MODIFIED COMMUNICATION NETWORKS FOR THE SIMULATION OF NEUROMORPHIC SYSTEMS

5 JULY 2021 I R. KLEIJNEN, P. EBRAHIMZADEH

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INTRODUCTION

The Advanced Computing Architecture (ACA) Project

Development of a novel NC simulation platform for computational neuroscience

- Biological connectivity level – 10.000 synapses per neuron on average
- Large scale – aiming towards human/mammal brain size [$\approx 10^{11}$ neurons]
- Simulated biological time step 0.1 ms
- 100x faster than biological real time simulation
- Perform and explore online learning by simulating different learning rules

Here we focus on the communication task at hand

- Computation/simulation of neuron and synapse behavior not considered
- Development of a novel high bandwidth, low latency spike communication infrastructure

  $\rightarrow$ Secondary interconnect layer

[More information: https://www.fz-juelich.de/aca/EN/Home/home_node.html]

INTRODUCTION

The Problem at Hand - Bandwidth in the Human Brain

Neuron count: 10^{11}

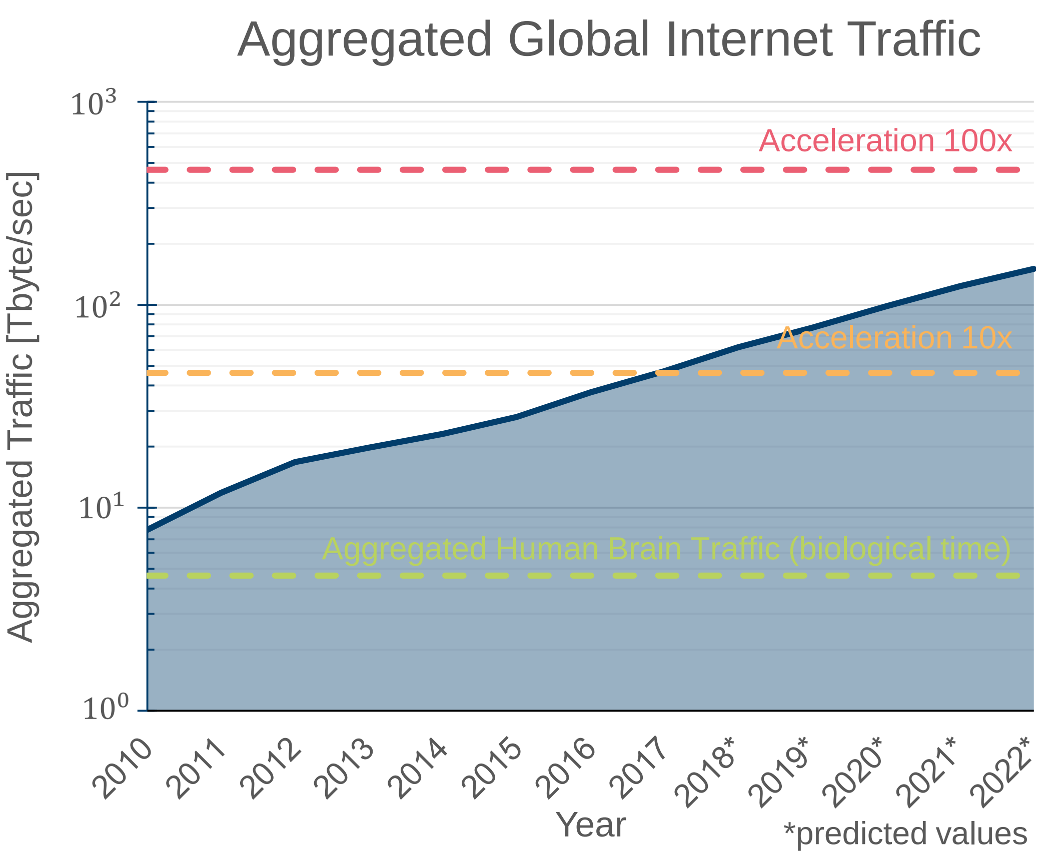
Avg. firing rate: $10\ \mathrm{Hz}$

Source AER coding:

$$\lceil \log_2(10^{11}) \rceil = 37\,\frac{\text{bits}}{\text{spike}}$$

Aggregate data generated:

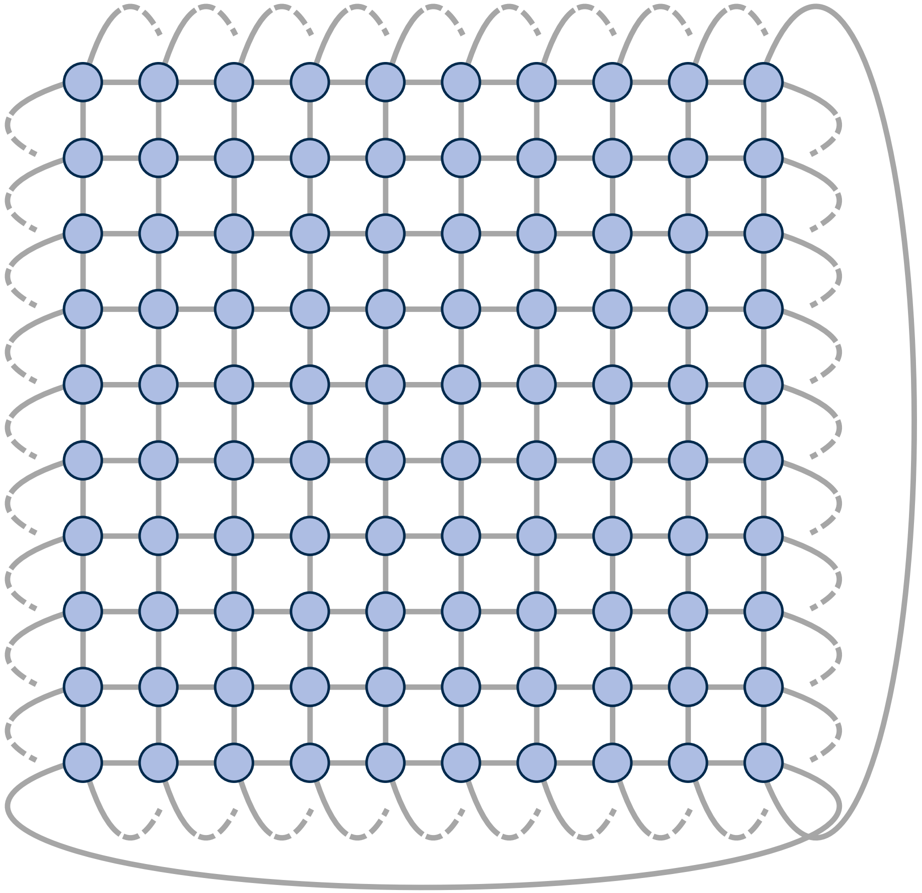
$$10^{11} \times 10\ \mathrm{Hz} \times 37\,\frac{\text{bits}}{\text{spike}} = 4.625\,\frac{\text{TByte}}{\text{sec}}$$



*predicted values
[Source Data: Cisco]

SIMULATION SETUP

Initial grid network



Start off with a N by N square mesh connected in a torus

50 Neurons per Node

Uniform connected NN with $\epsilon = 0.05$

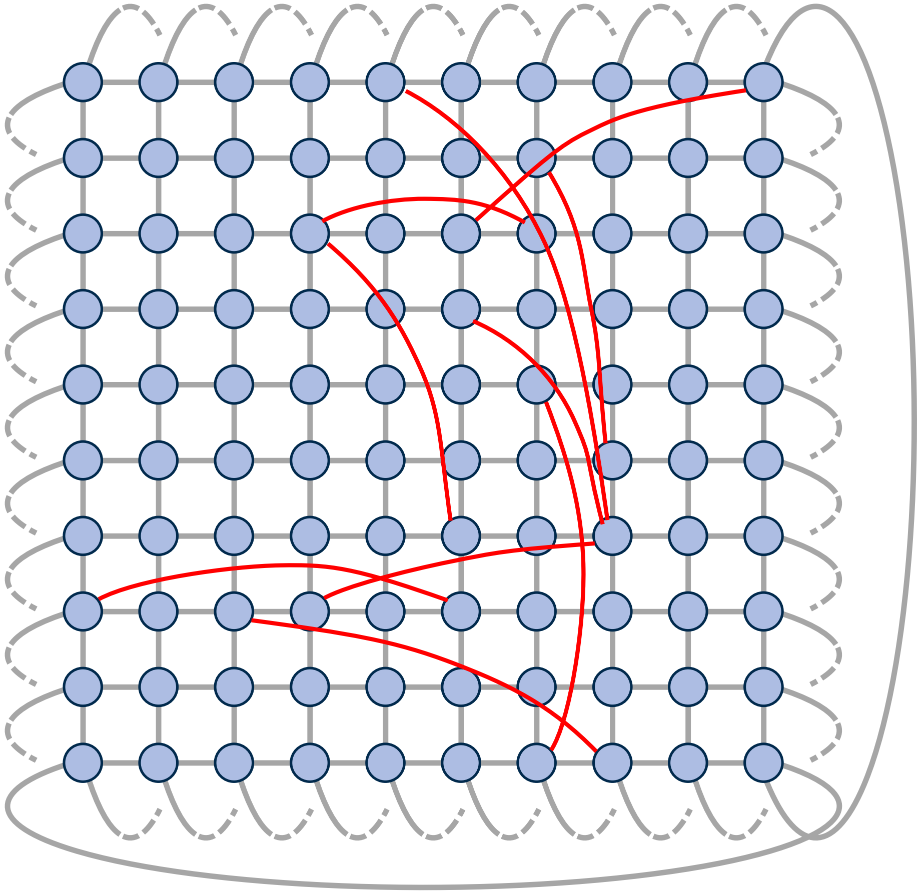
Routing using the Dijkstra algorithm

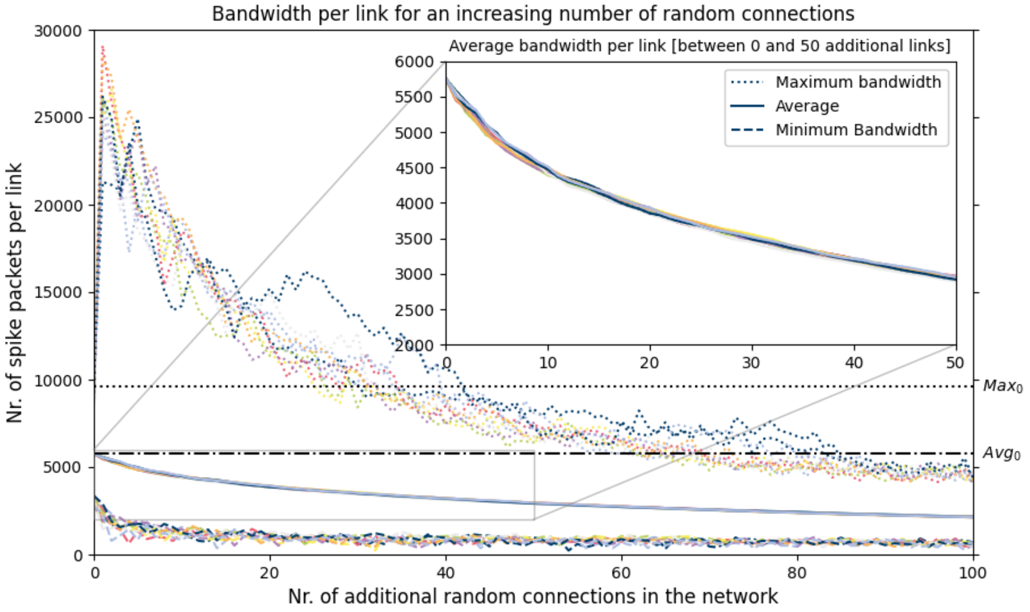
- Number of nodes crossed ("hops") used as distance/latency metric

Total number of bi-directional links: $2N^2$

SIMULATION SETUP

Modified grid – Adding Random Connections





SIMULATION RESULTS

Random Connection Lengths (20x20 grid network)

Short range connections:

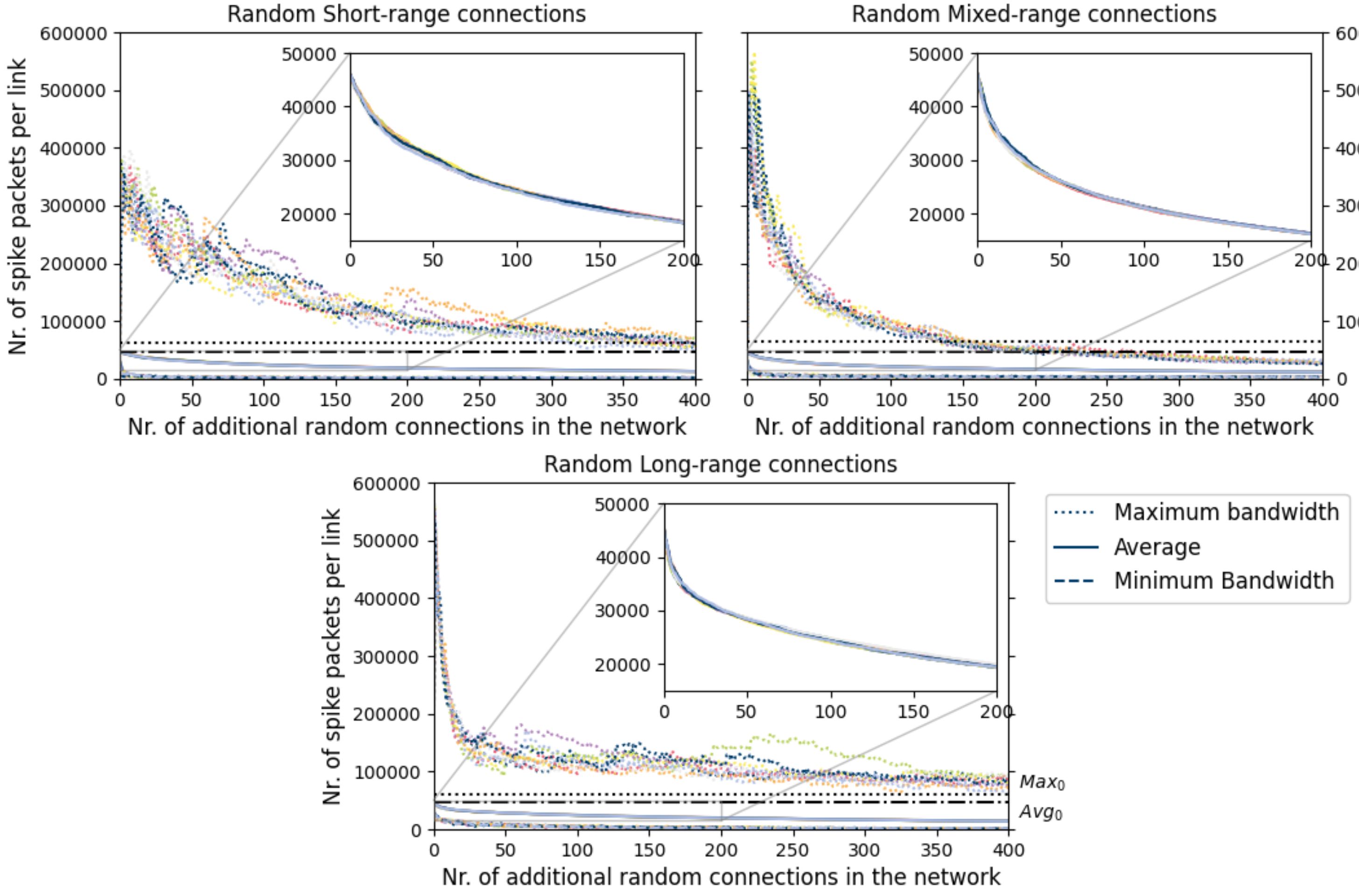
$$3 \leq dist_{Euclidean}(a,b) \leq 5$$

Mixed range connections:

$$3 \leq dist_{Euclidean}(a,b)$$

Long range connections:

$$12 \leq dist_{Euclidean}(a,b)$$



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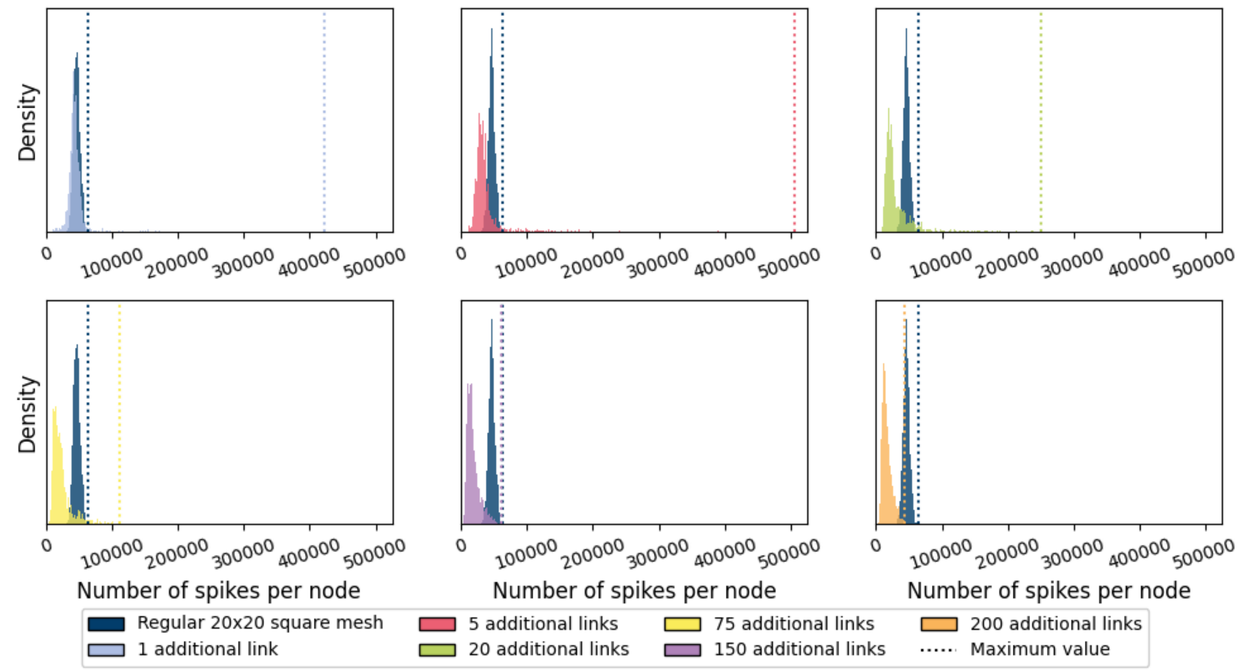
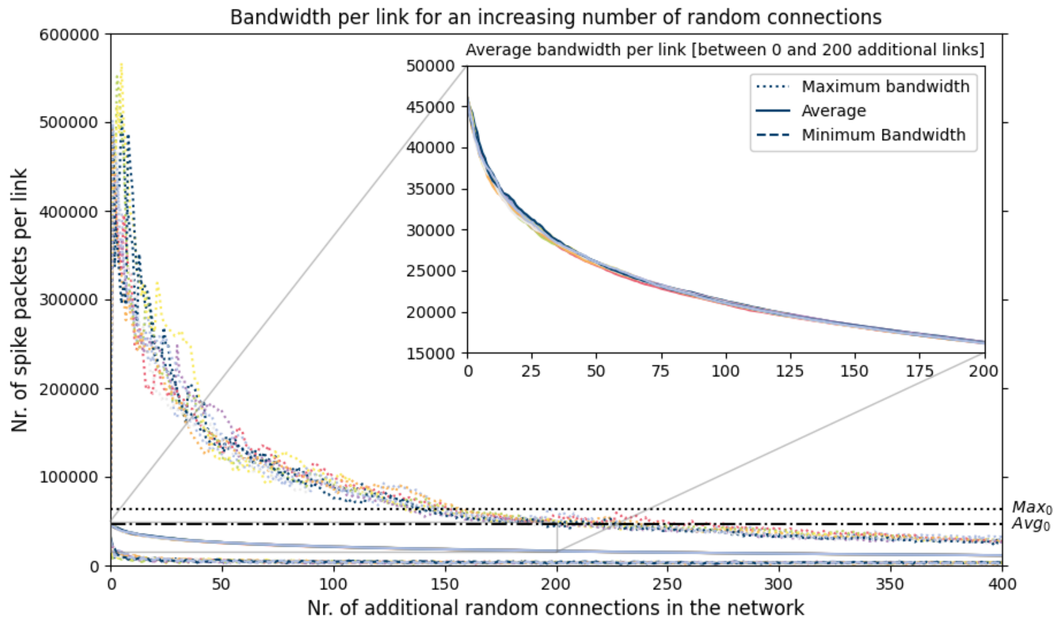
SIMULATION RESULTS

Evolution of the traffic distribution

Histograms of the traffic distribution for different number of additional connections.

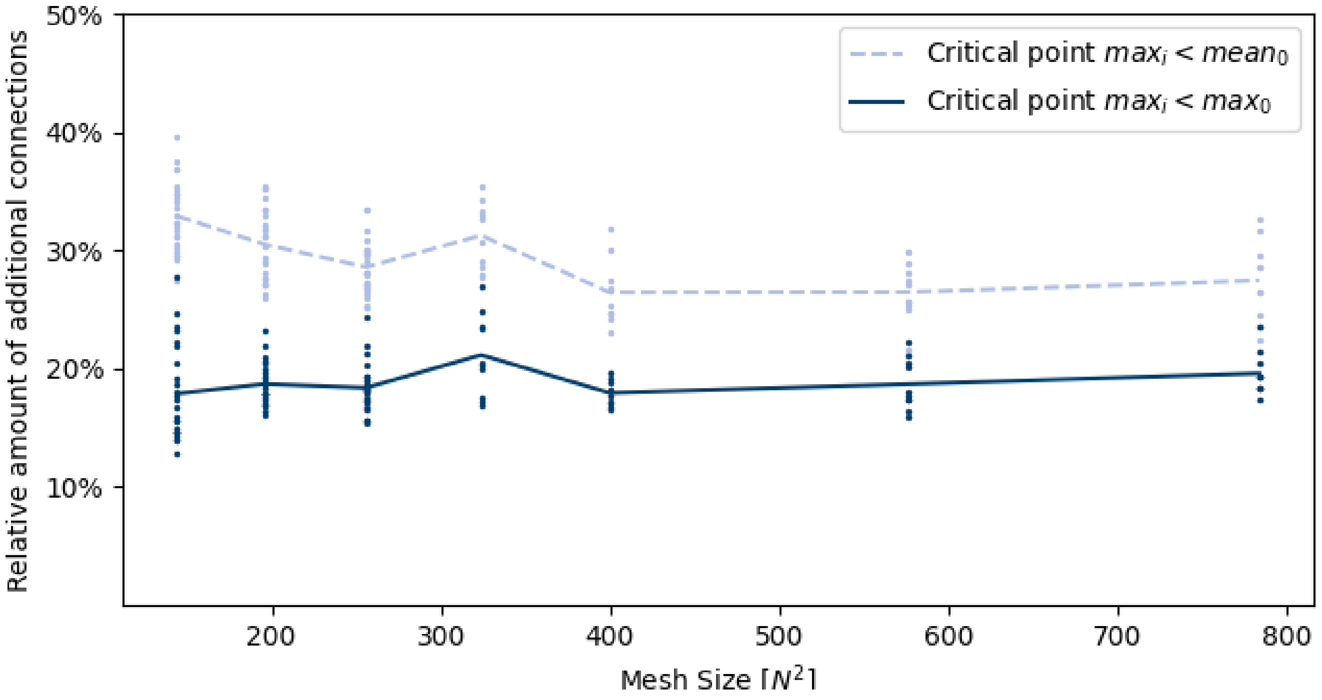




CONCLUSION

Cross-over point

- Solely additional short or long range connections increase the maximum load on parts of the network for increasing N
- Adding connections from different lengths, reduces the networks maximum load, even at larger N (N=28)
- Different configurations of random connections, i.e. different iterations, show only minor differences in performance.
  -> suggests that the structure is of less importance



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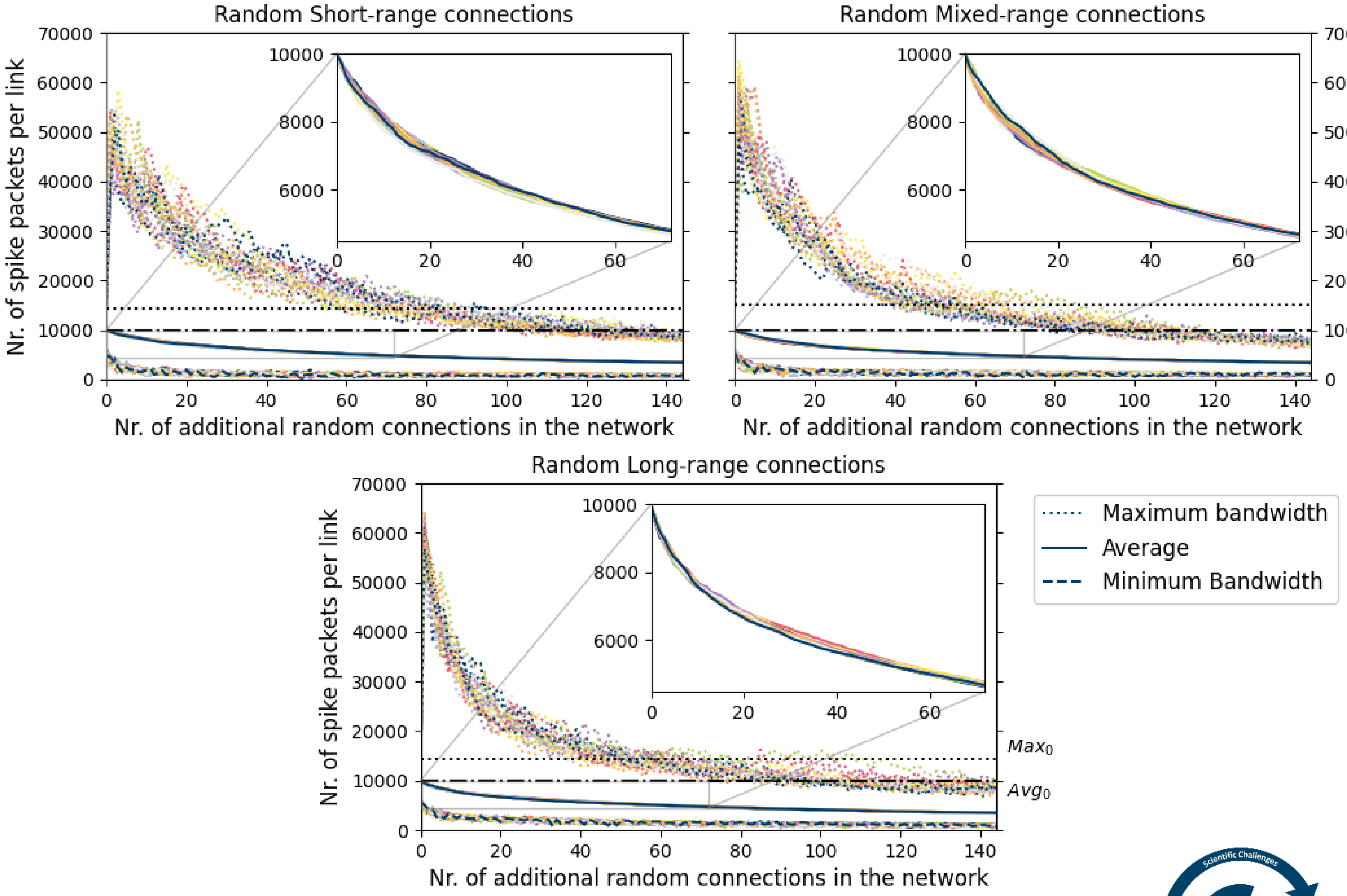
APPENDIX

Simulation Runs

N	Number of simulation steps:	Number of Iterations	Number of Parameter setups:	Total number of simulation runs
12	145	25	3	10875
14	197	25	3	14775
16	257	25	6	38550
18	325	10	3	9750
20	401	10	6	24060
24	145	10	3	4350
28	50	10	3	1500

APPENDIX

12x12 Mesh



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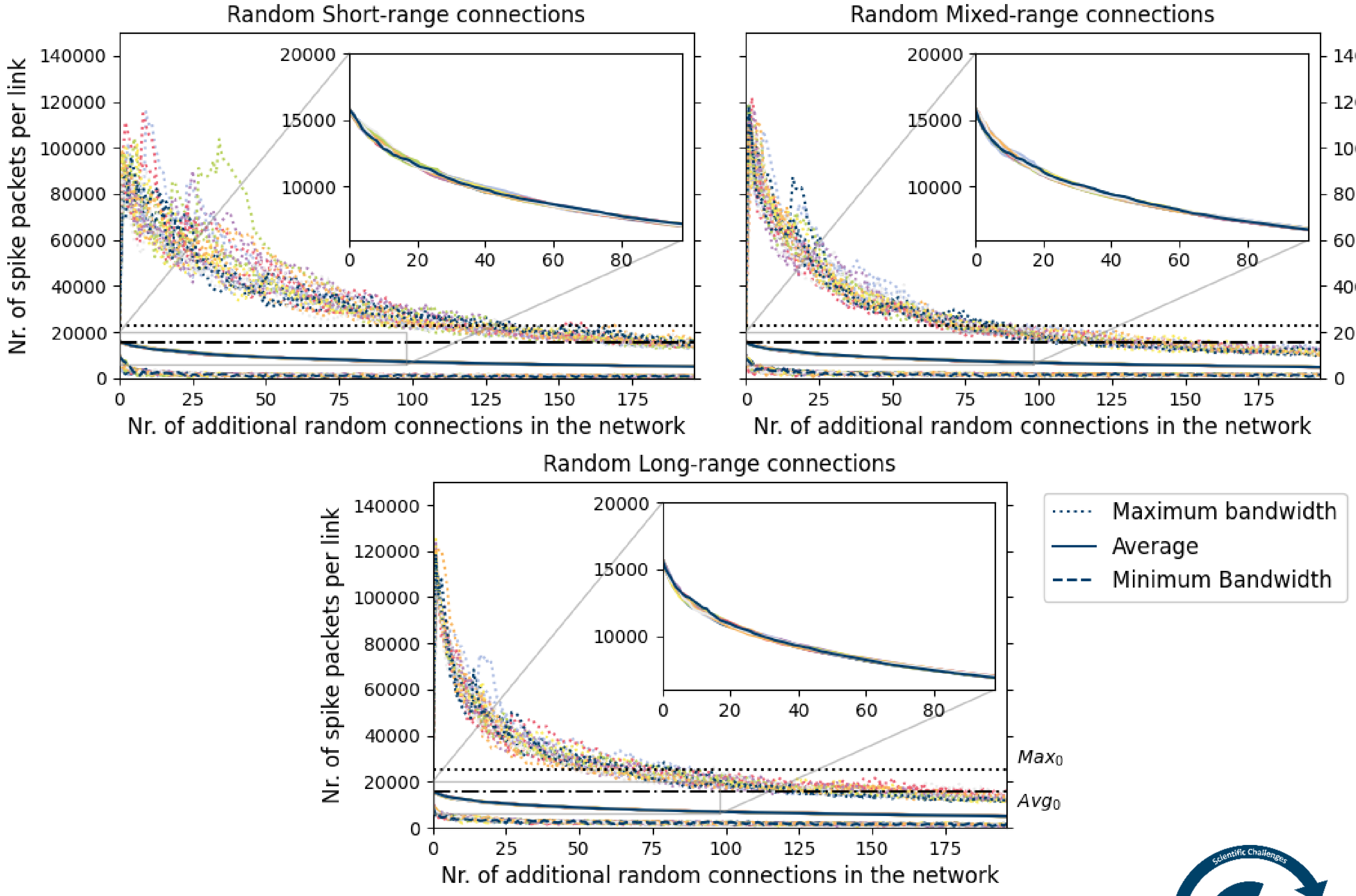
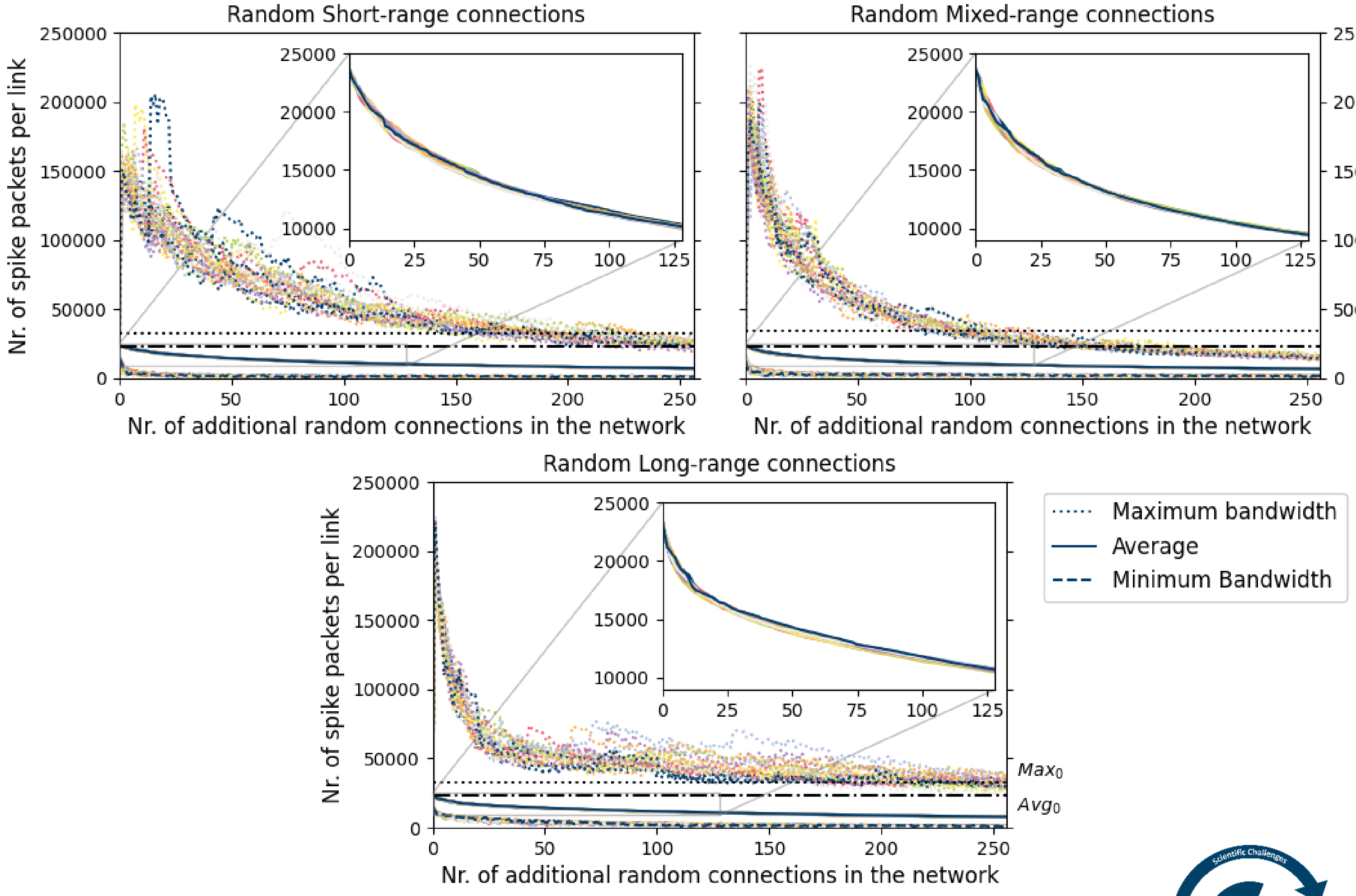
14x14 Mesh



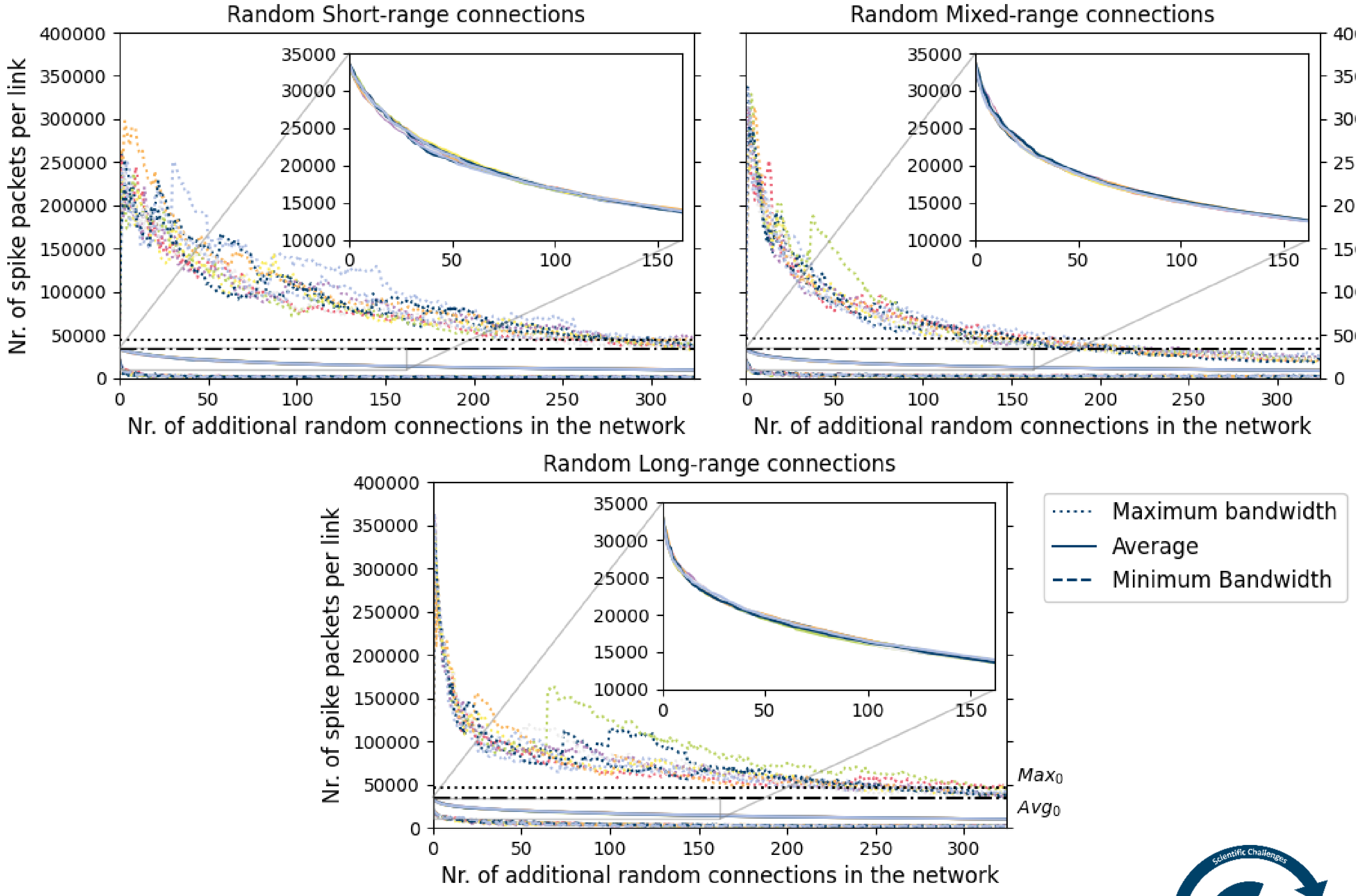
APPENDIX

16x16 Mesh



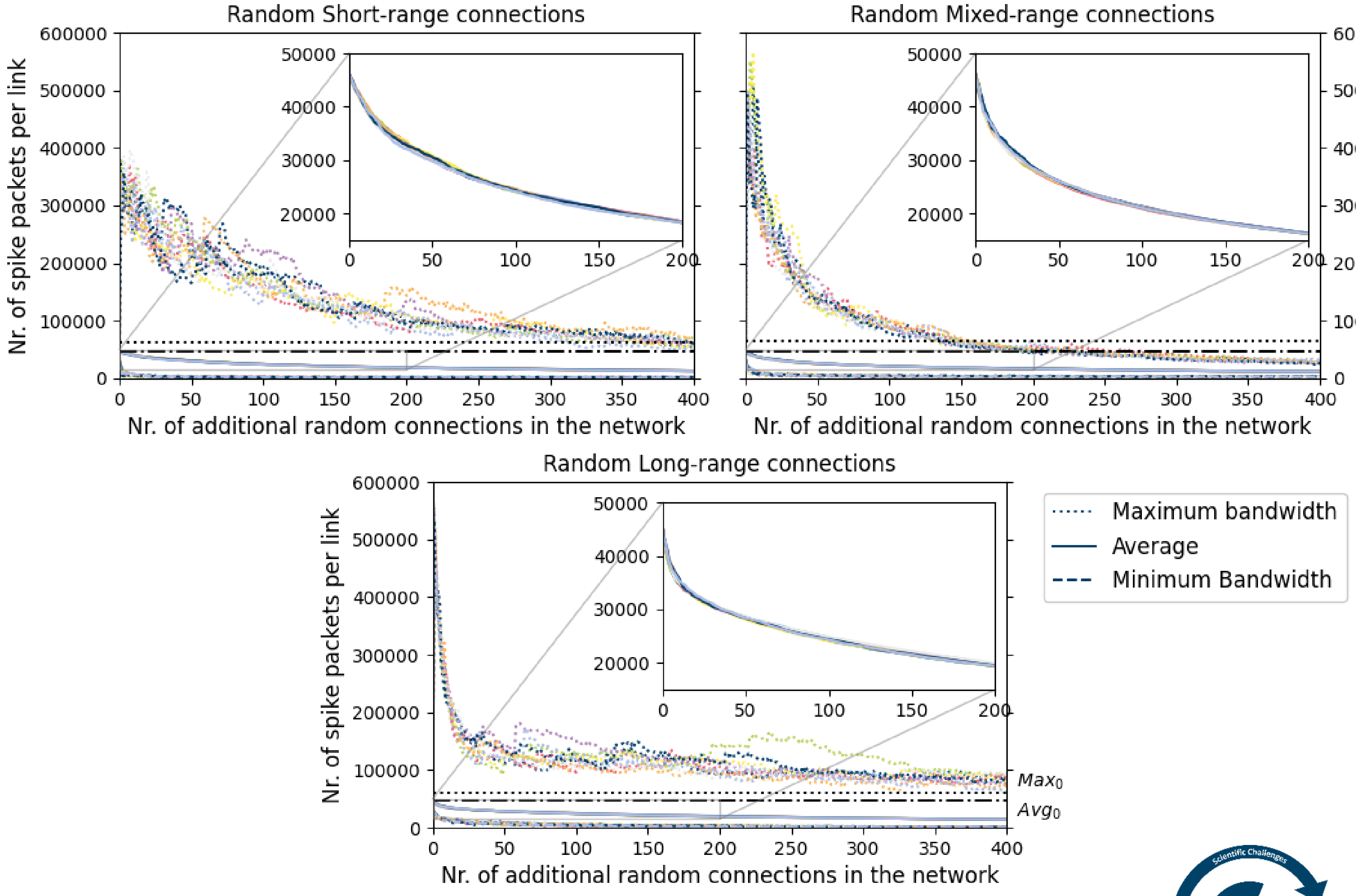
APPENDIX

18x18 Mesh



APPENDIX

20x20 Mesh



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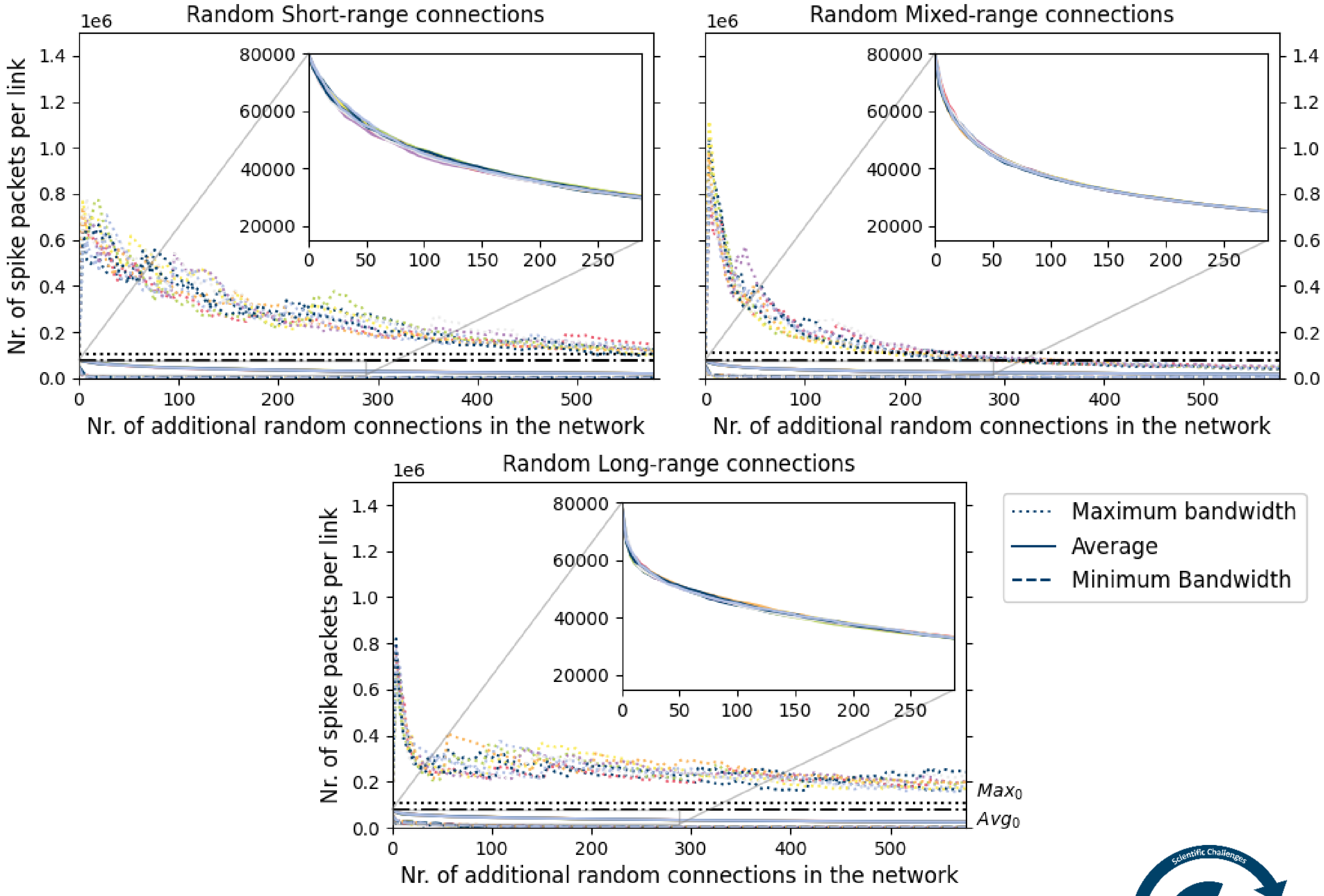
24x24 Mesh



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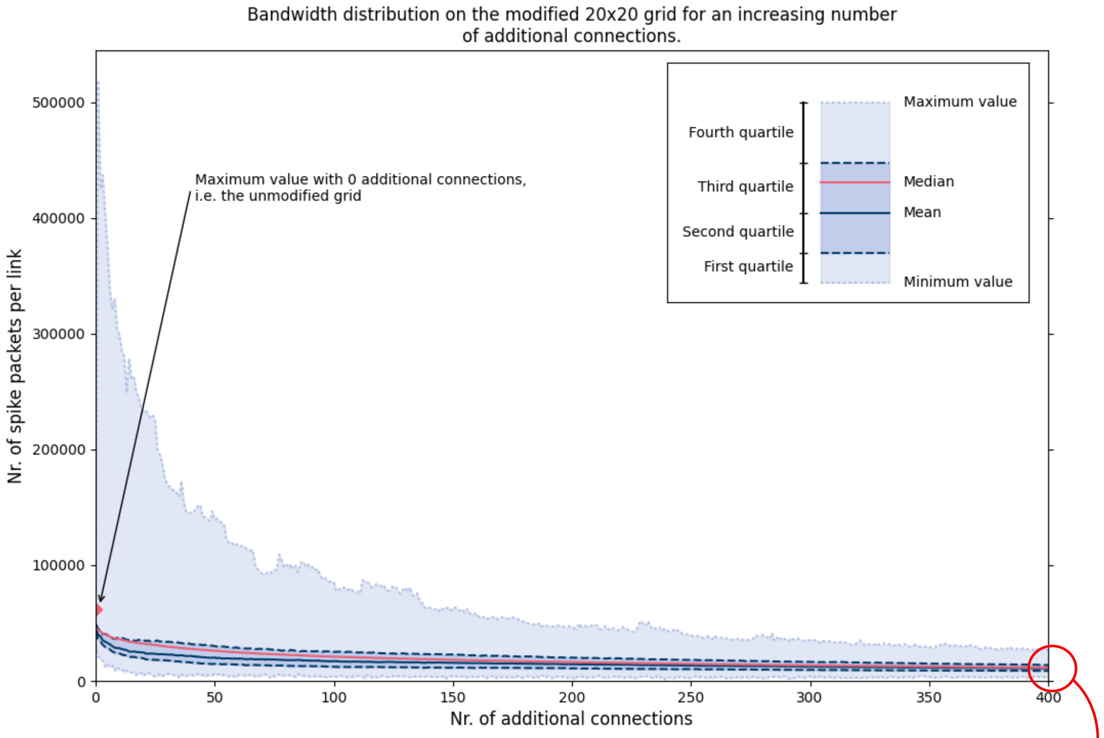
Distance Metric – Nr. Of “Hops” vs. Wirelength

Nr. of “hops



Median with 400 additional connections = 11460.225

Wirelength