A New Approach to Name-Based Link-State Routing for Information-Centric Networks

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Outline

- State of the Art
- Related Works
- LSCR
  - Concept
  - Communication
  - Operation
- Complexity Comparison
- Performance

State of the Art in Shortest-Path Routing to Content

- Problem: Compute the path of minimum cost from each router to each *Prefix* in the network.
- Routing in ICNs is inherently more difficult than routing in the traditional IP networks.
- Content objects are cached opportunistically in the network.
- Challenges:
  - Multi-homed instance
  - Find loop-free paths
  - Multi-path routing

Related Works

- ICN architectures implement one or some of the following mechanisms to constructing a path for acquiring data:
  - Flooding requests throughout the whole network.
  - Flooding topology information and the location of publishers.
  - Using source routes to content.
  - Creating spanning tree and use publish-subscribe signaling.
- Directed Diffusion
  - Interests are flooded throughout a sensor network
- NLSR
  - Flood the network with topology information as well as instance information.

Related Works

- NBRP
  - Name-prefix reachability is advertised among content routers
  - Path information is used to avoid permanent loops
- CBCB
  - Establishes a spanning tree of the network
  - Sends publish-subscribe requests for content
- DCR
  - Routers choose what information to share with their peers
  - Uses only distance information to calculate shortest path to the nearest copies of the content

Link-State Content Routing: Concept

- Every piece of content in the network is a named-data object (NDO)
- A set of one or multiple NDOs can be represented by *Prefix*
- A router that has local access to the content is called an *Anchor* of the prefix
- LSCR relies on two basic mechanisms:
  - Name resolution
  - Topology-based routing
- LSCR creates a lexicographic ordering among neighbors and calculates loop-free routes to the nearest anchor(s) of prefixes.

LSCR - Notations

- l_n^i : cost of the link from router i to its neighbor n
- N^i : set of neighbor routers of node i
- $|i|$: lexicographic value of the identifier of router i
- k_j^i : the king anchor for prefix j
- S_j^i : set of valid next hops toward prefix j
- rd_p^i : distance from router i *to router* p
- rd_{pn}^i : distance from router i *to router* p *through neighbor* n
- RS_p^i : set of valid next hops toward router p

LSCR Tables

- Link Cost Table (LT)
  - storing the cost of the link from router i to each of its adjacent routers
- Forwarding Table (FT)
  - stores the set of valid next hops to reach each router in the network
- Prefix Table (PT)
  - stores information about prefixes and their corresponding anchor(s)
- Routing Table (RT)
  - stores routing information for each known prefix

Link state advertisements

- Link state advertisements (LSAs) are used to create:
  - The network topology
  - Mapping schema from prefixes to router names
- Router LSA (RLSA)
  - Advertises topology information.
  - Flood to whole network.
- Anchor LSA (ALSA)
  - Advertises the existence of name prefixes.
  - One prefix update per ALSA
  - Propagated selectively.
  - "*vFlag*" indicates if the prefix is attached to anchor or detached
- Each LSA has a sequence number that is set by the originator of that LSA

LSCR

- Routing to nearest instances of destination:
  - Calculate valid next hops for each router
    - create the network topology
    - Run Dijkstra's SPF algorithm and calculate cost of the path to every destination
    - Check NOC condition
  - Select best neighbors from the previous step as valid next hops to the prefix
    - Maps prefixes to anchors
    - Determine the king anchor
    - Check SOC condition

LSCR

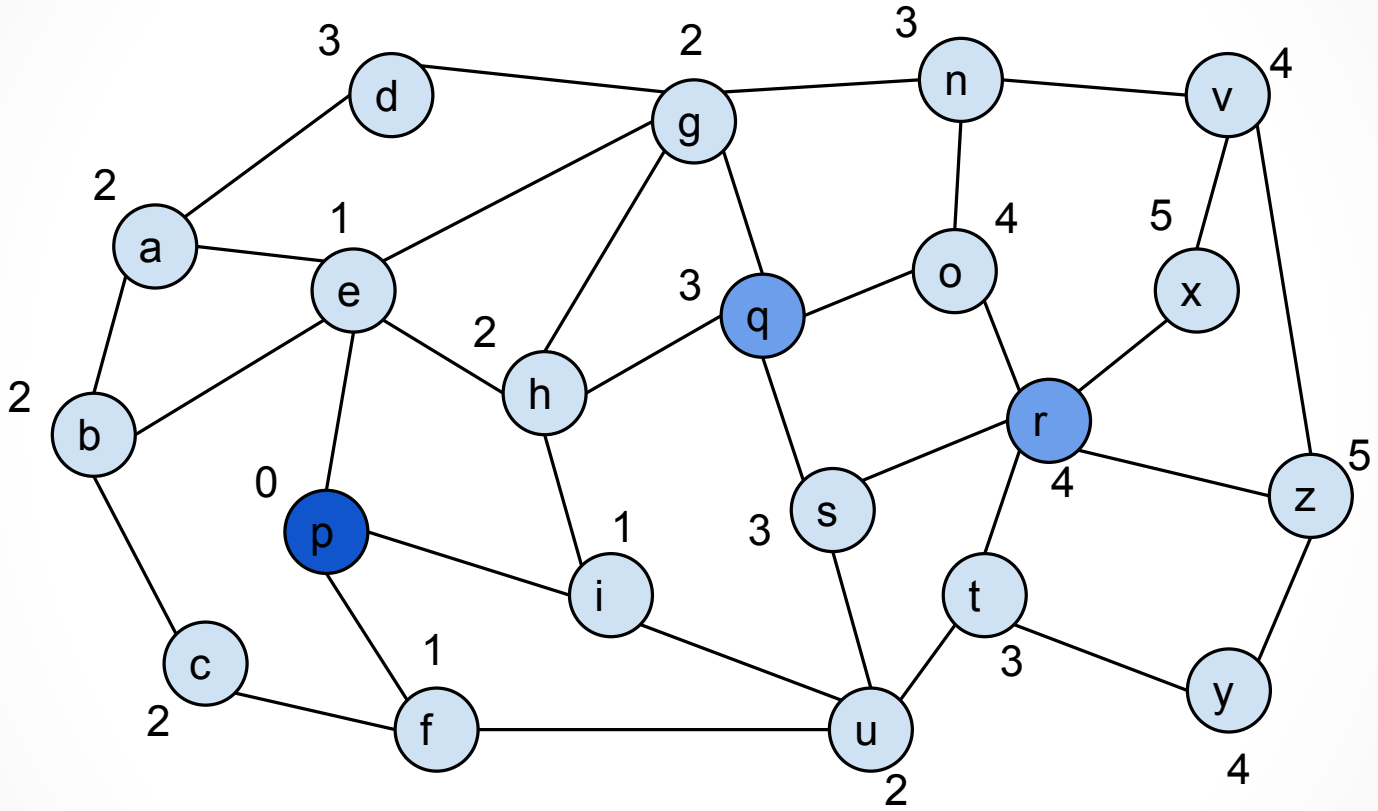
- Next-Hop Ordering Condition (NOC) to select its neighbor n as valid next hop toward router p if neighbor n:
  - reports up-to-date information
  - can reach the destination $(rd^i_{pn} < \infty)$
    - is closer to destination $(rd^i_{pn} < rd^i_p)$

  or

    - is at the same distance and has a smaller name

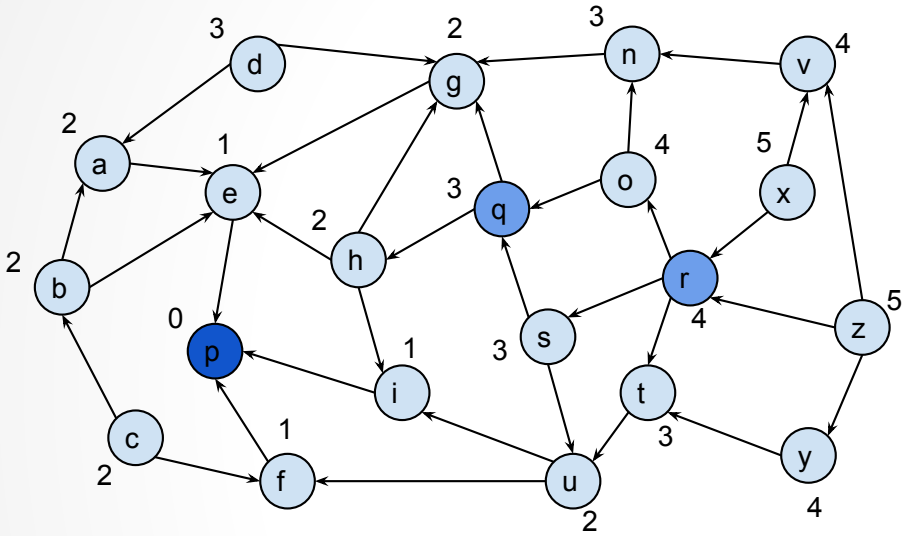
      $(rd^i_{pn} = d^i_p \wedge |n| < |i|)$
- NOC prevents permanent routing loops from being created

LSCR



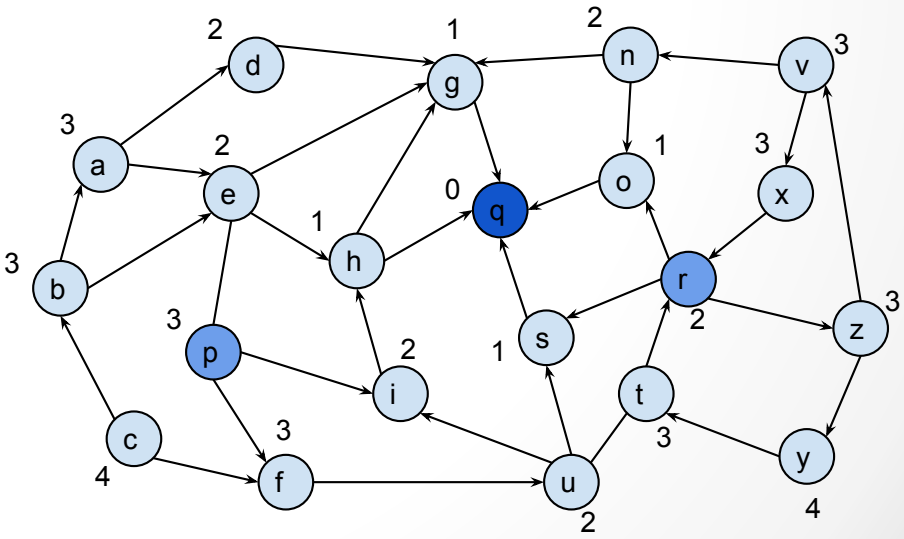
Sample Network

LSCR



Valid Next hops to destination p

Valid Next hops to destination q



LSCR

- The king anchor is an active anchor that is the smallest closest anchor among all active anchors
- One king anchor per prefix among known anchors
- Forward ALSA from king and HOLD other's
- King Selection Condition (KSO) to select anchor k as king anchor
  - The anchor advertises that prefix $(vf^i = 1)$
    - k is closest anchor $(rd^i_k < rd^i_a)$

  or

    - m is at the same distance as other anchors and has smallest ID $(\forall [a] \in PAI^i_j \ (rd^i_k = rd^i_a \wedge |k| < |a|))$
- Distance to a prefix is the distance to king anchor of the prefix

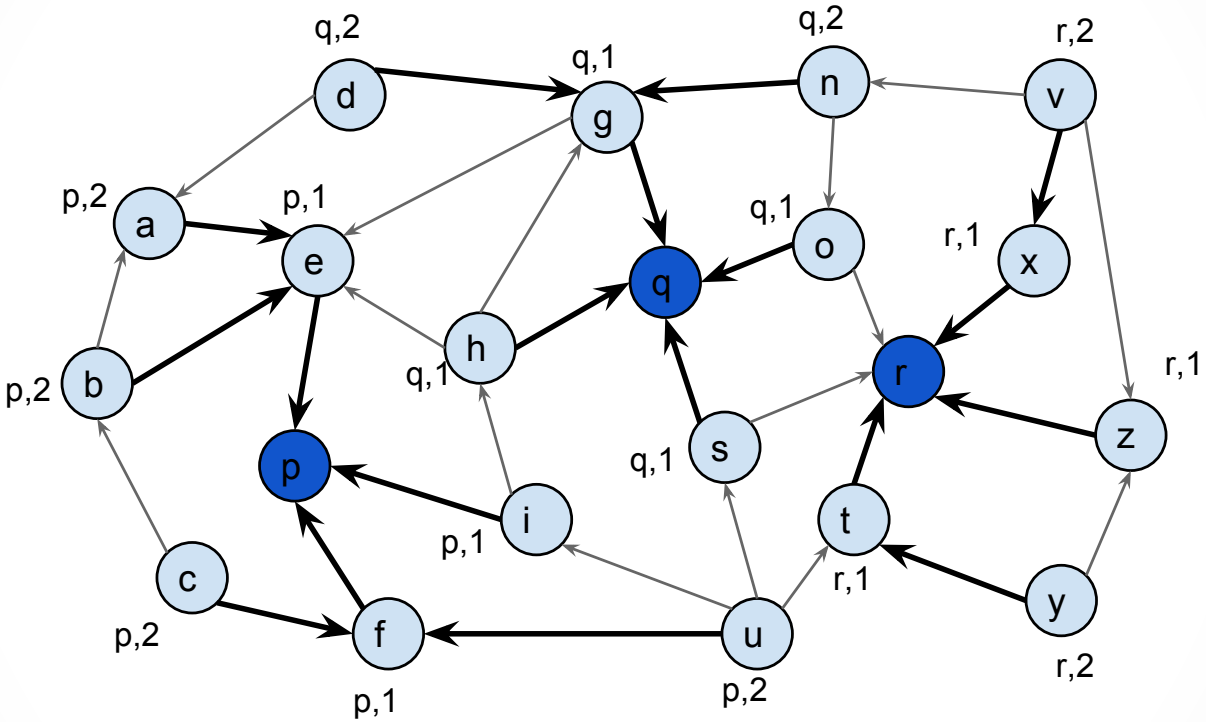
LSCR

- Successor-Set Ordering Condition (SOC) to select neighbor n as valid next hop toward prefix j if neighbor n:
  - is in finite distance toward prefix j $(d^i_{jn} < \infty)$
    - is closer to the prefix than router i $(d^i_{jn} < d^i_j)$

  or

    - Is in the same distance and has smaller name than the router itself $(d^i_{jn} = d^i_j \wedge |n| < |i|)$
- SOC prevents permanent routing loops from being created

LSCR: Example



- p, q, and r are instances
- Valid next hops to nearest anchor

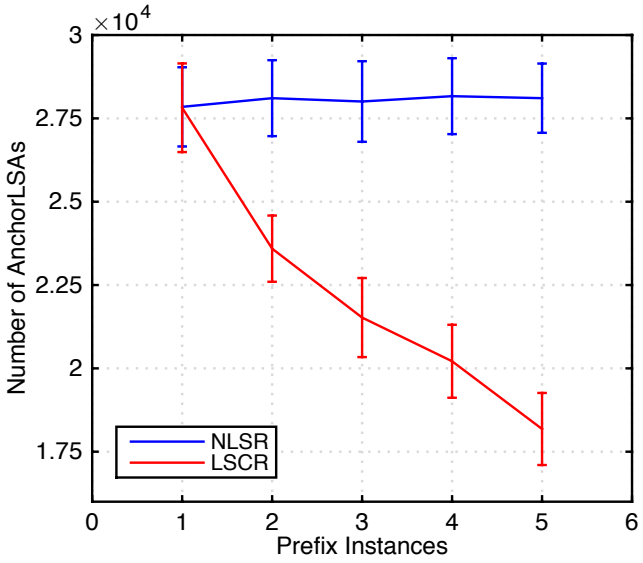
COMPLEXITY

- DCR:
  - CC = O(EC), SC = O(C)
- *LSR*:
  - CC = O(CER + lEN), SC = O(RC + E)
- LSCR:
  - CC_{add} = O(C), CC_{del} = O(CER), SC = O(C + E)

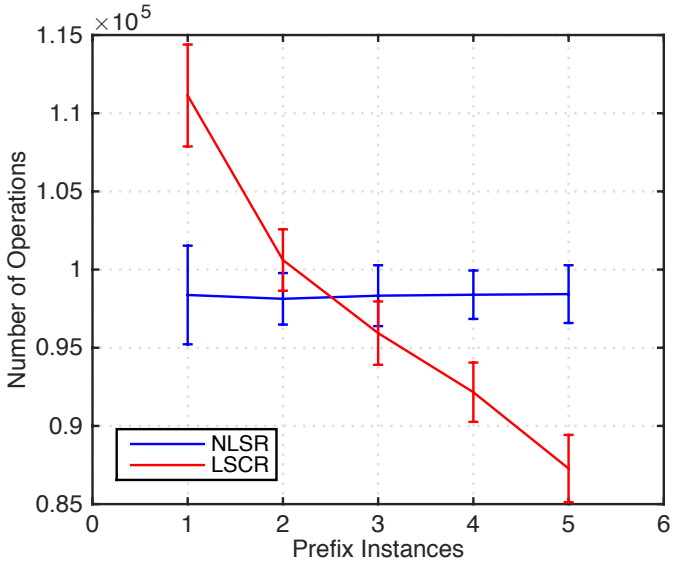
  ✓ N: number of routers
  ✓ E: number of links
  ✓ D: number of distinct anchors
  ✓ C: number of prefixes
  ✓ R: average number of instances
  ✓ l: average number of neighbors
  ✓ d: network diameter

PERFORMANCE

- Simulation Scenario:
  - SCo-Net, NS3 tool
  - AT&T topology
  - 210 content objects
  - 30 anchors
- Initialization:



(a)



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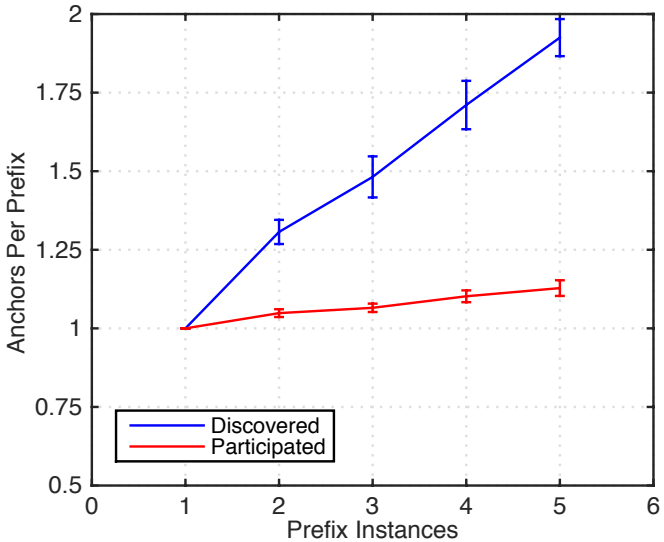
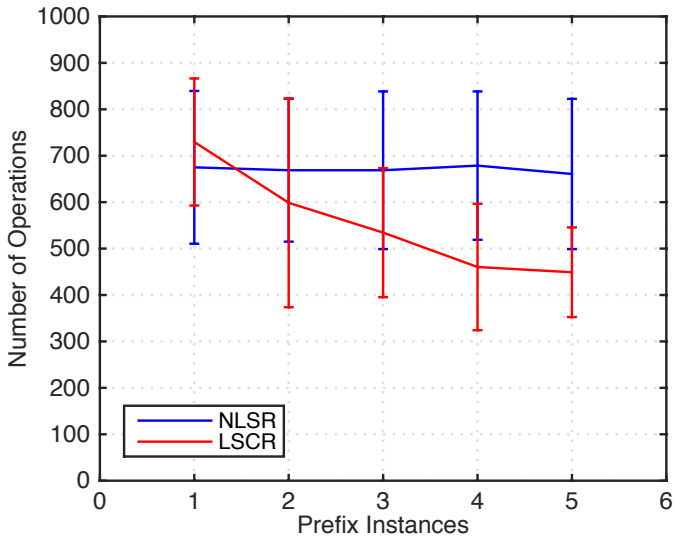


(c)

PERFORMANCE

- Simulation Scenario:
  - SCo-Net, NS3 tool
  - AT&T topology
  - 210 content objects
  - 30 anchors
- Computation:



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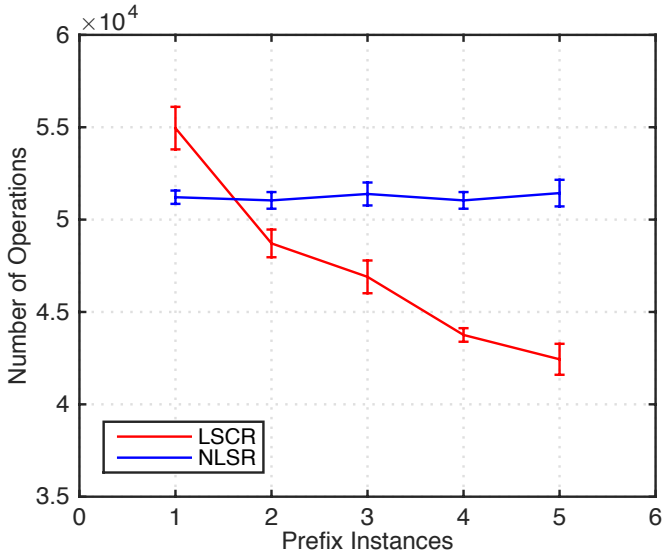

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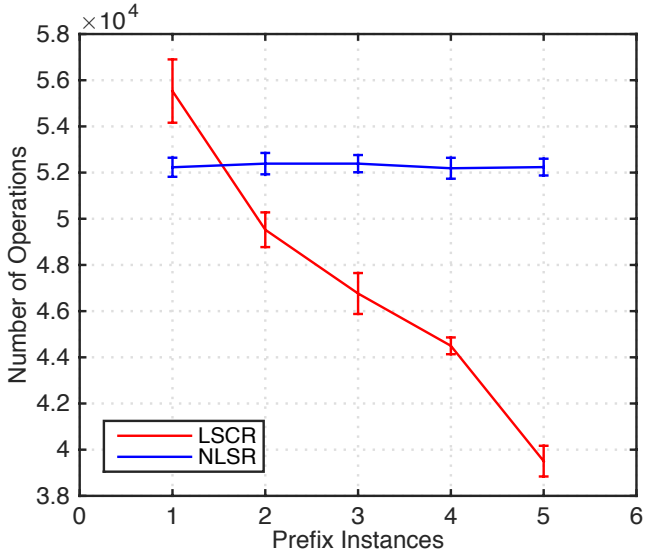

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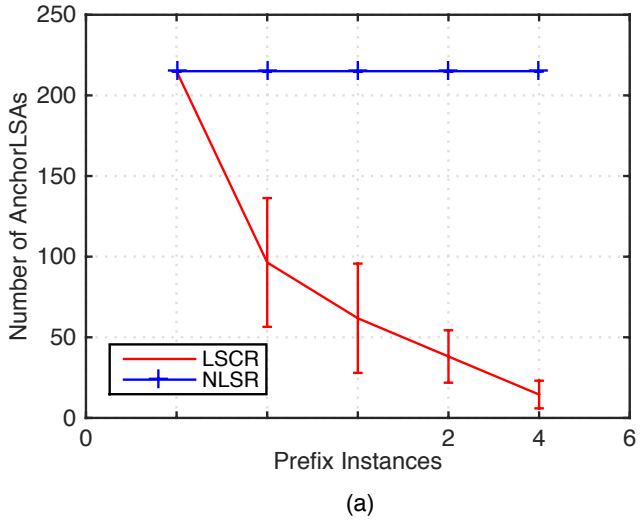
PERFORMANCE

- Simulation Scenario:
  - SCo-Net, NS3 tool
  - AT&T topology
  - 210 content objects
  - 30 anchors
- Add Prefix:



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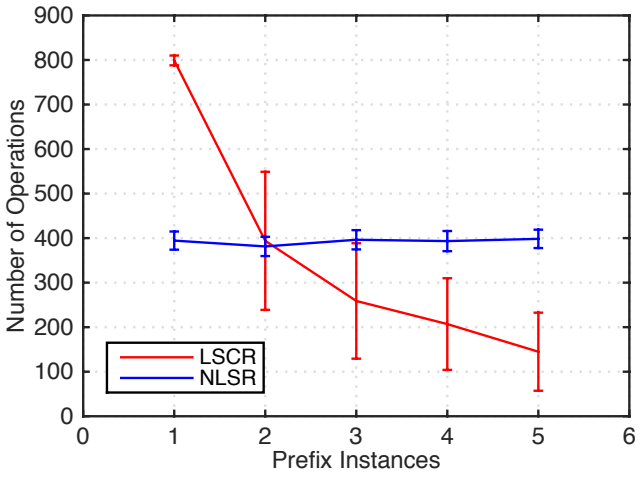

(b)

Conclusion

- LSCR offers:
  - Less Storage
  - Less communication
- NOC and SOC prevent permanent routing loops from being created
- KSO limits forwarded of LSAs and computation

- Thank You!
- Any Question?