Adaptive Source Routing and Packet Replication in wide-area networks

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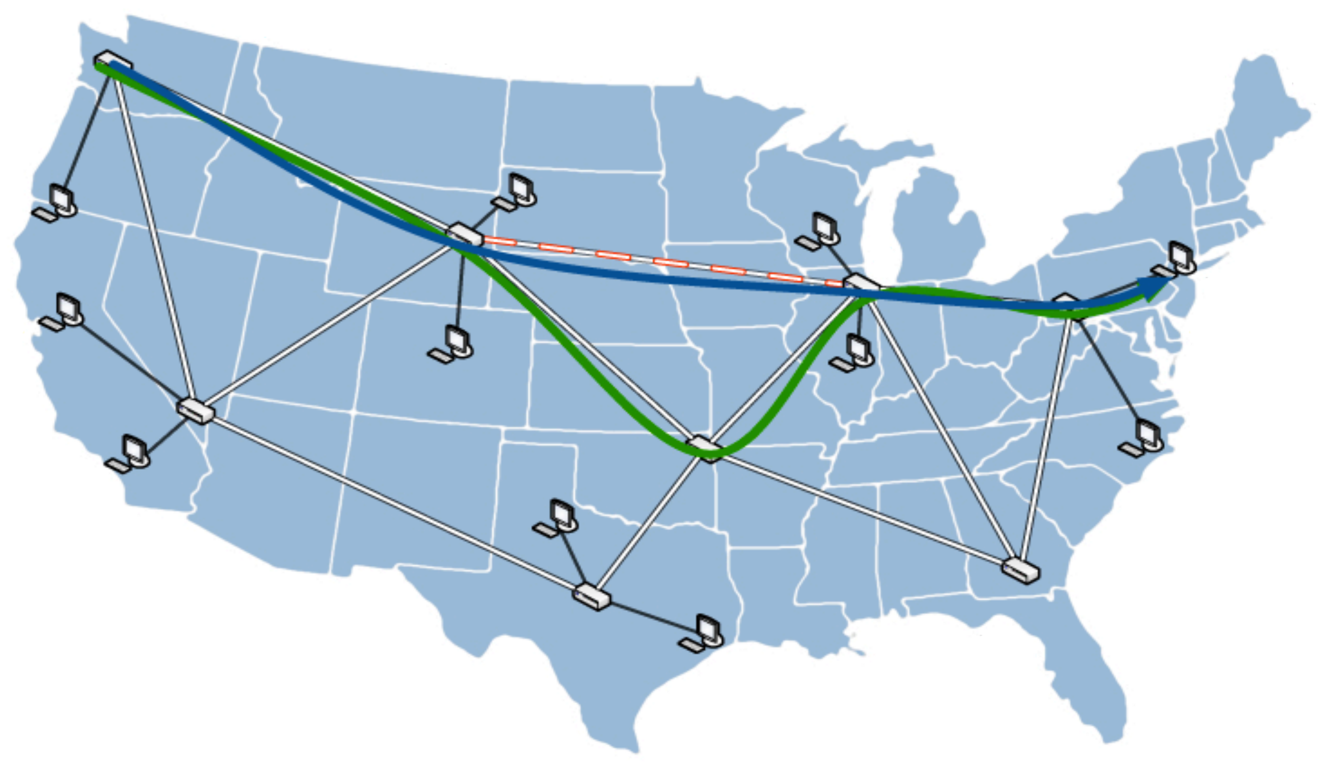
Background

- Today's routing techniques on the Internet rely completely on decisions taken within the network
- Lacking an end-to-end view, today's strategies often react slowly to dynamics and do not take into account the type of traffic routed
- Let sources define the path along a packet traverses the network!
- Source Routing offers a range of opportunities for optimization of today's Internet Routing and Traffic Engineering: e.G. Multi-Path Routing, Path Selection and Packet Replication



Path Selection

- Make routing decisions based on continuous end-to-end measurements to optimize end-to-end performance
- Simple Heuristics can be applied to select the best from a set of end-to-end paths
- Sources can optimize different metrics such as latency, loss rate or throughput

More is Less

- Low latency is critical for interactive networked applications
- Replicate packets over multiple best performing paths simultaneously to reduce the latency-tail
- Use whichever packet arrives first
- Overhead for certain use-cases reasonable (e.G. TCP handshakes, DNS requests, API calls)

- Live Run Experiments on PlanetLab/ProtoGENI using overlay routing over 3 different toplogies (two continental U.S., one trans-atlantic)

Results

- Depending on the distribution of flow-sizes the increase in network load caused by replication can be low (Figure 1)
- Intelligent Path Selection reduces experienced latency considerably; when using multiple paths concurrently, previous wrong path decisions often get "corrected" (Figure 2)

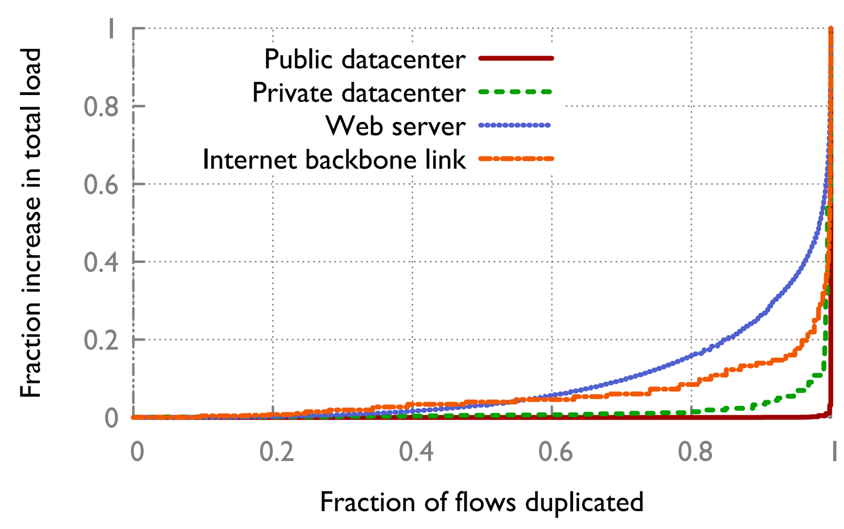


Figure 1: Total load increase for different degrees of traffic duplication

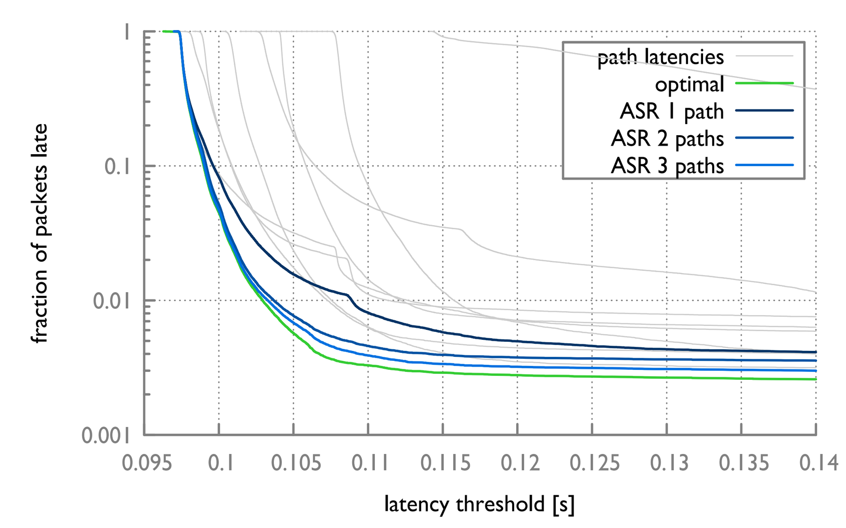


Figure 2: Performance of a Simple Moving Average Heuristic for Path Selection in a PlanetLab measurement without sending actual data compared to best path in retrospect

- When sending multiple copies of actual payload packets over the best selected paths, the latency tail can be cut down significantly (Figure 3, Figure 4)

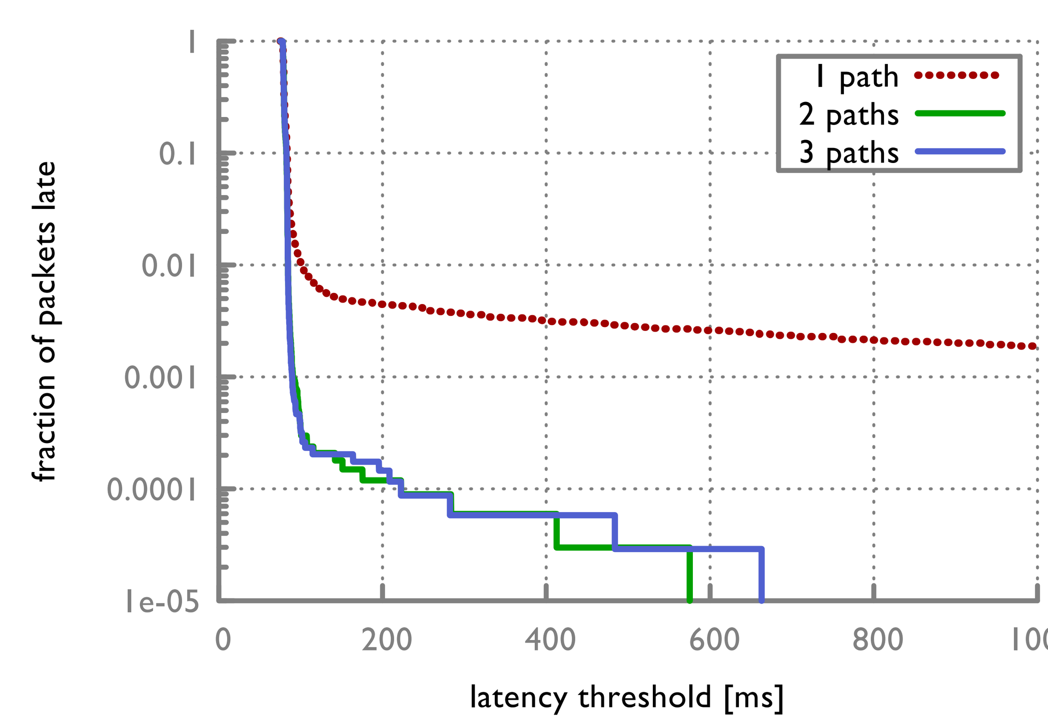


Figure 3: Latency Distribution in representative topology at a data-rate of 56kbit/s and replication over up to 3 distinct paths

	mean			99%-ile			99.9%-ile		
no. of paths	1	2	3	1	2	3	1	2	3
intra-U.S. 1	103.5ms	7.28%	6.3%	292.1ms	61.61%	59.62%	loss	1846.8ms	1997.0ms
intra-U.S. 2	86.0ms	6.63%	6.41%	101.9ms	17.19%	17.19%	1888.5ms	95.04%	95.22%
trans-atlantic	142.1ms	4.02%	4.19%	233.7ms	37.26%	37.27%	594.9ms	69.52%	71.81%

Figure 4: Measured RTT's in 56kbit/s experiment for 1 path and reduction when using replication (packets later than 4.5 seconds were considered lost)

- Packet Replication and intelligent Path Selection can be beneficial in a Future Internet setting where traffic sources have control over routing decisions

Future Work

- Verification of results in a larger-scale overlay experiment on PlanetLab or using OpenFlow in the GENI meso-scale experimental facility
- Implementation of this technique for a specific use-case or application (e.G. TCP connection establishment, DNS, critical mobile connectivity)