Experimental Comparison between Geohyperbolic and Hyperbolic Routing in NDN

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***Abstract*—In Named Data Networking (NDN), packets are routed based on their names. However, the Internet has a vast number of content names, making traditional routing schemes infeasible as their overhead will be prohibitively high upon topological changes. Hyperbolic Routing and Geohyperbolic Routing are potential solutions to this scalability problem. We perform an experimental comparison between these routing schemes with various topologies and failures scenarios. Our preliminary results show that both routing schemes perform well in delivering packets under failures, but geohyperbolic routing outperforms hyperbolic routing in packet delay.**

I. Introduction

Named Data Networking (NDN) is an Information-Centric Network (ICN) architecture that supports data retrieval by name. However, an enormous amount of named content can give rise to unmanageable routing overhead. Thus, the routing schemes for NDN network should be highly efficient to support a large name space. Hyperbolic routing (HR) [1] and Geohyperbolic Routing (GH) [2] are geometric routing schemes that rank neighboring nodes based on their distances to destinations in hyperbolic geometry. Since no routing control messages are exchanged even in case of node failures in these routing schemes, they have the potential to address the routing scalability problems in ICN – particularly in NDN. We have deployed HR on the NDN testbed based on promising emulation results [1]. However, we observed long delays and high losses for some content producers on the testbed. This motivated us to perform experimental comparison between HR and the newly proposed geohyperbolic routing scheme. Our study not only focuses on the packet delivery performance, but also investigates the relationship between overlay topologies and routing performance.

II. Background and Related Work

As NDN has a stateful forwarding plane [3], it can adapt to topological changes using smart forwarding strategies, which lessens its reliance on routing's adaptiveness to such changes [4]. More specifically, an NDN forwarding strategy chooses the next hop to forward a packet based on not only routing's ranking of the next hops, but also other factors such as the observed round-trip time of previous interest/data exchanges. As such, the routing protocol can be relatively static as long as the forwarding strategy is effective, making geometric routing a viable choice for NDN.

Hyperbolic Routing (HR) encodes radial and angular coordinates (r, θ) into a two-dimensional hyperbolic plane [5]. The radial coordinate represents the popularity of a node – the smaller the value, the more likely it is to attract a new node. The angular coordinate represents the similarity between two nodes. Lehman et. al. [1] showed that HR with the Adaptive SRTT-based Forwarding (ASF) strategy has a median delay stretch close to 1 and 95th-percentile below 2.

Geohyperbolic routing (GH) encodes a radial and two angular coordinates (latitude and longitude) into a three-dimensional (r, θ, ϕ) hyperbolic space [2]. The radial coordinate represents the centrality of a node, i.e., the probability of packet passing via a node. Voitalov et. al. [2] used the population of a city to compute the centrality score – the larger a city's population, the higher its centrality score. They compared several variants of geohyperbolic routing and found that a regionalized variant has the best performance.

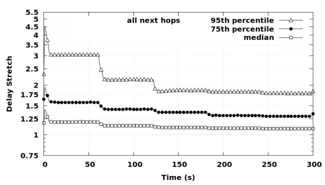
In this paper, we use the ASF forwarding strategy [1] in conjunction with the routing schemes to overcome suboptimal routes and failures. ASF periodically probes backup next hops to find the best routes based on RTT measurements.

III. Experiment Design

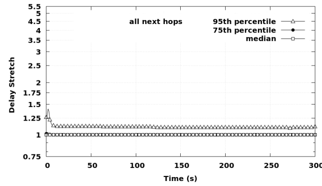
To compare HR and GH, we ran Mini-NDN [6] experiments with the following topologies and failure scenarios.

Topologies We first obtained the topology of the current NDN testbed [7] which is an overlay network connecting 42 nodes around the world with 117 links. We calculate their HR coordinates following the method in [1]. These nodes are then mapped to the corresponding city's information such as population, latitude, and longitude to generate their GH coordinates [2]. We generated two additional topologies, *H-Radii* and *G-Population*, each having 42 nodes, 120 links, and at least three links per-node, following the network growth model proposed by Voitalov et. al. [2]. In *H-Radii*, the nodes are ordered by their hyperbolic radius in ascending order and the first five nodes form a complete mesh as the initial topology. Then we select each remaining node in order, compute its *hyperbolic* distance with every node already in the topology, and connect it to the three nodes with the shortest hyperbolic distance. We use the same network growth model to generate *G-Population* except that we sort the nodes by their population and use *geohyperbolic* distance, instead of hyperbolic distance, for selecting neighbors. Furthermore, we used the geographic distance between the nodes to approximate the link delay [2].

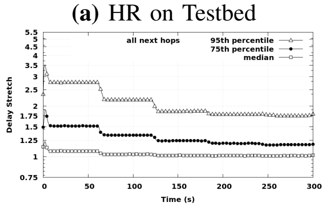
Scenarios We designed three types of failure scenarios: (1) no failure, (2) multiple failures: a different node is brought down



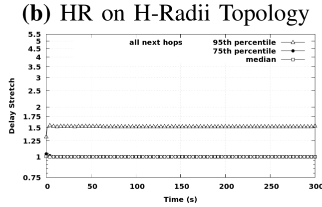
(a) HR on Testbed



(b) HR on H-Radii Topology



(c) GH on Testbed



(d) GH on G-Population Topology

Fig. 1: Overlay Delay Stretch of HR and GH on Various Topologies

Model	Growth Model	UDS 25th	UDS 50th	UDS 75th	UDS 90th	Avg UDS
HR	H-Radii	1.157	1.626	2.843	6.894	2.851
GH	G-Population	1	1.308	1.634	2.307	1.510

TABLE I: Underlay Delay Stretch

and up every 60 seconds, and (3) link loss: each link has a given loss rate. We ran ndnping on all the nodes which ping each other every second for 300 seconds.

We measure three performance metrics: (1) *overlay delay stretch* (ODS) – the ratio between a packet's delay with HR or GH and the delay along the shortest path, both in the overlay network; (2) *underlay delay stretch* (UDS) – the ratio between a packet's delay with HR or GH in the overlay network and the delay along the shortest path in the underlay network, and (3) *success ratio* (SR) – the percentage of ndnpings that have received corresponding replies.

IV. Evaluation Results

A. Overlay Delay Stretches (ODS)

We first compared the overlay delay stretch of HR and GH. Figure 1 shows the following: (a) for both HR and GH on the testbed, the stretches were high initially but significantly decreased over time, which means the ASF strategy is critical in finding the best path in this topology; (b) compared to the testbed topology, HR and GH work better on the H-Radii and G-Population, respectively, as they produce much lower stretches. This is not surprising as the testbed links were configured in an ad hoc manner, while the other topologies were constructed based on the popularity/centrality of nodes.

B. Underlay delay stretch (UDS)

To calculate UDS, we first compute packet delay in overlay network and divide it by the underlay delay between two nodes [2]. The underlay delay is approximated as follows:

$$Underlay\ delay \approx (Geographic\ delay\ + 1165)/45 \quad (1)$$

Table I shows that the UDS of running GH on the G-Population topology is better than that of running HR on the H-Radii topology, which suggests that even though the overlay delay stretches for HR are comparable to those for GH (Figure 1), the actual paths with HR have worse delay than those with GH. This is expected because nodes in GH are regionalized, meaning geographically closer nodes are placed in the same region and packets traveling among those nodes will stay within the region, thus significantly reducing the overall delay. However, HR does not consider network delay and geographic distance in the addressing scheme so it has a higher chance of suffering from suboptimal delays. We found that the 75^{th} percentile delay in HR is nearly 2.5 times of that in GH, and the 95^{th} percentile is almost 7 times of that in GH.

C. Failure Scenarios

For the multiple-failure experiment, the success ratio (SR) for GH on the G-population topology, HR on the H-Radii topology, and HR on the testbed was 0.98, 0.96, and 0.60, respectively. We then introduced 1, 2, and 5% loss rate per link (no node failure). For 1% link loss, SR was 0.95 for GH on G-Population, 0.95 for HR on H-Radii, and 0.89 for HR on the testbed. For 2% link loss, the SR was 0.90, 0.91, and 0.79, and finally, for 5% link loss, it was 0.78, 0.78, and 0.56, respectively. The above experiments show that the GH algorithm along with the G-population topology has the best success in transferring data.

V. Summary and Future Work

Our experiments show that, if we use geohyperbolic routing on the G-Population topology and hyperbolic routing on the H-Radii topology, both routing schemes perform well in delivering packets under failures, but geohyperbolic routing outperforms hyperbolic routing in packet delay. On the other hand, the current testbed topology does not support either routing schemes well. We plan to perform more experiments on the NDN testbed with the new overlay topologies specifically developed for GH and HR for rigorous comparison between the two geometric routing schemes. In addition, we will study their scaling performance on bigger topologies.

VI. Acknowledgements

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