SDProber: Software Defined Prober

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Delay Measurements

- Persistent delays in networks cause adverse effects
  - Disrupts quality of service in applications impacting revenue
- Delay measurements needs to be done constantly
- Trade-off between detection time and measurement cost
  - Lack of measurements increases detection time
  - Frequent measurements affect the network
- Network operator needs to balance between measurement cost and detection time

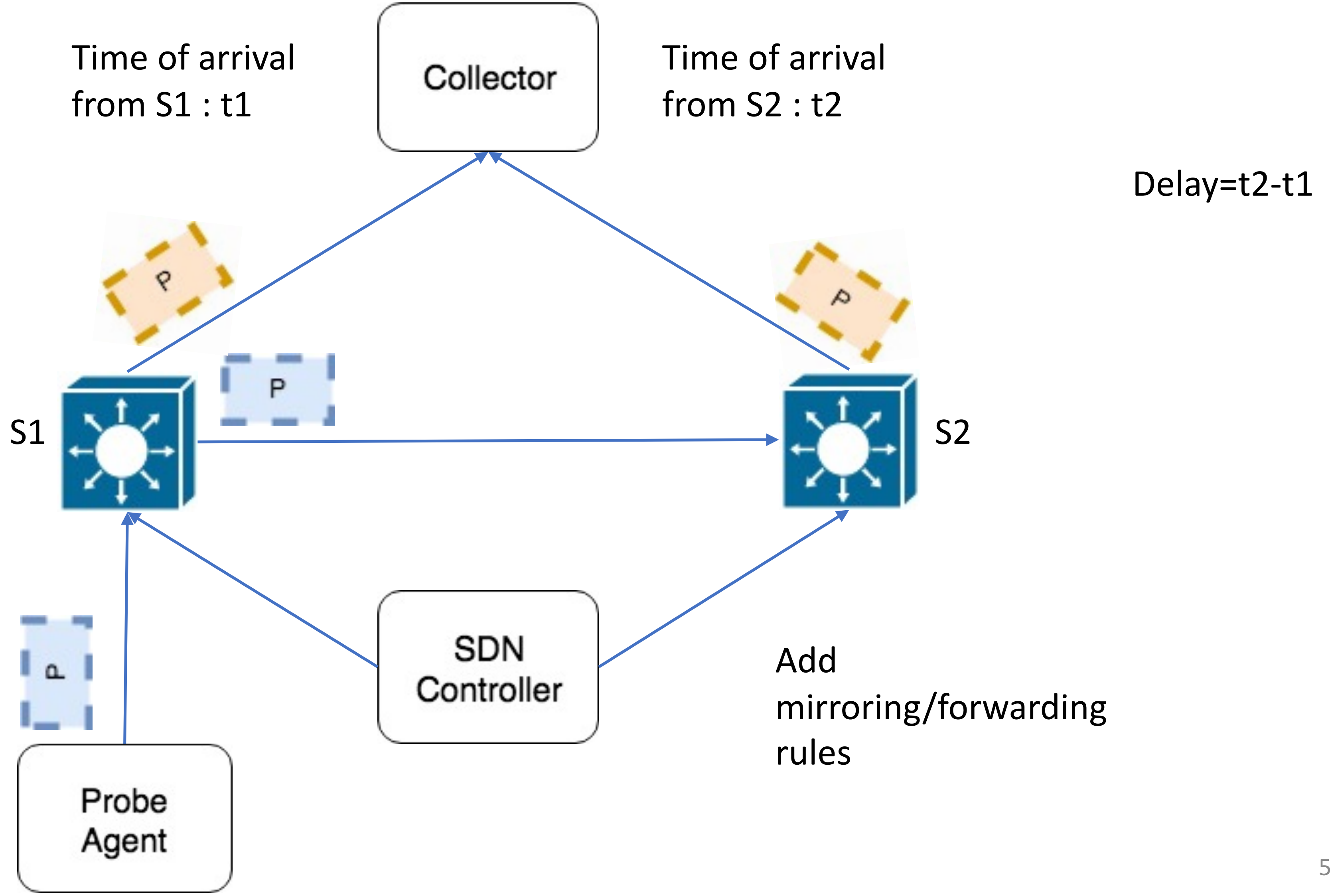
Measurements with bounds

- Bounding measurements can help in balancing the measurement cost and detection time to the network operator
  - Lower bound specifies the minimum number of inspections which needs to be performed on link
  - Upper bound limits the the number of inspections performed on link
- Existing tools such as ping and traceroute cannot apply such bounds
  - Depends on the underlying routing algorithm which is inflexible
  - Finding the optimal solution with pre-defined path solution is NP-hard

SDProber – Software defined prober

- SDProber allows adaptable and efficient delay measurements in networks with bounded constraints
- SDProber uses probe packets to estimate the time taken for traversing every link
- Probes in SDProber take a pseudo-random walk in a weighted graph
  - Avoids complex computation
- Weights are adapted to satisfy rate constraints on links
  - send more probe packets to links where lower bounds are not satisfied
  - send less probe packets to links where upper bounds are satisfied

SDProber – System Overview



SDProber – Pseudo random walk

- For every probe packet, the initial starting node and each traversing link are selected randomly
- By altering the initial node weights or weights on choosing the next node, SDProber can control how probe packets inspect the network
  - Easily adapts to changes in probing constraints or network
  - Reduces costs
- Implementation of Random walk is done using Openvswitches group tables and forwarding rules

SDProber – Pseudo random walk

Guides different types of probe packets

Match	Action
Destination MAC of probe packet	Forward to Group Table in ALL mode
Destination MAC mirrored probe packet	Forward packet to collector

Mirrors probe packets

Group table in ALL mode

Decrement TTL and forward to Group Table in SELECT mode
Change DST MAC, update UDP SRC port and forward to collector

Implements random walk

Group table in SELECT mode

Forward to port P1	W1
Forward to port P2	W2
Forward to port Pn	Wn

- SDProber uses binary exponential backoff to adjust weights
- Initial node weights and link weights are adjusted
  - Doubled/halved when probing rates are less/more than constraint

Evaluation: Competing approaches

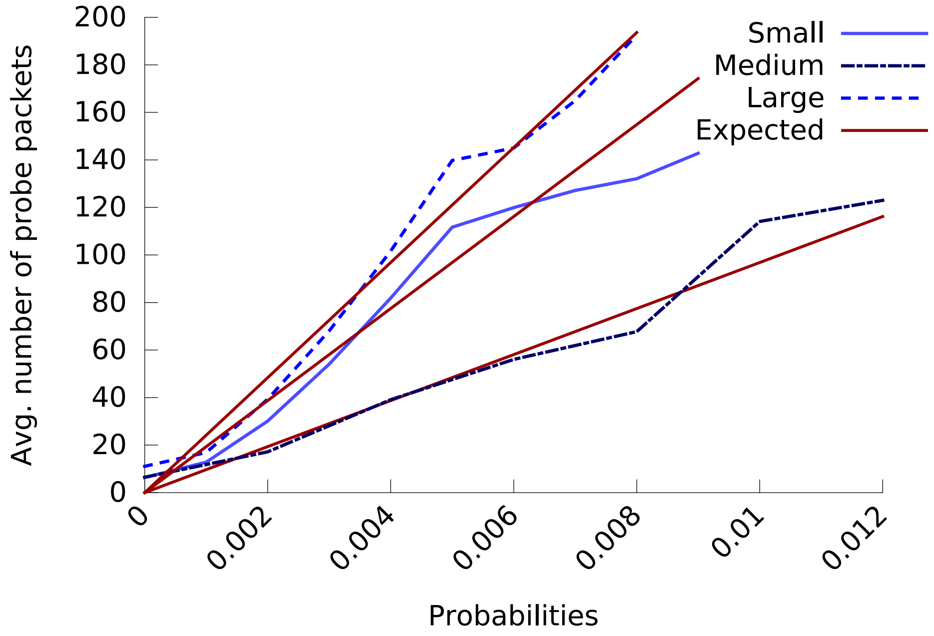
- Two approaches that use shortest path to send probe packets
- In each approach, the probe packet is mirrored at every node it traverses
- Random Pair Selection (RPS)
  - For every iteration, source and destination pairs are selected randomly and probe packets are sent through the shortest path between them
  - At every iteration, source and destination pairs are selected from pairs which have not been selected before
- Greedy Path Selection
  - At each iteration, pairs of source and destination are selected such that the sum of min-rate values of all unvisited links on paths is maximum

Evaluation: Setup

- Tested on 196 nodes + 243 links real topology
- Probing iteration was launched every 30 seconds
- Evaluated results on three probing profiles(small, medium, large) having different min-rate, max-rate
  - Network operators could choose probing rates based on SLA or historically analyzing delays

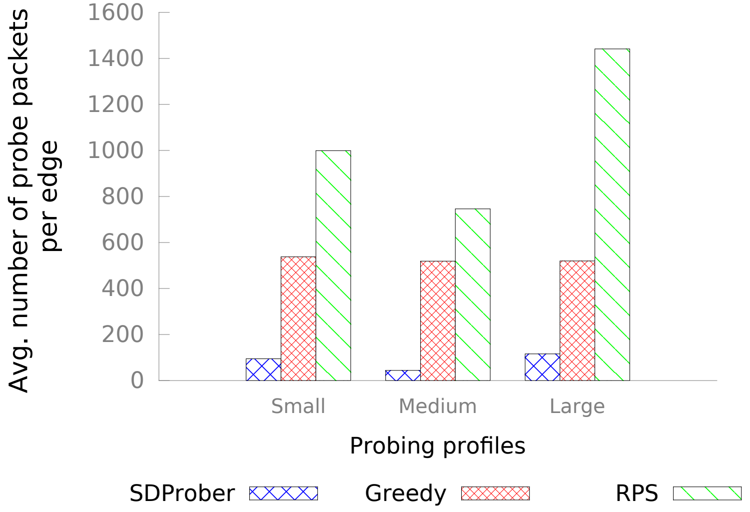
Evaluation: Control over inspection

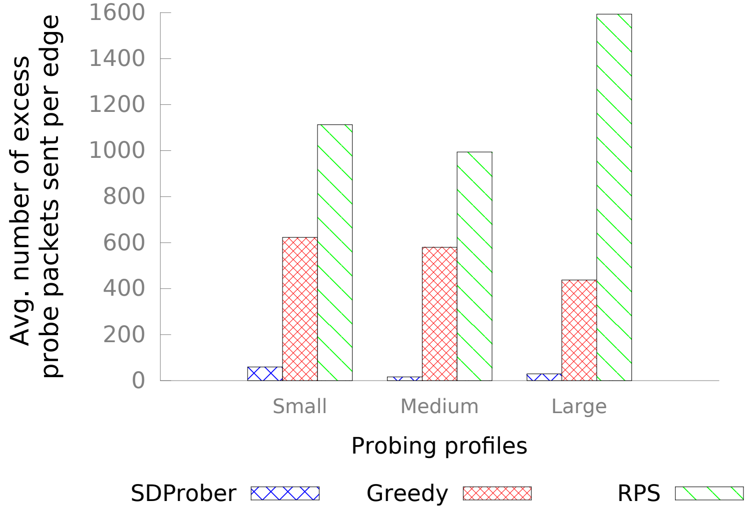
- Red line indicates the probability of traversing through link
- Blue line is the number of probe packets which traversed each link
  - Error is ±10% from expected value



Evaluation: Cost effectiveness

- For each method, we increased the number of emitted probe packets per iteration till min-rate constraints are satisfied
  - SDProber sends 4—12 times fewer probe packets than RPS and greedy
  - While satisfying min-rates on all links, SDProber sends 10—62 times fewer excess probe packets than RPS and greedy



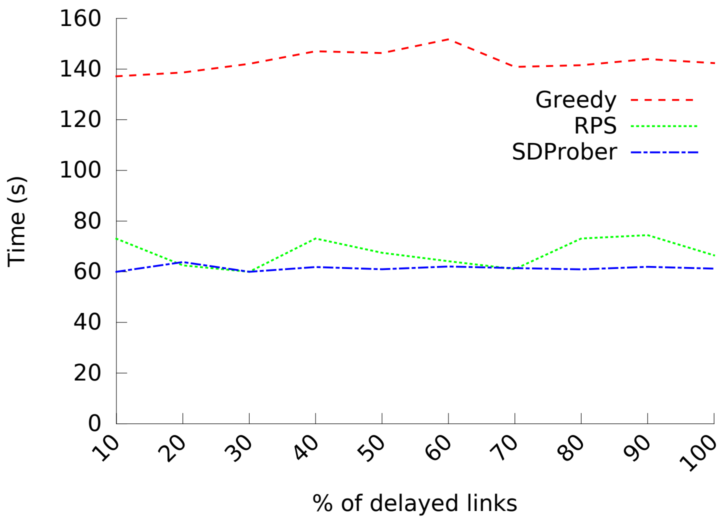


Conclusion

- SDProber provides an efficient and flexible delay measurements with measurement constraints on inspection rates
- SDProber uses probe packets to estimate delay on links
- Probes take a pseudo random walk
- Weights are adapted using binary exponential backoff to satisfy inspection rate constraints
- Evaluated SDProber on a real world ISP topology to show SDProber's control over probe packets and cost effectiveness

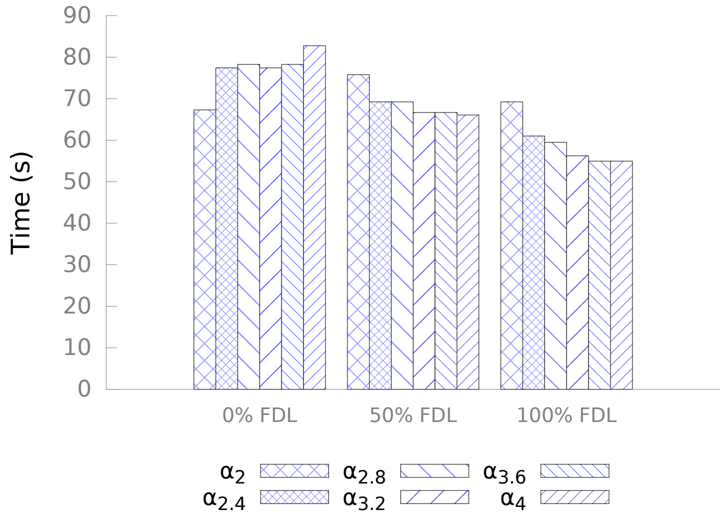
Evaluation: Detection time

- SDProber detects delays twice as fast as greedy
  - Links with low weights are visited last in greedy
- SDProber and RPS have comparable detection time
  - But RPS sends more packets to satisfy rate constraints



Evaluation: Learning

- Varied % of historically delayed links
- When there are more historically delayed links, increasing α reduces detection time by 2—6%
- When there are no historically delayed links, increasing alpha increases detection time by 4%



Choosing probing profiles

- Using SLA associated with customers
  - 99.9% uptime equates to 45 minutes of down time per month
  - Network operators can set the min-rate of probing such that the delayed links are detected with guarantees
- Using historical delay data
  - Links which have history of congestion can be probed more

Guarantees and convergence

- SDProber attempts to satisfy rate constraints with minimum violations given several parameters (TTL, packets available per iteration)
- Inspecting each link can provide tighter guarantees
  - But is expensive, requires more probe agents and is inefficient
- Random walk provides guarantees on inspection, provided there are enough probe packets per iteration
- Binary exponential backoff helps in expediting the satisfaction of constraints
  - There is no convergence – measurements are continuous and constraints are used as a driving factor for faster detection with low costs

Timestamp

- SDProber detects persistent delays in WAN where delays are usually in milliseconds
- Delay between switches and collector can be estimated using ping
  - Delays on link could therefore be bounded
  - Using historical measurements, delays greater than a particular threshold can be alerted to the network operator
- Timestamping can be done on packets using INT
  - Requires that there is clock synchronization at all switches