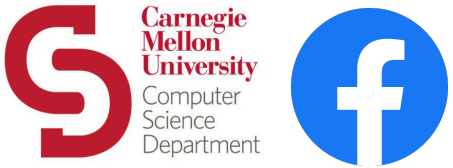
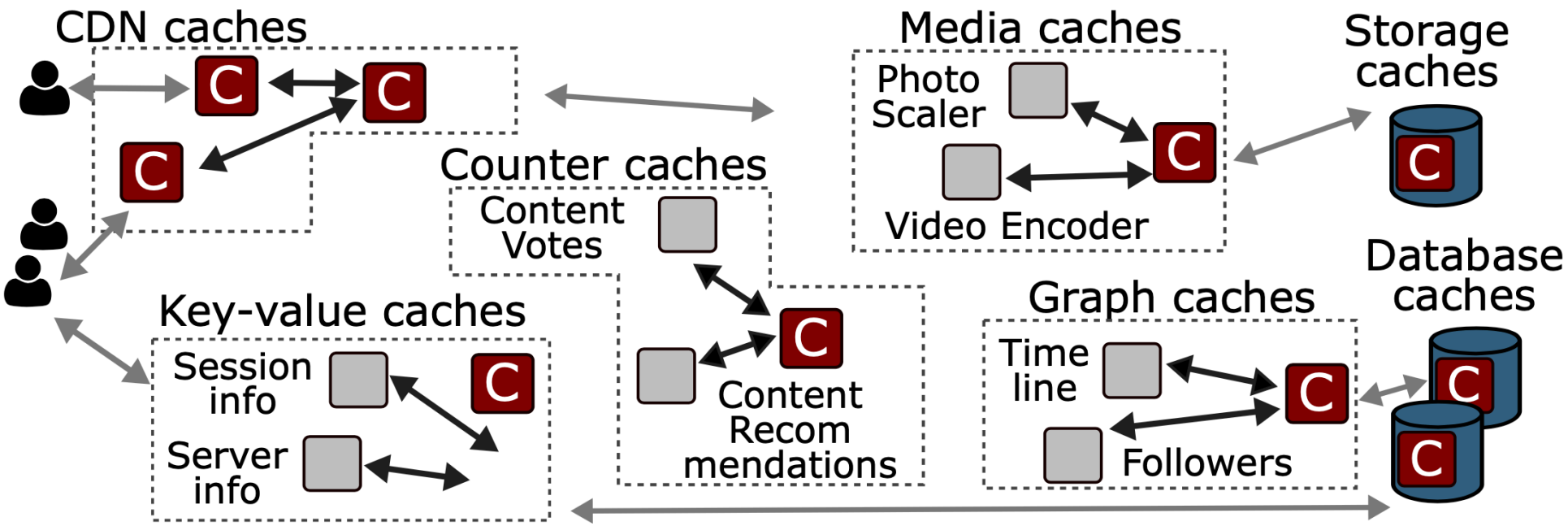
The *CacheLib* Caching Engine: Design and Experiences at Scale

Many Authors



Caching is Used in a Diverse Array of Systems

- You might be surprised at all the use cases found at Facebook



(And many more!)

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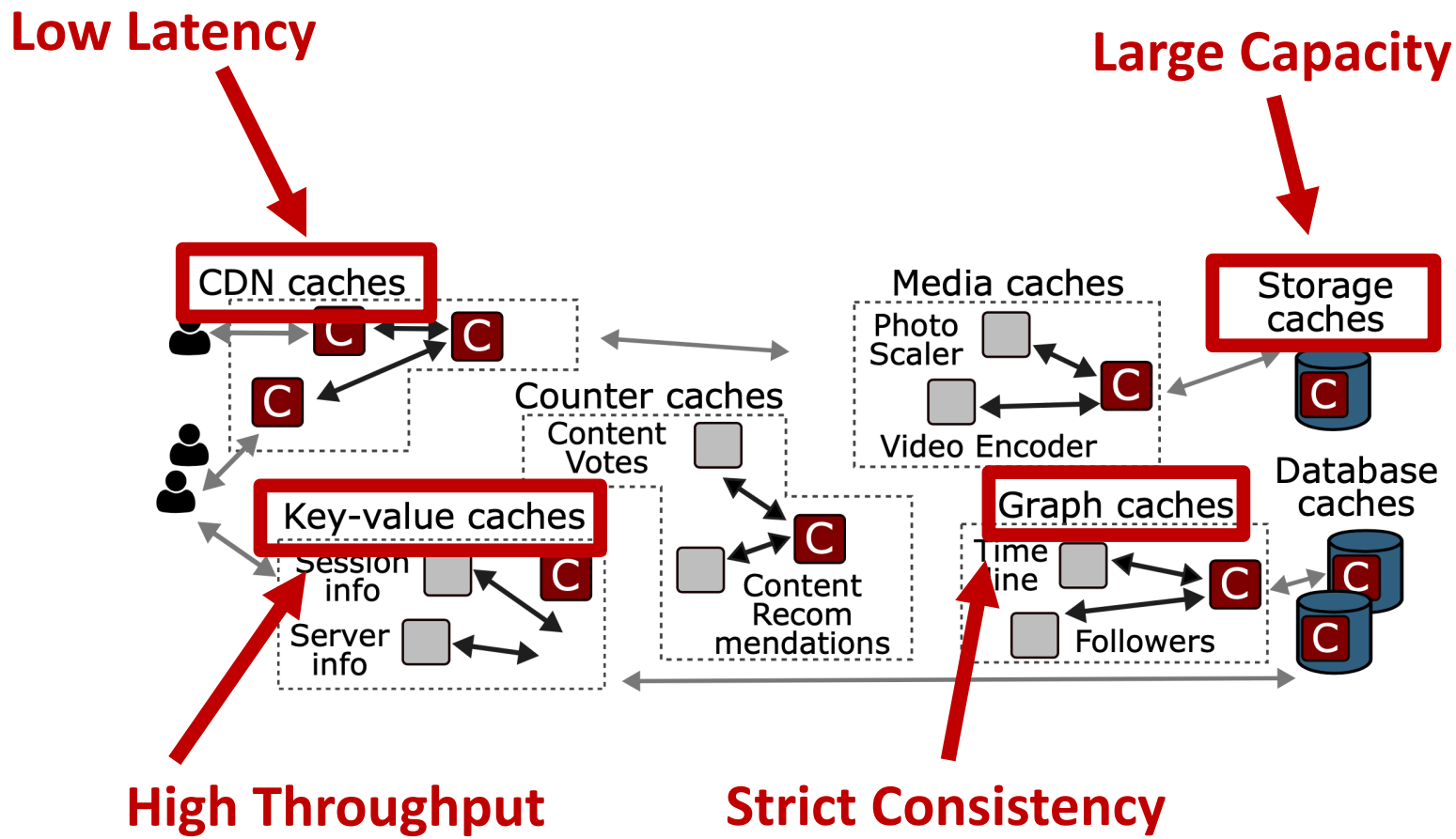
Caching is Used in a Diverse Array of Systems

- These systems to differ along several axes:
  - Performance goals
  - System topology



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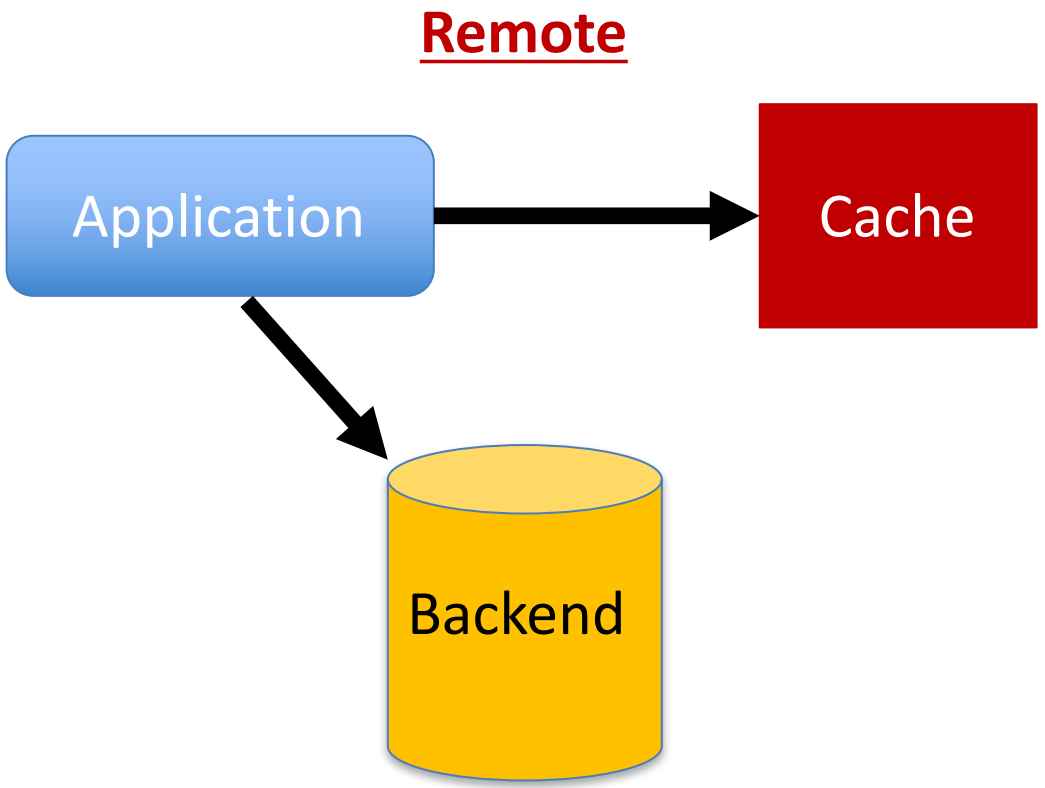

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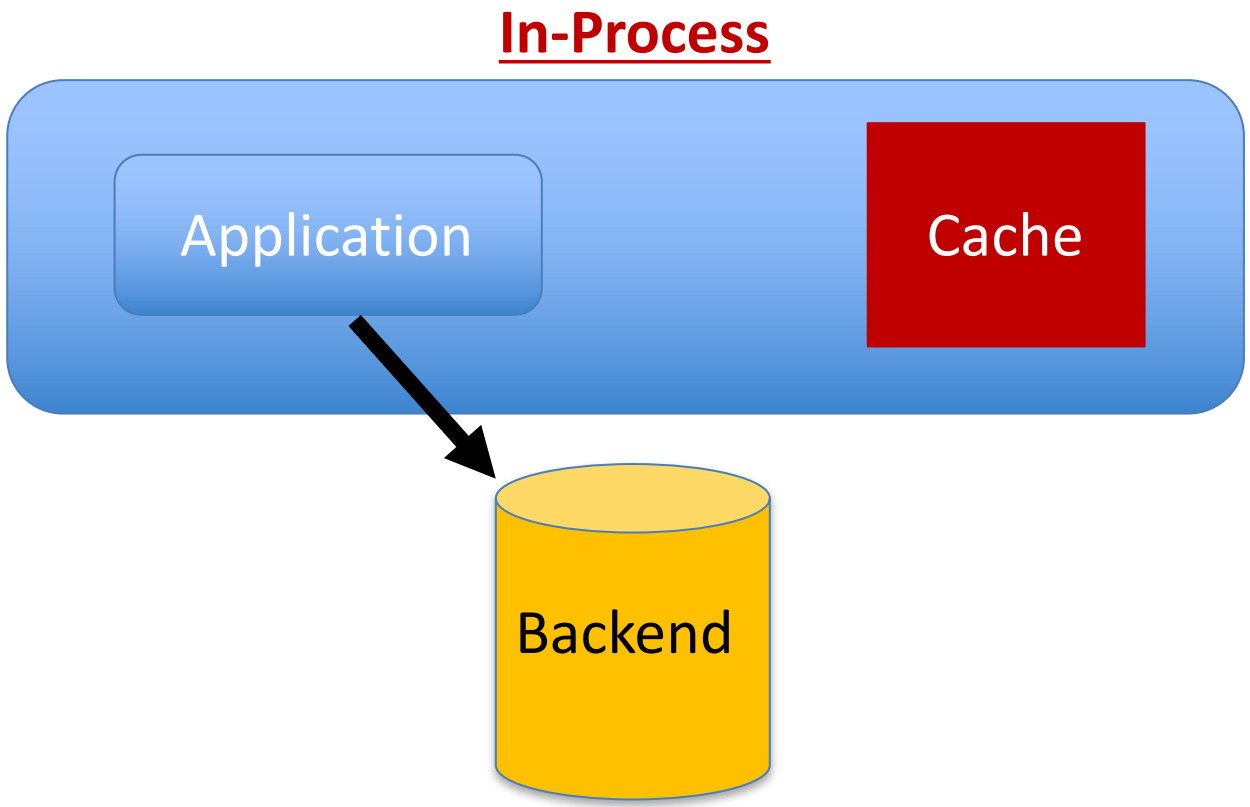
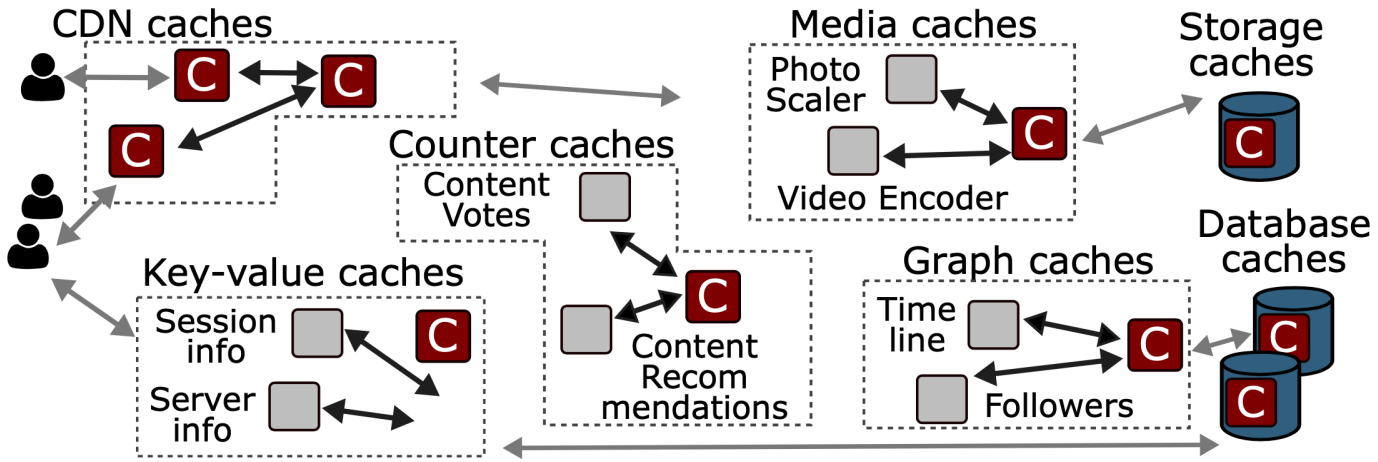


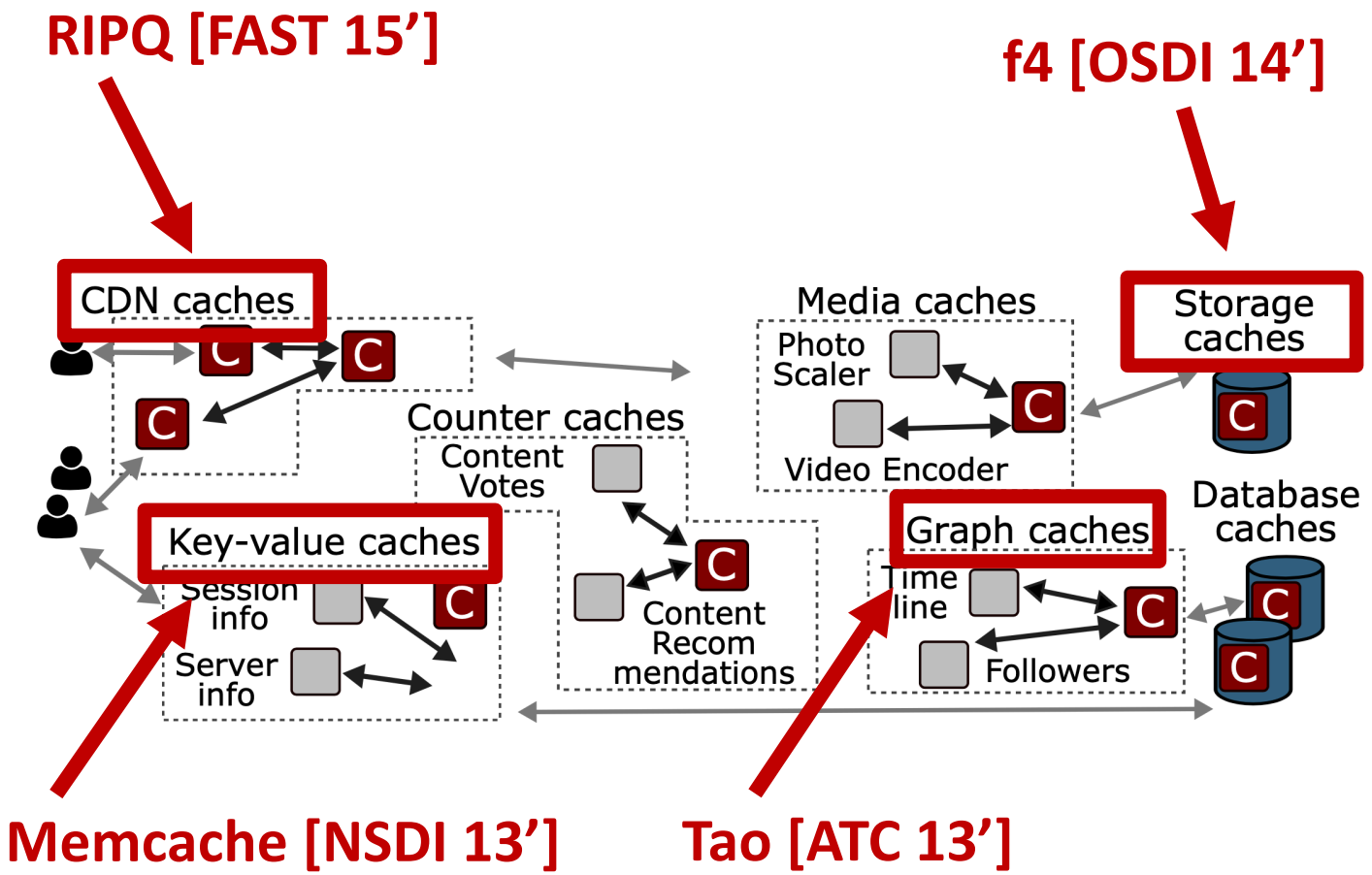
Caching is Used in a Diverse Array of Systems

- These systems differ along several axes:
  - Performance goals
  - System topology
  - Workload
  - Domain-specific features



Specialized Caching is the State-of-the-art

- Historically, Facebook maintained ***specialized*** caching implementations
- Long tradition of specialization in academia
  - Distcache, Kvell, Cliffhanger, many more



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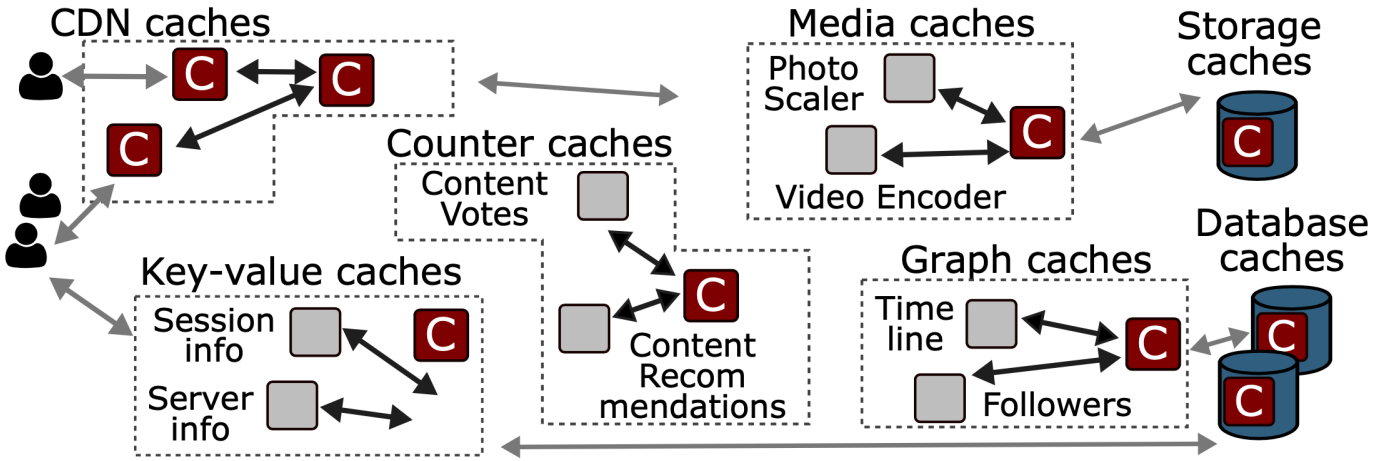
Problem:

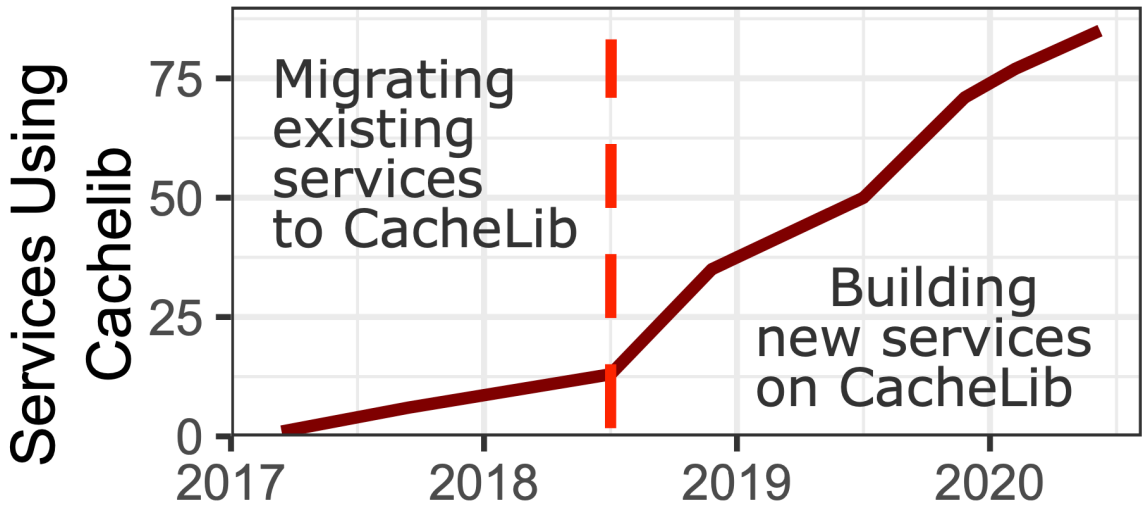
Hard to maintain an increasing number of specialized implementations

- Redundant code
- Narrow feature sets
- Barrier to implementing new ideas



Solution: CacheLib Caching Engine

- CacheLib is a widely used, **general-purpose** caching engine
  - Enables high-capacity caches
  - Provides a rich feature set
  - Aggregates optimizations
- Widely adopted at Facebook
  - replaced many specialized implementations

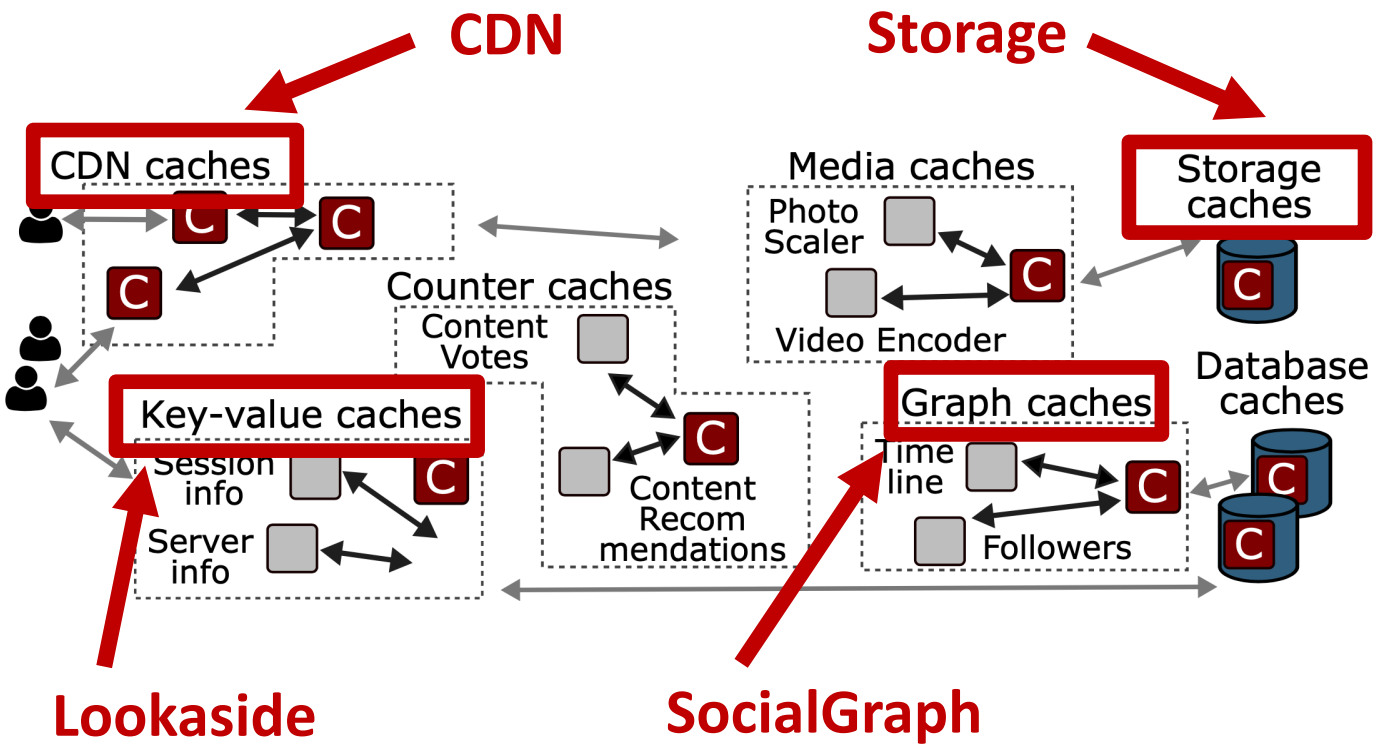


The CacheLib Caching Engine

- Common challenges/characteristics of caching systems
- Design of CacheLib
- CacheLib outperforms specialized implementations
- Lessons learned from deploying CacheLib in production

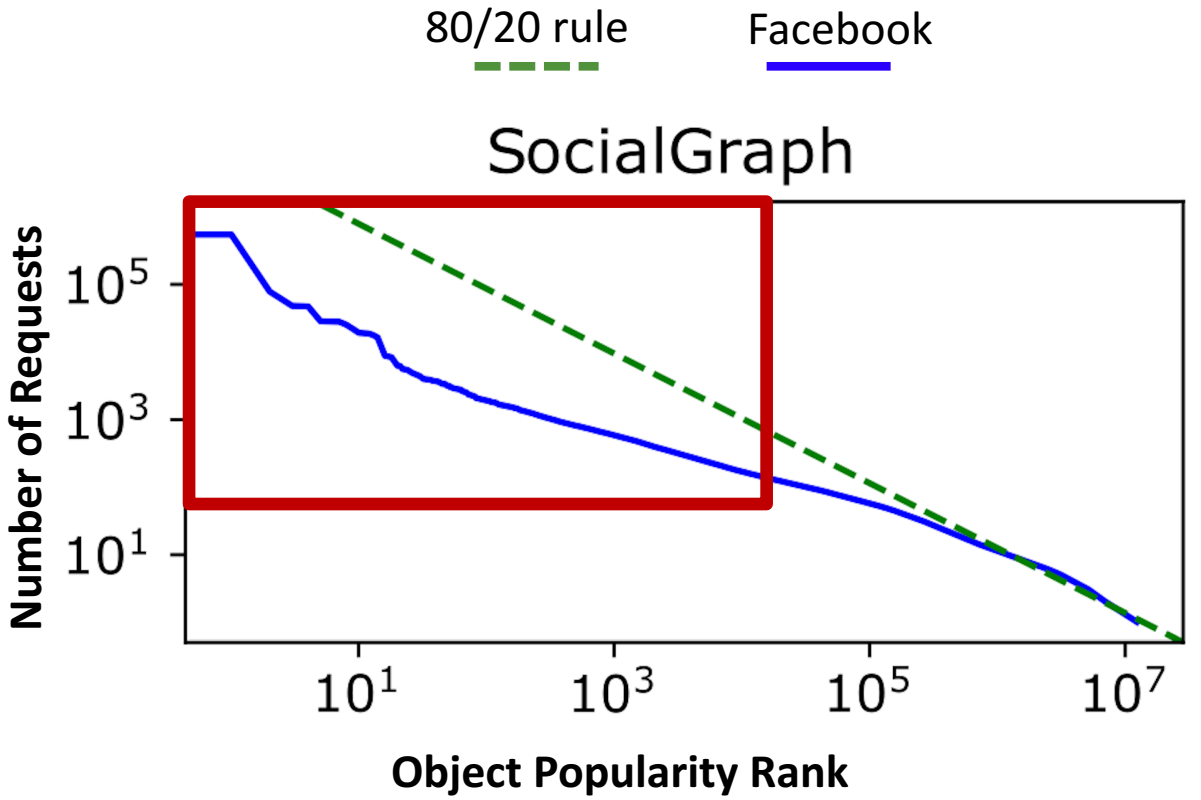
Identifying Common Challenges in Caching

Largest 4 caching systems at Facebook



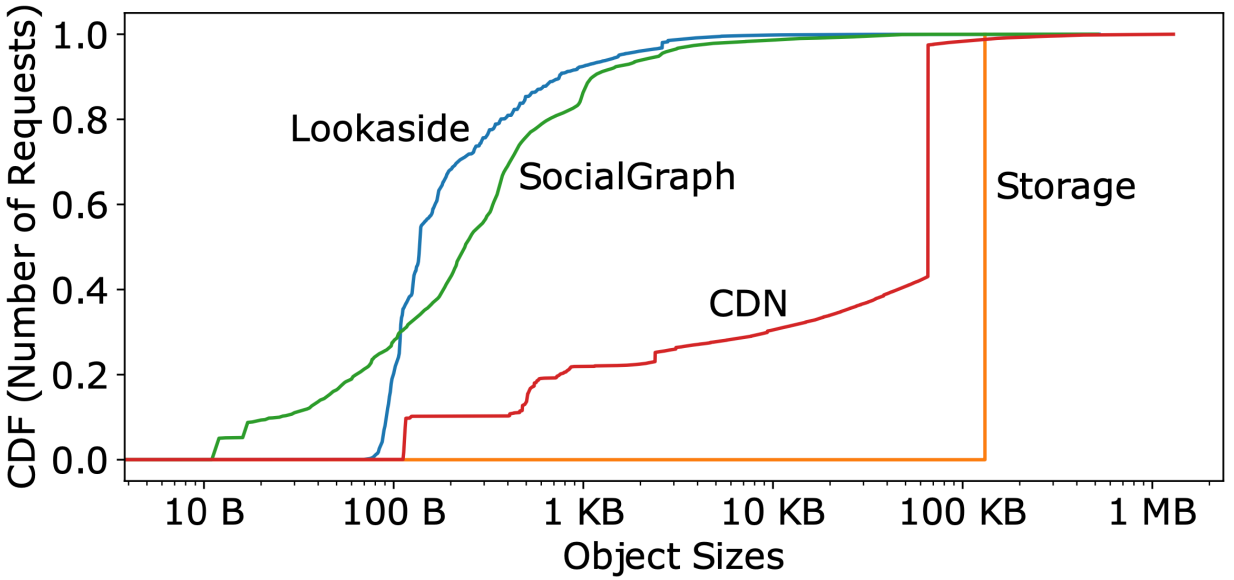
Popularity Distributions are Diffuse

- Request popularities are roughly assumed to follow the “80/20” rule
  - For SocialGraph: “50/20 rule”
  - For Storage: “40/20 rule”
  - For CDN “60/20 rule”
- Low popularity of hot objects → low hit ratio
- **Need large cache capacities**



Object Sizes are Highly Variable

- Object sizes are highly variable
- Small object sizes are common
  - Memcached: 56 B per object
  - MemC3 [NSDI 13'']: 40 B per object
  - 1 TB of 100B objects?
    - 256 GB DRAM overhead
- **Caches need low per-object overhead, ability to index billions of objects**



Common Challenges of the Production Environment

- Are there shared challenges of a “real deployed system”?

- Stability requirements for production caching systems
  - Bursty traffic
  - Frequent code updates / restarts

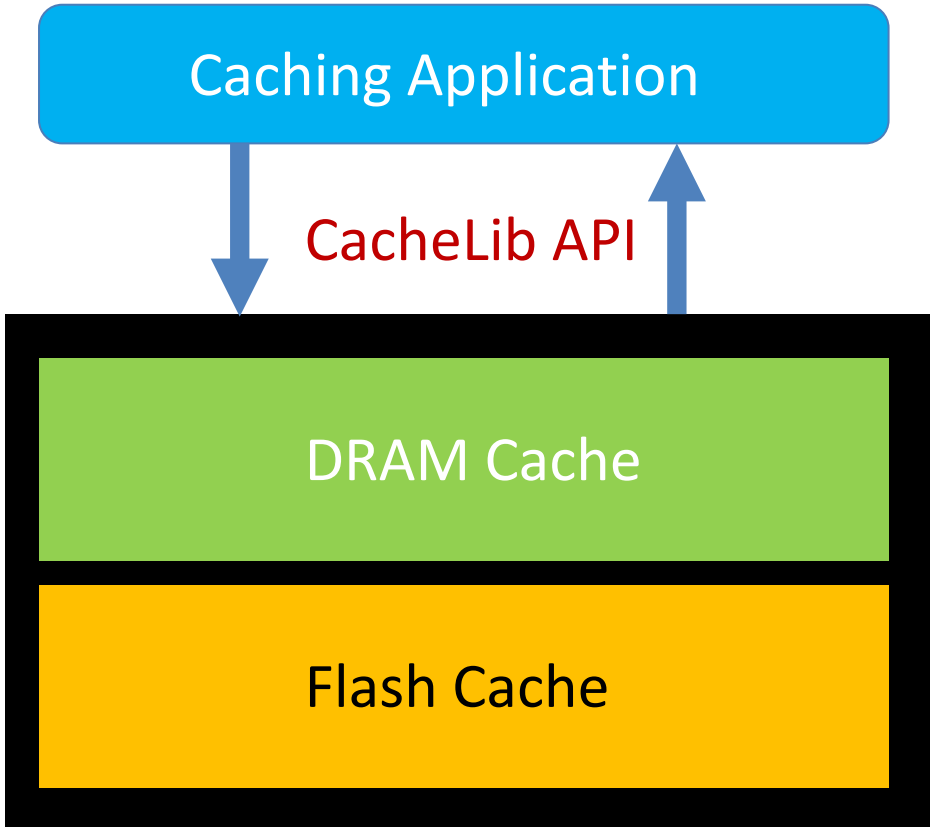
- **Solution: These challenges could be addressed once by a unified caching implementation**

The CacheLib Caching Engine

- Common challenges/characteristics of caching systems
  - Large cache capacity, low overhead, production features
- Design of CacheLib
- CacheLib outperforms specialized implementations
- Lessons learned from deploying CacheLib in production

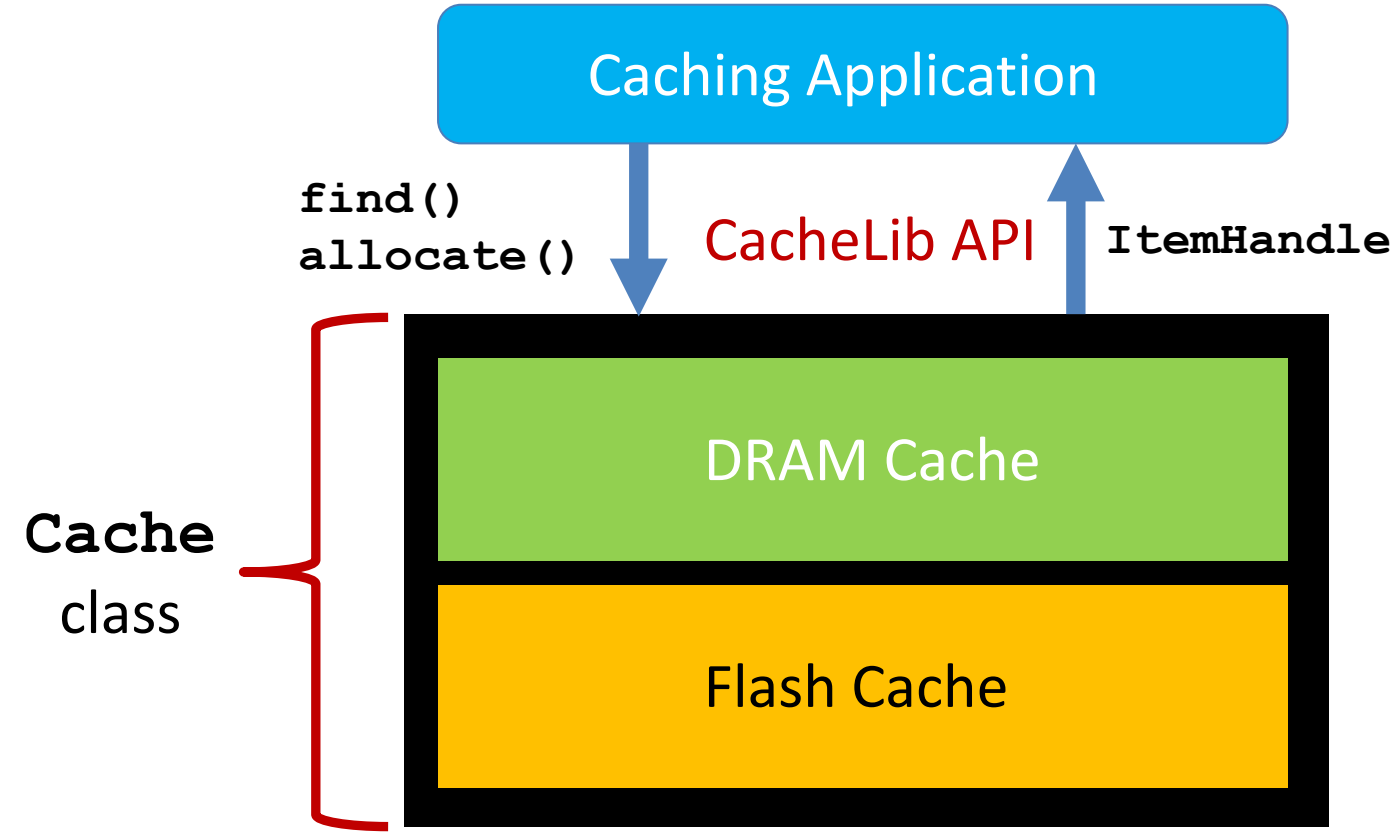
Caching Engine Requirements

- Want a library of customizable cache components
  - Easy for programmers (simple, expressive API)
- To accommodate workloads:
  - Transparent **hybrid DRAM-flash** caches for large capacity
  - Approximate indexes over billions of small objects
- For production deployment:
  - Sufficient single-machine throughput
  - Broad feature set



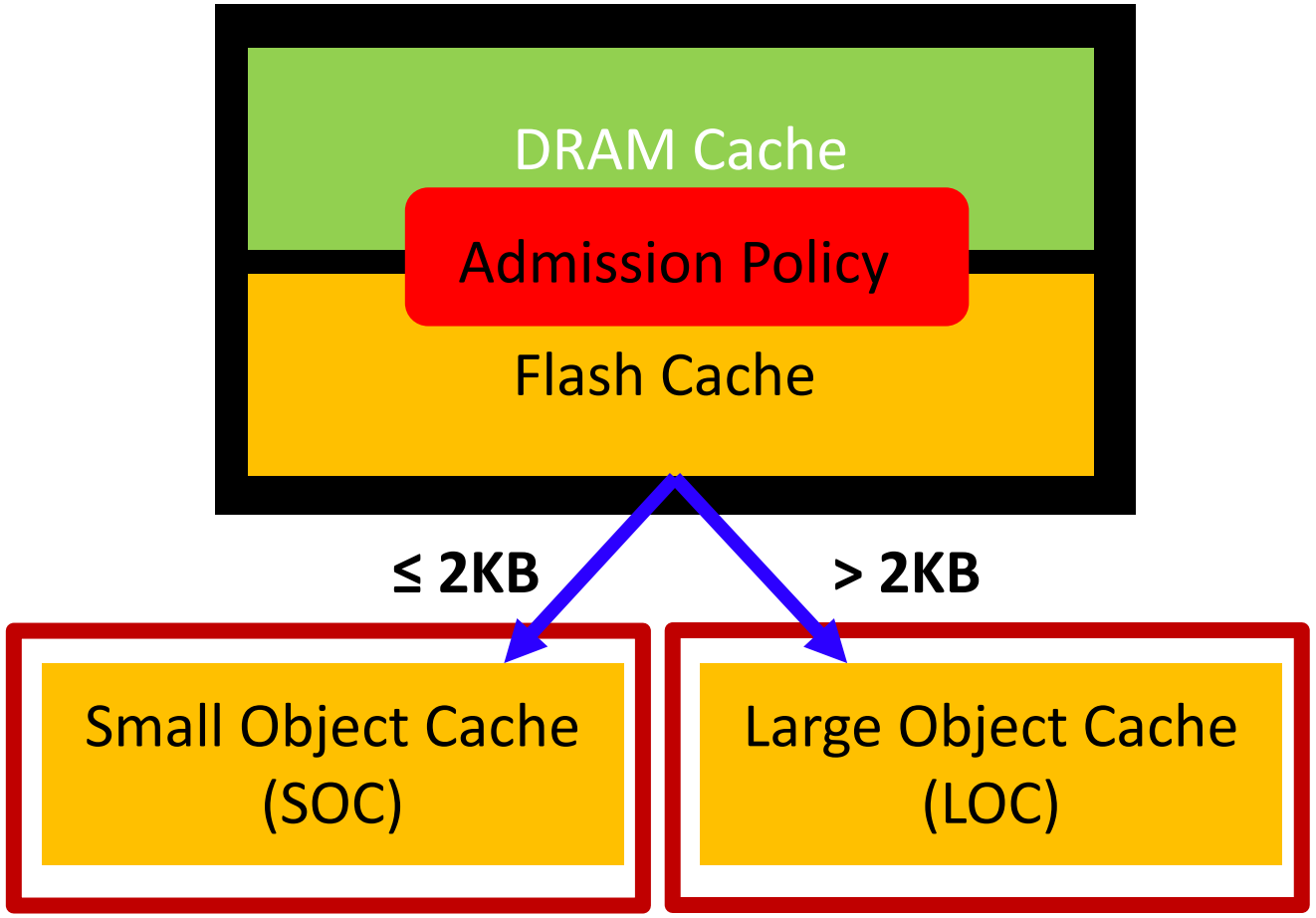
The CacheLib API

- Uniform, thread-safe API
  - Decoupled from cache configuration
  - Easy to build highly-concurrent, high throughput caches
  - Applications not tightly coupled to storage medium (DRAM, flash)



CacheLib's Caching Implementation

- DRAM uses chained hash table
  - 31B per object
- Flash cache partitioned by size
  - $< 0.2\%$ overhead in practice
- Flash has limited write endurance
  - **Admission** policies
  - Reduce **write amplification**



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CacheLib's Broad Feature Set

	Hybrid Cache	Warm Restarts	Negative Caching	Natively Structed Items
		Persistent cache across restarts	Cache empty results with no overhead	Optimized caching of data structures
CacheLib	✓	✓	✓	Arrays/Maps

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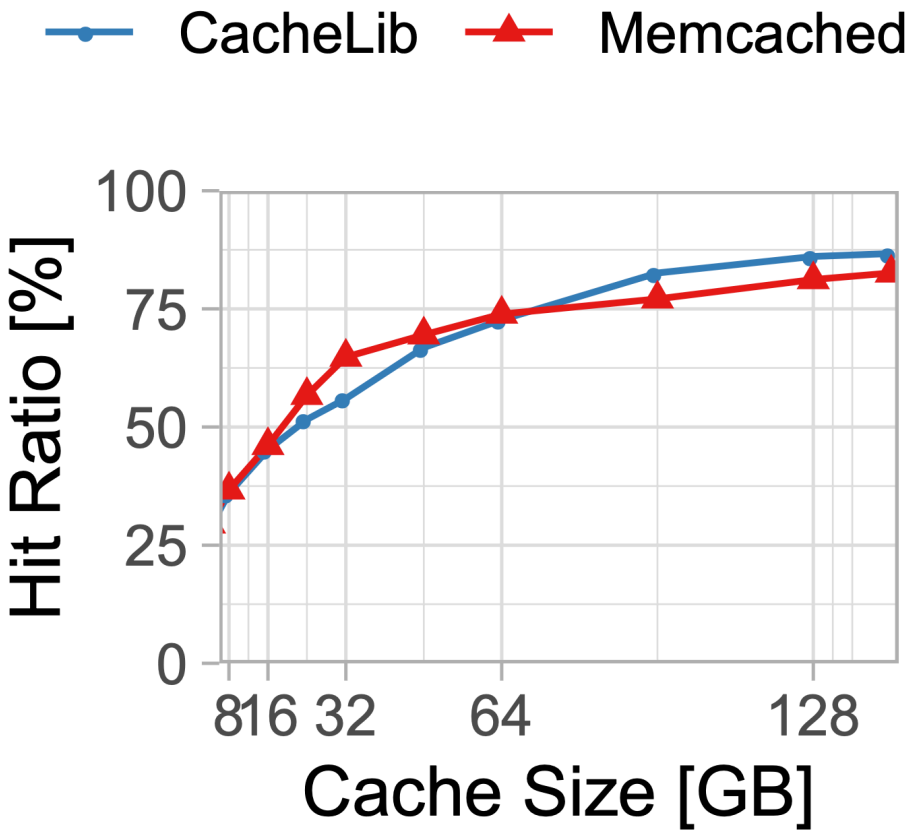
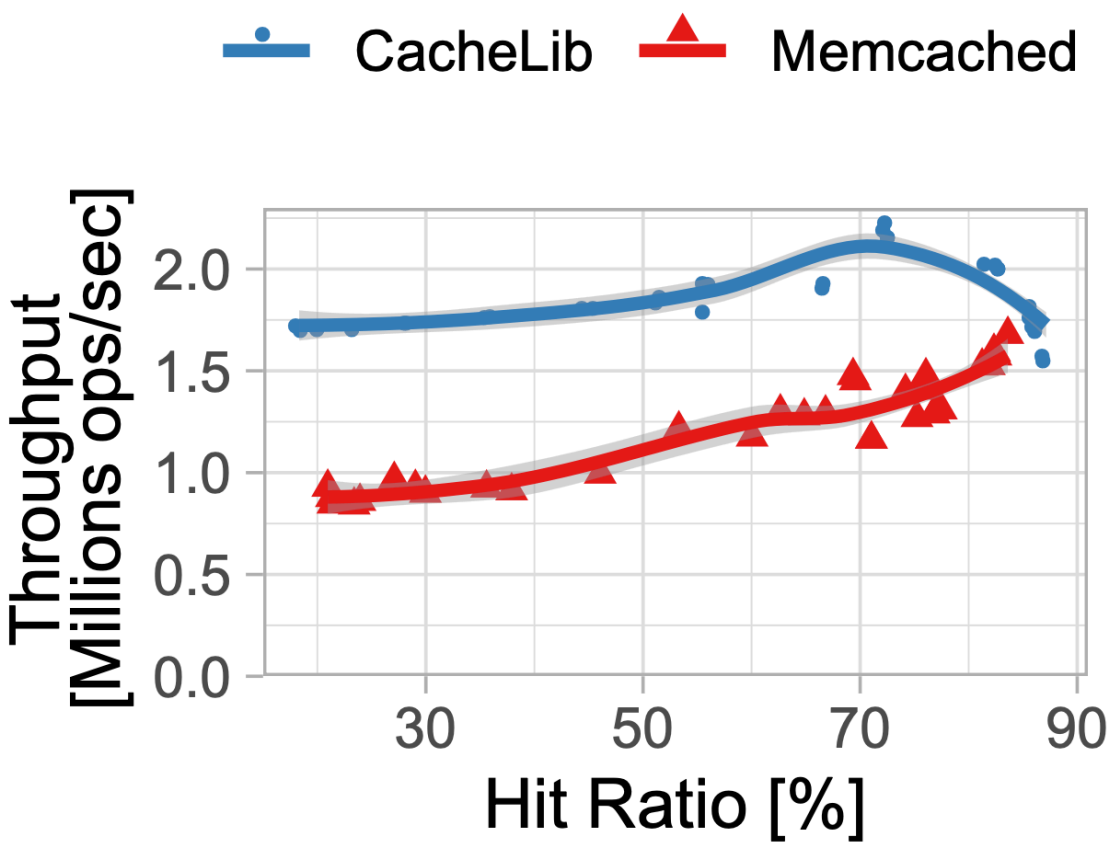
Existing Systems Do Not Replicate CacheLib

	Hybrid Cache	Warm Restarts	Negative Caching	Natively Structed Items
CacheLib	✓	✓	✓	Arrays/Maps
Memcached	✓	X	X	X
Redis	X	X	X	Many
MemC3	X	X	X	X
Flashield	✓	X	X	X
Apache Traffic Server	✓	X	✓	X
Varnish	X	X	X	X
FlashCache	✓	✓	X	X
Flashtier	✓	✓	X	X

Lookaside Caching: CacheLib Outperforms Memcached





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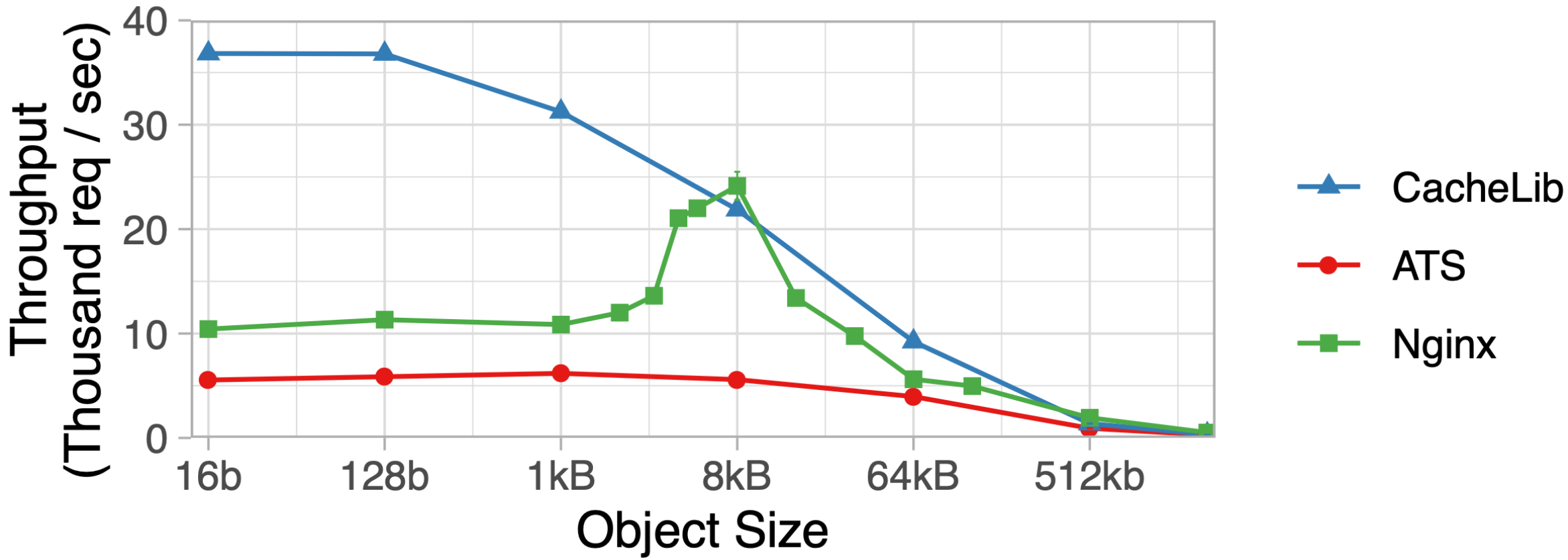
HTTP Server Caching: CacheLib Outperforms NGINX/ATS



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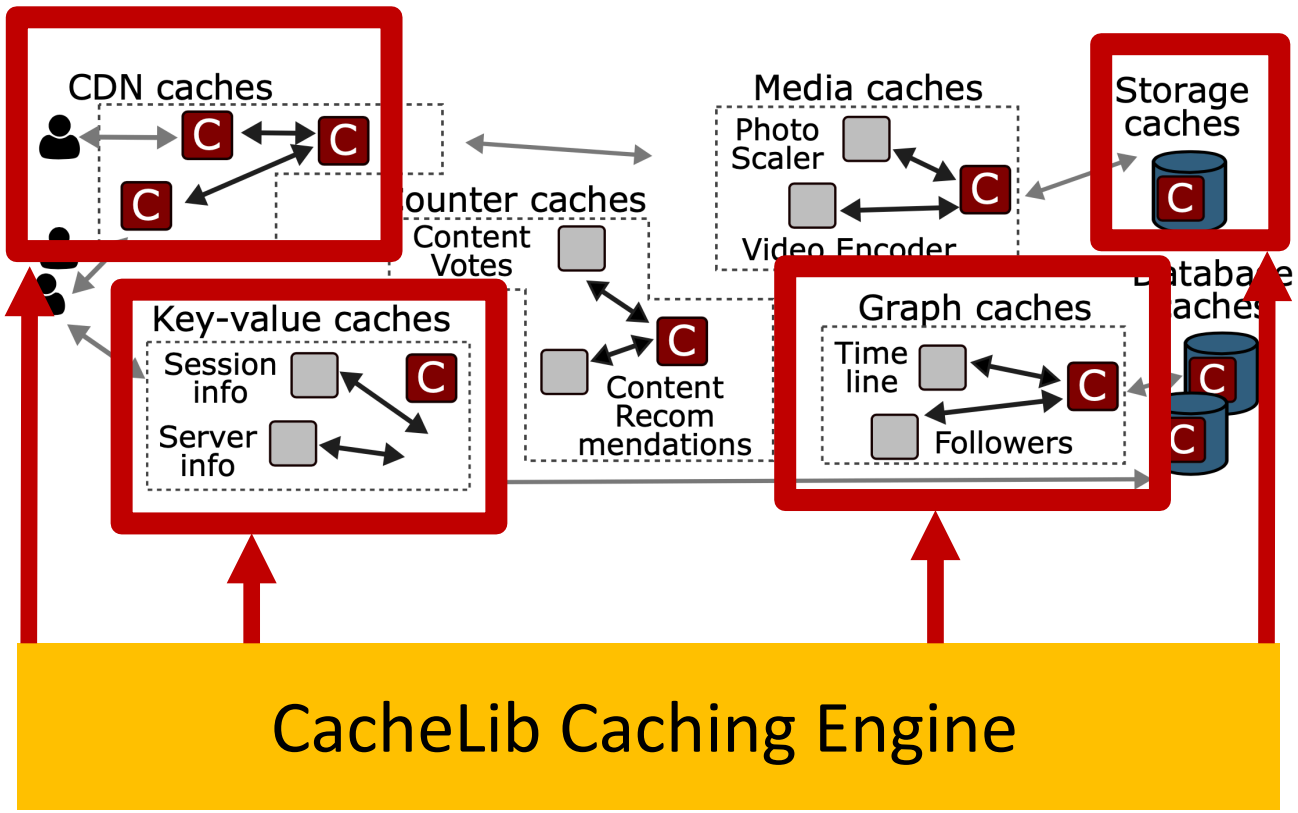
CacheLib is an Aggregation Point for Optimizations

- Specialized implementations enable localized improvements
- CacheLib exports optimizations to all use cases
  - Example: Optimizing the LOC for CDN
  - Hybrid cache performance improved **everywhere**



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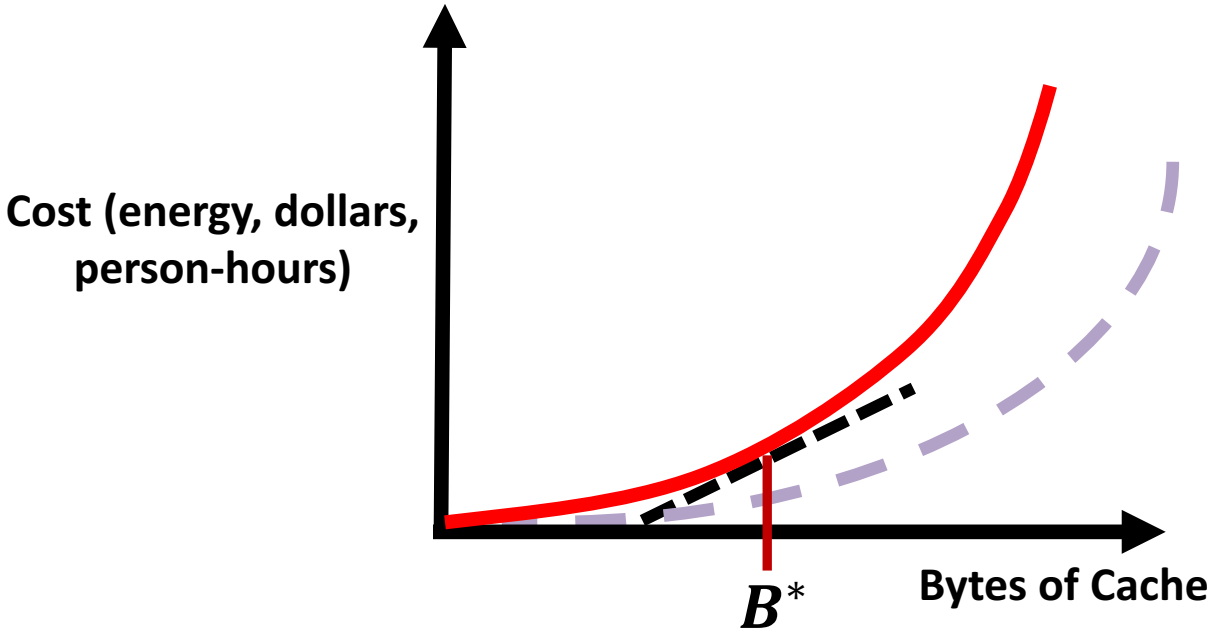
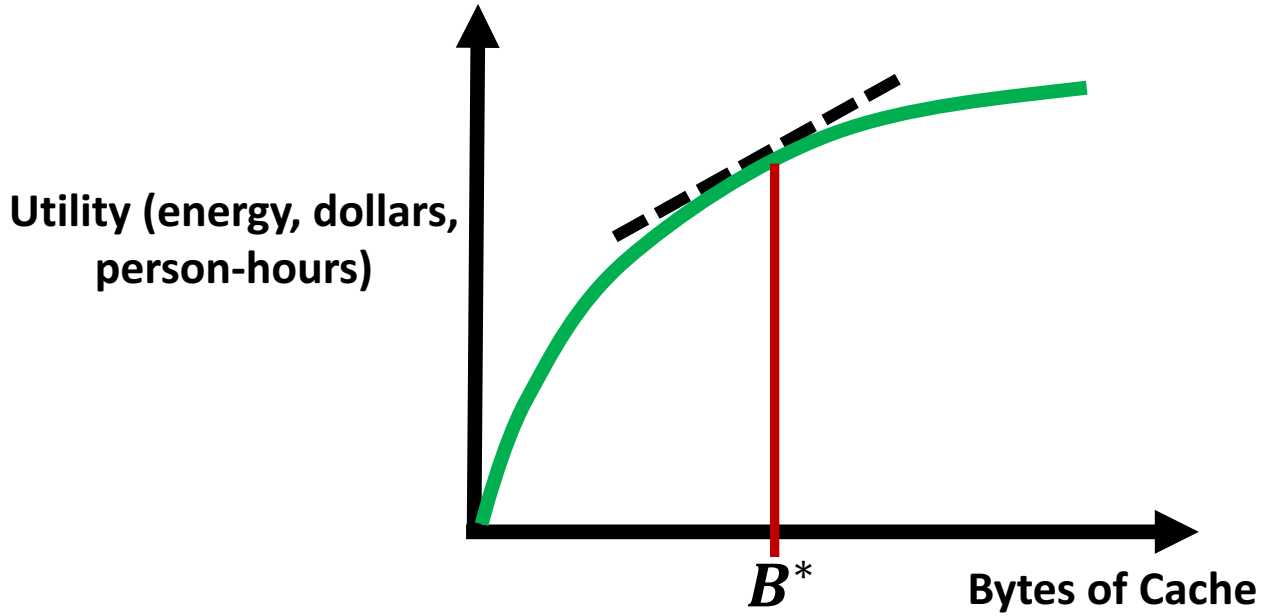
CacheLib Reduces the "Cost" of Caching

- Typical calculation in provisioning a cache:





Set marginal cost equal to marginal benefit

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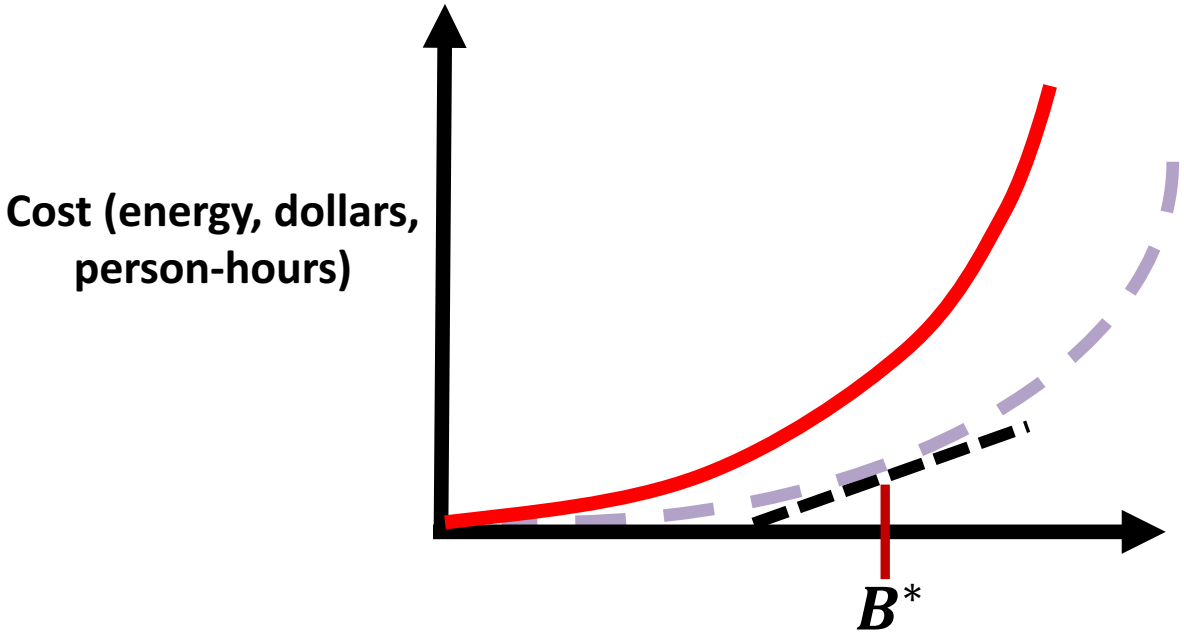
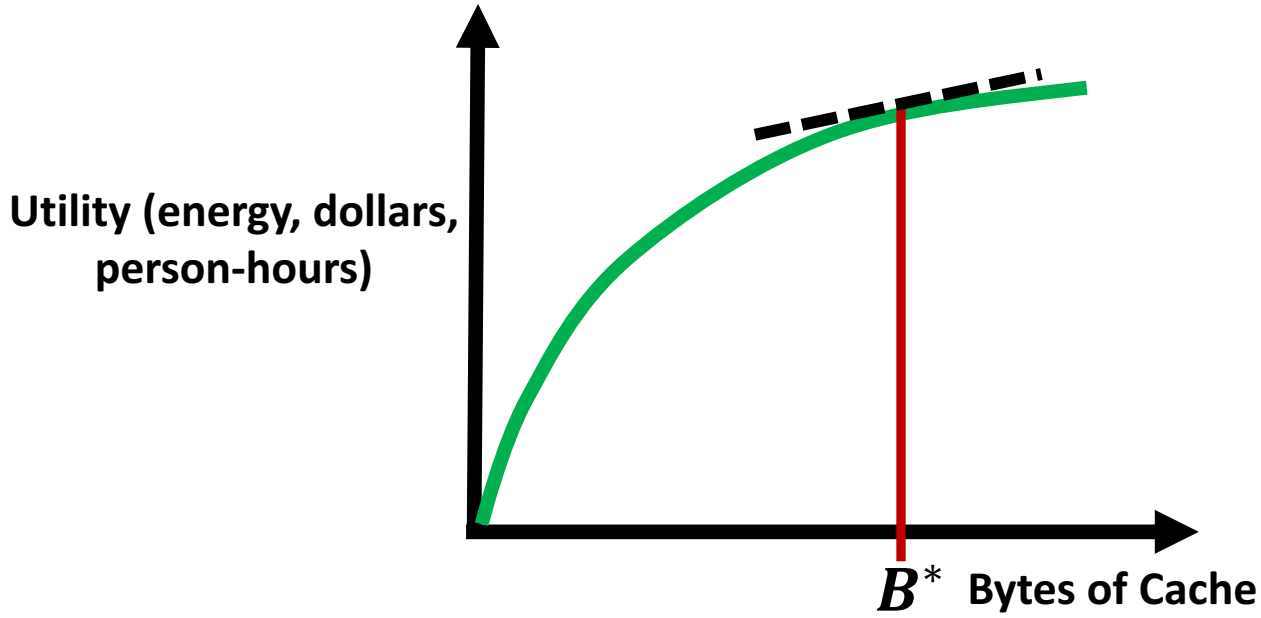




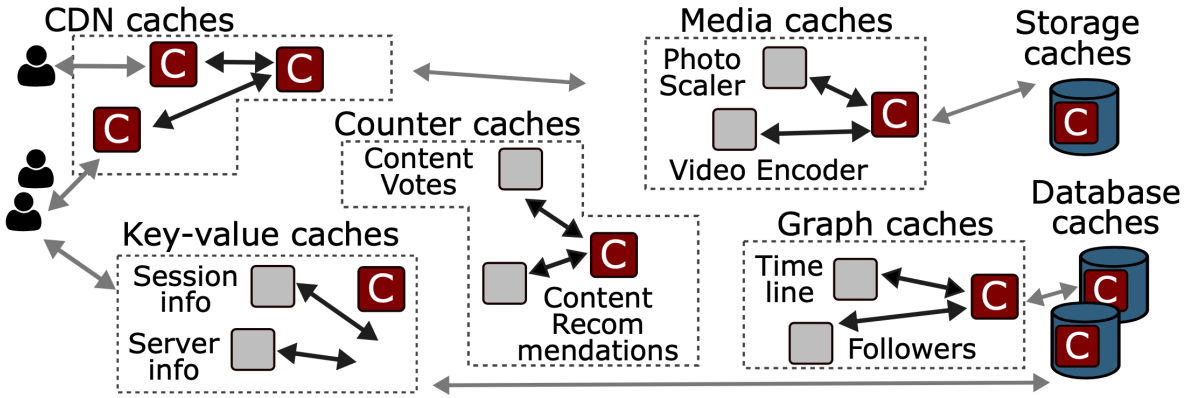
Set marginal cost equal to marginal benefit

Impact

- Cache capacities are growing
- Number of caches is growing

Conclusion

Historically cache implementations were **specialized**



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Solution: CacheLib, a widely used **general-purpose** caching engine

- Extracts common caching functionality
- Aggregates optimizations
- Reduces the "cost" of caching
- Widely used at Facebook

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Thank you!

- Contact the authors:
  - Benjamin Berg: bsberg@cs.cmu.edu

- See www.cachelib.org for more information