Neighborhood Search and Admission Control in Cooperative Caching Networks

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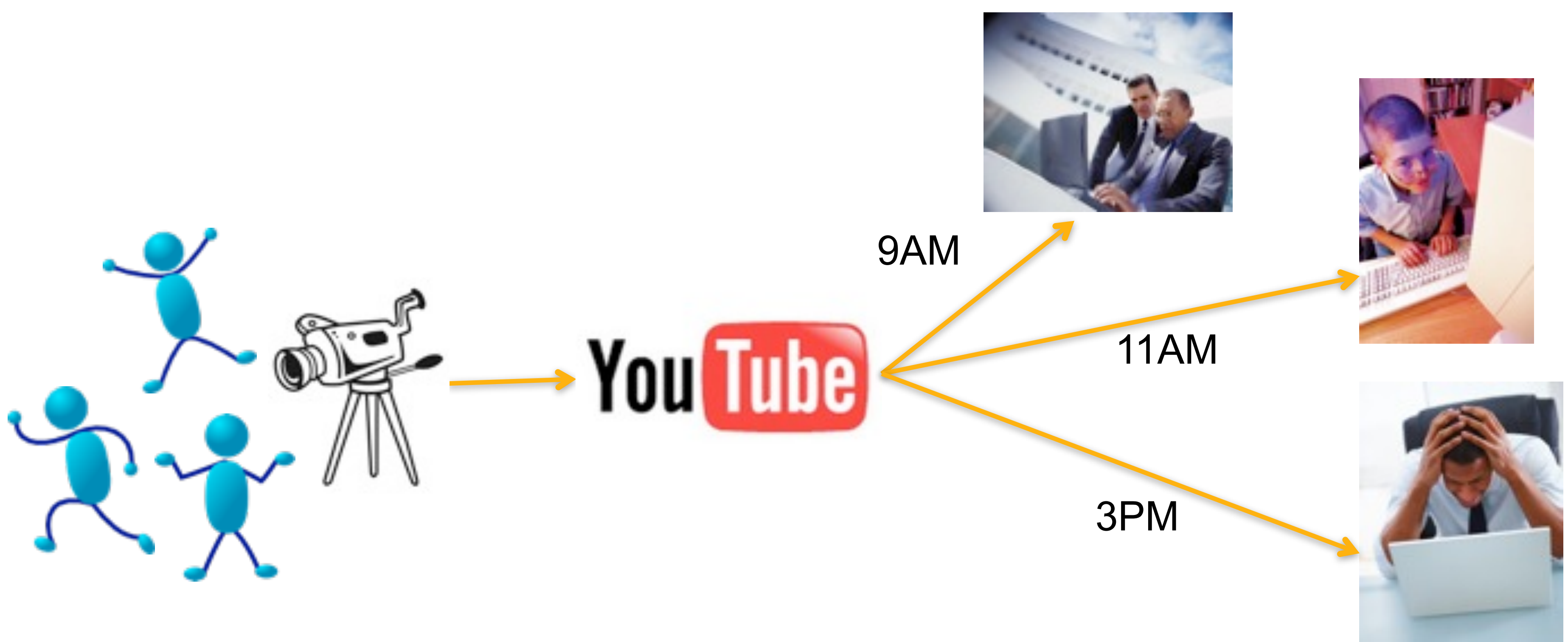
Motivation

Fast grow of user-generated content

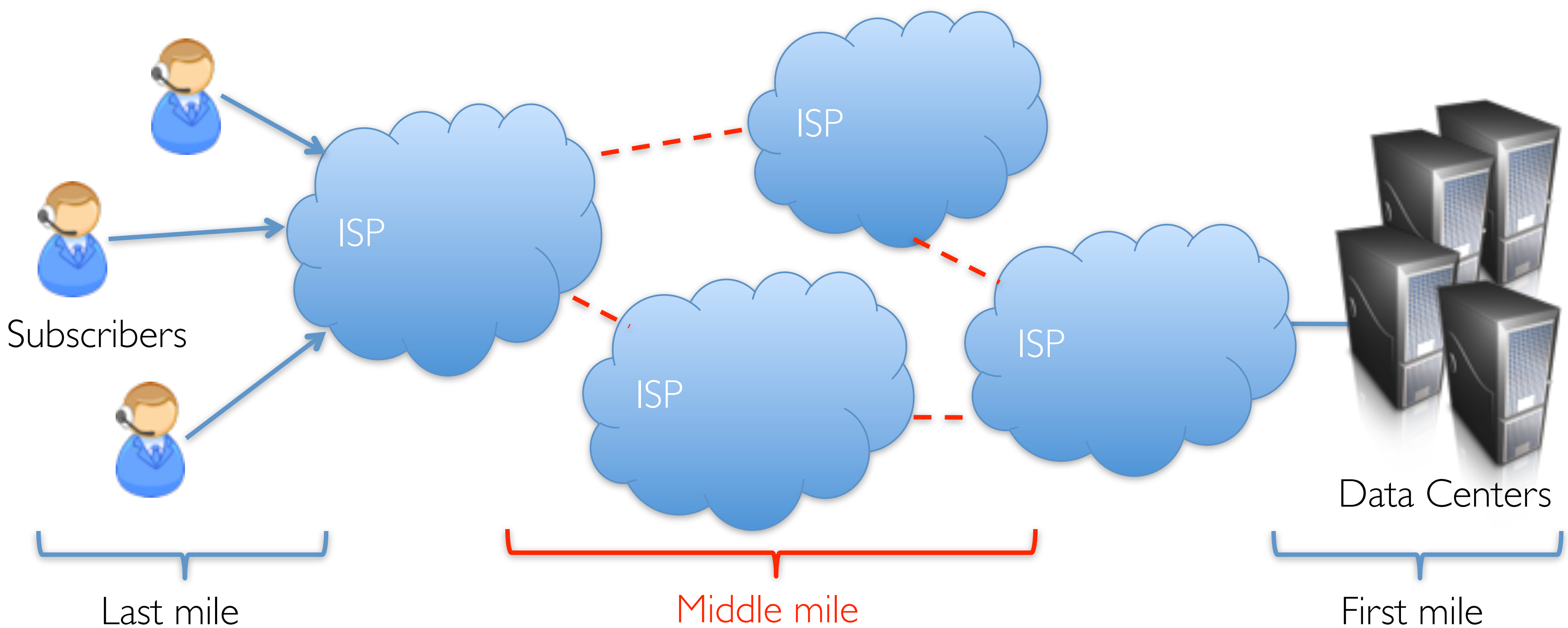
- According to the Cisco survey, the global IP traffic is expected to grow four times from 2009 to 2014.
- This puts the current Internet infrastructure under high burden.
- Content generated once, but consumed many times.



Motivation

Middle-mile problem

The infrastructure that interconnects the transit points between different ISPs



Motivation

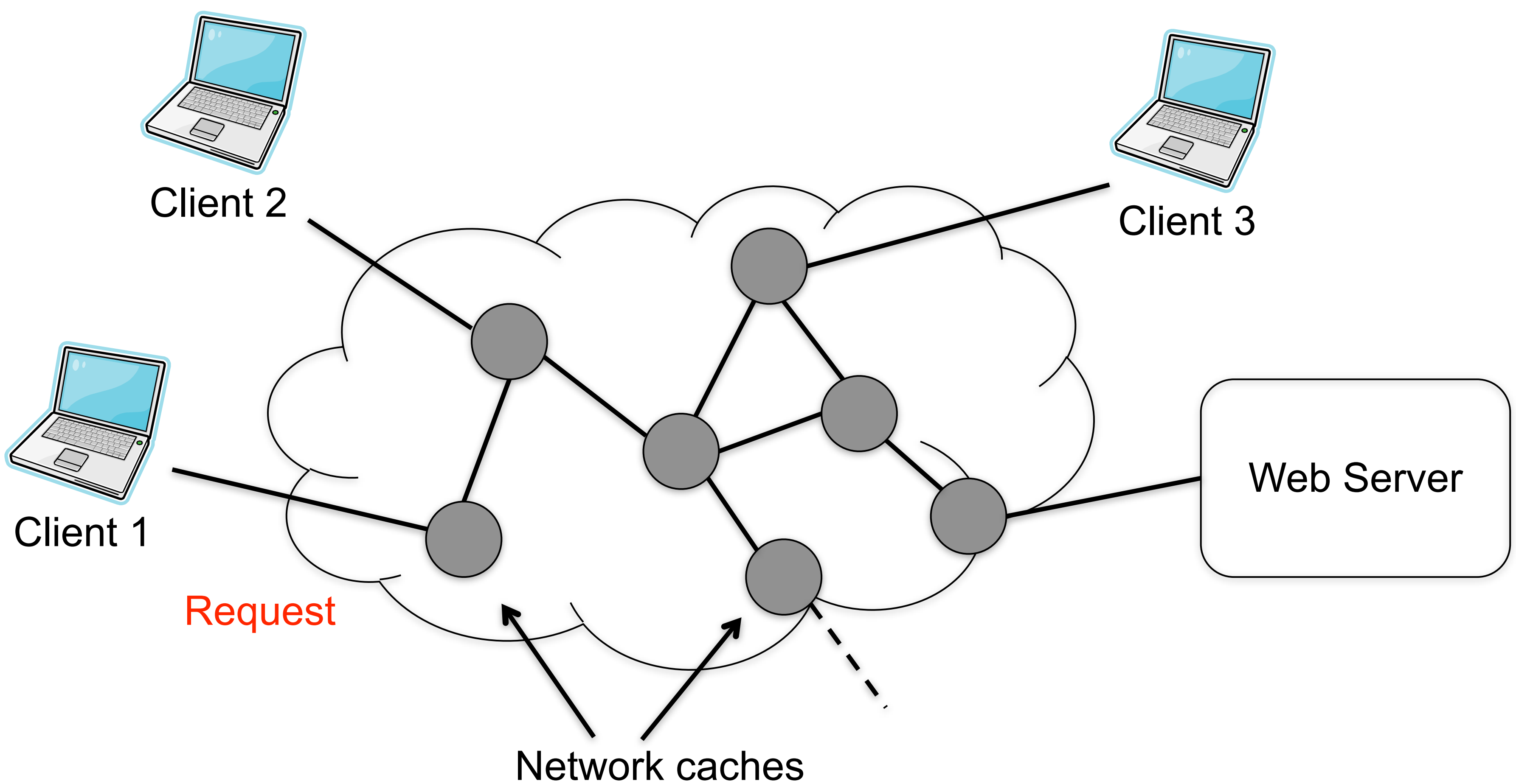
Improve network efficiency by:

- Reduce the redundant data transfer;
- Provide an extended life for the middle mile infrastructure;

Approach

- Place network-level routers ("Content Routers") in the network to store popular content
- Implement cooperative look-up between caches

Architecture



– An exp. how the content routers work in a network topology.

– The CRs use the basic store-n-forward model.

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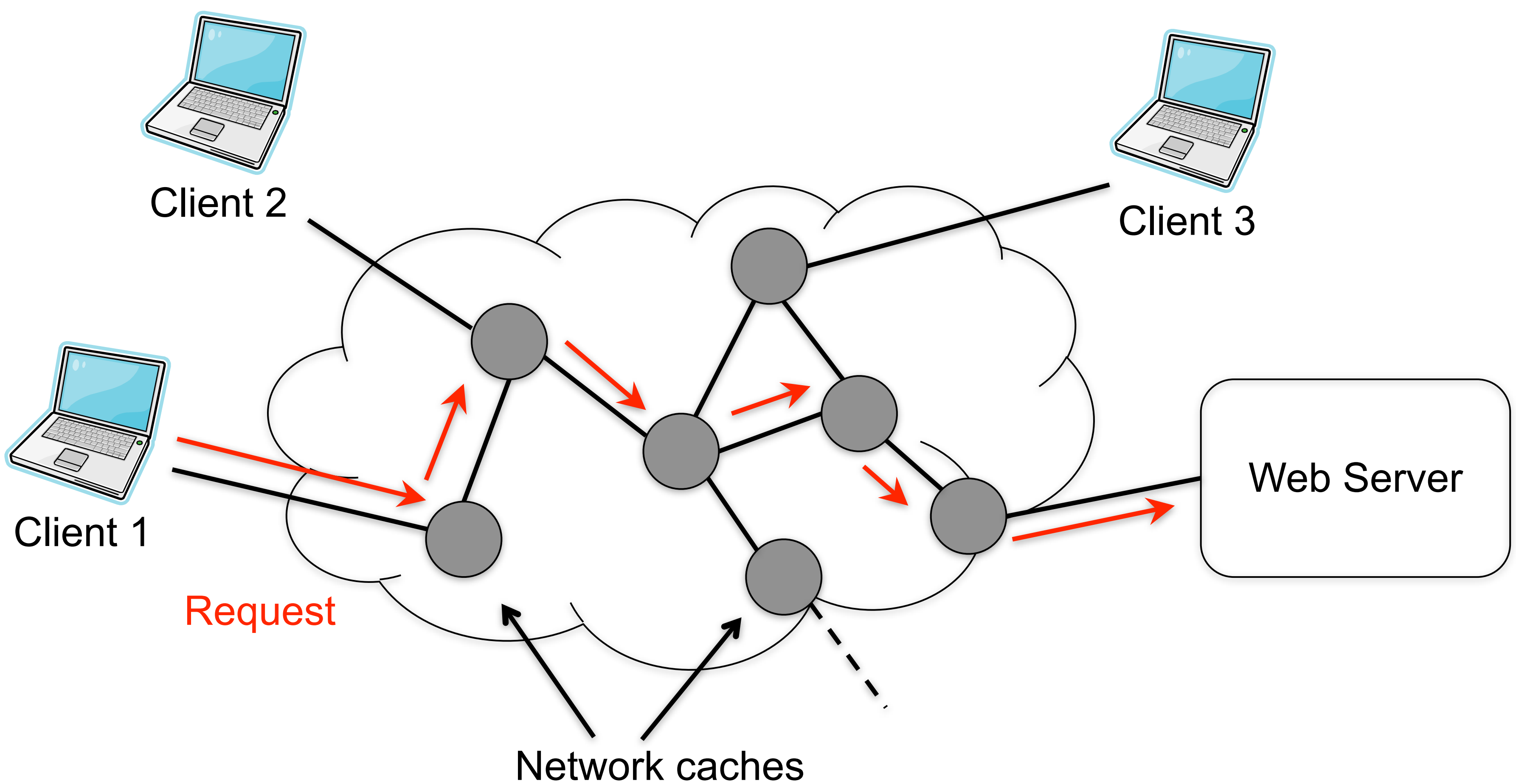

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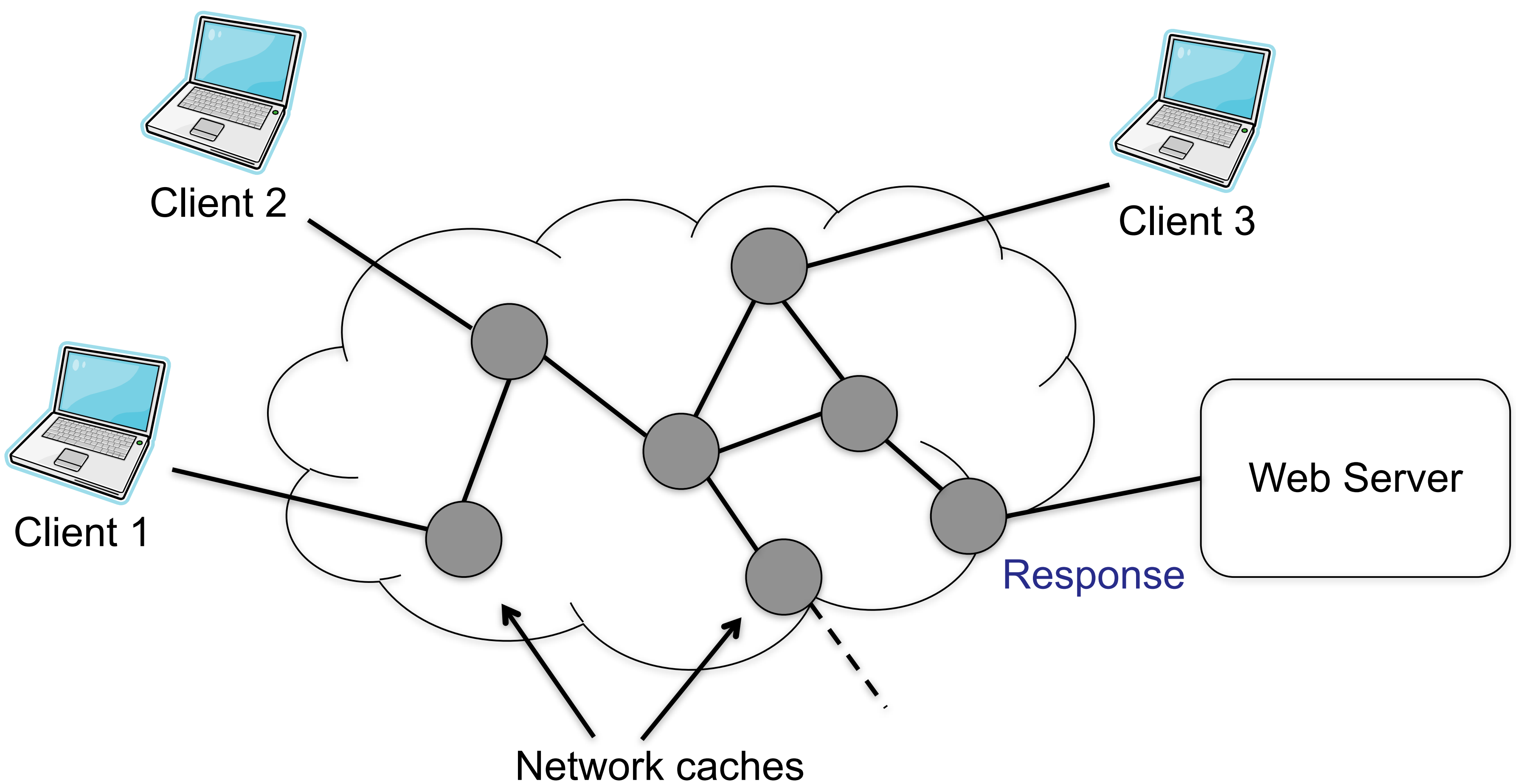

– When the response travels back to the client, every router it passes by will cache the content

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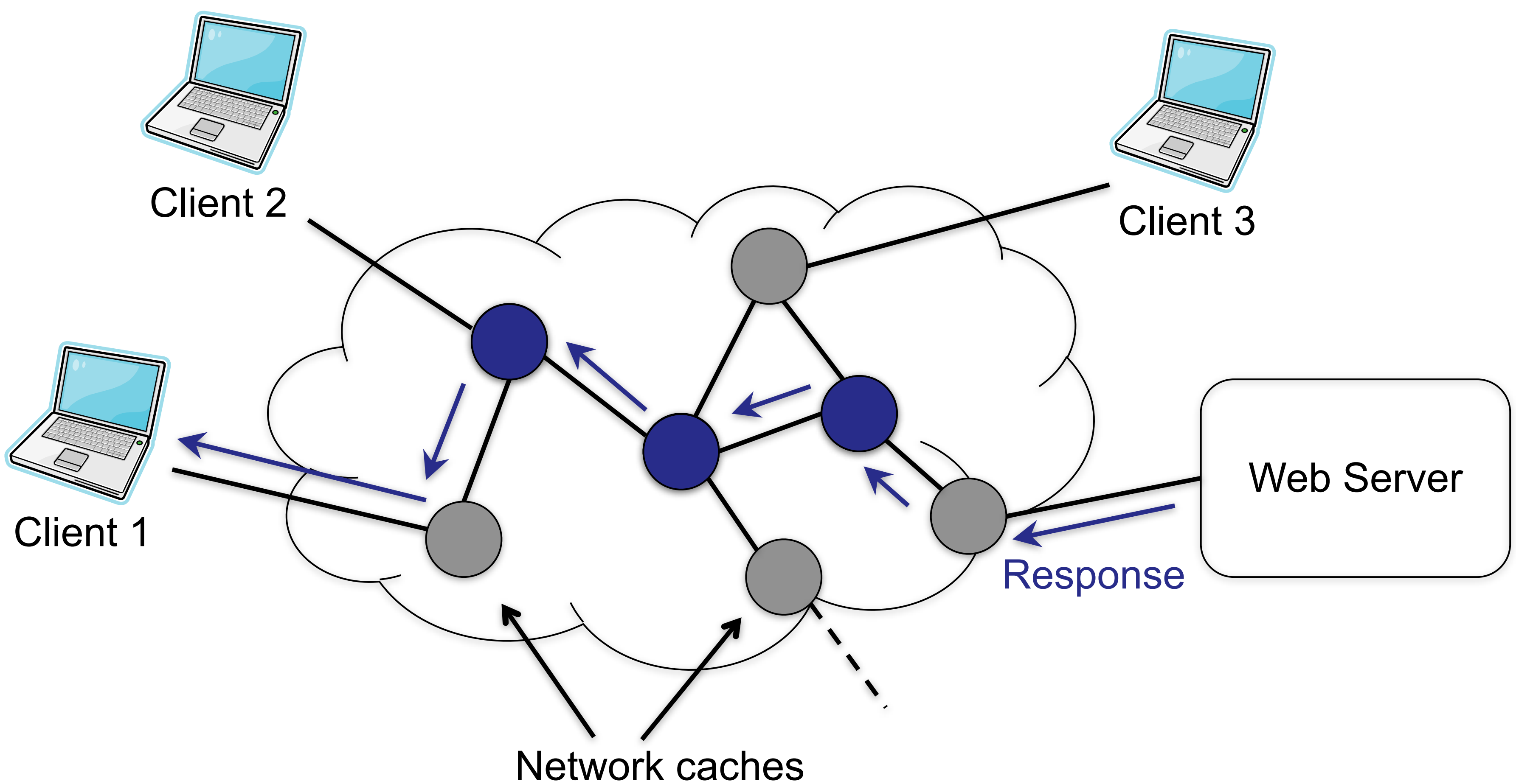

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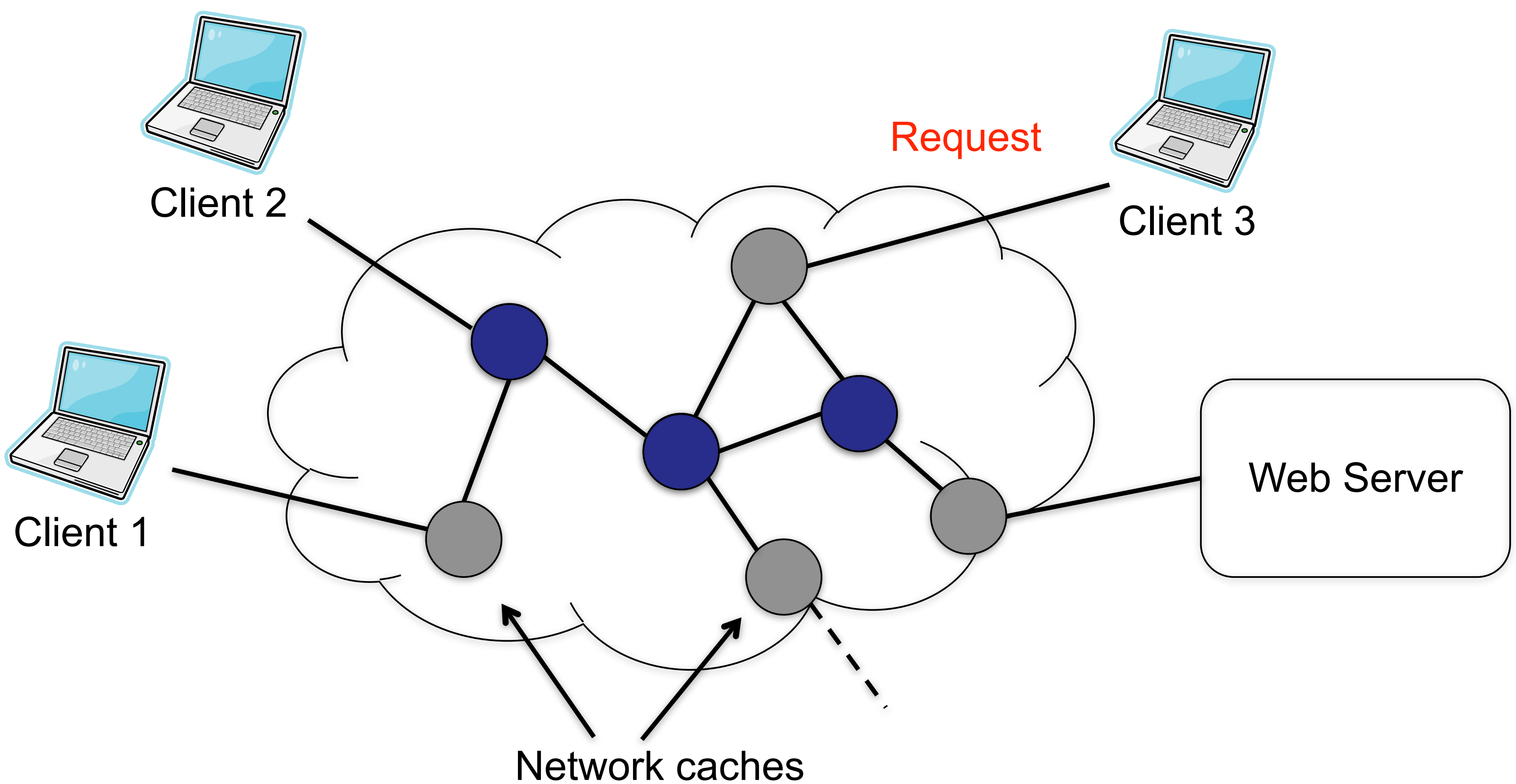

– Later, Client 3, maybe on the other side of the network, same content may be requested by different clients.

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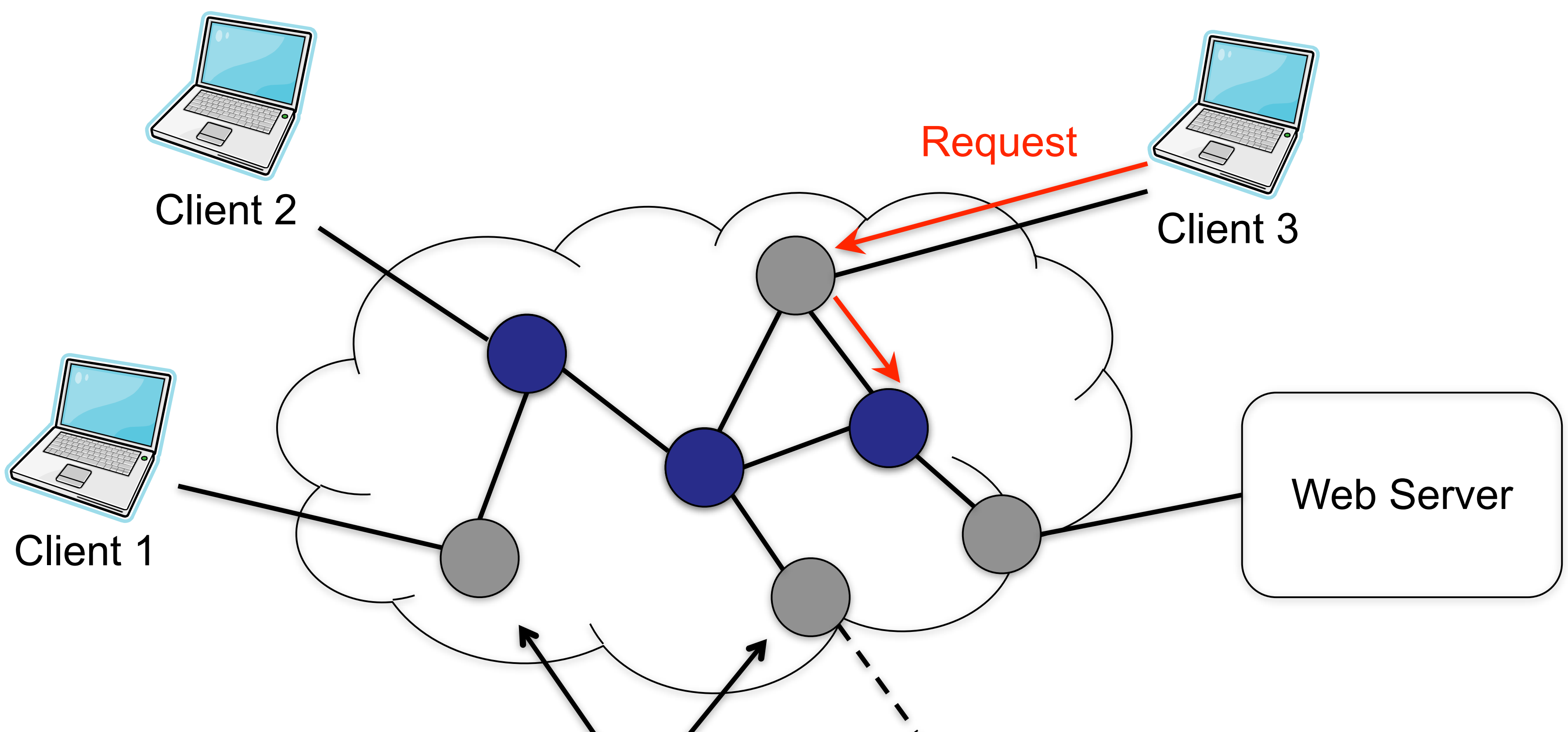

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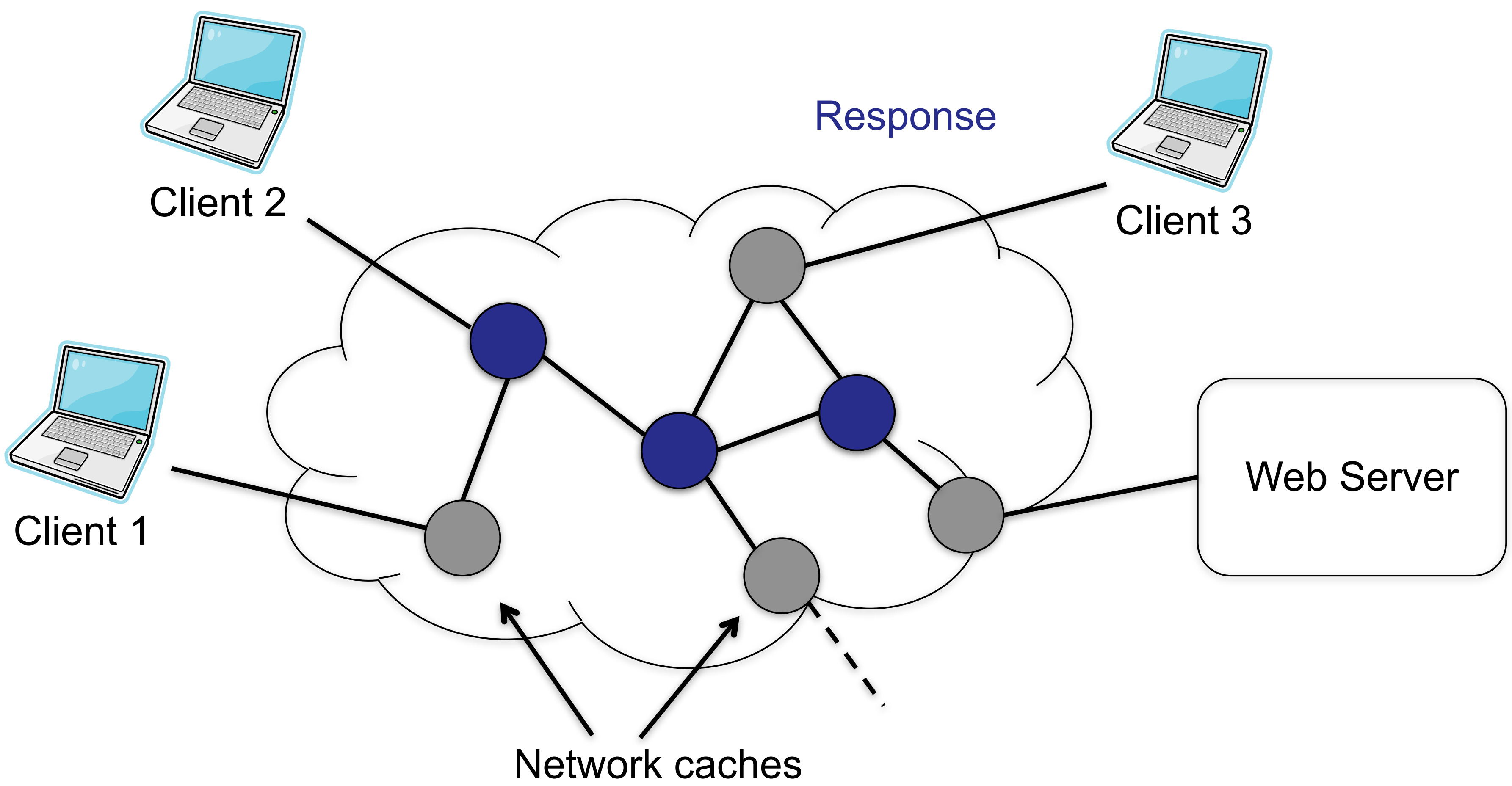

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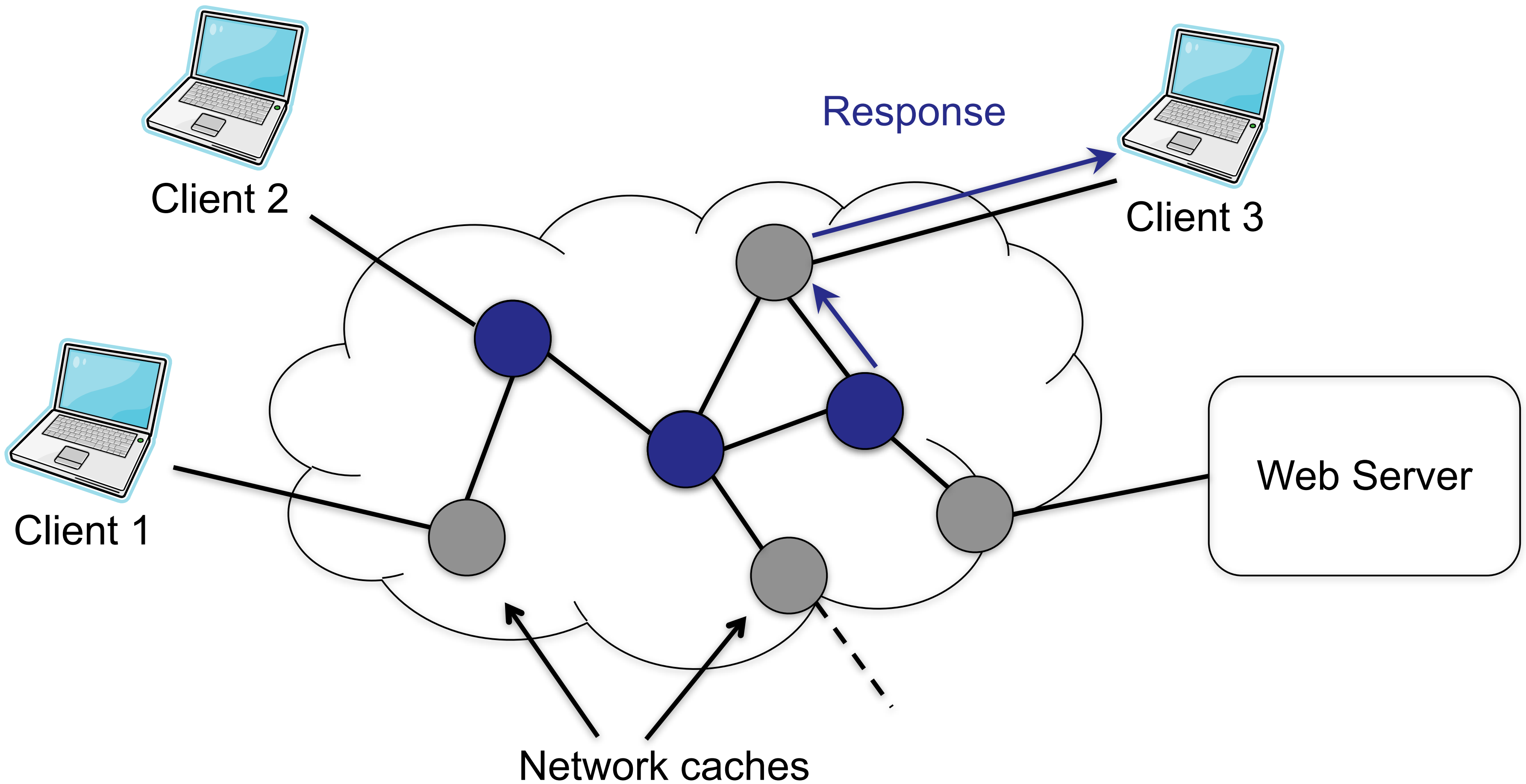

Architecture

Basic store-n-forward model

- Store everything passes by
- Simple to implement
- Limitations - low performance & low utilization of storage

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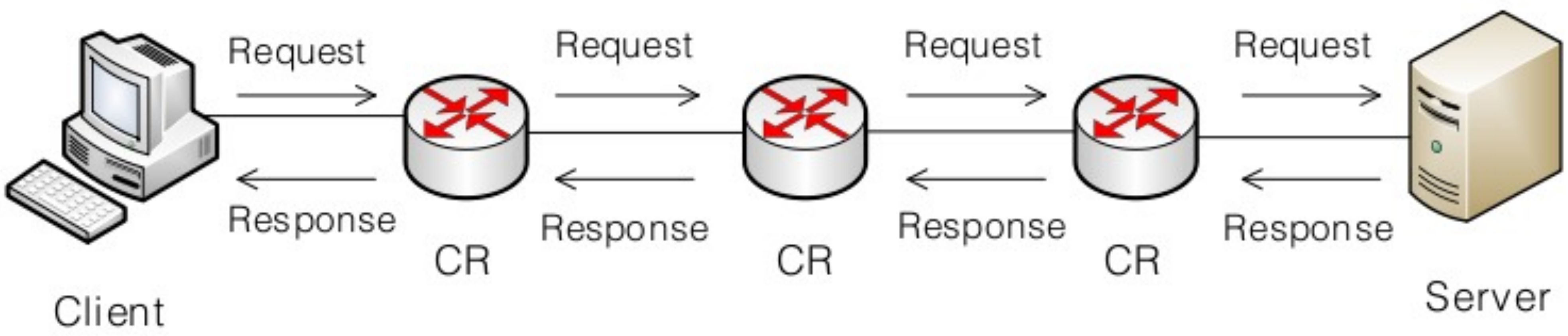

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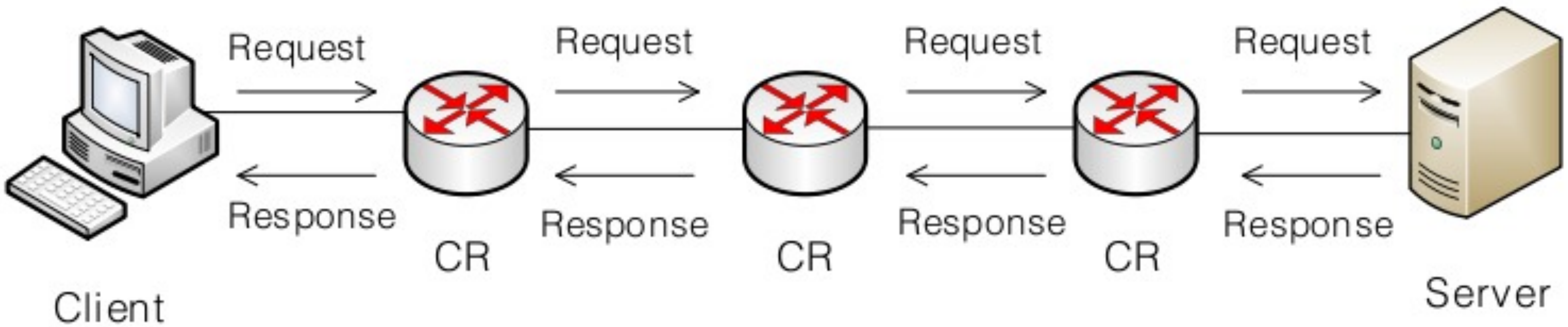


Basic model's limitation is due to lacking of good caching strategies

A good caching strategy should:

- maximize the utilization of network caches
- keep it simple

Caching Strategies

A Caching strategy consists of 3 parts

Admission policy - what to store?

Replacement policy - what to evict?

Cooperation policy - where to search?

Neighbor Search Caching Strategy

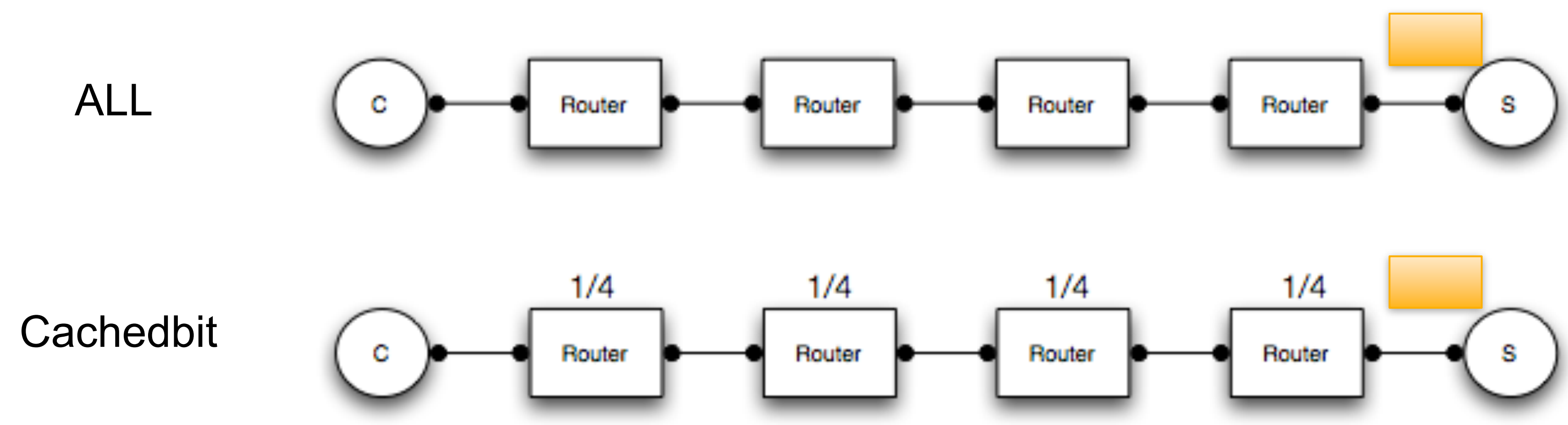
Two admission polices - ALL & Cachedbit

- ALL - cache everything passes by
- Cachedbit - cache based on probability

One replacement policy - LRU

One cooperation policy - Neighbor Search

Neighbor Search Caching Strategy - Admission Policy

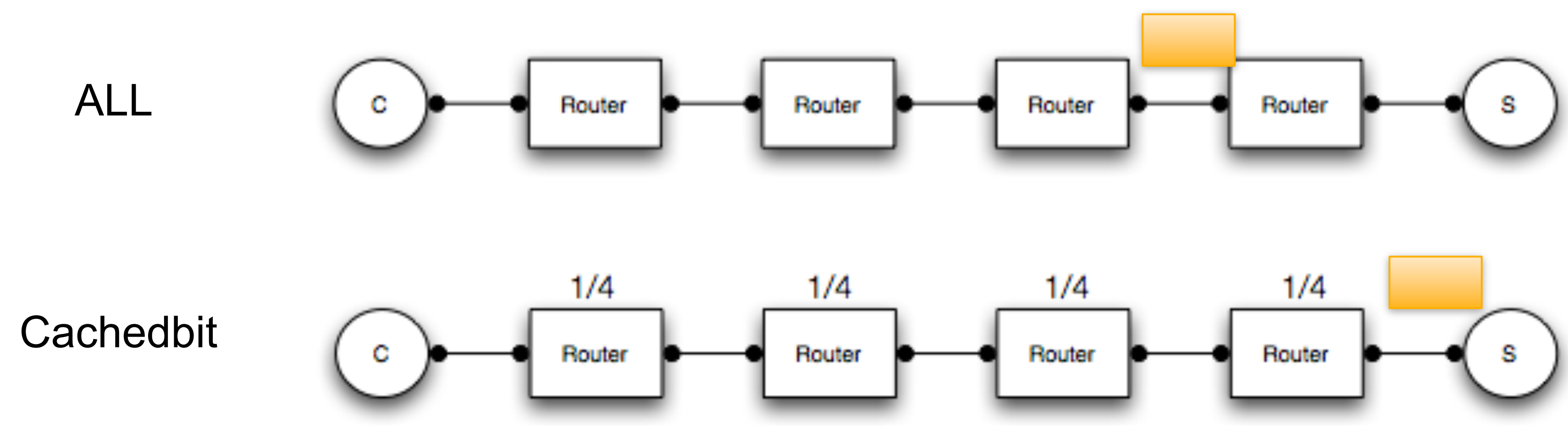


ALL caches everything everywhere

Cachedbit is probabilistic

- Each router caches a chunk with uniform prob.
- Set bit in header → No caching downstream

Neighbor Search Caching Strategy - Admission Policy



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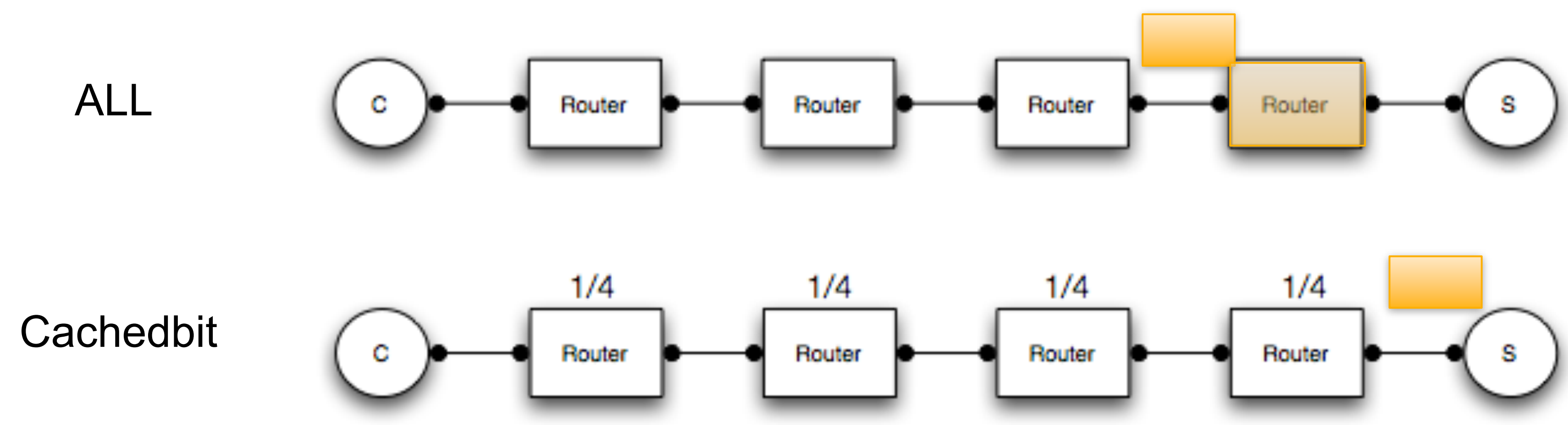

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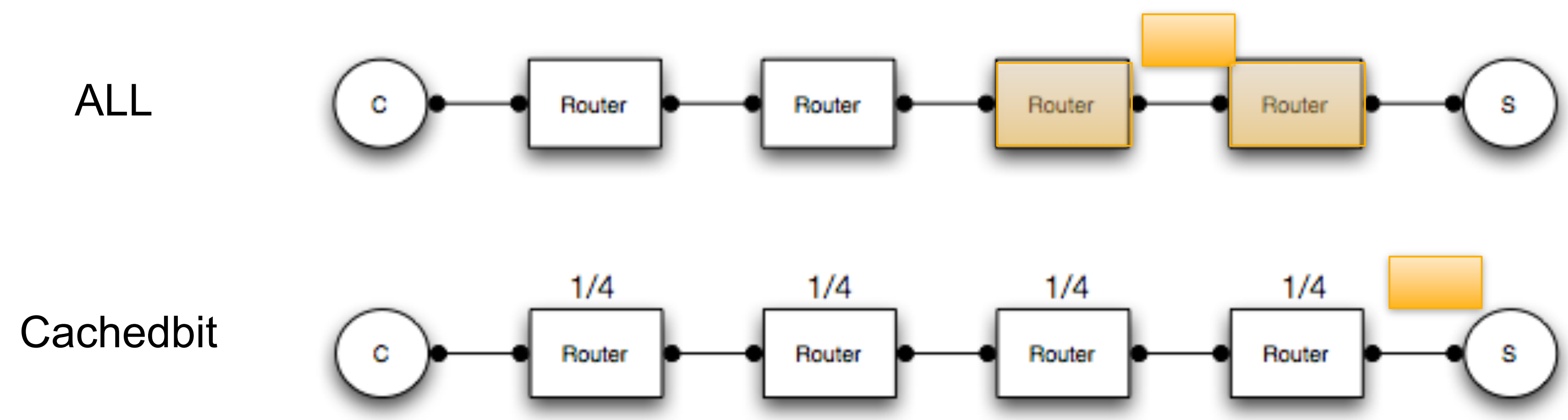

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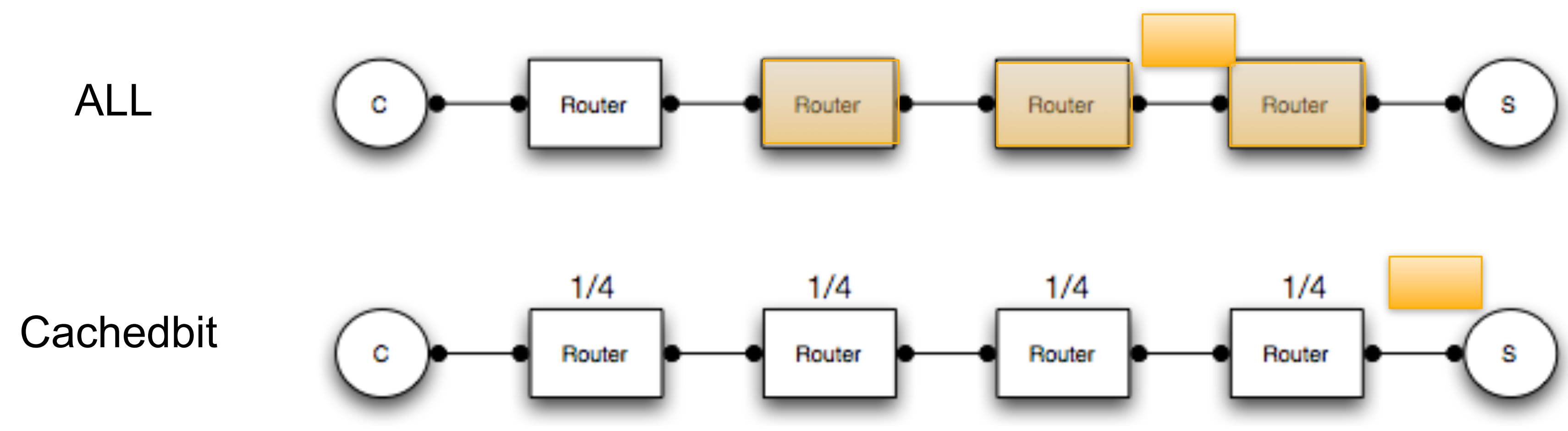

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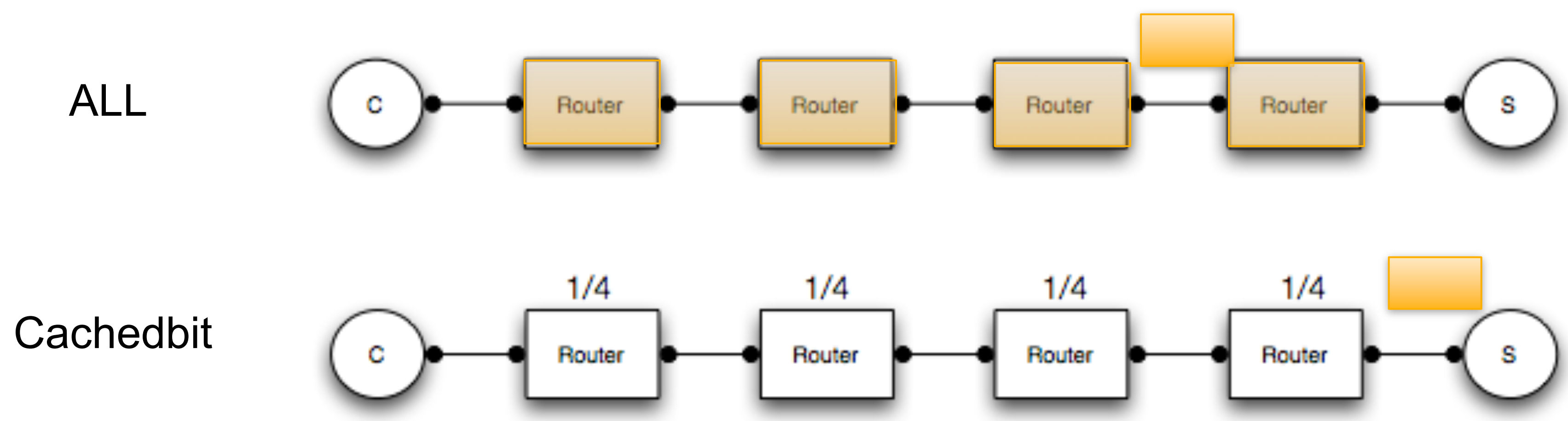

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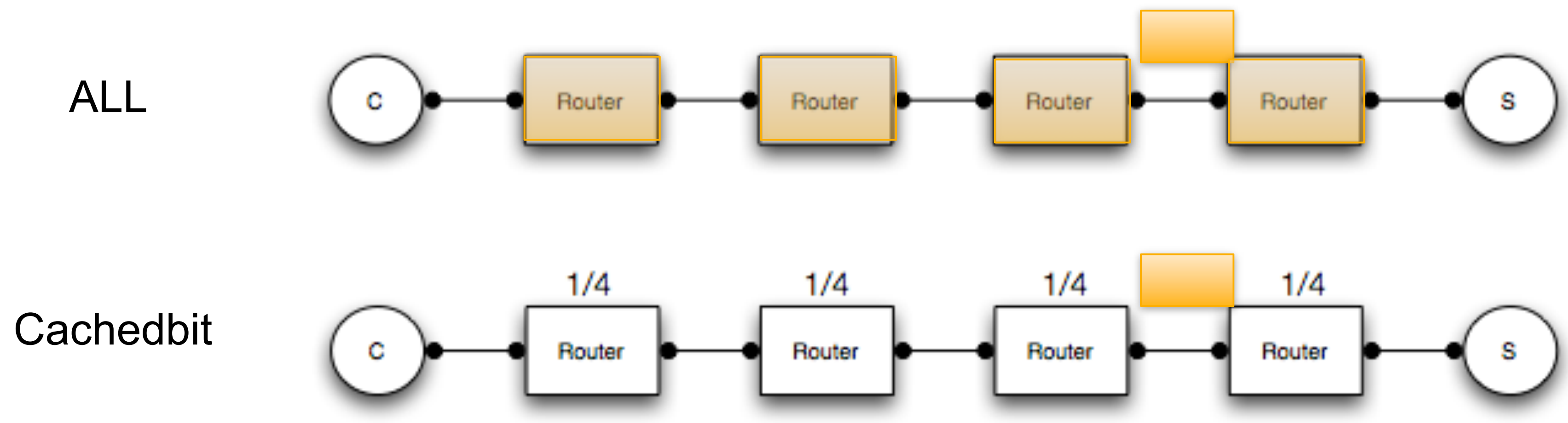

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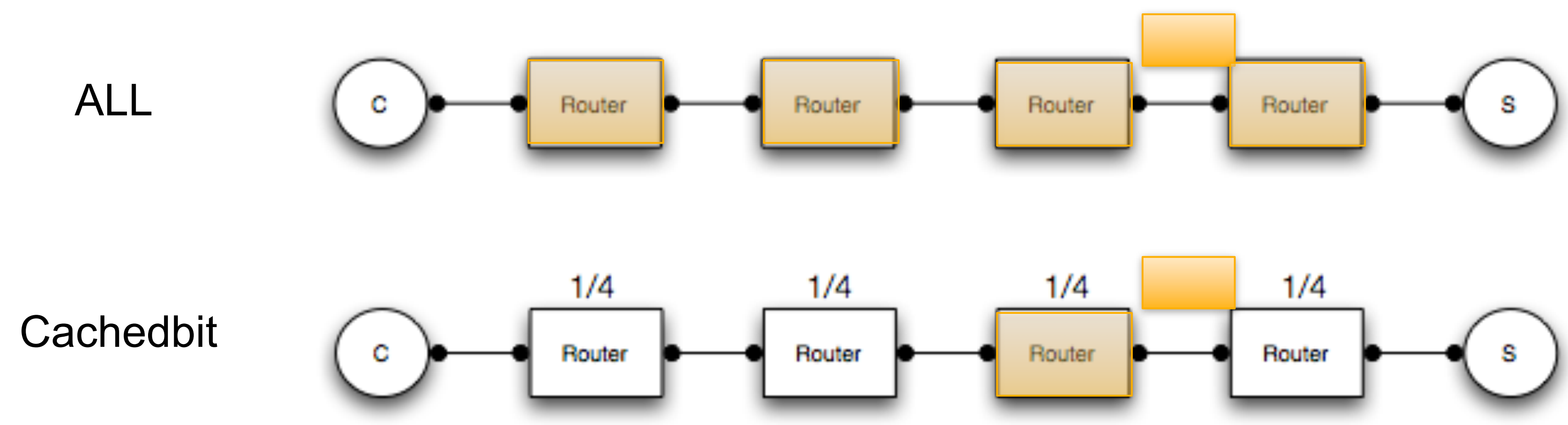

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Neighbor Search Caching Strategy - Cooperation Policy

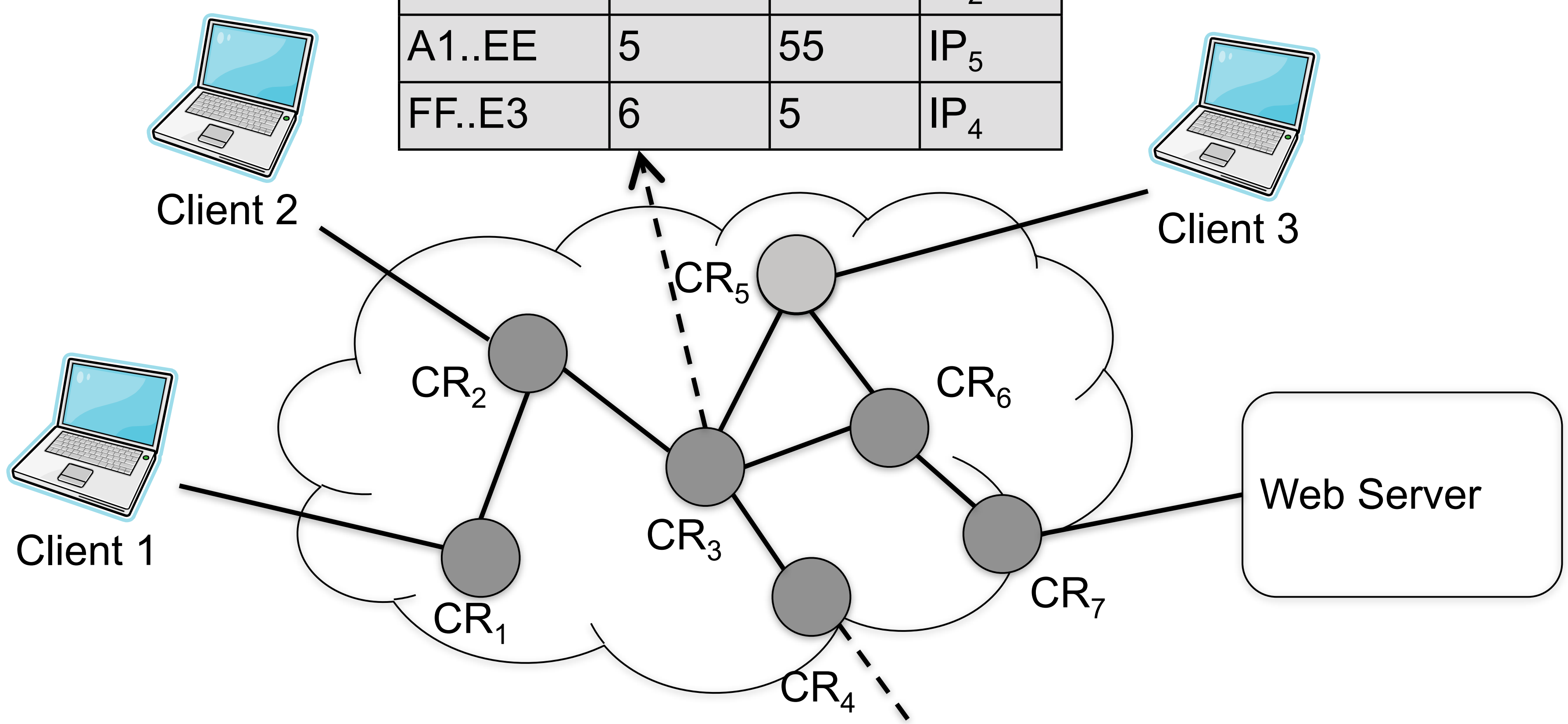
Exchange information with neighbors

- Maintain neighbors’ states
- Frequency-based update
  - – Redundant messages if traffic dynamics is low
  - – Need to find a proper broadcast frequency
- Content-based update
  - – A proper threshold can reduce overheads
- Use Bloom Filter to reduce communication overheads

Neighbor Search Caching Strategy - Example

cryptoID	CR ID	Time	IP
A1..C1	2	23	IP_2
A1..EE	5	55	IP_5
FF..E3	6	5	IP_4

Neighborhood Table



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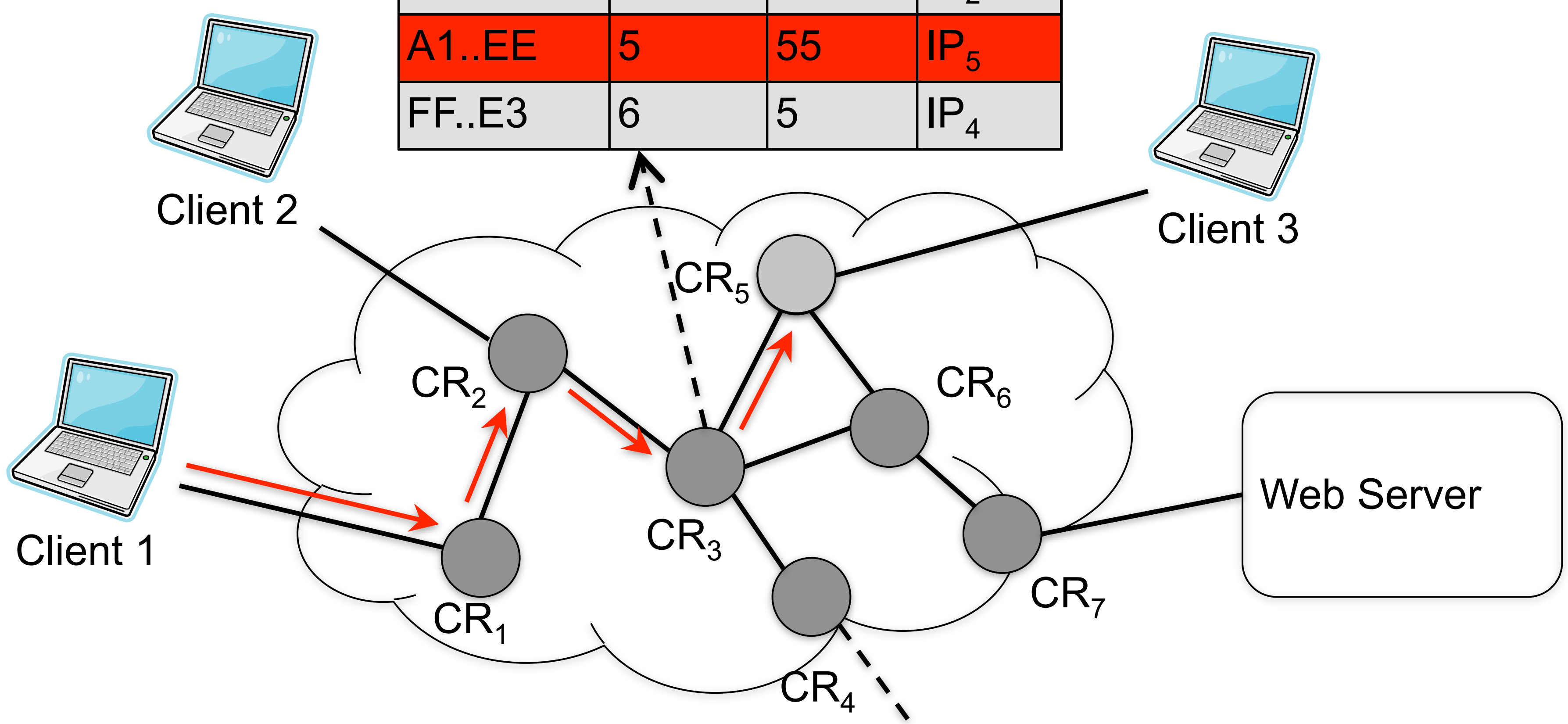


Evaluation - Topology

Evaluated on realistic ISP's network topologies

- The topology file is from Rocketfuel project

Both router-level topology and POP-level topology

- Router-level exp has better performance due to the longer path
- Results are consistent

Network	Routers	Links	POPs
Exodus	338	800	23
Sprint	547	1600	43
AT&T	733	2300	108
NTT	1018	2300	121

Evaluation - Experiment Design

Server placement - top-20 nodes with highest degree

Client placement - rest of the nodes

We use software routers to construct an overlay on top of a computing cluster

Evaluation - Trace & Traffic Pattern

Use both realistic trace and synthetic trace

- Popularity follows Zipf distribution

$$f(k;\alpha,N) = \frac{1/k^\alpha}{\sum_{n=1}^{N}(1/n^\alpha)}$$

- Realistic trace is from university lab, \alpha value is 0.93
- Synthetic trace - use 0.7, 0.9 and 1.1

Traffic pattern - constant and gravity model

- Constant - traffic is homogenous from all the clients
- Gravity model - amount of traffic based on the population

Evaluation - Metrics

Hit rate

- How much inter-ISP traffic we can reduce
- One packet represents one file object
- Hit rate is equivalent to the byte hit rate

Avg. hops

- Measure the content locality
- Locality represents how close the requested content is to the clients

Evaluation - Metrics

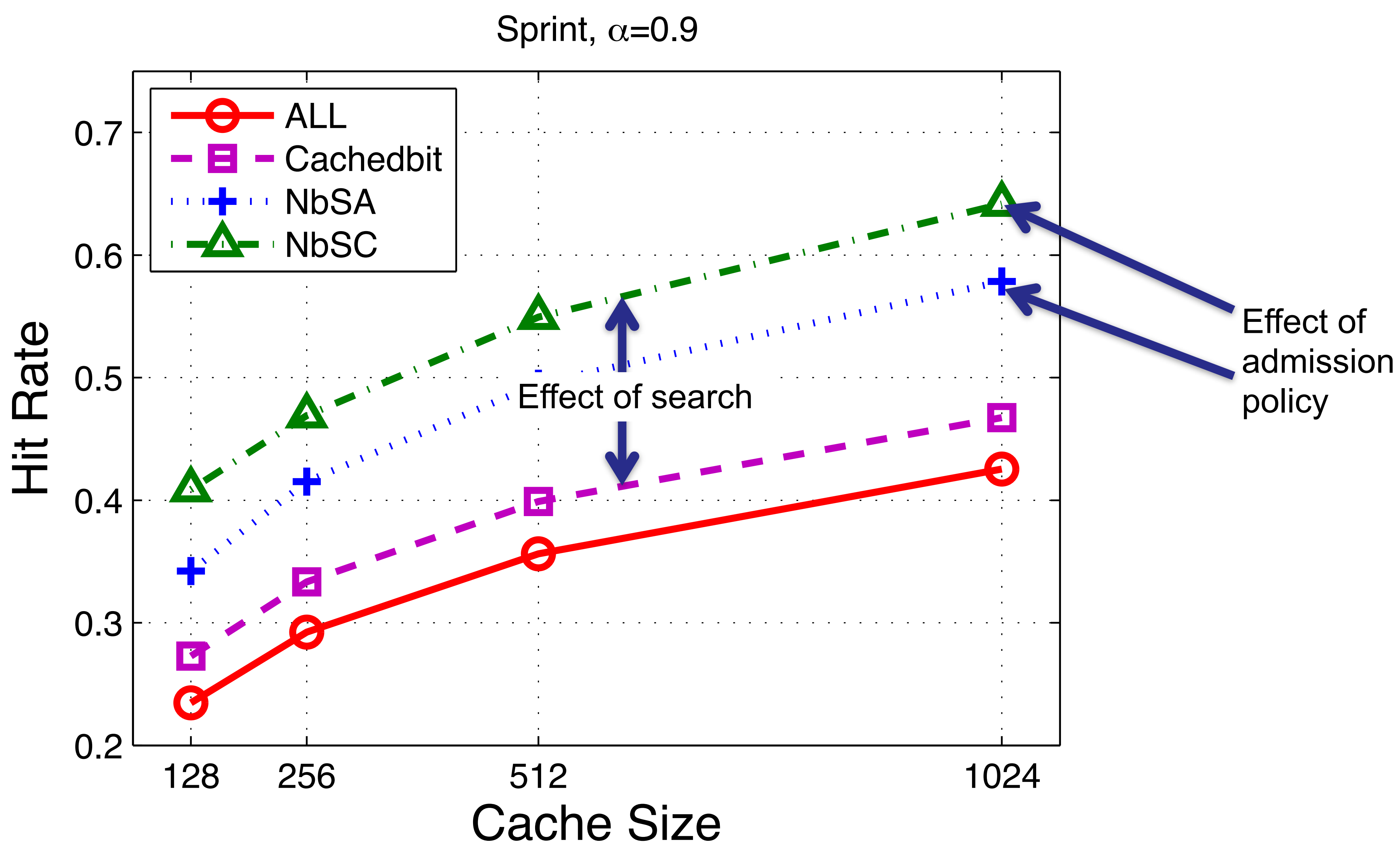
Footprint reduction

- How much intra-ISP traffic we can reduce
- How many bytes did not go on how many hops?

Example:

- N hops to egress, cache hit on 1st hop
- Traffic without caching is N * content_size
- With caching traffic is 1 * content_size
- Hence, reduction is (N-1) * content_size
- Footprint reduction: (N-1) / N

Evaluation - Hit Rate



Evaluation - Hit Rate

Main lessons:

As admission policy, LRU is the worst in all the cases

Neighbor Search gives a boost in hit rate at a small cost

Good admission policy is still a must

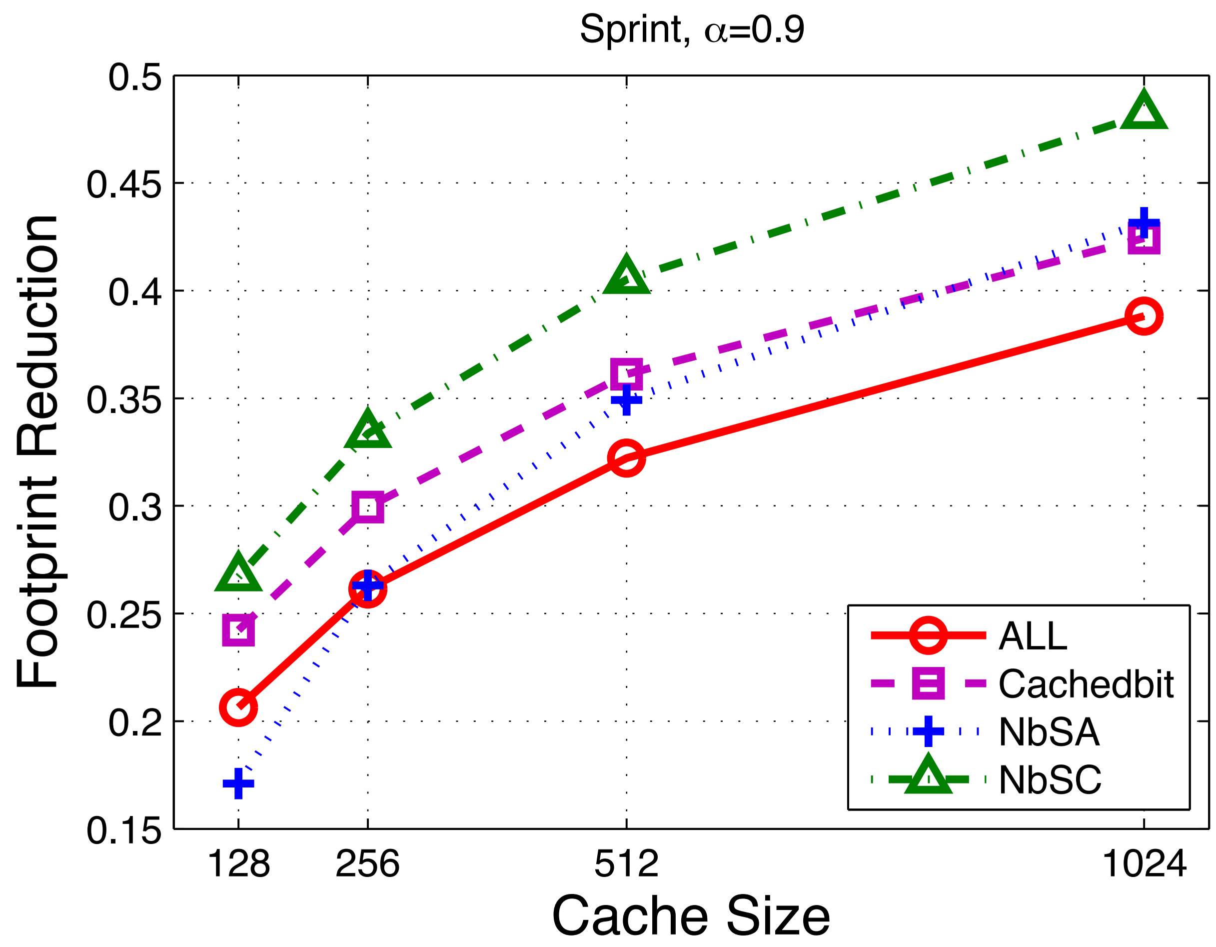
The difference varies on different topologies, but consistent

Evaluation - Footprint Reduction

Footprint reduction

- How much intra-ISP traffic we can reduce

- Large reduction means less intra-ISP traffic



Evaluation - Footprint Reduction

Main lessons:

NBS* might not perform well for small caches

- the neighbors are unlikely to have the content if a miss happens
- searching actually causes extra overheads for small cache

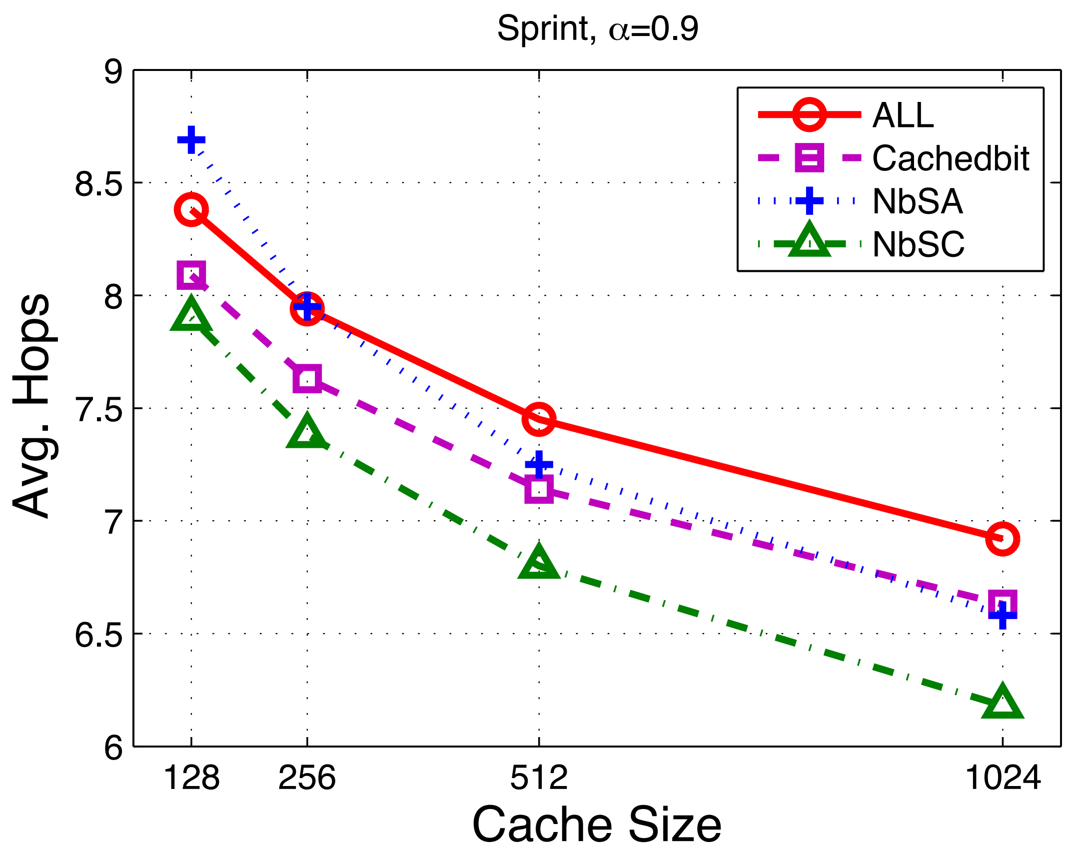
Neighbor Search improves quickly as the cache size grows

NbSC is the best strategy is all cases

Evaluation - Locality

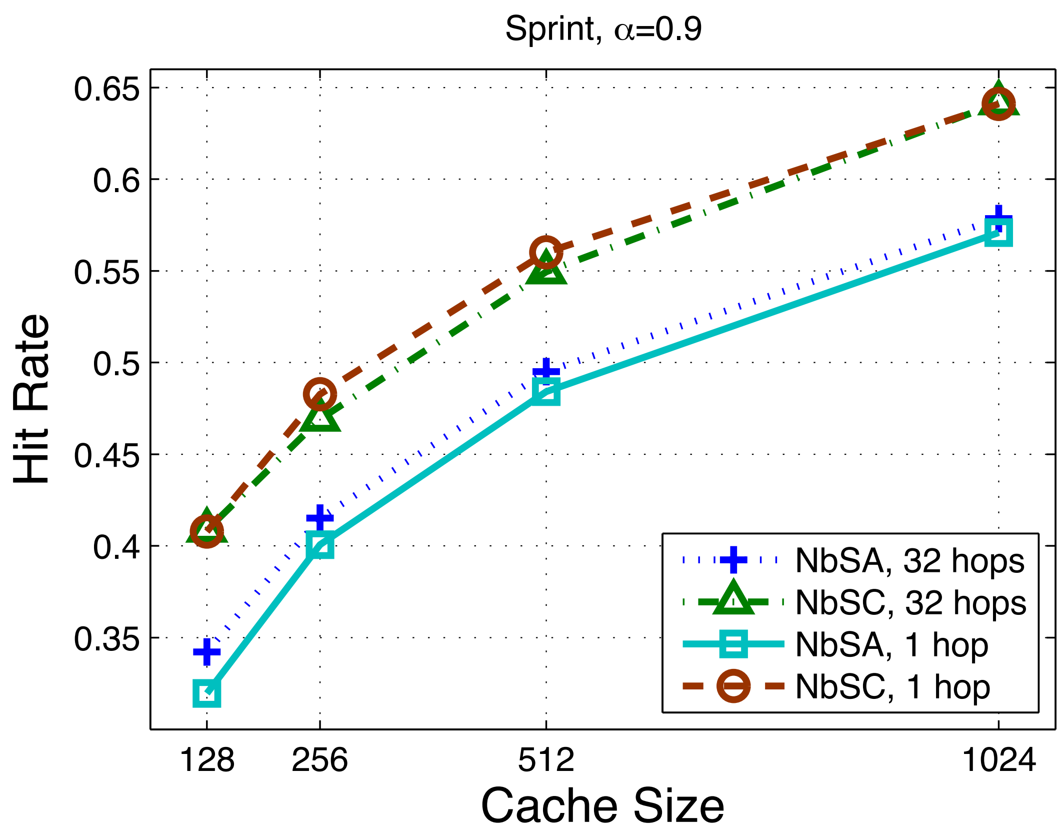
Avg. hops

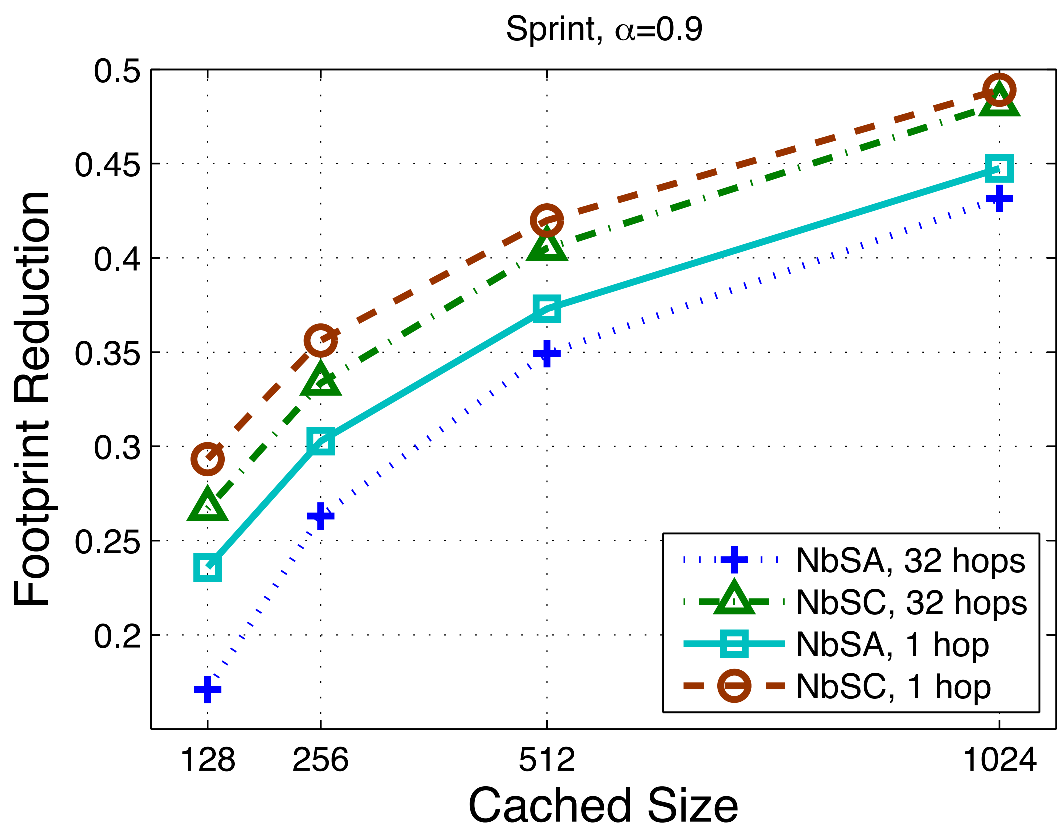
- Measure how close the requested content is to the clients



– We see the same behavior in avg. hops as that in footprint reduction

NbS* with Diff. Search Radius

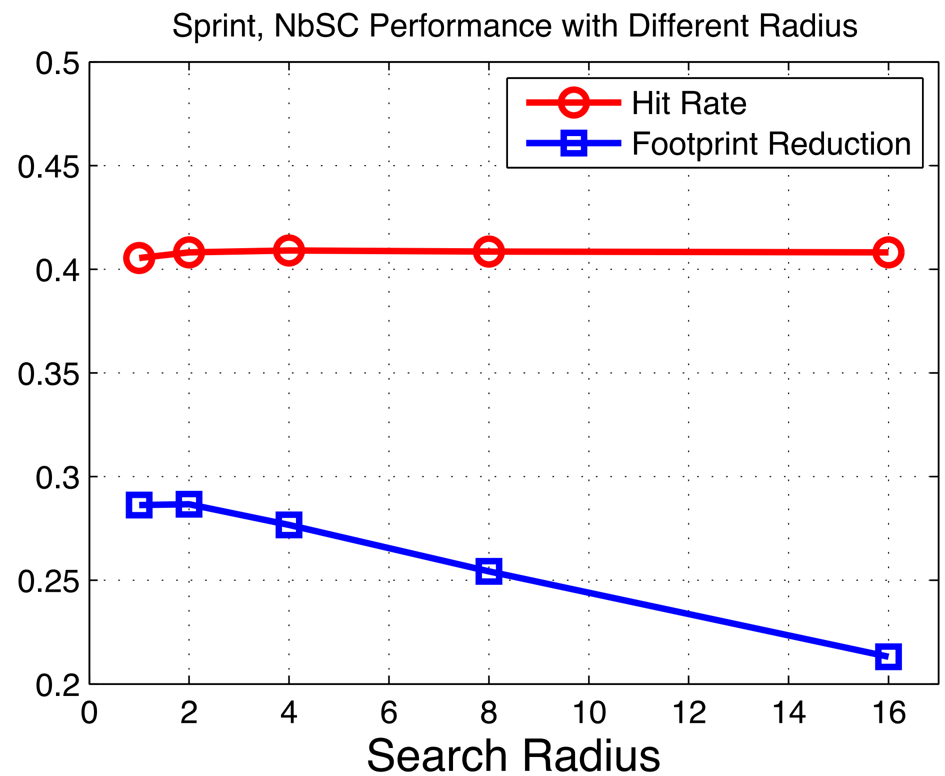




– In terms of hit rate, larger radius only gives marginal improvement

– In terms of footprint reduction, larger radius increases intra-ISP traffic, and also increases user latency. The request can go too far.

NbS* with Diff. Search Radius



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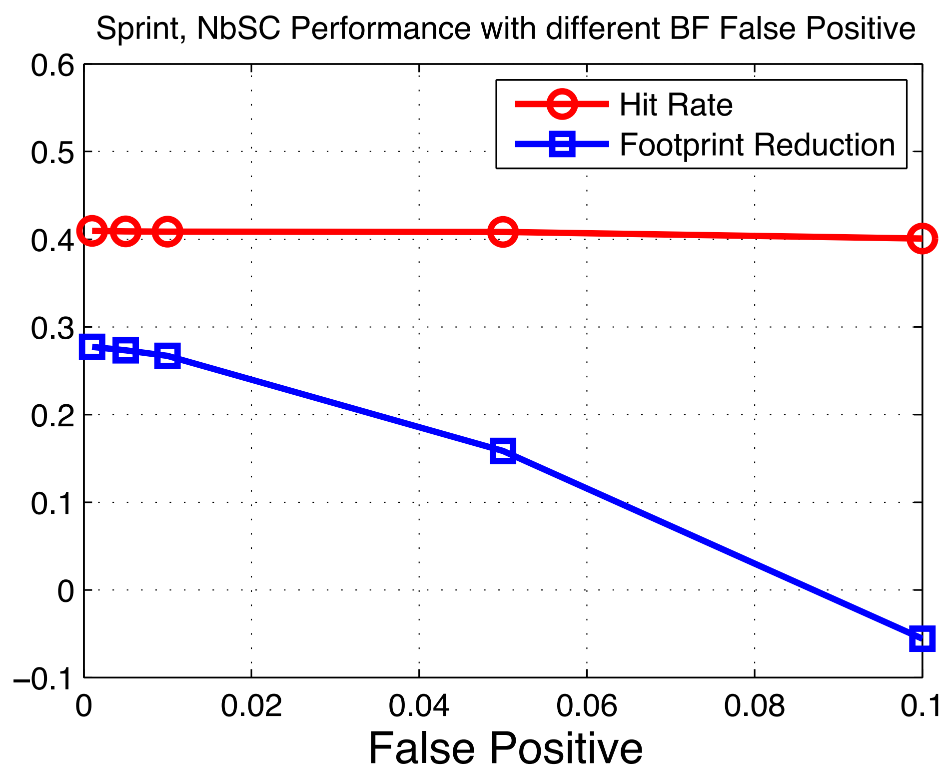
NbS* with Diff. False Positive Rate



– Large FP rate won't hurt hit rate too much

– Large FP rate hurts footprint reduction. Requests can be routed further because a router thought his neighbor has the content

Neighbor Search Caching Strategy - Parameters

Key parameters:

- Search radius: 1 hop is enough, more hurts network traffic
- False positive rate: 1% is enough

Main lessons learned:

- Searching neighbors is highly beneficial
- Need admission policy as well

Conclusion & Future Work

Conclusion

- Good caching strategy plays an important role in In-network caching performance.
- Good admission policy helps a lot
- Neighbor Search boosts the performance

Future work

- Integration to CCNx prototype.

Thanks!

Questions?