Stream2LLM: Overlap Context Streaming and Prefill for Reduced Time-to-First-Token

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Georgia Institute of Technology

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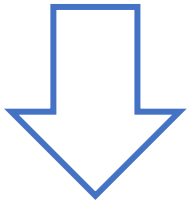
LLMs benefit from context retrieval



parametric knowledge

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External Knowledge Source

- Dense retrieval (e.g., vector search)
- Sparse retrieval (e.g., BM25)
- Tool use (e.g., web crawling)
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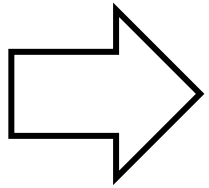

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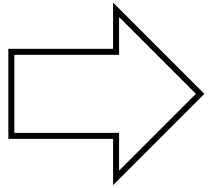

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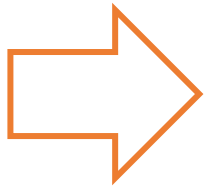
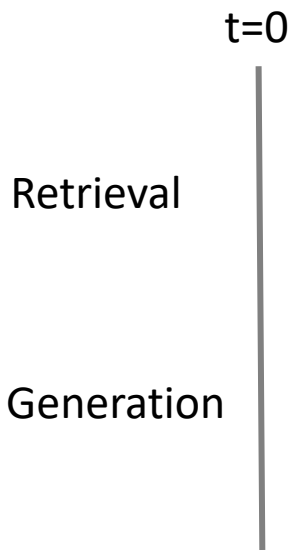


External Context

Context retrieval hurts request latency



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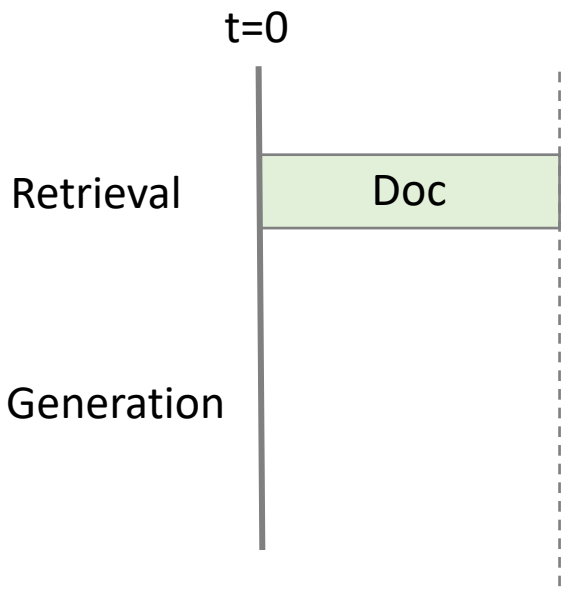
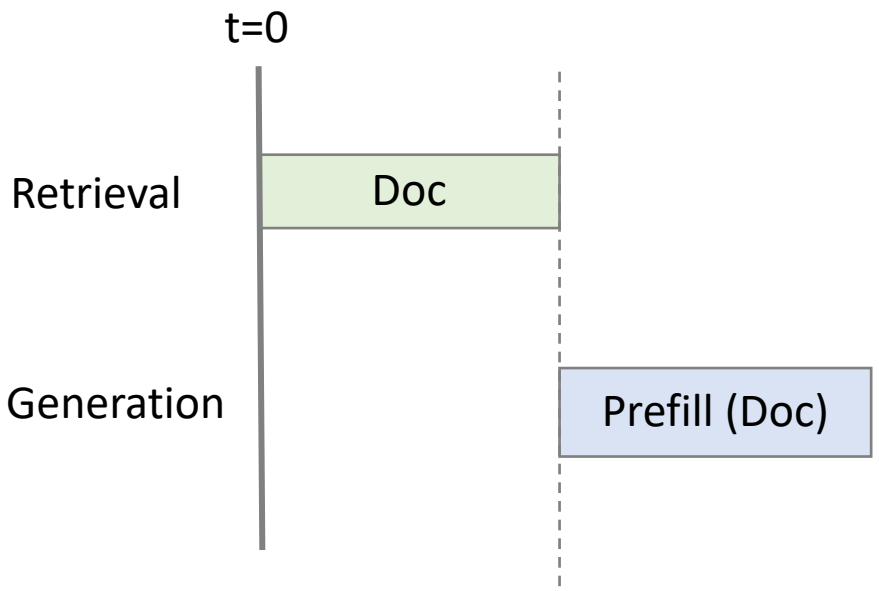
Retrieval latency



Context retrieval hurts request latency

Retrieval latency + *Prefill latency*



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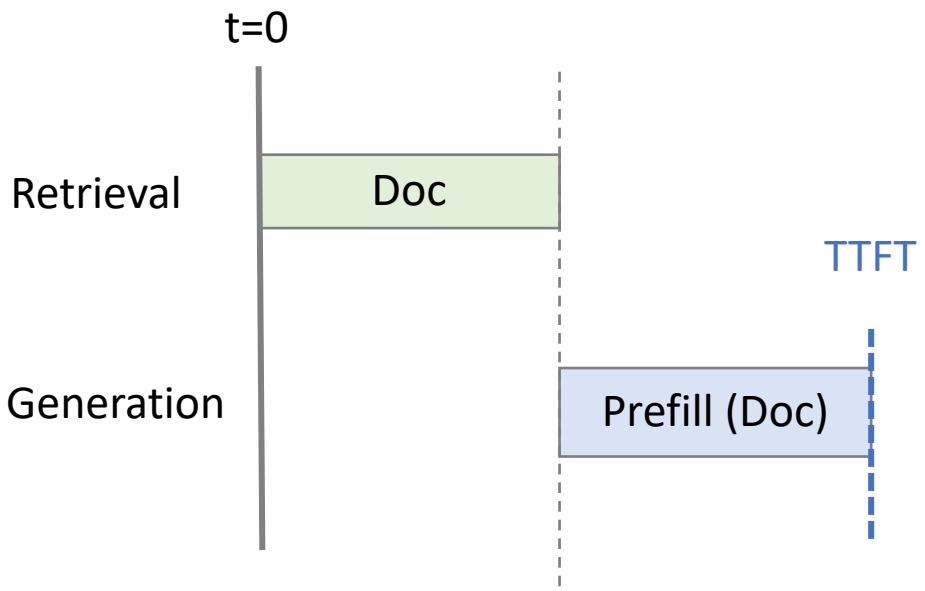
Time to First Token = Retrieval latency + Prefill latency



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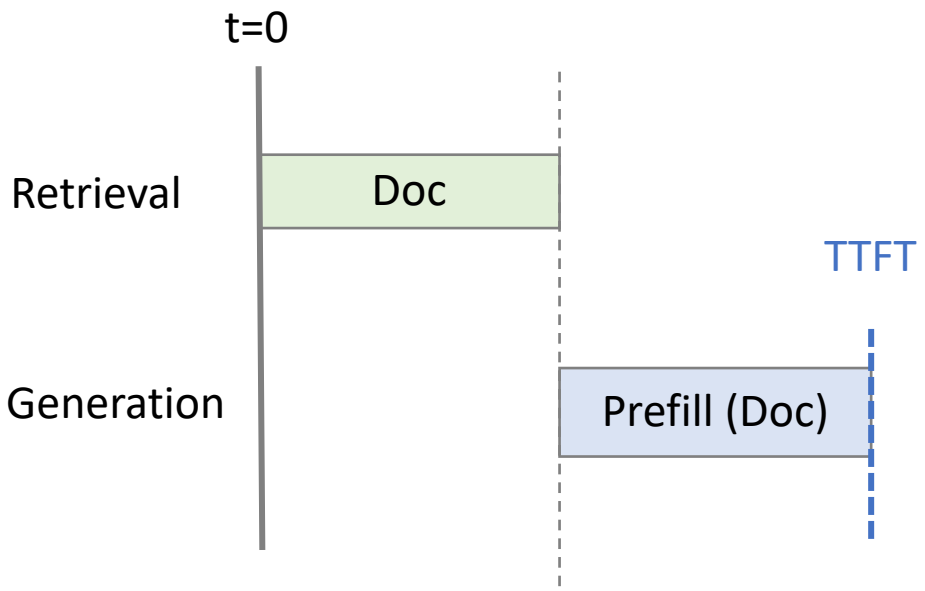
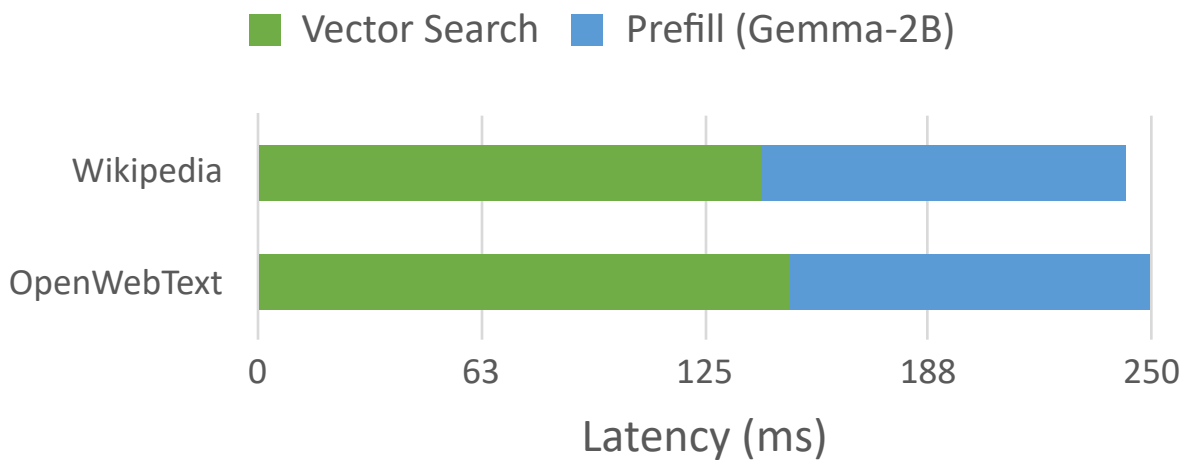
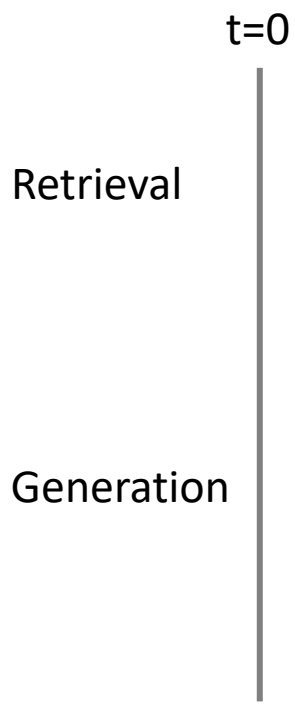




Stream2LLM: Streaming LLM Inference

Goal: Overlap retrieval and prefill to reduce TTFT



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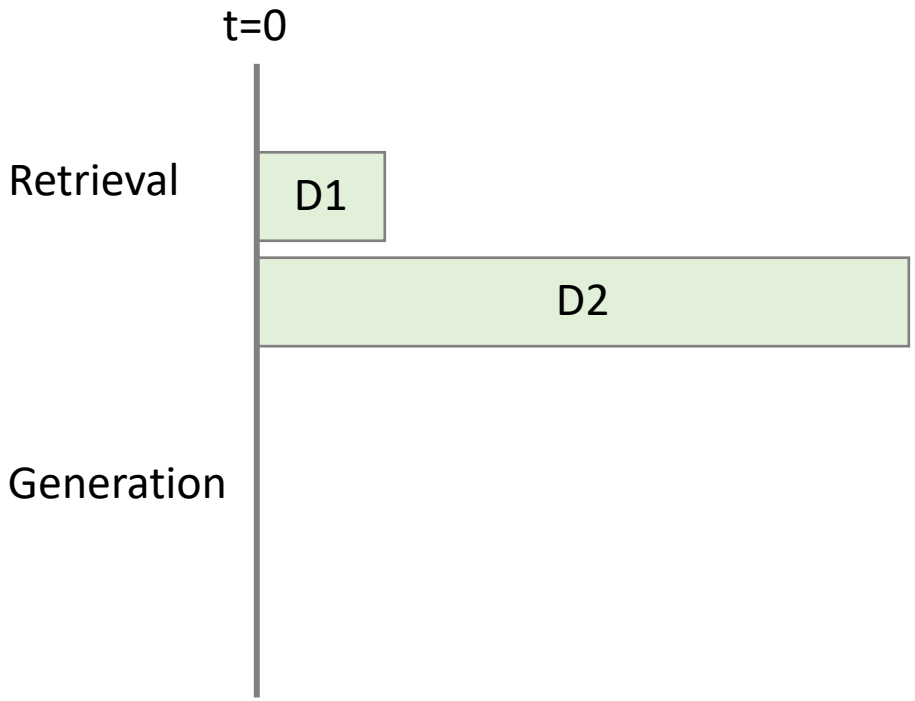

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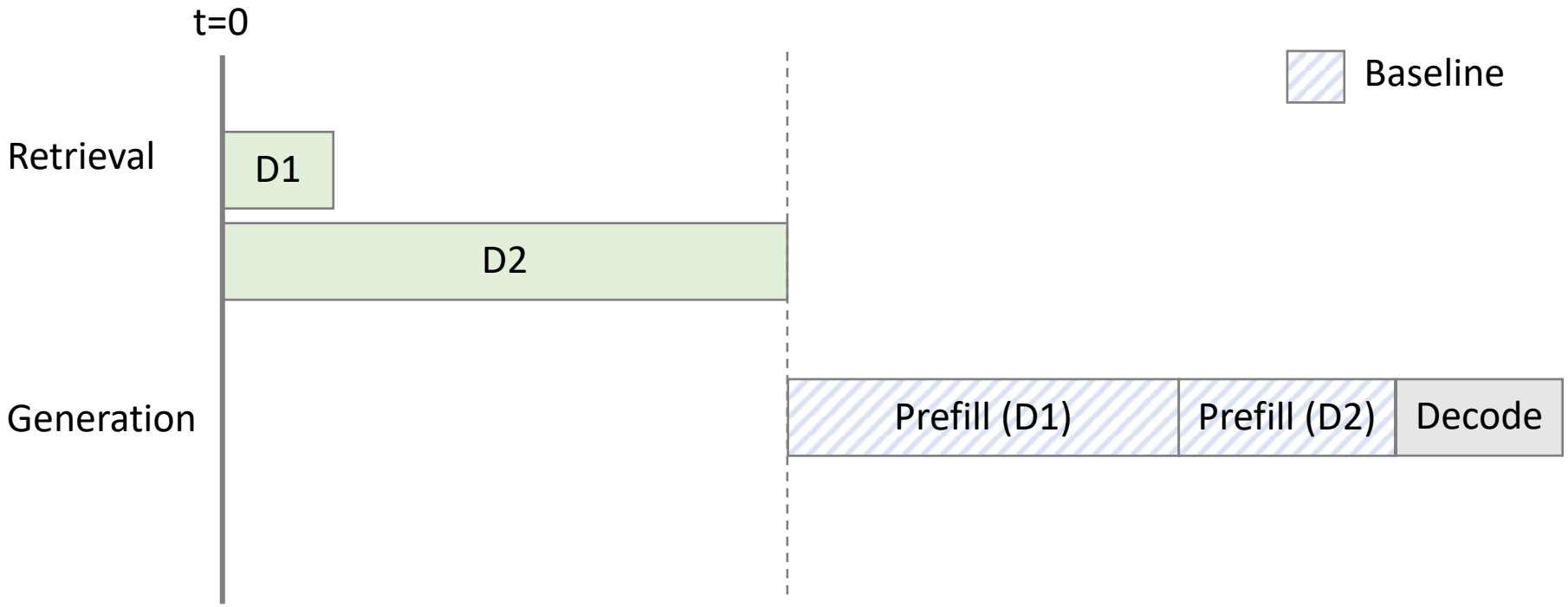

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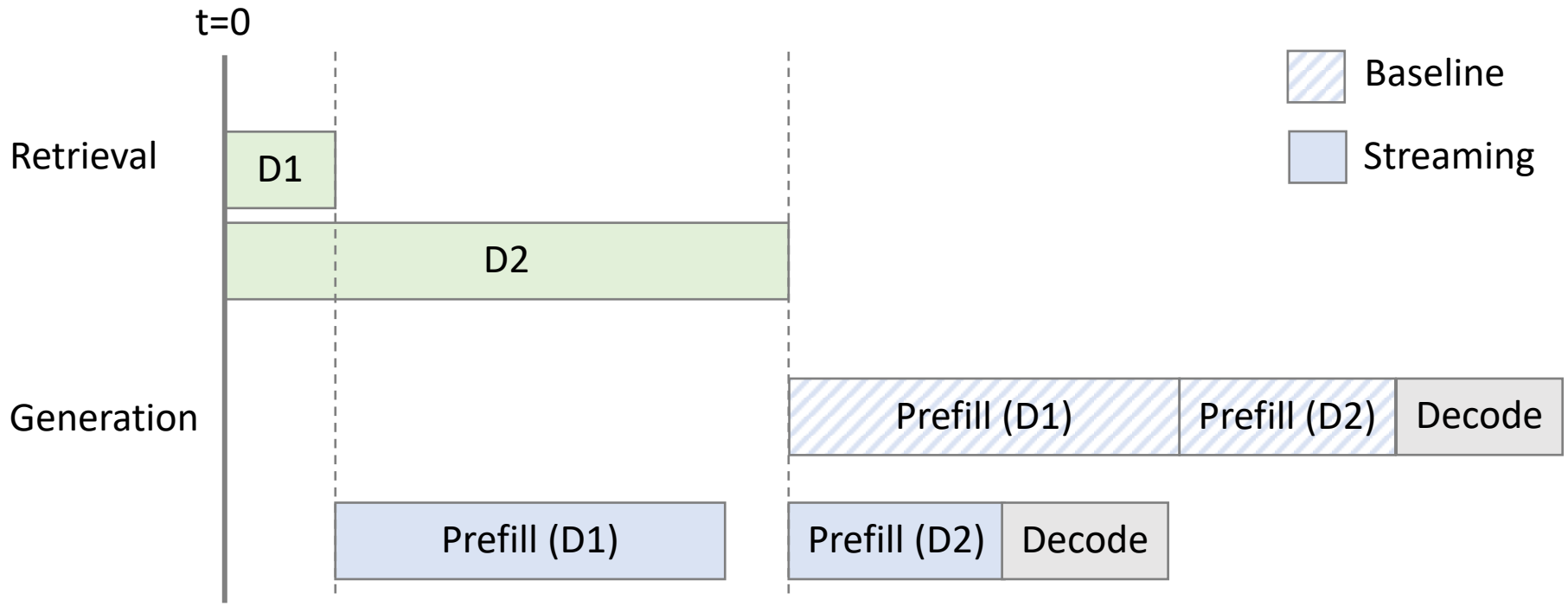

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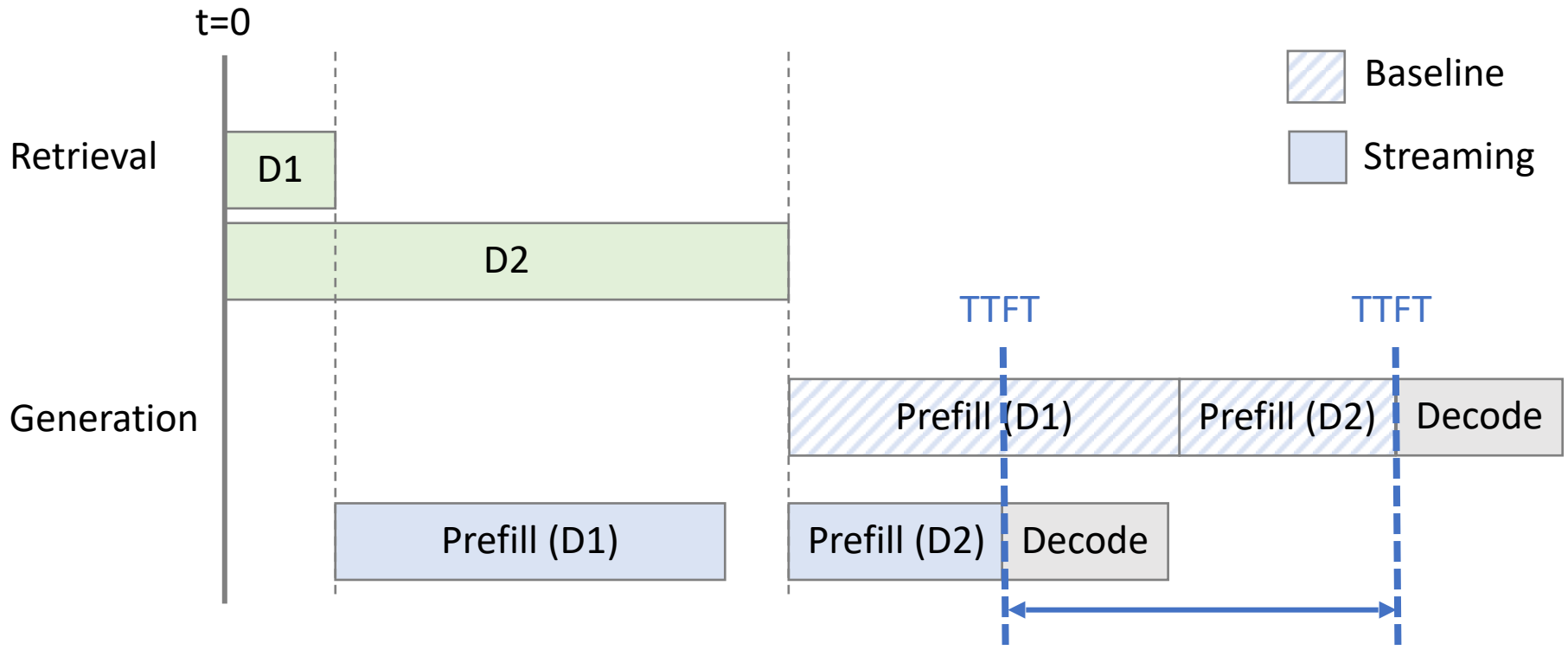

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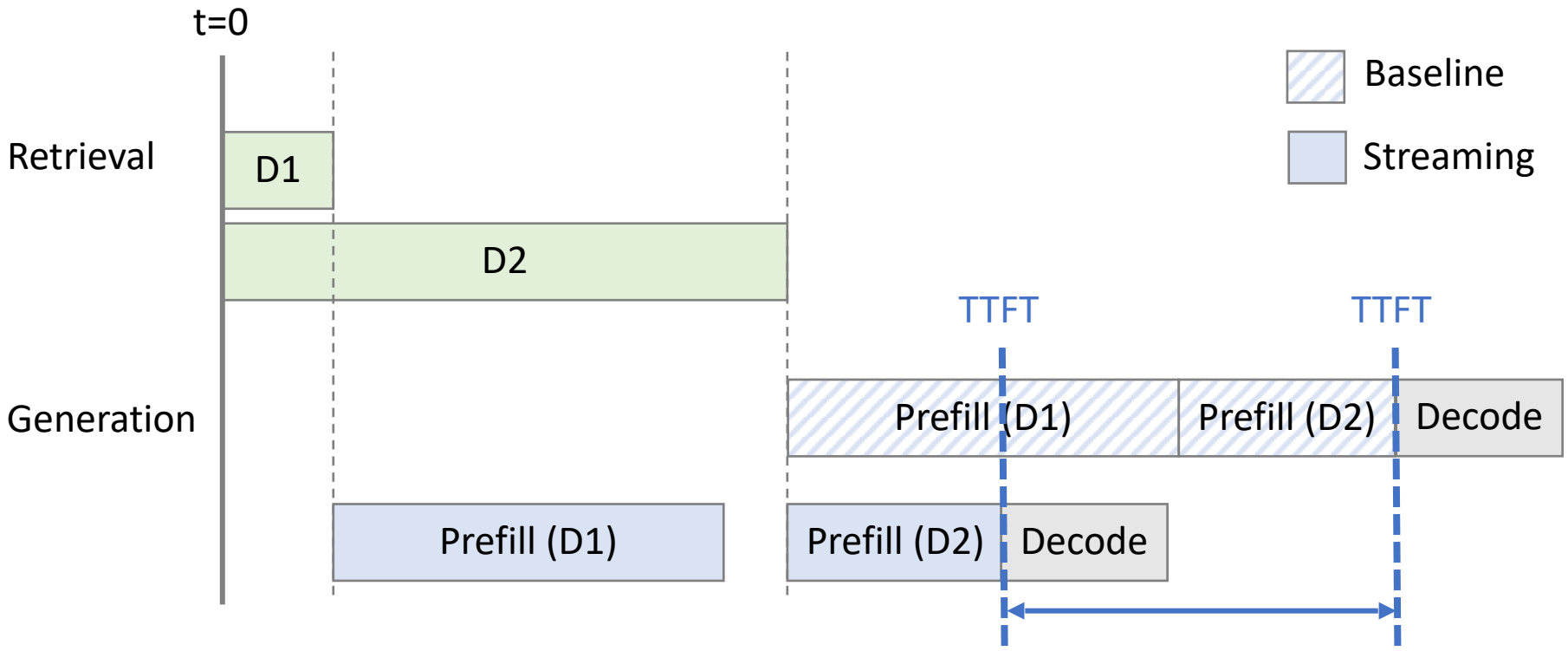
Deployment setting: prefill instances in P/D disaggregation

* Implemented on top of vLLM



Challenges with Context Streaming

Each iteration, the scheduler allocates compute (token budget) and memory (KV cache) across requests without knowing:

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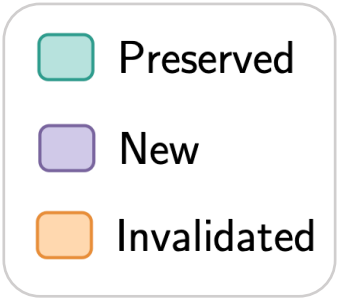
Gap: multi-tenant, streaming inference.

Characterize Retrieval Workloads

Two distinct behavior modes:



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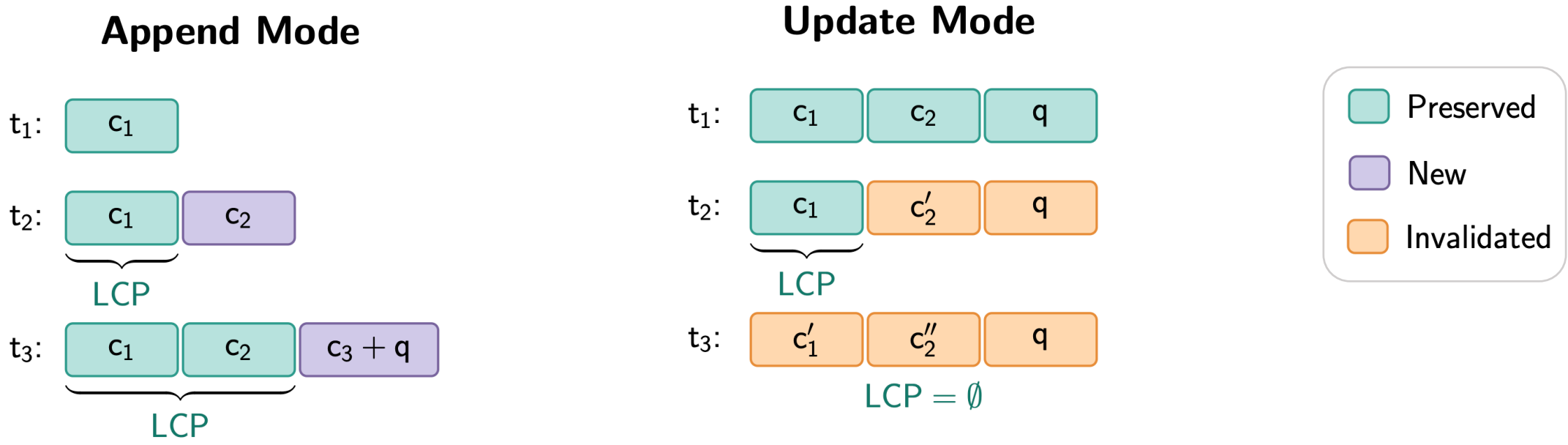

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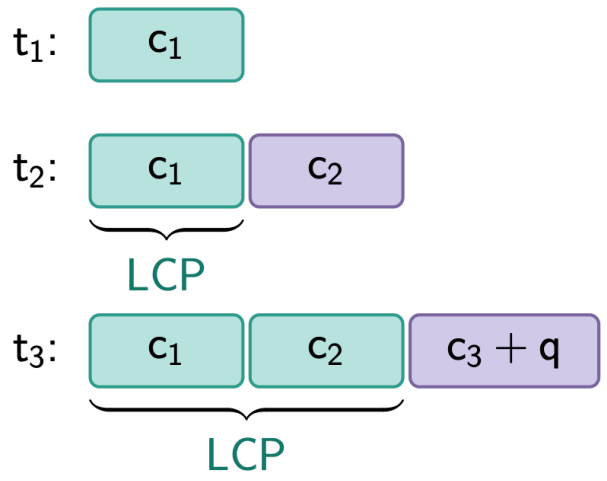
- Iterative refinement (e.g., vector search)
- Update could invalidate cache

Characterize Retrieval Workloads

Two distinct behavior modes:

Require different scheduling and cache management mechanisms

Append Mode



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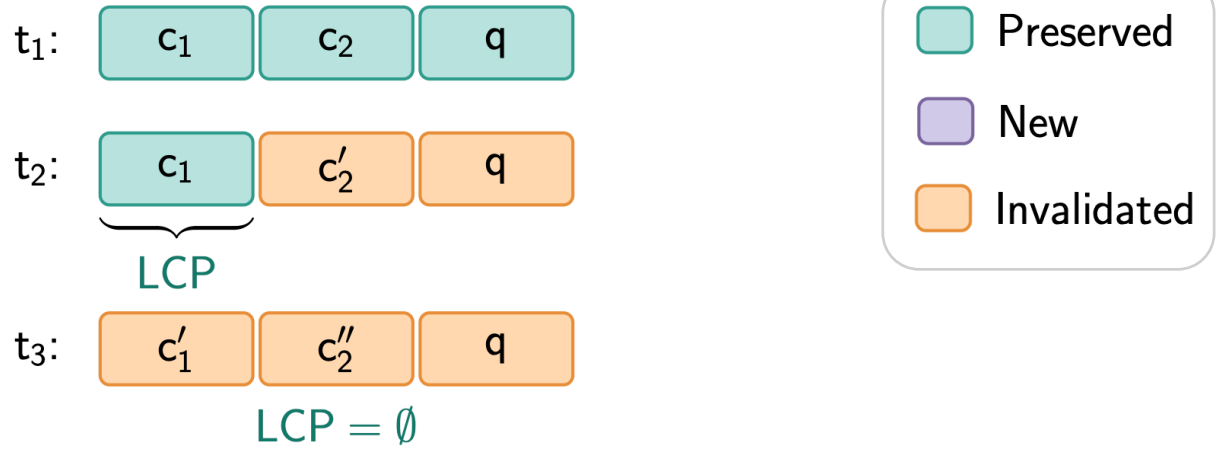
Update Mode



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Two-Phase Scheduling

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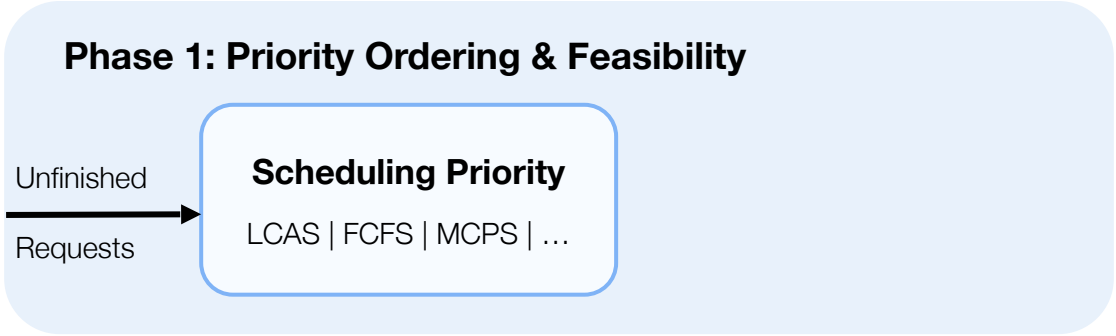
Select requests based on priority; check feasibility



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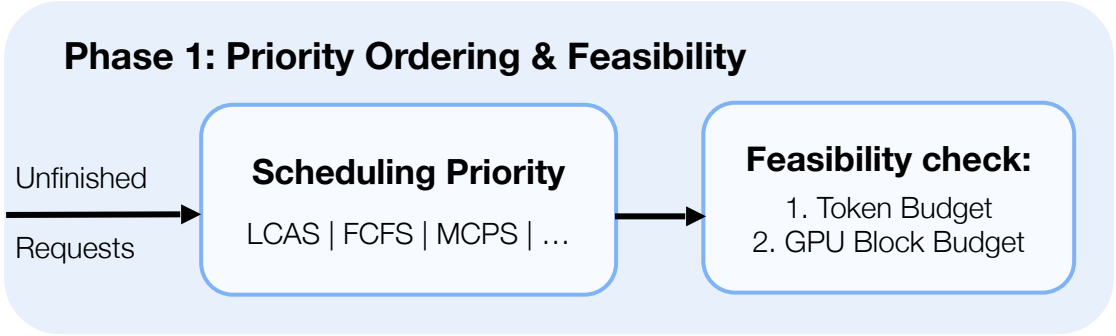

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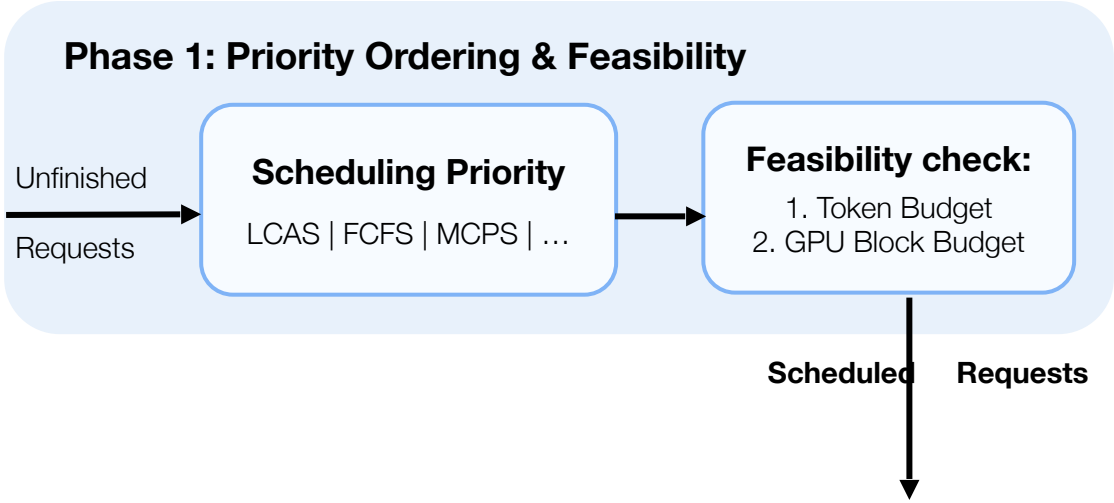

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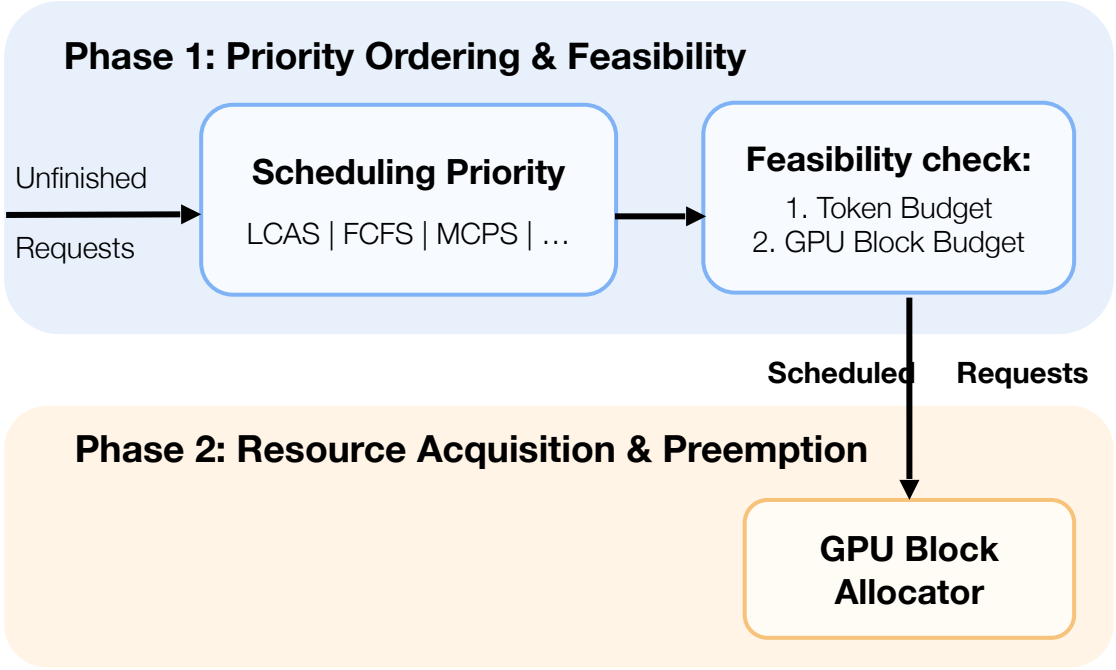

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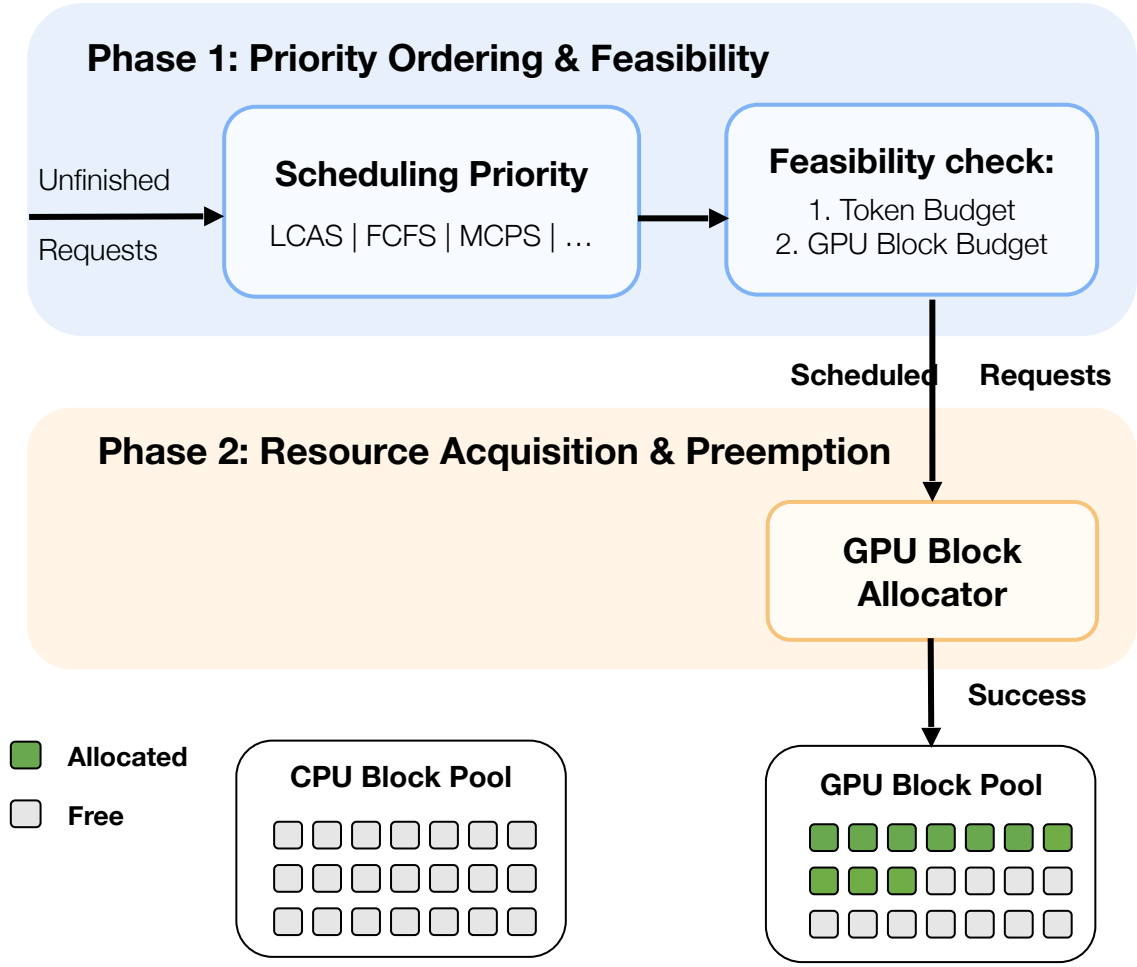

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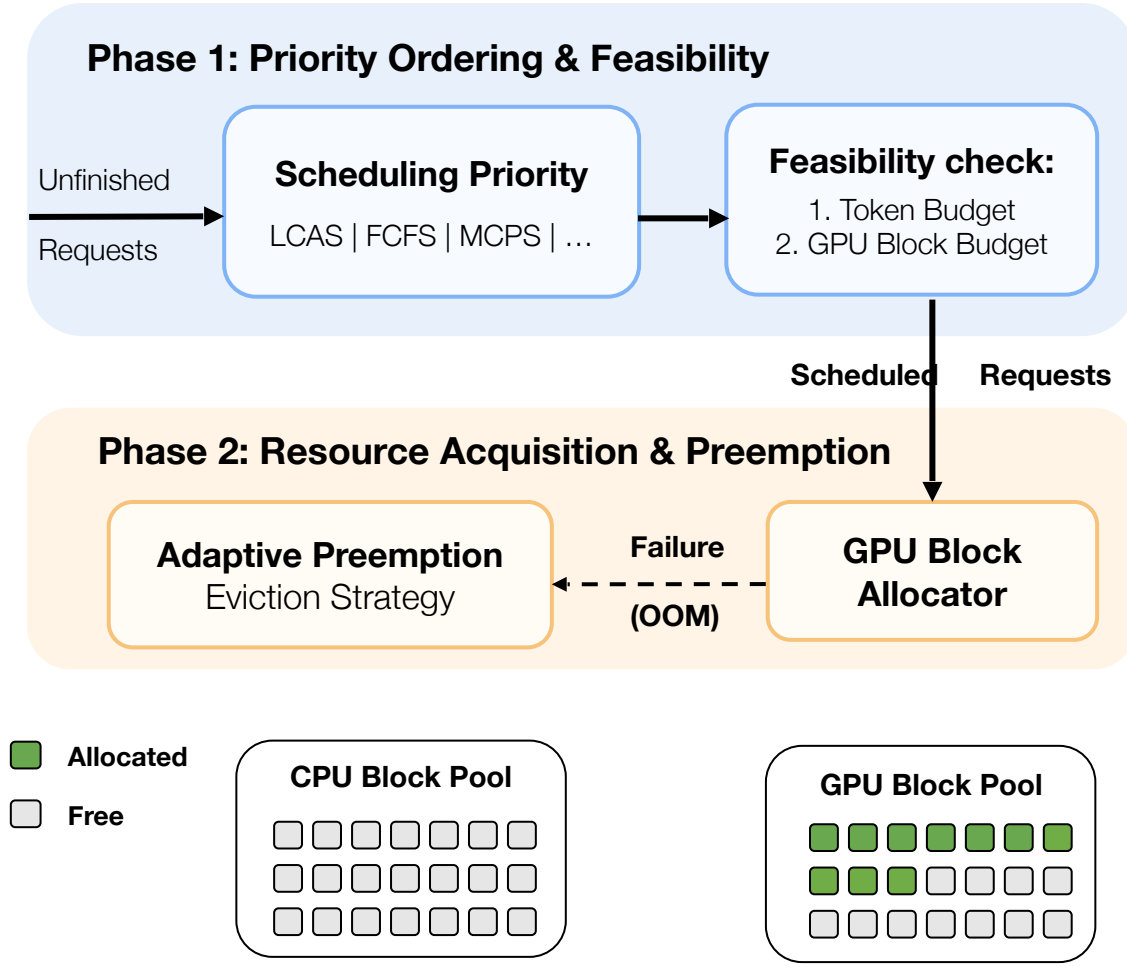

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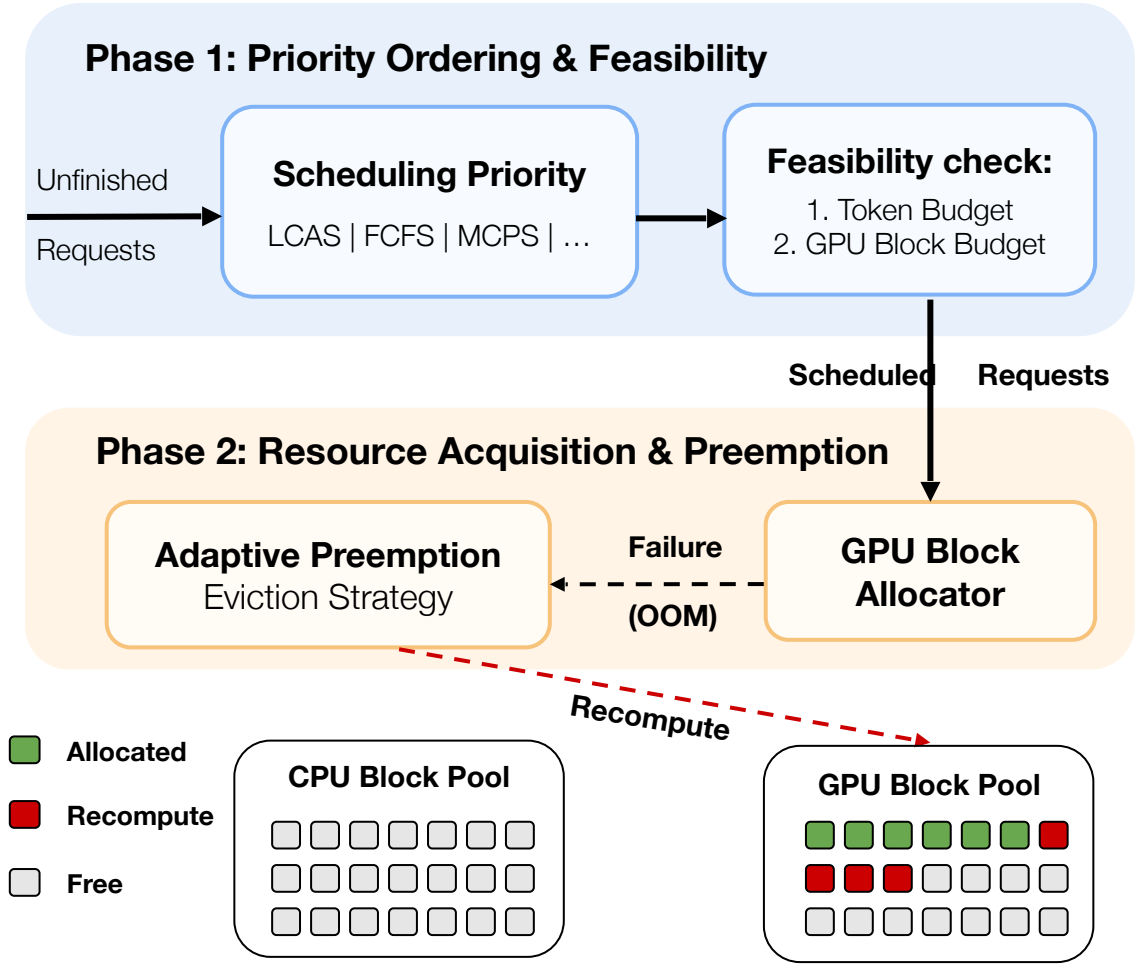

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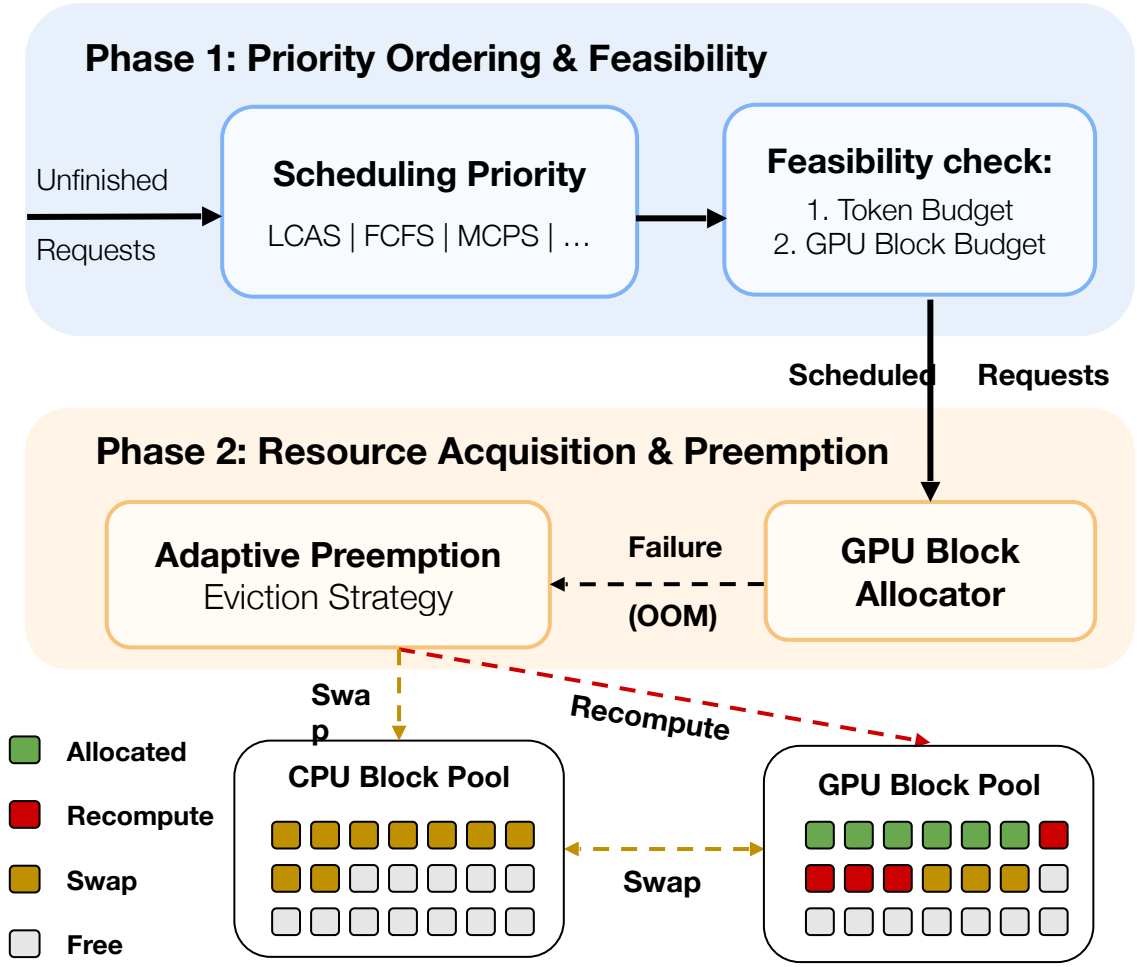

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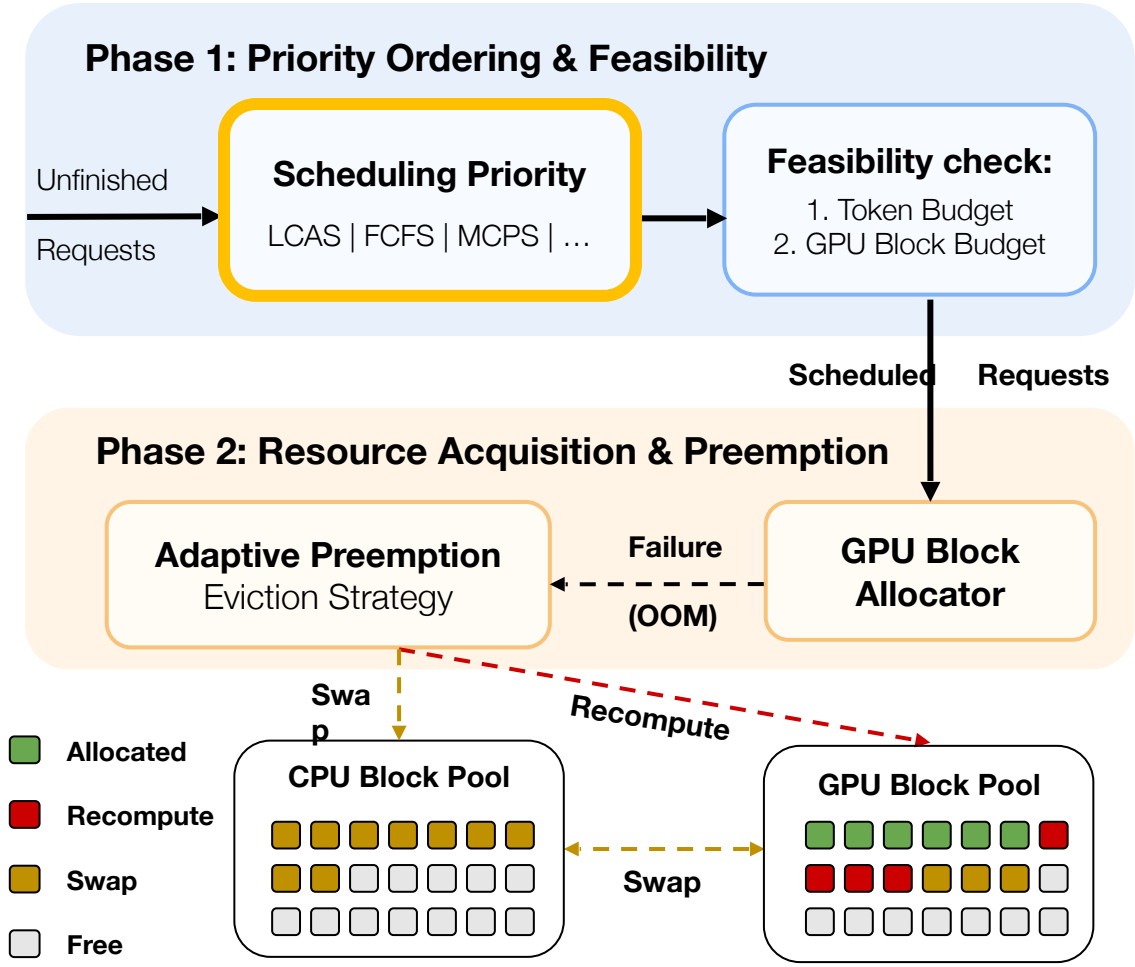

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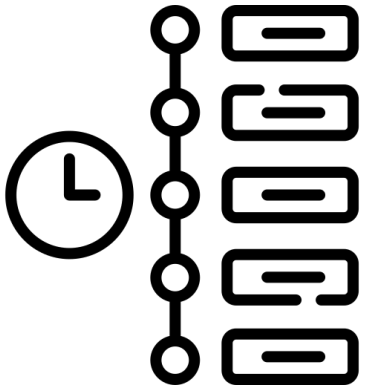
**Eviction in reverse scheduling priority*



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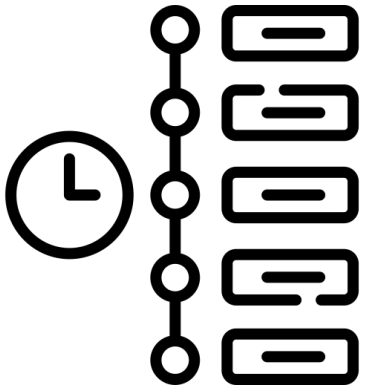

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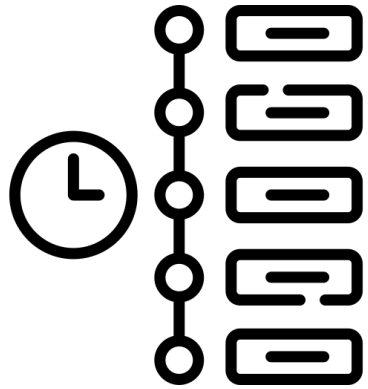

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First-Come-First-Served (FCFS)

- Sort request in each tier using request arrival order

Last chunk arrival time (LCAS)

- Sort request in each tier using last chunk arrival time

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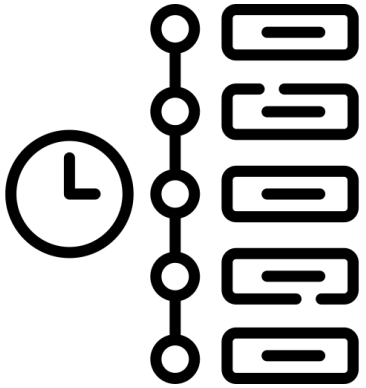

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Two-tier approach:

- *Intuition: Complete requests have higher priority over Partial*

Evaluation Setup

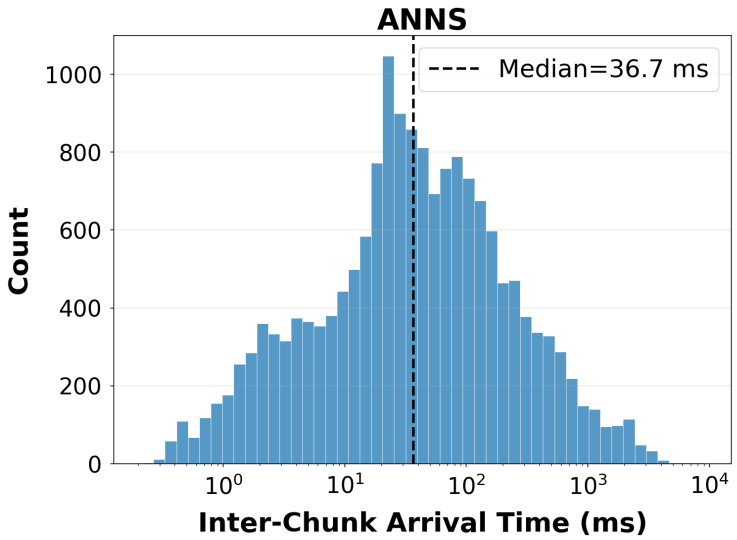
Model: Llama-3.1-8B-Instruct

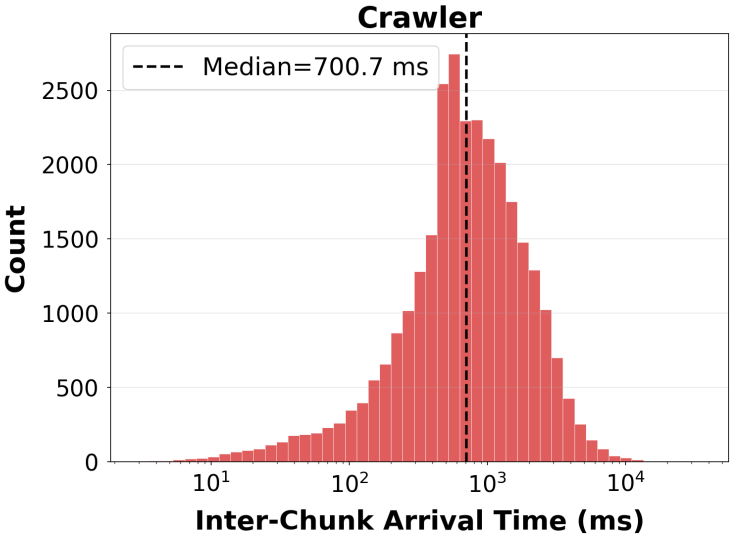
Hardware: H200 (TP=2)

Baselines: vLLM-NS vLLM-S

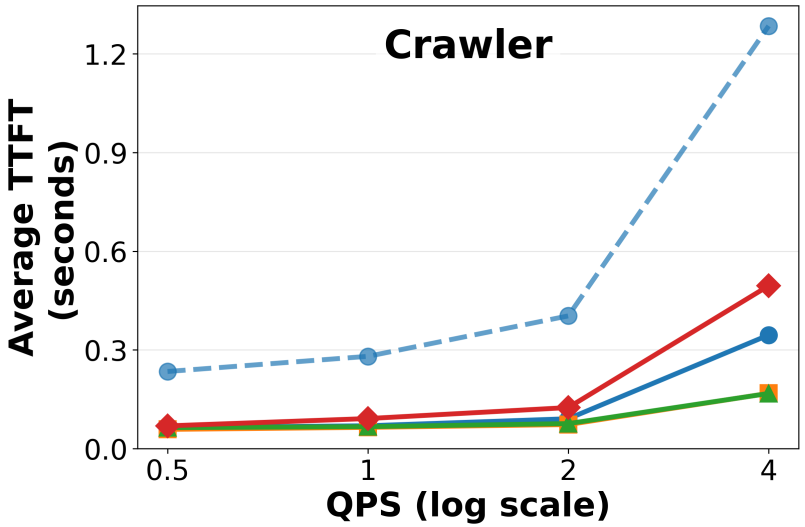
Retrieval Workloads:

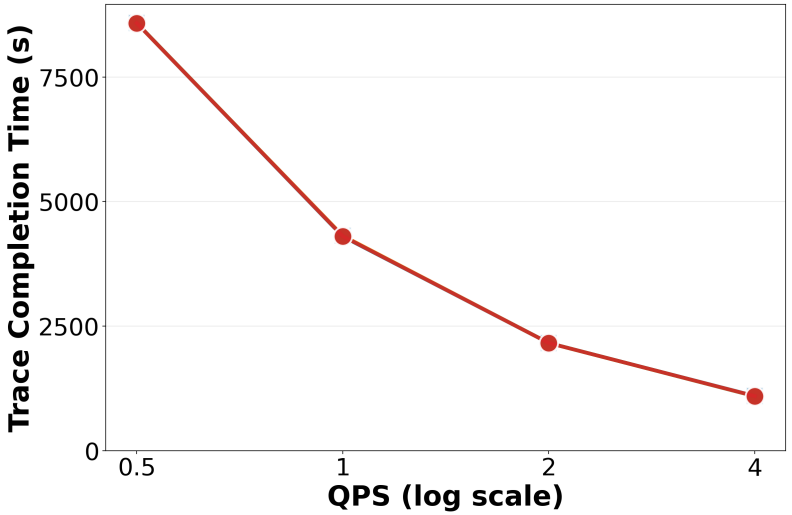
- Append – web crawler
  - Latency: median: 3.9s, P95: 8.5s
  - #Tokens/Query: median: 10K, P95: 31K
- Update – diskANN (AquaPipe [SIGMOD'25])
  - Retrieval Latency: median: 9.3s, P95: 16.7s
  - #Tokens/Query: median: 5.8K, P95: 28.9K





Evaluation (Append): TTFT vs QPS





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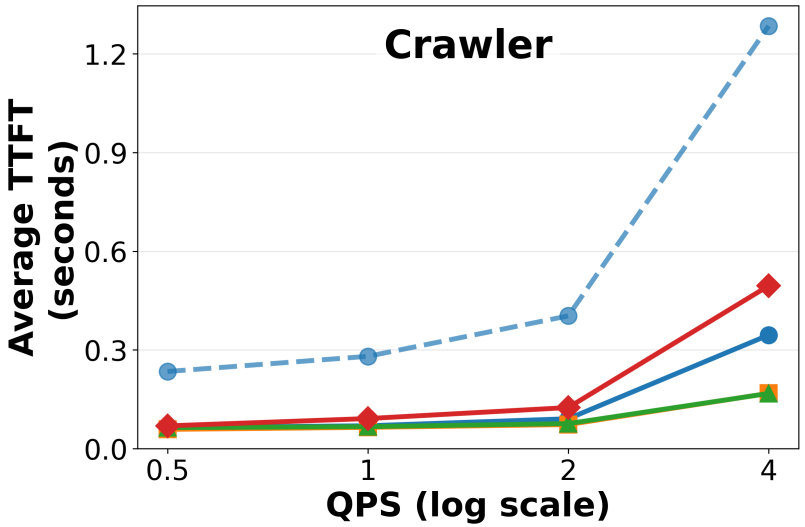

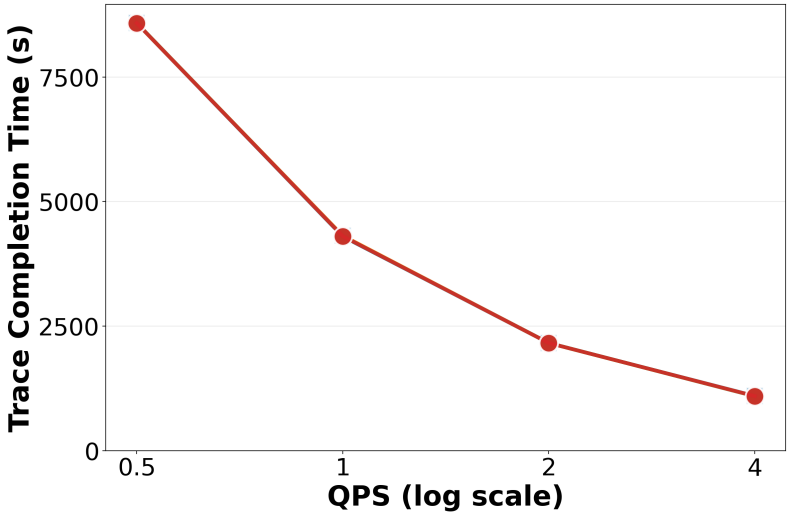

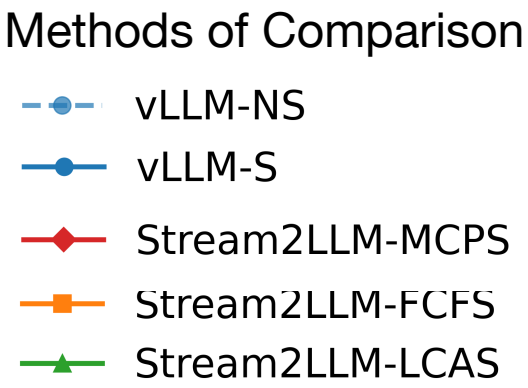

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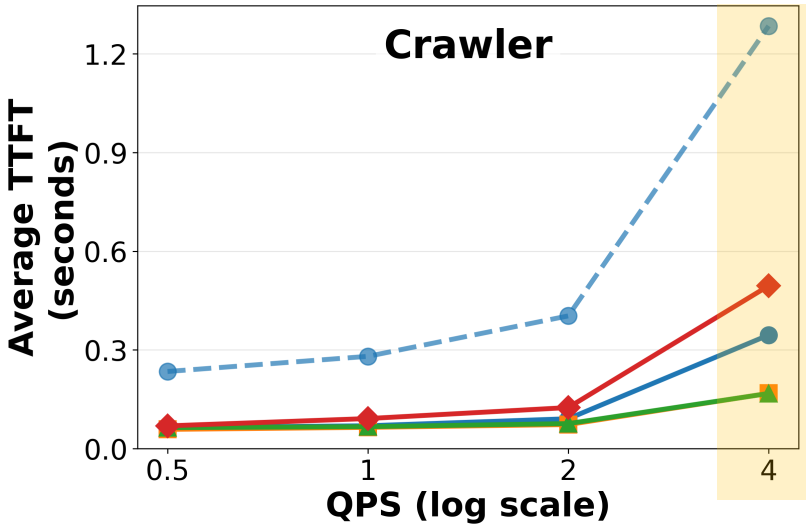

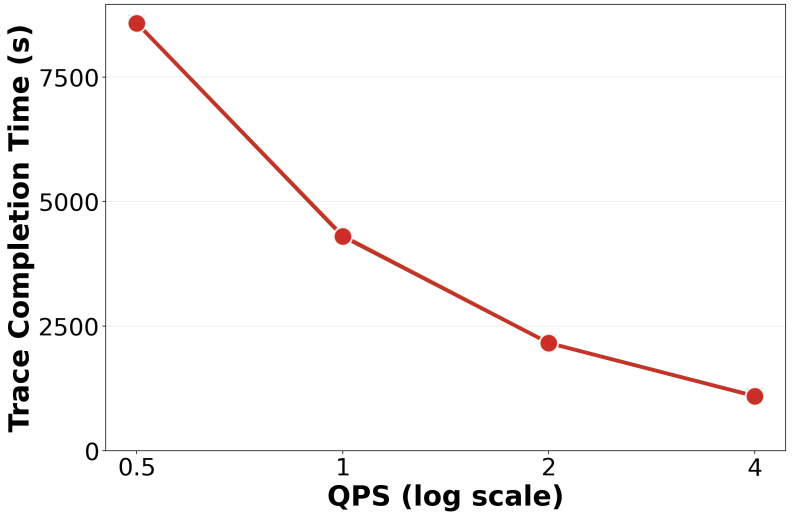

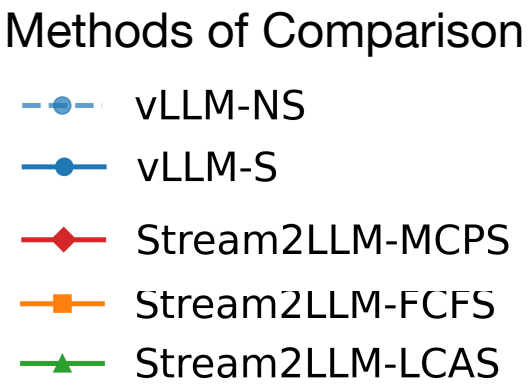

- Throughput is not reduced
- 11× speed up in median latency than non-streaming (QPS=4)

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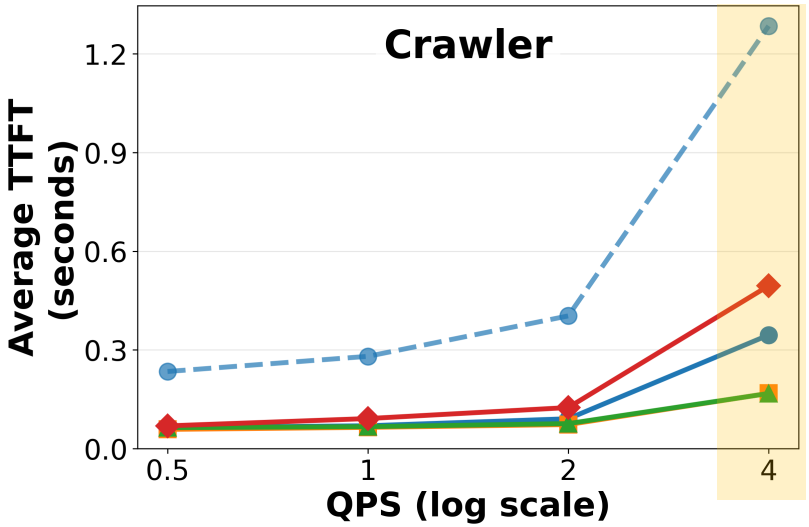

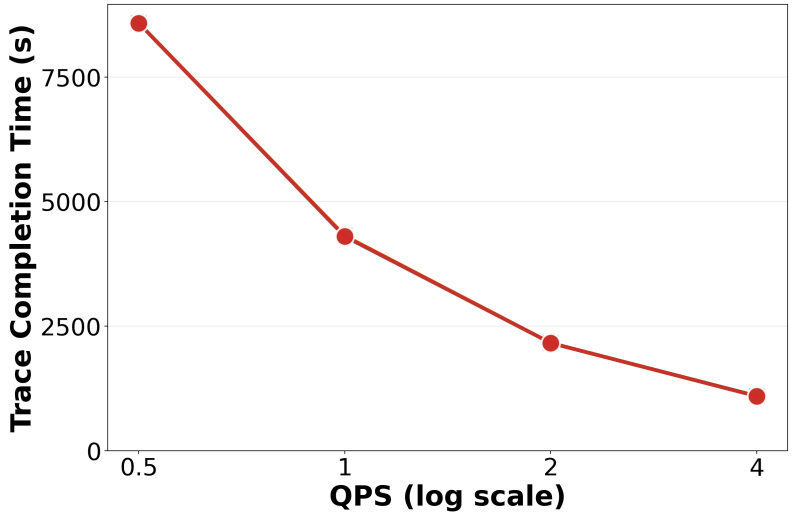

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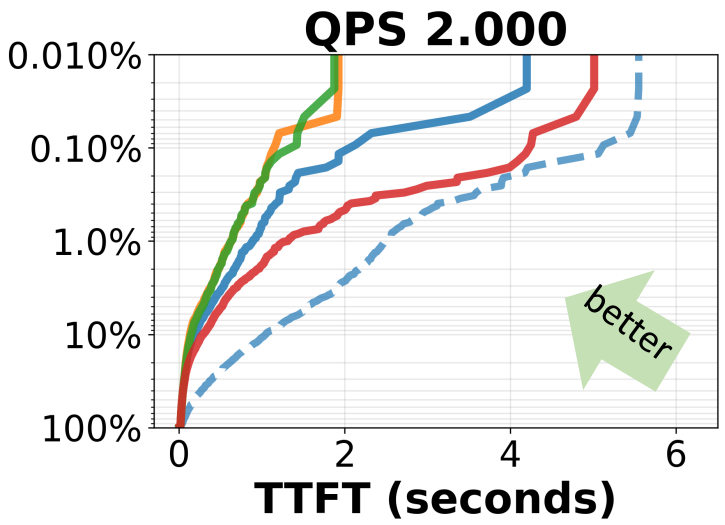

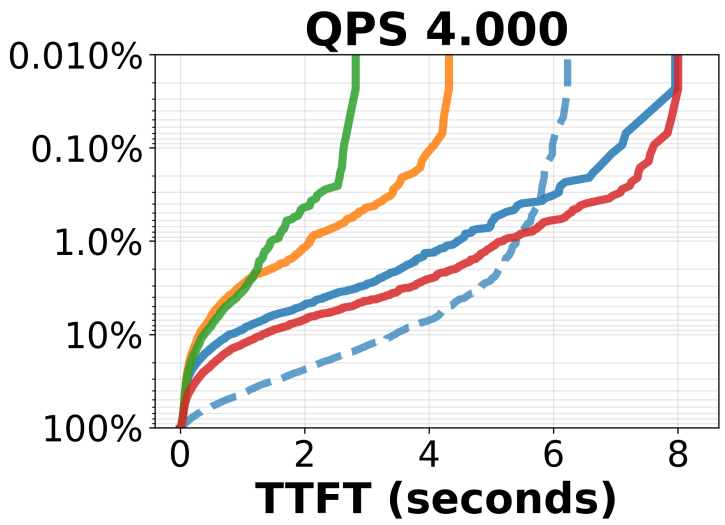

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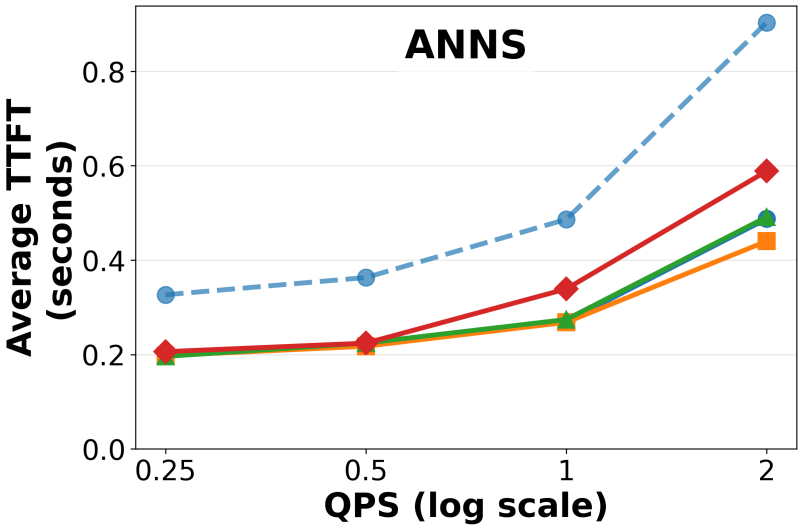
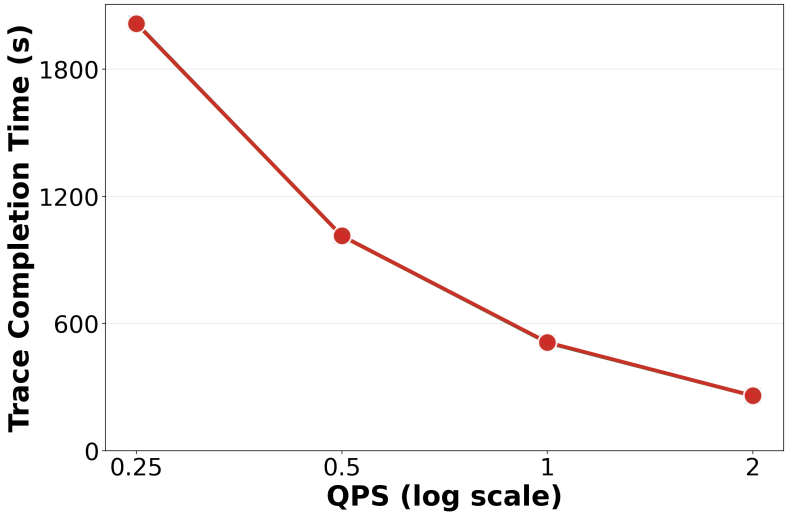
- 11× speed up in median latency than non-streaming (QPS=4)

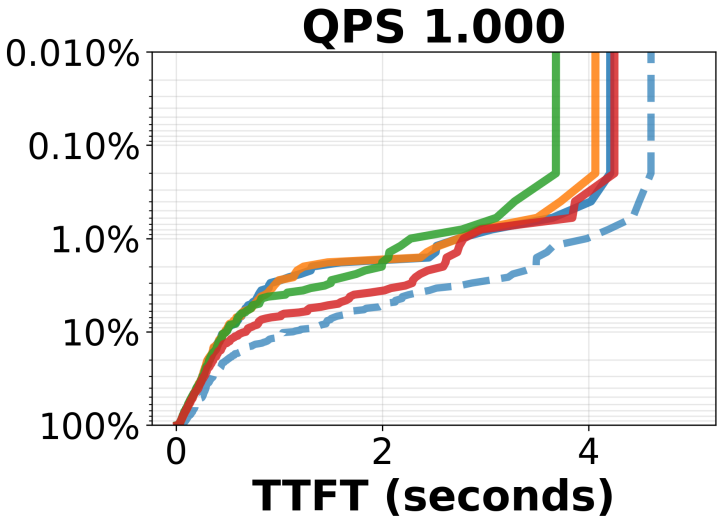
Evaluation (Update): TTFT vs QPS

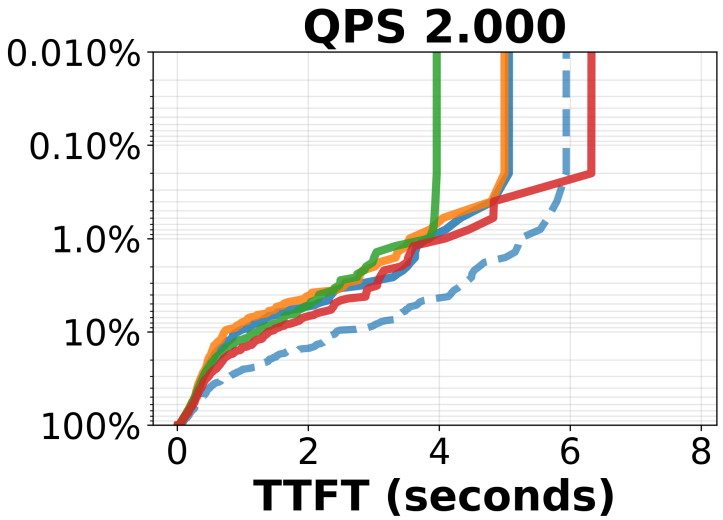




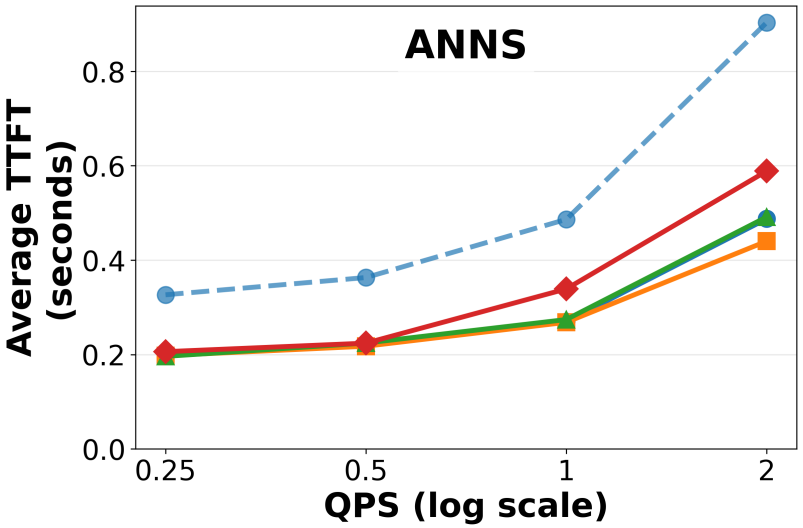
Methods of Comparison

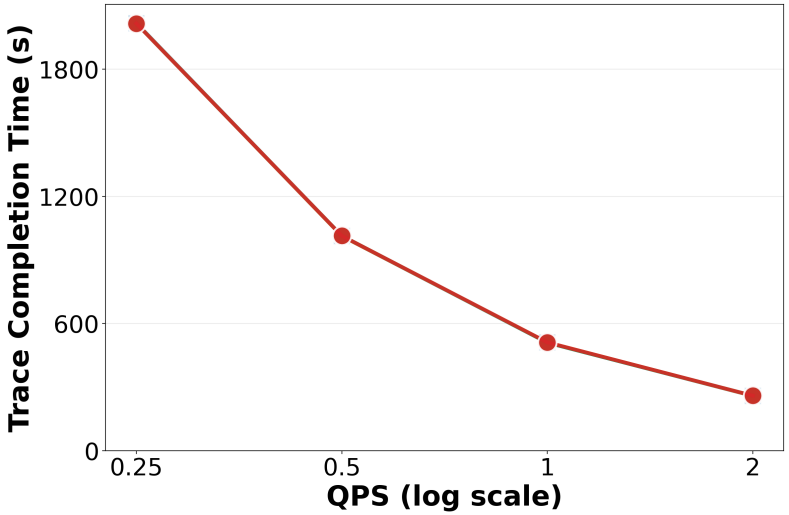
- vLLM-NS
- vLLM-S
- Stream2LLM-MCPS
- Stream2LLM-FCFS
- Stream2LLM-LCAS

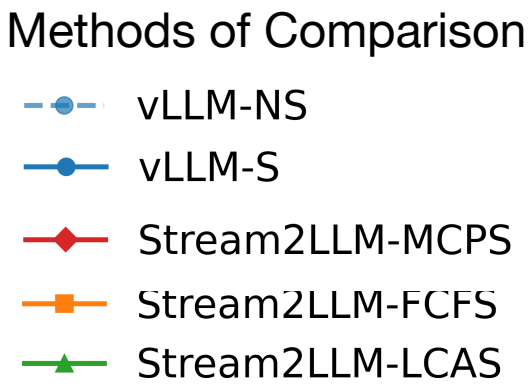


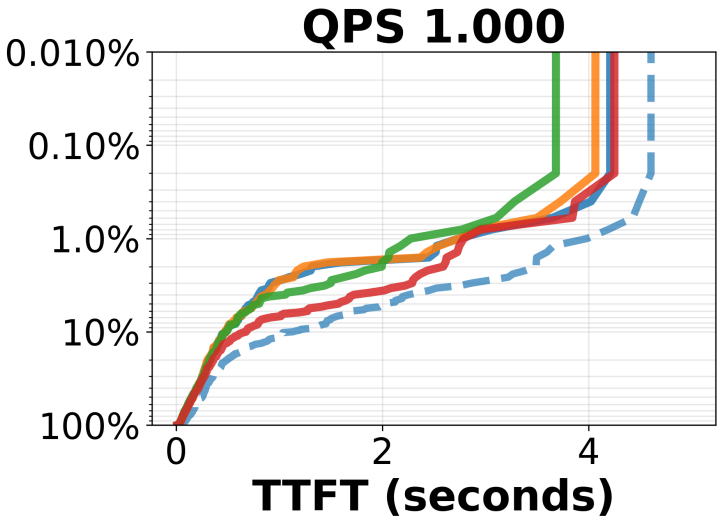


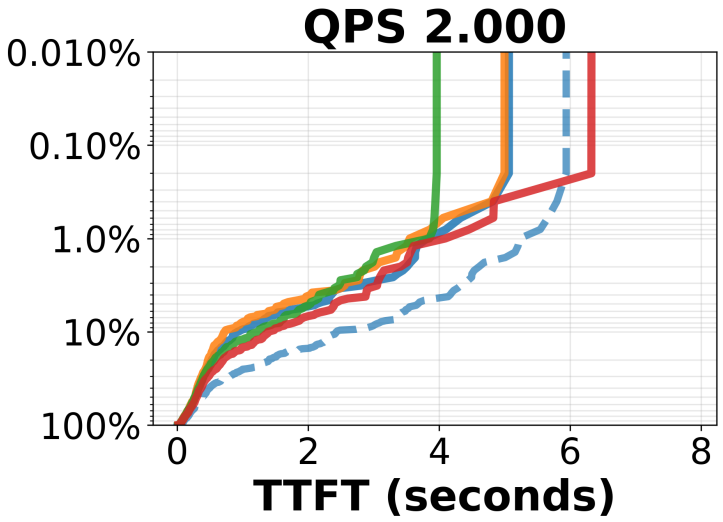
Evaluation (Update): TTFT vs QPS





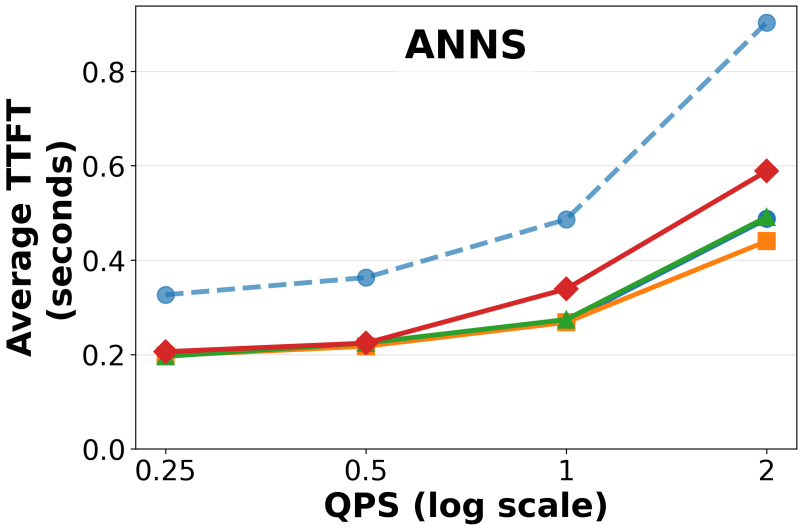


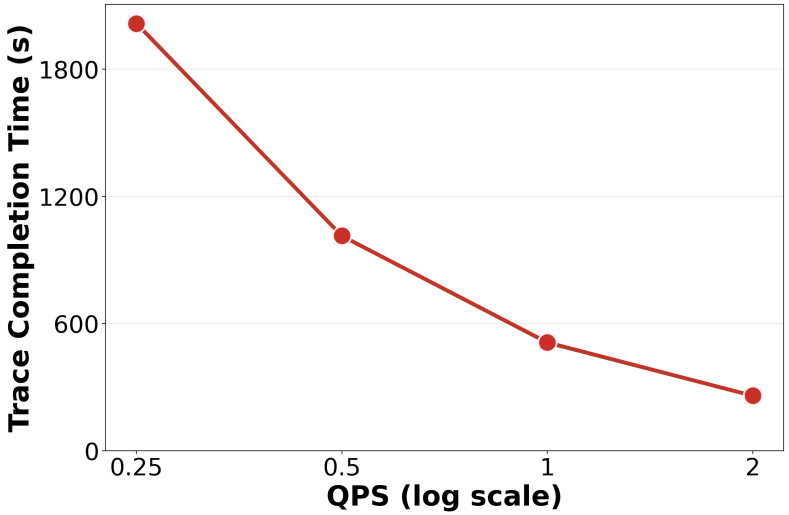


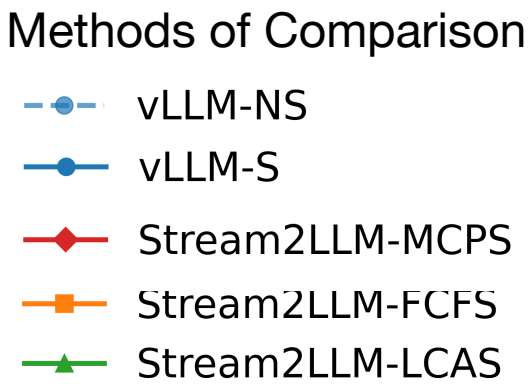


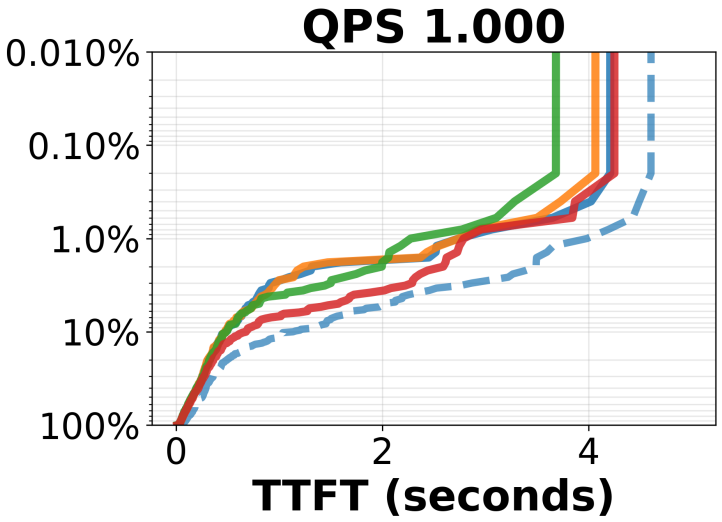
- Smaller gains compared to append mode: ~2× faster than non-streaming

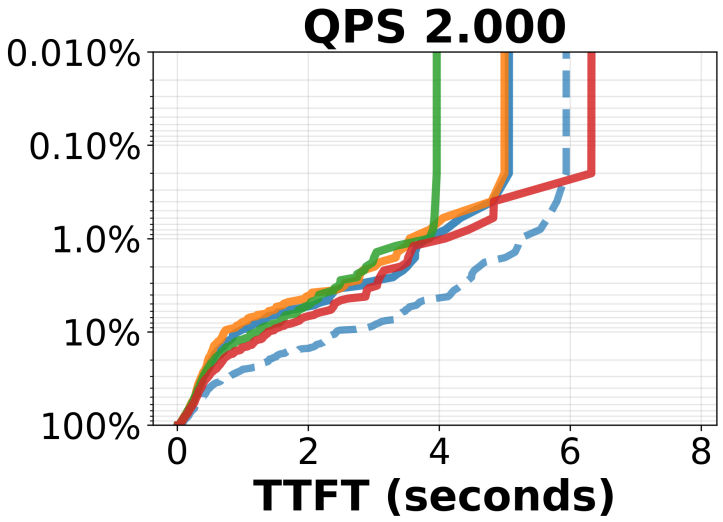
Evaluation (Update): TTFT vs QPS











- Smaller gains compared to append mode: ~2× faster than non-streaming
- >10% of requests invalidate over 10K tokens

Evaluation: Memory Pressure

Stress test: chunk inter-arrival delays to saturate GPU block pool

Scheduler	**Crawler** (4 QPS, 10× delay) P50	P99	**ANNS** (2 QPS, 30× delay) P50	P99
vLLM-NS (baseline)	1.00×	1.00×	1.00×	1.00×
vLLM-S (default stream)	8.25×	0.71×	2.63×	0.19×
Stream2LLM – FCFS	**8.30**×	8.62×	**2.70**×	**2.04**×
Stream2LLM – LCAS	7.82×	**9.14**×	2.44×	1.79×
Stream2LLM – MCPS	4.96×	0.77×	2.23×	0.19×

Naïve streaming algorithms could collapse under memory pressure!

Stream2LLM Summary

Scan for Code!

Overlapping retrieval with prefill to reduce TTFT

- Append vs update mode
- Streaming-aware scheduling design