ESnet
ENERGY SCIENCES NETWORK

Hecate Update

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Internet 2 TechEX
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BERKELEY LAB

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*.

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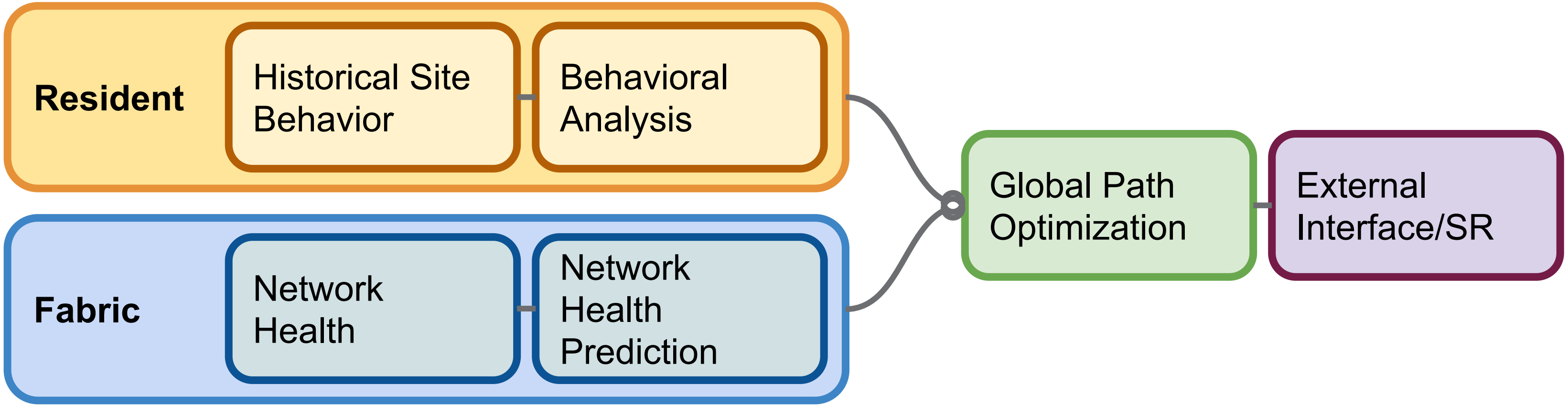
Project Overview

Objective: *Create efficient routing advice for traffic within ESnet based on a combination of historical site behaviors and current/projected network health.*



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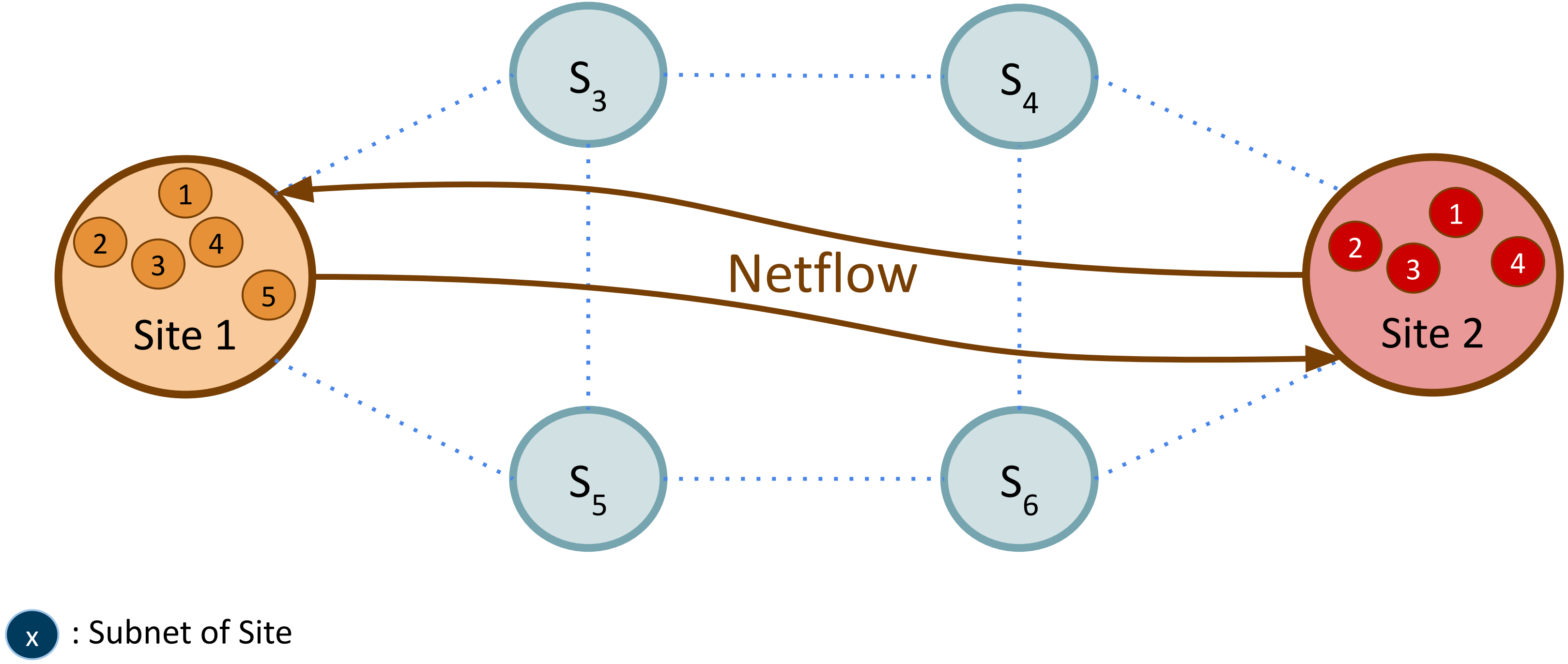
Data: What have we done?

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

Data: Historical Network Activity



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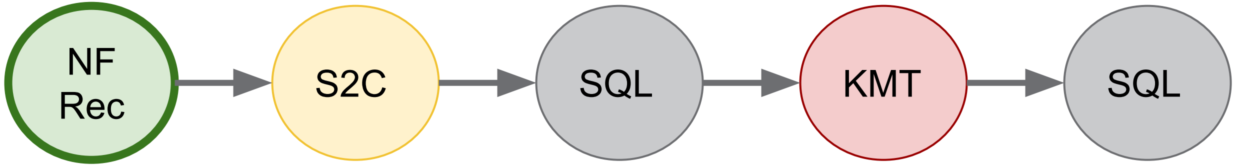
Data: Historical Site Activity



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

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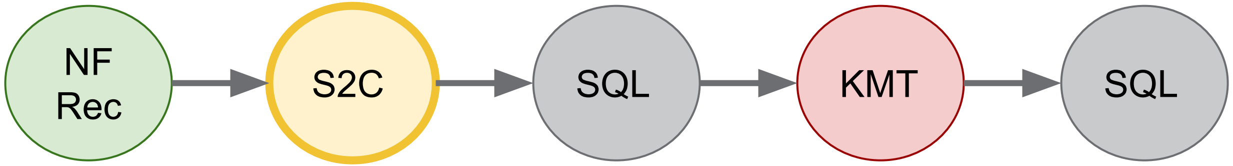

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Connection Metadata: splunk_to_conn.py

C/S Site	Ex: LBNL, ORNL
cs_data_ratio_norm	client/server ratio: data ratio imbalance
cs_psize_ratio_norm	client/server ratio: pkt size ratio imbalance
C,S velocity	data/duration
C,S avg_size	data/total packets
C,S,T packets, bytes	counting stuff
duration	
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	

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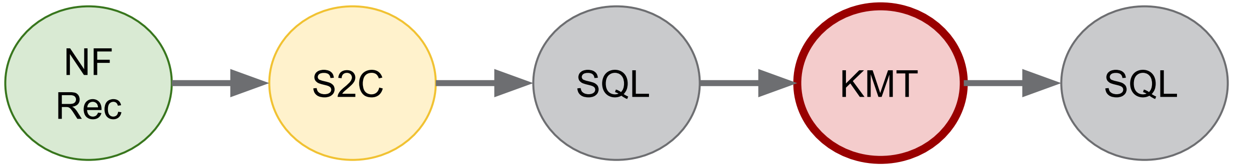
Data: Historical Site Activity



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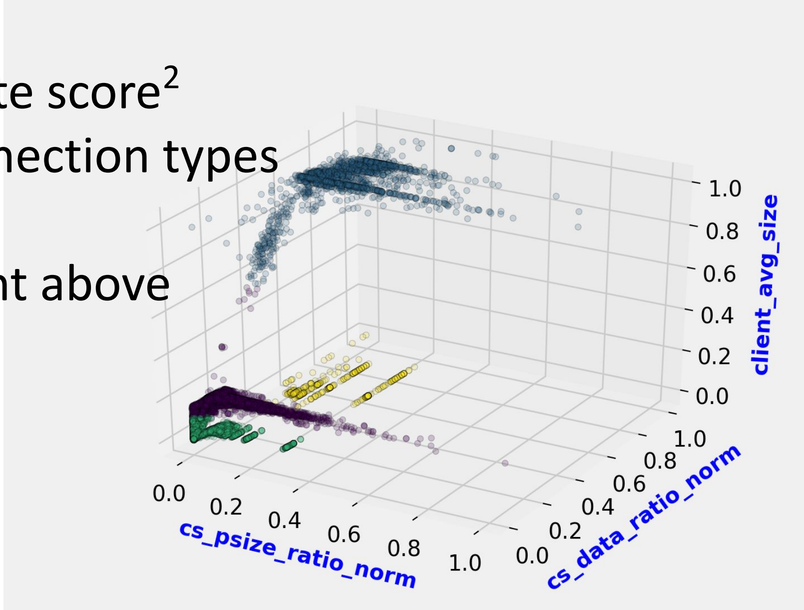
Unsupervised Clustering

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

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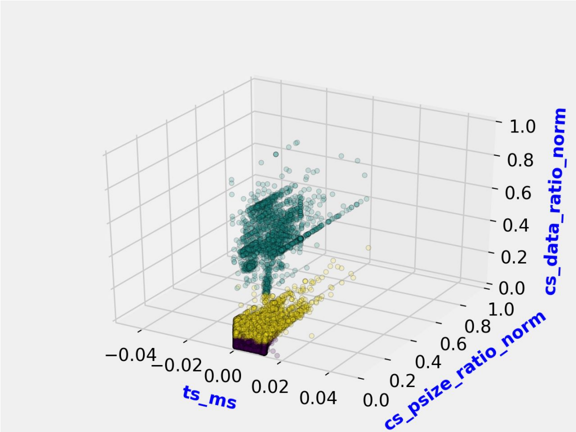
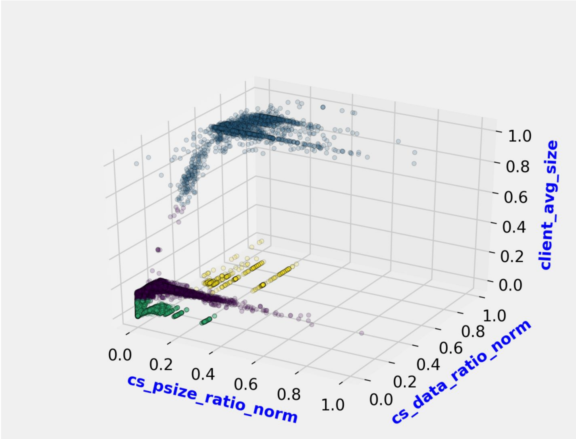
Data: Historical Site Activity





Time Focused Tag	Data Volume Focused Tag
Short|Med|Long : **000111** [n]	Small|Med|Large: **111000** [n]
Individual Site1[x_1] -> Site2[x_2] : **TTTVVV, W1**, **TTTVVV, W2**	

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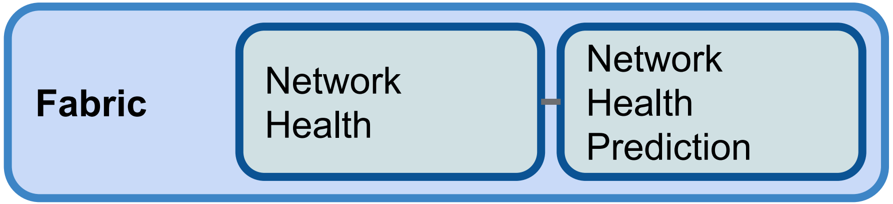
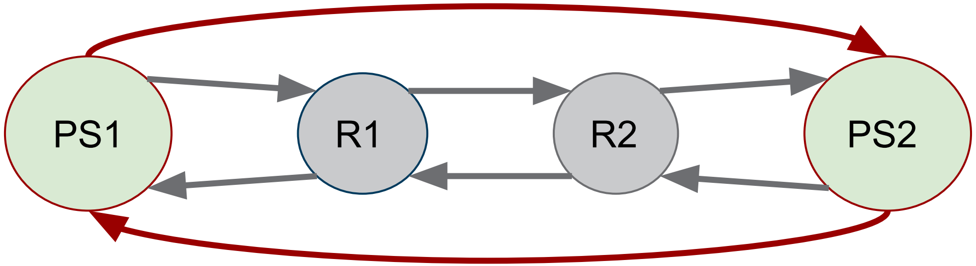
Data: What have we done?



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

Network Health



Perfsonar: Node to Node	SNMP Link Data: Router Link
latency_mean latency_sd	bytes_in bytes_out
packet_lost	error_in error_out
packet_reorder packet_dupe	discard_in discard_out

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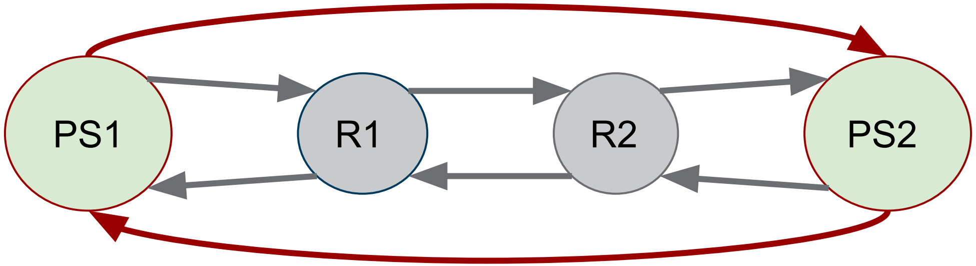
Network Health: Time and Value Normalization



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)

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

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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

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Our Agenda

So how do we get closer to our objective?

Lego 71004 Lego Movie Series 1 Lord Business #2 Minifigure ©M

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?

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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 <net1> <-> <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?

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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?

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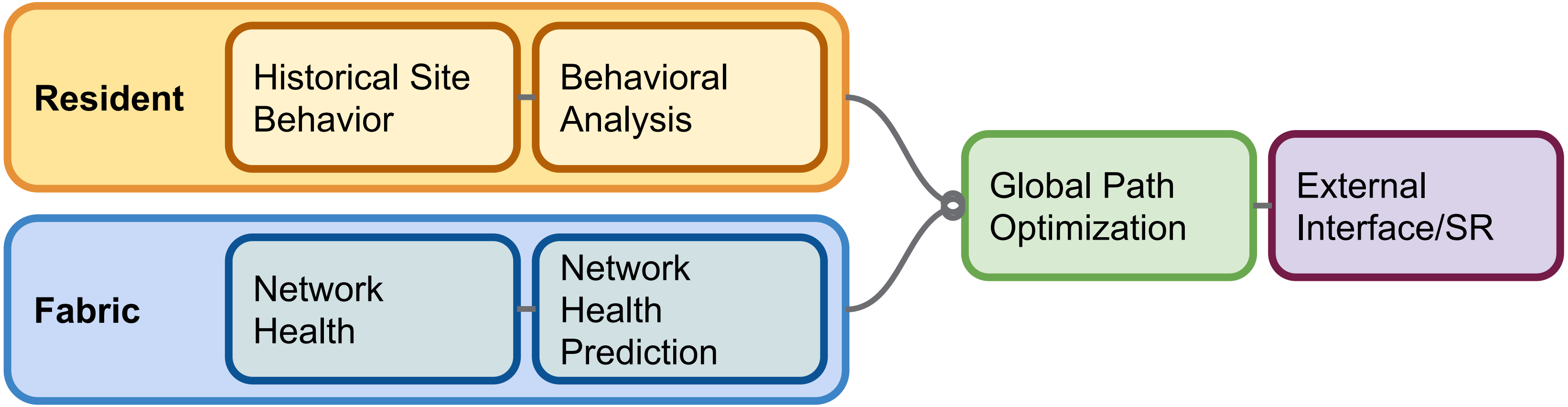

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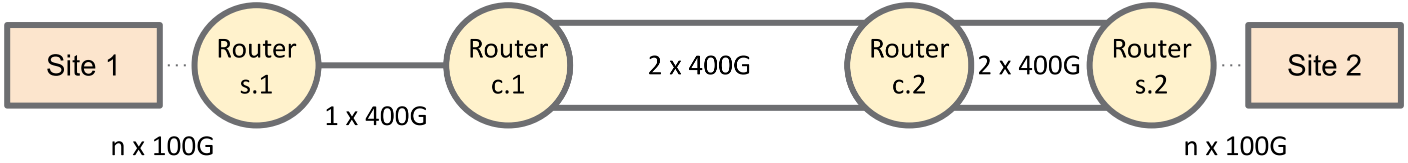
[1] Required Abstractions

Site$_1$ to Site$_2$: **Flow records** via ASN
dt = A

PS$_1$ to PS$_2$:
Latency,Jitter,Drops,Rxmits
dt = B
Active test data
Unidirectional

SNMP **<u>Interface Link</u> Bandwidth** Actual, drops,discards
dt = C
Passive data
Bidirectional



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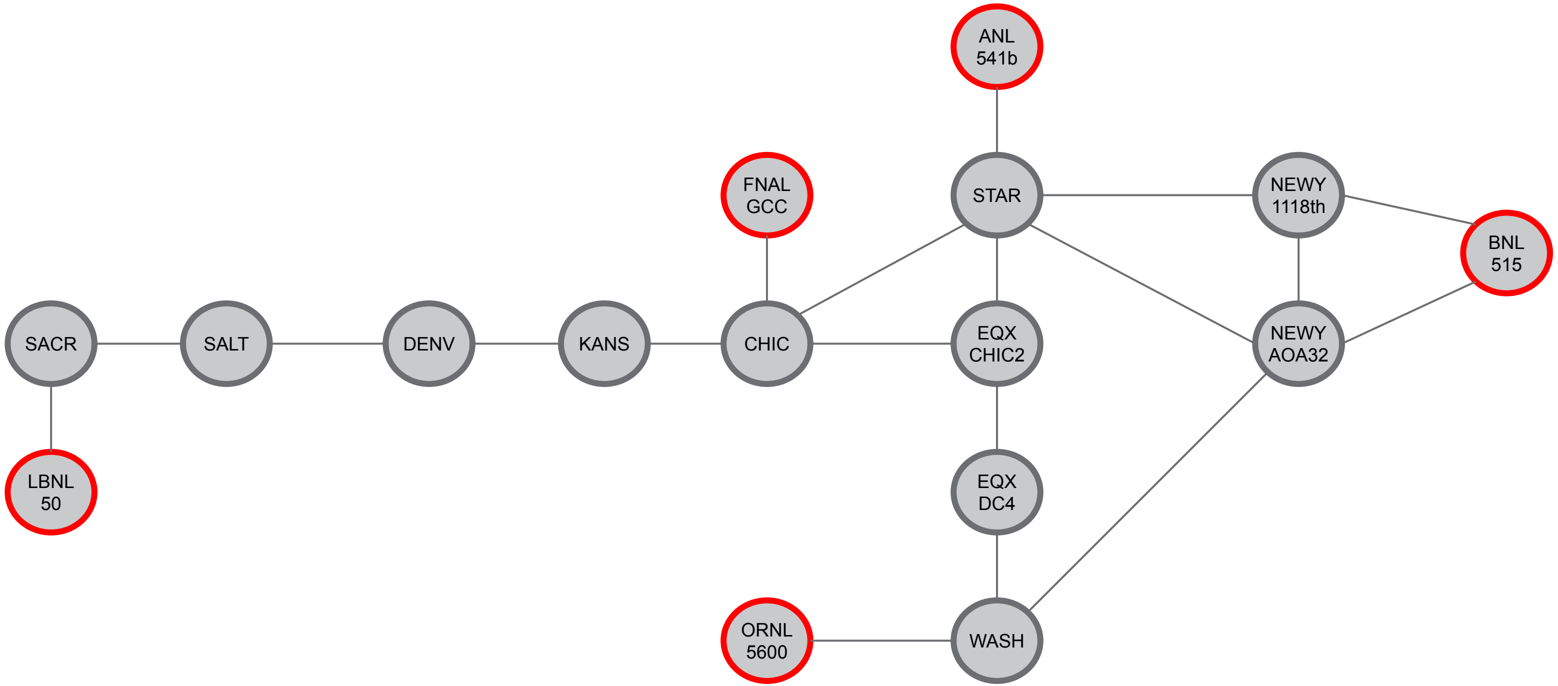
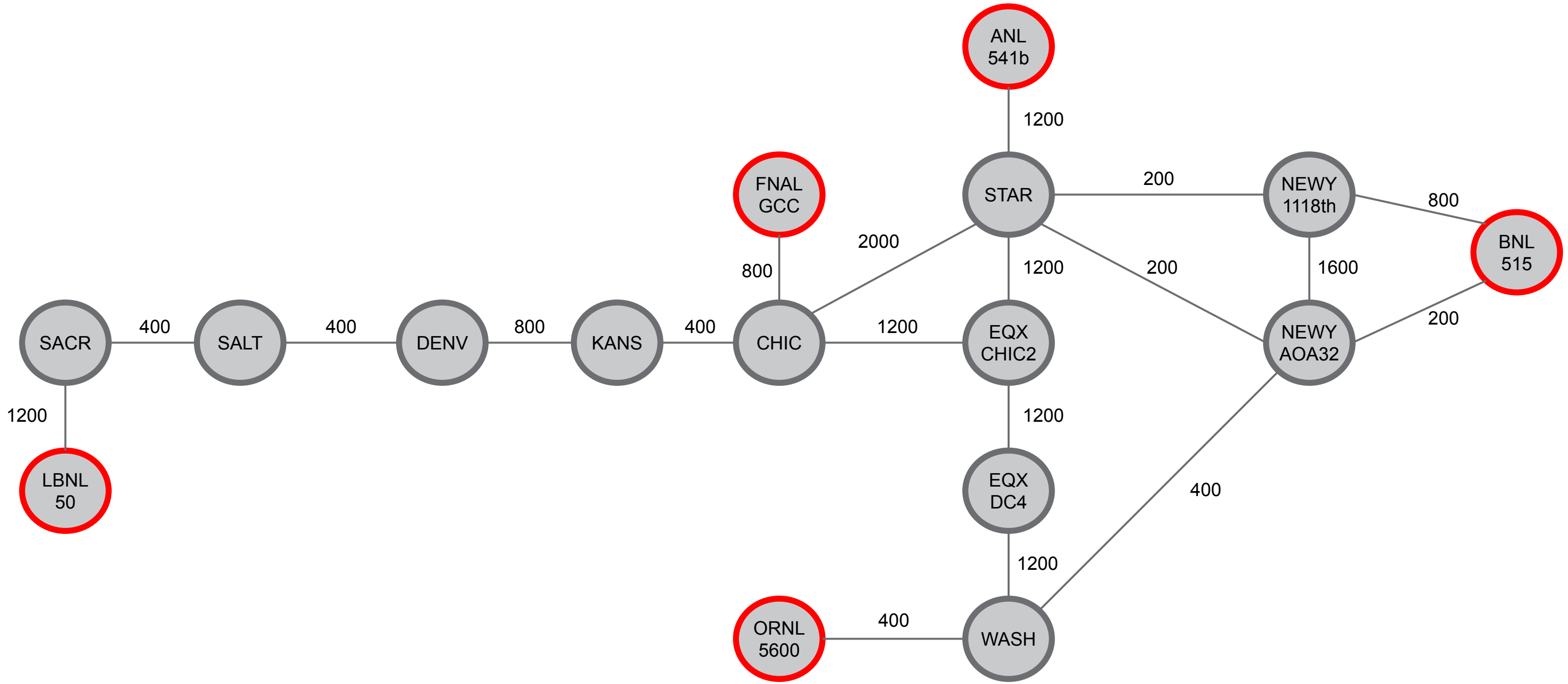
[2] Link Mesh: Logical



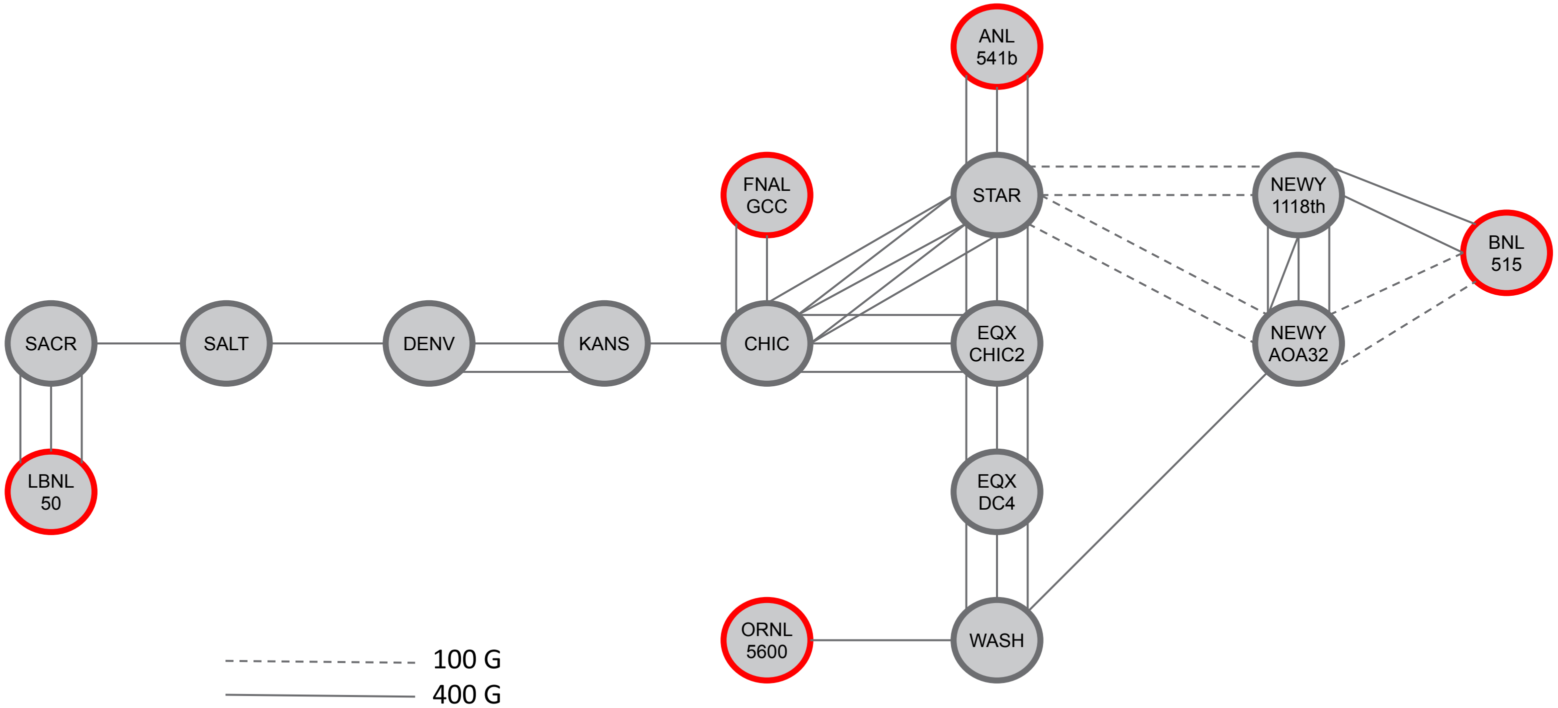
Data from Dec 2022

[3] Link Mesh: Logical, Weighted



Data from Dec 2022

[4] Link Mesh: Physical



Data from Dec 2022

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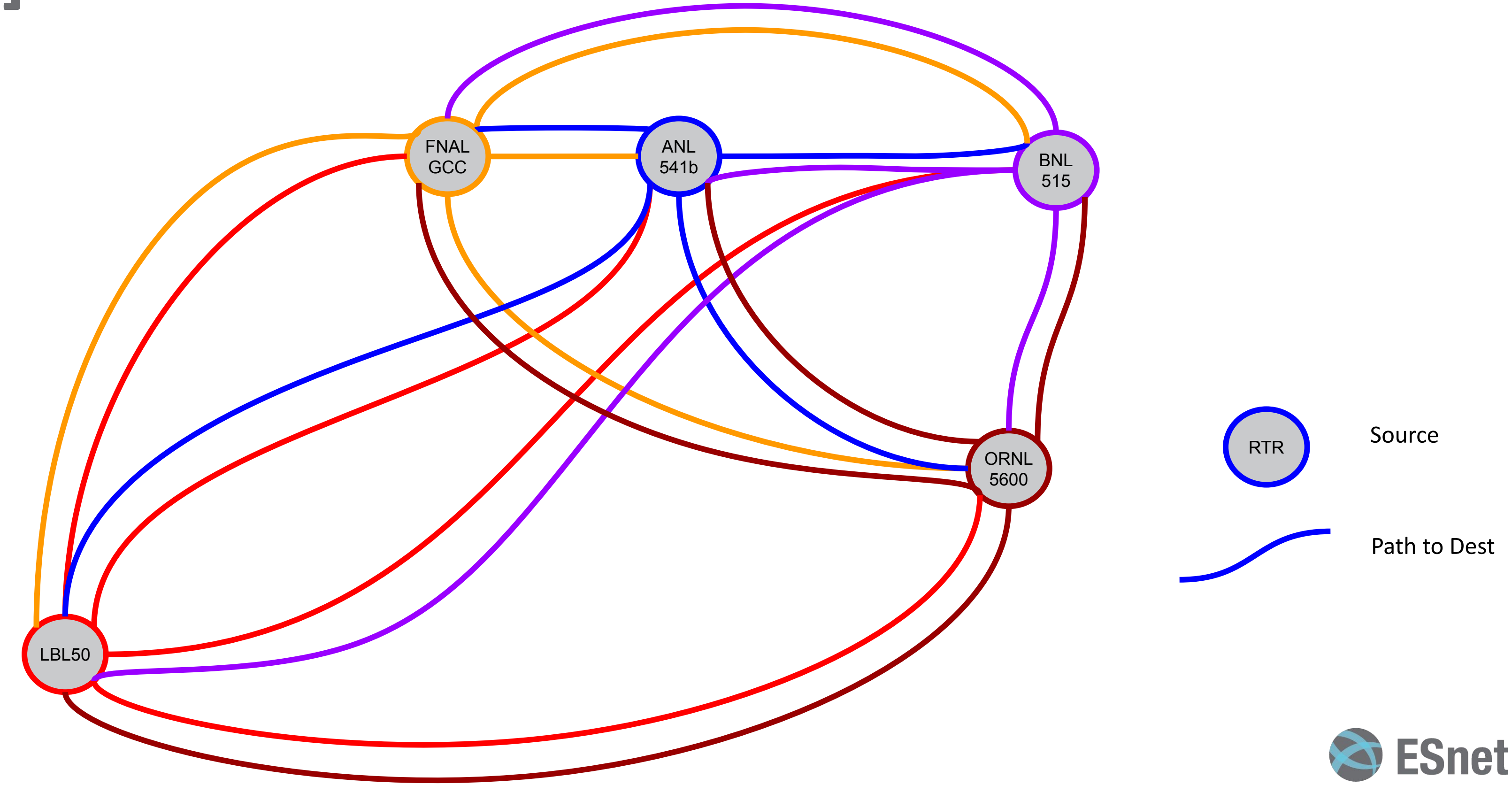
[5] PS Mesh: Abstract



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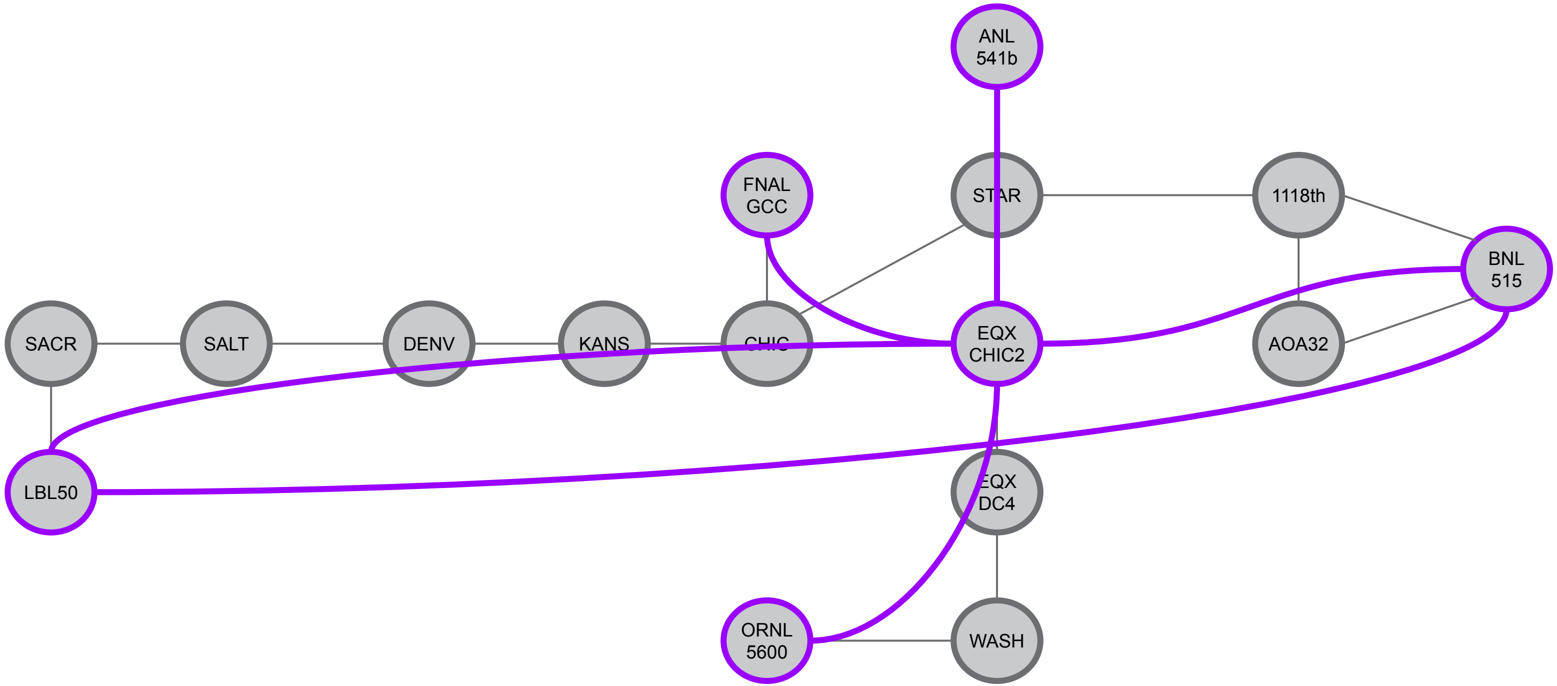
[6] PS Mesh: Real



All Data **Directional**