Discovering in-network Caching Policies in NDN Networks from a Measurement Perspective

Chengyu Fan (Colostate), Susmit Shannigrahi (Tennessee Tech), Christos Papadopoulos (Colostate), **Craig Partridge** (Colostate)

Colorado State University

NDN requires measuring in-network states

- Network measurement tools cover various aspects in IP networks
  - Network performance, states (routing, configurations, and topology, etc.), and traffic

- NDN measurements must capture in-network states
  - Caching policies, forwarding strategies, etc.

Goals and Assumptions

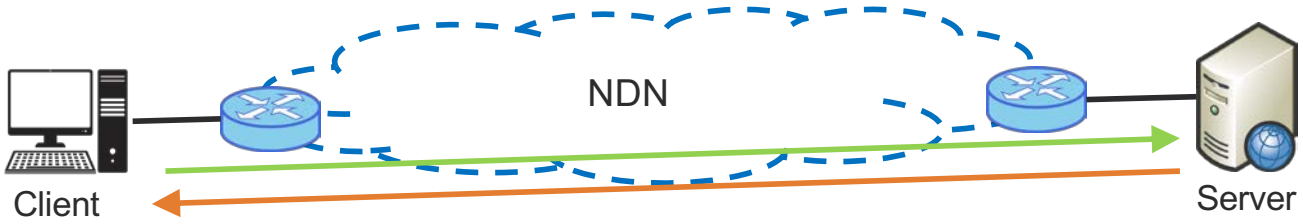
- Our goal: first work to detect caching decisions from a measurement perspective
  - Caching is a central feature of NDN
  - Caching policy = caching decision + cache replacement
  - Multiple caching decisions may exist in NDN networks, and they may interact poorly

- Assumptions
  - The best-route forwarding strategy and uniform caching decision policy are used
  - Priority-FIFO cache replacement policy is used (by default)
  - Only one producer exists

List of caching decisions developed for NDN

- Caching Everything Everywhere (CEE)
  - Cache every Data chunk locally
- Leave Copy Down (LCD)
  - Move down the cached copy one hop down
- Label-caching
  - Pre-decide assign labels to routers, caching chunks whose ID%N match the label value
- Static probabilistic caching (Prob-20, Prob-50, Prob-80)
  - Pre-define the probability value, and compare it with the generated random number for each chunk
- Dynamic probabilistic caching (ProbCache, ProbCache-inv)
  - Dynamically calculate a cache weight based on the ratio of hop count of Data and Interest

Measurement procedure



Pre-defined the target name prefix, Data payload size, and other Data packet parameters

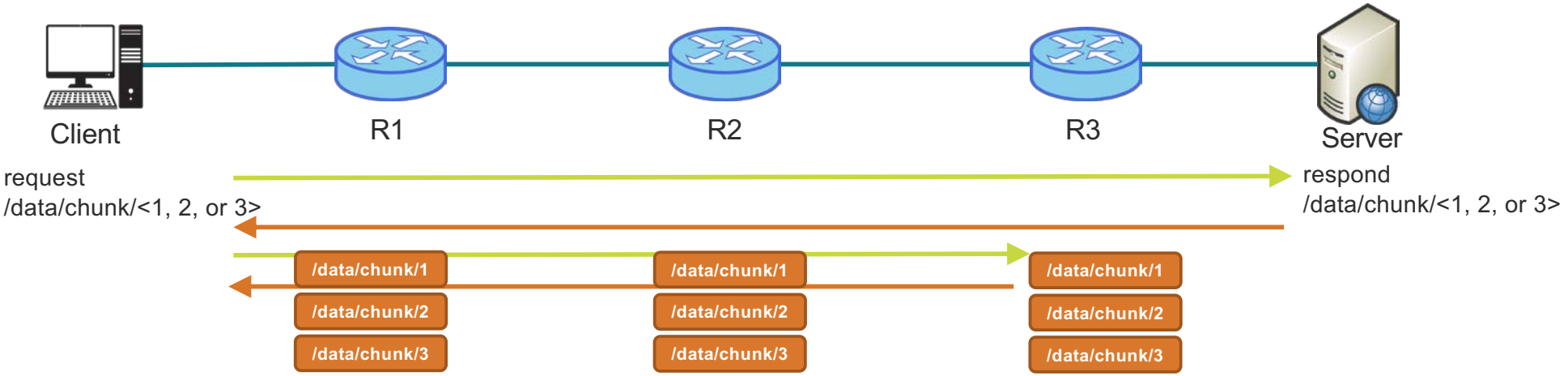
1. Send out a train (50) of Interests with the given name prefix
   - Each contains a unique name: **/<name-prefix>/<chunk-id>**

2. Answer each Interest

3. Save the hop count for each chunk

4. Repeat step 1 ~ 3 for ten times (cached copy can satisfy duplicate request), and plot the hop count distribution in the figure

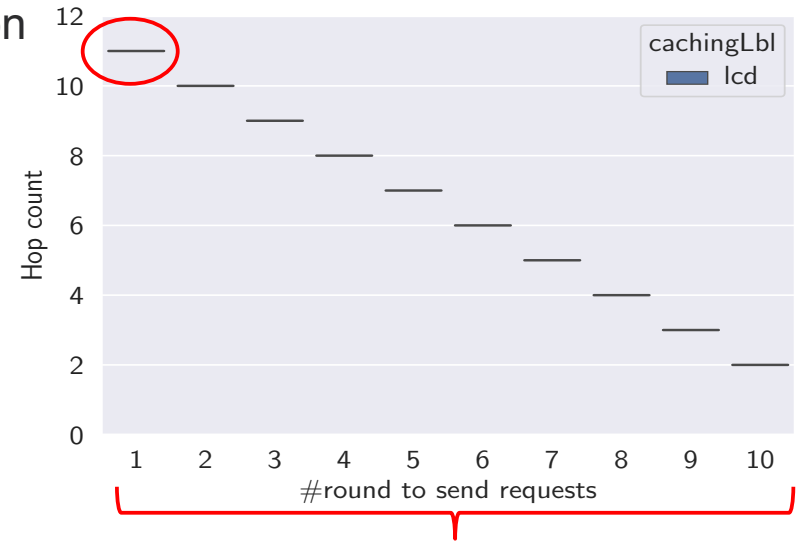
Example: LCD caching decision



- Leave Copy Down (LCD) caching decision mechanism
  - The requested chunks is cached only at the cache that below the location of the hit on the path
- Takeaways
  - All chunks are cached at specific hops in each round, and the hop count across rounds differs

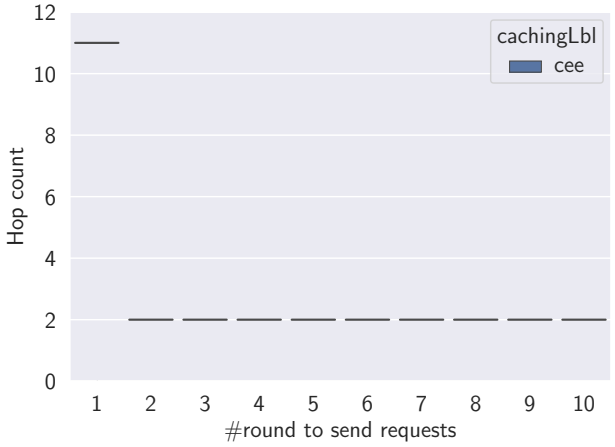
Fingerprint of LCD mechanism

- Simulations with ndnSIM
  - A linear topology with 10 routers
- Two metrics uniquely identify a caching decision
  - Hop count distribution in one round
  - The distribution change cross multiple rounds

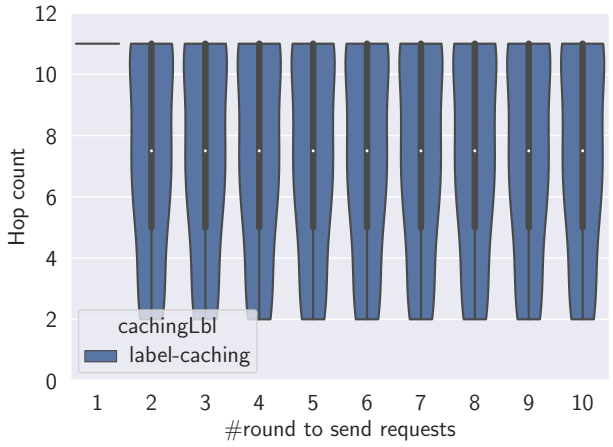


Fingerprints for other mechanisms

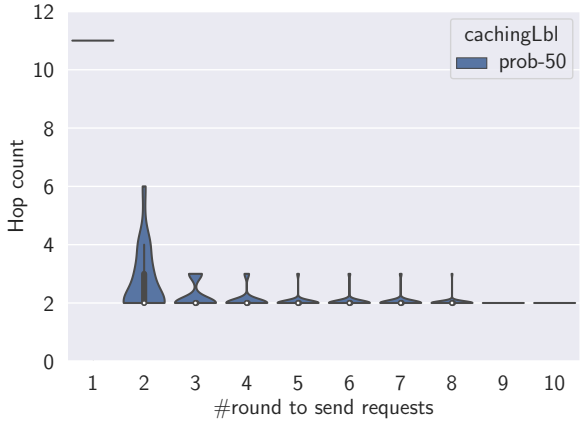
- Caching Everything Everywhere (**CEE**) - cache every Data chunk locally
- **Label-caching** - cache chunks whose ID%N match the pre-assigned label value
- Static probabilistic caching (**Prob-**X) - compare the random number with pre-defined probability value



CEE



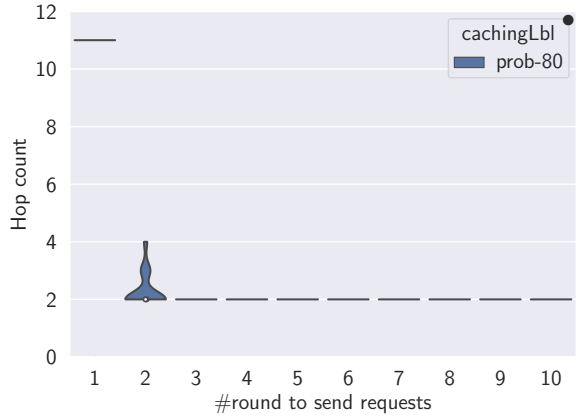
Label-caching

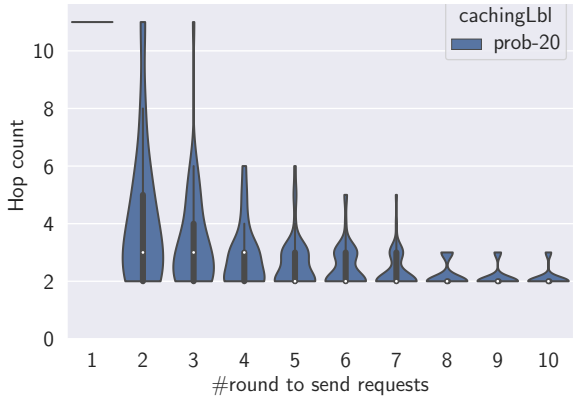


Prob-50

Fingerprints for probabilistic caching mechanisms

Static





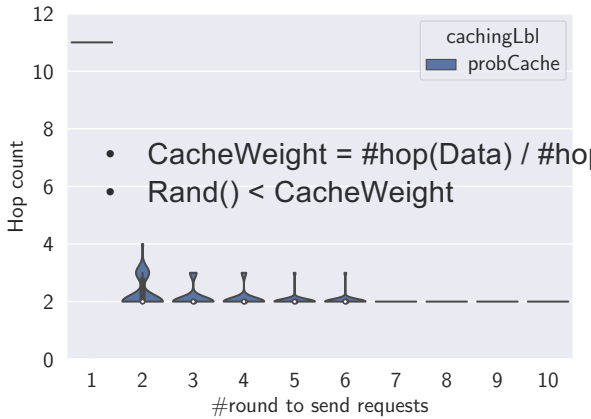
Dynamic probabilistic caching:

- ➢ Calculate a weight based on the ratio of the hop count of Data and Interest

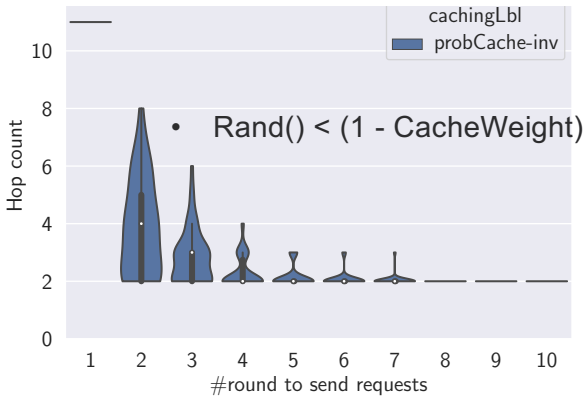
- ProbCache converges slower than prob-80

- ProbCache-inv converges faster than prob-20

Dynamic

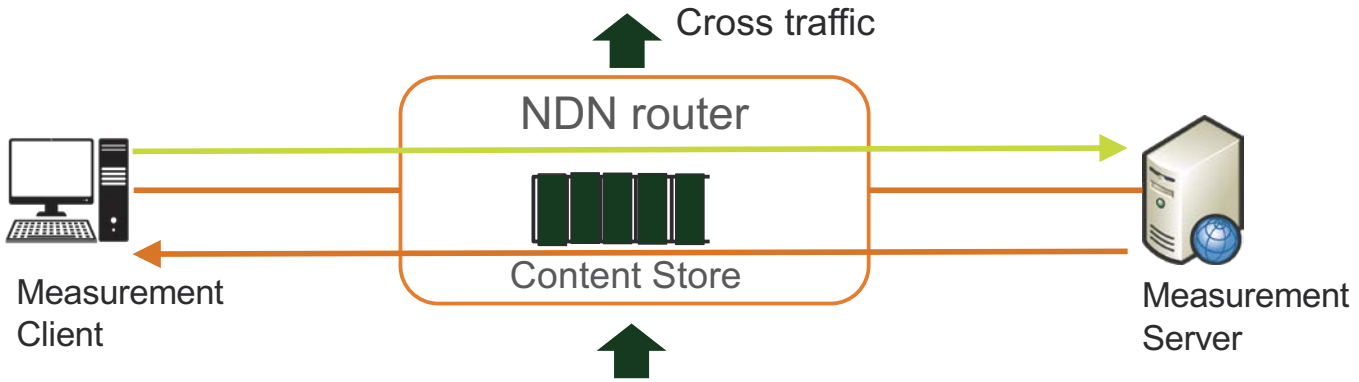


- CacheWeight = #hop(Data) / #hop(Interest)
- Rand() < CacheWeight



- Rand() < (1 - CacheWeight)

Cross traffic may hurt measurements

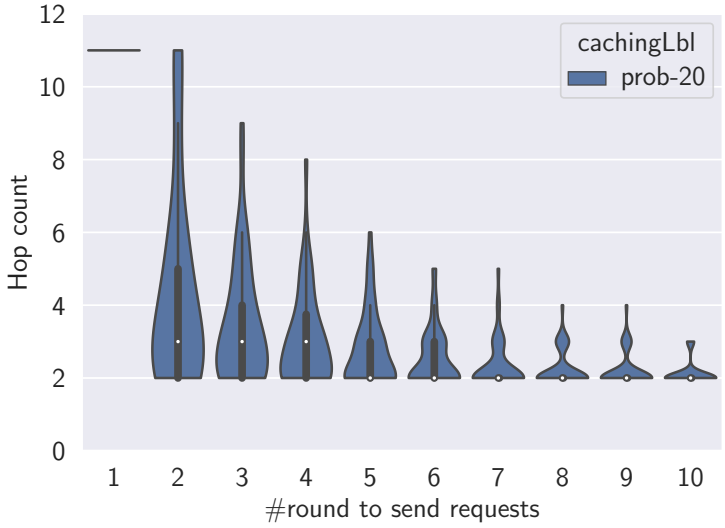


- Cross traffic may exist in networks
  - Occupy cache slots
  - Evict cached probe packets
  - Impact detecting caching policies
- We check the effects by introducing cross traffic at two ends of the linear topology

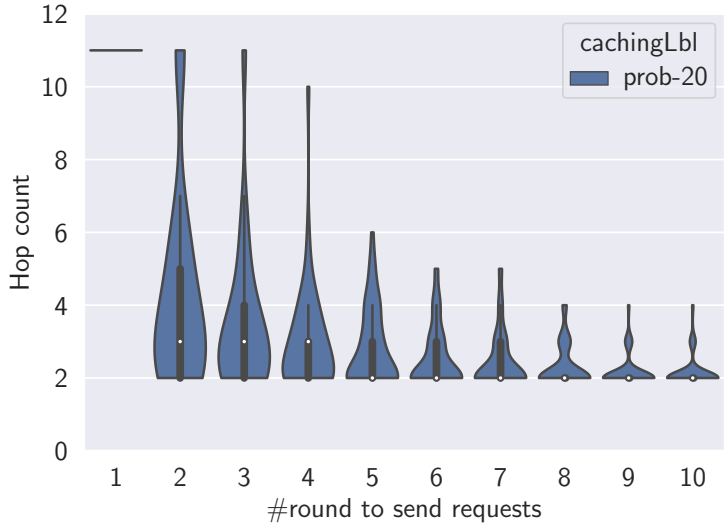
Robustness to cross traffic

- We can identify the caching mechanisms, as most plot shapes are almost unchanged

Client-side cross traffic



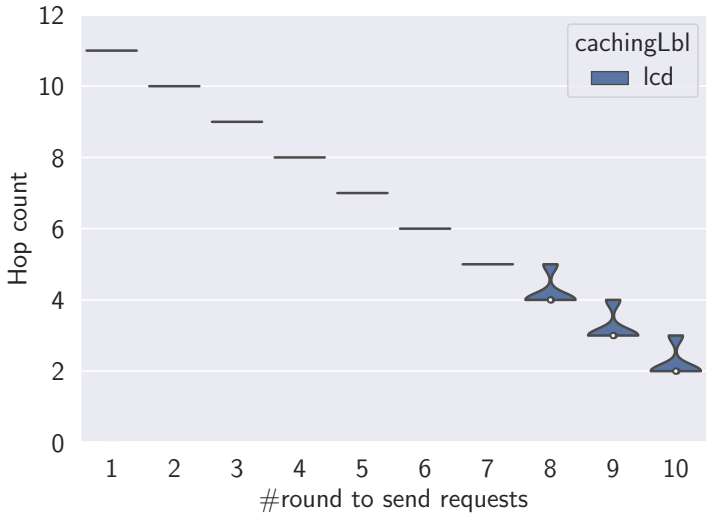
Server-side cross traffic



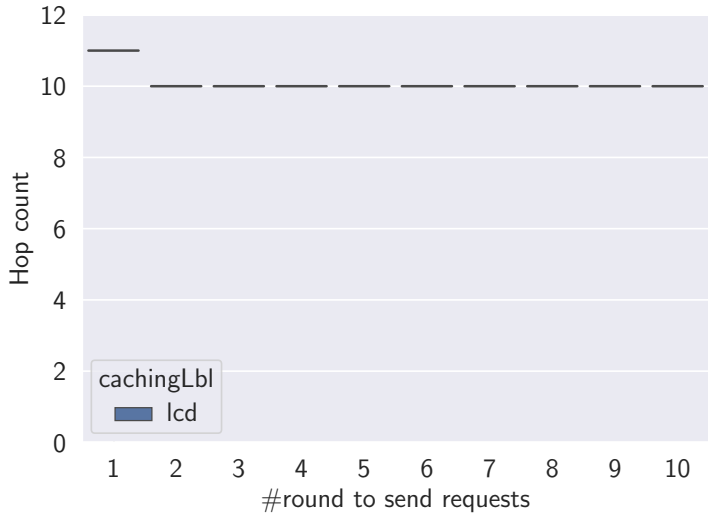
Robustness to cross traffic (cont.)

- Shapes for LCD are changed, but it has the unique feature

Client-side cross traffic

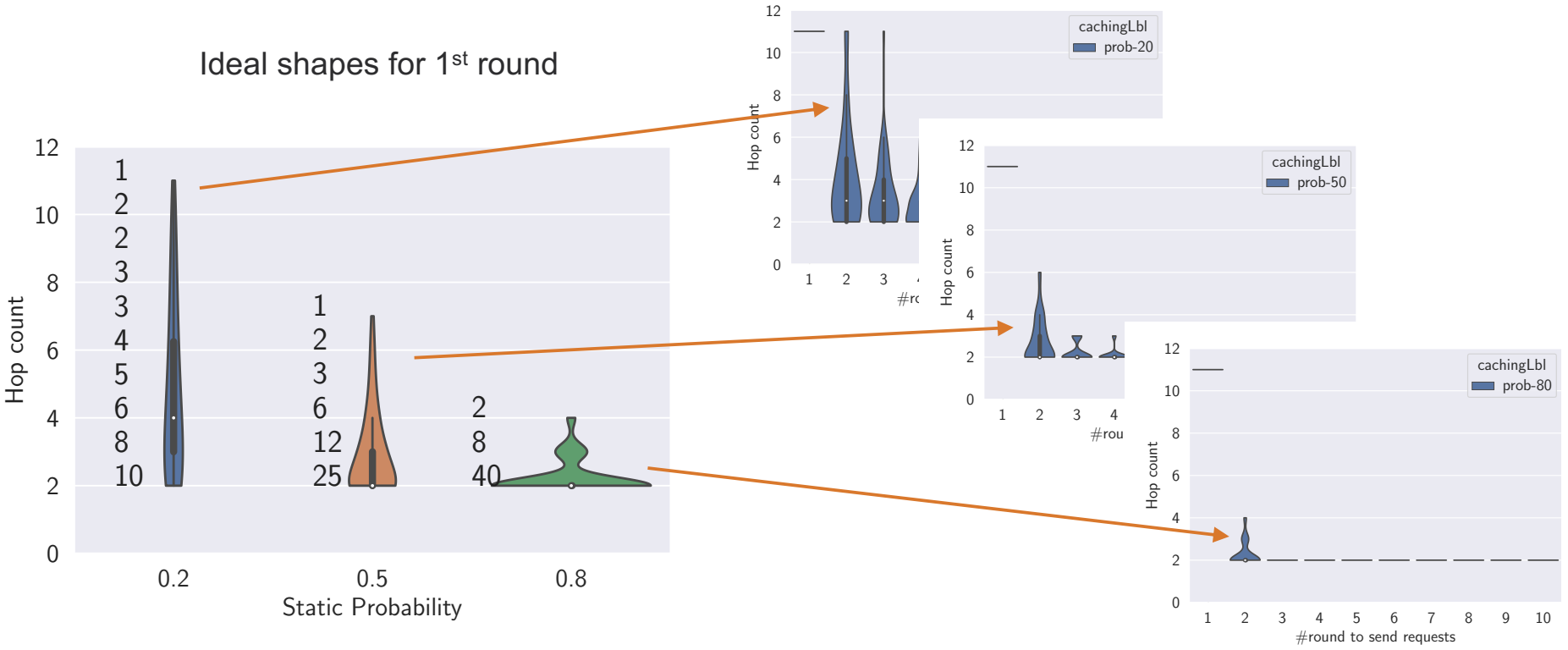


Server-side cross traffic



Estimate static probabilistic value

Shapes based on simulation results

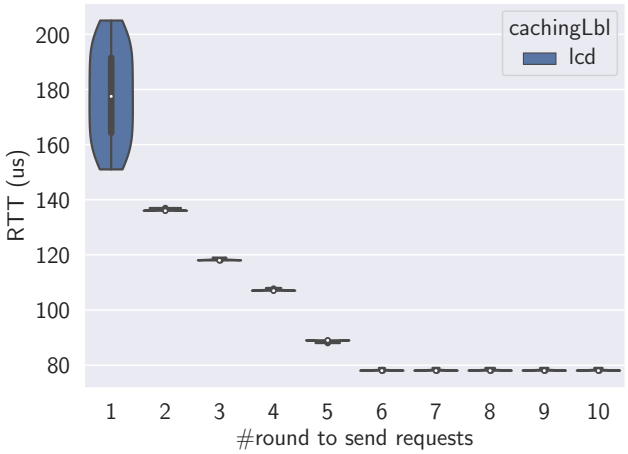


Detecting on real topology

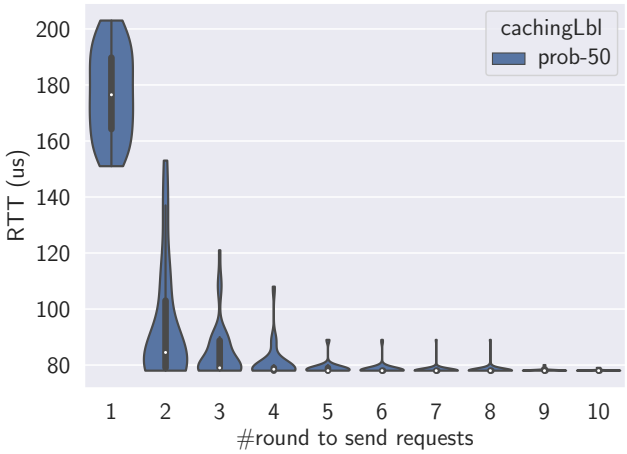
- The NDN stack does not expose the hop count information to applications
  - Can we use delays to infer the correct hops?
- Use topology Rocketfuel 7018 with randomly chosen client and server

Delays may produce "correct" hop counts

LCD

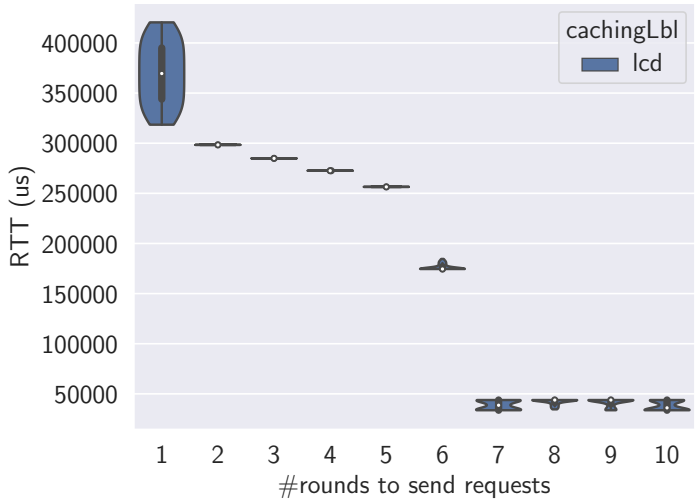


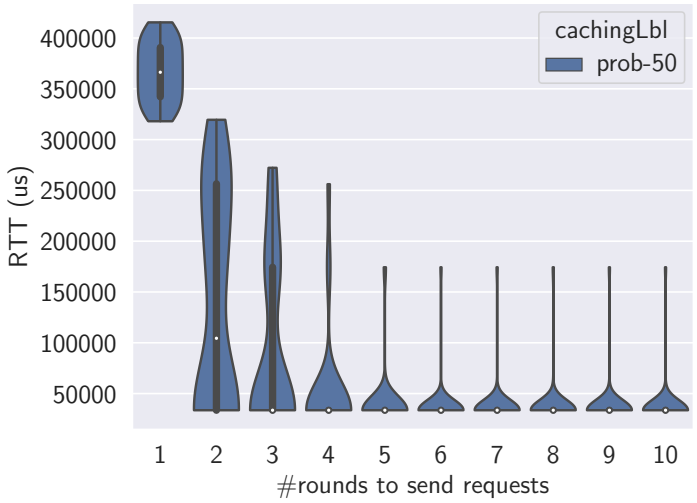
Prob-20



Delays do not always infer the correct hops

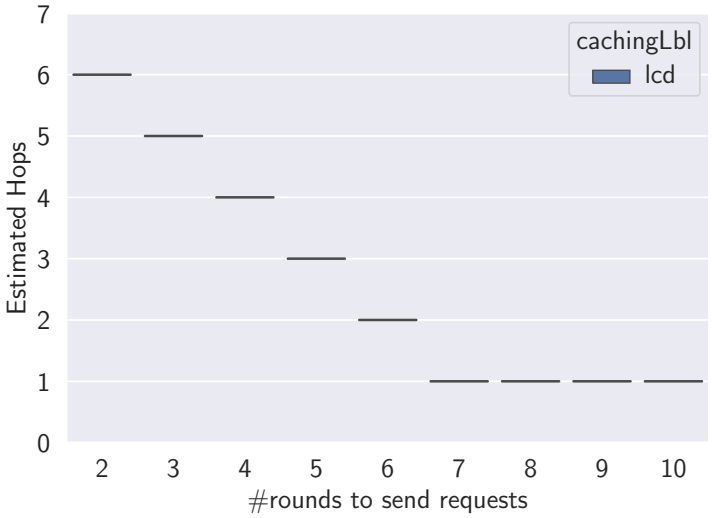
- In some cases, link delays may not be identical with hops

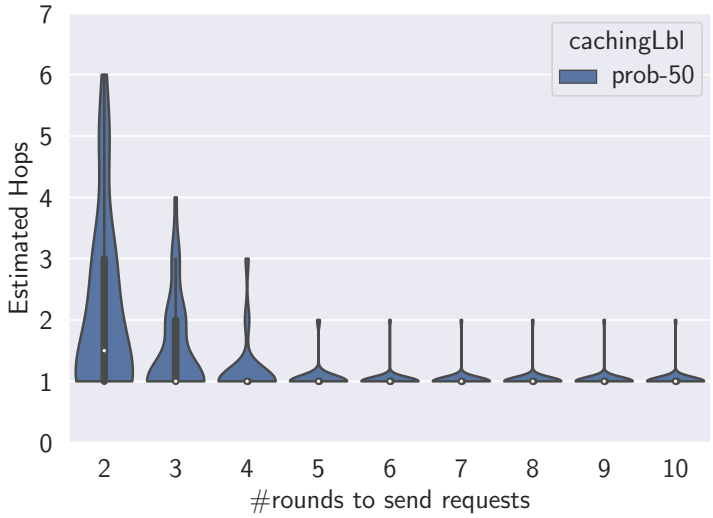




Estimating hop counts

- Using clustering algorithms (e.g. K-means) to group samples with similar delays
  - The figures approximately show the correct shapes





Conclusion

- Proposed a novel method to extract fingerprints for caching decision mechanisms
- The method can detect caching decisions mechanisms from end hosts
  - Not sensitive to cross traffic
  - Can estimate probability value
- Evaluated the method on a real topology
  - Applications use delays to estimate hop counts

Future work

- Evaluate the method with more caching mechanisms on a real testbed (i.e. NDN testbed)
- Study the robustness of our method with other cache replacement policies
- Integrate the measurement tool with the NDN measurement framework designed by NIST [1] [2]
- Study the scenarios where multiple producers exist and other forwarding strategies are used

[1] Pesavento, Davide, et al. "A network measurement framework for named data networks." *Proceedings of the 4th ACM Conference on Information-Centric Networking*. 2017.
[2] Nichols, Kathleen. "Lessons Learned Building a Secure Network Measurement Framework using Basic NDN." Proceedings of the 6th ACM Conference on Information-Centric Networking. 2019.

Thanks!