The $R^5N$ Distributed Hash Table

I-D: https://datatracker.ietf.org/doc/draft-schanzen-r5n/

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$R^5N$: Randomized-recursive routing for restricted-route networks

$R^5N$ is a DHT with the following design goals:

- **Open participation peer-to-peer routing.**
- Works in **restricted-route environments.**
- Supports **route path recording.**
- In-band **request (and response) validation.**
- Allows for **result filtering.**
• Access control requires authentication (and trust) and leads to centralization.

• RELOAD (RFC 6940): “RELOAD’s security model is based on each node having one or more public key certificates. In general, these certificates will be assigned by a central server, which also assigns Node-IDs, although self-signed certificates can be used in closed networks.”

• (Popular) DHTs today require classic Kademlia-style ad-hoc permissionless participation (e.g. IPFS).
Support for restricted-route environments

From “$R^5N$ : Randomized Recursive Routing for Restricted-Route Networks” by Evans et al.:

- **Restricted-route topology** refers to a connected underlay topology which does not support direct connections between some of the nodes (e.g. wireless mesh networks, NAT or firewalls).

- Common DHT routing algorithms (e.g. Kademlia) show diminished performance or even arrant failure when operating over a restricted-route underlay.

- A common solution is to prevent participation in the DHT to peers that are not encumbered by such restrictions.

- However, on the modern Internet the proportion of hosts with unrestricted communication capabilities is increasingly limited (e.g. CG NAT).
Implications of restricted-route environments

Problem:

- Some peers, which from the distance metric (XOR) may be close, may not be reachable (e.g. firewall).
- This leads to multiple (local) minima with respect to where data may be stored/can be retrieved.

Solution:

- Random walk before greedy decent to “escape” local minima.
- Assuming we have a small world topology, the random walk will cause us to land at a random peer in the network from where the greedy descent will find a random local minimum.
- Replication at multiple local minima combined with the birthday paradox provides reasonable availability.
Kademlia sunshine scenario (k=2)
Restricted route scenario
Local minima for "00*"
Local minimum for "110*"
Local minimum for "01*"

0000
0111
0001
1101
1100
0101
1001
1111

Local minimum for "00*"
Local minimum for "110*"
Local minimum for "01*"
PUT example — XOR

"PUT value under key: 0011"
PUT example — $R^5 N$ walk length = 1

Local minimum for "00*
Local minimum for "110*
Local minimum for "110*
Local minimum for "00*

"PUT value under key: 0011"
PUT example — $R^5N$ walk length = 1

"PUT value under key: 0011"
Special case: At least one descent-hop; no loops
Consider the following problem:

- Two peers want to use a communication channel.
- They cannot establish a direct link due to underlay restrictions.
- Assumption: Other peers are happy to provide relay services.
- Payload transmission via PUT and GET would be inefficient.

⇒ Discover a route through the overlay:

- Peer advertises existence of service via DHT PUT with route recording.
- Client discovers service provider via DHT GET with valid route of GET/PUT message path.
DHT values can be corrupted or invalid. $R^5N$ addresses this with pluggable, extensible block types:

- Given a key and a block type, it is possible to verify the integrity of the value.
- The verification should be possible for all hops on path, improving caching performance.
- A verification could include cryptographic signatures over the data or more sophisticated approaches (see GNS, RFC-to-be 9498)
Result filtering via mutated Bloom filter

Queries could have a unique or multiple results depending on the application.

- We provide capability to abort query forwarding early if unique answer has been found.
- We probabilistically filter results already known to the client to reduce traffic.
- To address false positives when using Bloom filters we use mutation.
Repeatedly visiting the same peer in GET or PUT operations is inefficient.

- Visiting new peers increases the chance of finding previously undiscovered results.
- Visiting new peers drives us away from the starting point and towards more distant local minima.

$R^5N$ uses a Bloom filter in GET/PUT messages to prevent routing loops.
For DISPATCH

- I-D is WIP at https://datatracker.ietf.org/doc/draft-schanzen-r5n/
- We have approached WGs since initial upload: dinrg, rtgwg, ...
- Which (other) WGs may be interested?
Funded by

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