Green Path Metrics for Sustainable Networking using IOAM Aggregation Trace Option

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Motivation

- Observability prerequisite for network optimization (incl for sustainability)
  - “You can’t manage what you can’t measure”
- Typical focus for metrics: on-device instrumentation
  - E.g. YANG data models for device energy usage – GREEN WG
  - Generally requires separate controllers and management systems to collect, correlate, aggregate data before further processing
- Other metrics scopes beyond device (not widely supported)
  - Network as a whole (what matters at the end of the day)
  - Flows – e.g. how much energy use can be attributed to a flow (or instance of a service)
  - **Paths (and path segments)**
- For sustainability metrics overall see https://datatracker.ietf.org/doc/draft-cx-green-green-metrics/ (expired but useful)
- Focus here: Metrics for Energy Efficiency of Paths, possible applications:
  - How can I select the “greenest” among multiple paths?
  - Assess path greenness for sustainability optimization

Green Path Metrics - example

- Determine attributed energy across a path
  - Raw device metric: Energy usage/efficiency of each hop encountered across the path
  - Derived device metrics:
    - Normalized by interface speed, attributed to each packet
    - Discounted by environmental rating of device
    - Weighed by sustainability factor of supplied power, etc

Hop Efficiency Indicator
(could be operator-defined formula)

  - Use to determine path metrics
    - Accumulated energy usage ***across a path***
    - Maximum usage / lowest efficiency of any hop ***on the path***, etc

Path Efficiency Indicator
(could be operator-defined formula)

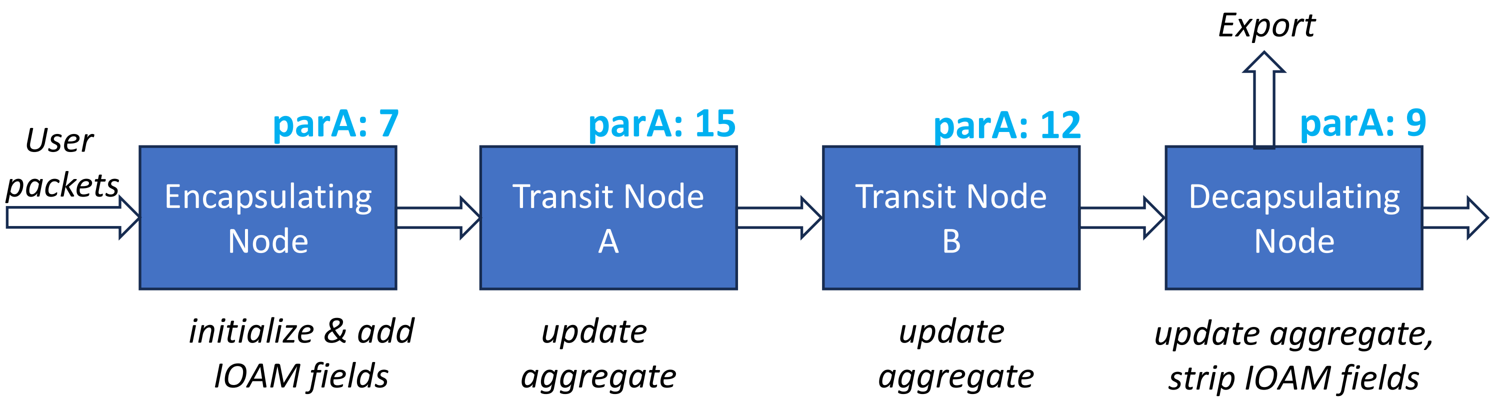
- How to obtain today
  - Retrieve by device
    - **Issues**: management system with access, determination of paths, path congruency, data processing, …)
  - IOAM to collect data from each hop
    - **Issues**: packet size (data records * n hops), need for correlation, data processing...

Proposal: Aggregation Trace Option for IOAM

- IOAM allows to collect certain telemetry data across hops along a path
  - Issues to contend with: packet size (data records * n hops), need for correlation, data processing...
- We propose a new option: Aggregation Trace Option
  - Aggregate data during traversal: min, max, sum, average*
  - Very simple operations (comparison, addition, increment)

    $\text{Aggregate}[\text{hop}_i] := \text{function}\ (\text{Aggregate}[\text{hop}_{i-1}], \text{data item})$
  - Uses
    - Sustainable networking (focus here): assess path carbon metrics / path efficiency indicators see also https://ieeexplore.ieee.org/abstract/document/10588907
    - Beyond sustainable networking:
      - Identify bottle necks and outliers (performance optimization)
      - Aggregate packet dwell times (service level guarantees)
- https://datatracker.ietf.org/doc/draft-cxx-ippm-ioamaggr/

Basic Idea



Aggregate

Max	7 →	15 →	15 →	15
Sum	7 →	22 →	34 →	43
…				

√ Limited+fixed packet overhead
√ Reduced data volume
√ Greater privacy – individual node data not exposed
√ Obviates need for off-node record correlation and processing
√ Potential operation at line speed* *(*depends on base parameters)*
√ Greater network intelligence

Data fields

Flag processing errors

```
 0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |         Namespace-ID          | Flags |       Reserved        |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                IOAM Data Param                |   Aggregator  |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                            Aggregate                          |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |               Auxil-data Node-ID             |   Hop Count    |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

want to generalize beyond current IOAM params

min, max, sum

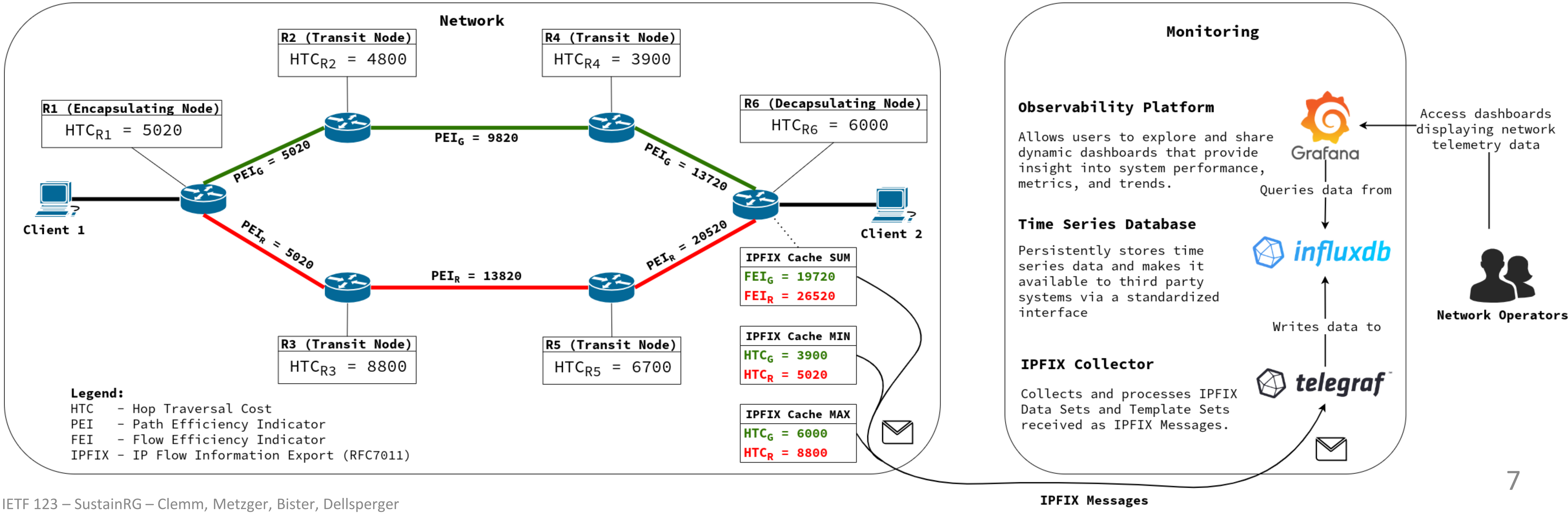
Use for min, max to identify bottleneck or for debug info in case of errors

Use to calculate average from sum

- See https://datatracker.ietf.org/doc/draft-cxx-ippm-ioamaggr/
- Will likely be aligned with https://datatracker.ietf.org/doc/draft-mbci-ippm-ioam-template-option/ (In Situ Operations, Administration, and Maintenance (IOAM) Template Option) depending on its progress

PoC implementation

- P4, BMv2 switches
- https://github.com/INSRapperswil/green-path-optimizer



Conclusions and next steps

- Next steps
  - Building out PoC: continuous monitoring, pollution-aware routing
- Standardization of Aggregation Trace Option?
  - Uses for sustainable networking and beyond
    (e.g. bottleneck analysis, end-to-end service levels, …)
  - Likely alignment with https://datatracker.ietf.org/doc/draft-mbci-ippm-ioam-template-option/ (In-Situ Operations, Administration, and Maintenance (IOAM) Template Option)
- Interested?
  - We are looking for interested collaborators