Routing in NDN

Lan Wang

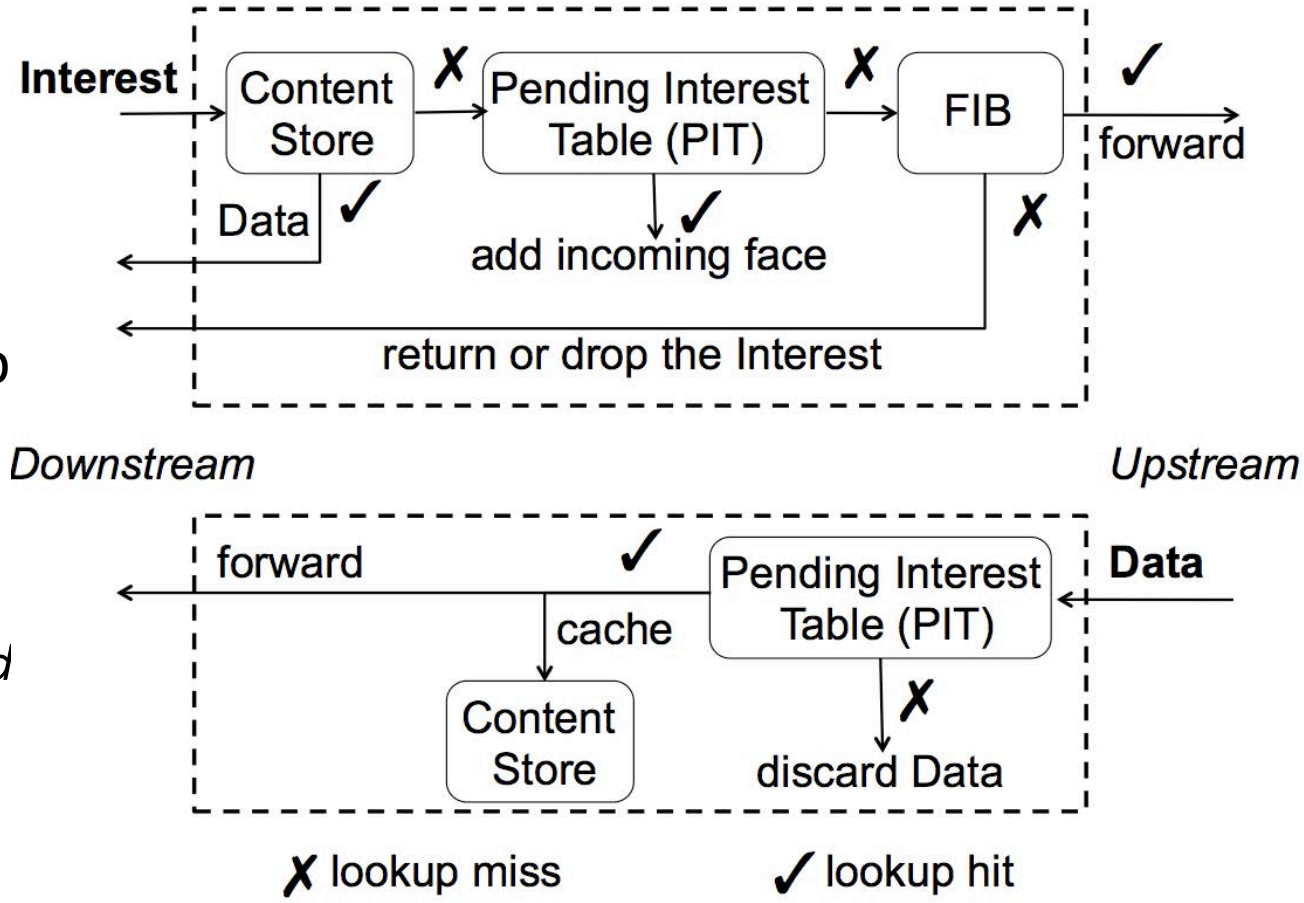
THE UNIVERSITY OF MEMPHIS.

Outline

- What's new compared to IP routing?
- What has been done?
  - NLSR
  - Hyperbolic routing
  - Geohyperbolic routing

NDN has smart forwarding, so routing can be dumb.

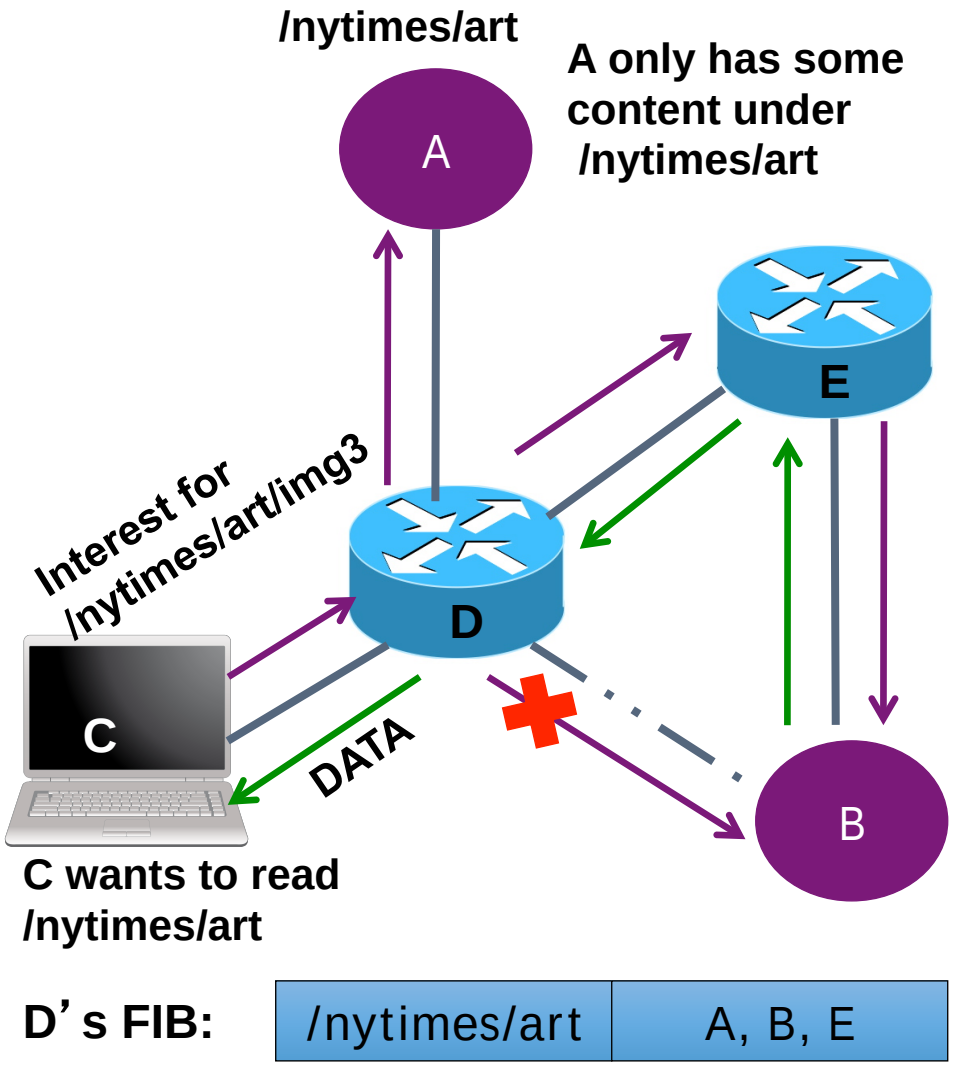
- PIT state -> stop loops and enable measurements
- Forwarding strategy can choose next hop
- Routing
  - should produce *multiple* next hops
  - can be more *relaxed*



New Routing Semantics

Superset of IP semantics

1. *Routing to names (address is a special case)*
2. *Multiple next hops (>= 1)*
3. *Not all the next hops lead to all the data.*
   - *Producer may not have all the data.*
   - *Links may fail.*
   - *Nodes may move.*



D's FIB:

/nytimes/art	A, B, E

New Design Pattern

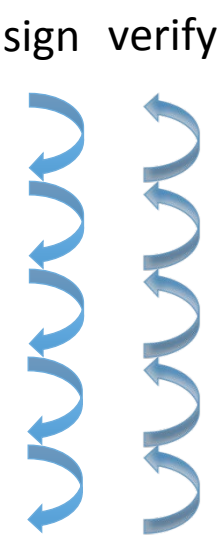
Any routing scheme in IP can be used in NDN, but needs to adopt NDN's design pattern.

- ***Use Interest/Data to retrieve routing information.***
- ***Naming***: names facilitate network management and trust derivation.
- ***Security***: routing data is signed by originator and verified by receivers.
- ***Sync mechanism***: a new notion of transport to ensure multiple parties have the same information.
  - efficient way of set reconciliation

Named-data Link State Routing (NLSR)

- Naming: follow the hierarchy within a network
  - Router: /<network>/<site>/<router>: e.g., /ndn/memphis/rtr1
  - Data: /<network>/NLSR/LSA/<site>/<router>/<process>/<type>/<version>
  - Keys: derived from the associated entity's name
- Routing security and trust model

Entity	Name
Root key	/<network>/key
Site key	/<network>/<site>/key
Operator key	/<network>/<site>/<operator>/key
Router key	/<network>/<site>/<router>/key
NLSR key	/<network>/<site>/<router>/NLSR/key
Data	/<network>/NLSR/LSA/<site>/<router>/<type>/<ver>



NLSR Development Status

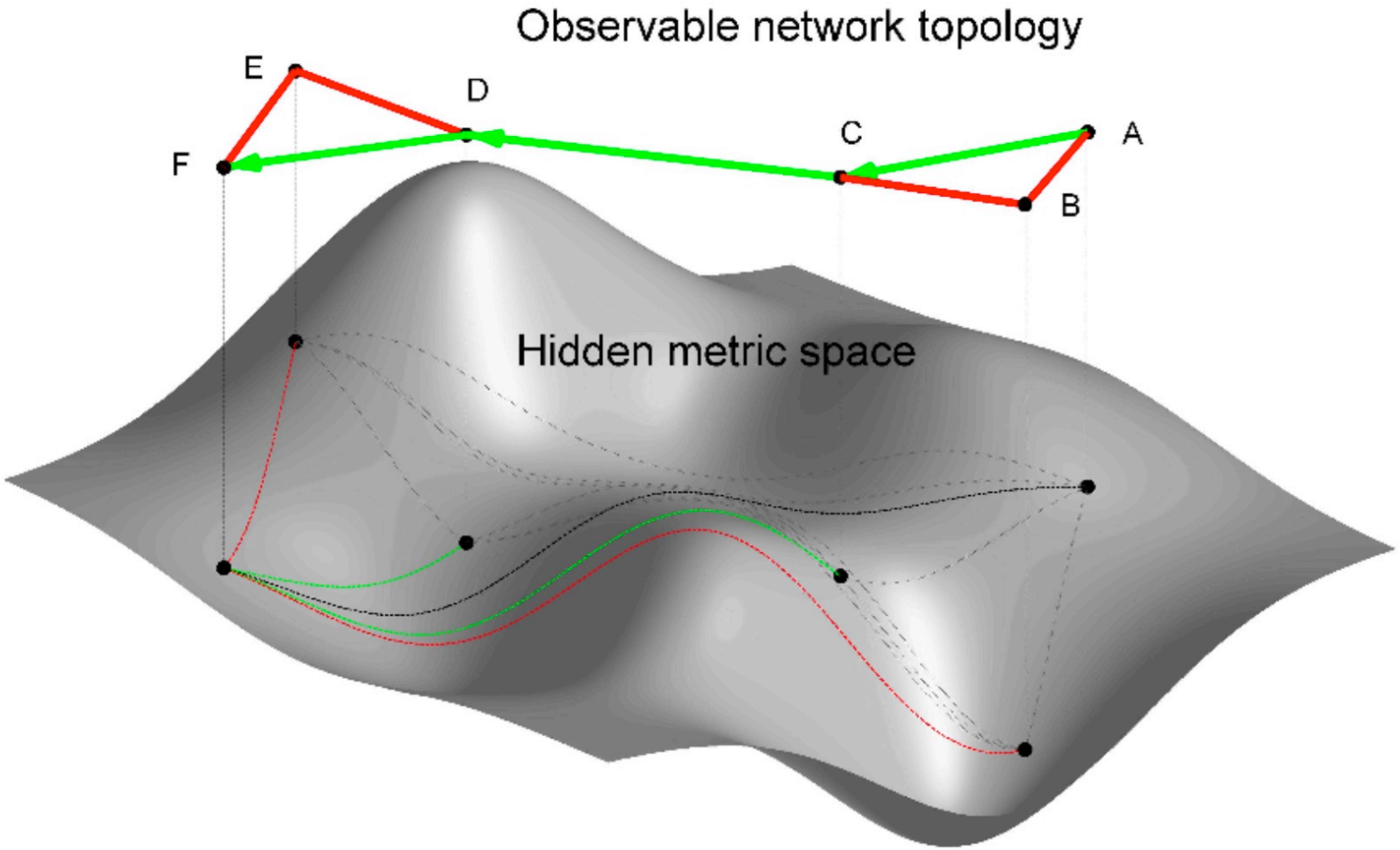
- NLSR 0.1 was released on 8/25/14.
  - Supports both link state and hyperbolic routing
  - Uses ChronoSync to synchronize routing data
  - Uses a hierarchical trust model for routing within a single administrative domain (validation rules are configurable).
- Deployed on NDN testbed from 8/14 to 3/17.
- Code and doc:
  - http://named-data.net/doc/NLSR

Routing Scalability in NDN

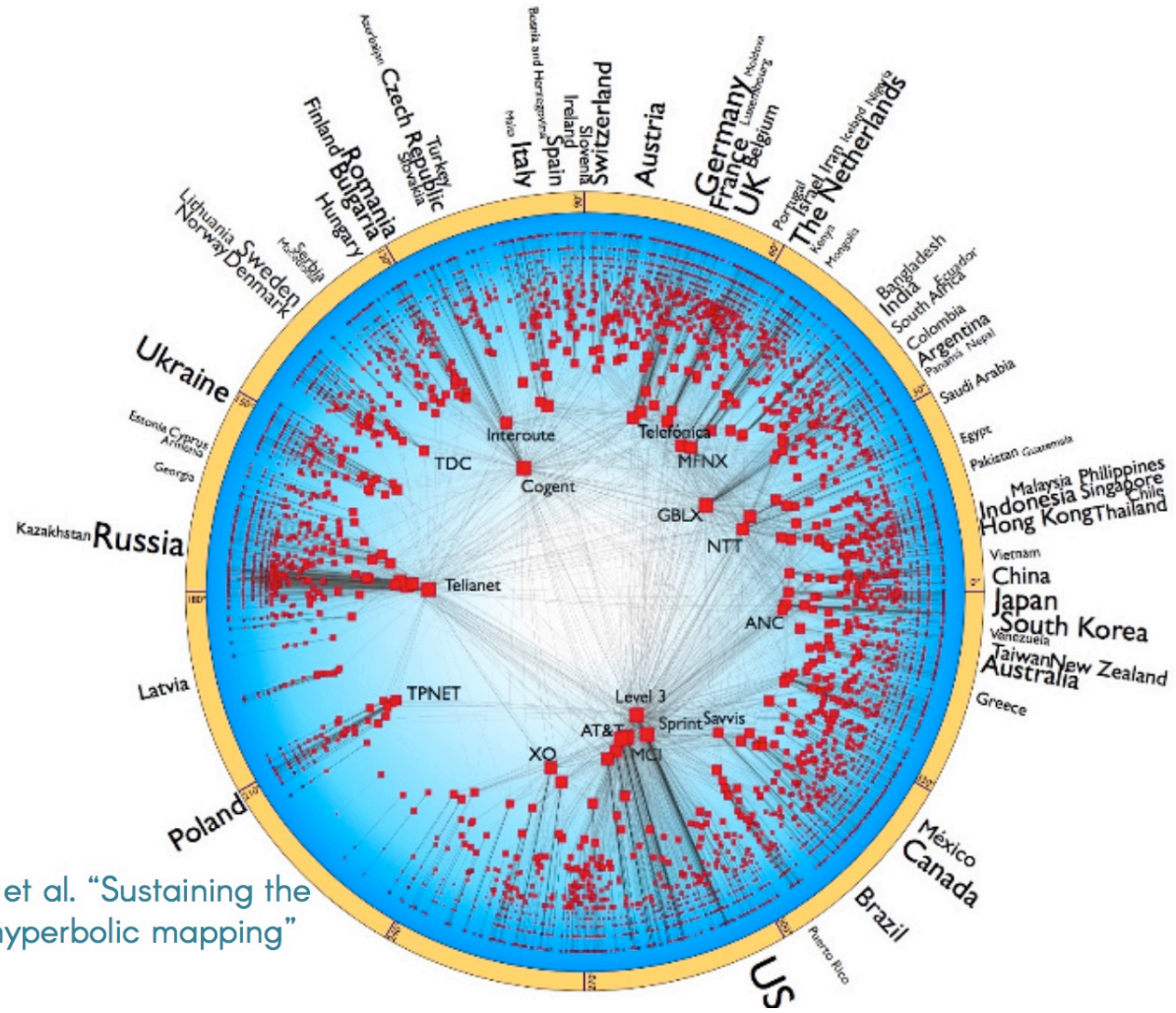
- Already large number of content names in today's Internet

- We want to bound the size of routing state while supporting an unbounded namespace
  - Small FIB size
  - Low number of routing updates
  - Comparable performance to shortest path routing algorithms

Greedy Geometric Routing

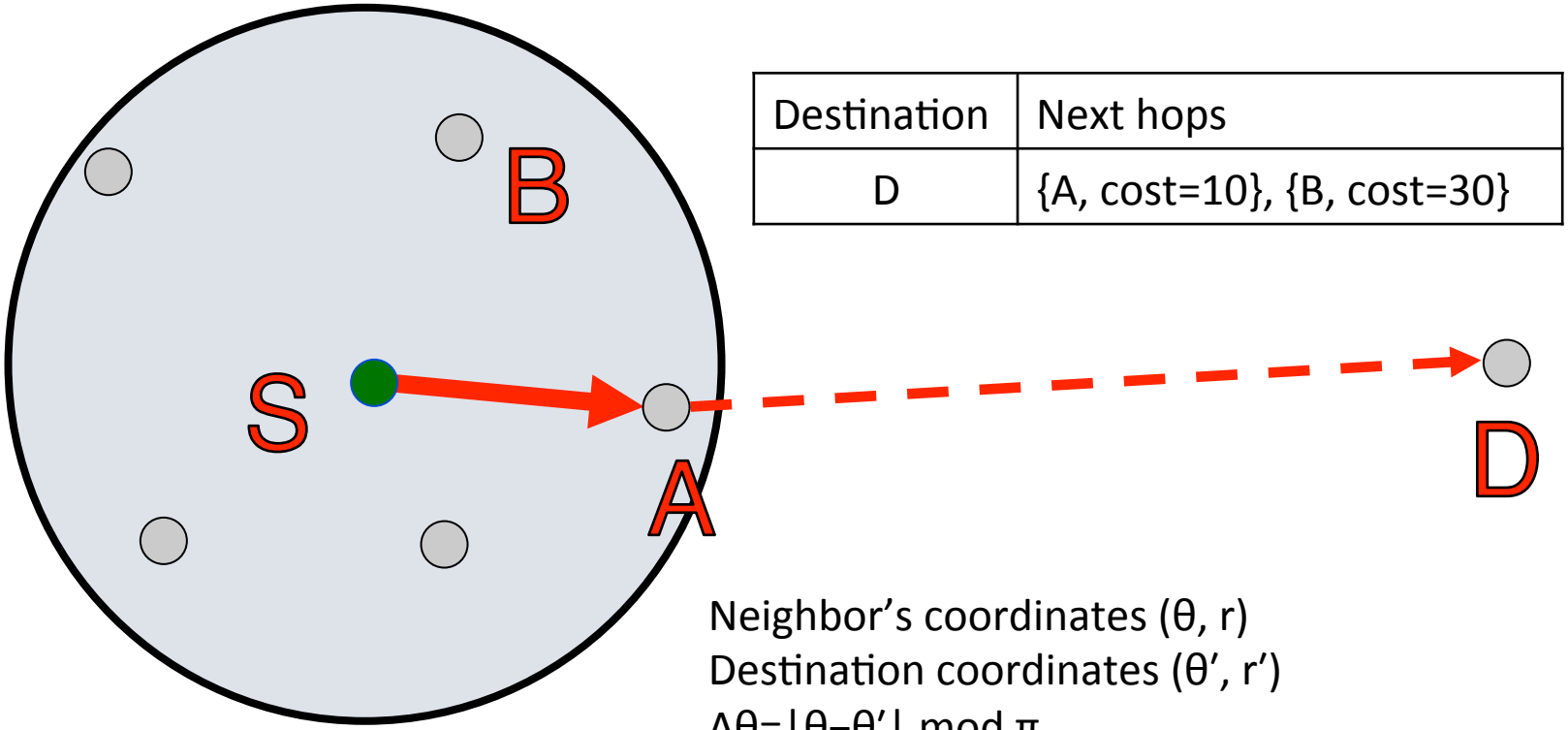


Hyperbolic Embedding



From Boguna et al. "Sustaining the Internet with hyperbolic mapping" (2010)

Greedy Forwarding in HR



Destination	Next hops
D	{A, cost=10}, {B, cost=30}

Neighbor's coordinates (θ, r)
Destination coordinates (θ', r')
$\Delta\theta = |\theta - \theta'| \bmod \pi$
distance = acosh(cosh r cosh r' − sinh r sinh r' cos Δθ)

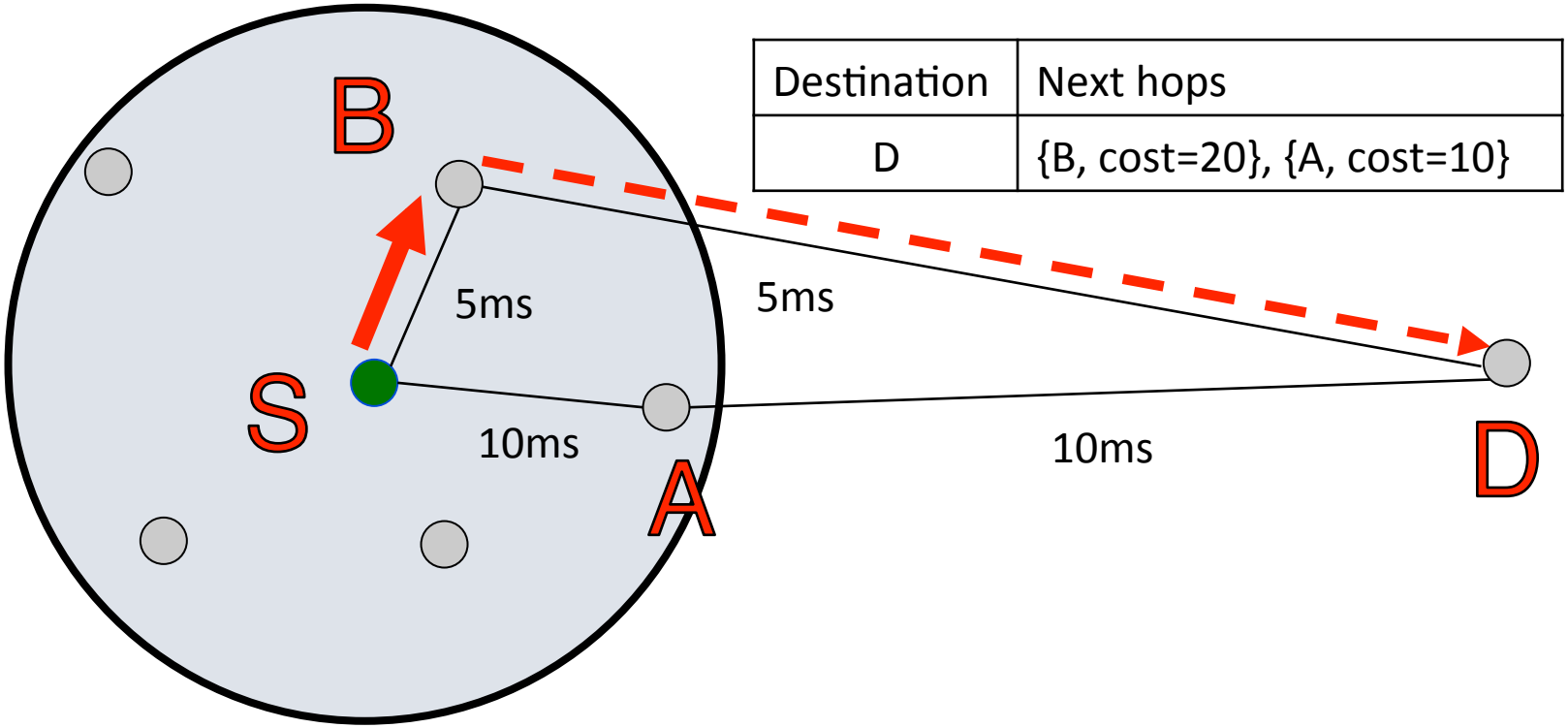
To forward a packet:

- Find the neighbor closest to the destination
- Forward the packet to that neighbor

Why Hyperbolic Routing in NDN?

- In the ideal case, no FIB is needed
  - Each node only needs to know their neighbors' coordinates
- Low communication cost
  - Few routing updates, as coordinates rarely change
- Have been shown to have low stretch in a power-law topology.
- NDN's smart forwarding can adapt to short-term topological changes.

Sub-Optimal Paths in HR



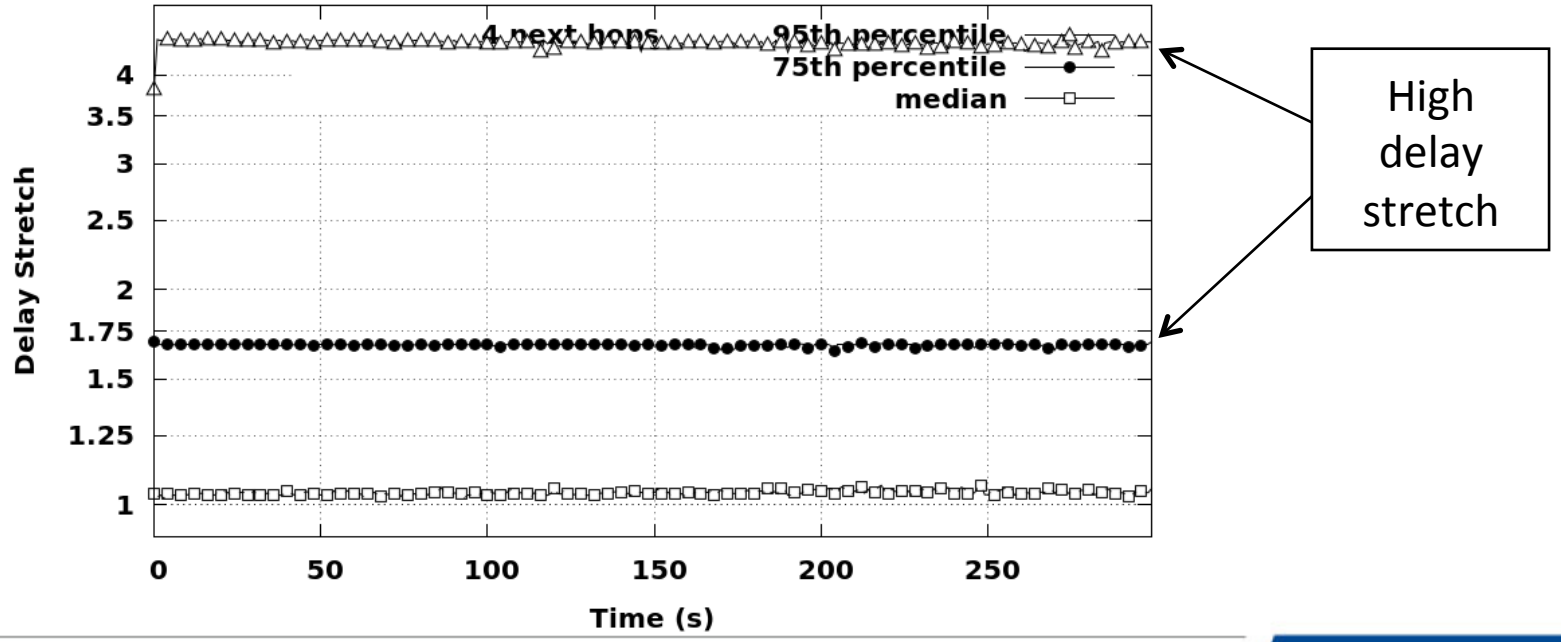
Destination	Next hops
D	{B, cost=20}, {A, cost=10}

To forward a packet:

- Find the neighbor closest to the destination
- Forward the packet to that neighbor

HR with Best-Route Strategy

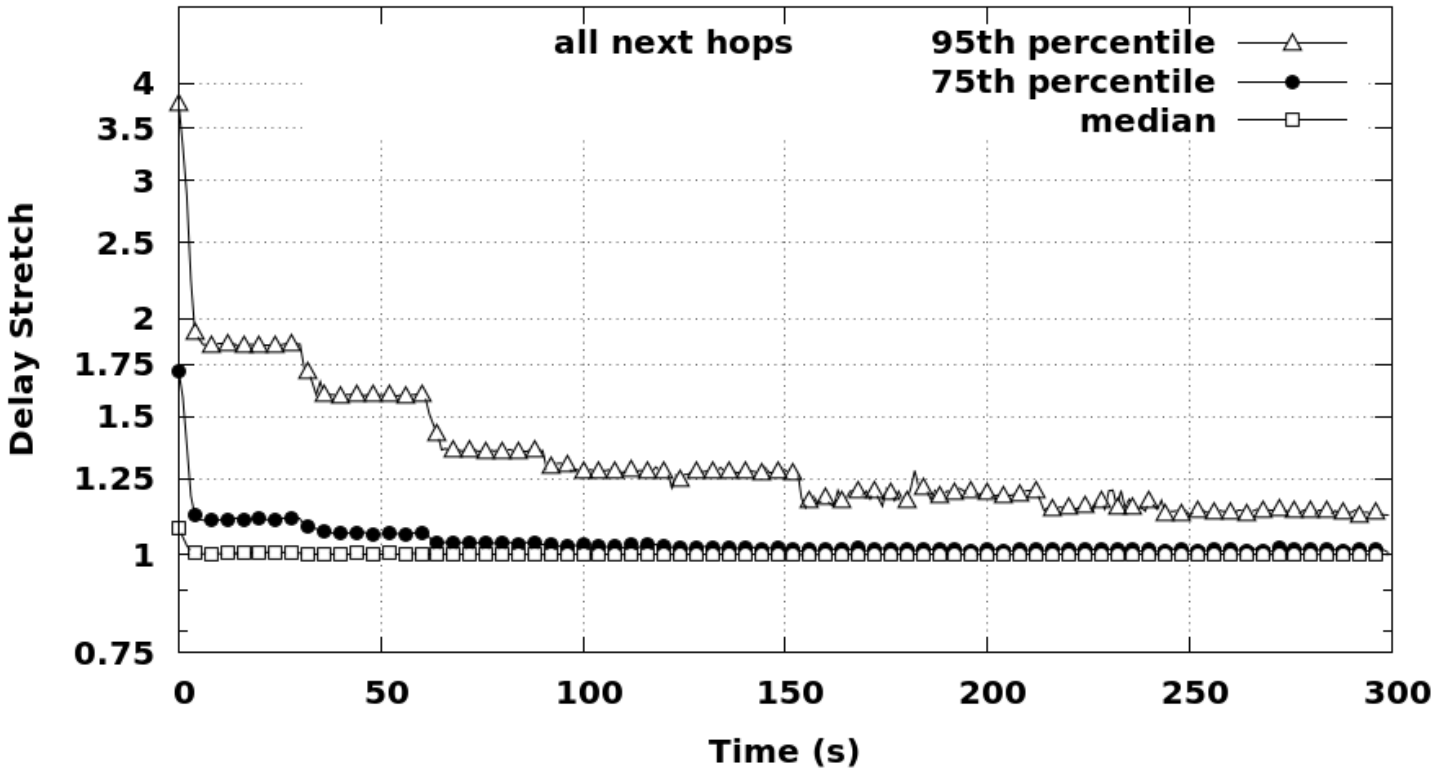
- Best Route Strategy simply uses the next hop ranked highest by the routing protocol
- Delay stretch – Packet delay ratio of RTT in HR over RTT in shortest path routing



Adaptive SRTT-Based Forwarding

- Consider Round Trip Time (RTT) when choosing next hop in HR
  - Use Smoothed RTT (SRTT) to allow variation
- Best SRTT-Based Forwarding
  - Choose next hop for each FIB entry based on SRTT
- Probabilistic SRTT-Based Probing
  - Periodically probe unused next hops to learn RTT
  - Next hops that performed well previously have higher probability

HR with ASF Strategy



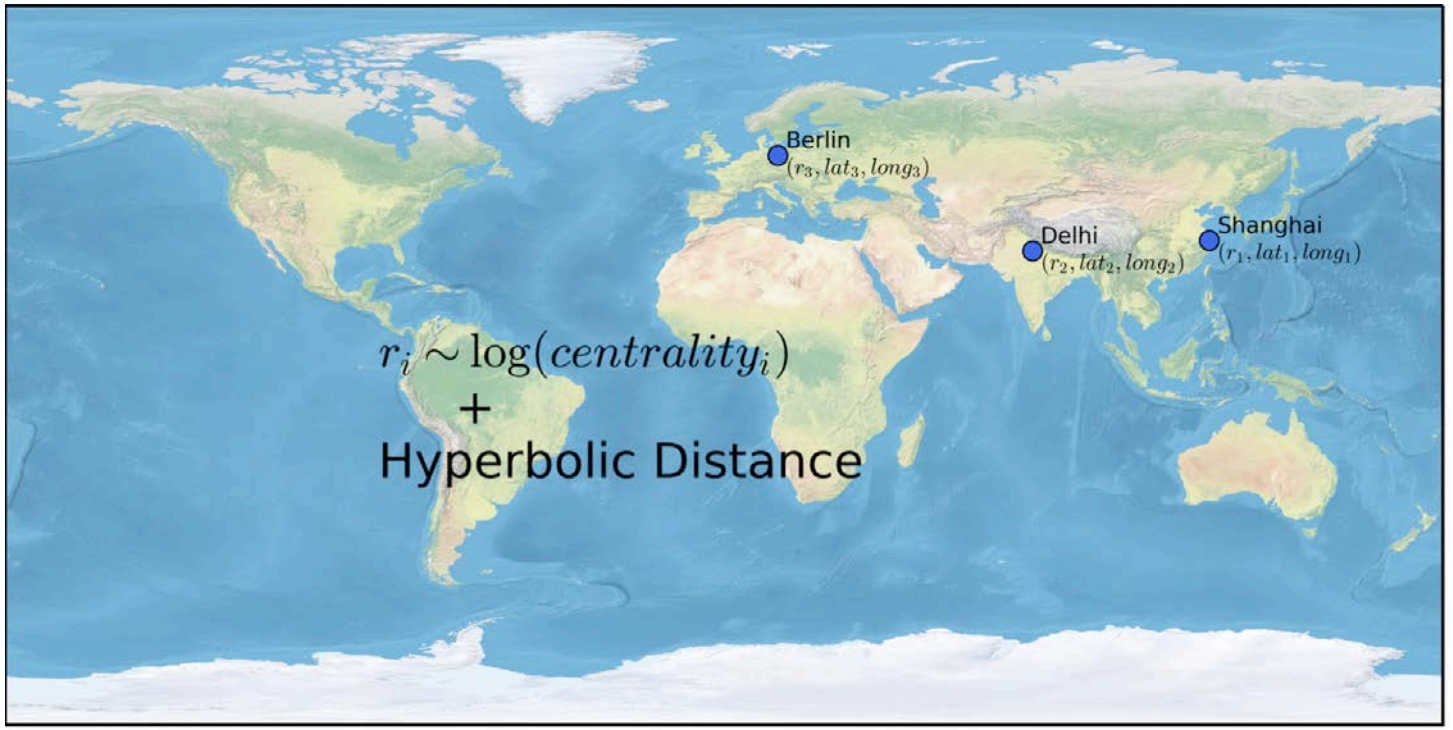
Deployed on the NDN testbed since March 2017.

HR is not good enough.

- HR has less than ideal stretch for testbed topology
- Geographic routing (GEO) works well for small topologies, but degrades quickly for larger topologies.
- Geohyperbolic routing: hybrid of HR and GEO

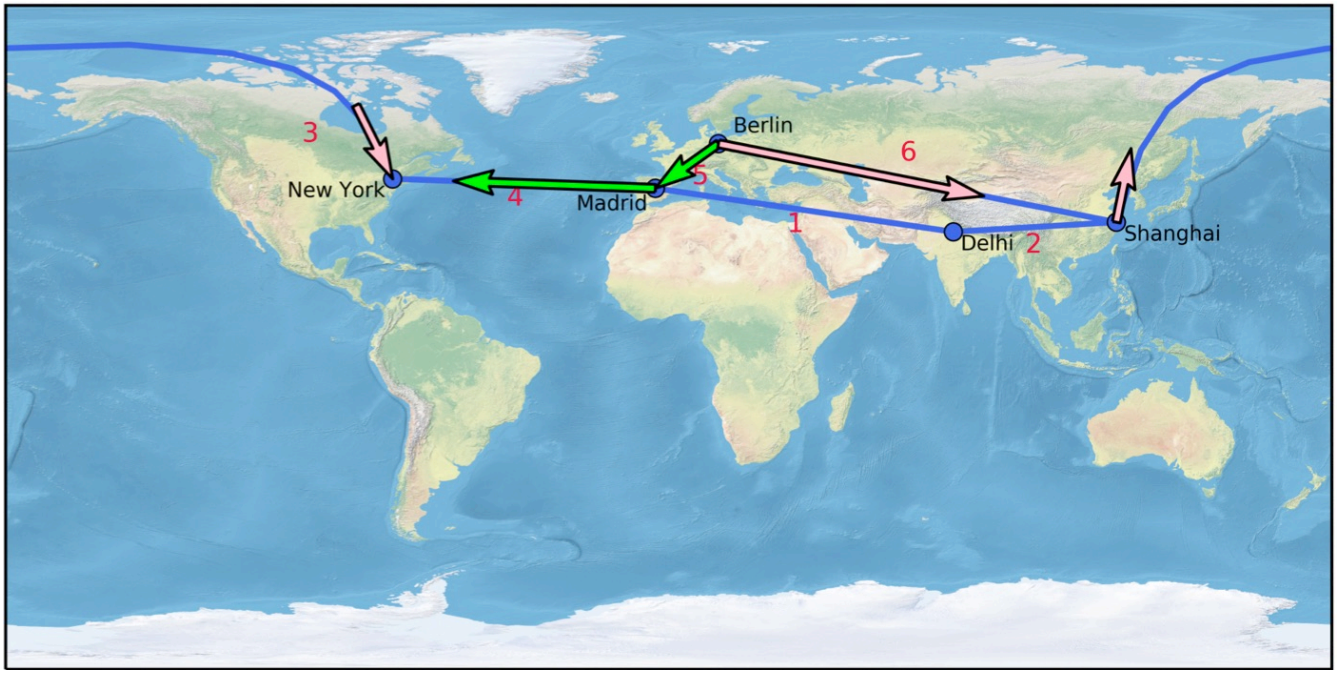
Geohyperbolic (GH) Routing and Addressing

- 3-dimensional coordinates
  - Use latitude and longitude as angular coordinates
  - Add a radial coordinate to a node's address that captures how "central" a node is in the network
- Use geohyperbolic distance to establish network links.



GH is still not good enough.

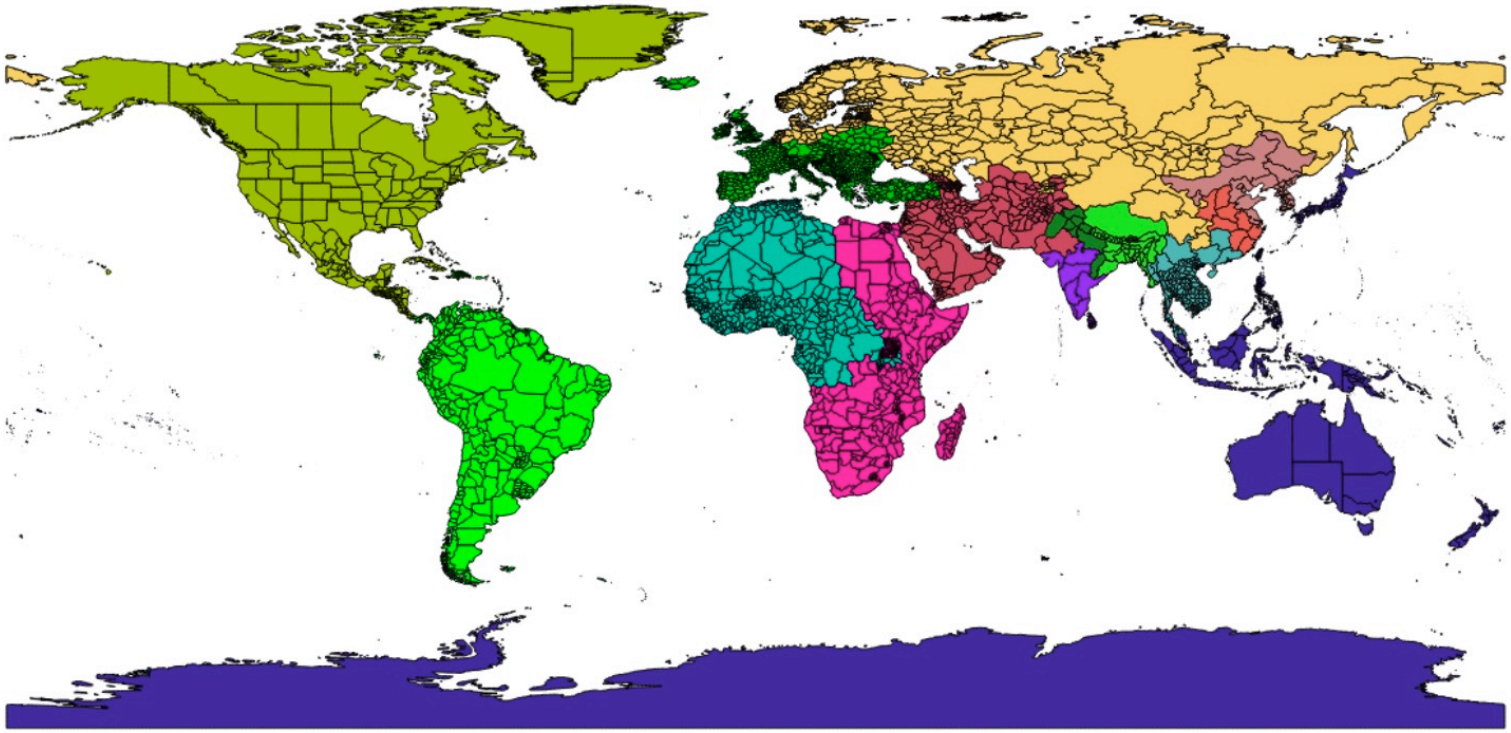
- Success ratio of GH is almost 1 for any network size and under severe connectivity failures.
- However, suboptimal delay-wise performance is observed.



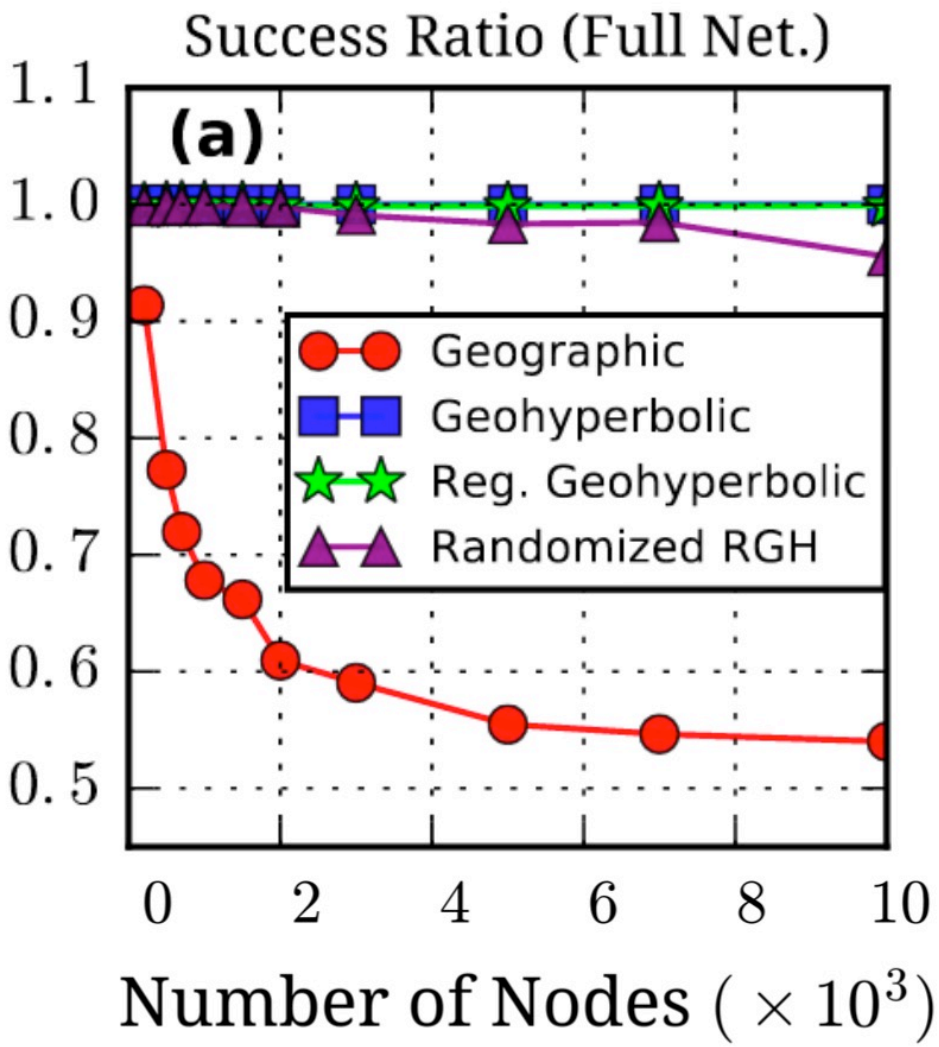
Bad delay performance example: packet forwarding from Berlin to New York via "super central" node in Shanghai.

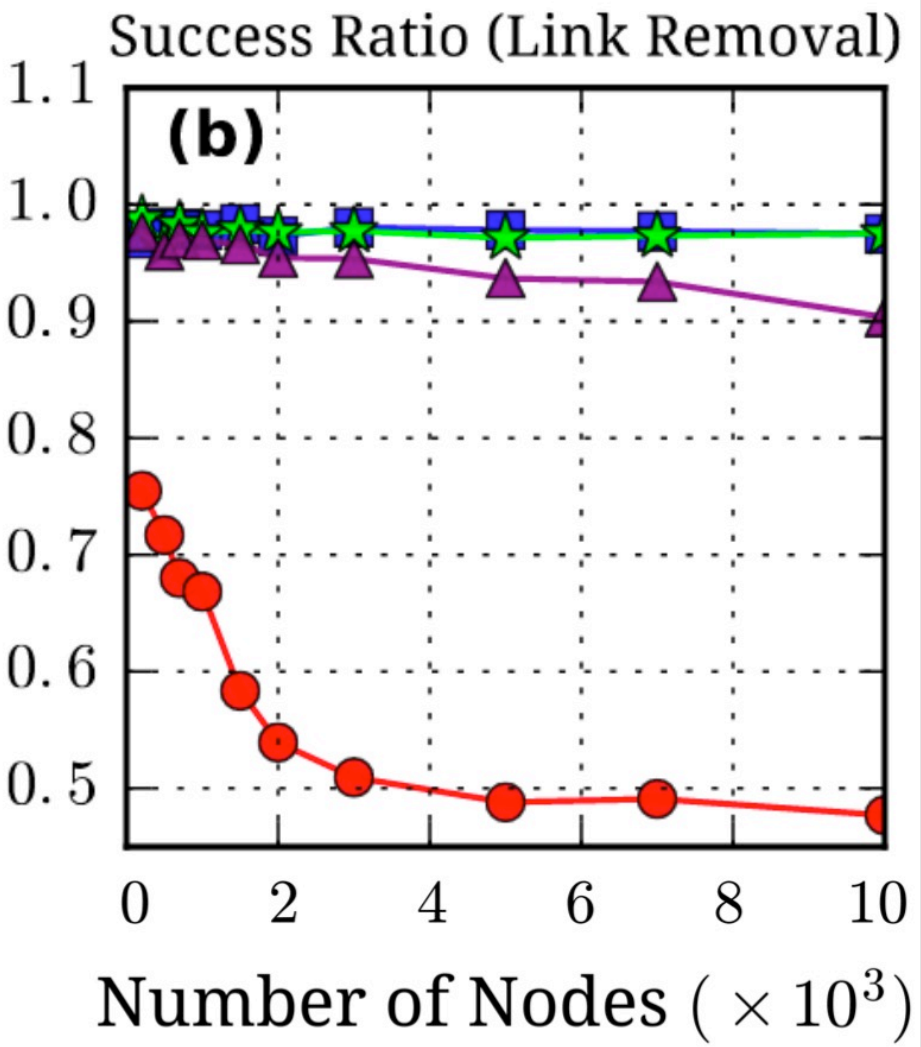
Regionalized Geohyperbolic Routing (RGH)

- Small tweak of GH: place multiple “local hubs” within large geographic regions to “attract” packets from peripheral local nodes.

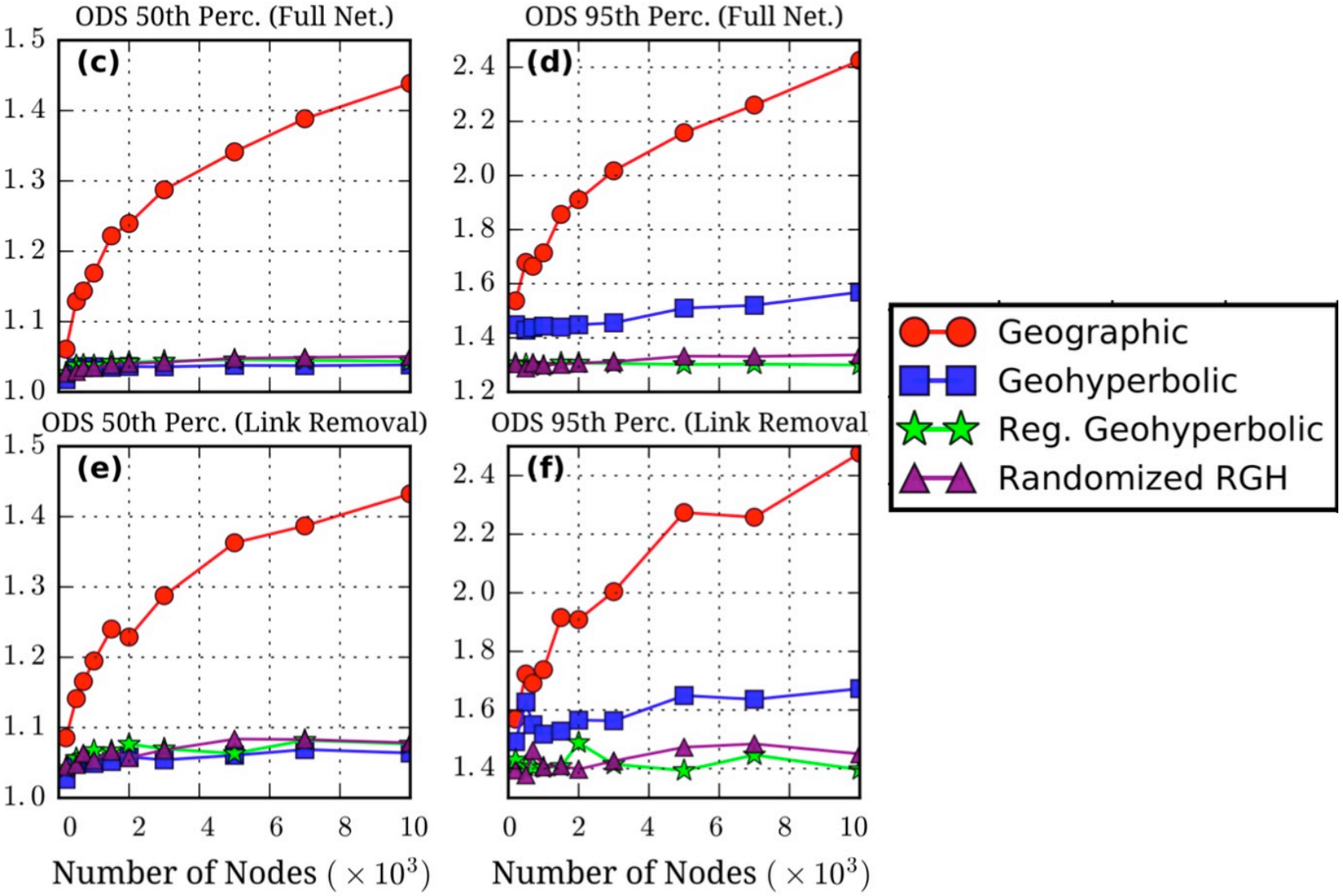


Validation – Success Ratio





Validation – Path Stretch



References

- NDN Routing
  - NLSR: intra-domain routing (ACM ICN 2013 and NDN TR-0037)
  - Hyperbolic Routing: inter-domain routing (IEEE IWQoS 2016 and NDN TR-0042)
  - Geohyperbolic Routing: combining geolocation and hyperbolic information in routing (SIGCOMM CCR July 2017)
- Forwarding strategy
  - Adaptive SRTT-based Forwarding (ASF): supporting hyperbolic routing (NDN TR-0042)
- Mini-NDN: lightweight NDN emulator
  - github.com/named-data/mini-ndn