



Barcelona
Neural
Networking
Center



UNIVERSITAT POLITÈCNICA
DE CATALUNYA
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Graph Neural Networking Challenge 2021

Creating a Scalable Network Digital Twin

ITU-ML5G-PS-001

<https://bnn.upc.edu/challenge/gnnet2021/>

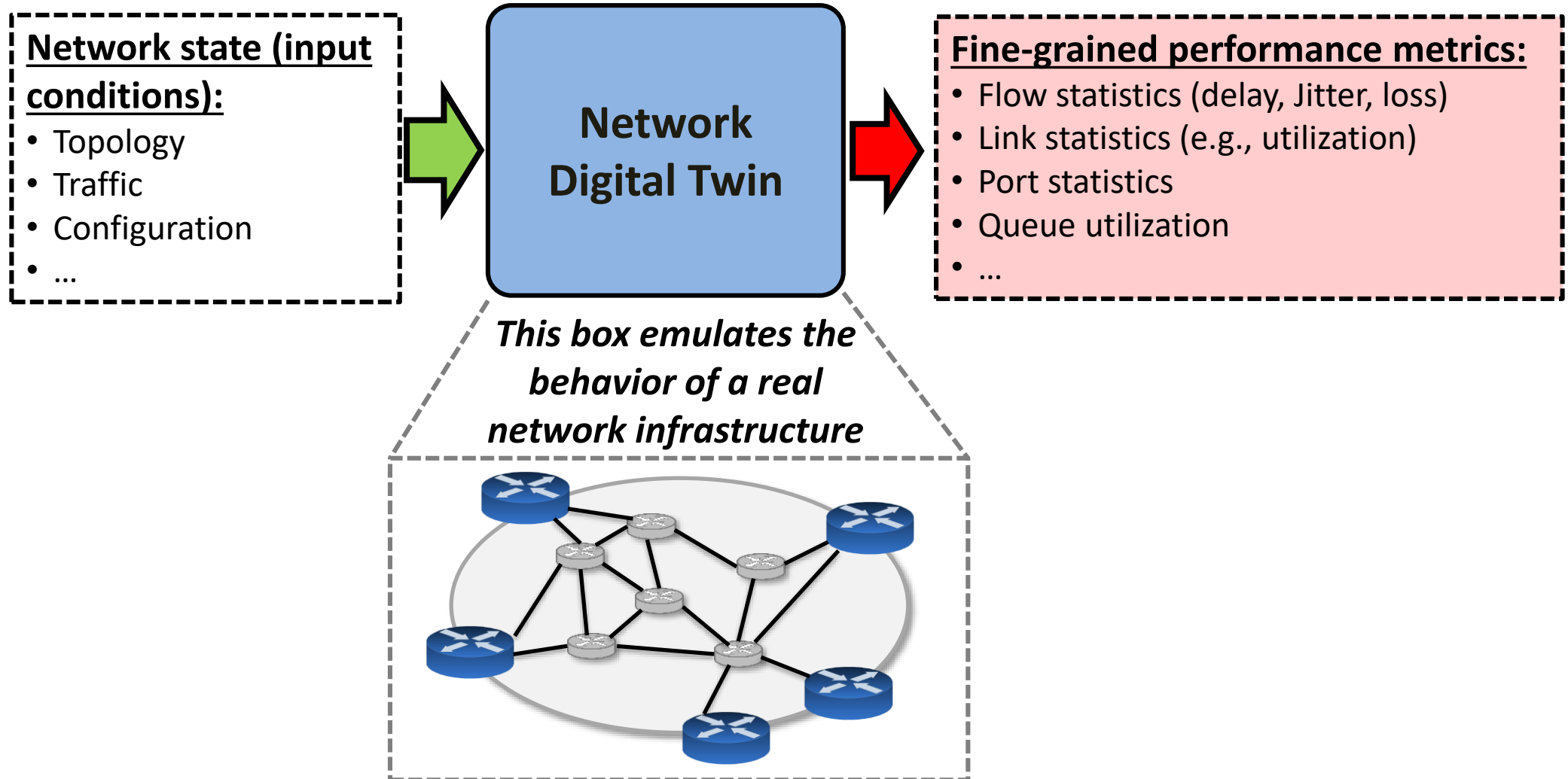
José Suárez-Varela

Barcelona Neural Networking center
Universitat Politècnica de Catalunya

August 4th 2021



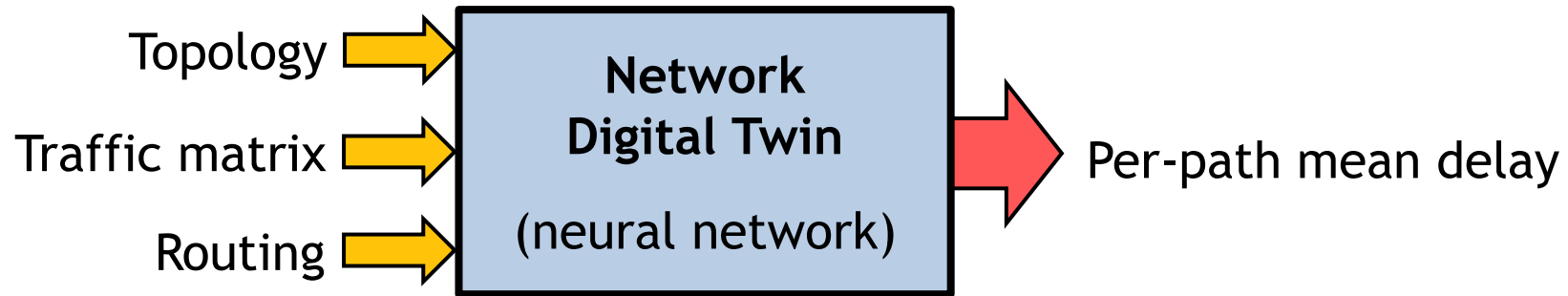
- A Network Digital Twin is fundamentally this box:



**What is the objective of
the challenge?**



Objective → Build this box



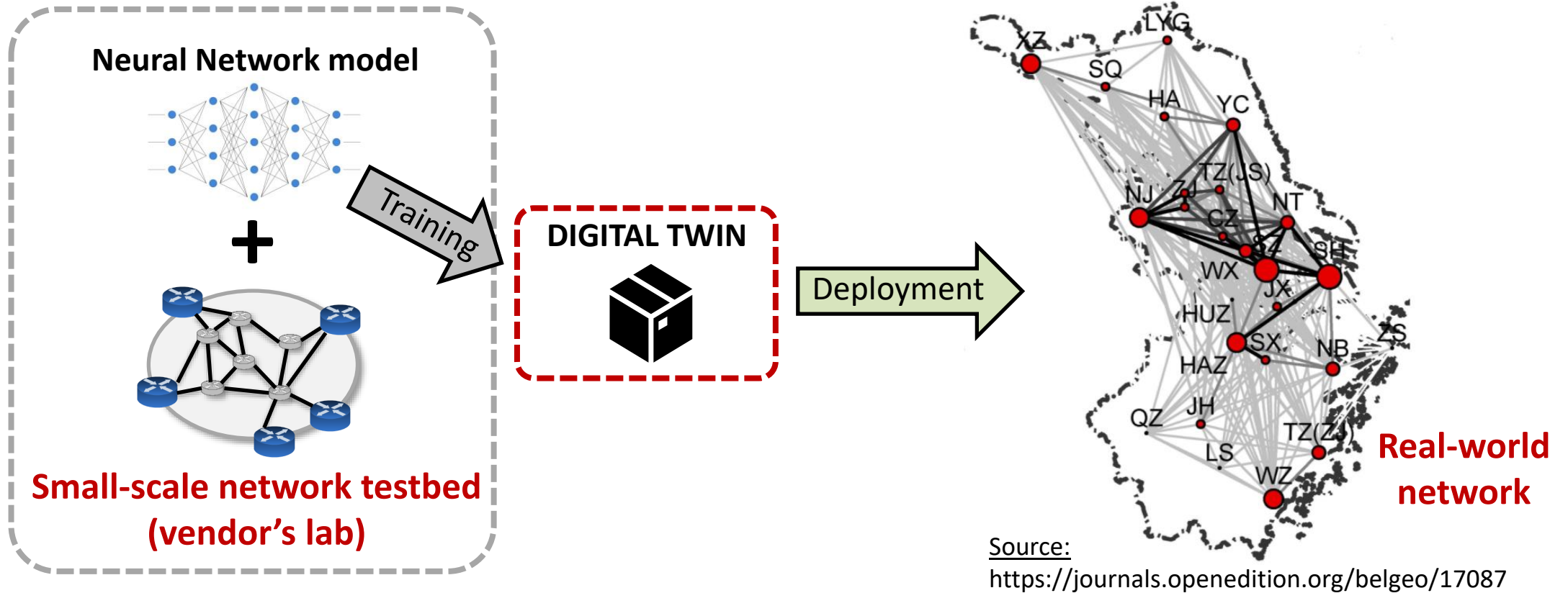
- Input:

- Network topology
- Source-destination traffic matrix
- Routing (source-destination paths)

- Output:

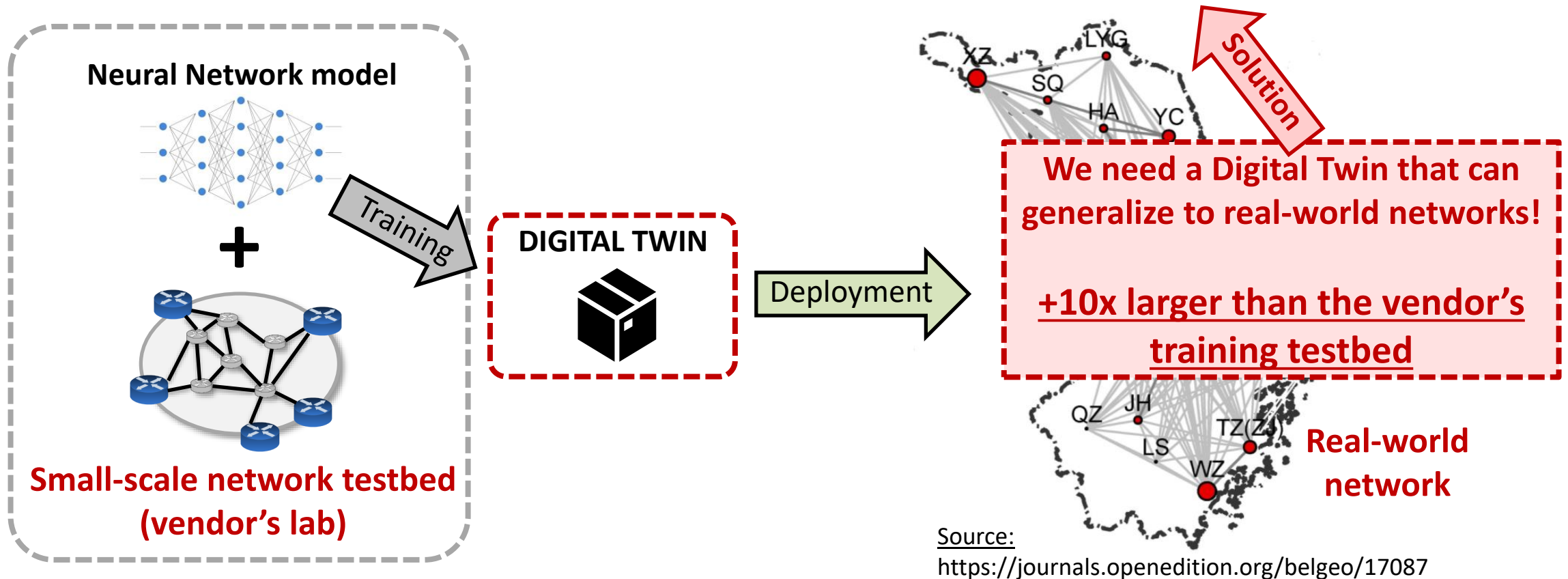
- Mean per-packet delay on each source-destination path

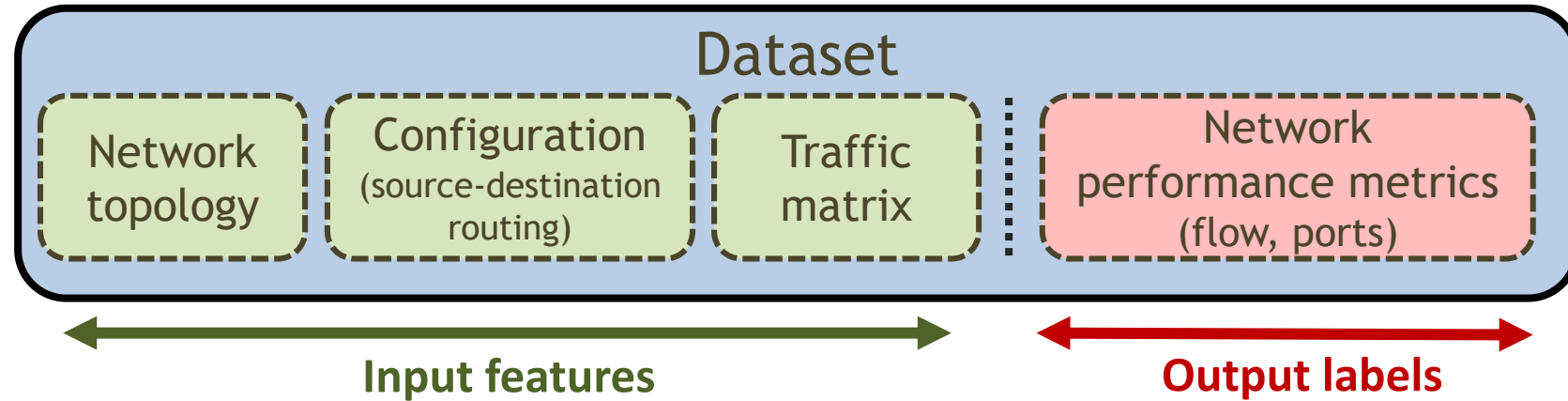
Problem Overview





Creating a scalable Network Digital Twin





- Data generated with OMNet++ (packet-accurate network simulator)
- Thousands of simulation samples with topologies, routing configurations, and traffic matrices (covering wide range of congestion levels)

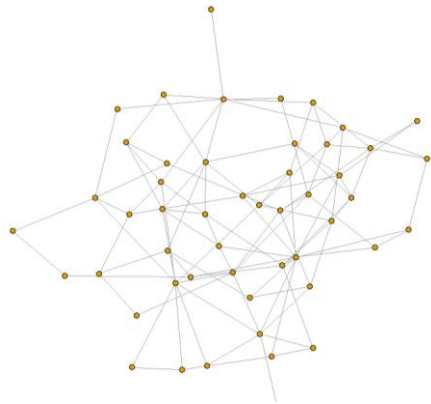
Evaluation → Test the scalability properties of proposed solutions

Training dataset:

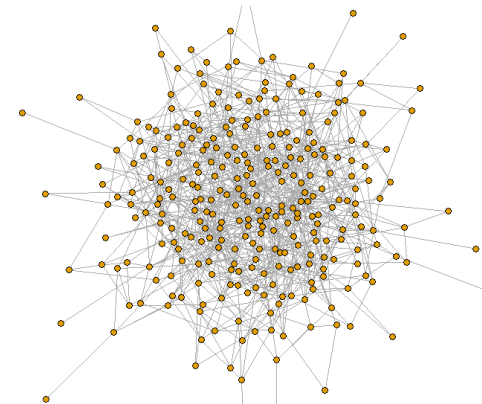
- Samples in a wide variety of networks from **25 to 50 nodes** (small)

Validation/Test datasets:

- Samples in networks from **51 to 300 nodes** (large)



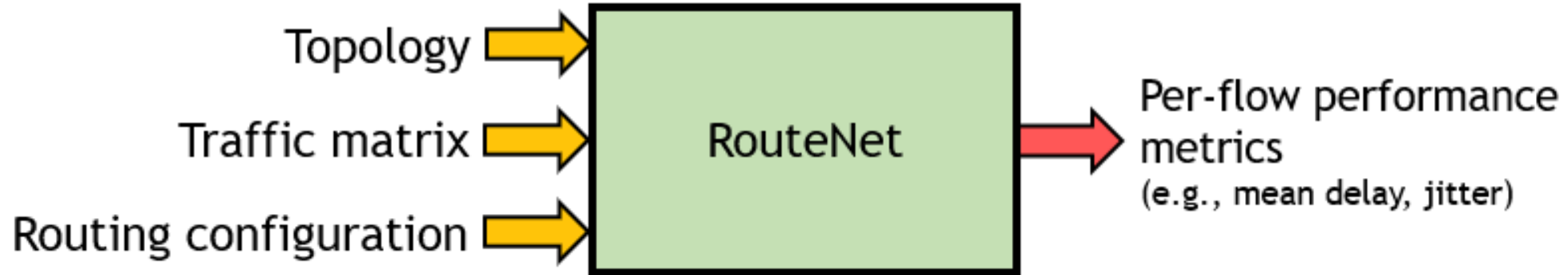
Training (small networks)



Validation / Test (large networks)

$$MAPE = \frac{100\%}{n} \sum_{i=1}^n \left| \frac{\hat{y}_i - y_i}{y_i} \right|$$

↑
(Lower is better)



✘ Limitation:

RouteNet* is not designed to model networks (graphs) considerably larger than those seen during the training phase (MAPE > 300% in our experiments)

- We provide open source implementations in TensorFlow and iGNNition
- It can be a good starting point for participants



*Rusek, K., Suárez-Varela, J., Mestres, A., Barlet-Ros, P. and Cabellos-Aparicio, A, “Unveiling the potential of Graph Neural Networks for network modeling and optimization in SDN”, *In ACM SOSR, 2019.*

Incentives



- **Good opportunity to be introduced in the application of GNN for networking (Hot topic!)
This is the only competition in the world on GNN applied to networks!**
- **Popular event** → The previous edition had **more than 120 participants from 24 countries**
- **Top-3 teams will be publicly recognized** in the challenge website and will receive certificates of recognition
- **Possibility to publish a paper** co-authored with the challenge organizers



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- **Access to the Grand Challenge Finale of the ITU AI/ML in 5G challenge:**
 - Top candidates will be evaluated by the ITU judging committee
 - ITU Awards and presentation at the final conference (Dec 2021)
1st prize: 5,000 CHF
2nd prize: 3,000 CHF
3rd prize: 2,000 CHF



<https://aiforgood.itu.int/about/aiml-in-5g-challenge/>

Timeline



Graph Neural Networking Challenge 2021

Creating a Scalable Network Digital Twin

<https://bnn.upc.edu/challenge/gnnet2021/>

Register at:

<https://bnn.upc.edu/challenge/gnnet2021/registration/>

- **Registration deadline: August 31st**
- Test dataset release: Sep 15th
- Score-based evaluation phase: Sep 16th-Sep 30th
- Final ranking and official announcement: Oct 31st
- ITU Grand Challenge Finale (Nov-Dec 2021)



Website: [\[here\]](#)

Slack channel: [\[here\]](#)



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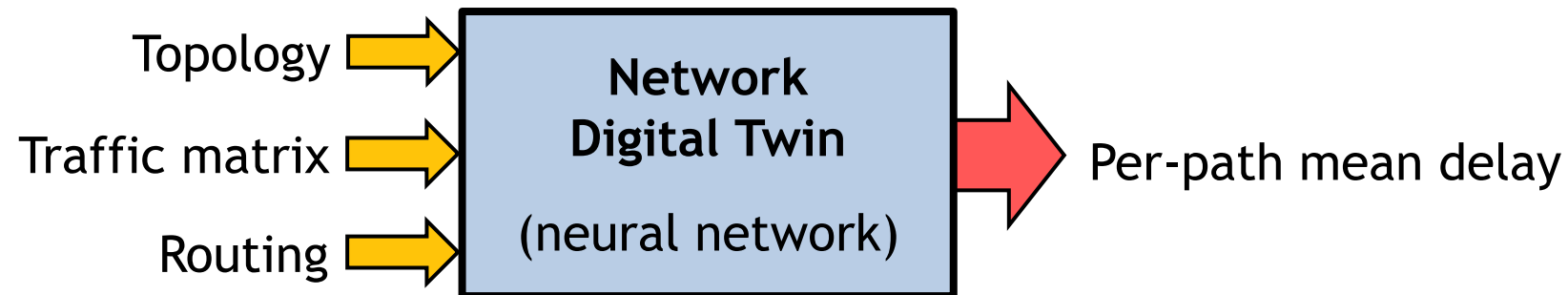
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Guidelines and tips



- **Participants are encouraged to update RouteNet or design their own neural network architectures**
- We provide a tutorial on how to run RouteNet and modify fundamental parts of the code
 - **TensorFlow** → https://github.com/BNN-UPC/GNNNetworkingChallenge/tree/2021_Routenet_TF
 - **iGNNition** → https://github.com/BNN-UPC/GNNNetworkingChallenge/tree/2021_Routenet_iGNNition





Check carefully the datasets

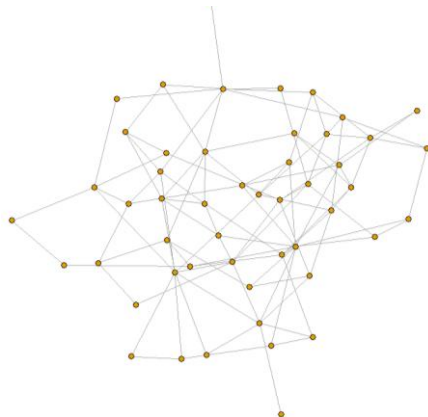
What means larger networks?

Two main features with respect to small networks (training):

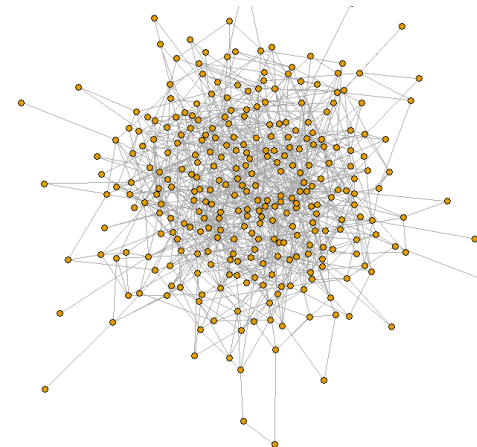
- 1) **Longer paths** (higher network diameter)
- 2) **Higher link capacities**

We need a model that can effectively scale on these two features!

Training (small networks)



Validation / Test (large networks)

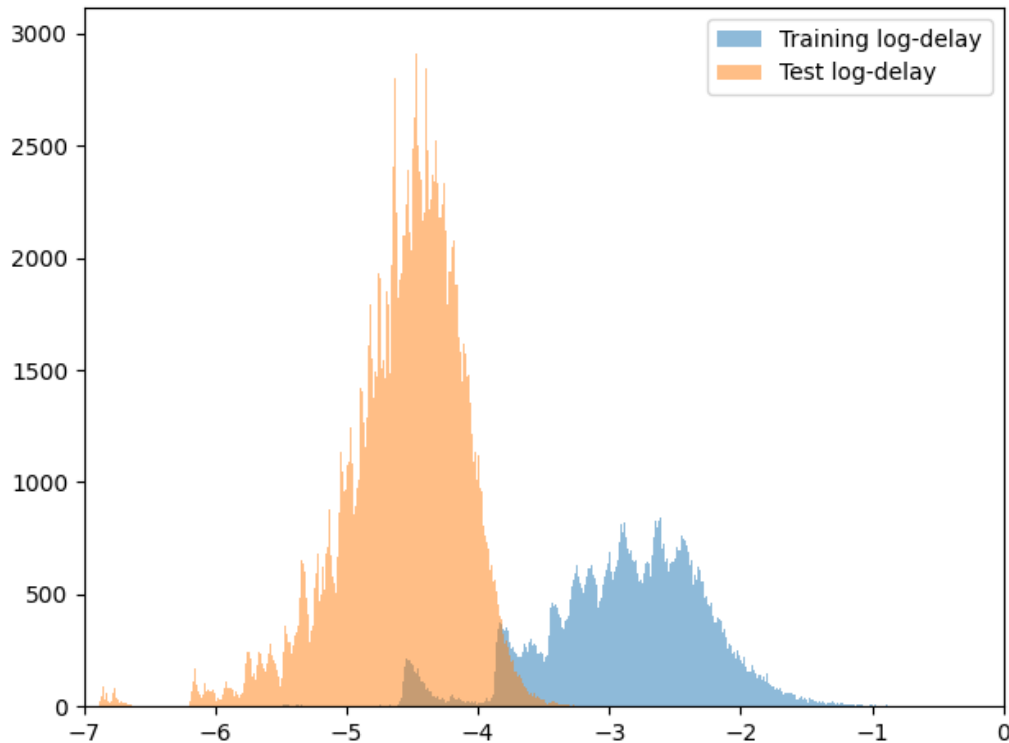




What means larger networks?

Another obstacle:

- Output distributions of the delay (log scale)



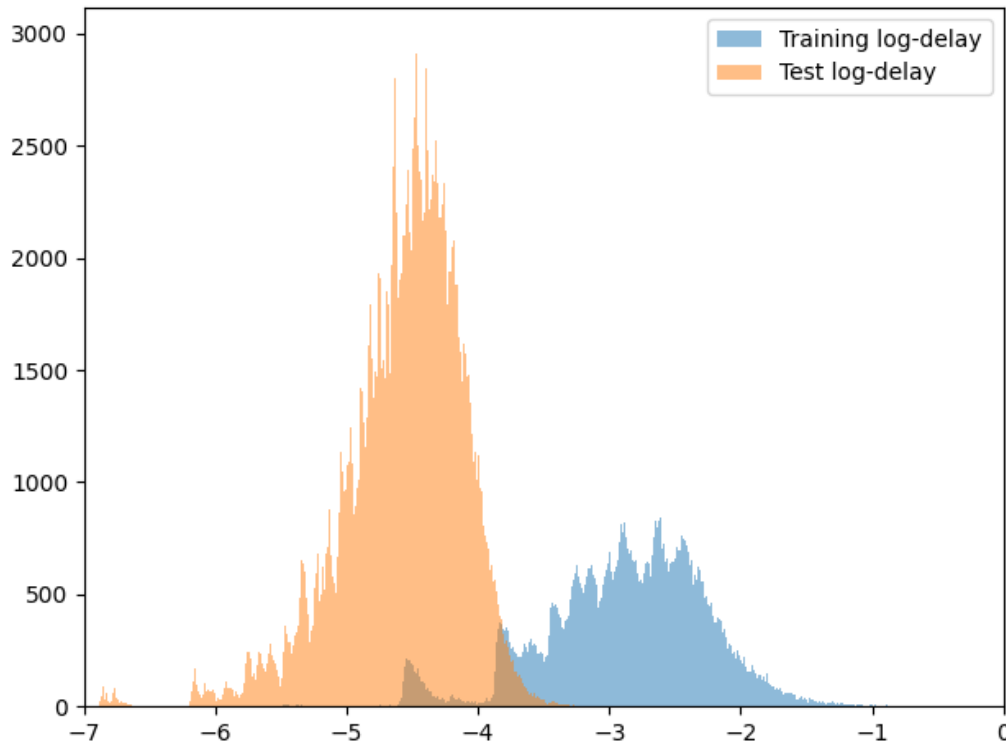
Producing out-of-distribution values with neural networks is an unsolved problem in the ML field!



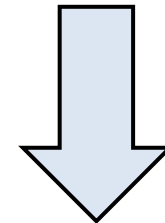
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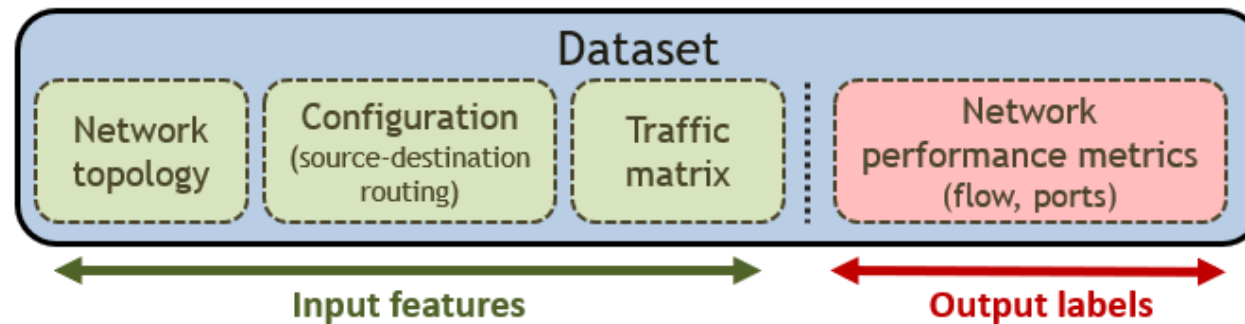
Can we transform the inputs/outputs of the NN to follow similar distributions in the training/validation datasets? (i.e., find “scale-independent” features)



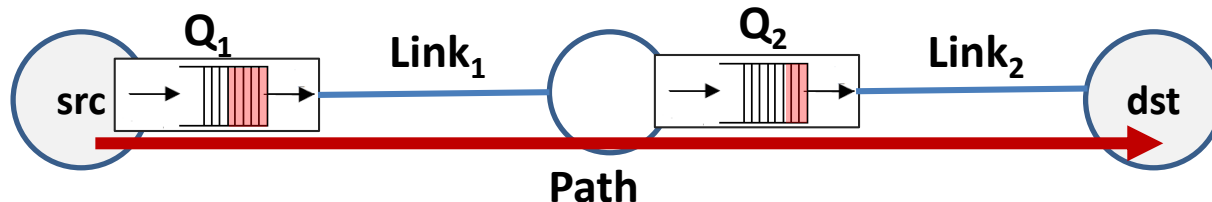


What means larger networks?

Coming back to the datasets:



- Pre/post-processing is allowed, as well as data augmentation from the training dataset
- Port statistics → Queue utilization ranges in $[0,1]$ (**both in training and test!**)
- The NN model can **predict queue utilizations** and then infer path delays with a simple **post-processing**



$$Delay_{path} = \sum_{k=1}^N links Delay_{L_k}$$

$$Delay_{L_1} = Avg_utilization_{Q_1} * Size_{Q_1} / Cap_{L_1}$$

FAQs



Where to start?

- Baseline model (RouteNet)
- Tutorial on how to change features of RouteNet
- Careful analysis of the training/validation datasets (e.g., feature distributions)

I have some technical problems and/or questions (e.g., problems to run the baseline, process the datasets). What are the official channels to contact organizers?

Please do not hesitate to use the challenge mailing list or the ITU slack channel:

Mailing list → challenge2021@bnn.upc.edu (you need to subscribe before: [[link](#)])

Slack channel → https://join.slack.com/t/itu-challenge/shared_invite/zt-eql00z05-CXelo7_aL0nHGM7xDDvTmA

Is it possible to make pre/post-processing in proposed solutions?

- Yes, you can do it either “online” during training/inference, or “offline” (e.g., transform the datasets before training).
- Data augmentation techniques are allowed as long as samples are derived from the training dataset. It is not possible to use new samples from other sources (e.g., network simulators) or the validation/test dataset.