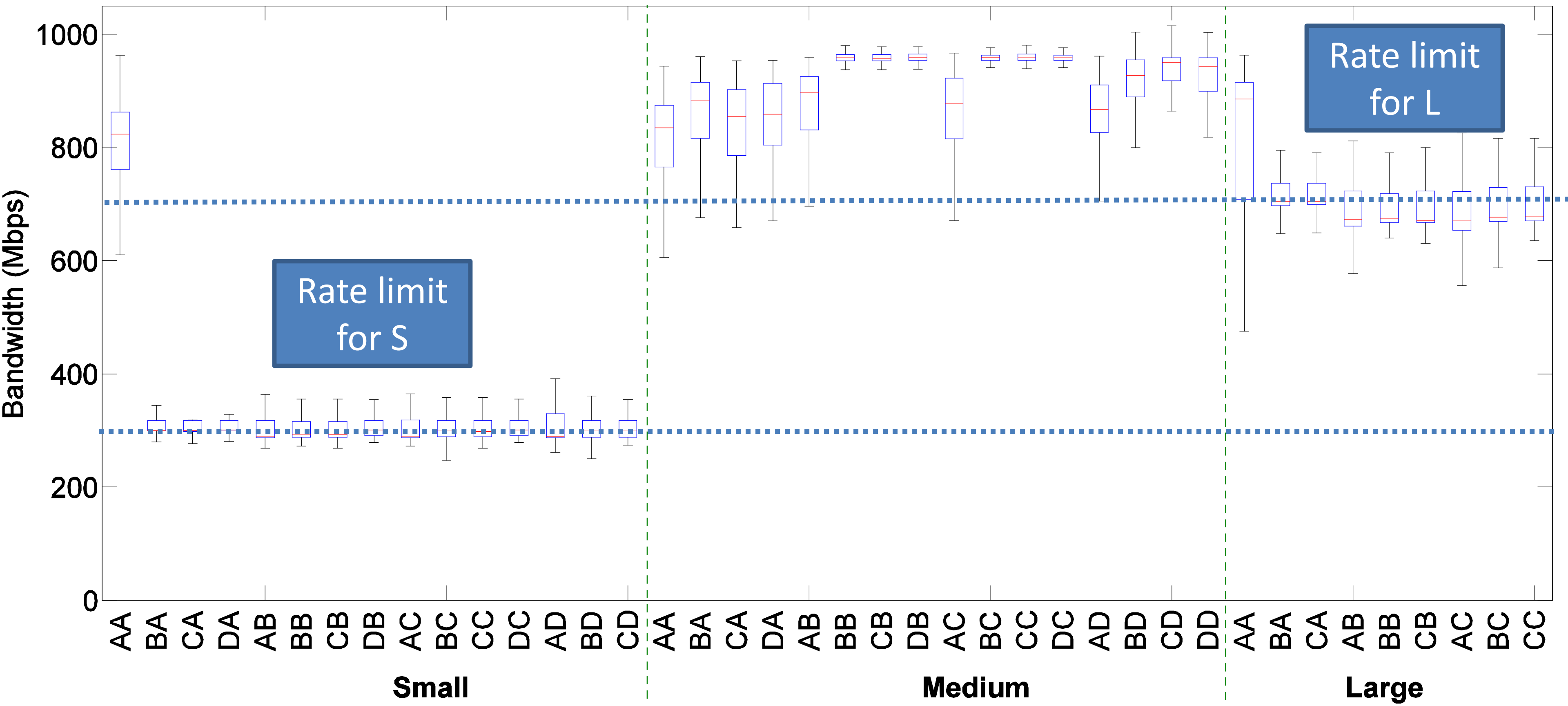
Intra-DC throughput



CPU type A was **better** though **older**

- Rate limiting policies evolved from initial offerings
- Overhead of updating policies on older hardware was too high

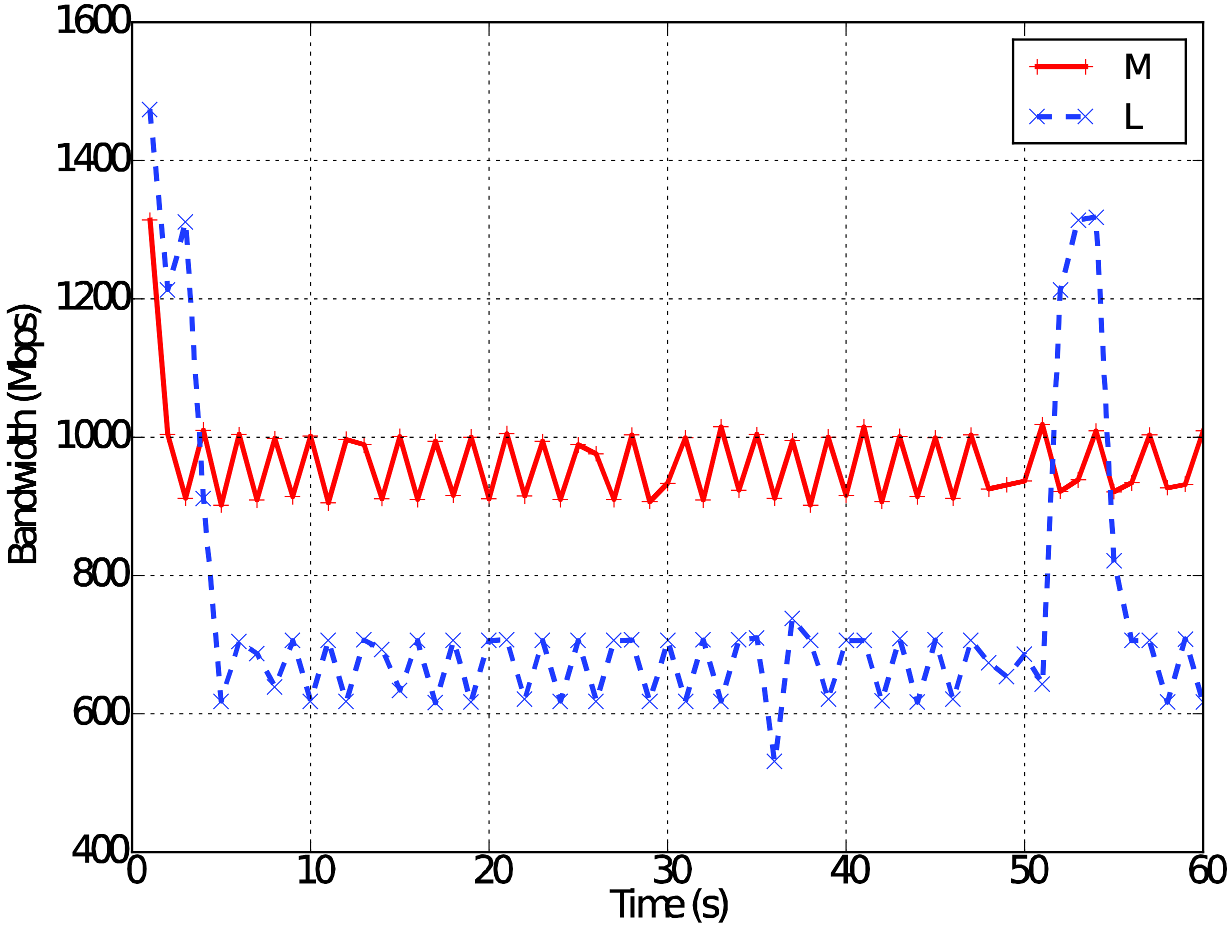
Intra-DC throughput



M achieved higher bandwidth than L

Rate limit behavior on M and L

- Conducted extensive study with dedicated VMs which isolate multi-tenancy

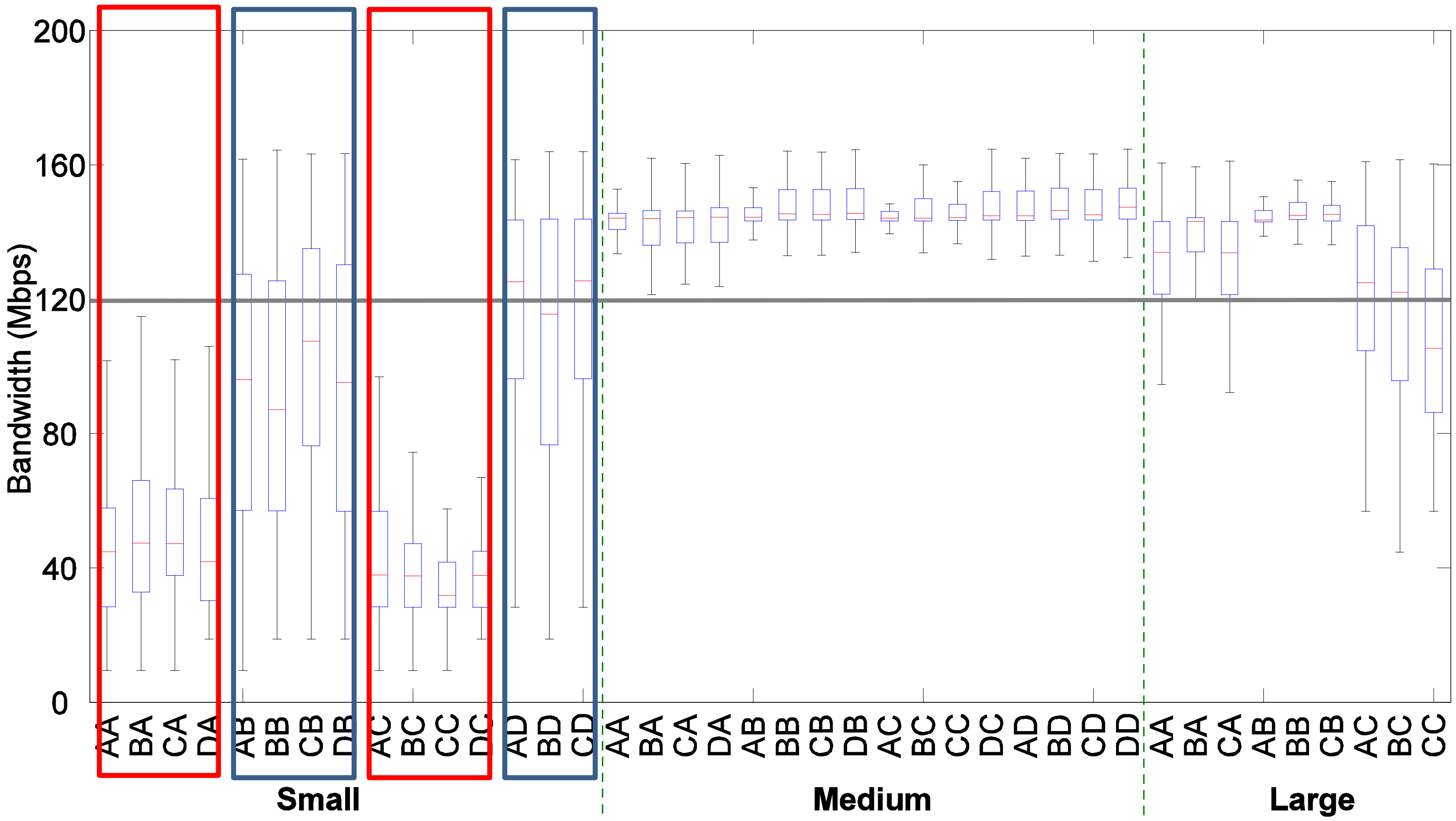


Rate limit behavior on M and L

- L VMs were more rate-limited than M VMs
- L VMs could tolerate higher bursts than M VMs

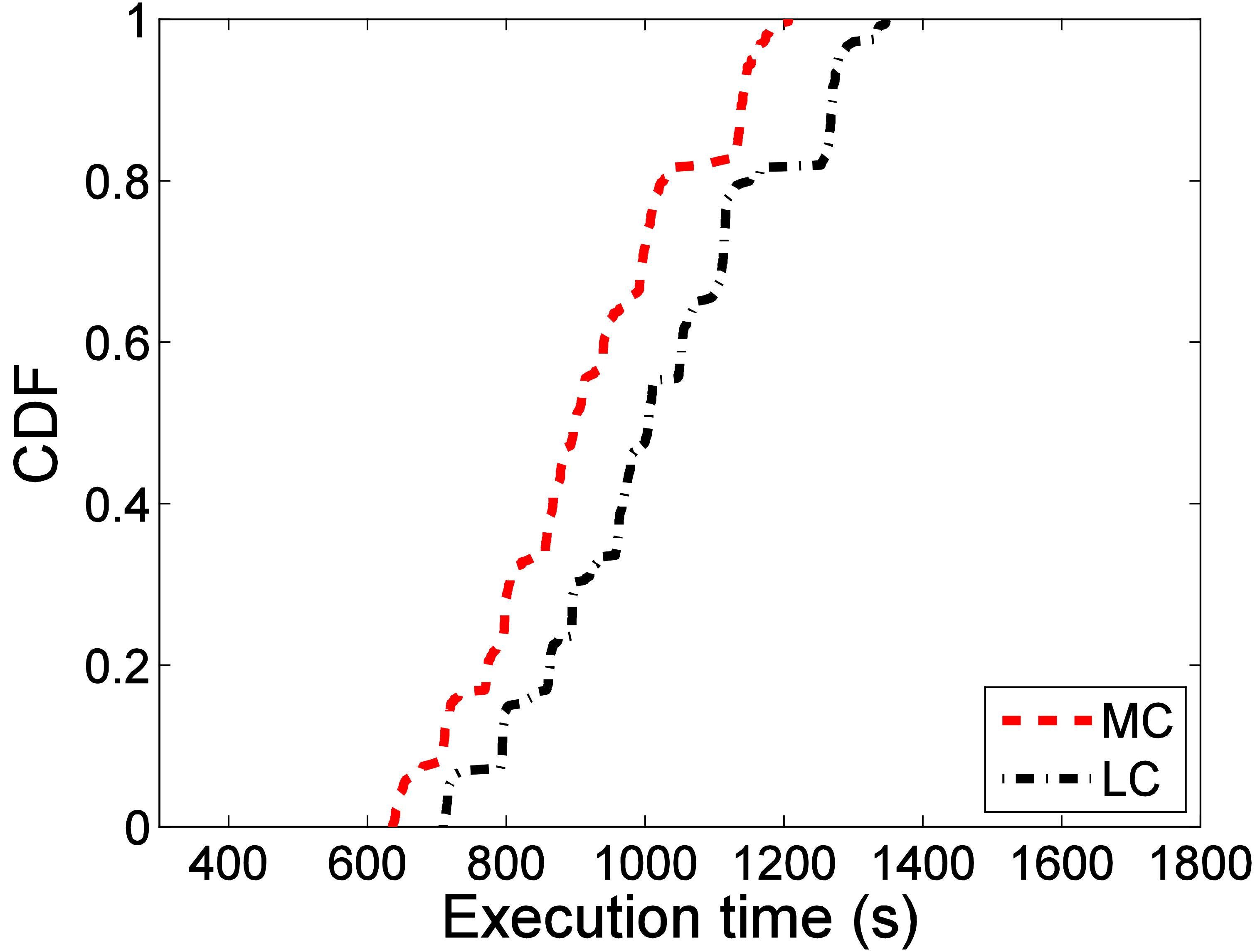
- Possible hypothesis
  - L VMs had more predictable performance under multi-tenancy
  - L VMs had more reserved capacity for higher priority traffic

Inter-DC throughput



- CPU type on the **receiver** side matters

Compute intensive applications: MC was better than LC



MC is better than LC

- Conducted auxiliary measurement on MC and LC
  - Measured the time to run constant multiplication
  - Measured memory access latency for all memory hierarchies using lmbench
- Findings
  - MC took less time than LC for multiplication
  - MC had lower access latency and less variation

Other findings

- Inter-DC throughput closely related to the CPU type of the receivers
  - Verified with UDP loss rate and traceroute data
- VM packing policies affected per-VM bandwidth
  - Verified with dedicated VMs locating on one physical machine
- CPU types A and C were more likely to experience high scheduling delay
  - Measured the actual elapsed time when having a process sleep for a short period
- Two cores on LC were scheduled in a more relaxed way than on LA, LB and LD
  - Measured the delay when two threads started running

Interplay of VM size, CPU type and **provider policy** impacts communication and computation performance

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Configuration selection is non-trivial, and **systematic testing** is necessary

Systematic testing

- Goal: select the configuration (combination of CPU type and VM size) that takes least time and/or money for an application

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- Straw man
  - Per-Configuration testing (PerConfig)
- More intelligent systematic testing techniques
  - Iterative pruning (iPrune)
  - Nearest Neighbor shortlisting

iPrune, example with K = 6

- Requirement: at least **K** deployments <u>per choice</u> in each configuration dimension
- Conduct M measurements per deployment
- *Deployments # = K ×max{|d1|, |d2|, . . . , |dn|}*

CPU / VM size	A	B	C	D	
Small		2	2	2	**6**
Medium	3		2	3	**8**
Large	3	4	2	1	**10**
	6	**6**	**6**	**6**	

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- Mark *poor* choices in each dimension for pruning
  - A is worse than B with a probability higher than 0.9, so A is pruned

iPrune, example with K = 6

CPU / VM size	A	B	C	D	
Small		2	2	2	**6**
Medium	3		2	3	**8**
Large	3	4	2	1	**10**
	6	**6**	**6**	**6**	

- Mark *poor* choices in each dimension for pruning
  - Large is worse than medium with a probability higher than 0.9, so large is pruned

iPrune, example with K = 6

CPU / VM size	A	B	C	D	
Small		2	2	2	**6**
Medium	3		2	3	**5**
Large	3	4	2	1	**7**
	6	**2**	**4**	**5**	

- Mark *poor* choices in each dimension for pruning
  - Large is worse than medium with a probability higher than 0.9, so large is pruned

iPrune, example with K = 6

CPU / VM size	A	B	C	D	
Small		5	2	2	**9**
Medium	3	1	4	4	**9**
Large	3	4	2	1	**7**
	6	**6**	**6**	**6**	

- Get more deployments to satisfy K

iPrune, example with K = 6

CPU / VM size	A	B	C	D	
Small		5	2	2	**7**
Medium	3	1	4	4	**5**
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	6	**6**	**6**	**6**	

- Repeat:
  - Perform pruning if possible

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- Repeat:
  - Perform pruning if possible
  - Get more deployments if needed

iPrune, example with K = 6

CPU / VM size	A	B	C	D	
Small		5	2	2	**7**
Medium	3	2	4	4	**6**
Large	3	4	2	1	**10**
	6	**7**		**6**	

- Finally: choose best configuration in each dimension

iPrune vs PerConfig

- Evaluated with iperf and Cassandra
  - iperf measures TCP throughput for a pair of VMs
  - Cassandra is a key-value store, measured with YCSB workloads (read + write)

	PerConfig	iPrune
iPerf	3000+	700
Cassandra	1800	1000

Number of tests for 5% error target

Systematic testing techniques

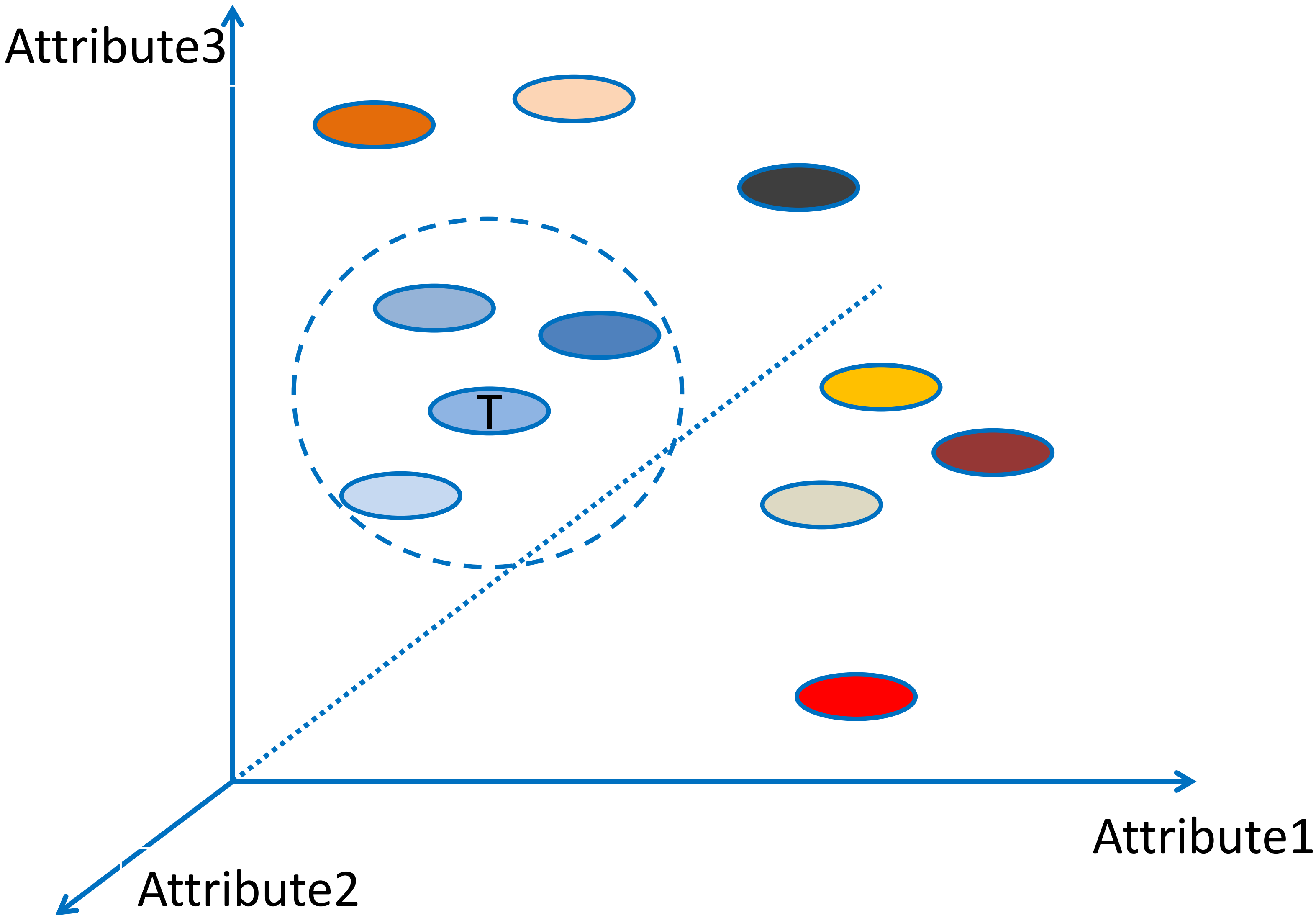
iPrune

- Conservatively prunes out bad VMs

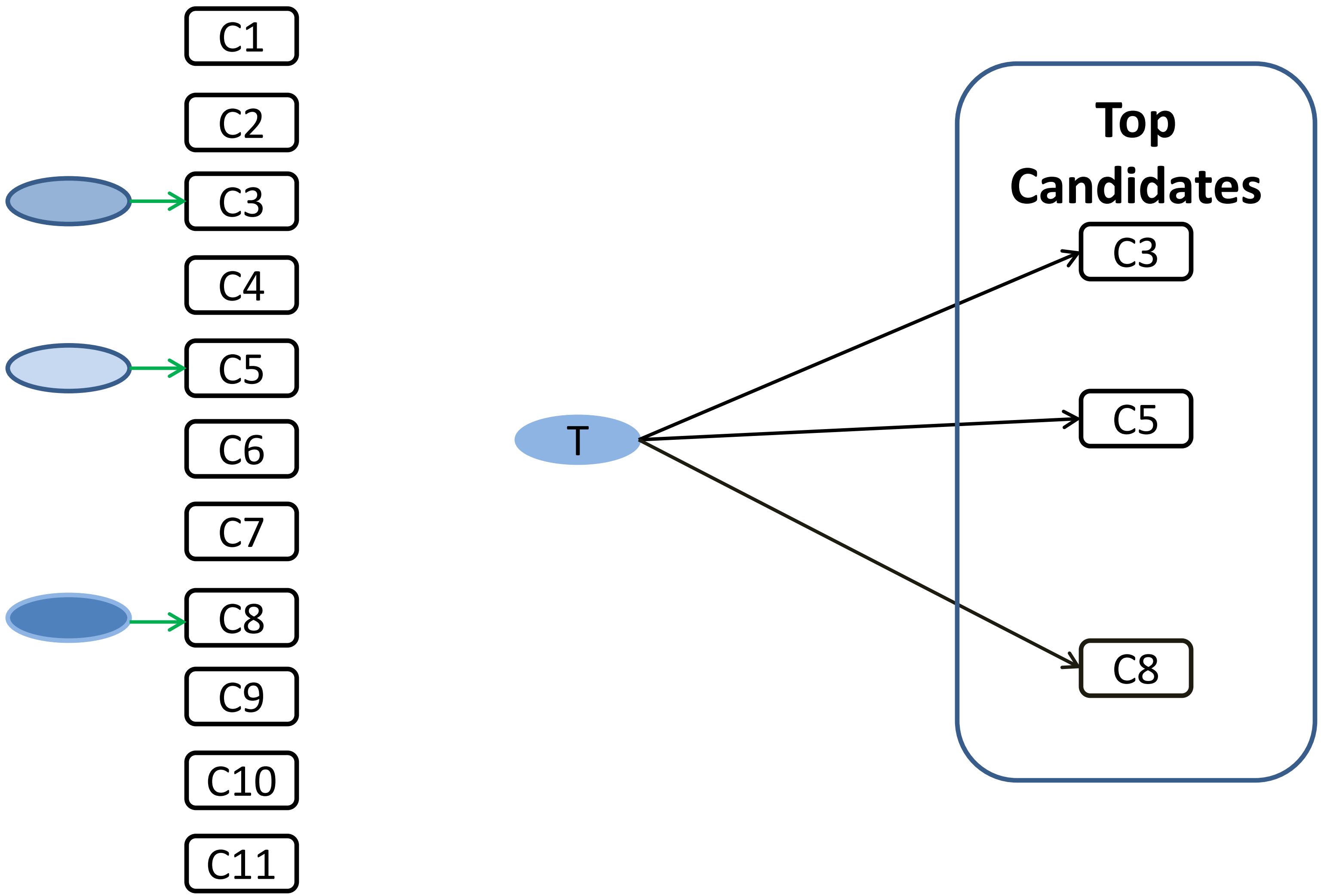
Nearest Neighbor

- Proactively shortlists good VMs
- Uses performance data of existing apps
- Assumption
  - Similar applications tend to have similar best configurations

Nearest Neighbor



Shortlist Configuration



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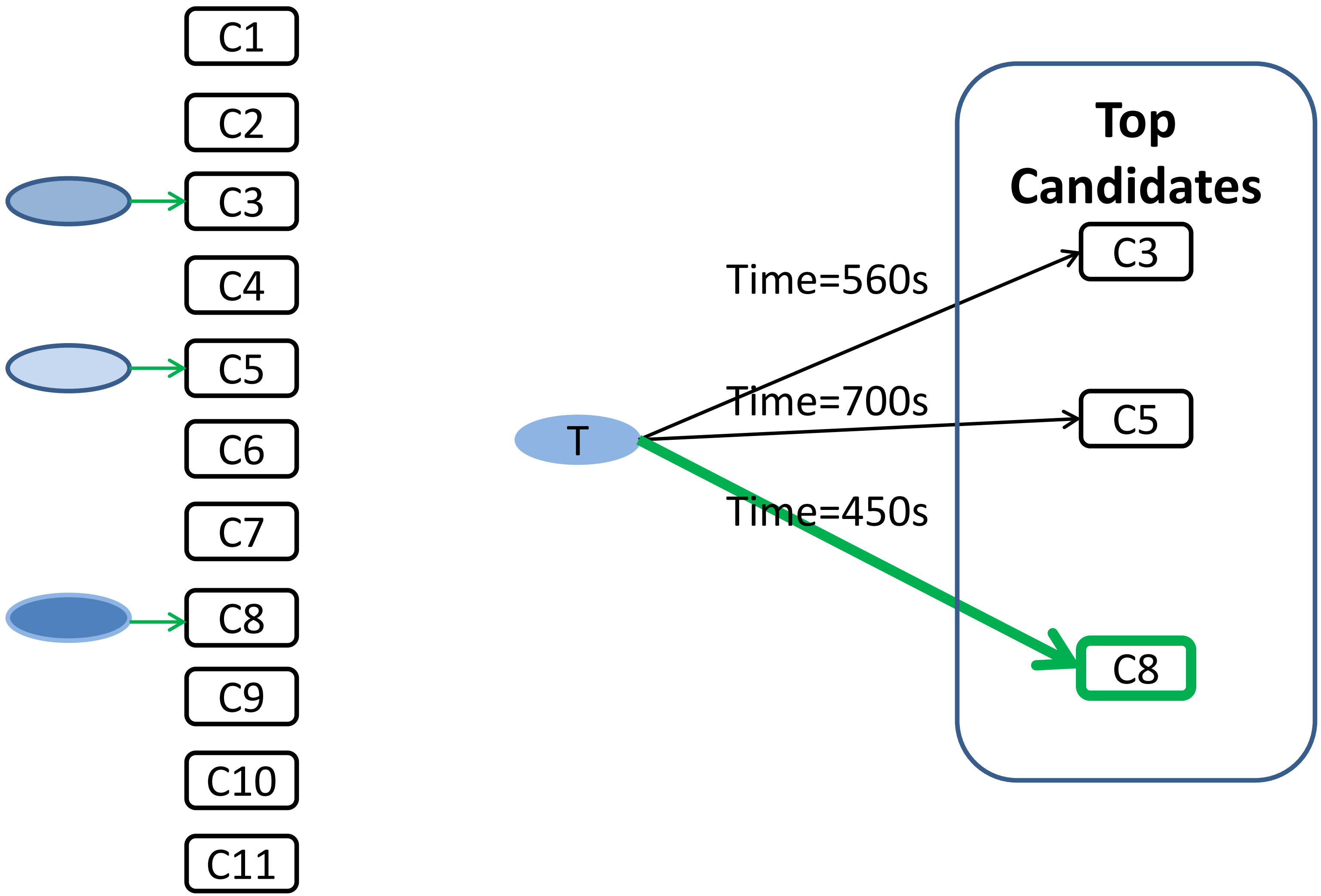

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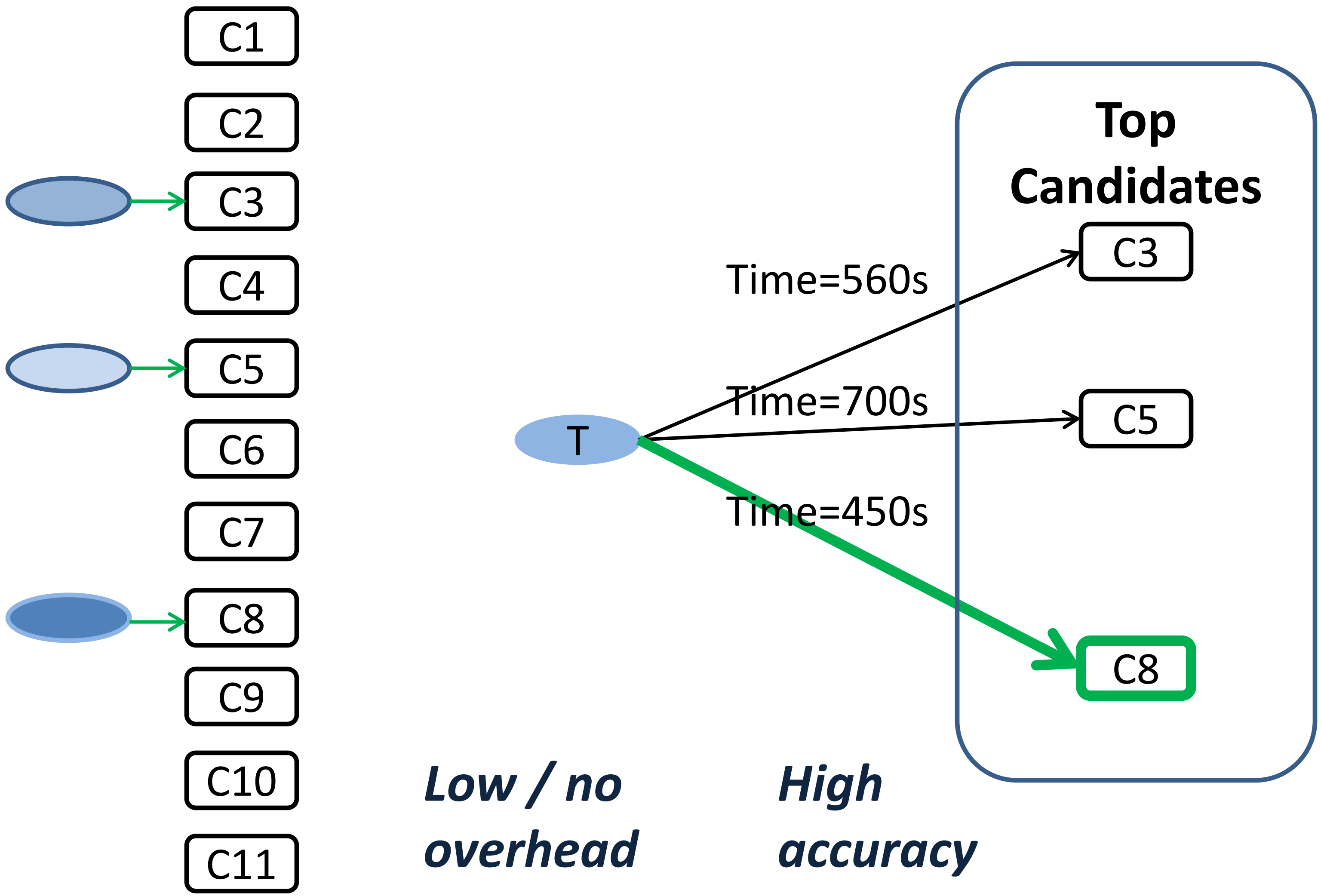
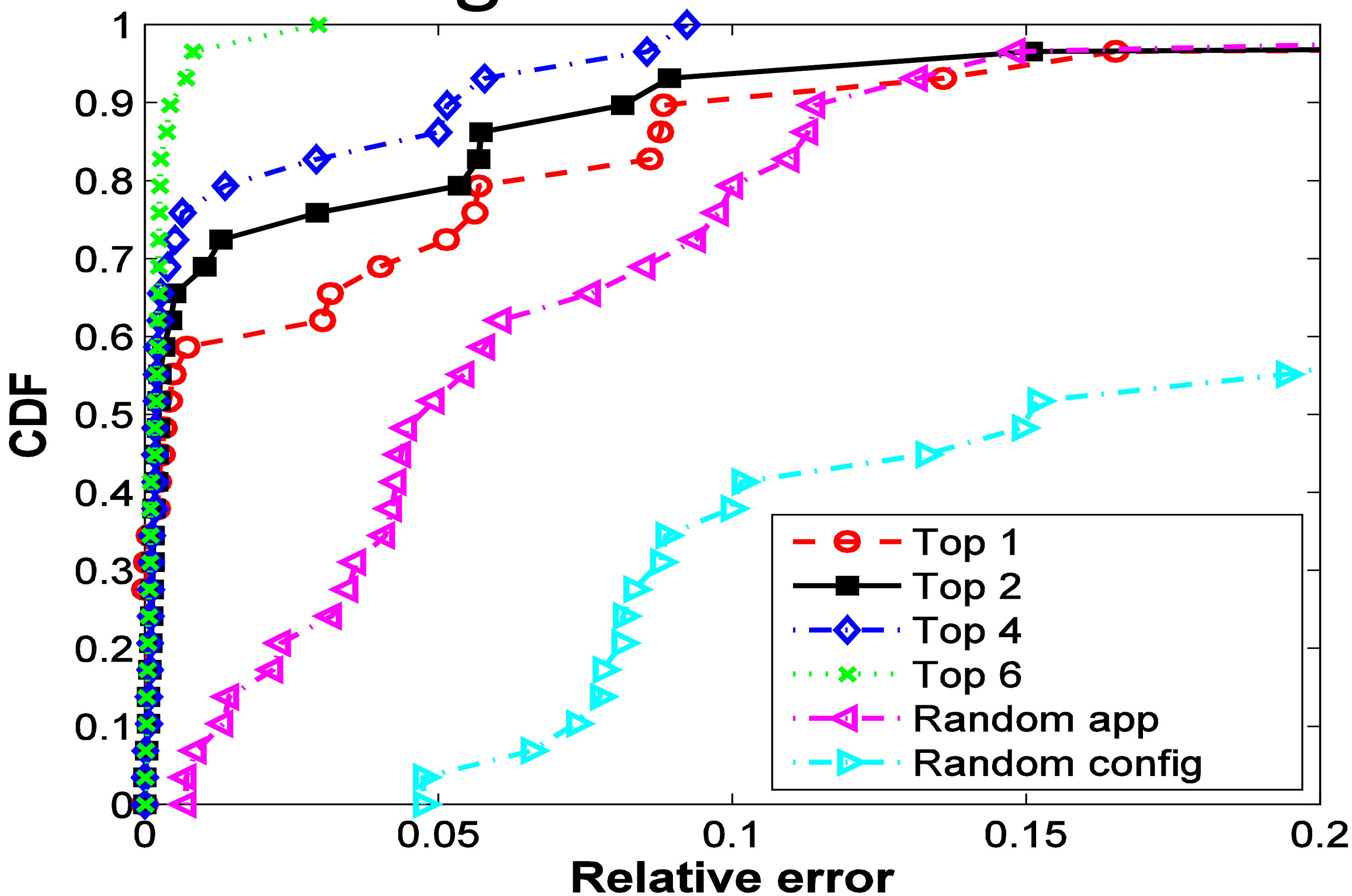


Low / no overhead

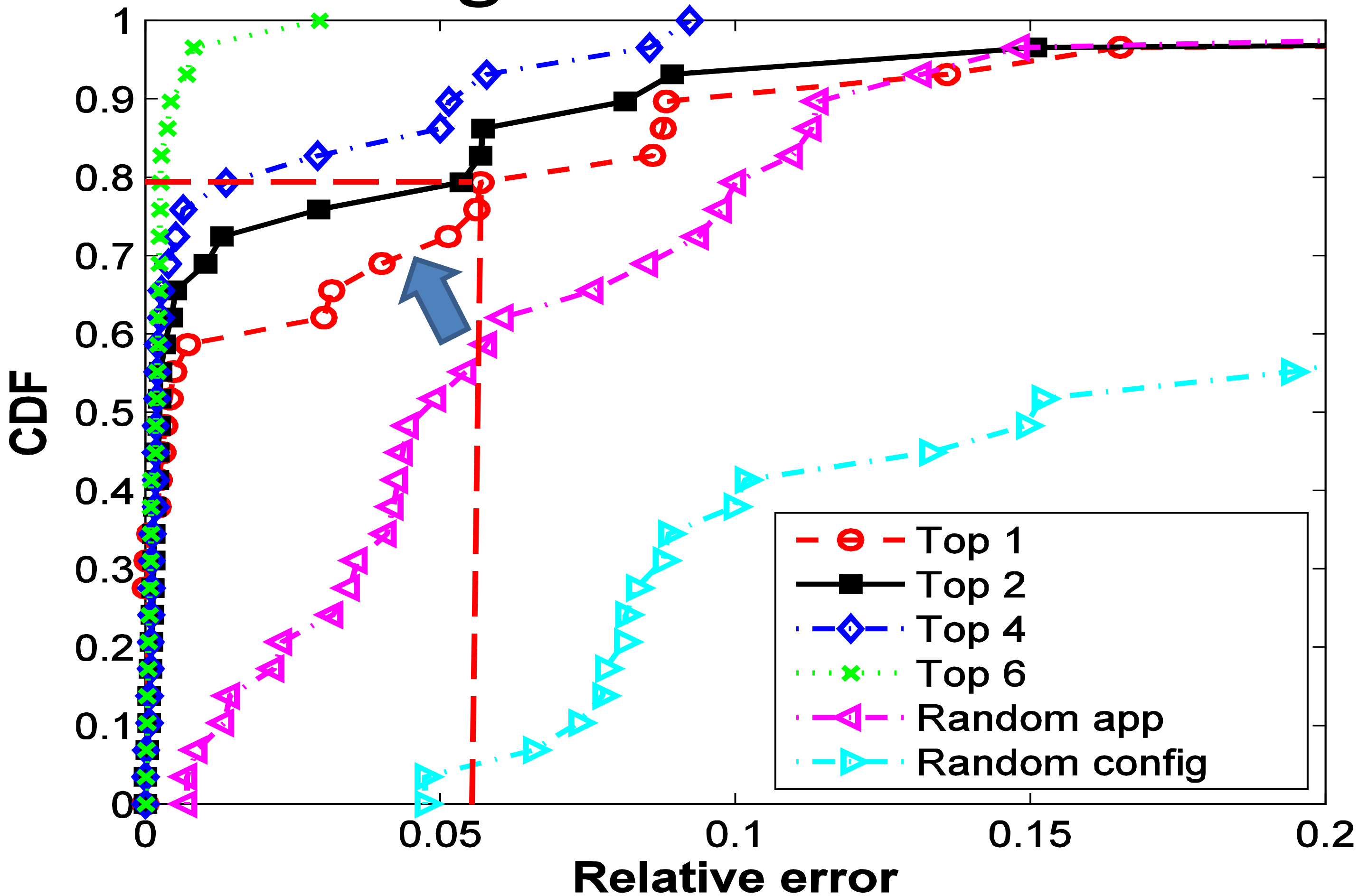
High accuracy

Nearest Neighbor vs random schemes



Evaluated with 29 compute-intensive apps

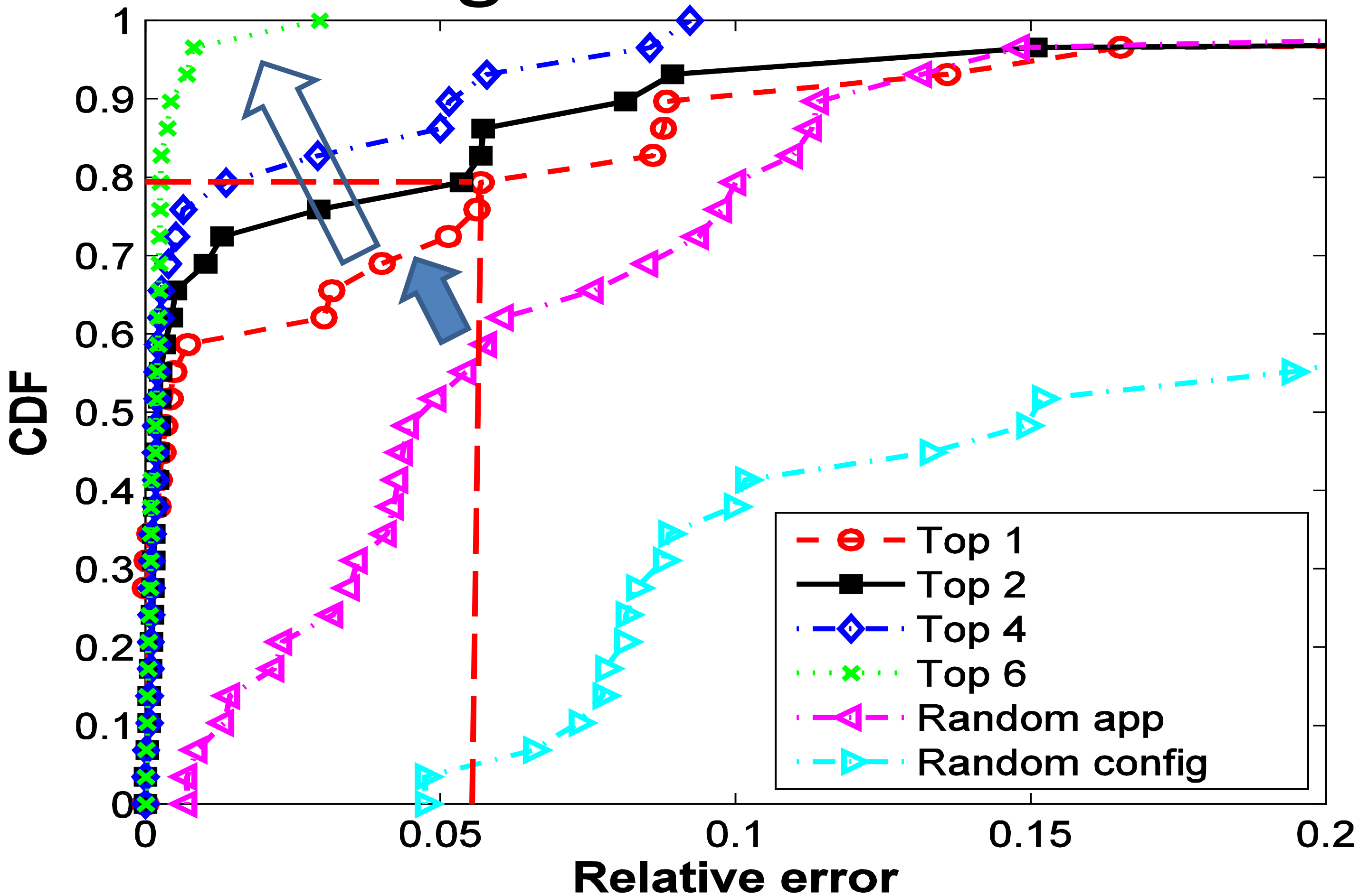
Nearest Neighbor vs random schemes



Evaluated with 29 compute-intensive apps

- Top 1 has no testing overhead, better than random

Nearest Neighbor vs random schemes



Evaluated with 29 compute-intensive apps

- Top 1 has no testing overhead, better than random
- More top candidates, greater testing overhead, higher accuracy

Implications of Nearest Neighbor

- Make a tradeoff between testing overhead and accuracy of the selected configuration
- Top 1 is promising for short running applications
  - No testing overhead, good configuration
- More top candidates is better for long running applications
  - Higher tolerance for testing overhead, higher accuracy of the selected configuration

Conclusions

- Provider policy affects the performance of applications in unexpected ways
  - Analyzed through large scale measurement study of Amazon EC2
- iPrune greatly reduces testing overhead
  - Iprune reduces the number of tests by 40% - 70%
- Nearest Neighbor incurs low testing overhead and achieves high accuracy
  - Nearest Neighbor selects the configuration within 6% of best for 80% cases with no testing overhead