Microsoft

Virtual Machine Allocation with Lifetime Predictions

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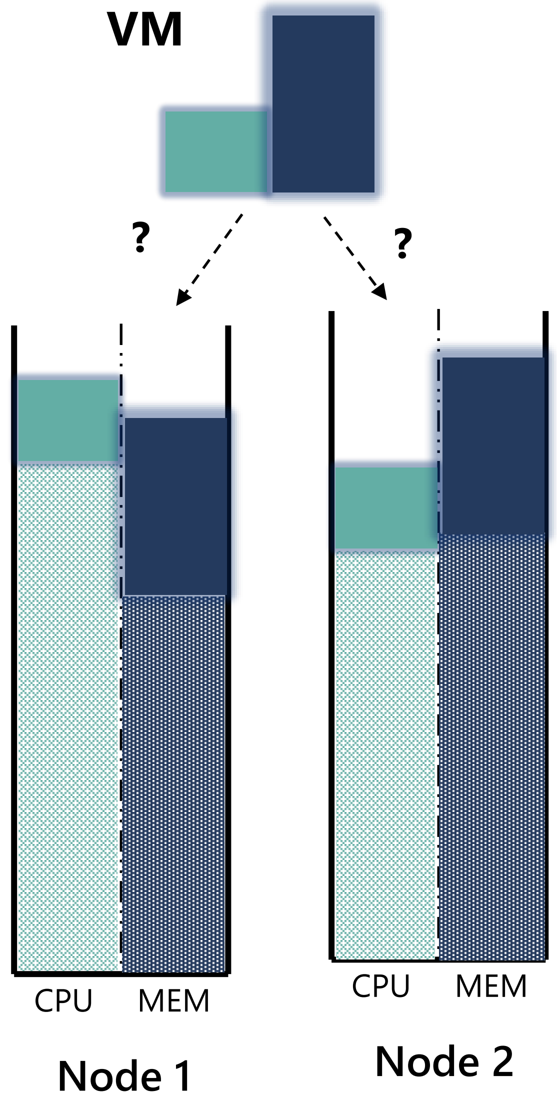
Motivation

- Allocation decisions have a direct impact on resource efficiency
- Inefficient placement might result in fragmentation and unnecessary over-provisioning
- Improvements of **1%** in packing efficiency can lead to cost savings of **hundreds of millions of dollars** (Hadary et al., 2020)

Goal: Increase Azure's packing efficiency with lifetime-aware algorithms

Problem: *Dynamic* multi-dimensional bin packing problem



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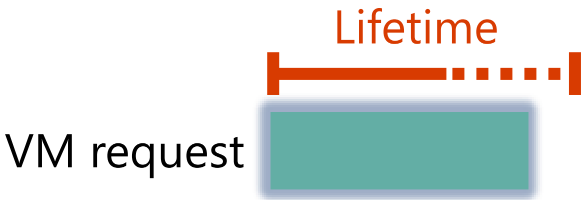

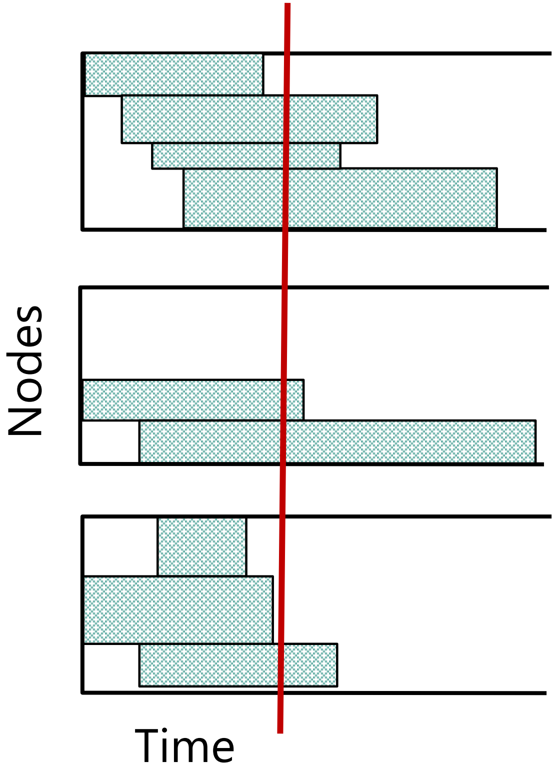

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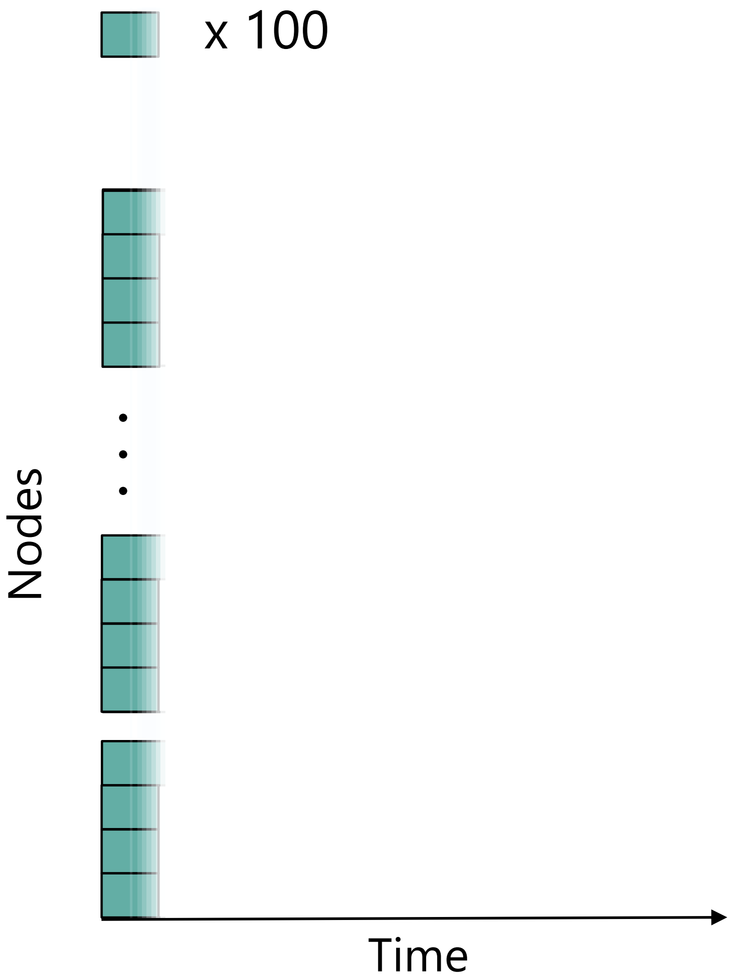
lifetime

Example

Why lifetime-aware allocations?



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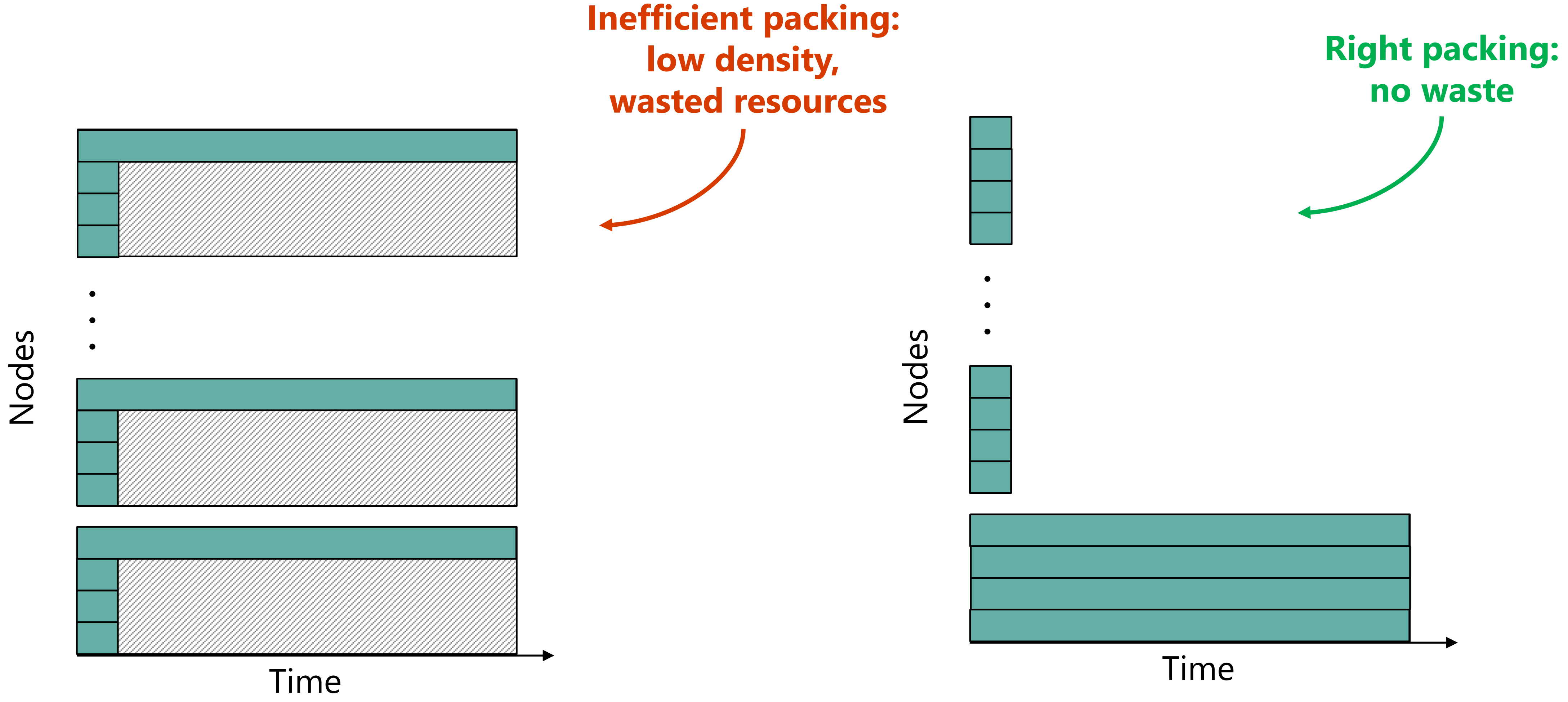
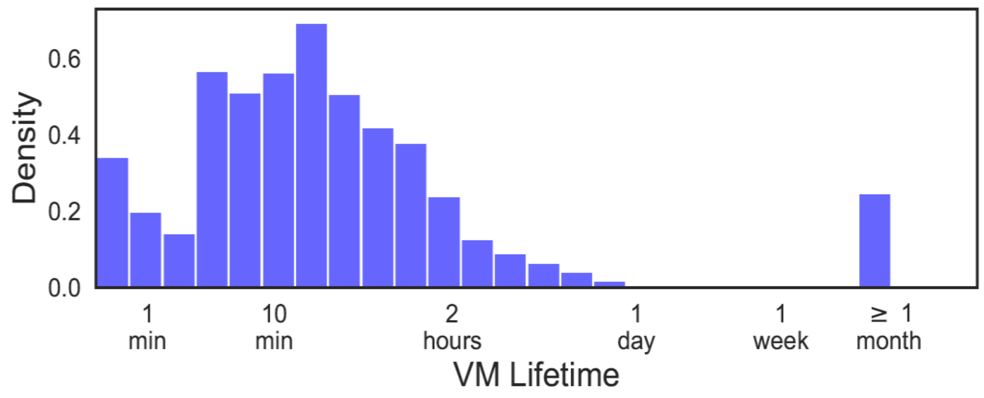
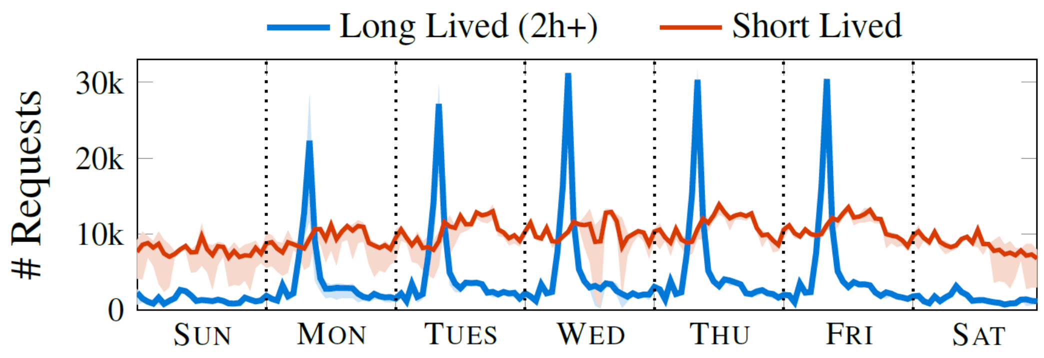


VM lifetime characterization

- How are lifetimes in our system?
- High variance of lifetimes
  - Median: 16 minutes
  - Average: +1 day
- Lifetime temporal patterns
  - Feasibility of VM lifetime prediction





Our contributions

1. Lifetime-aware **algorithm**
2. **ML model** for VM lifetime predictions
3. **System** to support it on real-time

Lifetime Alignment (LA) algorithm

Idea: "Prioritize putting jobs with similar lifetimes together"

- Lifetime ranges are partitioned into classes (where class 0 contains the smallest lifetimes)

For each incoming request:

- If the request is predicted **class 0:**
  - assign to **any** node using Best Fit
- If the request is predicted **class *j*:**
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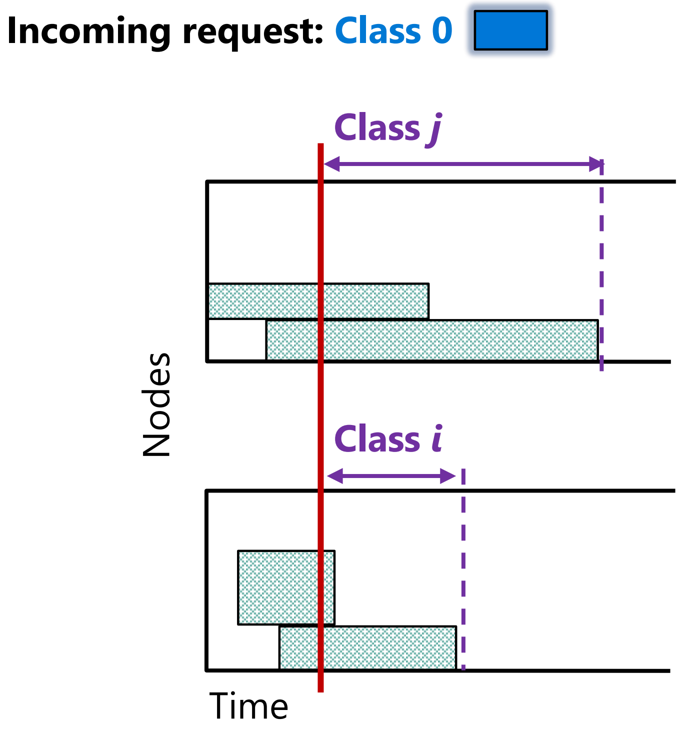

- Dynamically updates lifetime classification of nodes
  - Predicted remaining lifetime
- Theoretical indication that LA is **robust to prediction errors**

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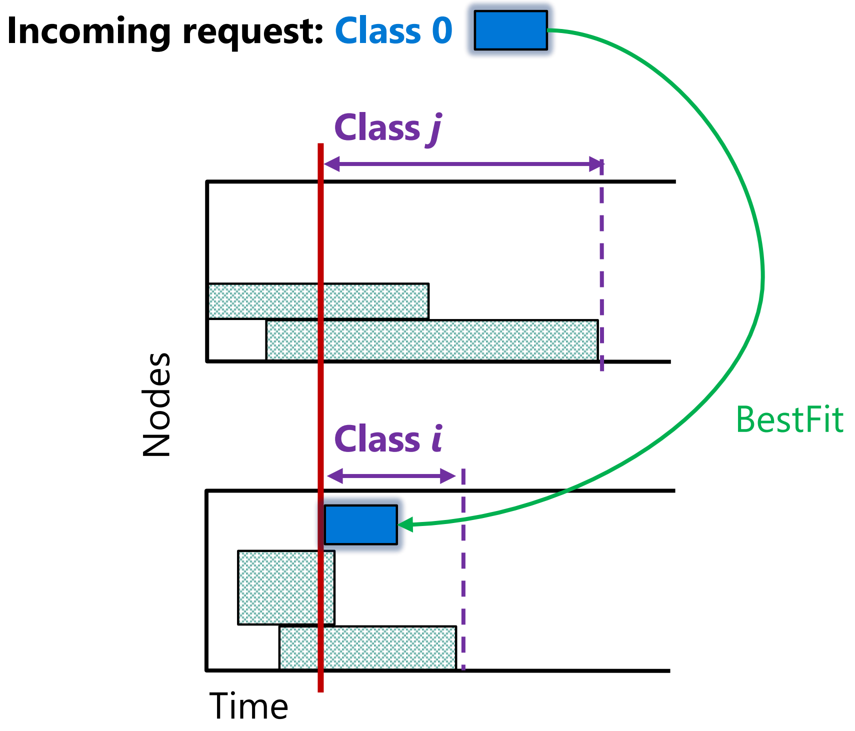

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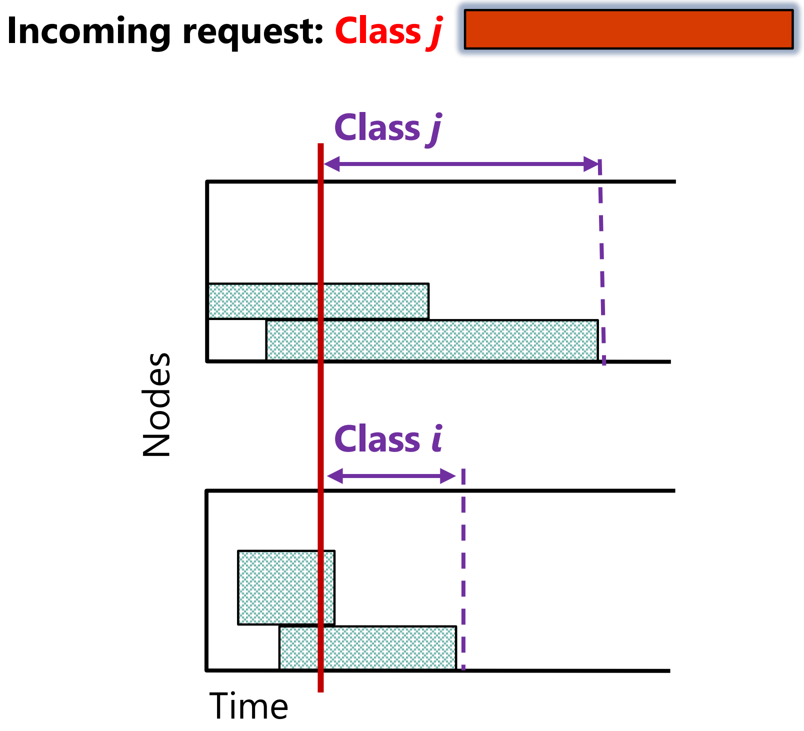

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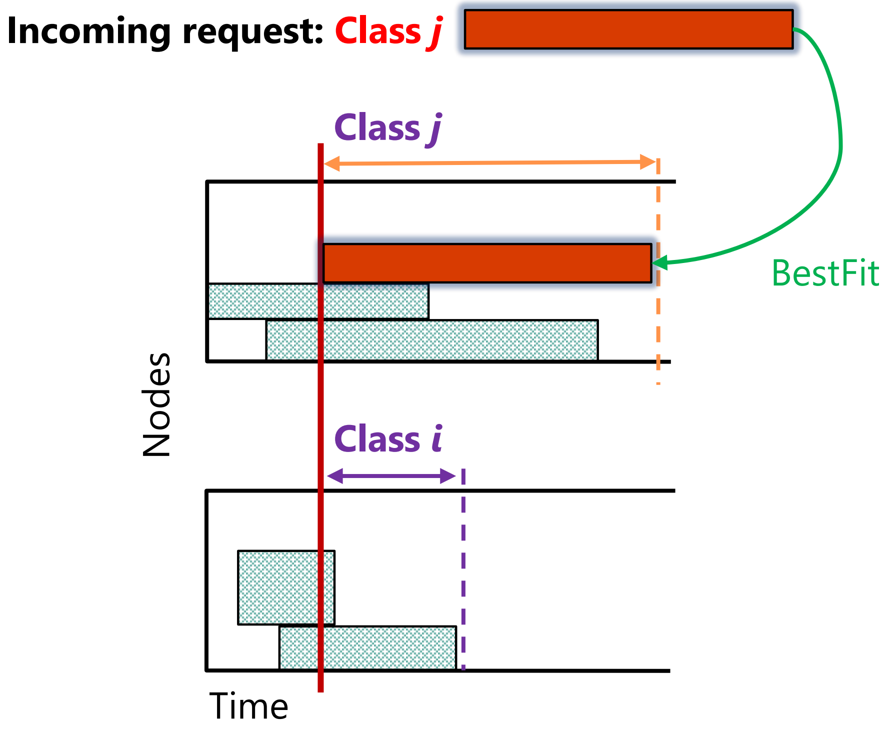

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Predicting lifetime

Challenges:

- Small feature set
- Fast inference time
- Missing data (loss or pruning)
- Skewed and long-tailed lifetime distribution

→

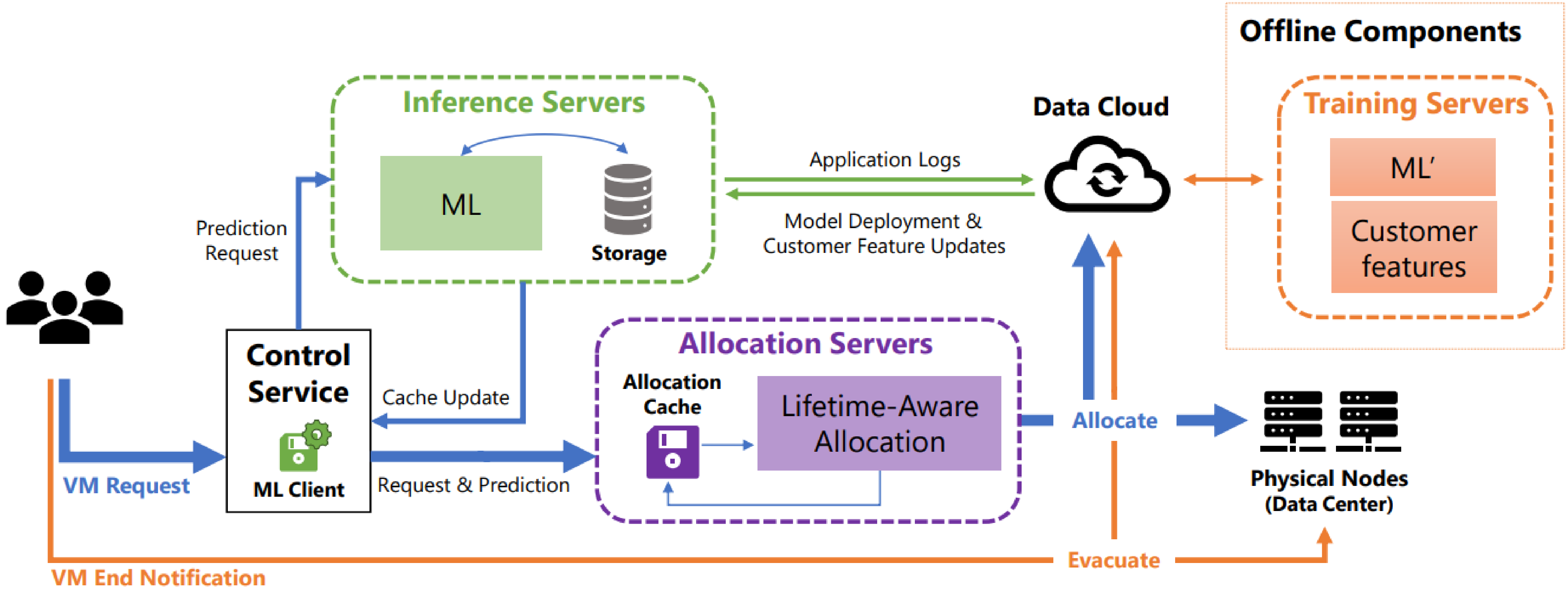
LightGBM model
Binary classification
Short/long threshold

Features:

- VM centric (VM type, OS, request time)
- Customer centric (temporal distribution)

System architecture

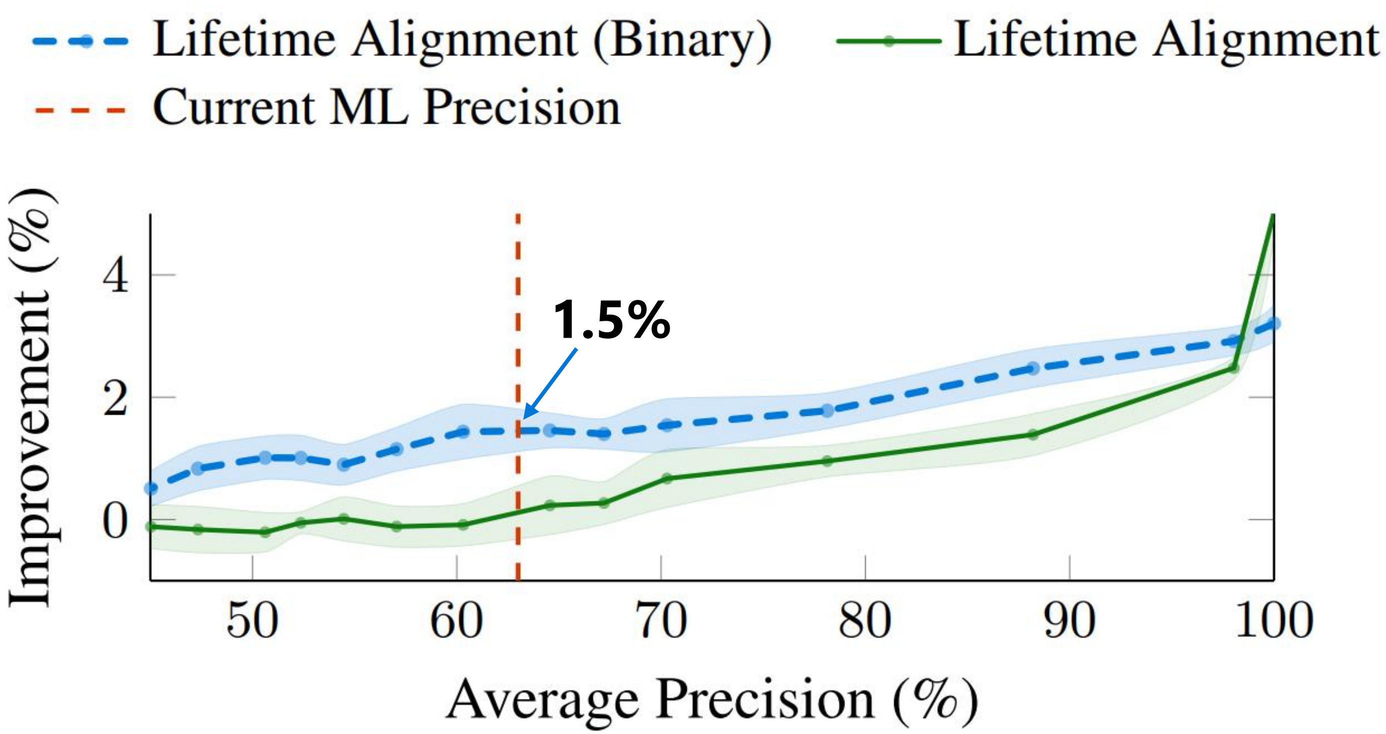
Challenge: How to predict on real time without causing delays?



Real-world production results

- Initial version (ML model + algorithm) in production
- 20 Million daily prediction requests
  - 200+ datacenters
  - 60+ regions
- 60% cache hit on inference results
- 99.2% predictions within time budget
  - Limit of 30ms
- ML model on production achieves expected performance

Experiments



Packing Density: Measures the average number of allocated cores on non-empty machines

Conclusion

We designed and implemented:

- **Lifetime-aware packing algorithm** robust to prediction errors
- **ML model** for VM lifetime predictions
- **System infrastructure** to support ML predictions in the critical path

➢ Packing improvements expected to save hundreds of millions of dollars per year

General methodology for resource management:

1. Produce data-driven intelligence (ML training, simulations) – offline, slower time-scale
2. Utilize the intelligence at real-time ("inference")
3. Applies to other scenarios, e.g., admission control (OSDI'23)

References

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Thank you