Intra-AS Cooperative Caching for Content-Centric Networks

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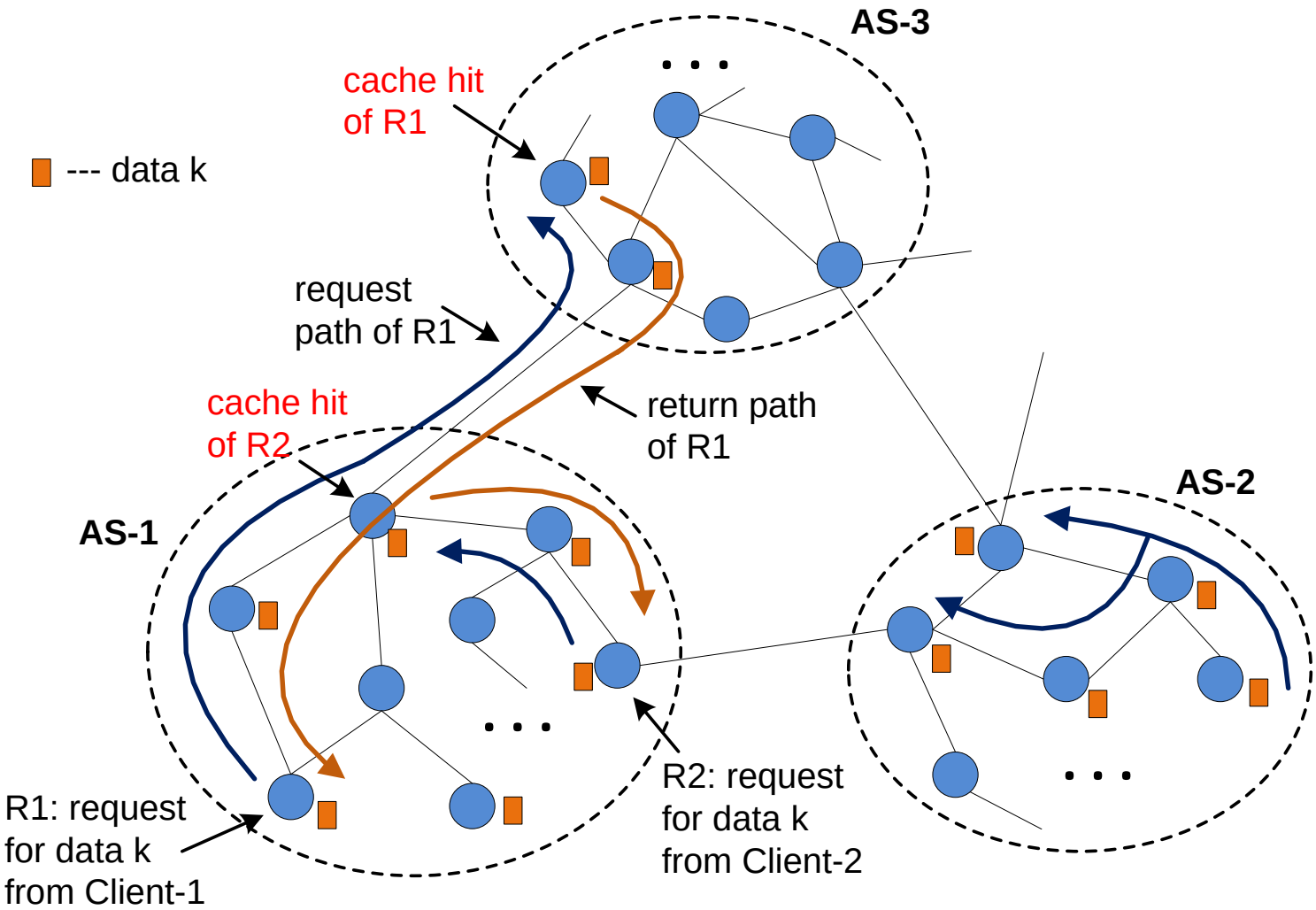
Outline

Request-Response Scenario in CCN



Motivation for Redundancy Elimination

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- CCN enables individual nodes to reduce redundancy by managing a local cache
  - the central abstraction is the **named-data**.
- However, redundancy can freely appear across different nodes:
  - the default **ubiquitous LRU** caching scheme;
  - the support of **multi-path routing**.
- **Controlling the redundancy level** is critical to improving the systematic caching performance of CCN.

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  - yet CCN is expected to **greatly offload** cross-AS traffic
- These two facts dictate **a frugal usage of limited caching resources** within the AS,
  - storing valuable content only;
  - avoiding storage waste by reducing redundancy;

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- Our work adopts the **horizontal-passive** approach.

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- $G = (N, E)$: a network managed by a single administrative authority
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Cooperation Scope

1. node i can own the view of cached items of nodes in N_i and can utilize them to serve its locally-unsatisfied requests;
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- x_{ik}: whether node i should keep item k (1: yes; 0: no)
- $(S_i - \sum_{k \in K_i} x_{ik})$: the released slots from the cooperative RE

Problem Formulation

- **Cooperative Redundancy Elimination** (CRE):

$$\begin{aligned}
\text{max} \quad & \sum_{i \in N} w_i U_i(S_i - \sum_{k \in K_i} x_{ik}) \\
\text{s.t.} \quad & S_i - \sum_{k \in K_i} x_{ik} \geq 0, \ \forall i \in N \\
& x_{ik} + \sum_{j \in N_i, k \in K_j} x_{jk} \geq 1, \ \forall i \in N, k \in K_i \\
& x_{ik} \in \{0, 1\}, \ \forall i \in N, k \in K_i.
\end{aligned}$$

- $U_i(\cdot)$: quantifies the benefit achieved from RE
  - $U_i(v) = \ln(1 + v)$ to achieve the proportional fairness
- w_i: the weight of node i's utility

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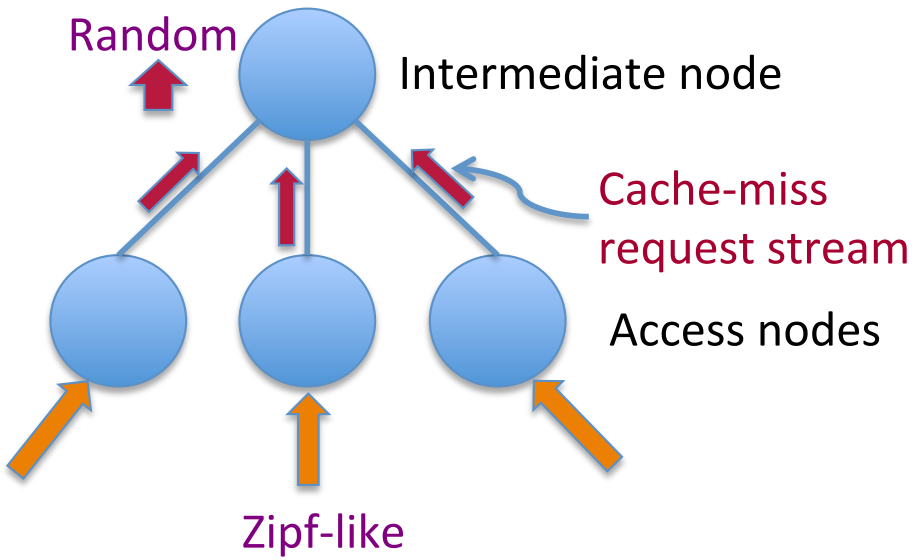

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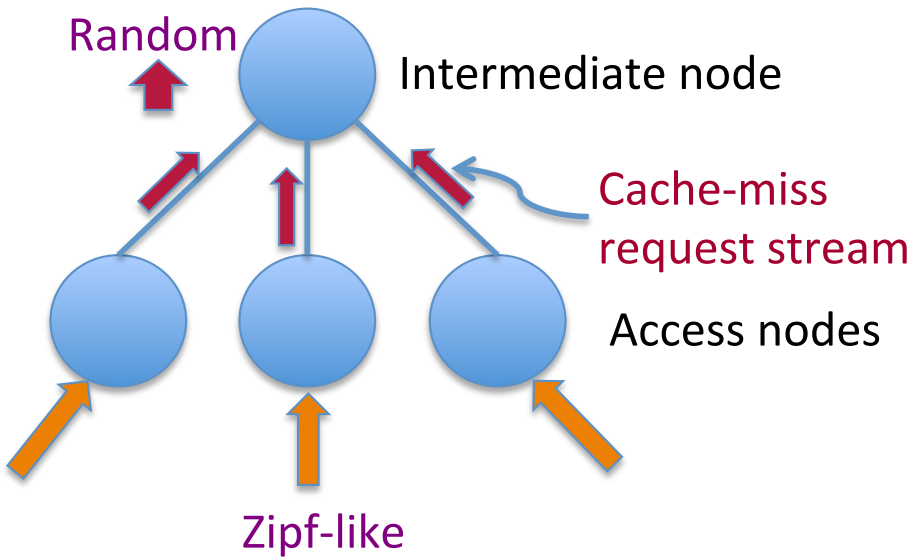
  - Two types of nodes in the AS: access nodes and intermediate nodes.
  - Due to "cache filtering effect", the caching performance of access nodes plays the major role in systematic caching performance.
  - Value more the gain of access nodes: larger w_i;
  - Value less the gain of intermediate nodes: smaller w_i;



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- **Limited cooperation scope**
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    - performance goal: minimizing the access latency;
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  - One-hop cooperation scope
    - eliminating duplicates in small groups controls overall redundancy level;
    - severs the dependence on request routing;
    - reduces the amount of signalling traffic needed for cooperation; yet,
    - only subtly prolongs access latency for evicted items;

Greedy Heuristic

- CRE is Non-linear Integer Programming and is NP-hard.
- With no fairness consideration and in absence of storage capacity constraint, CRE degenerates to solving a sequence of MDS problems.
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The greedy heuristic for MDS can be implemented in a distributed way [F. Kuhn PODC'03].

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  - "summary" encodes the information of currently cached items.
  - caveat: to avoid exposing short-lived items.

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Cache Cooperation + Cooperative Redundancy Elimination

Experimental Setup (I)

- Network topologies:

Topology	Nodes	Edges	Max degree
AS 1755	172	381	15
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- Workloads: generated using ProWGen.

	Zipf-slope	Object size	One-timers	Unique objects
Trace-1	[0.90, 0.96]	[5, 20]	[60, 70]%	[35, 40]%
Trace-2	[0.70, 0.76]	[5, 20]	[60, 70]%	[35, 40]%

Experimental Setup (II)

- CCN simulator:
  - implemented on top of OmNet++;
  - incorporate three basic components: CS, PIT, and FIB;
  - support per-chunk request, chunk-based caching, and request aggregation;
  - assume the shortest-path routing;

- The arrival process of requests (6,000) for objects is Poissonian.
- A request for object translates into a sequence of chunk requests;
  - the sending window: 1

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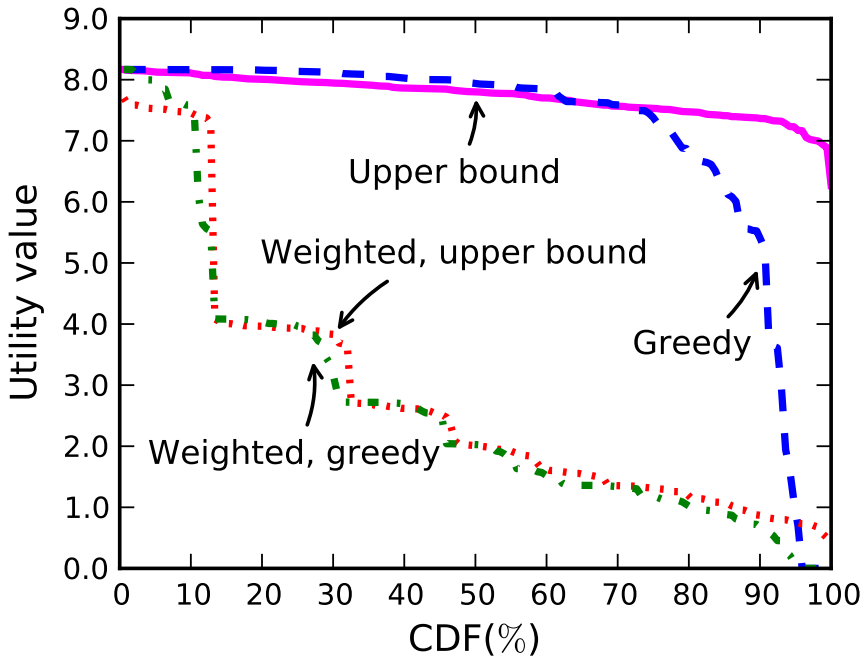

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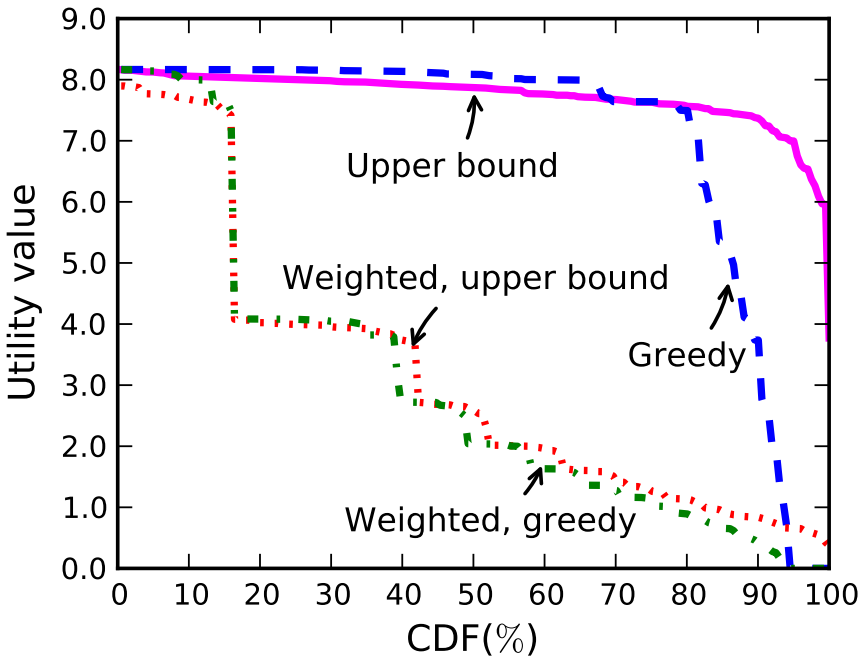

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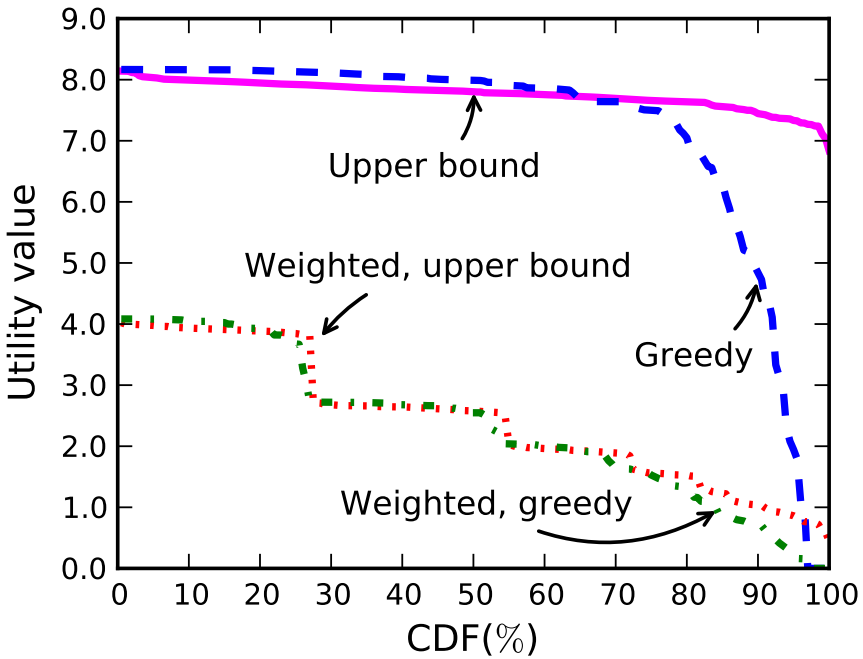

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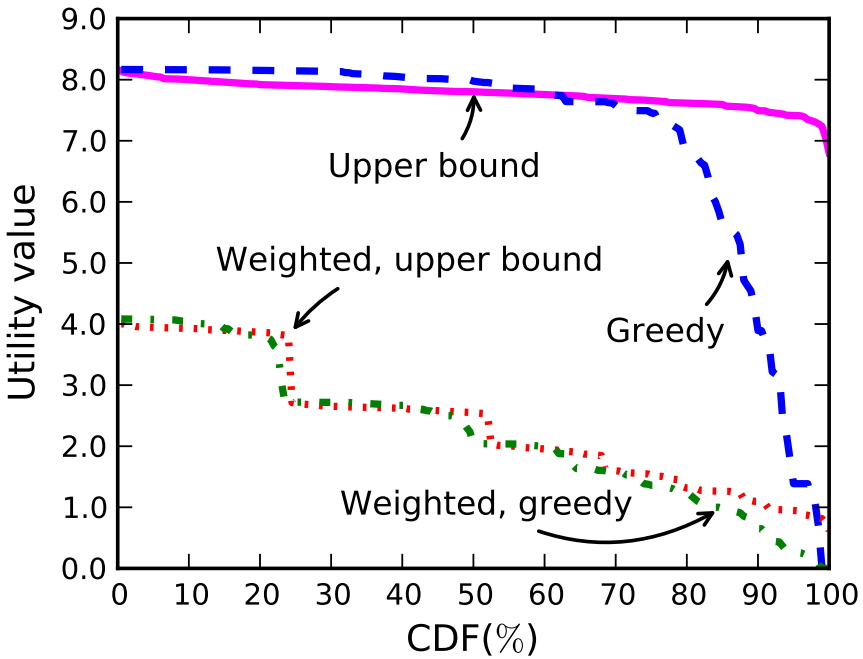

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- Report results on Trace-1, since similar results are observed for Trace-2.

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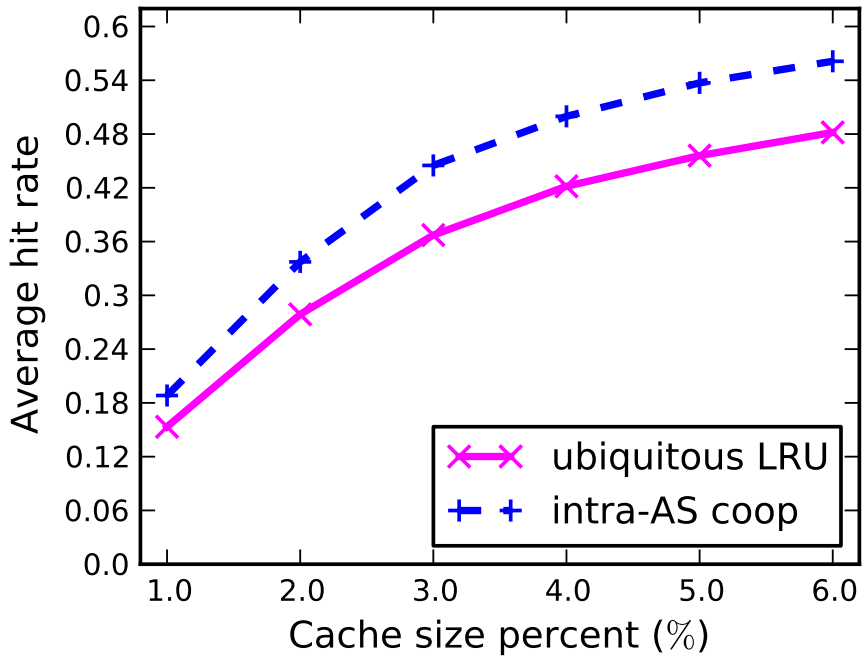

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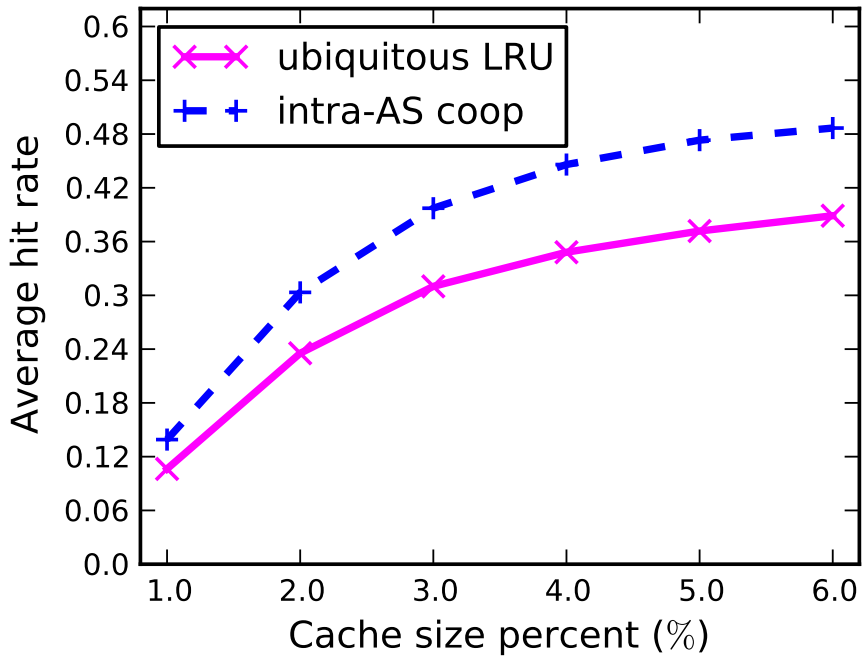

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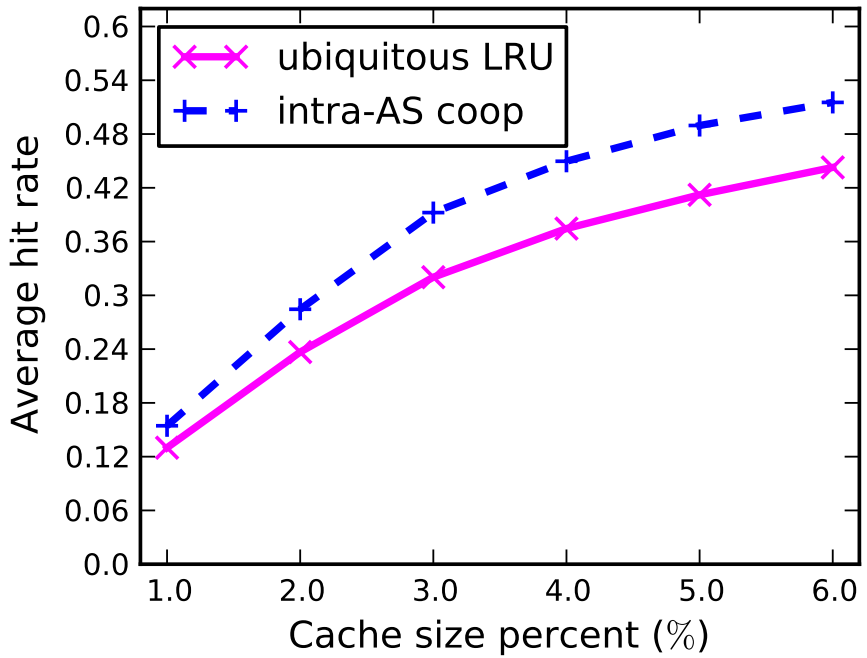

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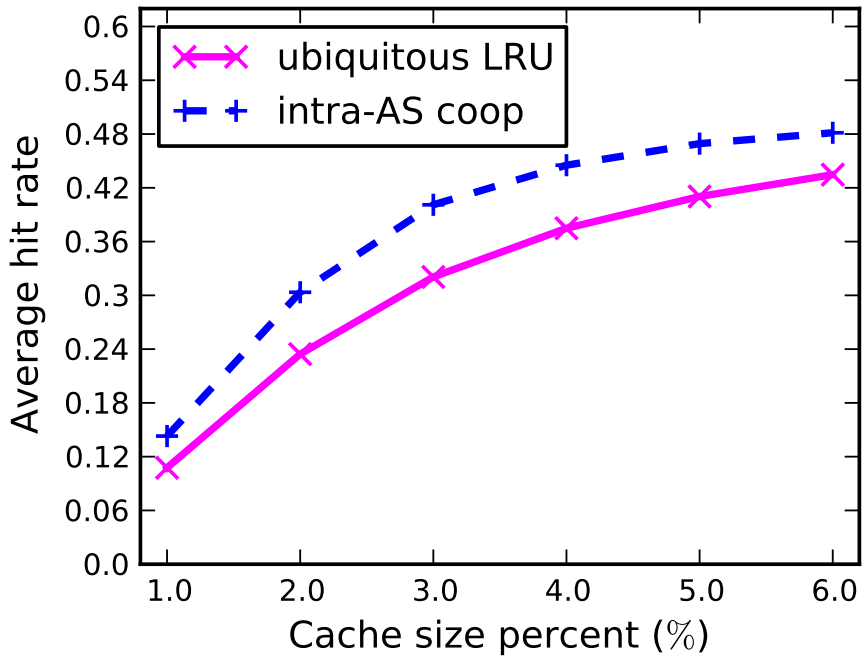

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	AS-coop	3.91	2.47	1.25	0.47	0.21	0.12
3967	ubi-LRU	5.33	3.62	1.97	0.83	0.37	0.20
	AS-coop	5.13	3.15	1.40	0.42	0.18	0.10
Brite1	ubi-LRU	4.73	3.38	2.06	1.16	0.70	0.45
	AS-coop	4.61	3.19	1.77	0.93	0.53	0.31
Brite2	ubi-LRU	4.86	3.08	1.44	0.54	0.24	0.12
	AS-coop	4.67	2.70	1.00	0.33	0.15	0.11

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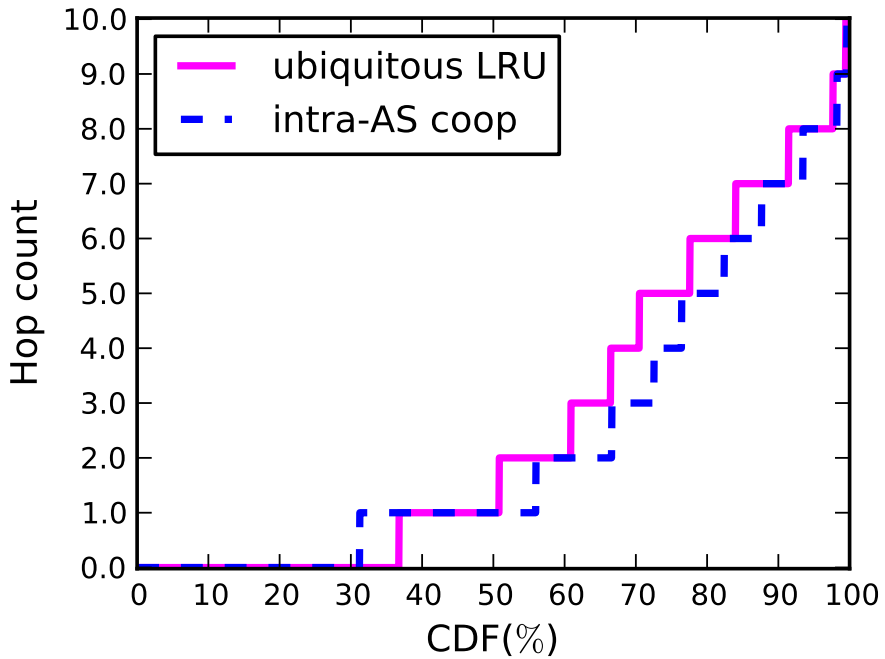

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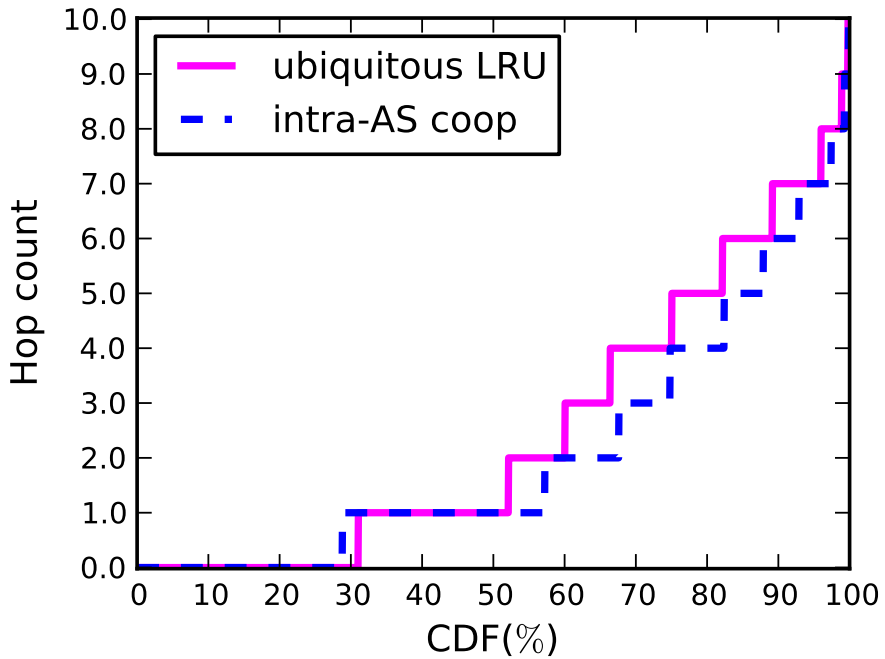

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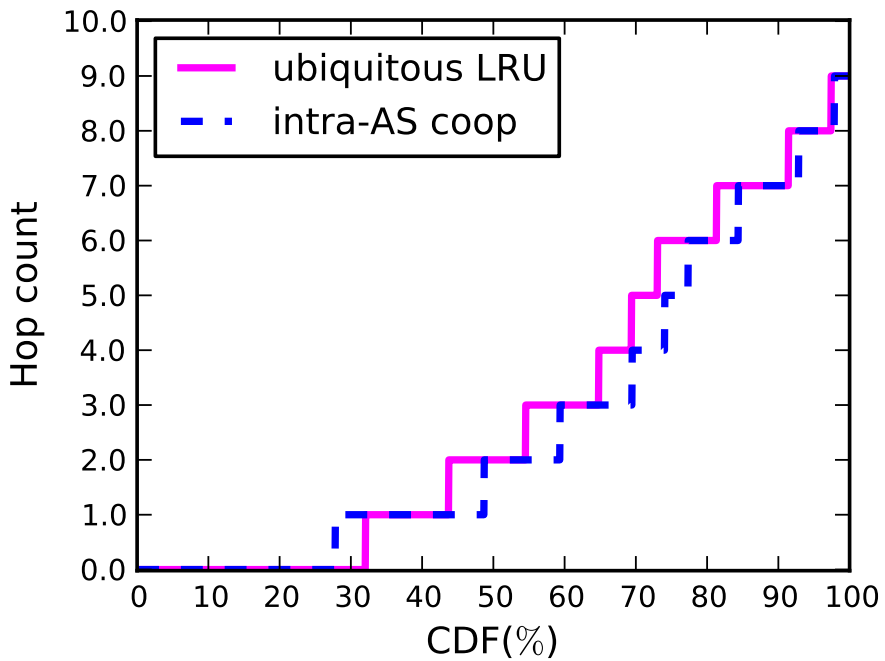

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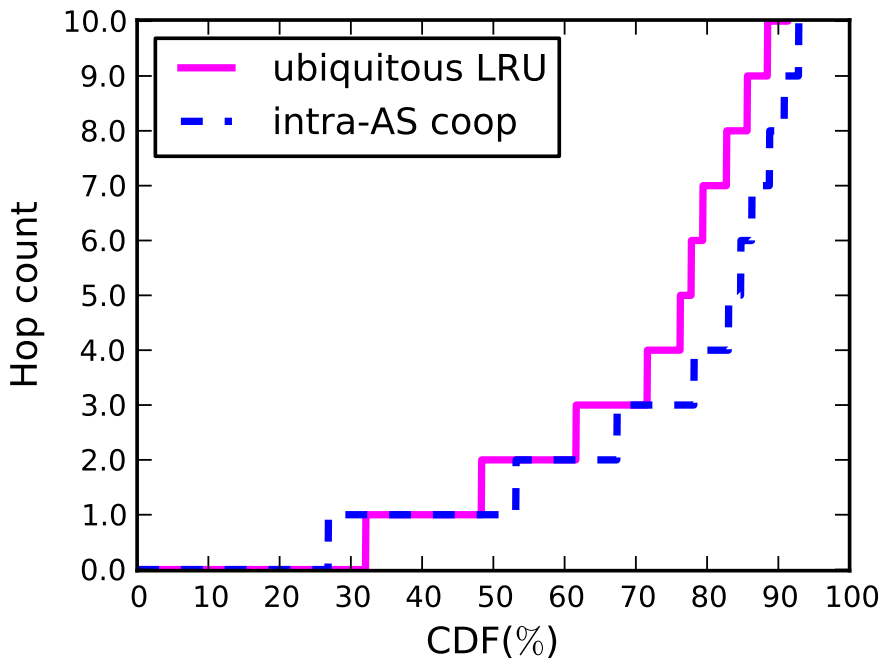

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- **Initial results**:
  - greedy is efficiency in eliminating redundancy;
  - intra-AS cache-coop improves caching performance of access routers;
  - and reduces the AS cross-traffic without overloading internal links.

Thank you very much!