Hecate Update

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20 slides, 20 minutes

- Project Overview: What is Hecate about?
- Project Update: What have we done?
- Planned research agenda: How are we planning on reaching our objective?

I will focus on where we are in terms of providing a deliverable or more realistically how we can best be in a position to deeply understand details around proposed vendor solutions.
Objective: *Create efficient routing advice for traffic within ESnet based on a combination of historical site behaviors and current/projected network health.*
Data: What have we done?

- Behavior of long term/permanent data plane residents: sites, facility, instrument
- Look backwards (time) for results
- Statistical not specific behaviors
Data: Historical Network Activity

Netflow

Site 1

Site 2

S_3

S_4

S_5

S_6

1

2

3

4

5

2

3

4


X: Subnet of Site
Data: Historical Site Activity

Raw Flow Records

- splunk_to_conn.py
  - Read time index flow records, process into connections w/ metadata -> SQLite

- k-means-time.py
  - SQLite -> Read time window get clustered size and duration information -> SQLite
Data: Historical Site Activity

- **Raw Flow Records**: Raw flow records in Splunk
- **splunk_to_conn.py**: Read time index flow records, process into connections w/ metadata -> SQLite
- **k-means-time.py**: SQLite -> Read time window get clustered size and duration information -> SQLite
### Connection Metadata: splunk_to_conn.py

<table>
<thead>
<tr>
<th>Metric</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/S Site</td>
<td>Ex: LBNL, ORNL</td>
</tr>
<tr>
<td>cs_data_ratio_norm</td>
<td>client/server ratio: data ratio imbalance</td>
</tr>
<tr>
<td>cs_psize_ratio_norm</td>
<td>client/server ratio: pkt size ratio imbalance</td>
</tr>
<tr>
<td>C,S velocity</td>
<td>data/duration</td>
</tr>
<tr>
<td>C,S avg_size</td>
<td>data/total packets</td>
</tr>
<tr>
<td>C,S,T packets, bytes</td>
<td>counting stuff</td>
</tr>
<tr>
<td>duration</td>
<td></td>
</tr>
</tbody>
</table>

Data taken from 1/1000 sampled flows; conn = IP1:high_port -> IP2:low_port
Ratio Norm designed to separate A/B~1 vs. A/B >>1 OR A/B << 1
Data: Historical Site Activity

- **Raw Flow Records**
- **splunk_to_conn.py**
- **k-means-time.py**

**NF Rec** → **S2C** → **SQL** → **KMT** → **SQL**

**Raw flow records in Splunk**

**Read time index flow records, process into connections w/ metadata -> SQLite**

**SQLite -> Read time window get clustered size and duration information -> SQLite**
Unsupervised Clustering

1. Embed connection in \{Packet size ratio, Data size ratio, client avg size\} \(^1\)
2. Calculate number of clusters via Silhouette score \(^2\)
3. ID cluster identities by taking known connection types and looking at each
4. Tag cluster members based on assignment above
5. Sanity check results

1: Test moving from mean to median to address outliers
2: if n>1000, sample set and calc SS from it
Data: Historical Site Activity

<table>
<thead>
<tr>
<th>Time Focused Tag</th>
<th>Data Volume Focused Tag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Site1[$x_1$] -&gt; Site2[$x_2$] : <strong>TTTVVV, W1, TTTVVV, W2</strong></td>
<td></td>
</tr>
</tbody>
</table>
Data: What have we done?

- Shorter term transient effects
- Project forward (time) for results
- More specific than statistical behaviors
Network Health

Perfsonar: Node to Node
- latency_mean
- latency_sd
- packet_lost
- packet_reorder
- packet_dupe

SNMP Link Data: Router Link
- bytes_in
- bytes_out
- error_in
- error_out
- discard_in
- discard_out
Network Health: Time and Value Normalization

Stardust/PerfSonar
Sample Time: ~15 min
Predict window: 1 hour

Stardust/SNMP
Sample Time: 60 sec
Predict window: 1 hour

Link vs. PS to PS
End-to-end measure vs. Link measure

introduces question about where and when the lost/reorder/duped packets happened
Network Health: Prediction

Initial work based on successful use of GNN in predicting Transatlantic WAN link traffic volumes over 24 hour windows.

(Based on Net Predict / DAPHNE)
Network Health: Prediction

Initial work based on successful use of GNN in predicting Transatlantic WAN link traffic volumes over 24 hour windows.

(Based on Net Predict / DAPHNE)

Current state of the art in predictive networking takes a different approach - ML architecture for sequence modeling called Transformer which can take into consideration the context of the data point within the sequence.

Think of this as a LLM/Chat Gpt for network traffic volumes and congestion/errors
Our Agenda

So how do we get closer to our objective?
Research Agenda

**Project 1: Prediction.** Can we take historical time series data for traffic volumes and accurately predict future values on individual links?

**Project 2: Data feature engineering.** What core features in terms of historical behaviors as well as network health are used/measured/required for optimal solutions.

**Project 3: Optimization.** How can we identify an optimal solution in terms of routing solution in terms of combining historical site behavior, current topological design, and predicted values?

**Project 4: Routing integration + testing.** How do we quantify changes to the (proposed) network to ensure that nothing bad is happening from our diffs?
Project 1: **Prediction**

- Can we take historical time series data for traffic volumes and accurately predict future values on individual links?
- Can this be done for errors, loss, jitter, and retransmits as well?
- There is some work already done here on this topic, but not much in terms of code, data, and reproducibility.

**Output if successful:**

- (Transformer) model capable of predicting bandwidth and (possibly) related error values 1-24 hours in advance
- Paper describing method and related code
- Explore releasing model if possible
Project 2: **Data feature engineering**

- Look at current workflow wrt unsupervised clustering of historical network behavior from sites
- Measure continuity across time to ensure that \(<\text{net1}\> \leftrightarrow \ <\text{net2}\>\) generalizations are stable enough to be used for optimization purposes
- Are there additional data features beyond the usual candidates? Think about this in terms of higher degree moments to better express stability and efficiency in prediction/optimization
- Explore **HT** as a data source: what (if any) new or additional metrics can we look at for health prediction and route optimization?
Project 2: **Data feature engineering**

Output of a successful project:

- Paper describing in detail how unsupervised clustering works across time and at scale for site related analysis
- Confirmation that the health values being looked at are relevant - are there others that could be used with greater utility?
- What would very high time resolution bring to a statistical measurement?
Questions?

FIN

- Resident
  - Historical Site Behavior
  - Behavioral Analysis

- Fabric
  - Network Health
  - Network Health Prediction

- Global Path Optimization
- External Interface/SR

ESnet
[1] Required Abstractions

Site\textsubscript{1} to Site\textsubscript{2}: Flow records via ASN
dt = A

PS\textsubscript{1} to PS\textsubscript{2}:
Latency, Jitter, Drops, Rxmits
dt = B
Active test data
Unidirectional

SNMP Interface Link
Bandwidth Actual, drops, discards
dt = C
Passive data
Bidirectional

Router\textsubscript{s.1} Router\textsubscript{c.1} Router\textsubscript{s.2}
Site\textsubscript{1} Site\textsubscript{2}
[3] Link Mesh: Logical, Weighted

Data from Dec 2022
[4] Link Mesh: Physical

Data from Dec 2022
[6] PS Mesh: Real

All Data Directional