Distributed Iceberg Detection with SDN-enabled Online Learning

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This work was partially supported by BBN under the GENI 4 subcontract 1953 under NSF CNS-1346688

➢ Network Measurement

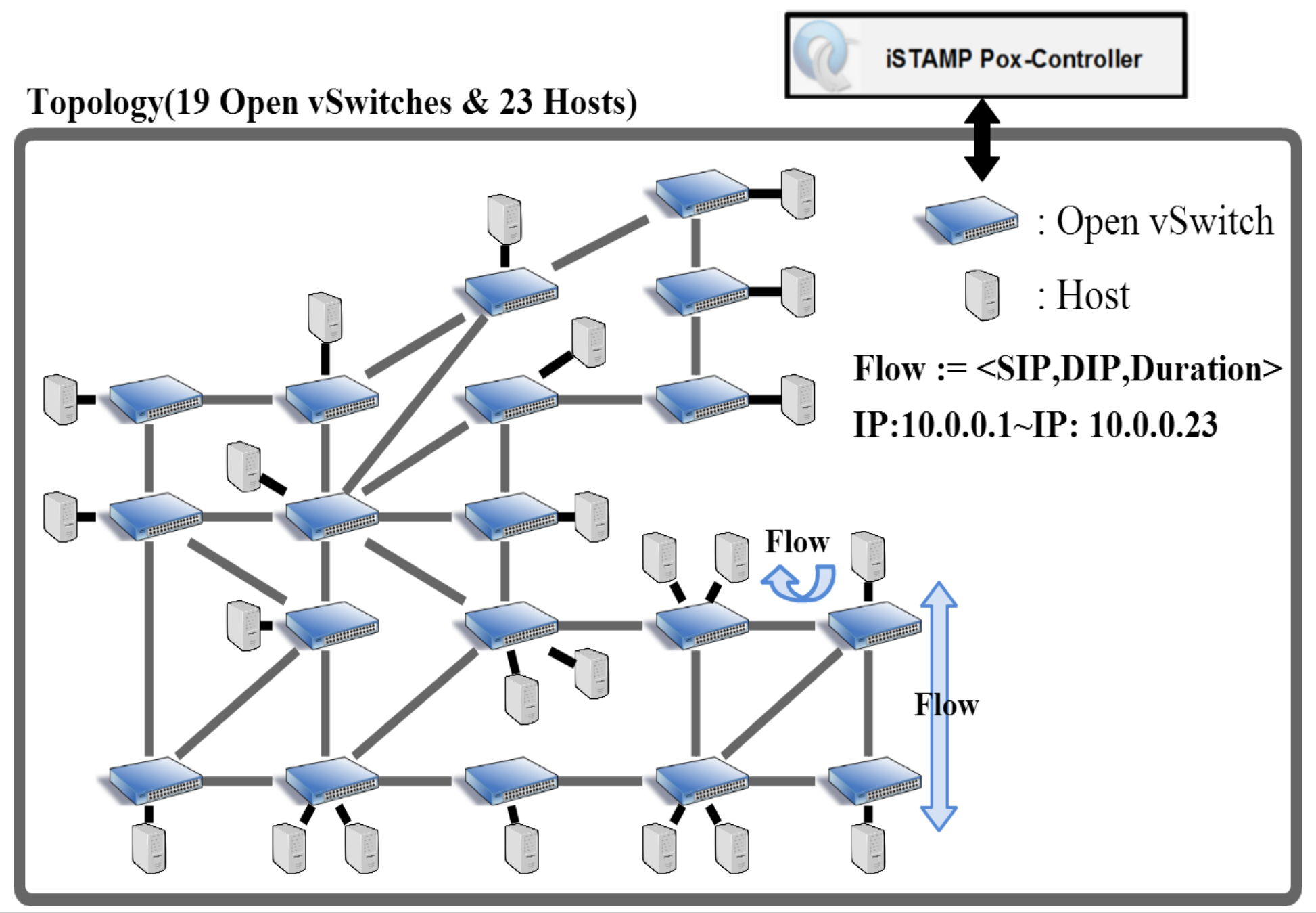
- ○ Accurate and timely traffic matrix (TM) measurements provide essential inputs for today's various network operations, such as traffic engineering, capacity planning, network troubleshooting and anomaly detection.

➢ Software Defined Networking (SDN)

- ○ SDN is considered as a promising element to implement traffic monitoring, management and control.
  - Separation of control plane from data plane
  - Centralized controller with a network-wide view enabling global optimization
  - Dynamically reprogram switches in a timely manner

➢ Network Tomography with Online Learning in Software Defined Networks

- ○ Revisit the traffic matrix estimation (TME) problem in OpenFLow-based network.
  - Limited routing entries & measuring entries
- ○ Utilize the online learning feasibility provided by SDN to target measuring "important" flows
- ○ Heuristic solutions to allocate "important" flows to distributed TCAM resources


iSTAMP Pox-Controller
Topology(19 Open vSwitches & 23 Hosts)
: Open vSwitch
: Host
Flow := <SIP,DIP,Duration>
IP:10.0.0.1~IP: 10.0.0.23
Flow
Flow

➢ Network Tomography with Online Learning in Software Defined Networks

- ○ Objective:
  - Our goal is to estimate the network-wide traffic matrix by collaboratively managing the distributed measurement resources (TCAM entries) in the network.
- ○ Solution:
  - Install per-flow measurements in the measuring entries to avoid aggregation and routing feasibility issues
  - Use an intelligent online learning algorithm to sample the most important flows
  - Utilize the online learning feasibility provided by SDN to update the measuring entries periodically to target the most important flows
  - Heuristic solutions to allocate "important" flows to distributed TCAM resources

Algorithm 1 Lasthop

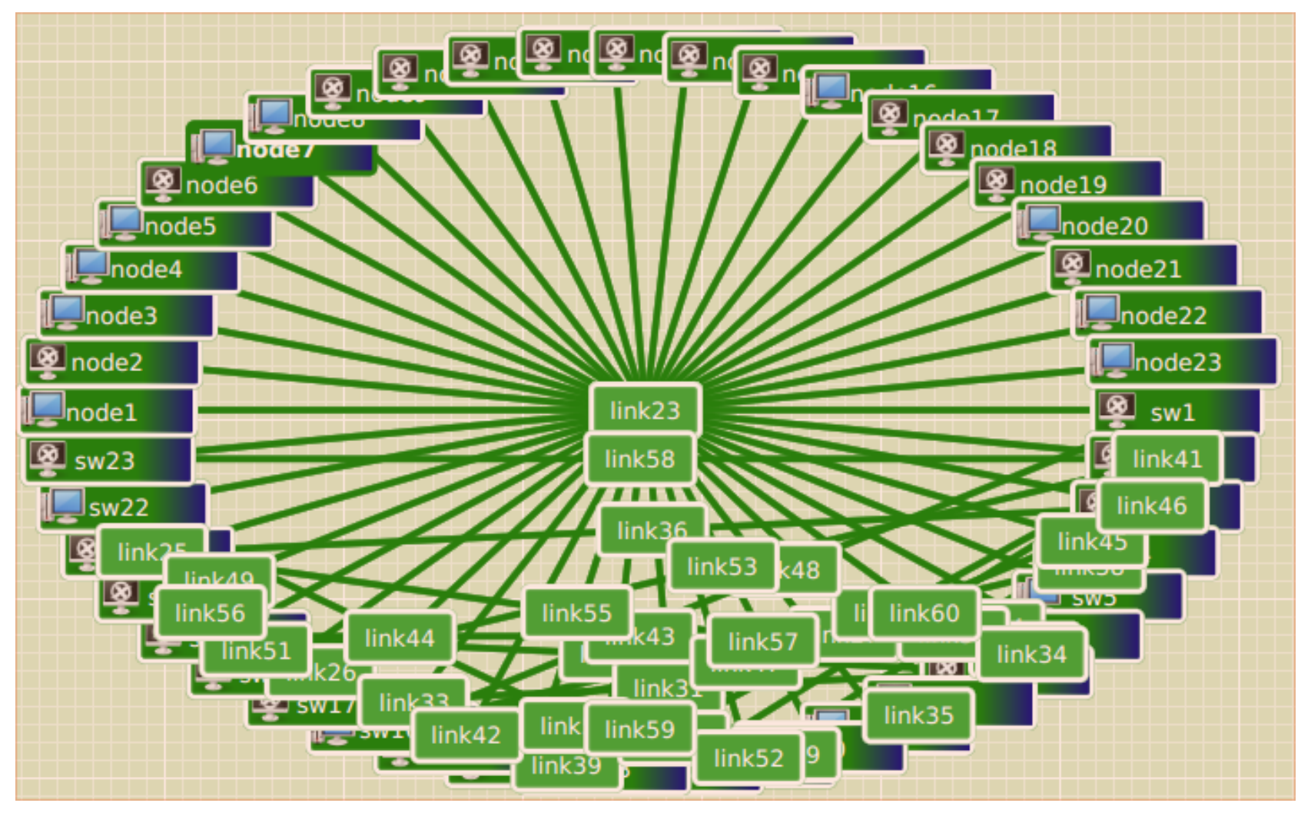
```
Input: index=[ranking flows based on their "importance"], distribution of measuring entries, assume $k_j$ TCAM entries available at switch $j$
Output:a feasible switch-flow allocation
for each flow $fl$ in index do
    switch_list = [switches flow $fl$ goes through from dst to src]
    for each switch $j$ in switch_list do
        if $k_j > 0$ then
            install per-flow measurement for flow $fl$ here
            $k_j = k_j - 1$
            break
        end if
    end for
end for
```

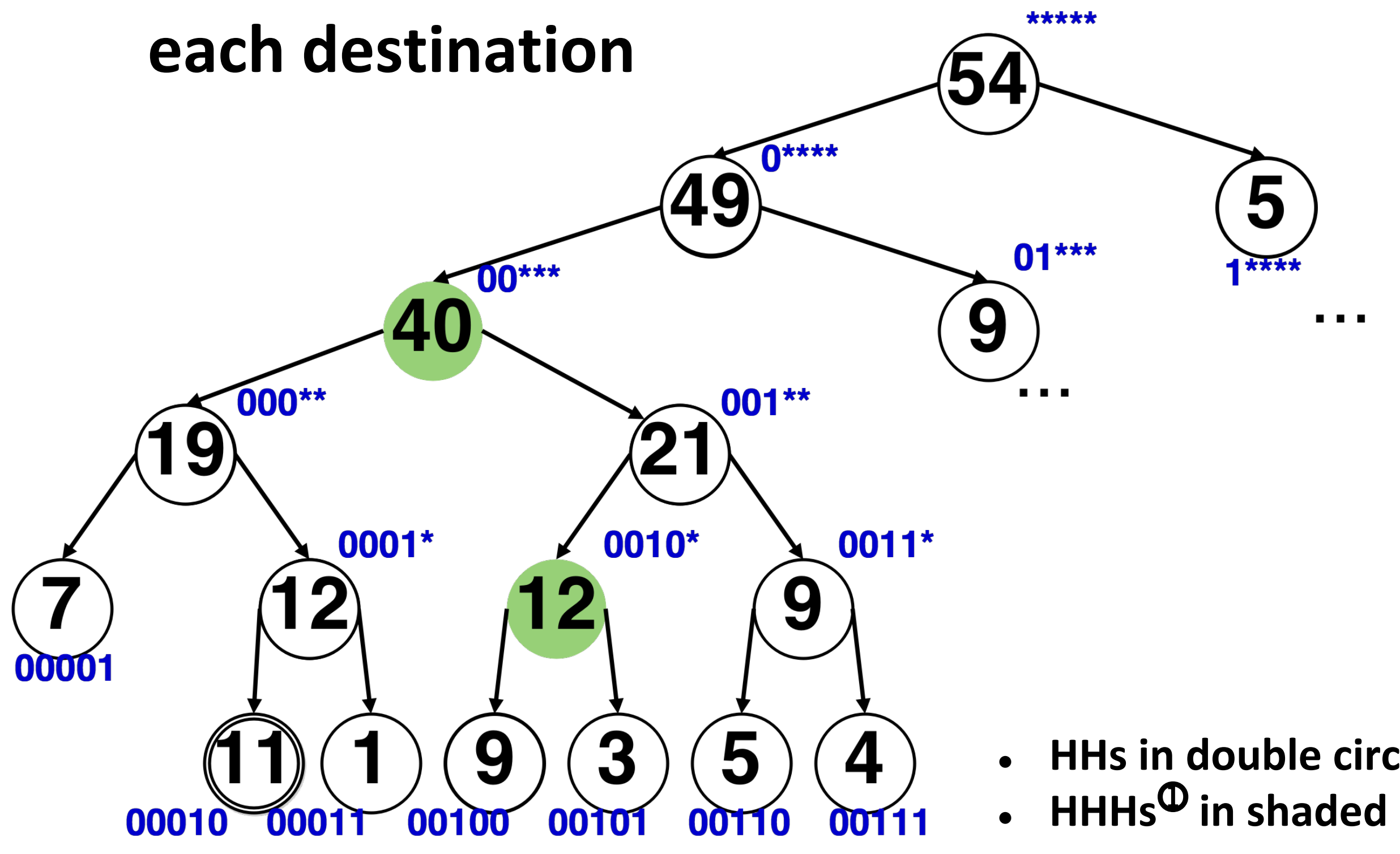
Algorithm 1 Greedy

```
Input: index=[ranking flows based on their "importance"]; distribution of measuring entries, assume $k_j$ TCAM entries available at switch $j$; load for each switch: number of important flows passes trough this switch
Output: a feasible switch-flow allocation
for each flow $fl$ in index do
    switch_list = [switches flow $fl$ goes through from dst to src]
    choose switch $j \in switch\_list$ where $k_j$ is largest
    if there is a tie then
        choose switch $j$ which has the least load
    end if
    if $k_j > 0$ then
        install per-flow measurement for flow $fl$ here
        $k_j = k_j - 1$
        break
    end if
end for
```

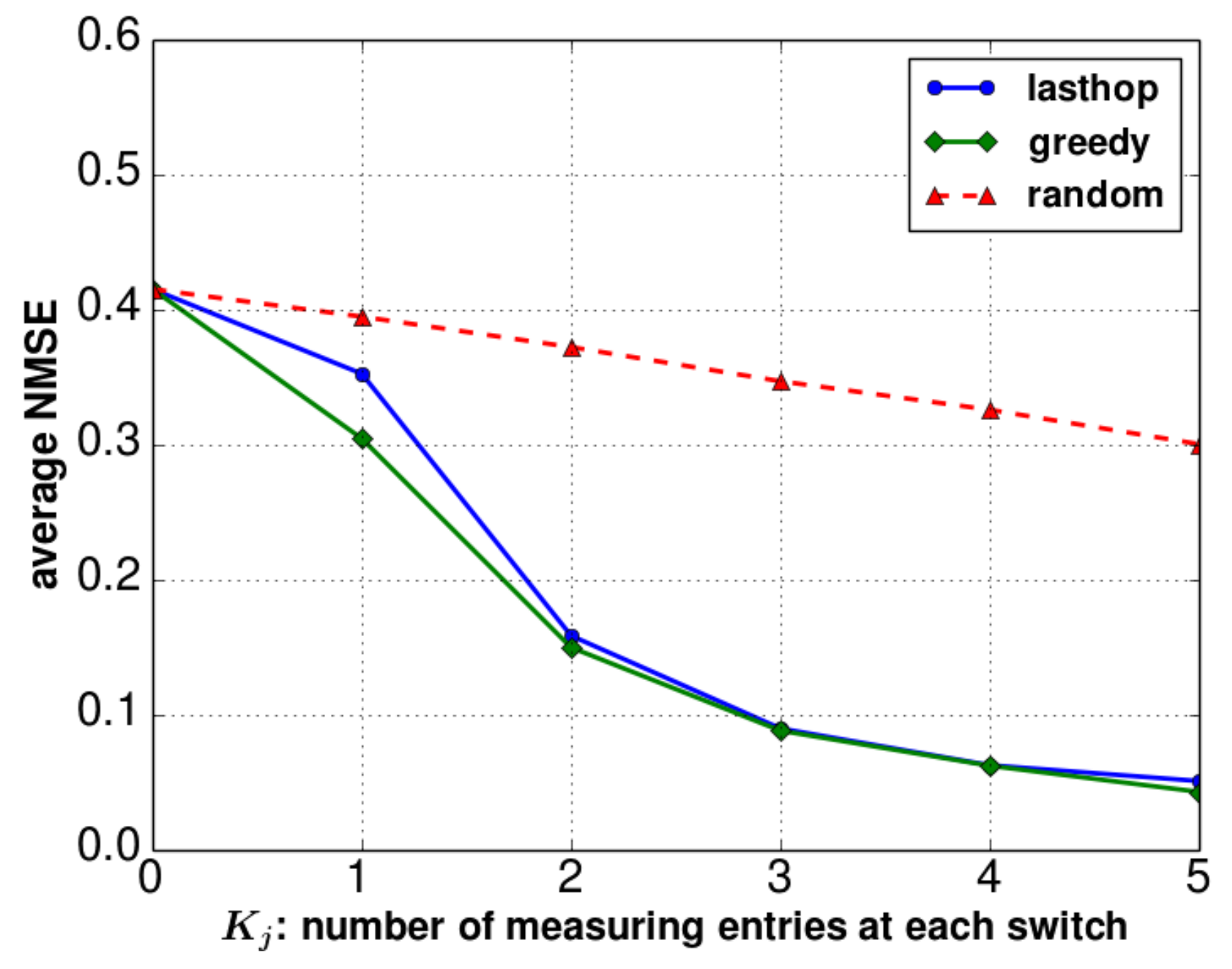
➢ Simulation Results

- ○ Simulate our framework using GEANT topology
  - 23 switches, 37 links
  - Real traffic traces of GEANT network is used
- ○ Application of TME
  - Heavy Hitter (HH) Detection
    - Flows with a flow size larger than a threshold
  - Hierarchical Heavy Hitters (HHH) Detection
    - Build a prefix tree of source IP address for each destination





- HHs in double circles
- HHHs[①] in shaded circles

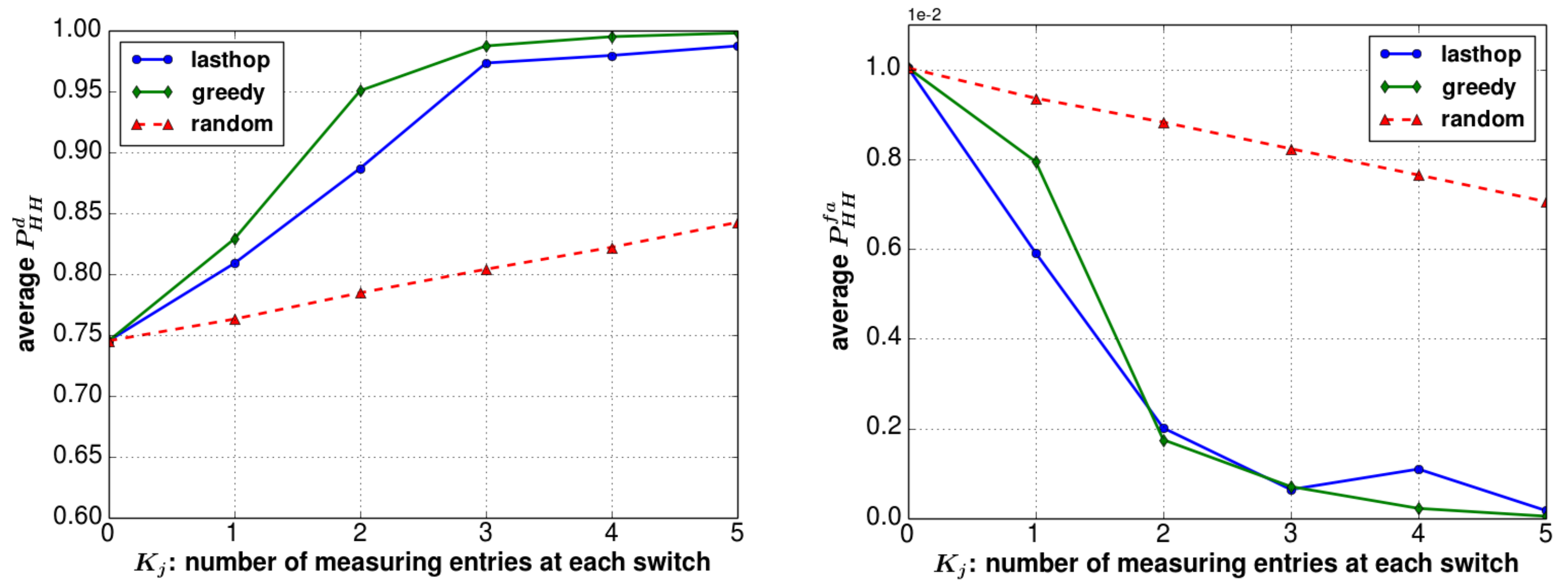


- K_j: number of measuring TCAM entries at each switch
- NMSE measures the accuracy of traffic matrix estimation

[①] Jose, Lavanya, Minlan Yu, and Jennifer Rexford. "Online measurement of large traffic aggregates on commodity switches." *Conference on Hot Topics in Management of Internet, Cloud, and Enterprise Networks and Services–Hot-ICE. USENIX*. 2011.

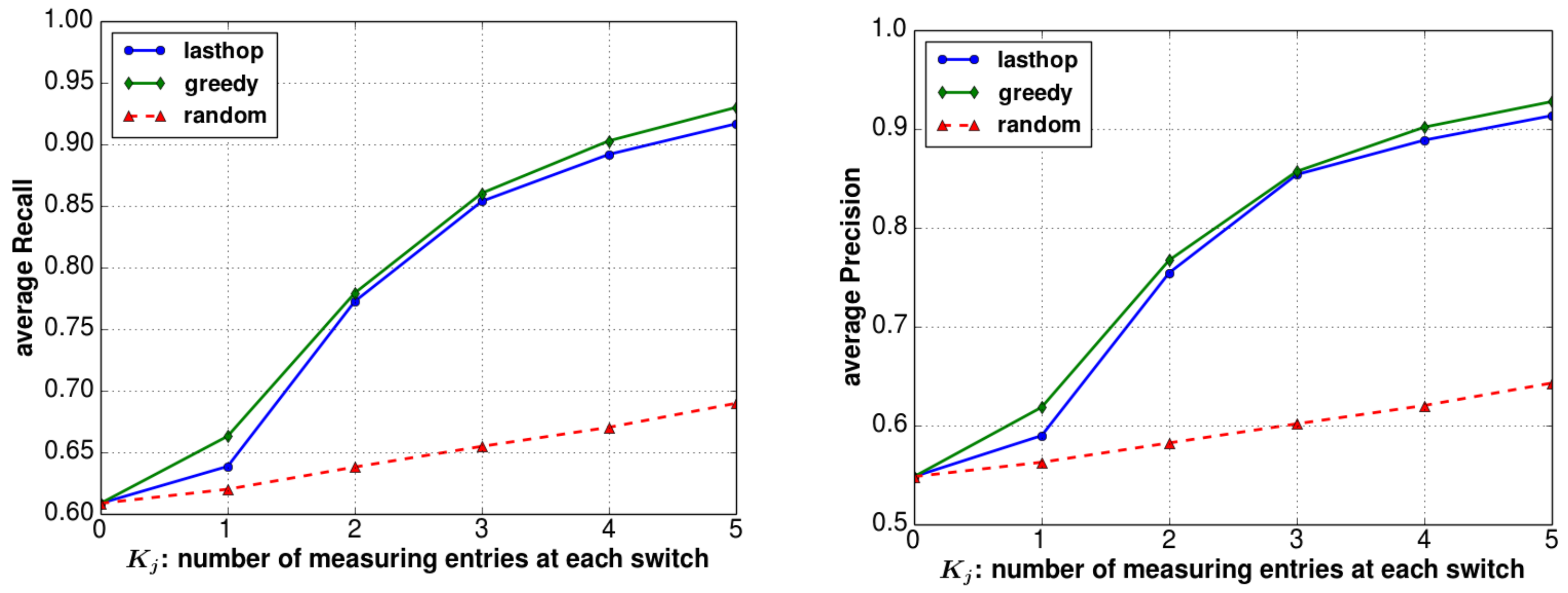
➢ Global Iceberg Detection

- ○ Global Heavy Hitter (HH) Detection



- Threshold: 10% of link capacity
- P^d_{HH}: probability of detection
- P^{fa}_{HH}: probability of false alarm

- ○ Global Hierarchical Heavy Hitters (HHH) Detection



- Threshold: 10% of link capacity
- Recall: the total number of true HHHs detected over the real number of HHHs
- Precision: the total number of true HHHs detected over the total number of HHHs reported