Chair of Communication Networks
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Empowering Self-Driving Networks

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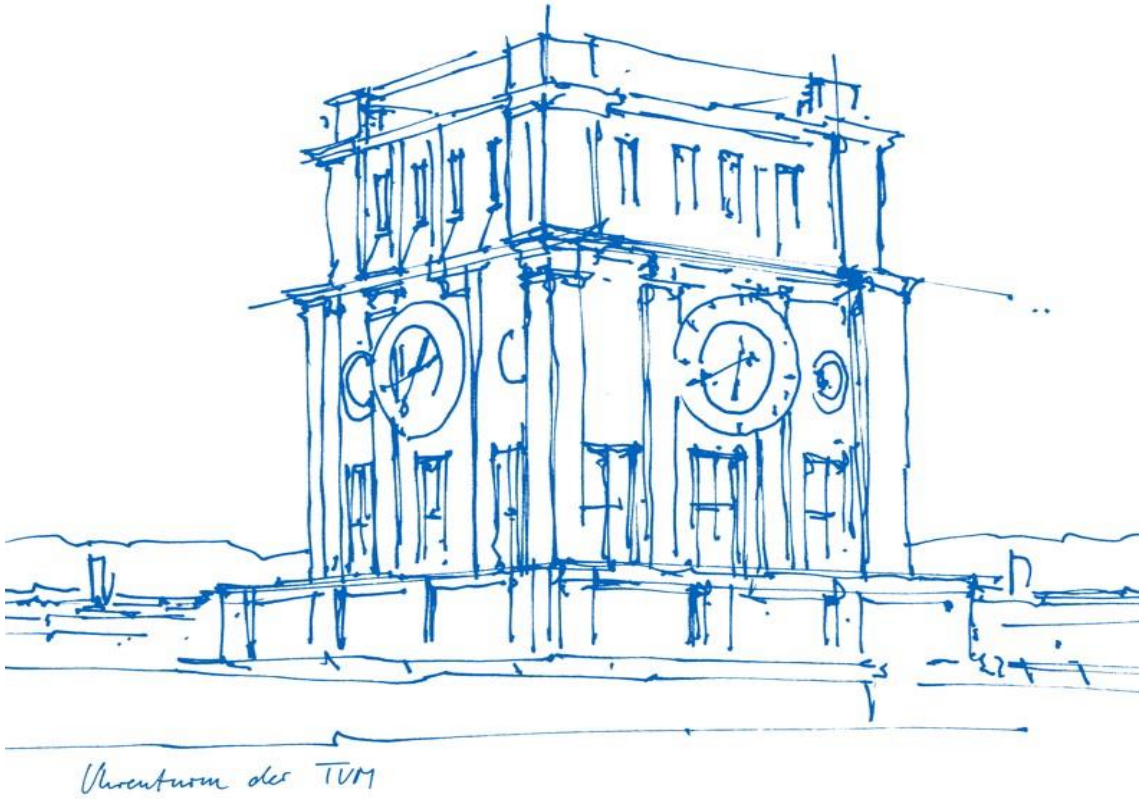
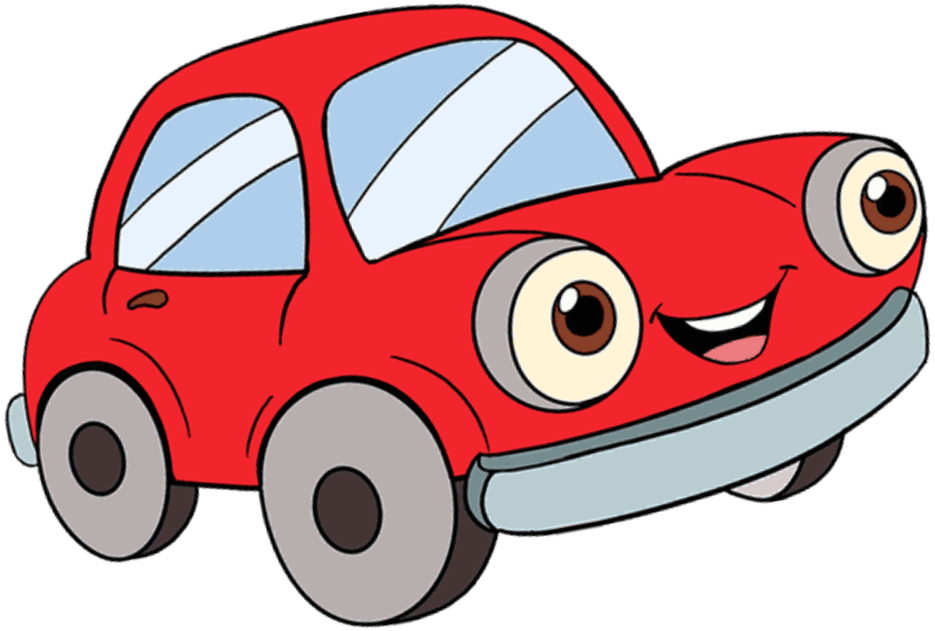
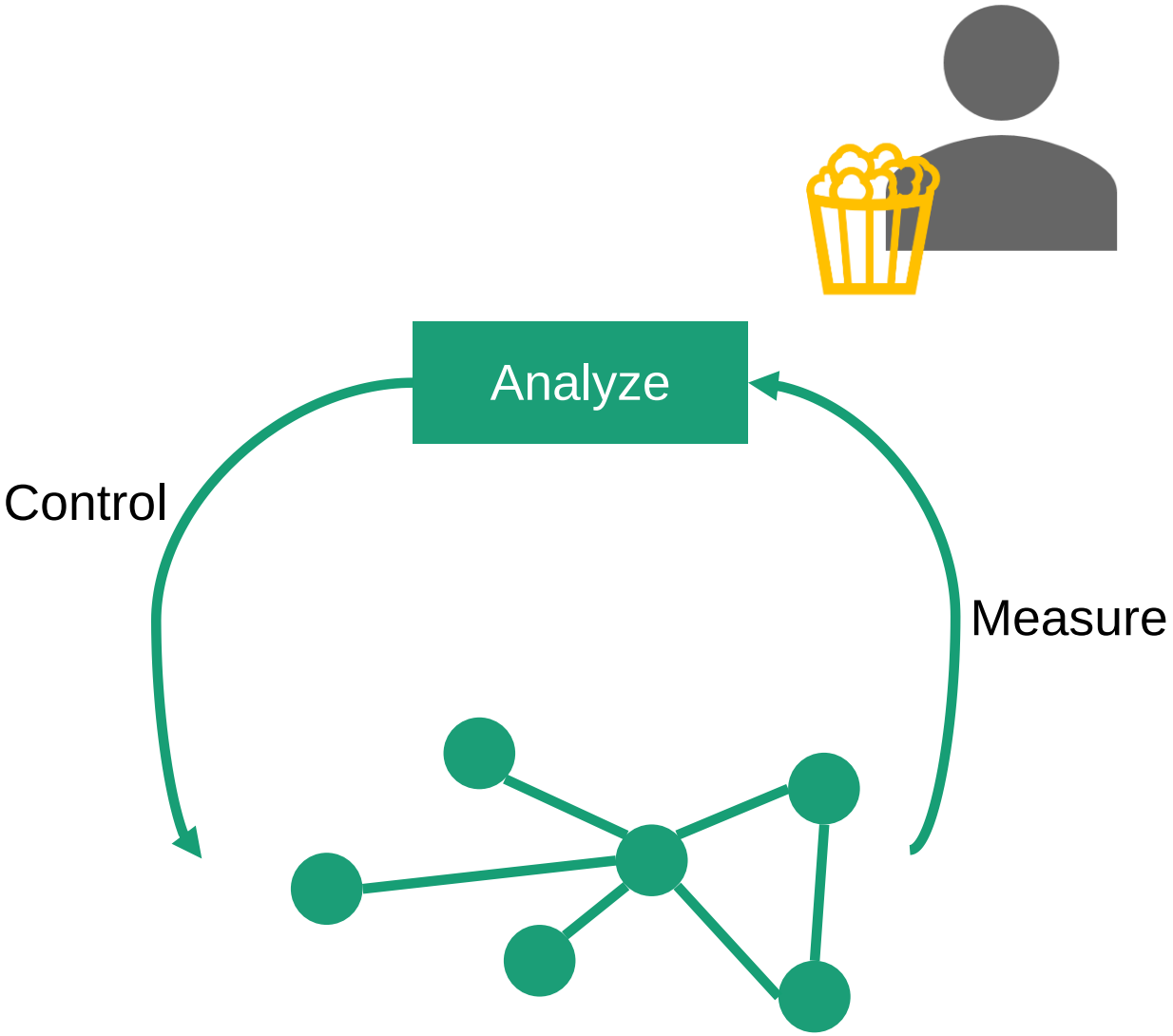


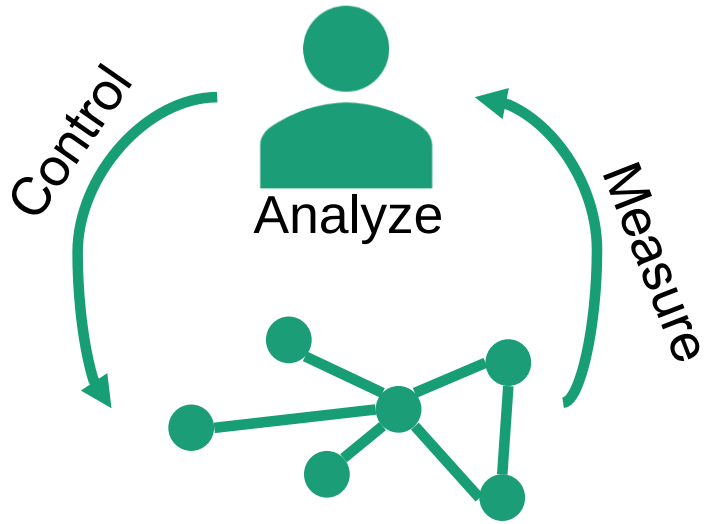
Self-***Driving*** Networks?

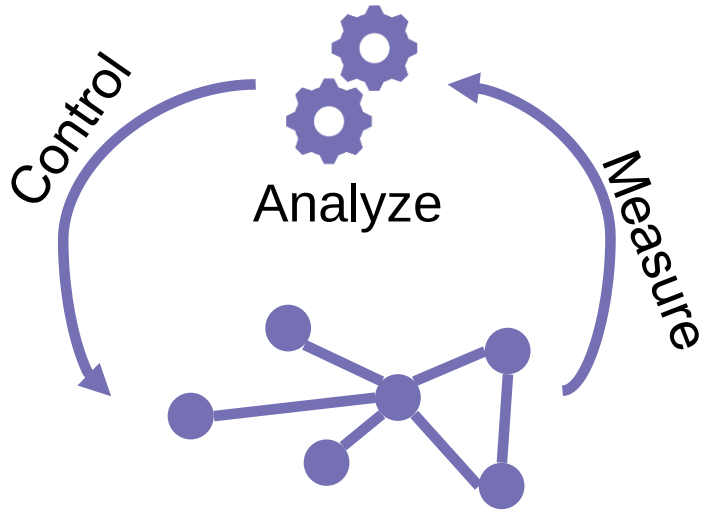


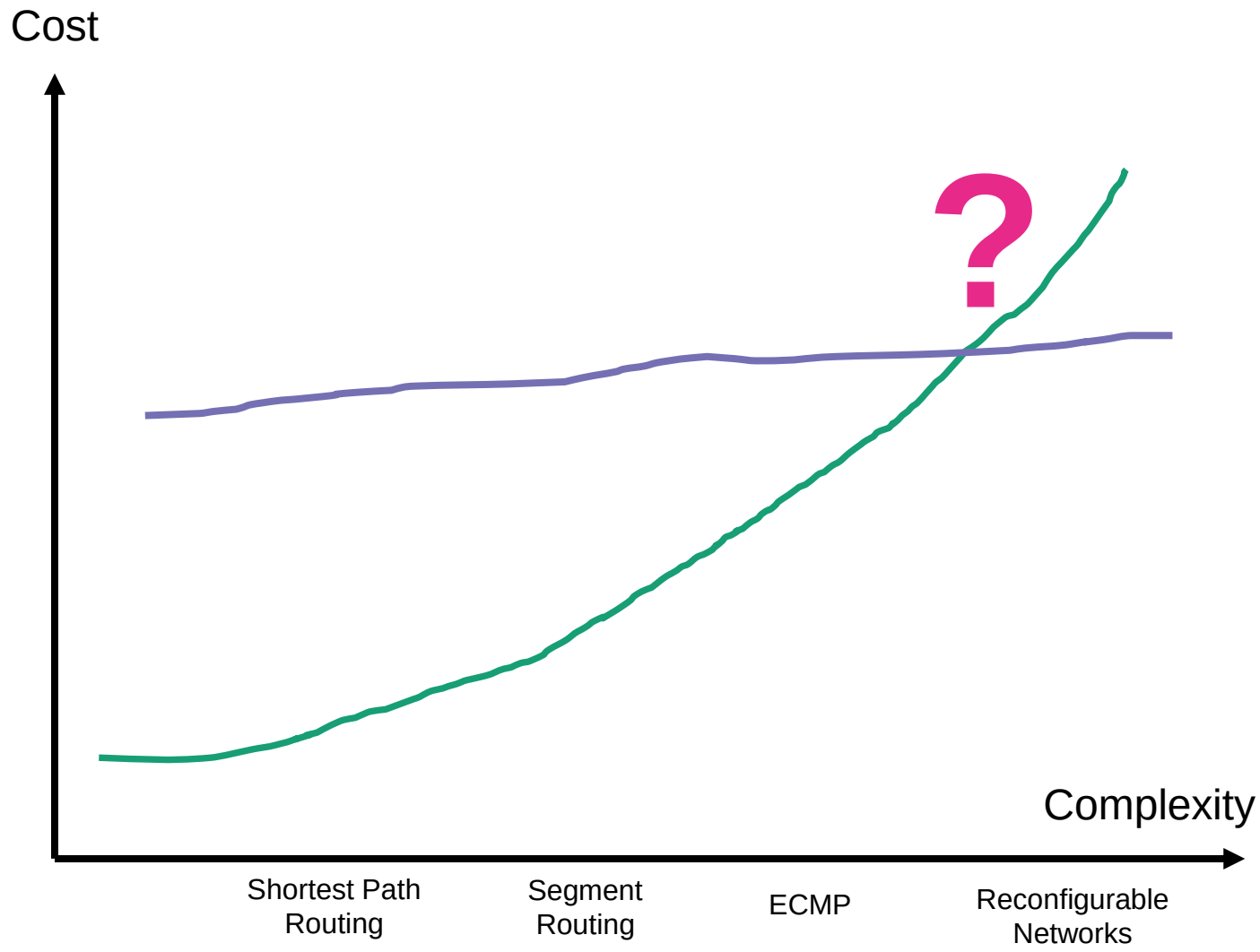


N. Feamster and J. Rexford, “Why (and How) Networks Should Run Themselves,” CoRR, vol. abs/1710.11583, 2017.

Why Self-Driving Networks?

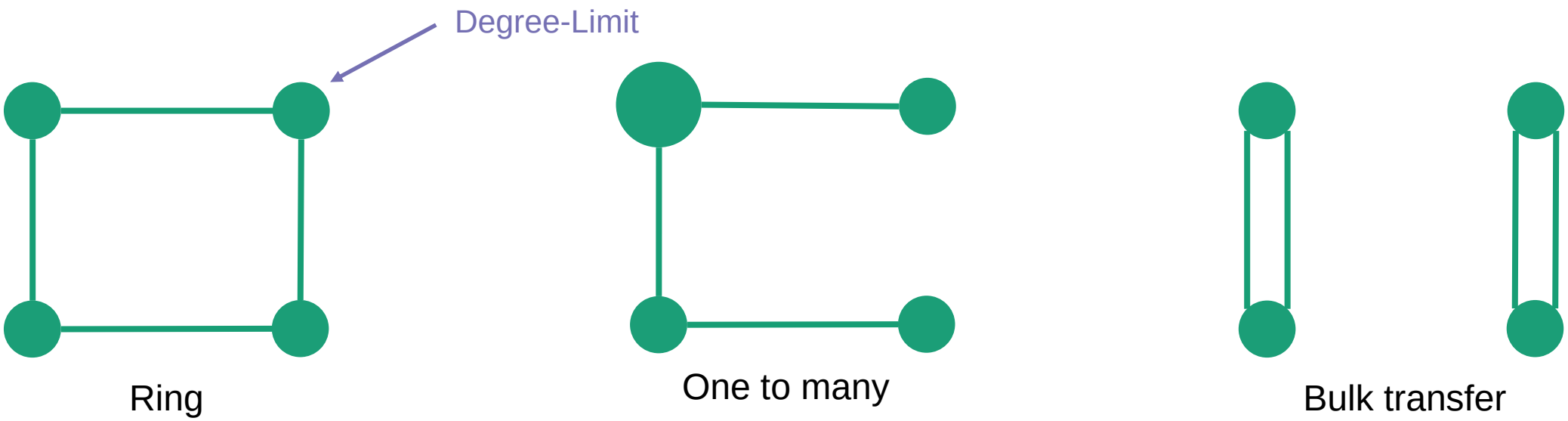






Case Study: Reconfigurable Topologies

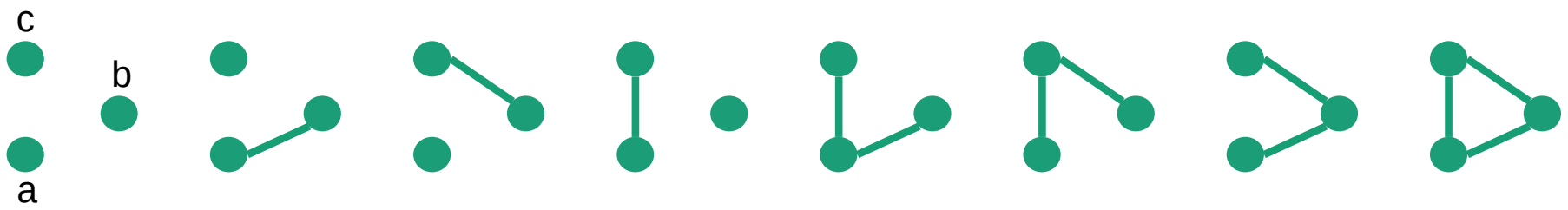
- Each node can connect to any other node
- Limited number of reconfigurable edges per node (degree limit)



M. Ghobadi et al., “ProjecToR: Agile Reconfigurable Data Center Interconnect,” in Proceedings of the 2016 ACM SIGCOMM Conference, New York, NY, USA
X. Jin et al., “Optimizing Bulk Transfers with Software-Defined Optical WAN,” in Proceedings of the 2016 ACM SIGCOMM Conference, New York, NY, USA

Expectation to a Self-Driving Network

Configuration Space:



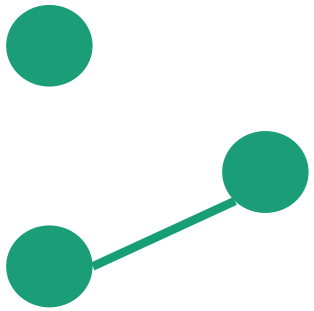
Request: a - b

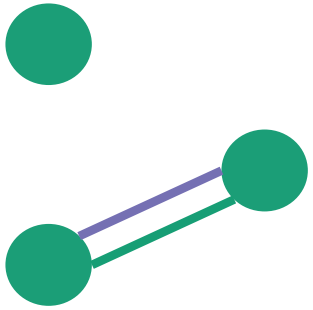
Headroom

Use headroom intelligently!

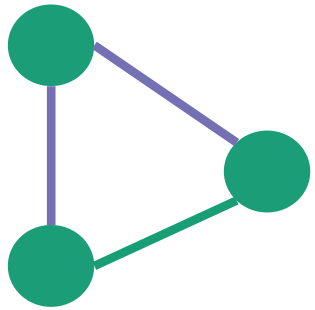
“Intelligently” – A word simply said. But what does it mean?

“Everything else being equal, states are preferred that increase future possible options”





Potential for one request

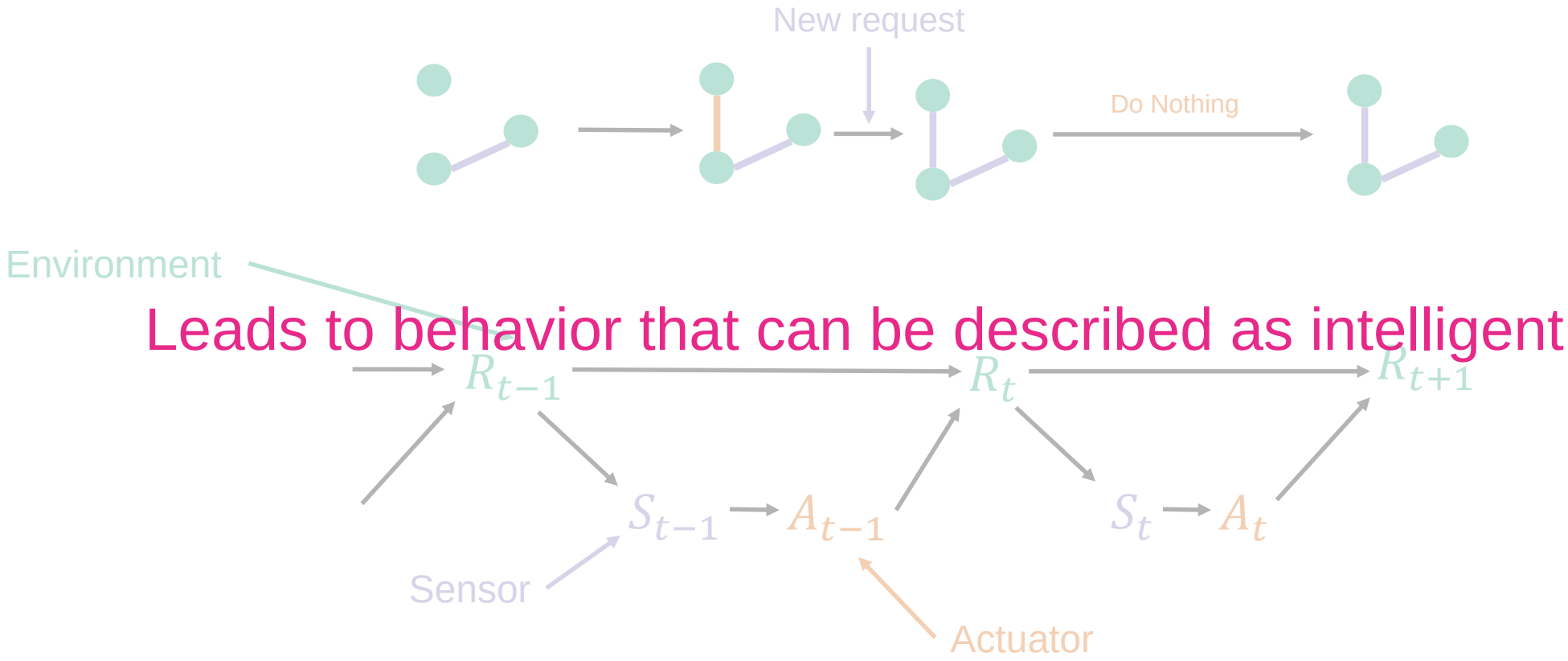


Potential for three different requests

How to formalize this notion of preparedness?

A. S. Klyubin, D. Polani, and C. L. Nehaniv, “Empowerment: a universal agent-centric measure of control,” in 2005 IEEE Congress on Evolutionary Computation, 2005, vol. 1, pp. 128-135 Vol.1.
A. D. Wissner-Gross and C. E. Freer, “Causal Entropic Forces,” Phys. Rev. Lett., vol. 110, no. 16, p. 168702, Apr. 2013.

Empowerment



$$\max_{p(a_t)} \left(\mathrm{H}(S_{t+1}) - H(S_{t+1}|A_t) \right)$$

Mutual Information

A. S. Klyubin, D. Polani, and C. L. Nehaniv, “Empowerment: a universal agent-centric measure of control,” in 2005 IEEE Congress on Evolutionary Computation, 2005, vol. 1, pp. 128-135 Vol.1.

Empowerment – Strengths and Weaknesses

- **Agent Centric:** Only information available to the agent is used.
- **Local:** No complete world model needed.
- **Semantically unbiased:** No external reward system is introduced.
- **Universal:** Can be applied to arbitrary agent environment interactions.

BUT: Model needed that tells agent how actions influence the sensor to compute empowerment

→ Learn from data.

→ Use model free approaches.

Many Research Challenges for Networking!

First Experiences

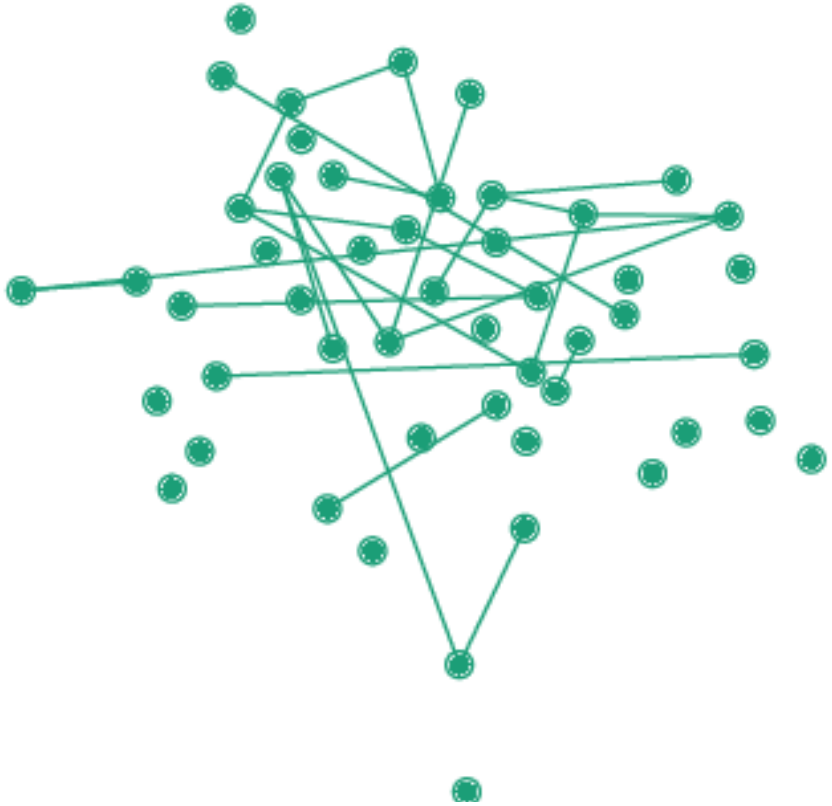
Actuator: Place edge, remove edge, do nothing

Sensor:

- Number of routed flows (Simple)
- Set of routed flows (Exact)

First Experiences

Actuator: Place edge, remove edge, do nothing



Sensor:

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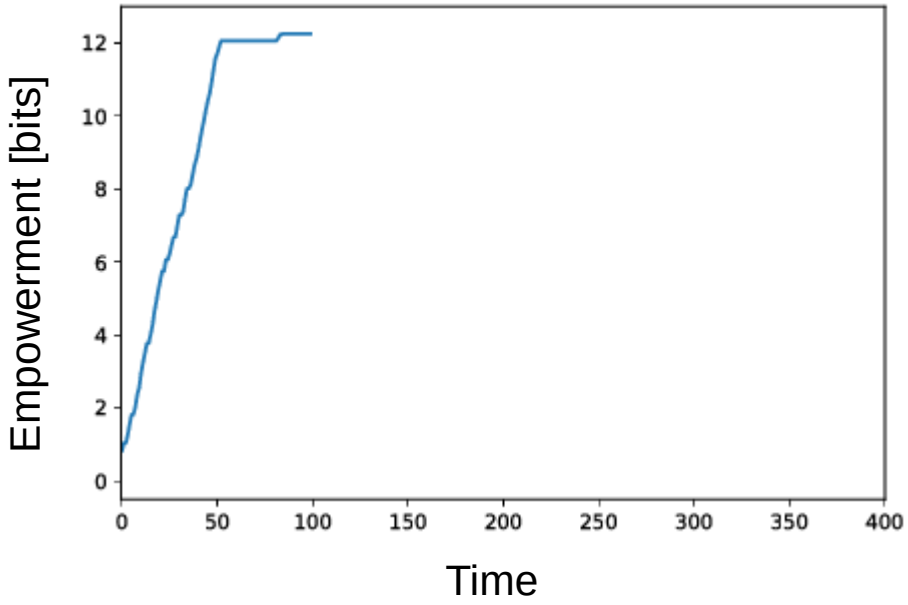
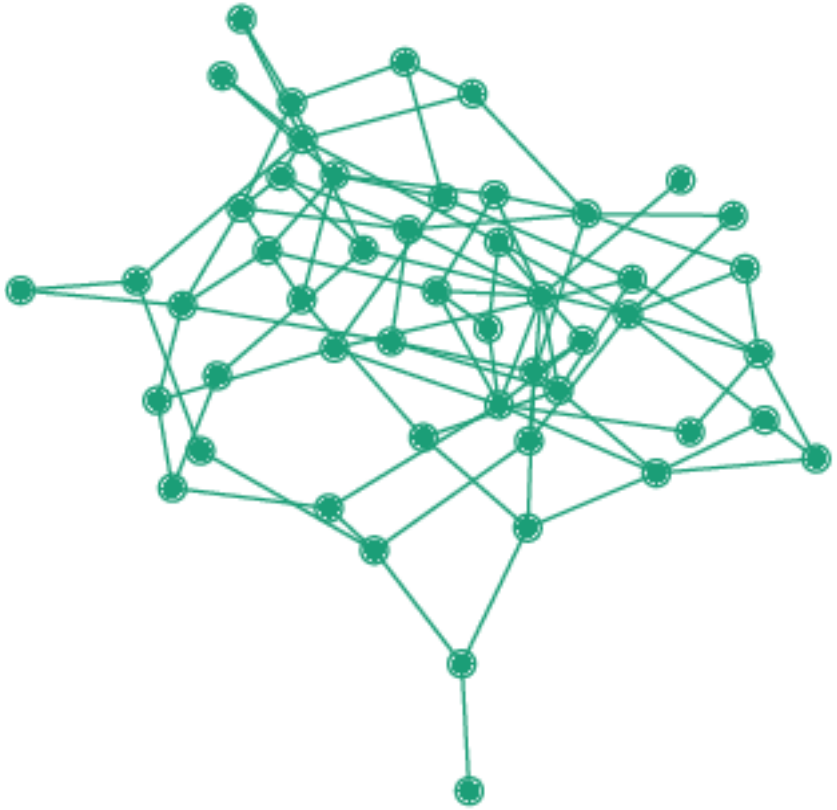


Agent places edges at beginning to obtain sensor readings

First Experiences

Actuator: Place edge, remove edge, do nothing



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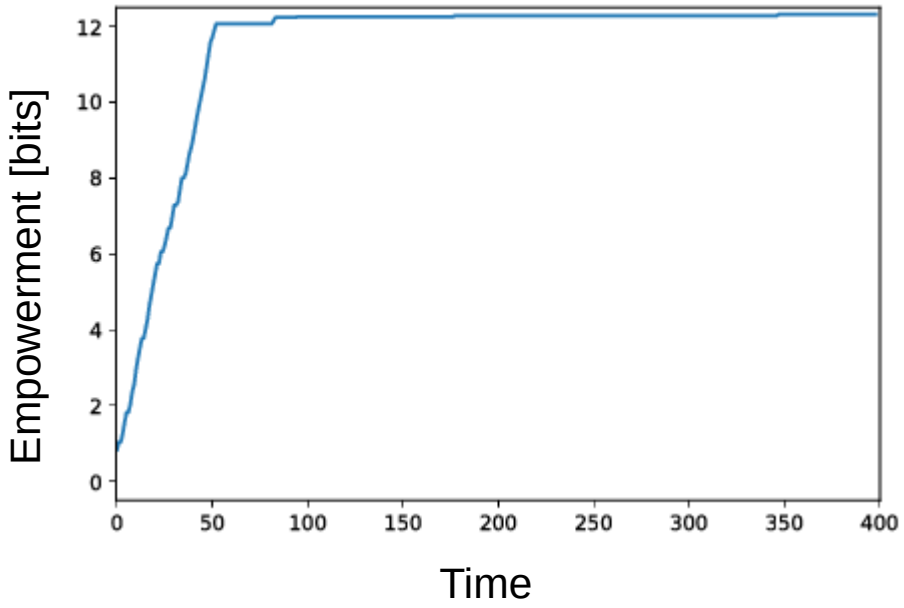
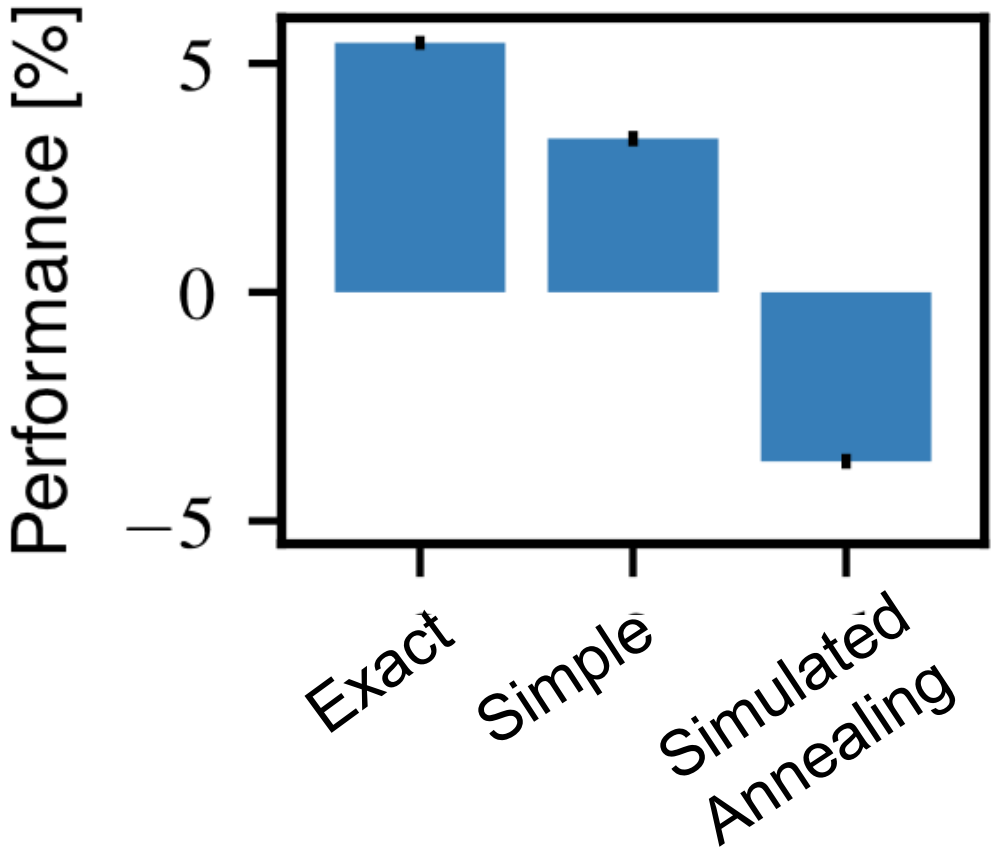


Agent rearranges edges to further increase empowerment

First Experiences

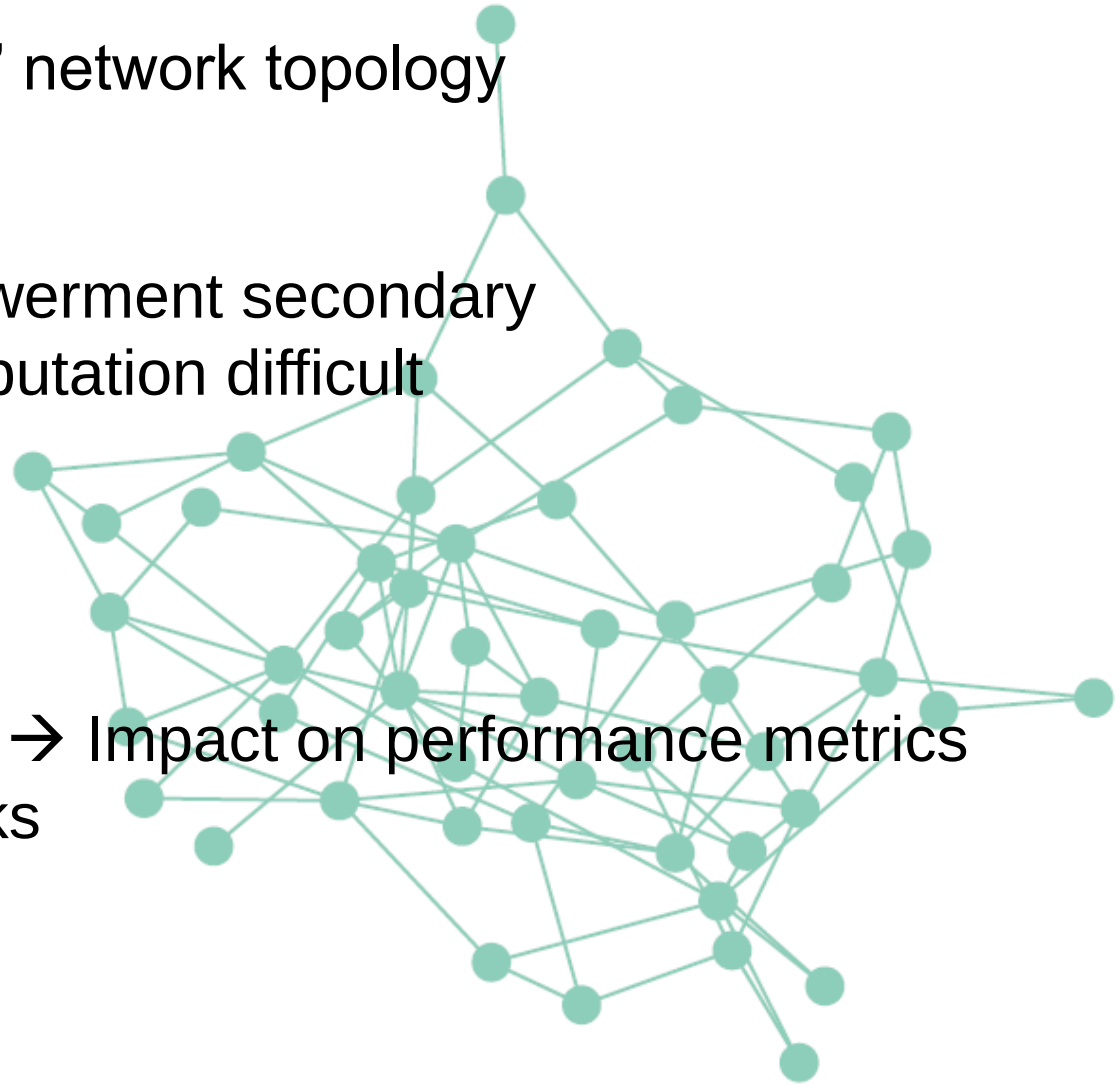


Empowerment maximization prepares for more future requests

Summary, Lessons Learned and Outlook

- *Empowerment*-driven agent builds a “good” network topology

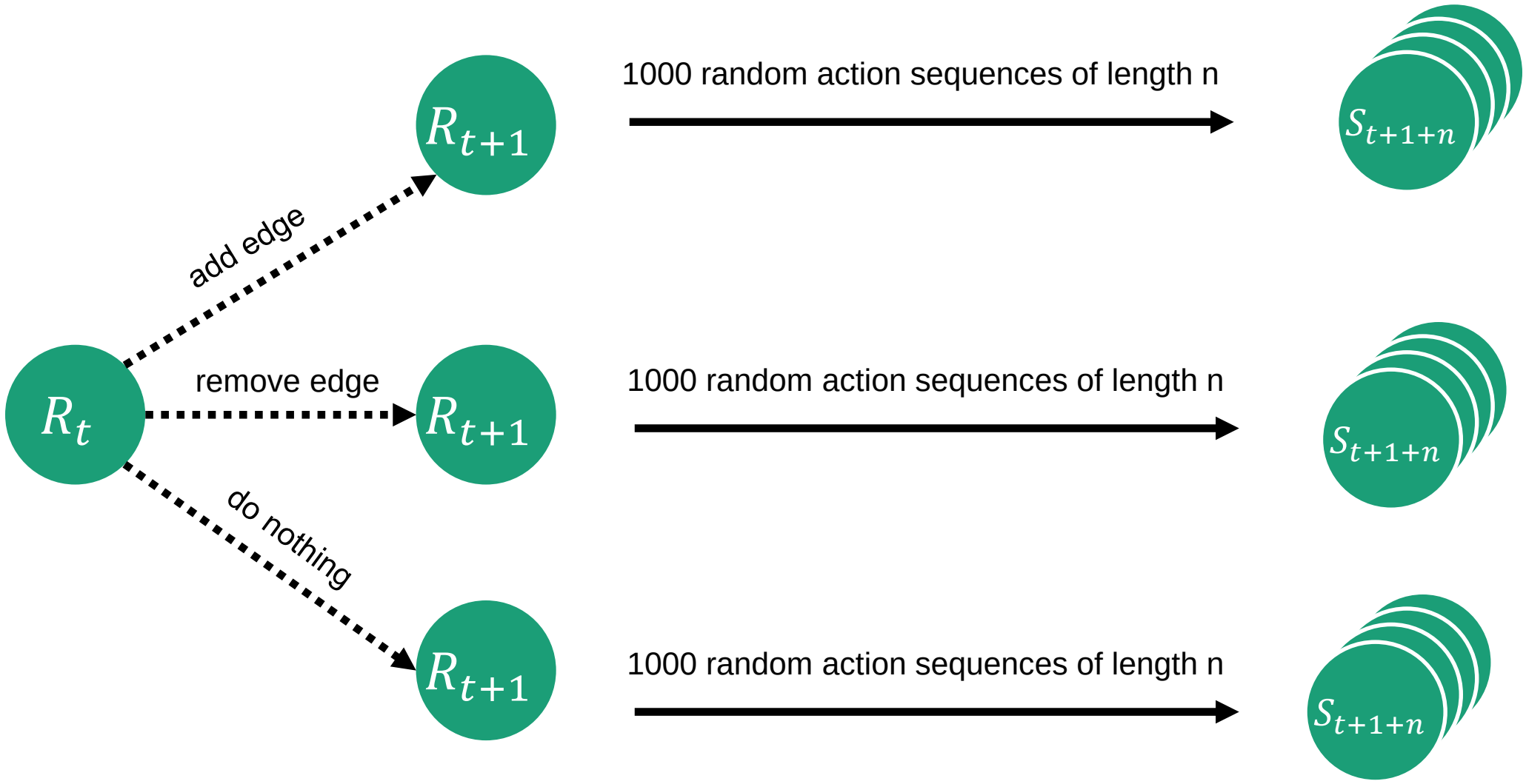
- Empowerment vs. extrinsic goals → Empowerment secondary
- High dimensional sensor states make computation difficult
- Actuator should be higher level actions



- Empowerment as universal utility function? → Impact on performance metrics
- Sensor evolution in communication networks
- Unsupervised learning of control strategies

Thank You!

N-step empowerment



Obtaining Results