Routing on Multiple Optimality Criteria

Introduction to Networking - Final Project

1 Abstract

We chose to replicate the findings of ”Routing on Multiple Optimality Criteria” [1]. The paper presented an experiment composed of 25 trials over different network events for the routing protocols it described on AS1239 topology from Rocketfuel project [2]. We succeeded in fully replicating the findings of the paper on AS1239 as well as extended the experiments to all other topologies provided in the artifact. The results for all networks show the same properties described in the paper, and are almost identical in the case of AS1239 where we had plots to compare to. This gives further support to the claims made by the paper’s authors, and strengthens our belief that the protocols work as advertised.

2 Introduction

Optimal pathing is bound to a set of attributes which represent the performance metrics and a total order which defines the relative preferences between them. We define the optimal attribute from source to destination in a network is the most preferred of all path attributes from source to destination. We calculate the attributes of a path via a binary extension operation which aggregates the attributes of the links which compose the path.

Standard vectoring algorithms, such as EIGRP [3], BGP [4], DSDV [5], or Babel [6] iterate at every node of the network and perform extension via the attributes advertised from the neighboring nodes, and select attributes in accordance to the total order.

This though only discovers optimal attributes and paths if the total order is consistent (isotone) with the extension operation. Without the isotonicty, the standard vectoring algorithms fail to route optimally for the most part.

Most total orders which represent real-world preferences do not satisfy isotonicty. e,g., file transfer which requires low latency and high bandwidth. Since current routing protocols work optimally under specific constraits, which makes them fail at many interesting (and needed) optimally criteria, the paper aims to optimally route in the cases the other protocols fail. Since we do not know which constraints might be required, the goal of the paper is to create the ability to optimally route for arbitrary optimally criteria.

Another problem which is present in this type of routing is routing efficiently for multiple criteria. Most approaches route the entire network per criteria, which is not scalable. Hence, the paper also aims to create an algorithm which routes for all criteria at the same time.

The proposed solution is based on the substitution of the total preference order on attributes by a partial order that satisfies isotonicity while respecting the total order. Then, this idea is extended to account for multiple total orders, combining them into a single isotone partial order which respects all total orders.

This algorithm is materialized into two dominant-paths vectoring protocols that compute on partial orders. A non-restarting version in which the destination initiates the routing computation only once; and a restarting version where the destination regularly initiates fresh computation instances during which newly elected attributes replace those from older instances.

3 Methodology

The artifact [7] that was left by the original authors consists of a simulator for dominant-paths vectoring protocols, both non-restarting and restarting versions, and the scripts for: (1) transforming Rocketfuel topologies into network data sets that serve as input to the simulator; and (2) generating plots with CCDFs for the number of dominant attributes and for the termination times of dominant-paths vectoring protocols from the data sets that are outputted by the simulator. The Rocketfuel topologies files were also provided.

The simulator was provided with a docker file and easy-to-use instructions to set it up. The only hurdle we had to overcome was to learn how to run docker separated from the shell so it could work in the background and when we are not connected to the machine.

The authors also left a script called "run-SmallScaleEvaluation.sh", which runs a full start-to-finish replication of the tests and plots from the paper on AS3967 for 5 independent trials as the authors thought it would take too long for a full 25 trials on AS1239 replication for review purposes. We ran it as-is and tested the results it provided before proceeding to change it and run a full-scale replication of the paper.

We forked this artifact and added a very simple extension [8]. The script "run-SmallScaleEvaluation.sh" is now able to receive three parameters specifying the AS ID number, number of trials, and if to compile the simulator or not. In addition, we edited the rest of the Python scripts under /Scripts to be able to run arbitrary tests by supporting the new added parameters.

The full scale evaluation included all provided Rocketfuel topologies. We ran 25 independent trials for each test for each topology, as the authors did for AS1239 in the paper. We used three machines which ran for about a week in order to reproduce the paper fully (and create plots for the other topologies).

4 Results

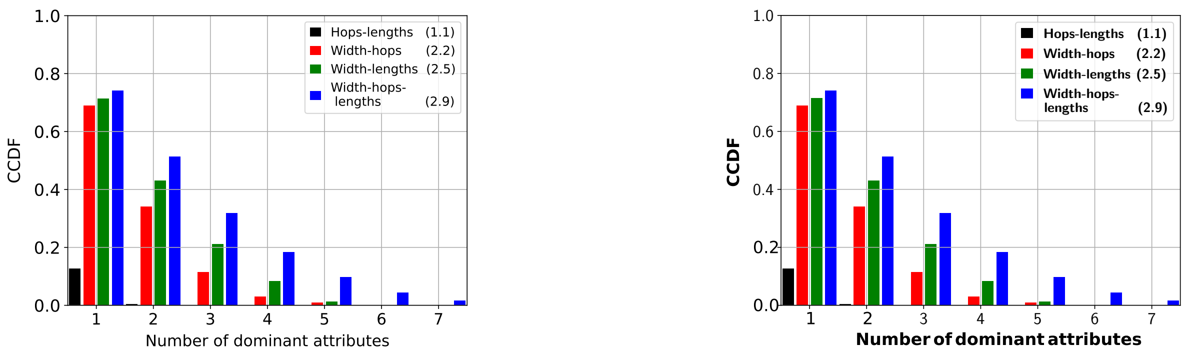
The evaluation in the paper was done on the largest biconnected component of the ISP topologies inferred by the Rocketfuel project [2]. Every link in a topology is annonated with OSPF weight and a propagation delay. The simulator for this evaluation was built for four instantiations of attributes: width-length, hops-length, width-hops, width-hops-length. Widths were extended with the minimum operator, and lengths and hops were extended with addition.

The evaluation in the paper aimed to mainly answer two questions: How big are the sets of dominant attributes in realistic networks? And how do dominant-paths vectoring protocols behave during periods of convergence following a network event?

In the following subsections, we will compare the plots we replicated using the same 25 independent trial process the authors used in the paper for AS1239. We also did this process for all other networks, whose plots can be seen in the appendixes.

4.1 Number of Dominant Attributes

Here the authors tested the number of dominant attributes from sources to destinations once the routing protocol reached a stable state. This figure shows the Complementary Cumulative Distribution Function (CCDF) of the number of dominant attributes per node in the network. As you can see, our replication produced the same results. This substantiates the claims of the authors, as a different set of 25 independent trial produced an identical plot to the one which appears in the paper. This strengthens the belief in the viability of this approach, as most nodes ended up with a small set of attributes (less than 3).



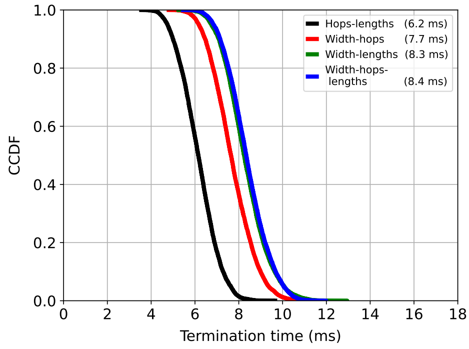
(a) Replication

(b) Original

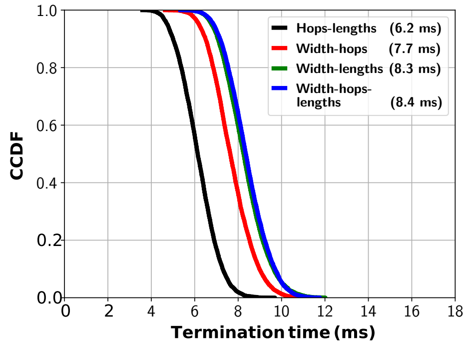
Figure 1: Number of dominant attributes

4.2 All Instantiations Termination Time for Destination Announcement

Termination time is defined as the duration of the interval of time elapsed from the moment a network event occurs until the protocol reaches a stable state. Here we tested the termination time for a new destination node network-wide announcement for each node in the network. Again, we replicated the same results, and this would follow us until section 4.6.



(a) Replication

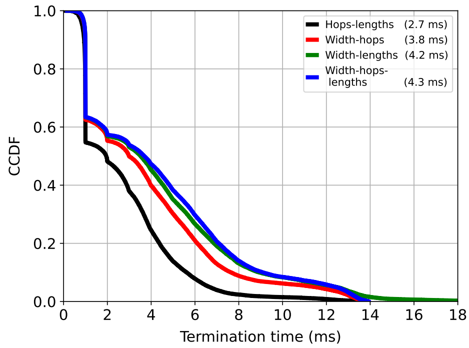


(b) Original

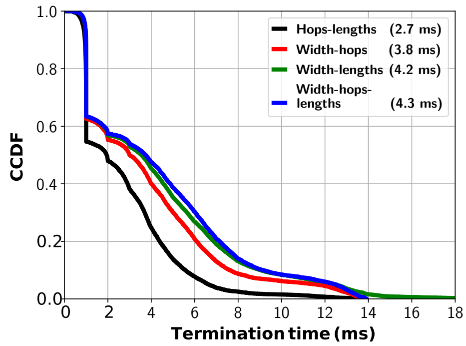
Figure 2: Termination time for destination announcement for all instantiations

4.3 All Instantiations Termination Time for Link Failure

This tested the termination time in the case of a link failure for every link. Here we can see the CCDF for termination time after a link failure over all possible links and all trials.



(a) Replication

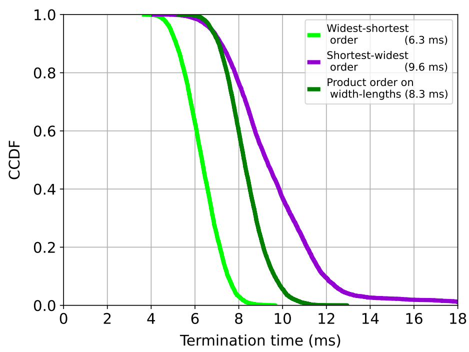


(b) Original

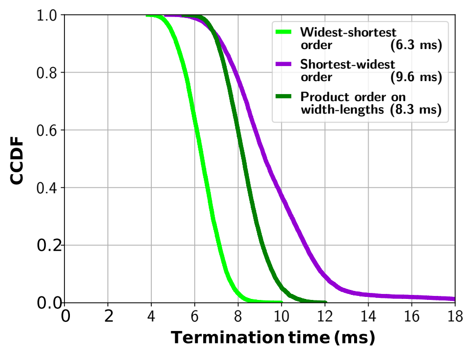
Figure 3: Termination time for link failure for all instantiations

4.4 Width-Length Orders Termination Time for Destination Announcement

This is the same experiment as in Section 4.2, only this time for Width-Length orders.



(a) Replication

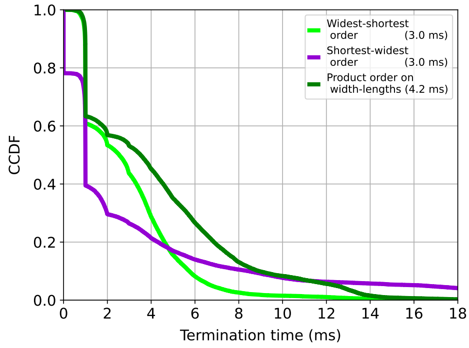


(b) Original

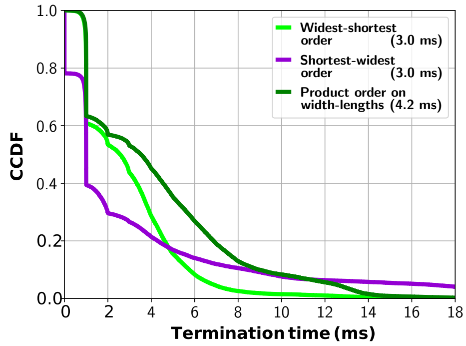
Figure 4: Termination time for destination announcement for width-length orders

4.5 Width-Length Orders Termination Time for Link Failure

This is the same experiment as in Section 4.3, only this time for Width-Length orders.



(a) Replication



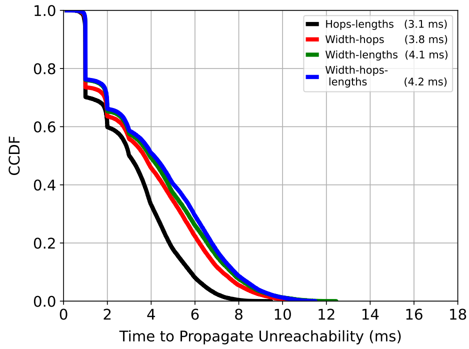
(b) Original

Figure 5: Termination time for link failure for width-length orders

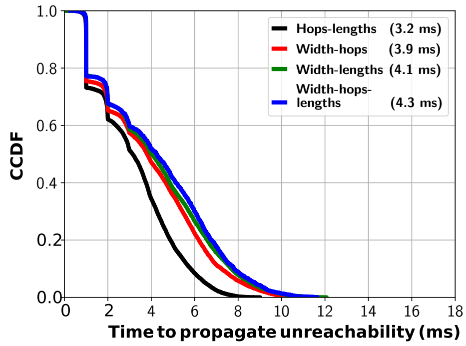
4.6 Time to Propagate Unreachability

Every computation instance initiated by the destination in a dominant path restarting vectoring protocol behaves like a network-wide announcement of a destination in the non-restarting protocol as can be characterized by the termination times shown in Section 4.2. Therefore, the authors elected to show only the time it takes to a node affected by a link failure to propagate its unreachability information upstream.

This is the only case where we produced different results, though the difference is incredibly small. This is likely due a sampling error when running the experiments. Our replicated results still provide further support to the findings of the paper, despite not being identical.



(a) Replication



(b) Original

Figure 6: Time to propagate unreachability

5 Discussion

We managed to reproduce all of paper's experiments in their entirety for AS1239 as well as for all other networks. The importance of our replication is to check if the paper's results are indeed reproducible and are representative of the average case, or were a statistical outlier. Our results were extremely similar (to almost identical) to those of the paper. This strengthens our belief that the paper's results and protocols' behavior reported in the paper are accurate and can be expected in production as well.

Furthermore, our experiments on the other, smaller networks produced results which show similar properties, suggesting even further that the protocols work as advertised and their performance is consistently good across different topologies and not good only on a specific one.

References

[1] João Luıés Sobrinho and Miguel Alves Ferreira. "Routing on Multiple Optimality Criteria". In: SIGCOMM ́20. 2020, pp. 211–225.

[2] Neil Spring et al. "Measuring ISP Topologies with Rocketfuel". In: *IEEE/ACM Trans. Netw.* (2004), pp. 2–16.

[3] Donnie Savage et al. *Cisco's Enhanced Interior Gateway Routing Protocol (EIGRP)*. RFC 7868. 2016.

[4] Yakov Rekhter, Susan Hares, and Tony Li. *A Border Gateway Protocol 4 (BGP-4)*. RFC 4271. 2006.

[5] Charles E. Perkins and Pravin Bhagwat. In: *Proceedings of the Conference on Communications Architectures, Protocols and Applications*. SIGCOMM '94. 1994, pp. 234–244.

[6] Juliusz Chroboczek. *The Babel Routing Protocol*. RFC 6126. 2011.

[7] Miguel Alves Ferreira. *rmoc-sigcomm2020-artifact*. `https://github.com/miferrei/rmoc-sigcomm2020-artifact`. Accessed: 2022-01-20.

[8] Lior Siag. *Fork for rmoc-sigcomm2020-artifact*. `https://github.com/lior8/rmoc-sigcomm2020-artifact`. Accessed: 2022-01-20.

A AS1221 Plots

(a) Number of Dominant Attributes

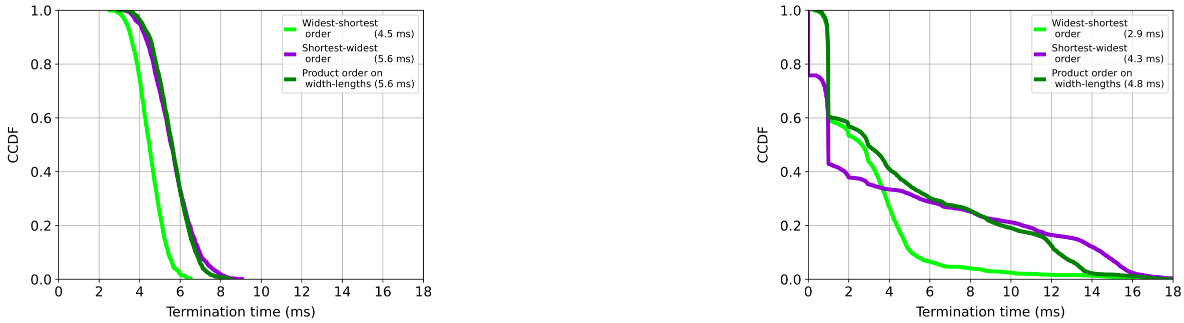
(b) Time to Propagate Unreachability

Figure 7: Number of dominant attributes and time to propagate unreachability in restarting-protocol.

(a) Termination Time Announcement

(b) Termination Time Failure

Figure 8: Termination Times for All Orders



(a) Termination Time Announcement

(b) Termination Time Failure

Figure 9: Termination Times for Width-Length Orders

B AS1755 Plots

(a) Number of Dominant Attributes

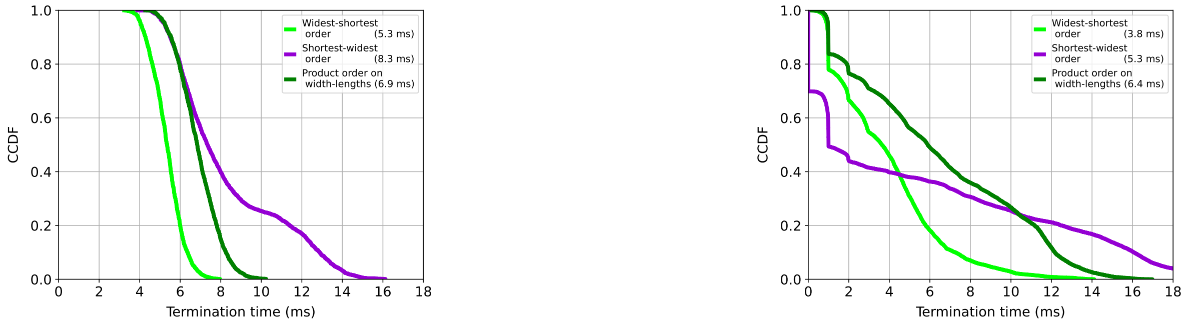
(b) Time to Propagate Unreachability

Figure 10: Number of dominant attributes and time to propagate unreachability in restarting-protocol.

(a) Termination Time Announcement

(b) Termination Time Failure

Figure 11: Termination Times for All Orders



(a) Termination Time Announcement

(b) Termination Time Failure

Figure 12: Termination Times for Width-Length Orders

C AS3257 Plots

(a) Number of Dominant Attributes

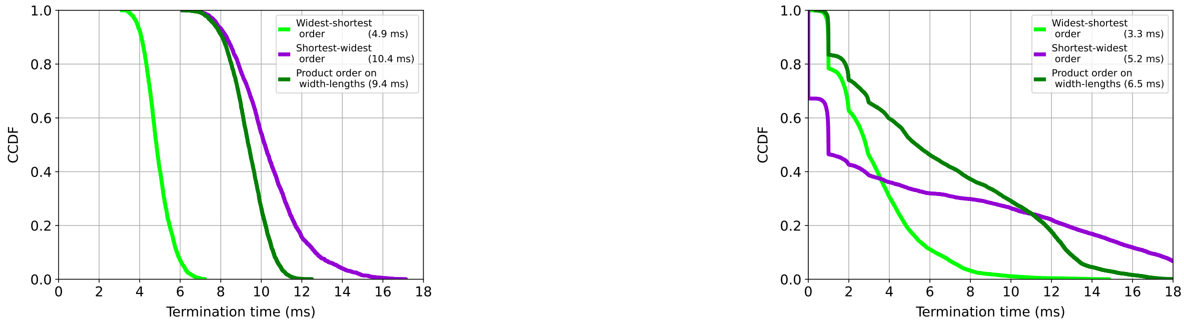
(b) Time to Propagate Unreachability

Figure 13: Number of dominant attributes and time to propagate unreachability in restarting-protocol.

(a) Termination Time Announcement

(b) Termination Time Failure

Figure 14: Termination Times for All Orders



(a) Termination Time Announcement

(b) Termination Time Failure

Figure 15: Termination Times for Width-Length Orders

D AS3967 Plots

(a) Number of Dominant Attributes

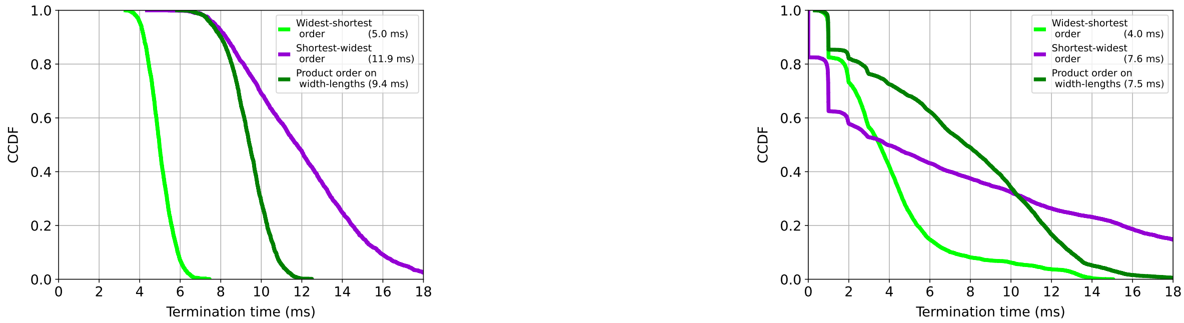
(b) Time to Propagate Unreachability

Figure 16: Number of dominant attributes and time to propagate unreachability in restarting-protocol.

(a) Termination Time Announcement

(b) Termination Time Failure

Figure 17: Termination Times for All Orders



(a) Termination Time Announcement

(b) Termination Time Failure

Figure 18: Termination Times for Width-Length Orders

E AS6461 Plots

(a) Number of Dominant Attributes

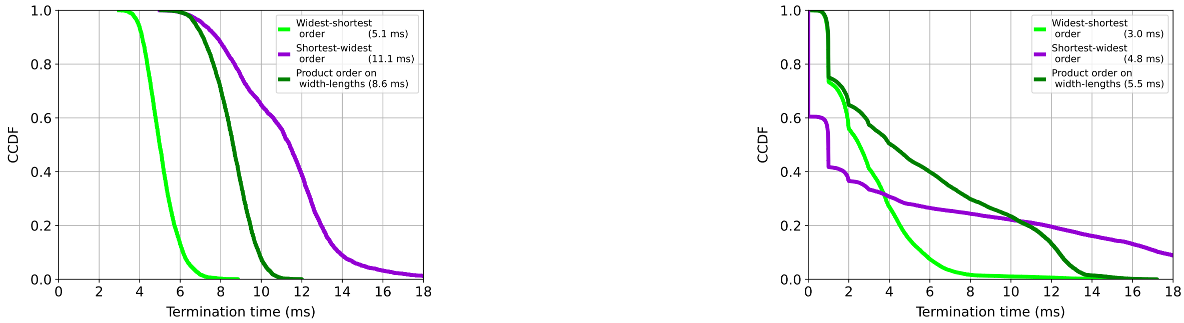
(b) Time to Propagate Unreachability

Figure 19: Number of dominant attributes and time to propagate unreachability in restarting-protocol.

(a) Termination Time Announcement

(b) Termination Time Failure

Figure 20: Termination Times for All Orders



(a) Termination Time Announcement

(b) Termination Time Failure

Figure 21: Termination Times for Width-Length Orders