Scalable and private media consumption with Popcorn

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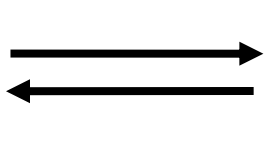
90 minutes/day

give me The Godfather

The Godfather

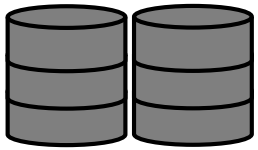
NETFLIX

User media consumption has increased …



NETFLIX

database of request trace, movie ratings, etc.



… leading to large centralized datasets …

… subject to risks such as server hacks, accidental disclosures, etc.

anonymized dataset of movie ratings

researcher

de-anonymized dataset of movie ratings

NETFLIX SPILLED YOUR *BROKEBACK MOUNTAIN* SECRET, LAWSUIT CLAIMS

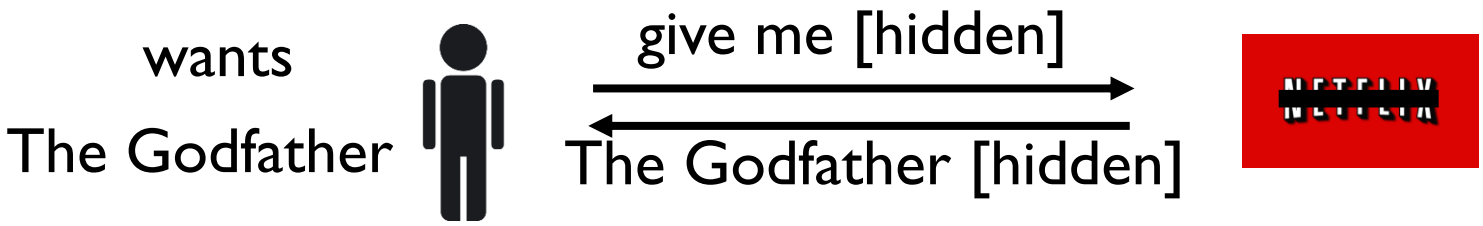
How can we build a Netflix-like system that

a) provably hides media diet,

b) has low dollar cost, and

c) is compatible with commercial media streaming?

Private Information Retrieval (PIR) provably hides requests but …



- Each request must touch the entire library.
- There is a tension between overhead and content protection.
- PIR assumes fixed-size objects, but media sizes vary.

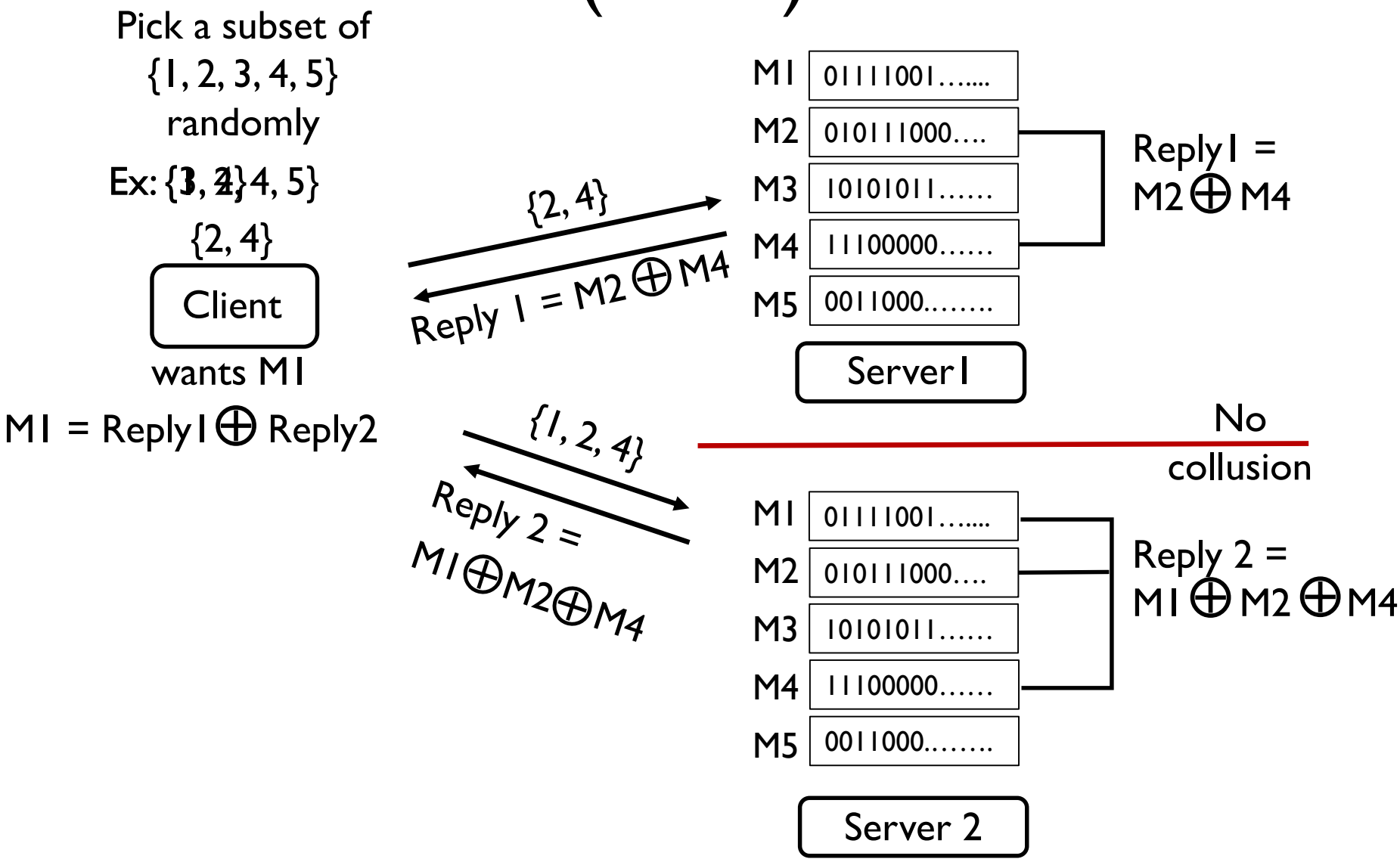
Popcorn tailors PIR for media to meet our three requirements.

Its per-request dollar cost is 3.87x times that of a non-private baseline.

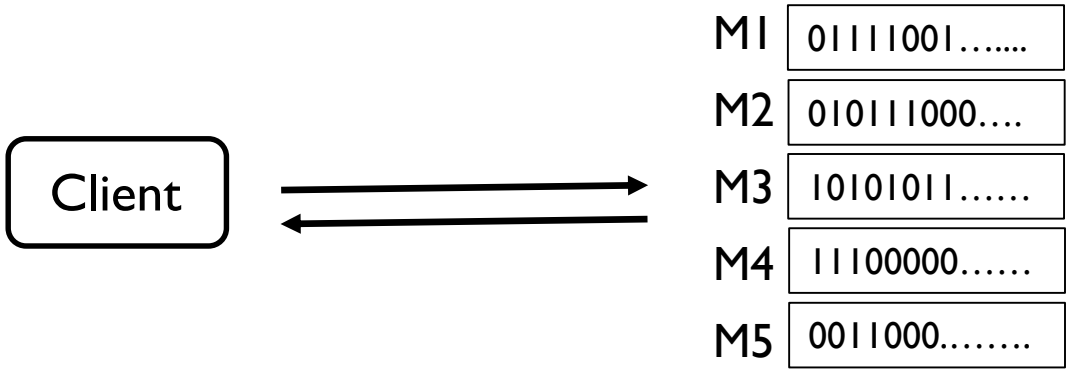
Rest of this talk

- Background on PIR.
- Challenges of using PIR (in detail).
- Design (tailoring of PIR) and evaluation of Popcorn.

Background on information-theoretic PIR (ITPIR)



Computational PIR (CPIR) from 10,000 feet



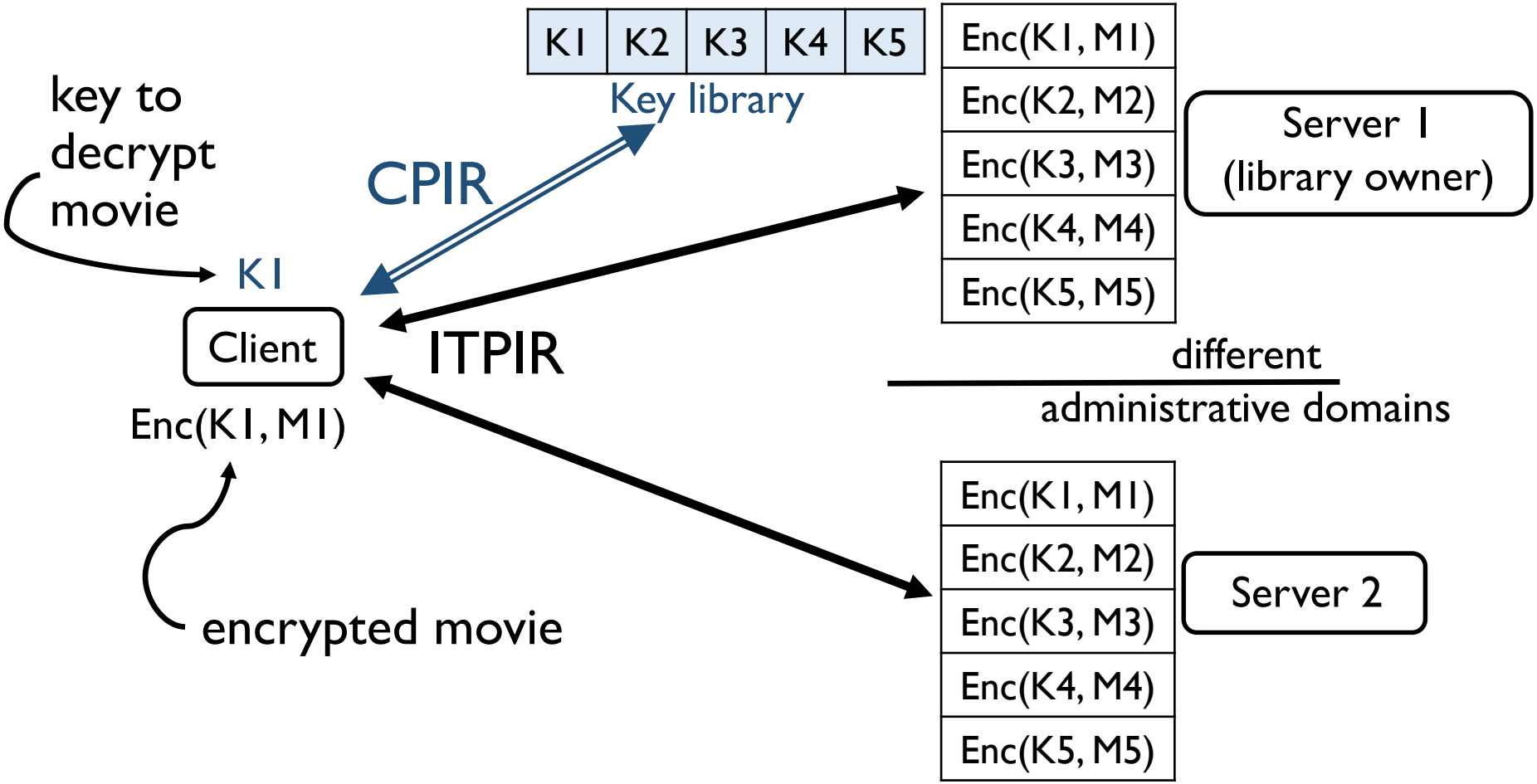
- one server
- instead of XORs, expensive server-side cryptographic operations

Challenges of using PIR

ITPIR	CPIR
content can disseminate in an uncontrolled manner	content disseminates in a controlled manner
cheap operations (XORs) but process entire library per request	expensive operations and process entire library per request
assumes fixed-size objects	assumes fixed-size objects

Given these, how can we build a system that controls content and is low cost?

Popcorn composes ITPIR and CPIR to get desirable properties from both



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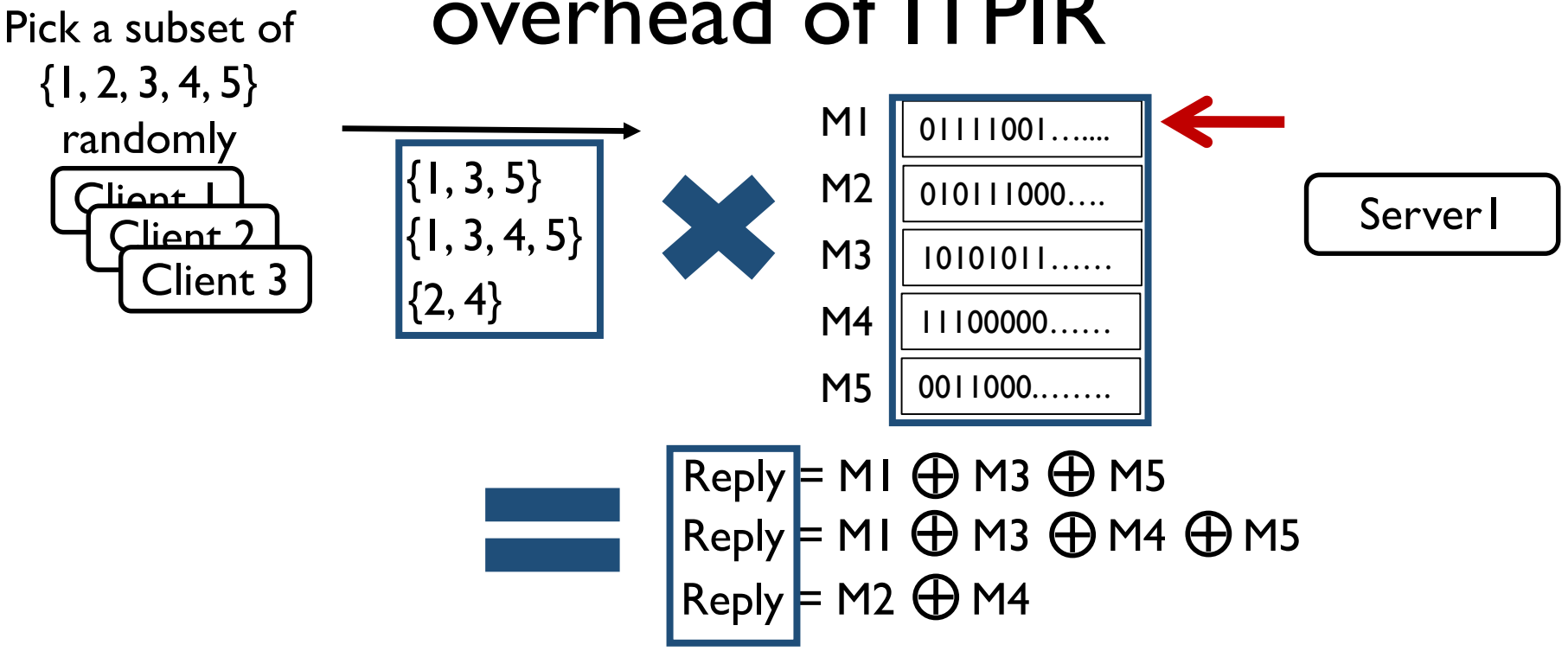
Popcorn

Popcorn batches requests to amortize the overhead of ITPIR

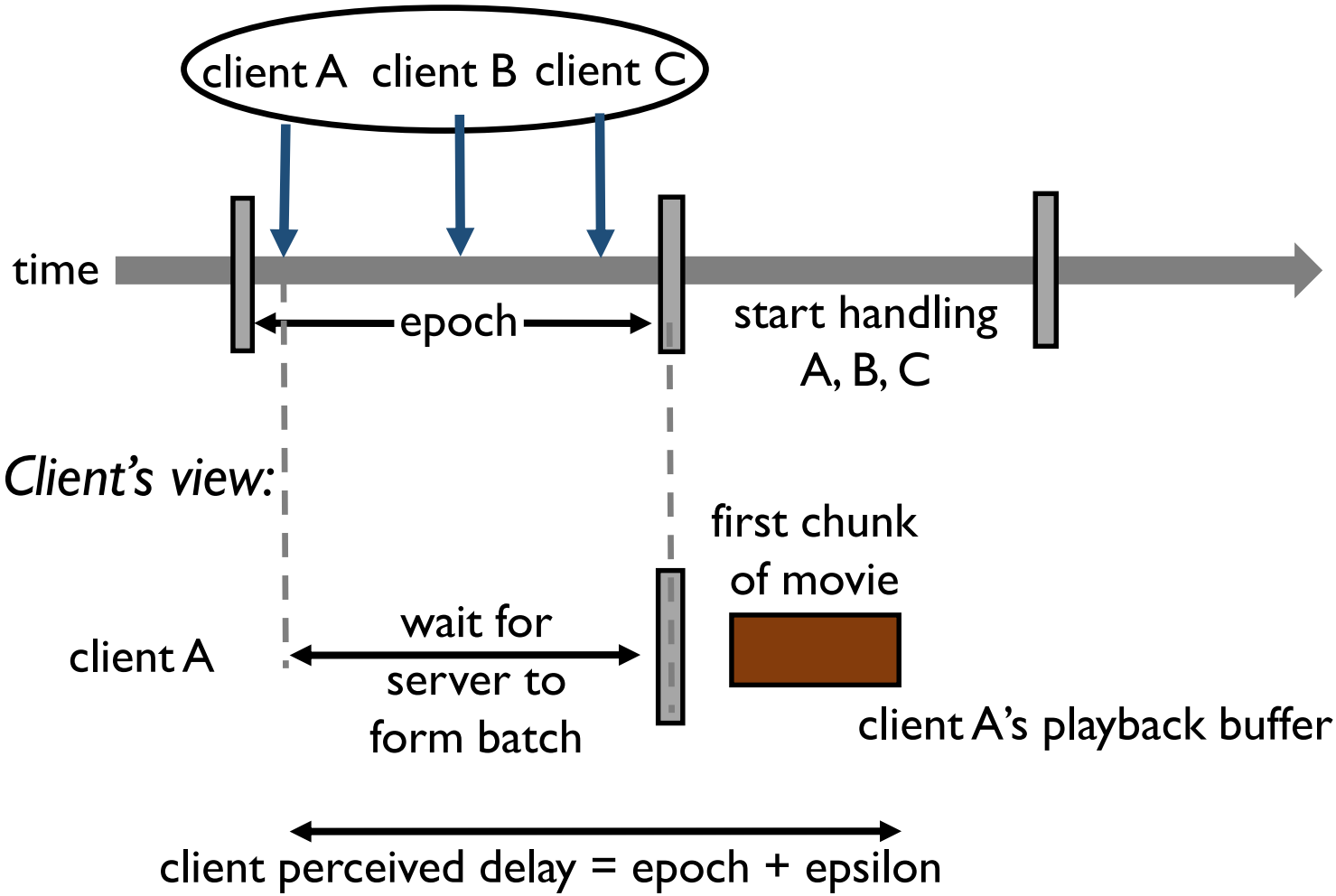


Observation: Very similar disk I/O for each request!

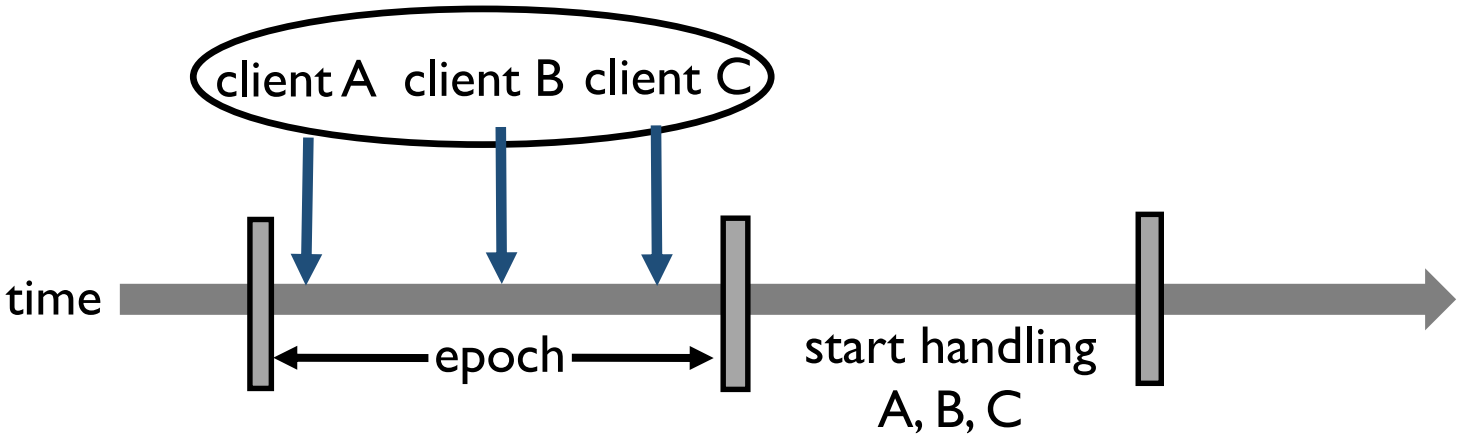
Benefits of batching:

- Disk I/O transfers are amortized.
- CPU cycles are reduced as matrix multiplication algorithms exploit cache locality.

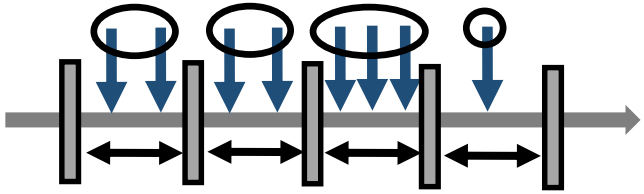
Straw man: Group requests that arrive during an epoch



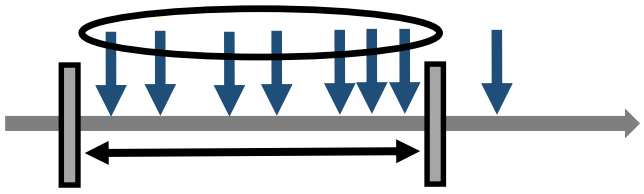
Straw man: Group requests that arrive during an epoch



Server's choices:



Small batch, small delay



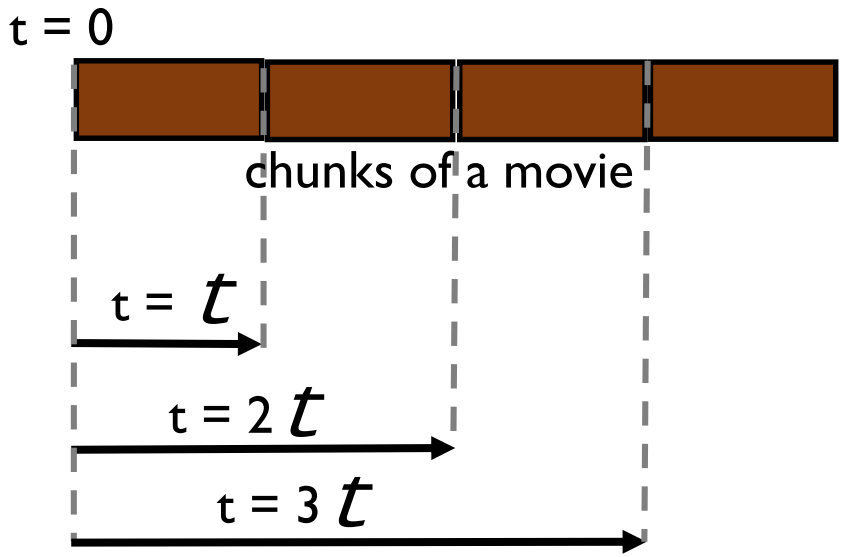
Large batch, large delay

Issue: Hard to get both small delay and large batch

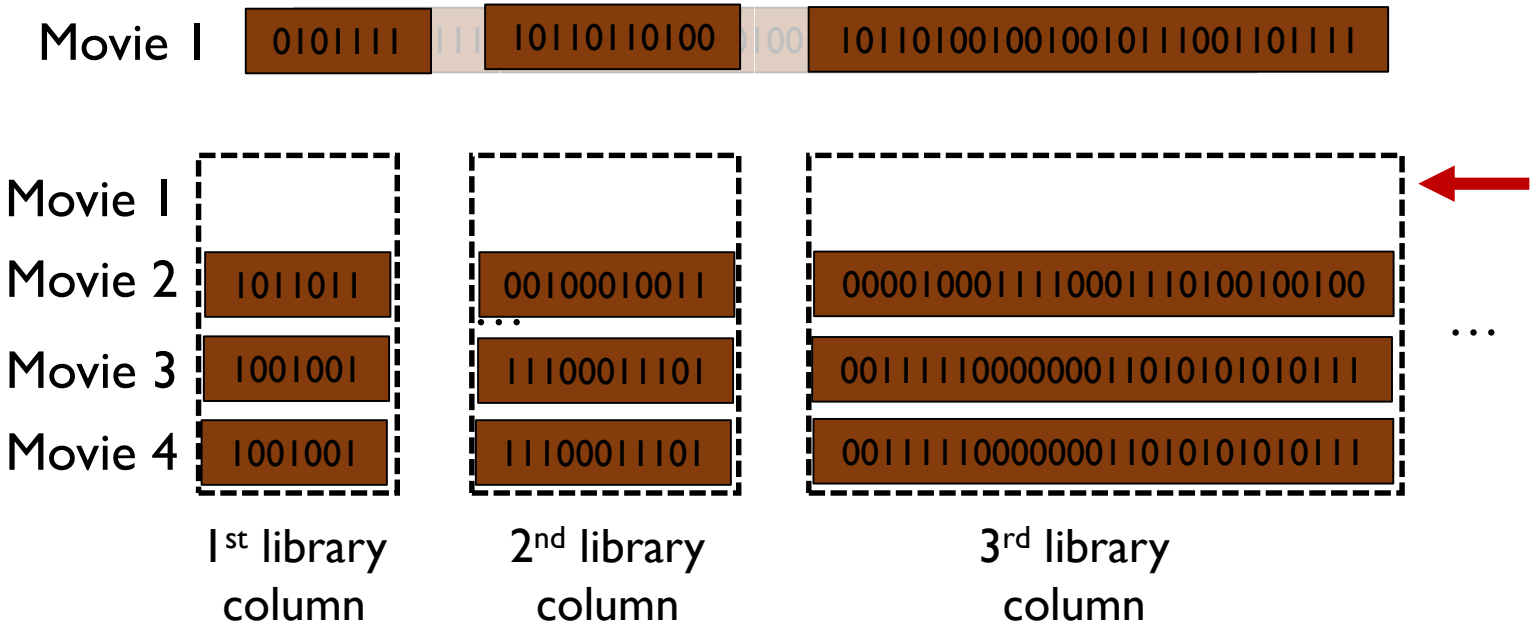
Popcorn exploits streaming to form large batches with small startup delay

t = times at which a client needs movie chunks

t = time it takes to consume a single chunk



Observation: Client needs only the first chunk immediately.



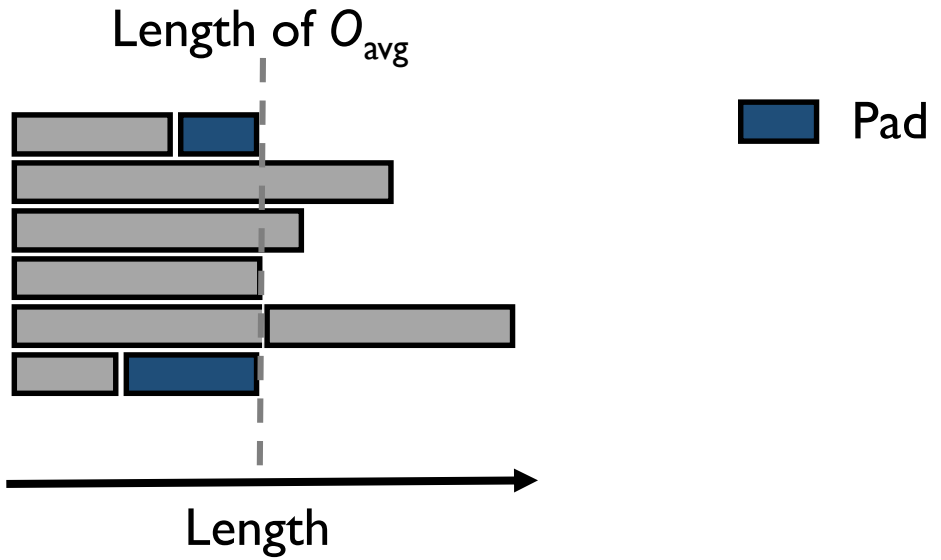
Narrow first column => small startup delay

Wider columns => longer processing times …

… ***but bigger batches***

ITPIR	CPIR	Popcorn
content can disseminate in an uncontrolled manner	content disseminates in a controlled manner	content disseminates in a controlled manner
cheap operations but process entire library *per request*	expensive operations, process entire library *per request*	cheap operations, process entire library *per batch*
assumes fixed-size objects	assumes fixed-size objects	?

Popcorn exploits compression to address fixed-size requirement



- Small variations in bitrate have limited impact on user satisfaction [SIGCOMM 11, LANC 11, CCNC 12].

- 85% of movies close to the average size.

Outline

Popcorn

✓Background on PIR.

✓Design (tailoring of PIR) of Popcorn.

• Evaluation of Popcorn.

Experiment method

Baselines:

- Non-private system (Apache server)
- State-of-the-art CPIR [XPIR PETS16]
- State-of-the-art ITPIR [Percy++]
- ITPIR++: ITPIR extended with the straw man batching scheme

Netflix-like library: 8000 movies, 90 minutes, 4Mbps

Workload: 10K clients arrive within 90 minutes according to a Poisson process

Estimate per-request dollar cost using Amazon's pricing model

- CPU: $0.0076/hour
- Disk I/O bandwidth: $0.042/Gbps-hour
- Network: $0.006/GB

System	# of CPUs	Disk I/O (Gbps)	Network (relative to non-private)	$ relative to non-private
Non-private	0	0	1x	1x
CPIR	11.6	64	5x	265x
ITPIR	3.1	64	2x	256x
ITPIR++ (delay 15s)	0.65	3	2x	14x
Popcorn (delay 15s)	0.74	0.23	2x	3.87x

Popcorn is private and affordable but …

- Assumes that the ITPIR servers do not collude.
- Incurs costs that are linear in the size of the library.
- Does not support recommendations, aggregate view statistics.

  Solution: Use prior work [Canny S&P '02, Toubiana et al. NDSS '10]

Related work

- Improving performance of PIR.
  - Distributing work [FC13, TDSC12], cheaper crypto [PETS16, ESORICS14, ISC10, TKDE13, WEWoRC07], bucketing [DBSec10, PETS10], batching [FC15, JoC04], secure co-processors [PET03, FAST13, NDSS08, IBM Systems Journal01]
- Protecting library content in ITPIR [RANDOM98, S&P07, WPES13]
- Handling variable-sized objects [CCSW14, NDSS13]
- Prior PIR implementations [Percy++, PETS16, CCSW14]
- Video-on-demand [MMCN95]

Take-away points from Popcorn

- It is possible to build a private, functional, and low-cost media delivery system …
- … by tailoring PIR to media delivery.
- The per-request cost in Popcorn is 3.87x that of a non-private baseline.