5G Networks: Slicing and Function Placement

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SENDATE PLANETS
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erc European Research Council

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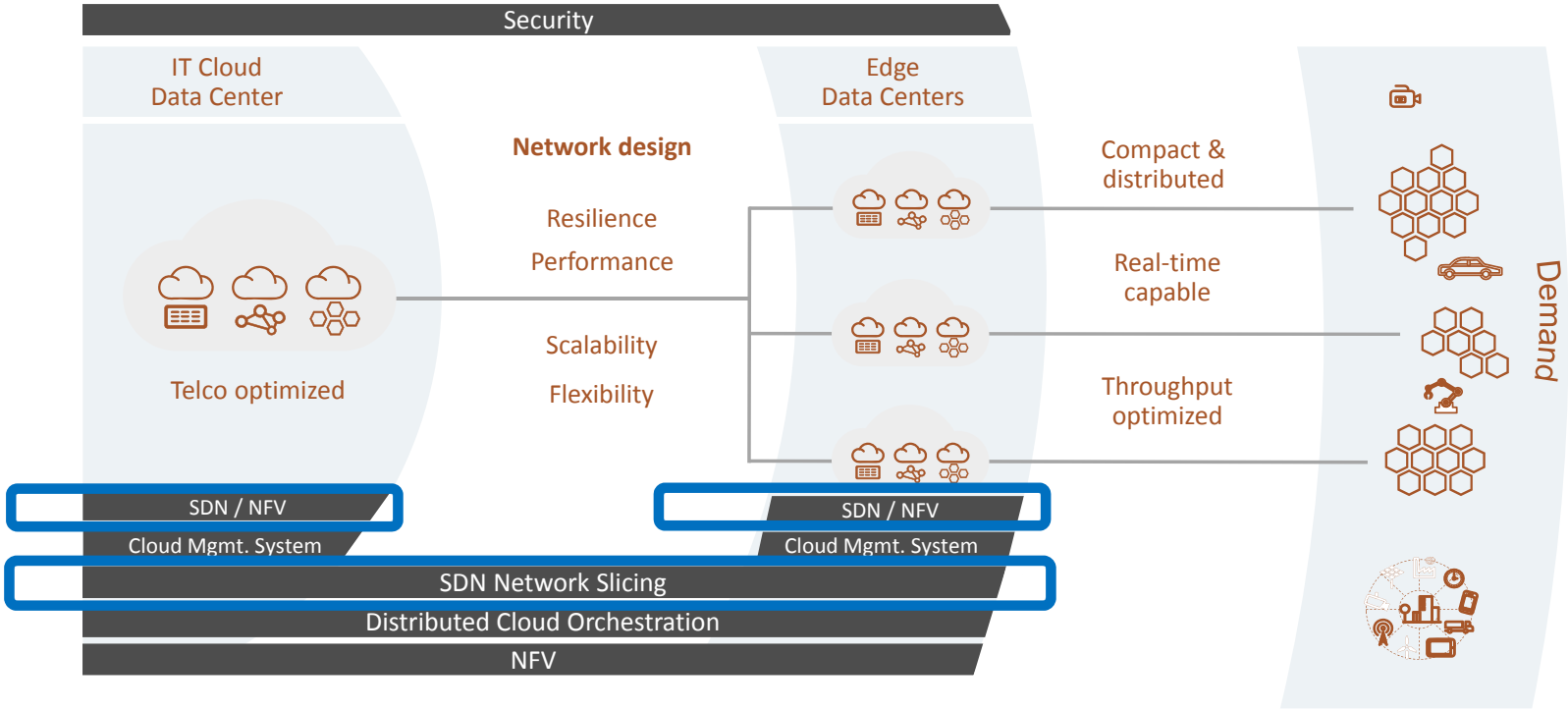
5G Networks – my viewpoint



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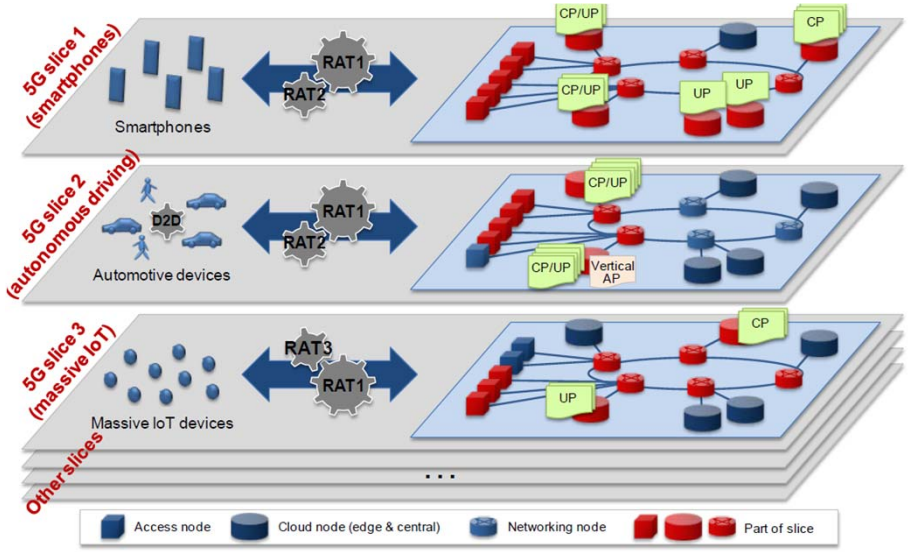
Slicing and Network Functions



Source: NGMN 5G white paper

Flexibility [1] to react to dynamic requests

for

- *Slicing*: embedding and isolation
- *Network functions placement* [2]

Network softwarization helps:
SDN, NV, NFV as enablers

[1] W. Kellerer, et al: **How to Measure Network Flexibility? A Proposal for Evaluating Softwarized Networks**. IEEE Communications Magazine, 2018

[2] A. Basta, W. Kellerer, M. Hoffmann, H. Morper, K. Hoffmann, **Applying NFV and SDN to LTE Mobile Core Gateways; The Functions Placement Problem**, ACM SICGOMM 2014 Workshop on AllThingsCellular (ATC), Chicago, IL, USA, August 2014.

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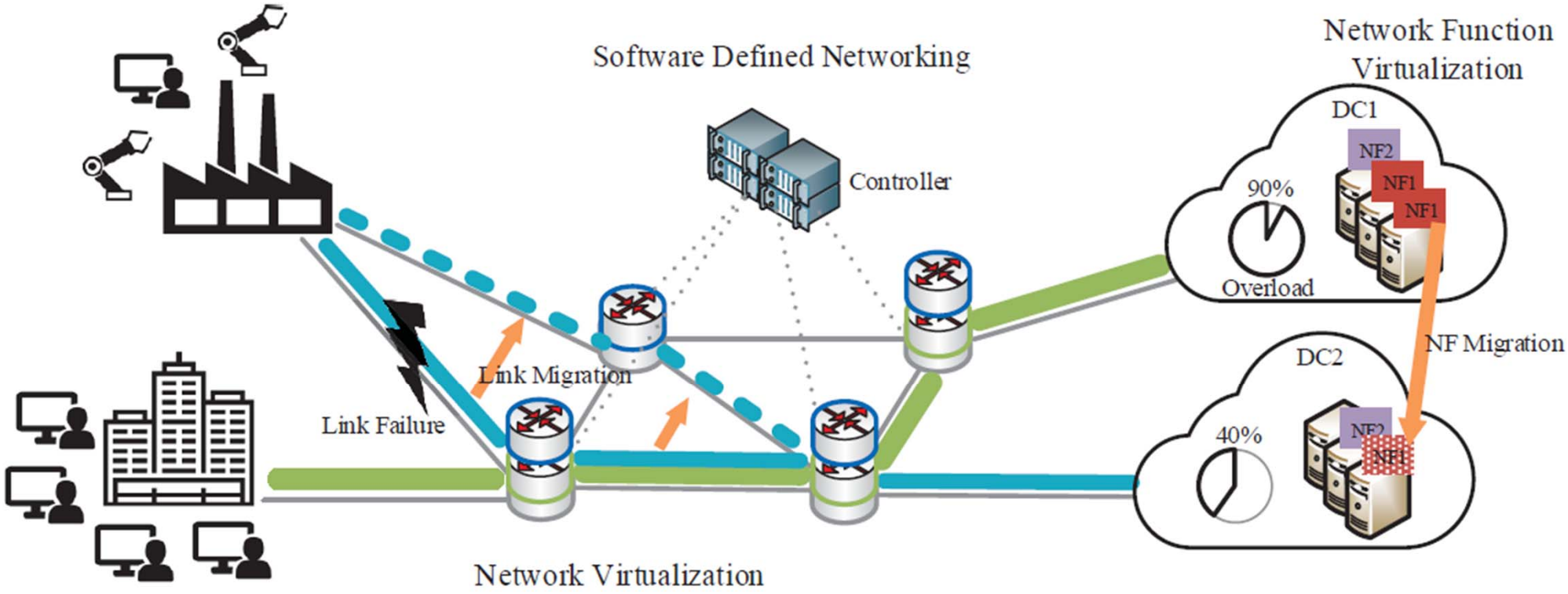
Network Softwarization can provide a solution



Unleashing 5G flexibility through combining NV + SDN + NFV

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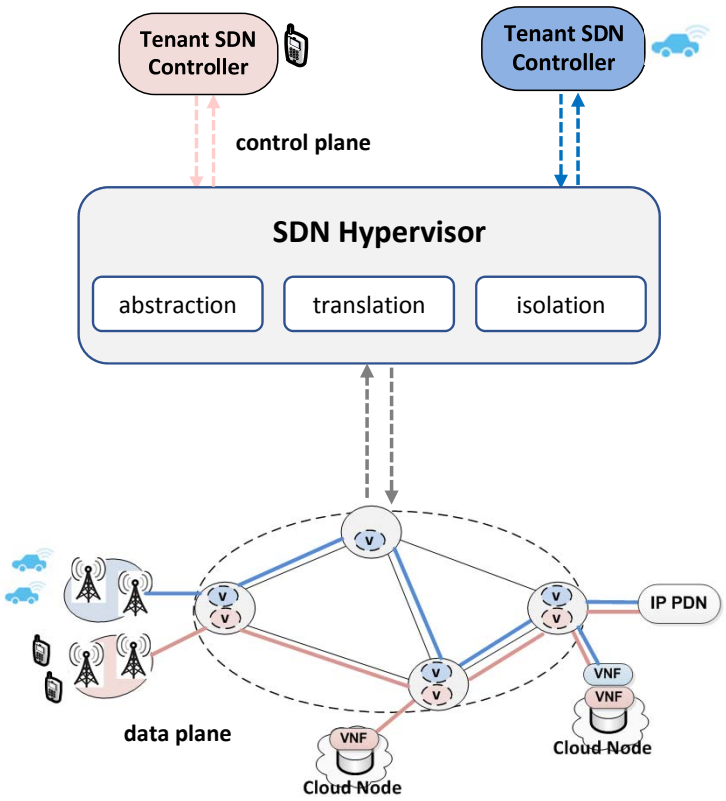
Possible Realization: HyperFLEX [3]

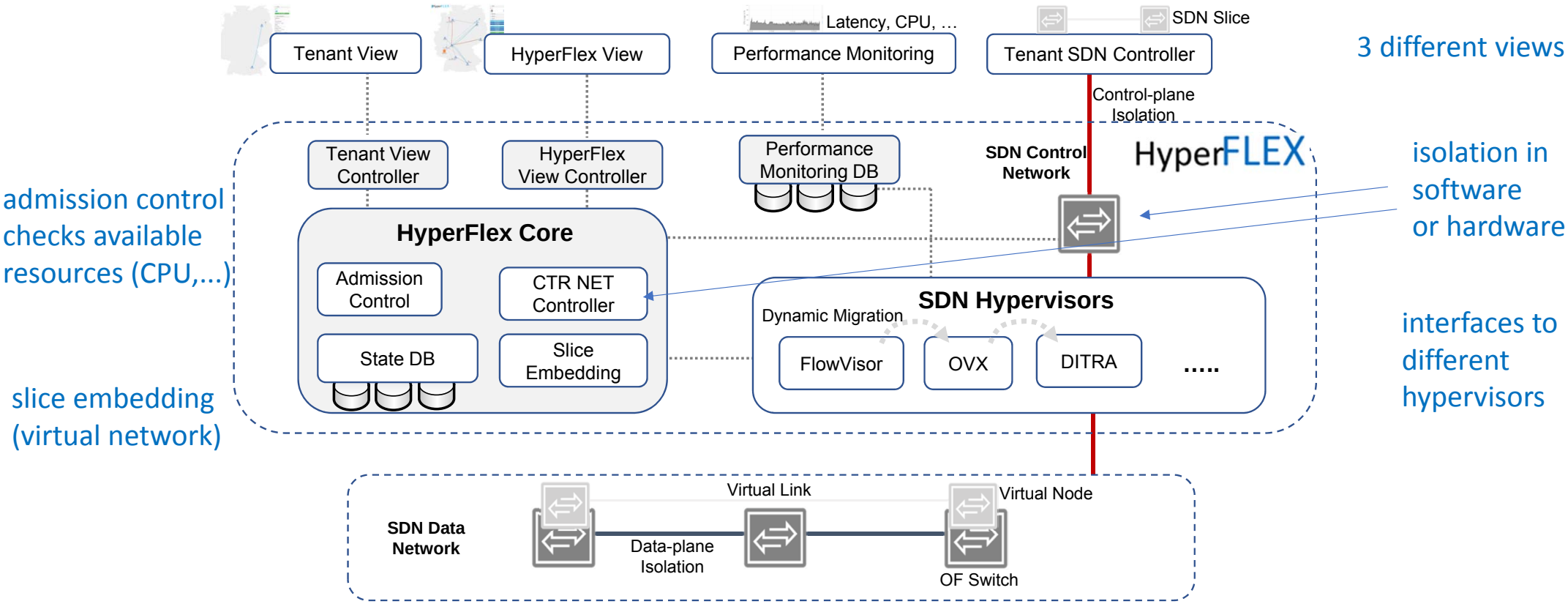
bring your own SDN controller



- **HyperFLEX**: SDN virtualization layer for flexible, reliable and dynamic SDN slicing and interconnecting Virtual Network Functions
- On-demand virtual network resources to the service providers, i.e. tenants
- Dynamic changes during the run-time – coping with VNF migrations
- Isolation and performance guarantees for the tenant
- Multiple tenants or service providers coexist on the same network without performance degradation

[3] A. Blenk, A. Basta, W. Kellerer. **HyperFlex: An SDN virtualization architecture with flexible hypervisor function allocation.** Integrated Network Management (IM), 2015 IFIP/IEEE International Symposium on. IEEE, 2015.

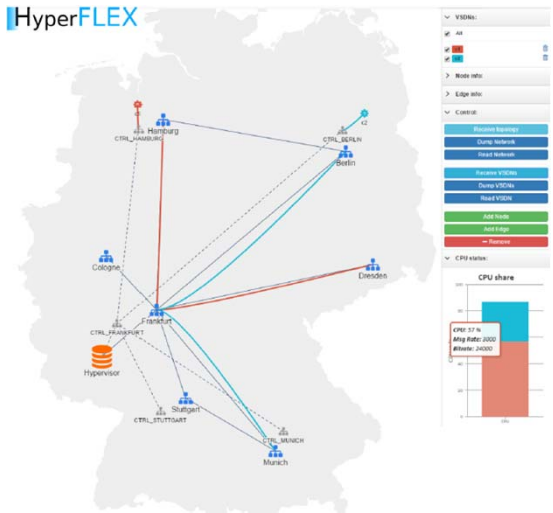
HyperFLEX Architecture



HyperFLEX: Admission Control

- Automated request of virtual SDN slices
- Guarantees for control plane, i.e., mapping of slice requests to HV resources
- Run time update to slice
- Embedding of virtual links on the physical network

(a) Tenant View



(b) HyperFlex View

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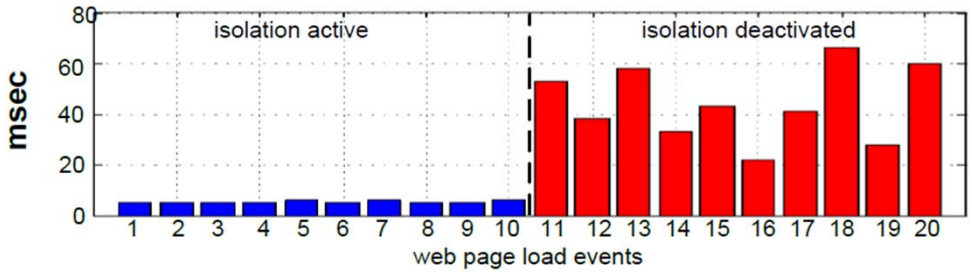
HyperFLEX: Isolation

- correlation between control message rate and hypervisor CPU consumption
- assign control plane rate to each slice → hypervisor CPU isolation
- change isolation option on run time: “net“ vs. “soft“

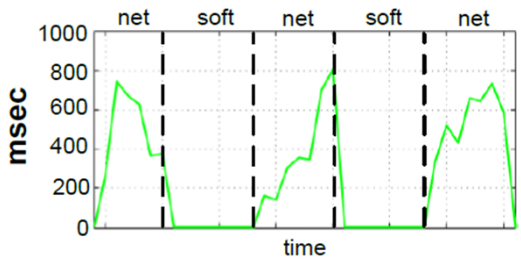


(a) vSDN1: web page load latency

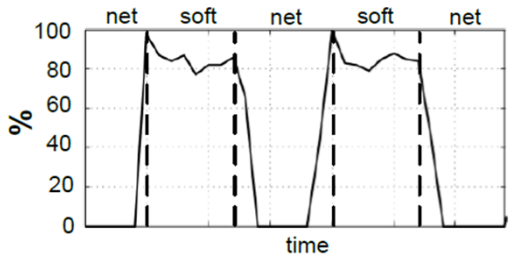
- vSDN2 exceeds its SLA
- isolation minimizes impact on vSDN1 latency

isolation options

- net: no control plane loss, at cost of latency
- soft: low latency, at cost of possible loss



(b) vSDN2: control-plane latency



(c) vSDN2: control-plane loss

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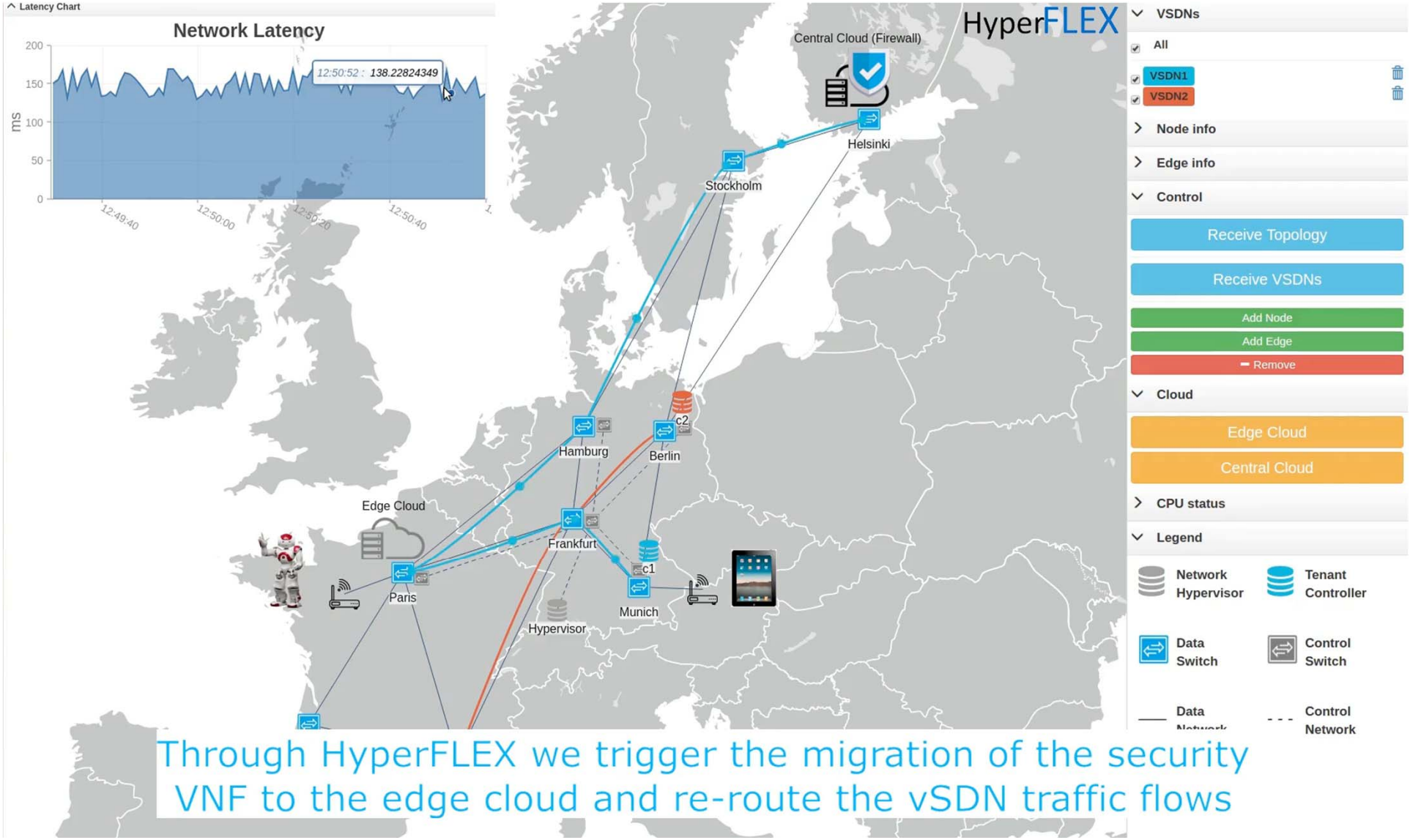
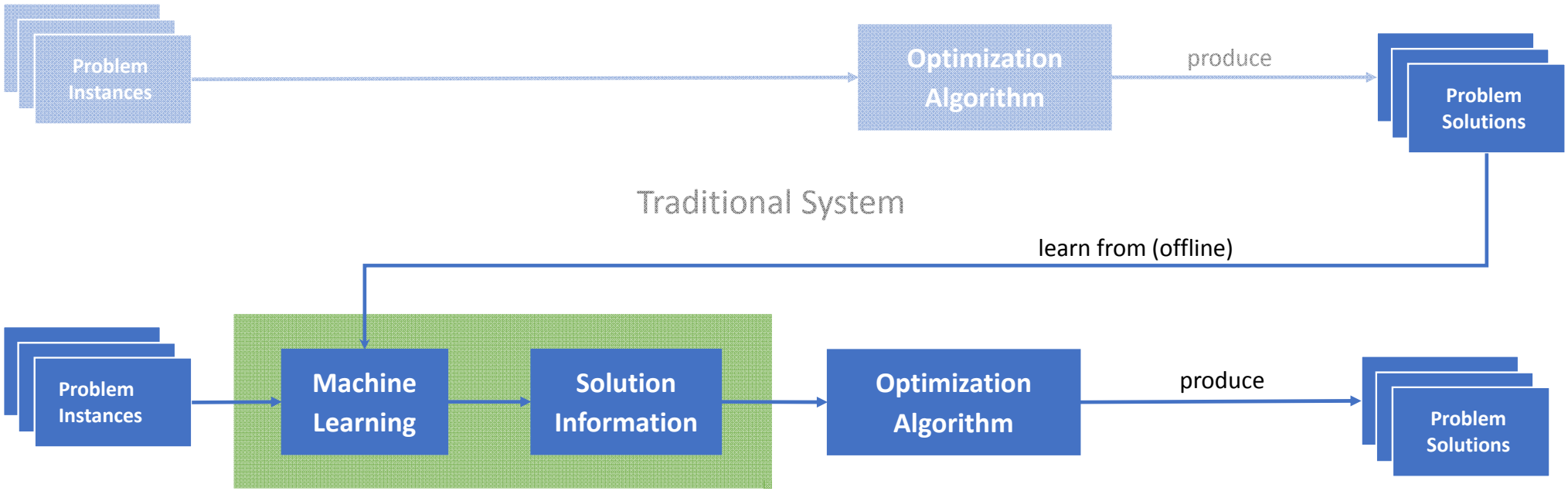
HyperFLEX in Operation



Through HyperFLEX we trigger the migration of the security VNF to the edge cloud and re-route the vSDN traffic flows

How can we boost the solving of the related optimization problems?



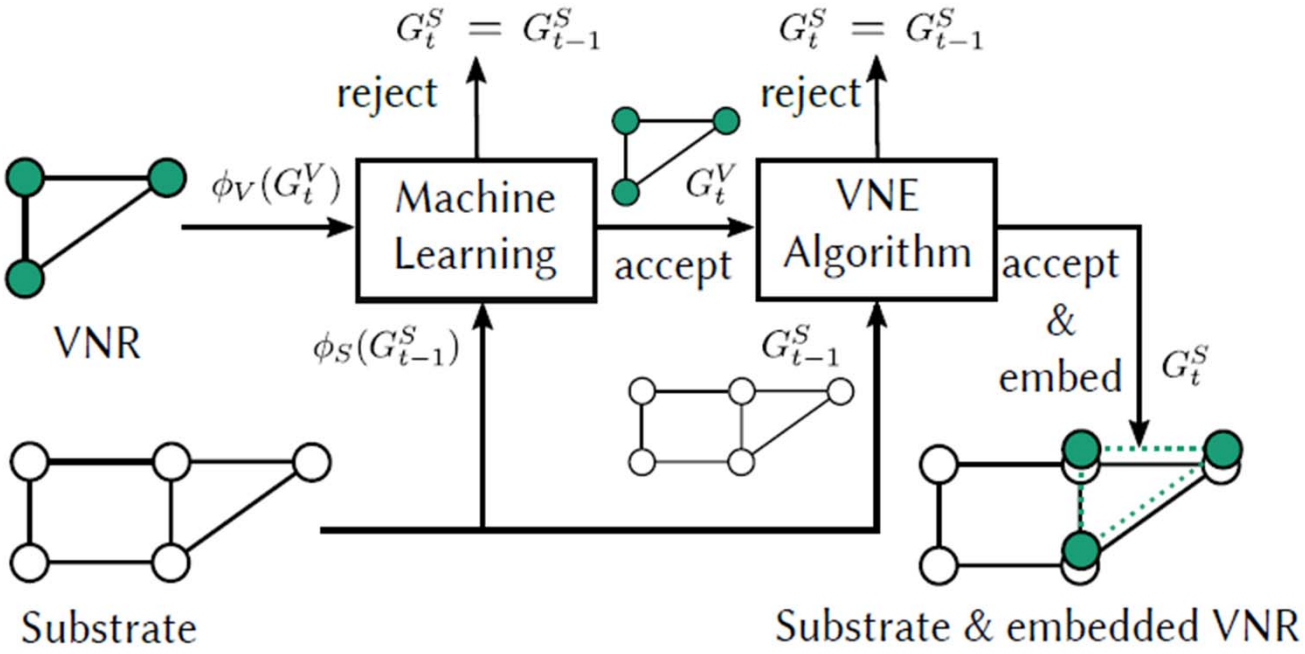
o'zapft is framework [4]

- State-of-the-art: Neglects produced data!
- Idea: Use problem/solution data generated by algorithms regularly solving problems

[4] A. Blenk, P. Kalmbach, S. Schmid, W. Kellerer: ***o'zapft is: Tap Your Network Algorithm's Big Data!***
ACM SIGCOMM 2017 Wrksp. on Big Data Analytics and Machine Learning for Data Communication Networks (Big-DAMA), 2017.

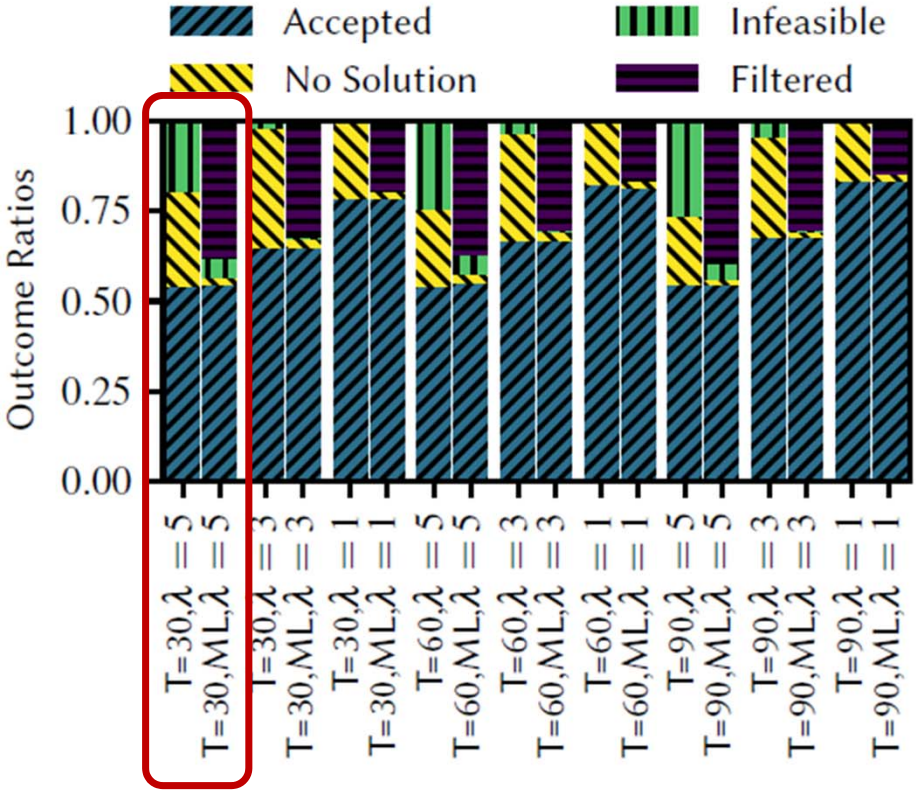
Data Available: P. Kalmbach, J. Zerwas, M. Manhart, A. Blenk, S. Schmid, W. Kellerer. Data on "o'zapft is Tap Your Network Algorithm's Big Data!",2017 https://doi.org/10.14459/2017md1361589

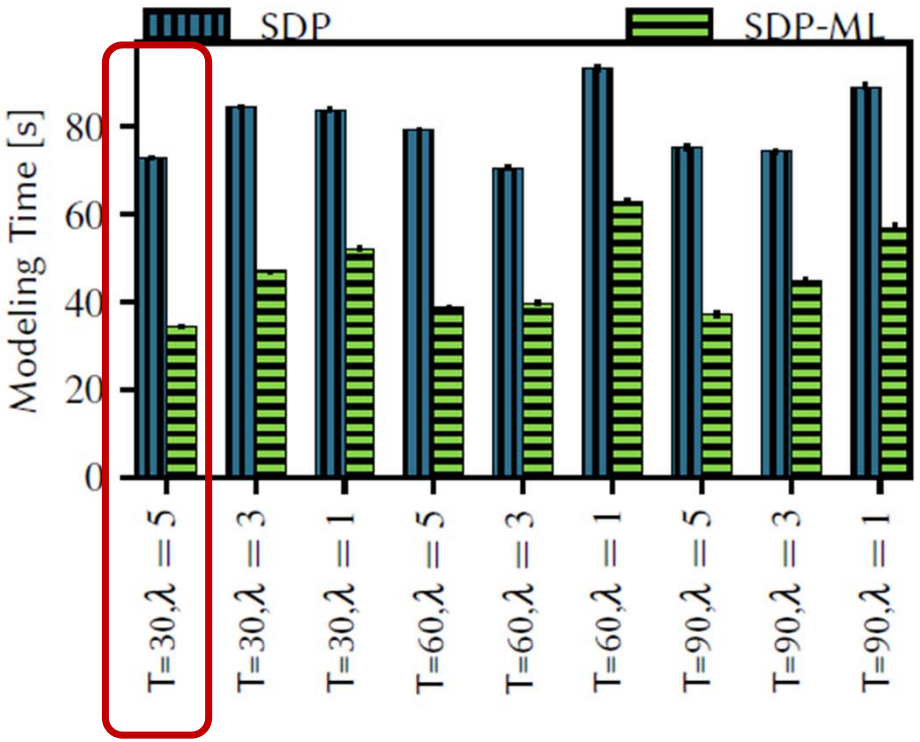
Case Study: Predicting Acceptance Probabilities of VNE Requests



- Supervised learning: use data with accepted and rejected requests! Offline training!
- Recurrent neural network (RNN) for classification
- Filter infeasible and requests with unacceptable algorithm runtime (“no solution“)

Can we speed-up optimal algorithms using admission control?





- Efficient Filtering of infeasible and unacceptable requests
- Efficient saving of model creation time

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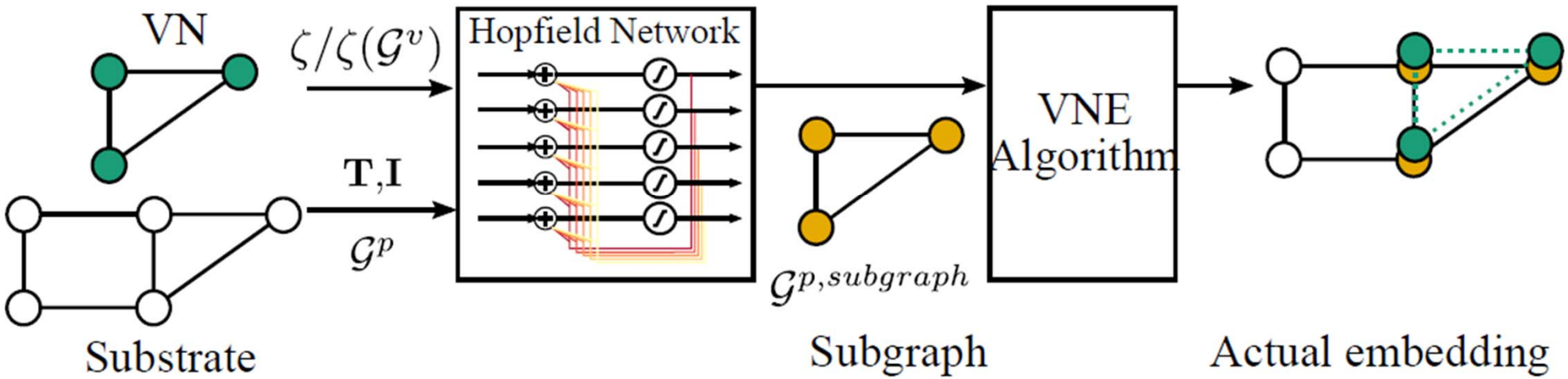
Latest Results: Neurovine [5]

Hopfield neural network to preprocess (subgraph extraction) VNE algorithms
– tailored filtering



- Idea: Extract subgraph with physical nodes close to each other and high available capacities

[5] A. Blenk, P. Kalmbach, J. Zerwas, M. Jarschel, S. Schmid, W. Kellerer: ***NeuroViNE: A Neural Preprocessor for Your Virtual Network Embedding Algorithm***
IEEE INFOCOM 2018 (main conference), Honolulu, HI, USA, April 15-19, 2018.

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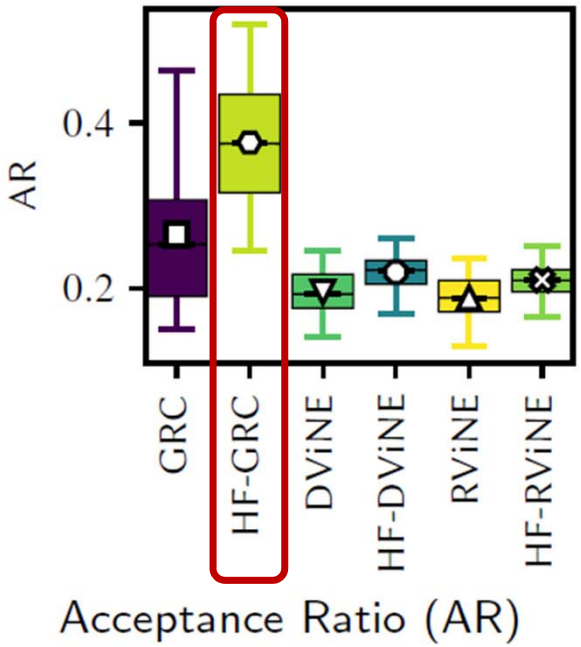
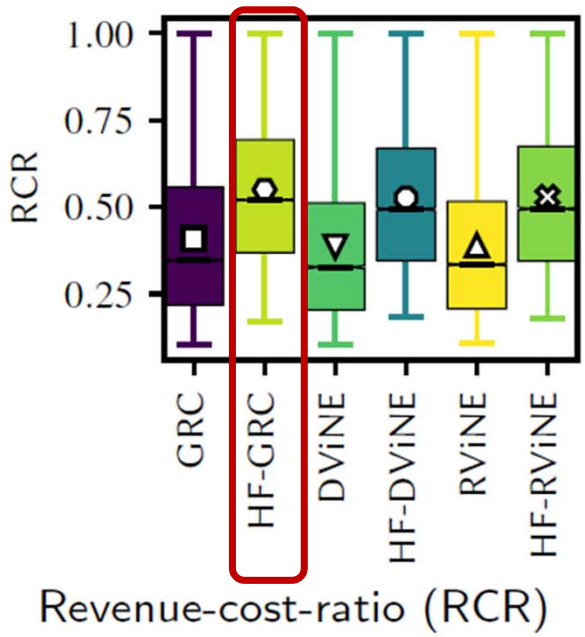
Neurovine: Efficiency on Real Network Topologies





- VNE algorithms (GRC, DViNE, RViNE) vs. Hopfield variants (HF-GRC, HF-DViNE, HF-RViNE)
- NeuroViNE accepts more networks with less costs

Conclusion

Key takeaways

- 5G → flexibility for slicing and function placement
  combining network softwarization enablers: SDN + NV + NFV
- Example for effective combination keeping the flexibility: HyperFLEX
- Speedup slice embedding and function placement through Machine Learning-based preprocessing!

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Key References

Andreas Blenk, Patrick Kalmbach, Johannes Zerwas, Michael Jarschel, Stefan Schmid, Wolfgang Kellerer:
NeuroViNE: A Neural Preprocessor for Your Virtual Network Embedding Algorithm
IEEE INFOCOM 2018 (main conference), Honolulu, HI, USA, April 15-19, 2018.

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ACM SIGCOMM 2017 Wrks. on Big Data Analytics and Machine Learning for Data Communication Networks (Big-DAMA), 2017.

A. Basta, W. Kellerer, M. Hoffmann, H. Morper, K. Hoffmann,
Applying NFV and SDN to LTE Mobile Core Gateways; The Functions Placement Problem,
ACM SICGOMM 2014 Workshop on AllThingsCellular (ATC), Chicago, IL, USA, August 2014.

A. Blenk, A. Basta, J. Zerwas, M. Reisslein, W. Kellerer,
Control Plane Latency with SDN Network Hypervisors: Cost of Virtualization,
IEEE Transactions on Network and Service Management, Sept. 2016.

A. Blenk, A. Basta, W. Kellerer.
HyperFlex: An SDN virtualization architecture with flexible hypervisor function allocation.
Integrated Network Management (IM), 2015 IFIP/IEEE International Symposium on. IEEE, 2015.

HyperFLEX: https://github.com/tum-lkn/HyperFLEX

W. Kellerer, et al: **How to Measure Network Flexibility? A Proposal for Evaluating Softwarized Networks**.
IEEE Communications Magazine, 2018.

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