Network Measurement Framework and Path Tracing Utility for NDN

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Network Measurement

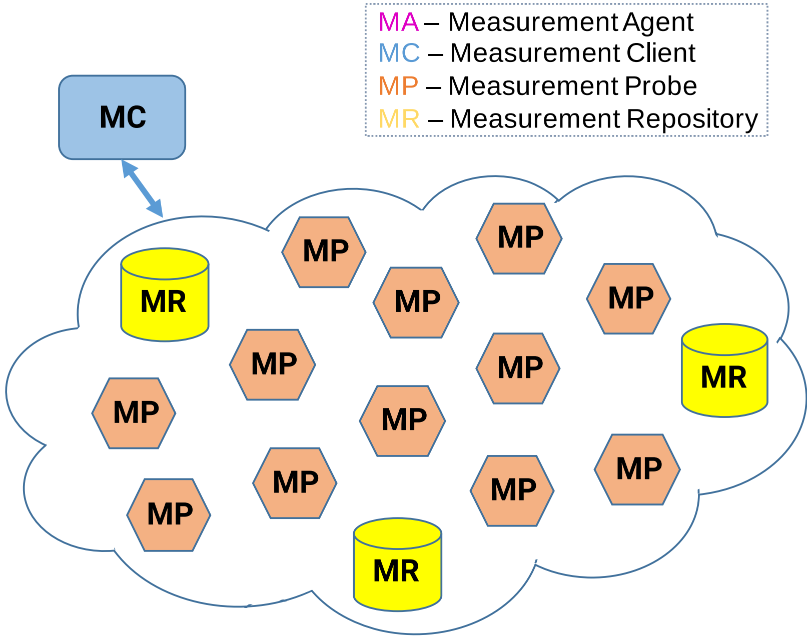
- Network measurement is fundamental to network operation, application performance, and policy (not just research)
- Stakeholder communities involved:
  - Network user community
    - What the network is doing to my packets
      measure QoS/QoE/SLA
    - Academic community: networking research
  - Network operators
    - Anomaly detection/capacity planning
    - Monitor network health/network forensics
  - Network policy makers
    - Define baseline for policies/pricing
    - Measure adoption of technologies

Goal

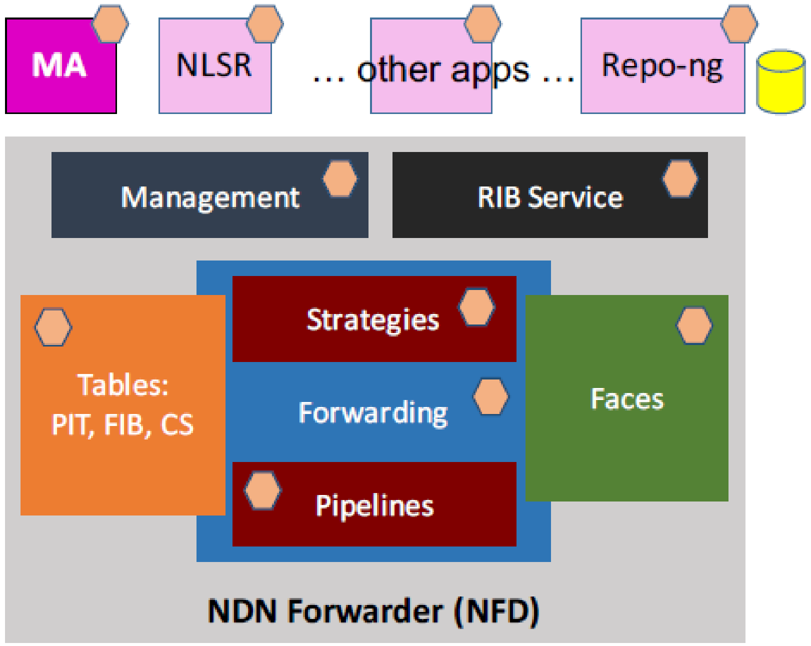
- Empower NDN with a built-in measurement framework that
  - can support multiple use cases,
  - can be used by different applications that need to produce and/or consume network measurements

- As new applications are developed, they
  - can be instrumented with measurement probes, and
  - make use of the framework to meet their measurement needs

Design



MA – Measurement Agent
MC – Measurement Client
MP – Measurement Probe
MR – Measurement Repository



- Client-Agent interaction:
  - 4-way handshake
  - Similar to RICE approach
    - Measurement request
    - Reply containing token
    - Interest with token
    - Data with results

New Effort

- DNMP: Distributed Network Measurement Protocol
  - Pollere’s project funded under a NIST SBIR Phase1, started August 1.

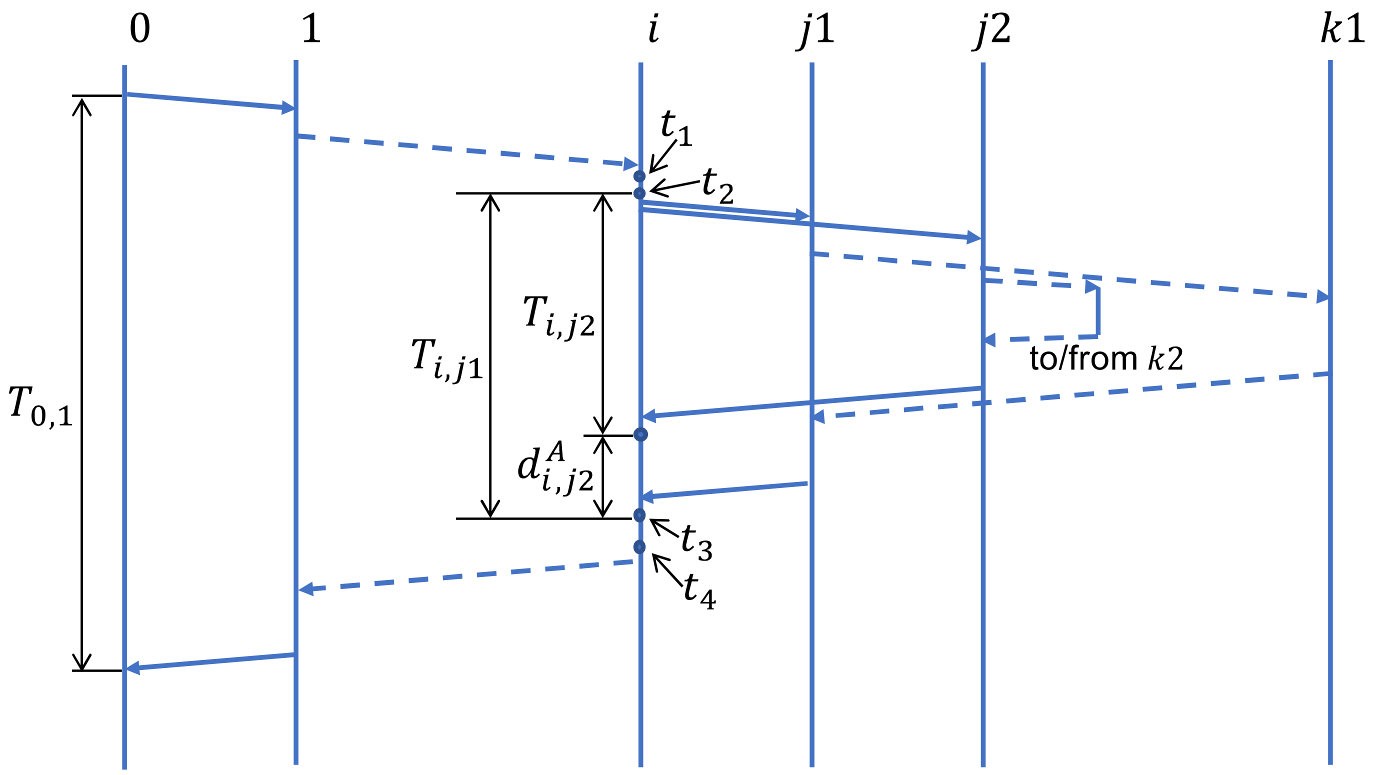
- Uses a brokerless publish-subscribe communications model for both the measurement requests and the resulting measurement data
  - with goal to automate process of adding measurement probes using trust schema templates

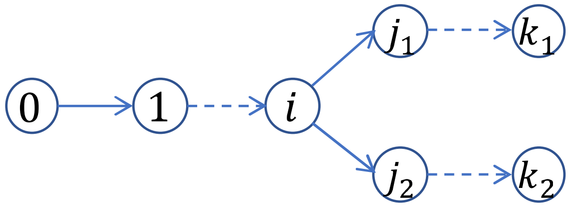
	Purpose	Duration	Funding level
Phase I	Feasibility	6 months	Up to $100K
Phase II	R&D with commercialization plan	2 years	Up to $300K

Path Tracing

- Think of path tracing as just one of the probes within the NDN Measurement Framework
- Challenges for tracing in ICN vs. in IP
  - In IP: one next-hop, one path
  - In ICN, due to Caching/Multiple paths/Forwarding strategy: path(s) followed by one Interest can change over time even if routing (i.e. FIB entry) doesn't change
- Send a "trace" Interest to discover how a "regular" Interest would be routed
  - Returns list of traversed nodes
  - Associated RTTs
  - Potentially other information as well
- Parameters in trace request include:
  - Exploring multiple paths
  - Discover all available paths while bypassing strategy
  - Ignore cached content to discover producers

NDN-Trace Design





t_1 : time Interest arrives at trace daemon from NFD

t_2 : time Interest (for upstream) is sent to NFD

$d_i^I = t_2 - t_1$

t_3 : time Data arrives at trace daemon from NFD

t_4 : time Data (for downstream) is sent to NFD

$d_i^D = t_4 - t_3$

Other Traceroute Proposals

- **CCNinfo** / Contrace (https://tools.ietf.org/html/draft-asaeda-icnrg-ccninfo-01)
    - For tracing multiple paths:
        - requires PIT entries (created by trace requests) to be kept alive for some timeout period
        - represents a significant departure from the “flow balance” principle
    - Does not provide RTT measurements between the client node and intermediate nodes on the path
        - only provides RTT between client and the node where the content is found (same as ping)
        - also provides one-way delay, but requires synchronized clocks
    - Trace built in the request packet as it travels upstream

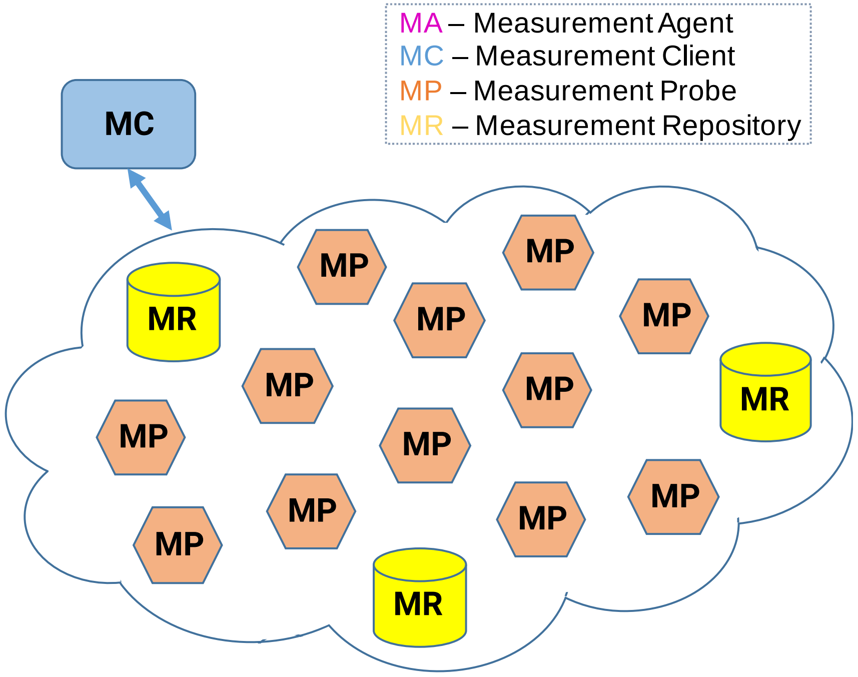
- **ICN Traceroute** (https://tools.ietf.org/html/draft-mastorakis-icnrg-icntraceroute-03)
    - Resembles the mechanism used by IP traceroute tool
    - Iteratively discovers the path by issuing Interests with a progressively increasing HopLimit field
    - Uses new PathSteering header:
        - constructed hop-by-hop while the reply travels back to the client
        - included in subsequent trace requests that must be forwarded along the same path

NMF: NDN Network Measurement Framework

NDN-Trace is just one of the many “probes” of the **NDN Measurement Framework.**

Poster at ACM ICN’17

- https://conferences.sigcomm.org/acm-icn/2017/proceedings/icn17-1005.pdf



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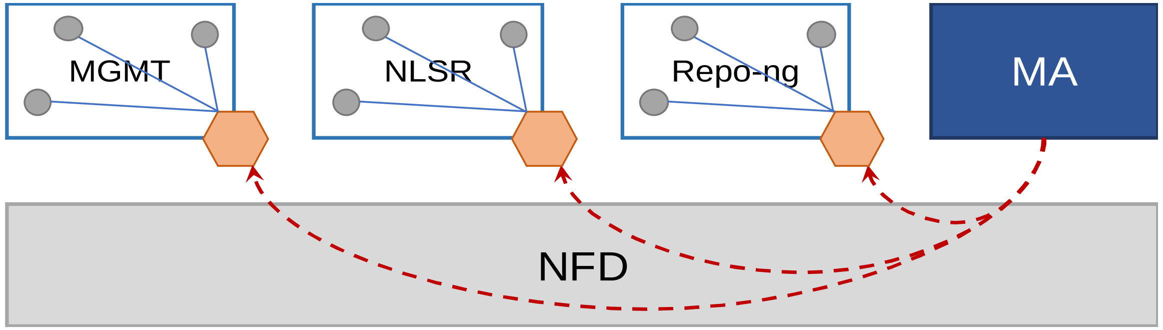


NMF: Status

Completed implementation of first version, including:

- Node agent with a few measurement probes
  - https://github.com/usnistgov/nmf-agent
- C++ client library and interactive command-line tool
  - https://github.com/usnistgov/nmf-client

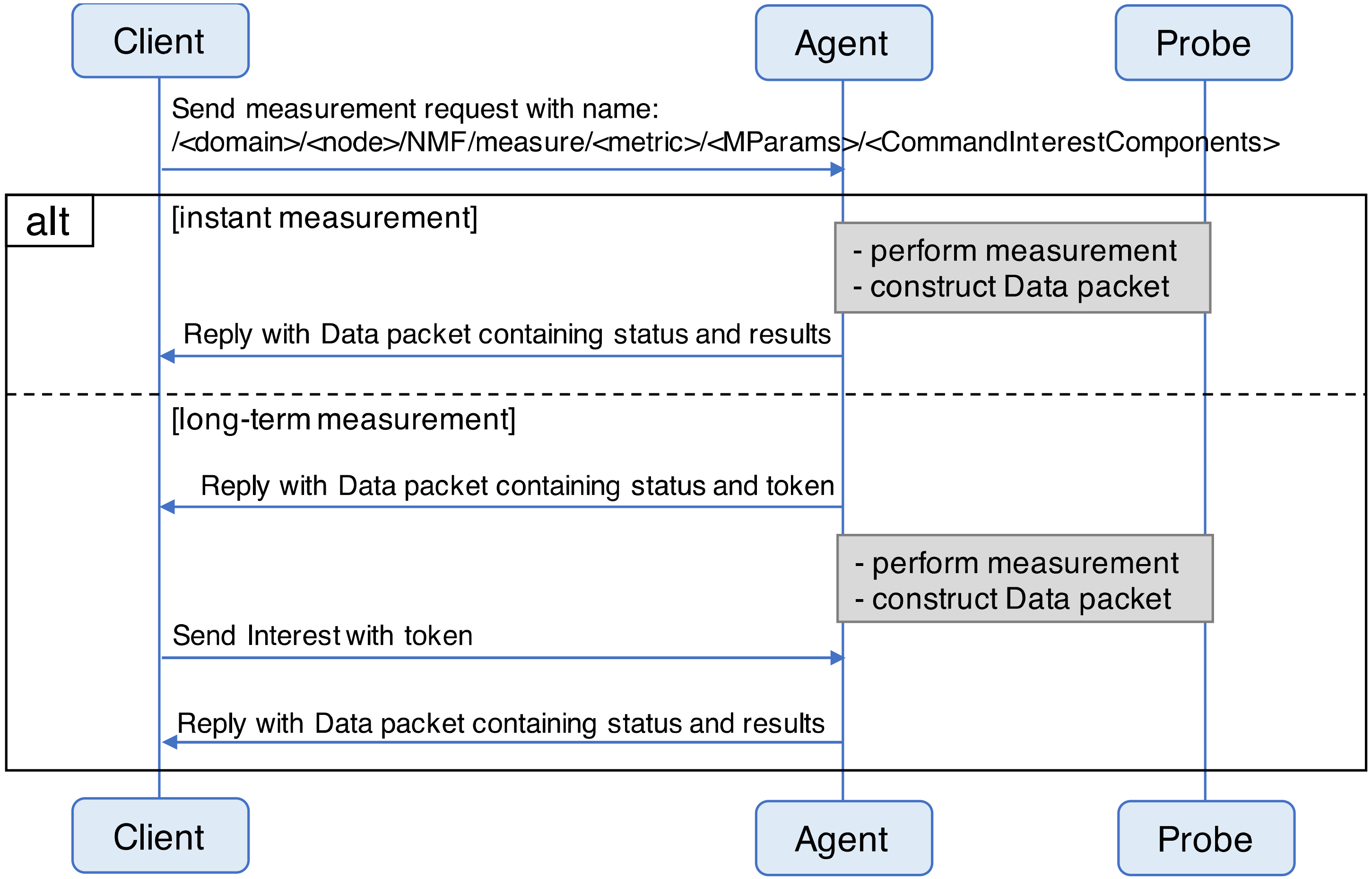
Design of new features ongoing

- "Long-term" storage of measurements data (repo?)
- Access control (NAC?)
- Capability discovery/negotiation (pub-sub?)

Two main use cases

- Monitoring of operator networks, POV of the operator
- Measure/probe the network from the edge (RIPE Atlas, CAIDA Ark)

NMF: Basic Interaction


Client
Agent
Probe
Send measurement request with name:
/<domain>/<node>/NMF/measure/<metric>/<MParams>/<CommandInterestComponents>
alt
[instant measurement]
- perform measurement
- construct Data packet
Reply with Data packet containing status and results
[long-term measurement]
Reply with Data packet containing status and token
- perform measurement
- construct Data packet
Send Interest with token
Reply with Data packet containing status and results
Client
Agent
Probe

NMF: Eventual Goals

Extensibility

- Anyone can add a custom probe
- We will define an internal API for probes and provide a small library to help writing new probes
- App developers can integrate the framework in their app

Integration with access control protocols

- Measurement data can be sensitive
- Different clients have different access privileges

Long-term storage and querying of historical data

NMF: Protocol Details

Verbs

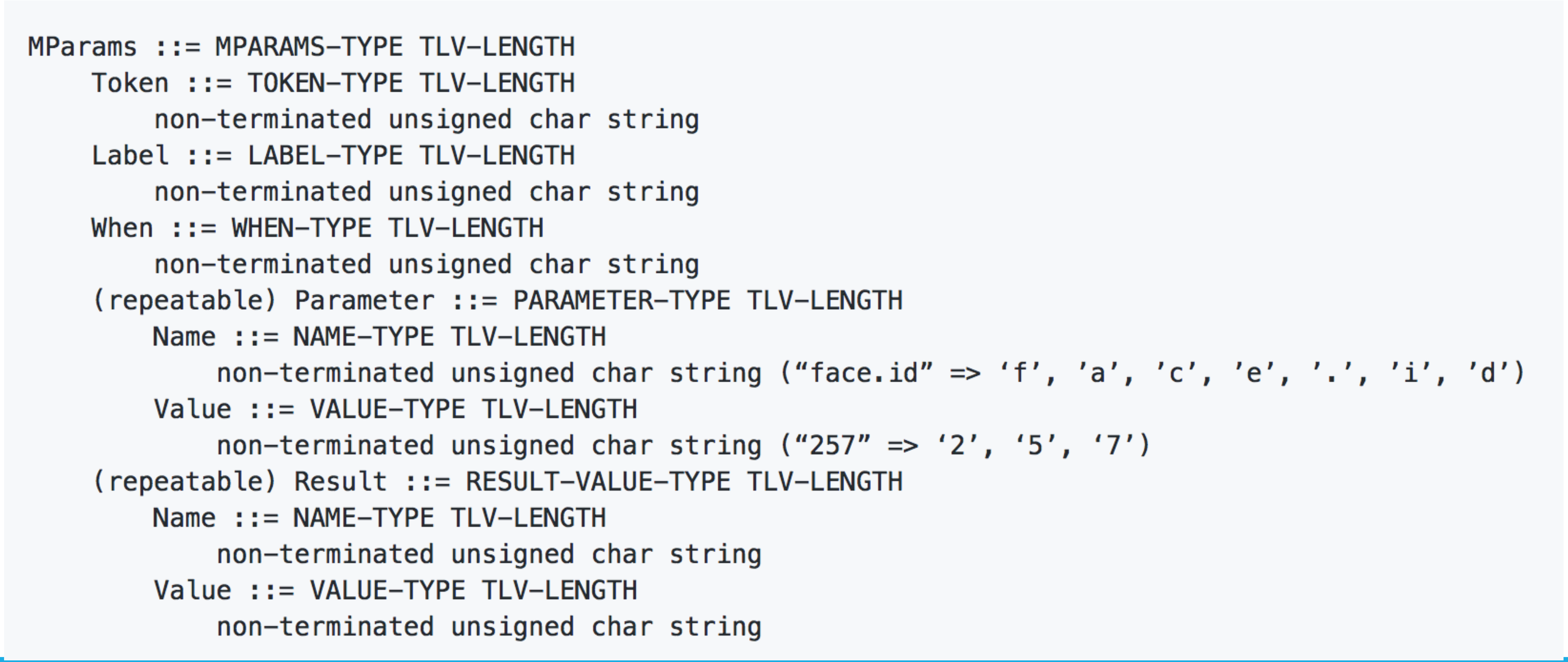
- measure
- query
- retrieve
- interrupt

We have defined:

- Packet format, including TLV encoding
- Client <-> agent protocol

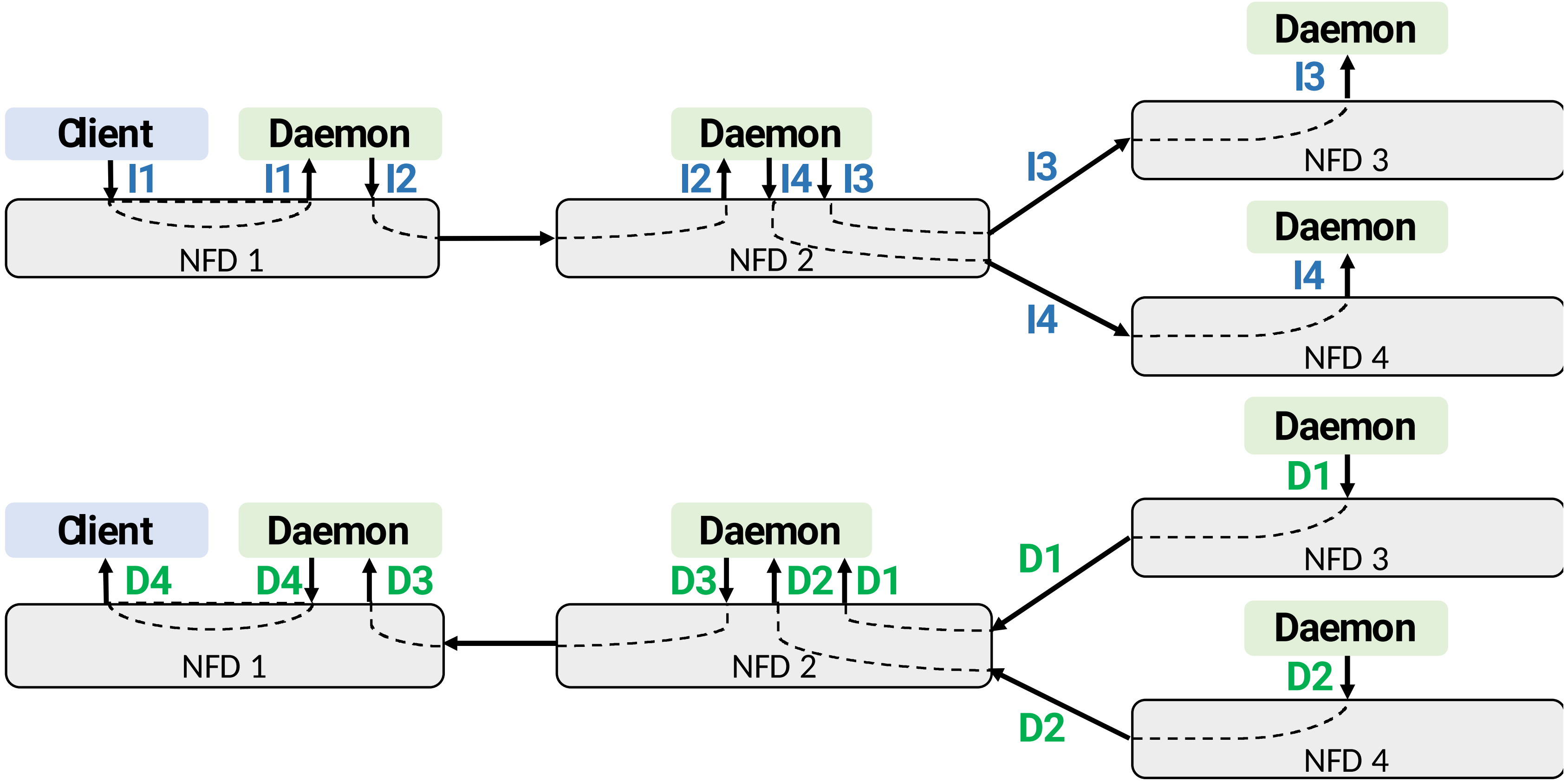
NMF: Protocol Details

`/<domain>/<node>/NMF/<verb>/<MParams>/<CIComps>`
(still based on v0.2 packet format)



```
MParams ::= MPARAMS-TYPE TLV-LENGTH
    Token ::= TOKEN-TYPE TLV-LENGTH
        non-terminated unsigned char string
    Label ::= LABEL-TYPE TLV-LENGTH
        non-terminated unsigned char string
    When ::= WHEN-TYPE TLV-LENGTH
        non-terminated unsigned char string
    (repeatable) Parameter ::= PARAMETER-TYPE TLV-LENGTH
        Name ::= NAME-TYPE TLV-LENGTH
            non-terminated unsigned char string (“face.id” => ‘f’, ’a’, ’c’, ’e’, ’.’, ’i’, ’d’)
        Value ::= VALUE-TYPE TLV-LENGTH
            non-terminated unsigned char string (“257” => ‘2’, ‘5’, ‘7’)
    (repeatable) Result ::= RESULT-VALUE-TYPE TLV-LENGTH
        Name ::= NAME-TYPE TLV-LENGTH
            non-terminated unsigned char string
        Value ::= VALUE-TYPE TLV-LENGTH
            non-terminated unsigned char string
```

Old NDN-Trace Design



Old NDN-Trace Design

Current v1 implementation is considered “done”

- Paper at ACM ICN’17
  - https://conferences.sigcomm.org/acm-icn/2017/proceedings/icn17-86.pdf
- Tested by John DeHart on ONL

However:

- It requires non-trivial changes to every strategy
- Code is hard to maintain
- We’d like to have more power over the tracing process (e.g., trace only a subset of next hops)

NDN-Trace: New “In-Forwarder” Design

Forwarding plane dispatches trace requests and responses to a **traceroute module**.

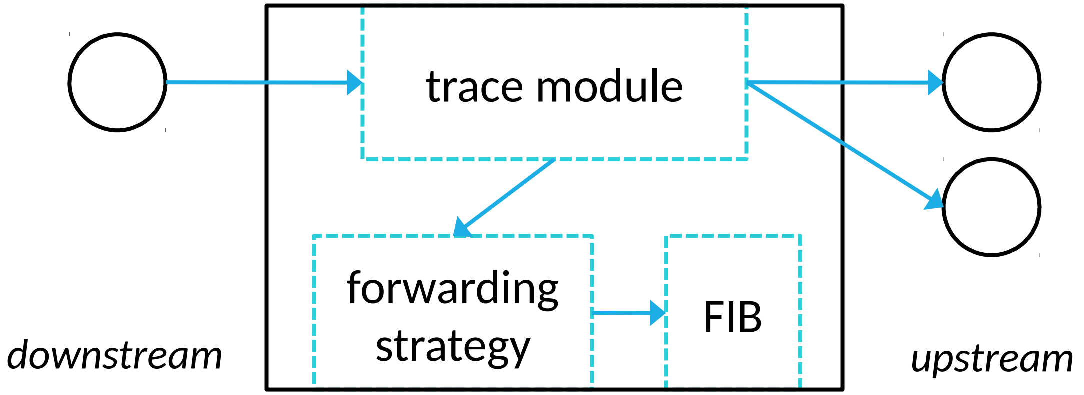
Strategy’s Interest forwarding API adds a **dry-run mode**.

- In dry-run mode, the chosen strategy offers its forwarding decisions, but does not transmit Interests or alter any state or data structures.

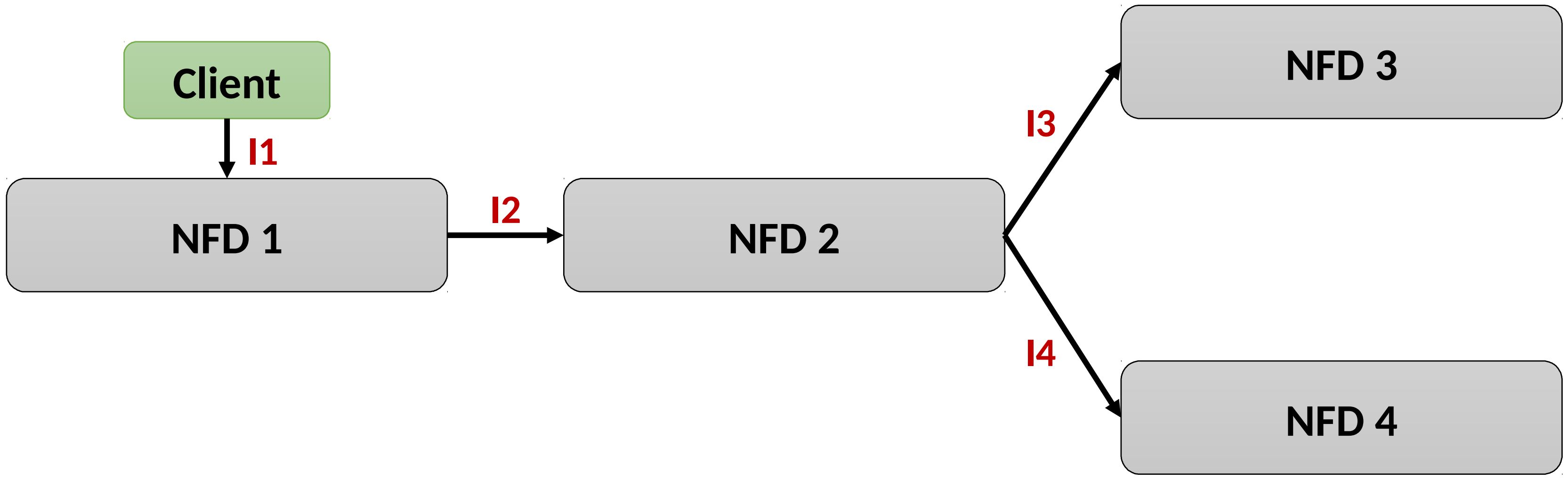
The traceroute module invokes strategy dry-run mode, transmits trace requests to next hops as needed, and collects and returns responses.

NDN-Trace: Router Behavior

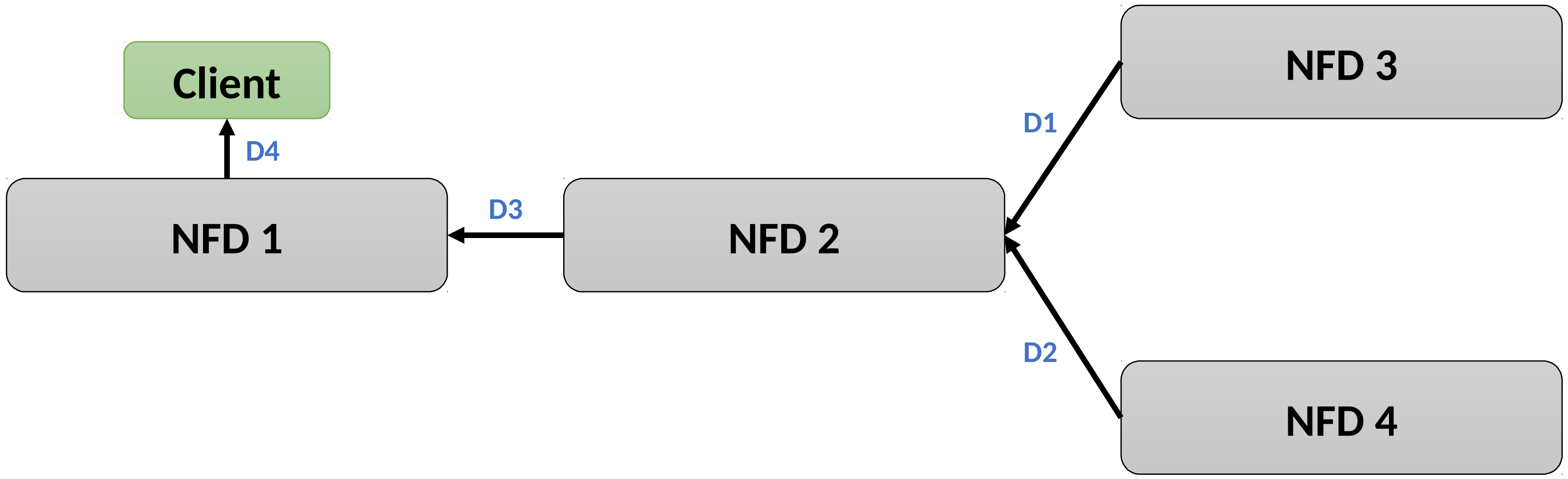
1. Let the strategy decide which next hops it would use for an Interest, assuming the Interest was retransmitted *T* times (*T*=0 for new Interests).
2. Send trace requests to the first *K* next hops chosen by the strategy.
3. Collect the first *R* trace responses that come back before a timeout *TO* expires, discard the rest.
4. Combine the responses into one (how?) and send it back.



NDN-Trace: Request



NDN-Trace: Reply



NDN-Trace: Router Behavior

Reply forwarding/aggregation: two approaches

- Hop-by-hop wrapping and signing, maintains existing signatures
- Discard signature, re-sign, send downstream

Trace process termination

- Producer
- Cache
- Either producer or cache, whichever is found first
- Abnormal termination
  - No route
  - Administratively prohibited
  - …

Bypassing the Forwarding Strategy

It can be argued that a path (next hop) that appears in FIB but would never be considered by a strategy is not a meaningful path.

- Some strategies do not use the FIB, e.g.:
  - Flooding strategy always floods.
  - Self-learning strategy may flood. FIB may be empty.
  - Hyperbolic FIB (in eventual implementation) maps prefixes to coordinates instead of next hops. FIB does not contain next hops.
- Therefore the traceroute module should never look at the raw FIB entries without going through a strategy.

But what if we need to explore alternative paths that the current strategy would not consider?

- Do we need this functionality, e.g. for strategy debugging?

NDN-Trace: Future Work

Currently exploring how to adapt NDN-Trace to take advantage of new features in NDN Packet Format v0.3

- Use **typed name components** to recognize trace Interests?
- Carry parameters in Interest **Parameters** TLV

Explore deployment/testing on the NDN Testbed

Lots more…