Carbon-Intelligent Content Scheduling in CDNs

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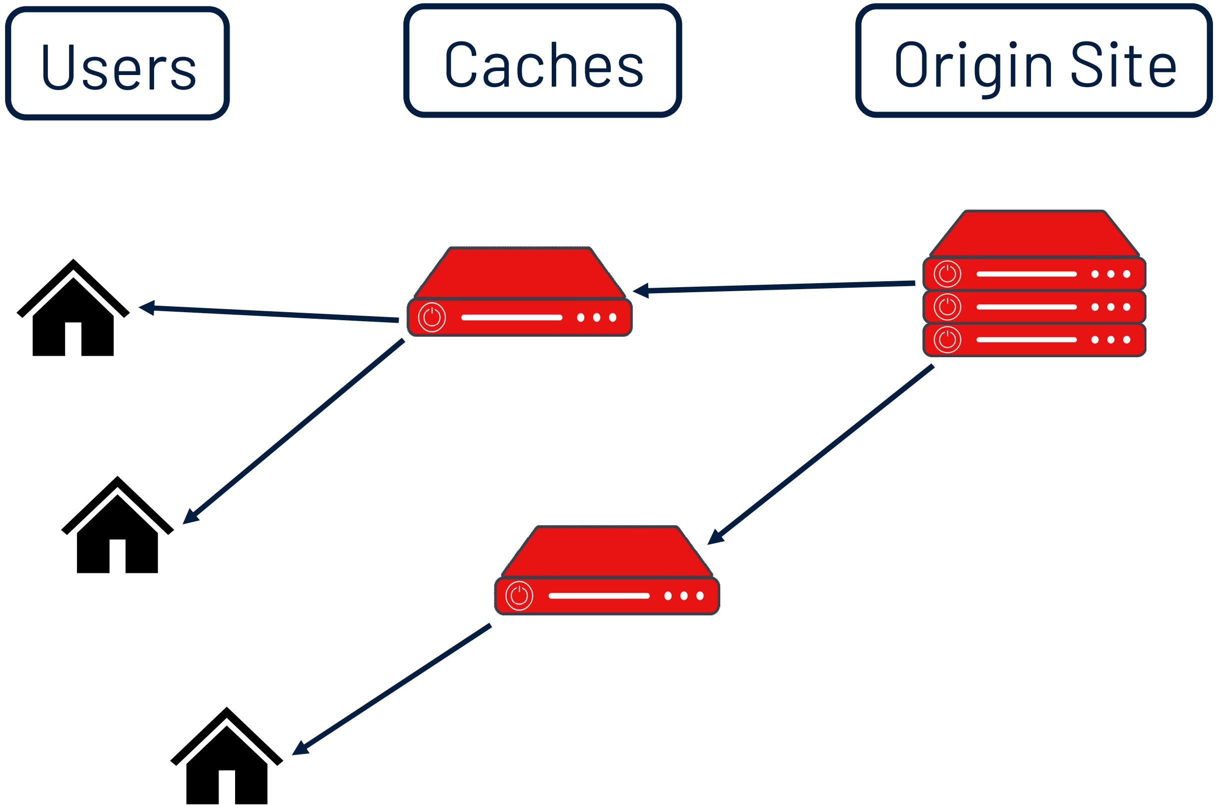
Carbon Cost of Content

- Video traffic is 65% of all downstreaming traffic
- Moving content from origin to servers has a high carbon cost
- Can we make it greener?



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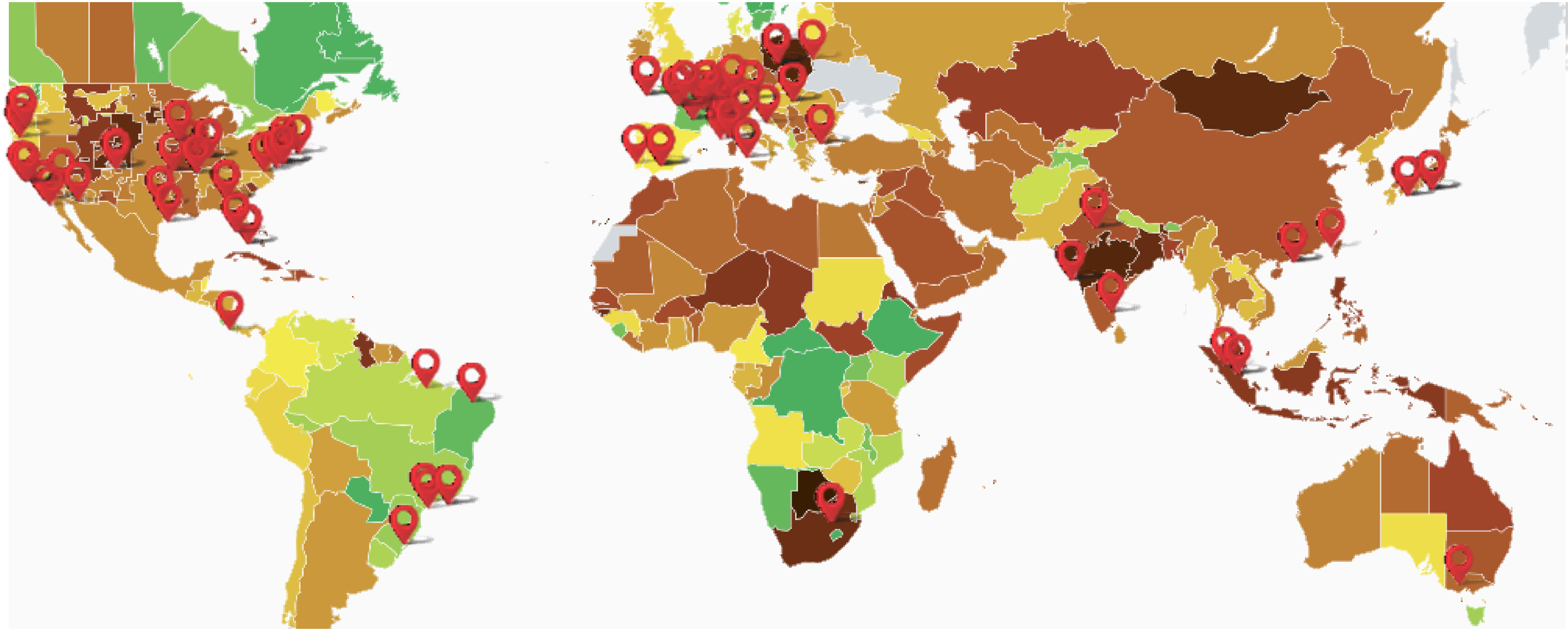
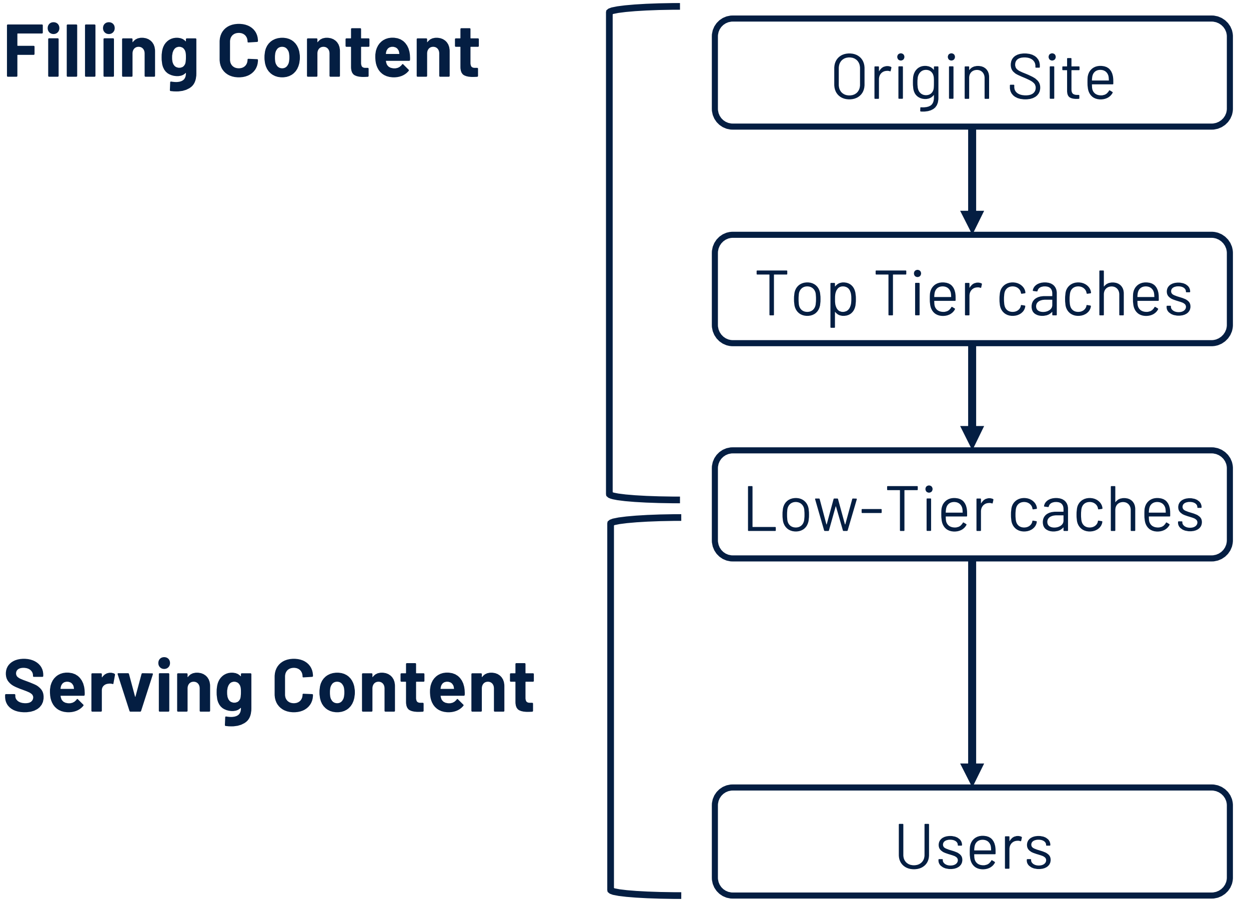


Scope

- Goal: carbon-aware content filling
- Focus on content fill
- Prepositioning content → scheduling
- Leverages the variability in carbon intensity
- Netflix as a Use-case



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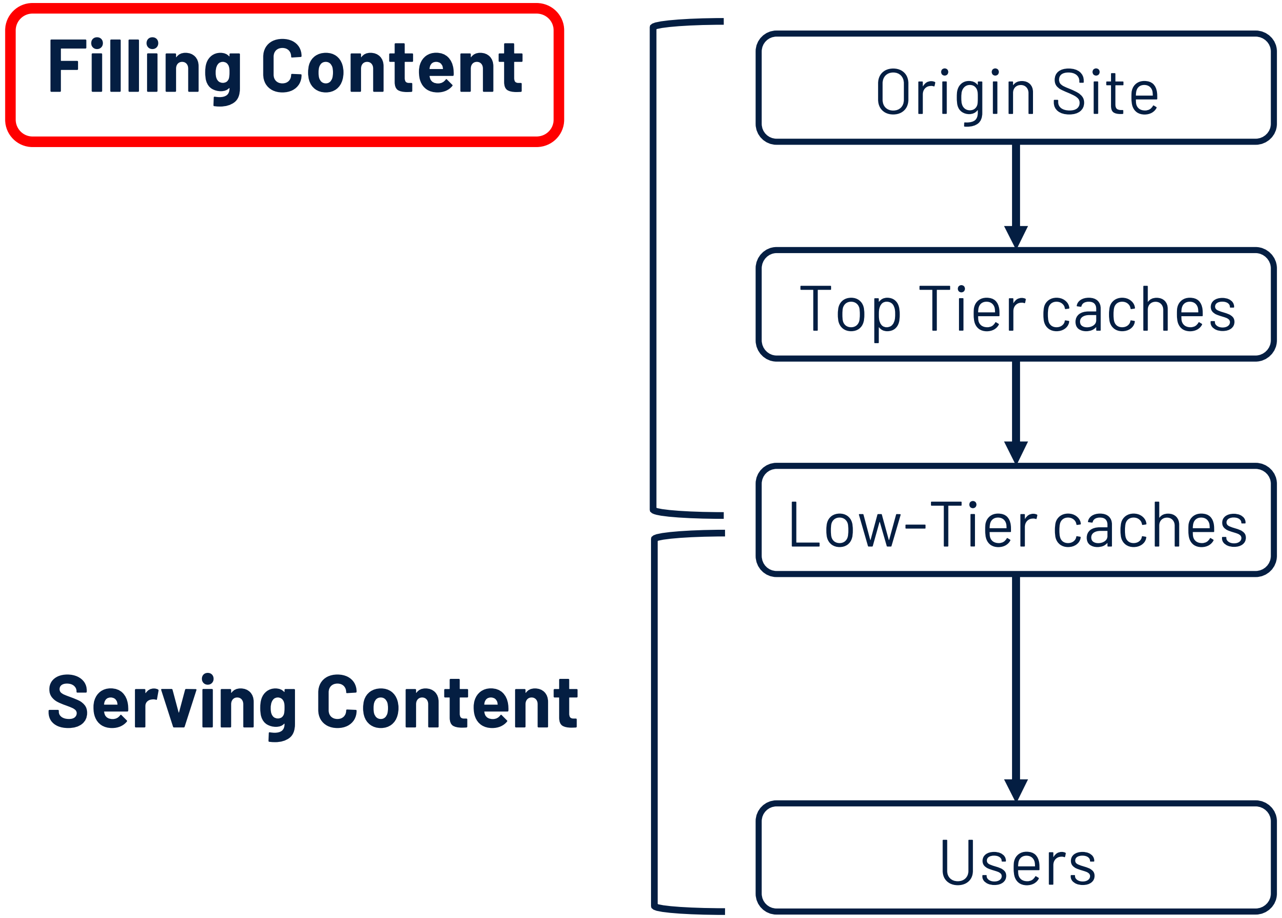
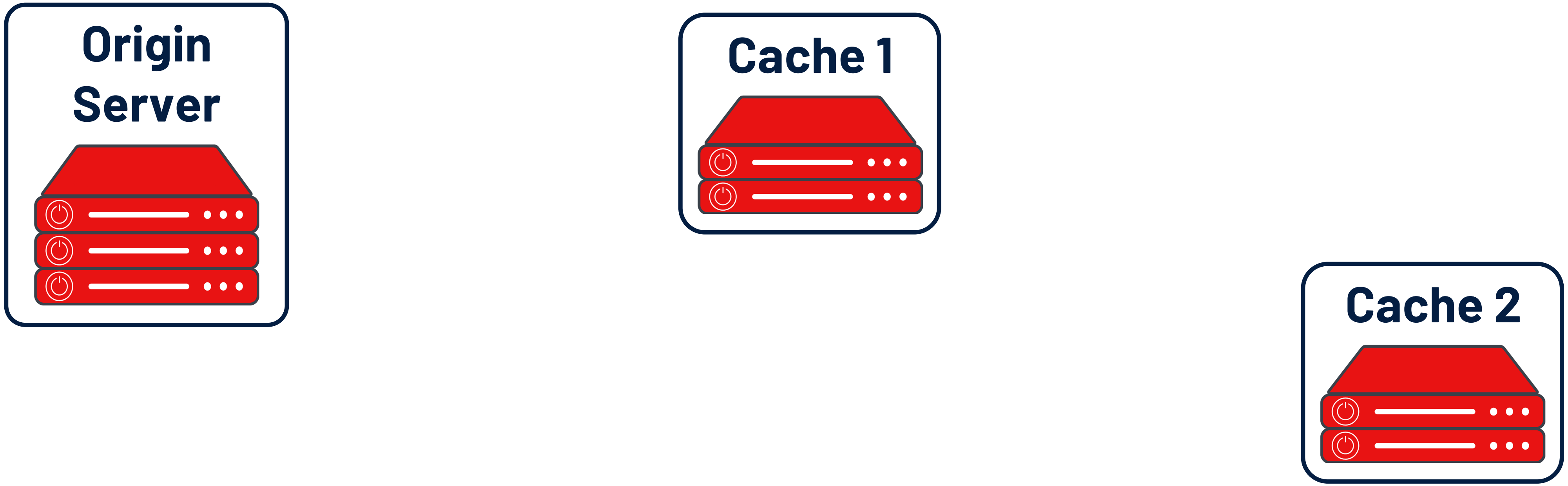


Traditional Scheduling

- Content fill happens during off-peak hours



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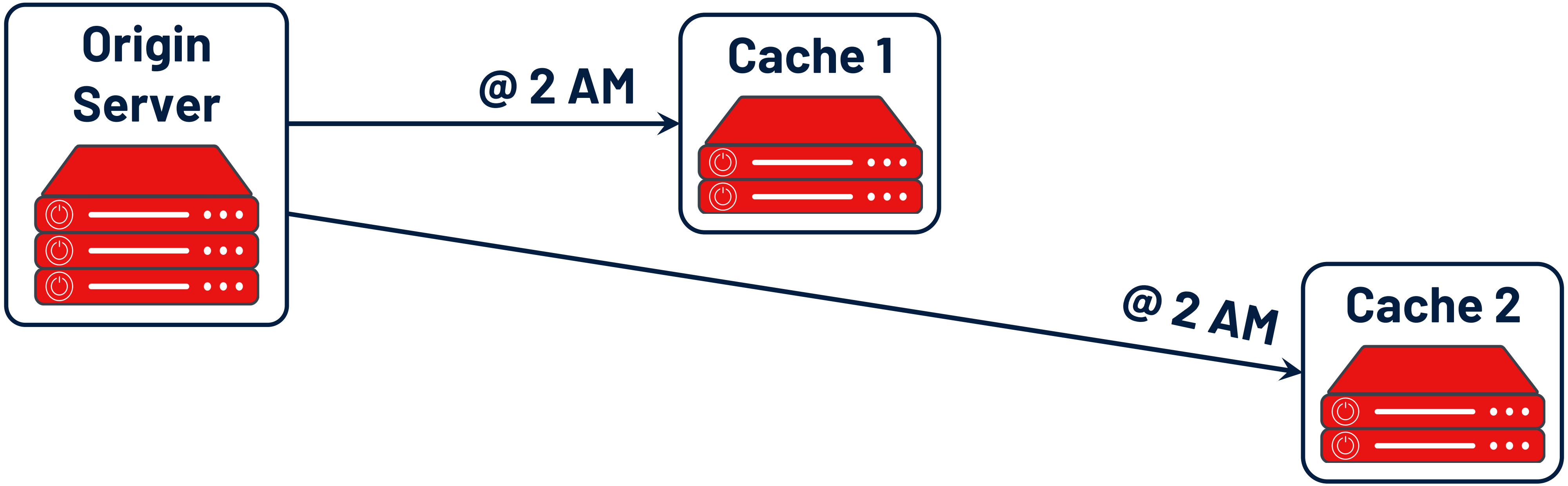
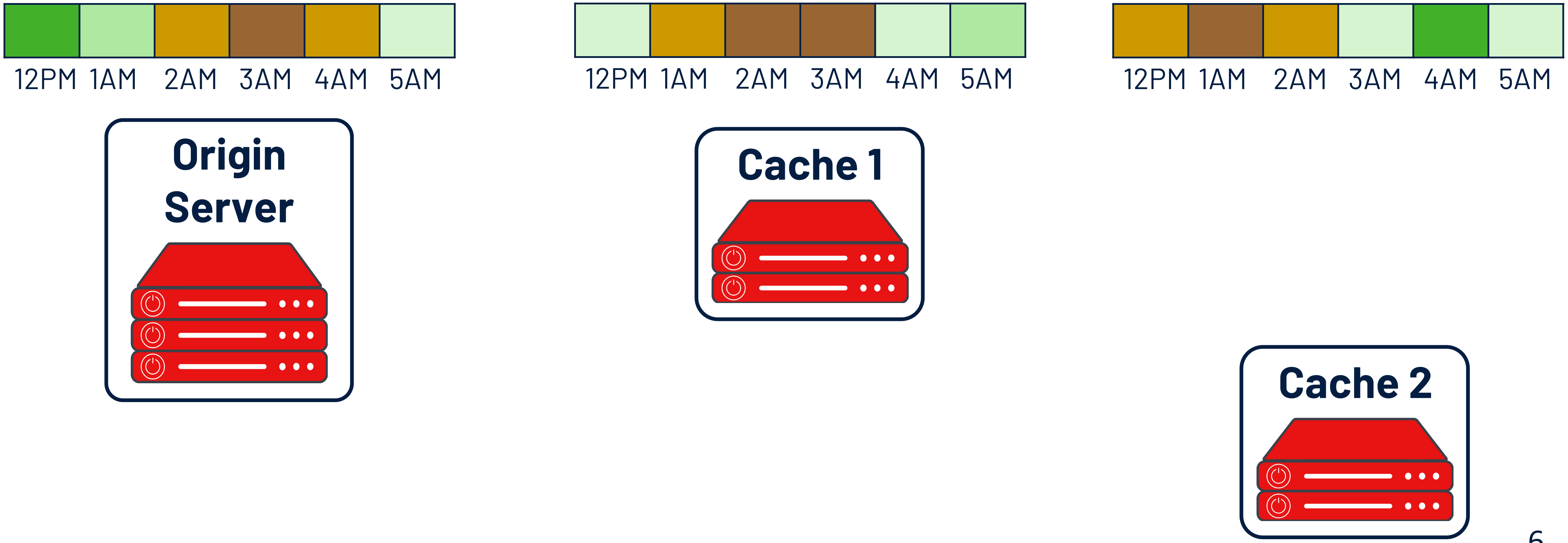


Carbon-Aware Scheduling

- Within off-peak hours, carbon intensity varies per hour



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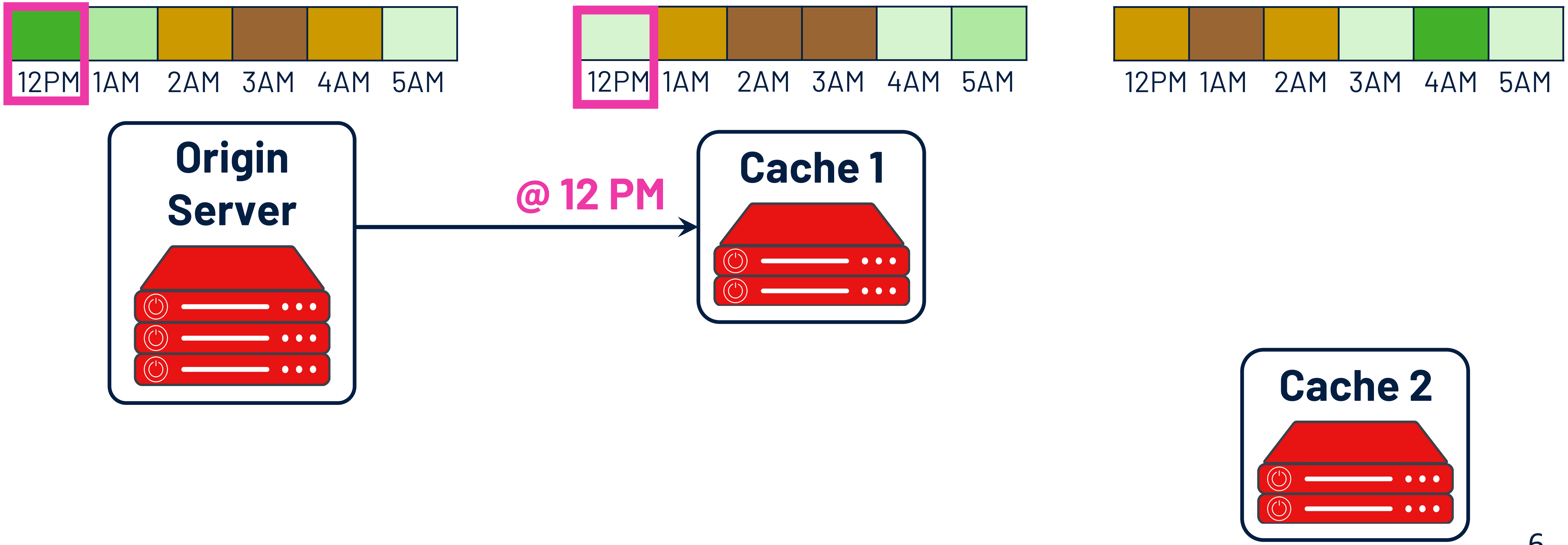

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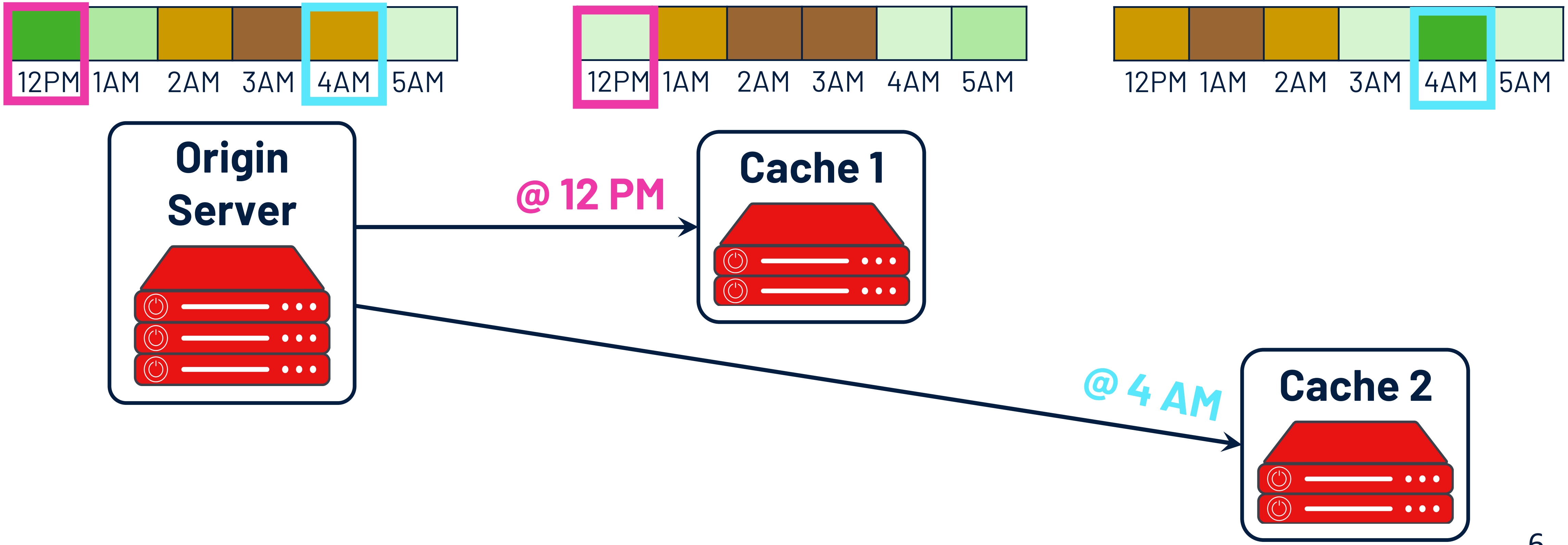
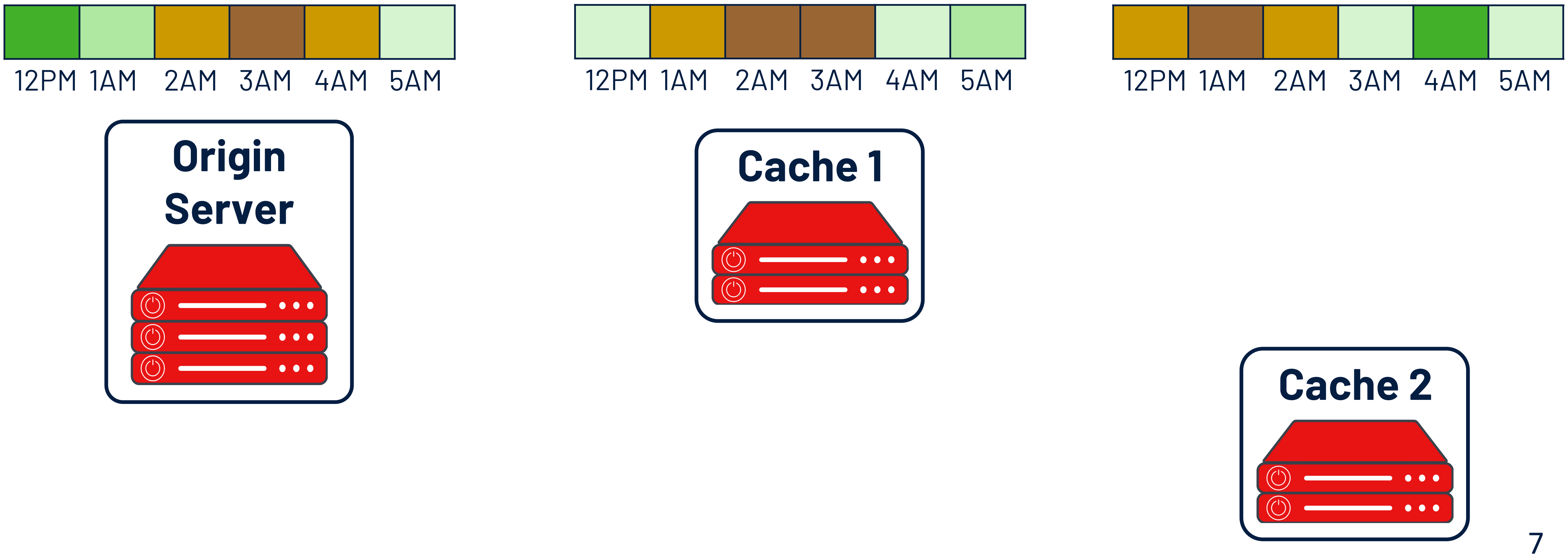


Carbon-Intelligent Scheduling

- Allow multi-hop transmission
- Similar to delay-tolerant networks (DTN) behaviour



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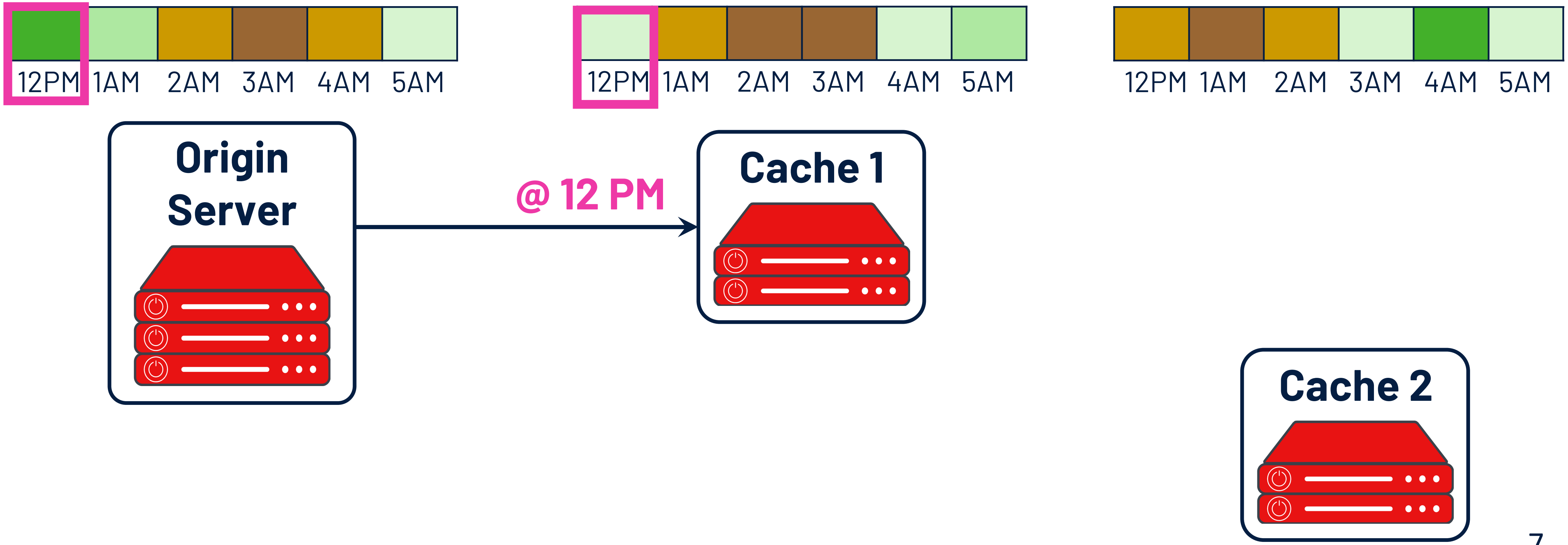

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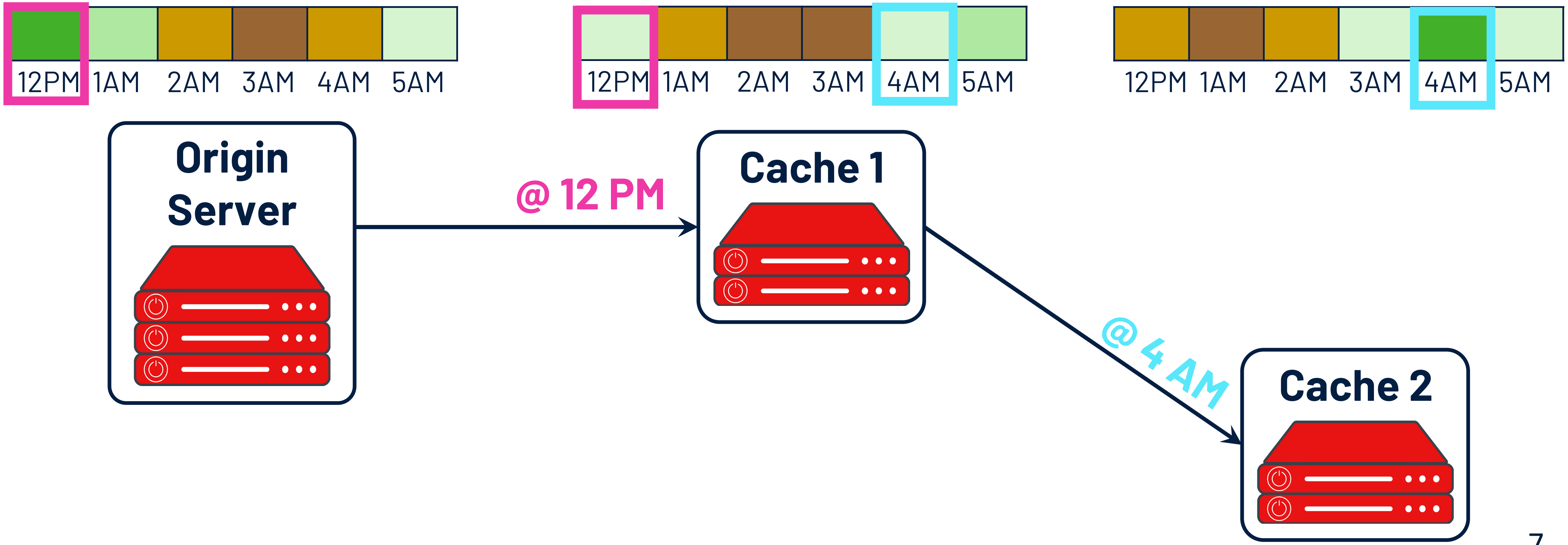
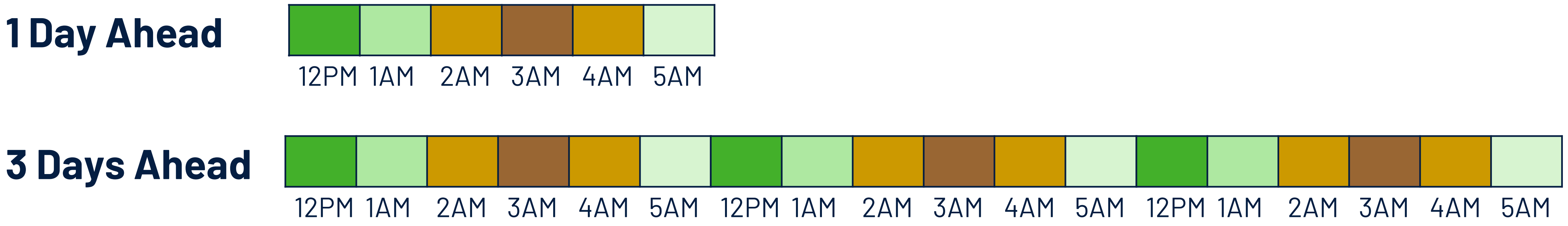


Data Collection

- Open source dataset
- Netflix peering points
- Netflix Top 10 to estimate new content
  - Number of cumulative weeks in top 10 per title
  - If content is in top 10 for the 1st time → new content
  - Average content distributed weekly is 3.53 TB (distributed to each cache)
- Carbon intensity data collected from Electricity Maps
- Data for the year 2023

Approach

- Tested the 3 cases: naïve, one-hop and multi-hop scheduling
- Problem formulated as Mixed-Integer Linear Programming (MILP)
- Tested different time windows for content distribution



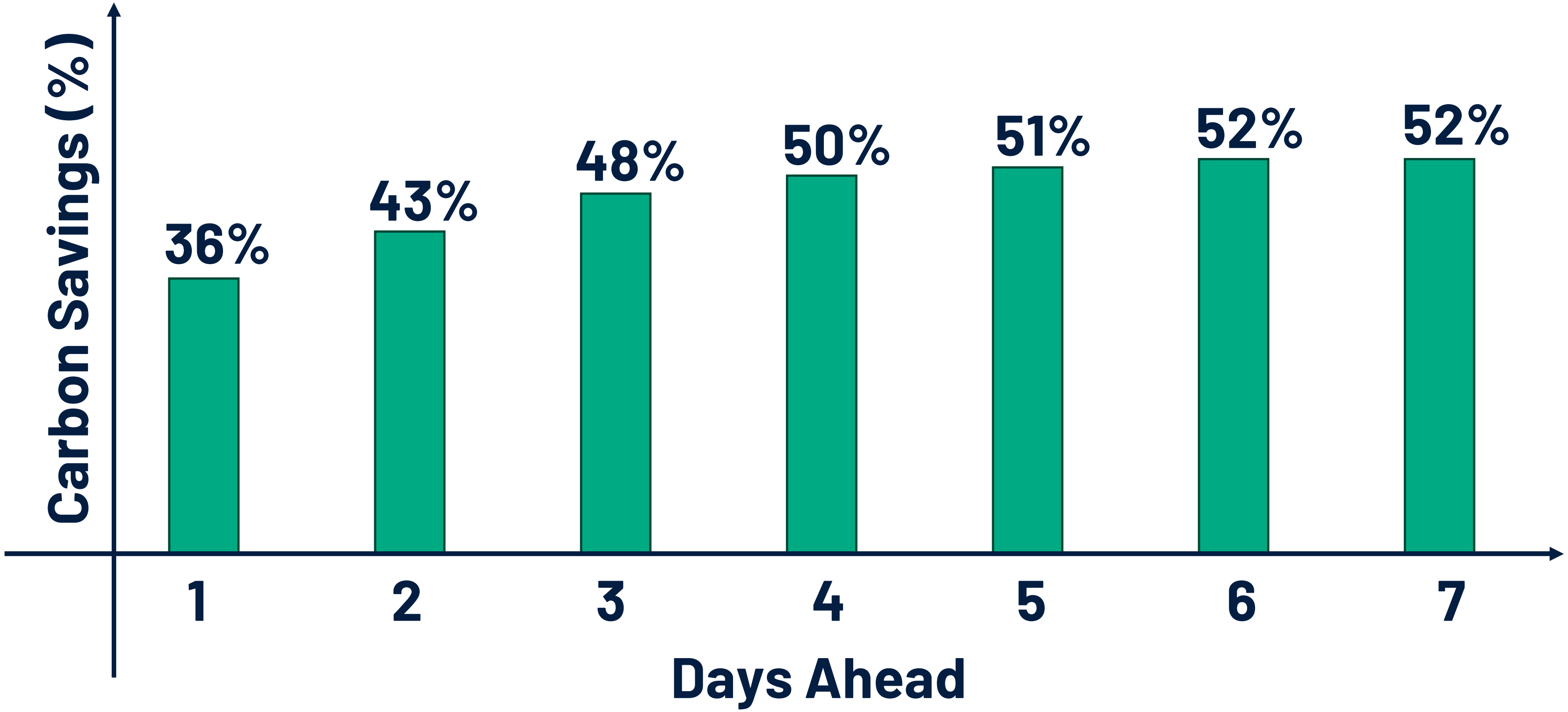
Results: Carbon Savings

- Savings for Europe sites are higher than the US
- No violation of off-peak hours constraint
- Savings achieved without changes to infrastructure

Strategy	US Savings	Europe Savings
One-Hop Scheduling	13%	17%
Multi-Hop Scheduling	53%	64%

Results: Scheduling Window

- Savings increase if scheduling time window is higher
- Plan at least 3 days ahead to get the highest carbon savings possible.



Other Lessons Learned

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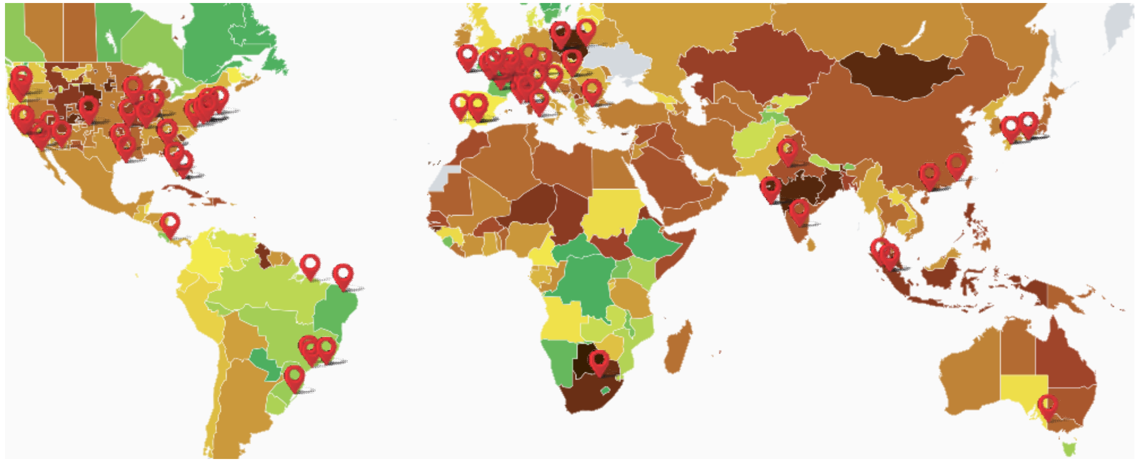
1. Carbon-intelligent approach uses same energy while saving on operational carbon.
2. Algorithm applicable to many prepositioned content delivery workload (e.g., VoD, software updates, game releases).
3. Weekly schedules can be planned at different time frames: weekly, monthly, annually…
   - A fixed annual schedule can still have 39-47% carbon savings.

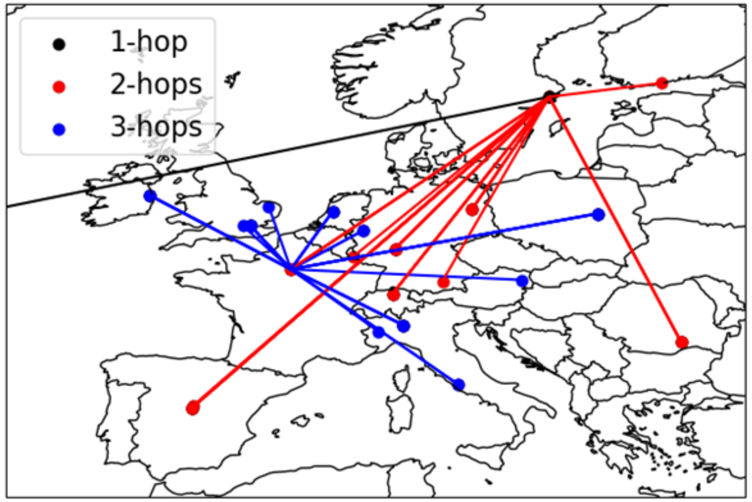
Summary

1. Proposed a carbon-intelligent content scheduling algorithm for CDNs.
2. Demonstrated the approach on Netflix's Open Connect dataset, achieving up to 64% reduction in operational carbon emissions.
3. Validated that emission reductions are possible without violating traffic constraints or modifying infrastructure.
4. Ongoing work: cache-to-user delivery and cache placement optimization.

Questions?

Code is available! https://github.com/ox-computing/CICS





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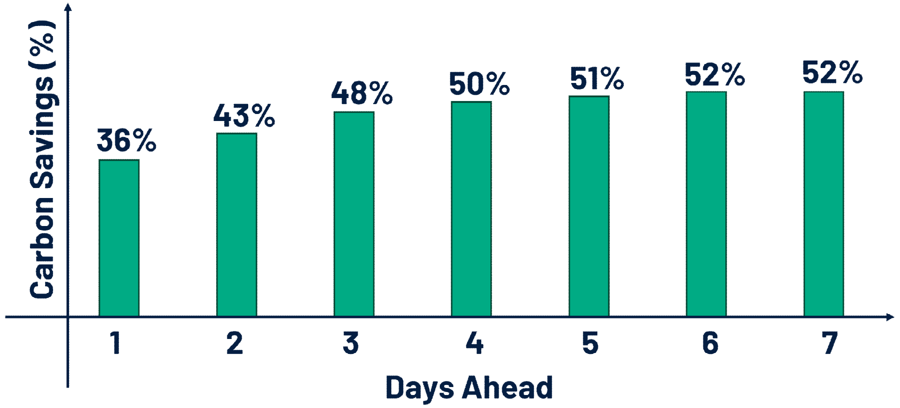

Backup Slides

Carbon Model

- Considered caches
- Only scope 2 emissions
- Dynamic Power: proportional to the utilization