Market Driven Multi Resource Allocation

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Cost Efficient Scaling
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Resource Allocation

- One of the main challenges of public and private cloud providers
- Needs to serve all the clients on each server according to their their service-level-agreement (SLA)
- Affects utilization
  - Hence, affects the number of clients per server
  - Thus, affects the provider's operation cost per client

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- Affects utilization
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  - Thus, affects the provider's operation cost per client
- Can reduce the provider's operation costs
- Coupled with a fitting pricing scheme, it can increase the provider's profits

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- Explore designs for such resource allocation schemes
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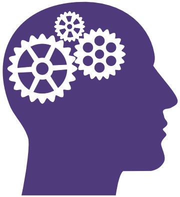
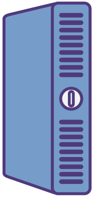


- What is the gap between the current resource utilization to an optimal one?
- What is the origin of the gap?
- What are the provider's economic requirements?
- What are the clients' economic requirements?

The Problem: Fixed Resource Bundles

- Resources in the cloud are underutilized
- The main cause of resource underutilization is fixed performance bundles



- Clients rent the resources to sustain their highest workload
  - But they do not use the resources all the time
- The provider guarantees with good probability that the clients will be able to use their rented resources at any given time
- It must reserve these resources
  - It cannot resell them or use them to other purposes

Our Approach

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  - With an option to add resources on the fly on demand
- How? By designing an allocation mechanisms that incorporates a smart pricing scheme

Our Mechanisms

Two different mechanisms, each is suitable for different goals

- **Auction-based mechanism**: optimizes the clients' economic benefit
  Liran Funaro, Orna Agmon Ben-Yehuda, and Assaf Schuster. "Ginseng: market-driven LLC allocation". In: *Proceedings of the 2016 USENIX Conference on Usenix Annual Technical Conference*. USENIX Association. ACM, 2016, pp. 295–308
- **Stochastic allocation mechanism**: allocate a stochastic amount of resources alongside a fixed, reserved, amount
  Liran Funaro, Orna Agmon Ben-Yehuda, and Assaf Schuster. "Stochastic Resource Allocation". In: *Proceedings of the 15th ACM SIGPLAN/SIGOPS International Conference on Virtual Execution Environments (VEE '19)*. USENIX Association. Providence, RI, USA: ACM, 2019. ISBN: 978-1-4503-6020-3/19/04

Both mechanisms improve hardware utilization by using some kind of economic mechanism that incentivize clients to reduce the fixed, reserved, portion of their bundle

Auction-Based Mechanism

- Auction mechanism that optimize the *social welfare*
  - The aggregated value all the clients draw from the cloud
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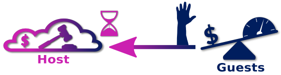

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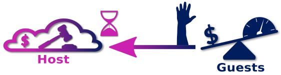

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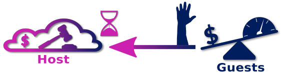

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The host informs the guests of their allocation and charges them according to the **exclusion-compensation** principle

Exclusion-Compensation Principle

- **Exclusion-Compensation Principle**: Each guest pays for the damage it inflicted on the other guests in the system
- If the demand is low, clients can rent the additional resources in a very low price, which is financially beneficial to them
- It incentivizes clients to rent a smaller bundle because the client can bid for additional resources at a lower price on average compared to the reservation price

Auction-Based Mechanism (2)

- First introduced by Orna Agmon Ben-Yehuda for RAM allocation
  Orna Agmon Ben-Yehuda et al. "Ginseng: Market-driven Memory Allocation". In: *Proceedings of the 10th ACM SIGPLAN/SIGOPS International Conference on Virtual Execution Environments (VEE)*. vol. 49. 7. Salt Lake City, Utah, USA: ACM, 2014. ISBN: 978-1-4503-2764-0
- We extended this mechanism to last-level-cache (LLC) allocation
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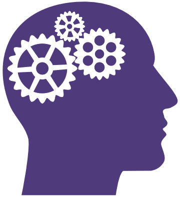
  - Our mechanism can improve the aggregate benefit of the clients in a single physical machine
  - Guests can utilize their cache fast enough to allow rapid changes in the allocation

New Challenges



- High computational complexity
- Memory elastic applications

Efficient Auction Algorithm

- Finding the optimal allocation has a high computational complexity
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- We introduced a new efficient multi-resource auction algorithm with a pseudo near linear complexity
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- Allow a multi-resource auction every two minutes for up to 256 clients
  - On a single core
  - Embarrassingly parallel

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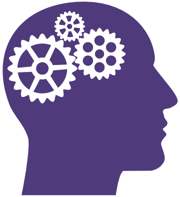

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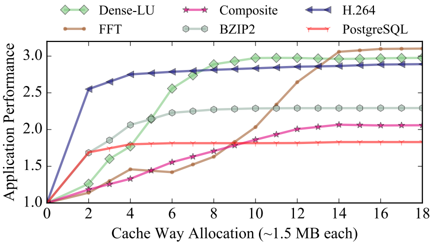
Memory Elastic Applications

- Resource elastic applications performance is proportional to the resource availability
- For example, cache elasticity
  - Looks similar for CPU and BW



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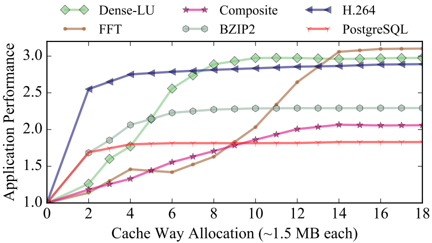
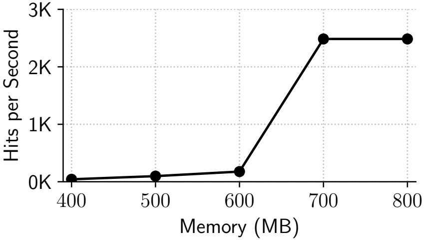


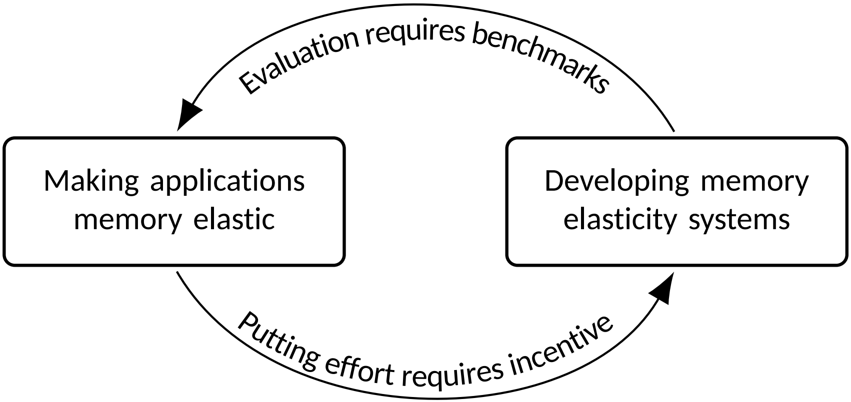
- Memory elastic applications are scarce
- Usually looks like this (thrashing)



Where are the Memory Elastic Applications?

- Why do developers toil towards making performance scale nicely with the CPU and bandwidth, but neglect doing this for memory?

Circular Dependency



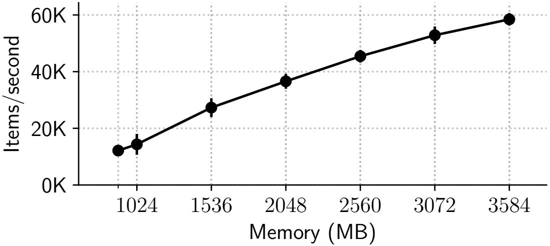
- A proof that memory-elastic applications exist or can be created is essential to break this circular dependency

Applications with Resource Trade-off

- Mechanisms that were designed to allow trade-off between memory and other resources can be used to provide memory elasticity

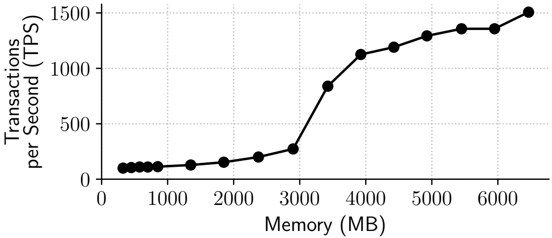
Memory as Cache

- Some applications use the RAM to cache computation results, network traffic, and so on (e.g., using memcached)
- They can seamlessly improve their performance when more memory is available to the operating system



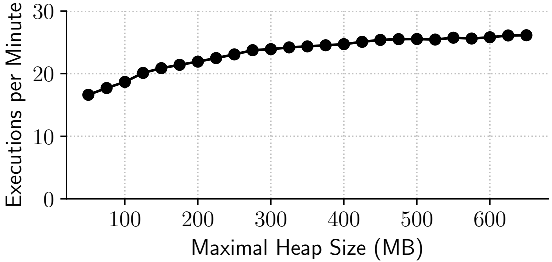
Intermediate Calculations

- Applications that handles data that is larger than the available memory
  - E.g., databases, Spark (map/reduce), deep neural network
- Can use larger memory buffers to reduce secondary memory access and speed up temporarily data-heavy operations
  - E.g., sorting, large matrix multiplication, deep neural network data propagation



Garbage Collected Memory

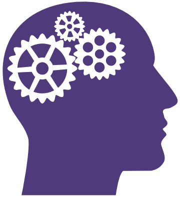
- Applications with automatic memory management (e.g., Java applications)
  - May need fewer garbage-collection cycles with a larger heap, and improve their performance as depicted in Figure 3.



Multiple Short-Lived Jobs

- Some applications have multiple short-lived jobs, each with different memory requirements
  - For example, web servers might require a certain memory to handle each session
  - They may be able to handle more concurrent sessions when more memory is available
- To deal with lack of memory, they can cap the number of concurrent sessions
  - They trade off memory for latency and throughput

New Challenges



✓ High computational complexity

✓ Memory elastic applications

Auction Drawbacks

- Requires a large and constant amount of computational power
  - Could have been allocated to the clients
- Does not take the provider's profits into account

Stochastic Allocation (SA)

- Under the **SA** mechanism, the provider offers clients a combination:
  - an amount of reserved resources
  - with a choice of a stochastic allocation class

- The provider posts fixed unit-prices for both goods
- And periodically publishes statistics on resource availability for each SA class
- Each client may choose to rent reserved and/or stochastic resources

Conclusions

- We developed new market-driven resource allocation schemes
- We showed how they can improve
  - Financial properties: social welfare and profits
  - Technical properties: resource utilization and the number of clients per server
- We designed, developed and implemented as open source frameworks
  - Algorithms to support these mechanisms
  - Rigorous evaluation methodologies
- Our work has demonstrated how sophisticated allocation and pricing mechanisms can improve hardware—and thus energy—efficiency in the cloud significantly
- We believe that more research on resource allocation mechanisms in the cloud would help cloud providers immensely

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- Liran Funaro, Orna Agmon Ben-Yehuda, and Assaf Schuster. "Memory Elasticity Benchmark". In: 2019

Questions?

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