A Distributed Reinforcement Learning Approach for Energy and Congestion-Aware Edge Networks

Original

Availability:
This version is available at: 11583/2870934 since: 2021-07-26T10:16:18Z

Publisher:
Association for Computing Machinery (ACM)

Published
DOI:10.1145/3386367.3431670

Terms of use:
This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright
ACM postprint/Author's Accepted Manuscript

(Article begins on next page)
Poster: A Distributed Reinforcement Learning Approach for Energy and Congestion-Aware Edge Networks

Alessio Sacco
alessio_sacco@polito.it
Politecnico di Torino

Flavio Esposito
flavio.esposito@slu.edu
Saint Louis University

Guido Marchetto
guido.marchetto@polito.it
Politecnico di Torino

ABSTRACT
The abiding attempt of automation has also pervaded computer networks, with the ability to measure, analyze, and control themselves in an automated manner, reacting to changes in the environment (e.g., demand) while exploiting existing flexibilities. When provided with these features, networks are often referred to as "self-driving". Network virtualization and machine learning are the drivers. In this regard, the provision and orchestration of physical or virtual resources are crucial for both Quality of Service guarantees and cost management in the edge/cloud computing ecosystem. Auto-scaling mechanisms are hence essential to effectively manage the lifecycle of network resources. In this poster, we propose Relevant, a distributed reinforcement learning approach to enable distributed automation for network orchestrators. Our solution aims at solving the congestion control problem within Software-Defined Network infrastructures, while being mindful of the energy consumption, helping resources to scale up and down as traffic demands fluctuate and energy optimization opportunities arise.

CCS CONCEPTS
• Networks → Network algorithms; • Computer systems organization → Redundancy; • Computing methodologies → Reinforcement learning.

KEYWORDS
reinforcement learning, self-driving networks, auto-scaling

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

CoNEXT '20, December 1–4, 2020, Barcelona, Spain
© 2020 Association for Computing Machinery.
ACM ISBN 978-1-4503-7948-9/20/12...$15.00
https://doi.org/10.1145/3386367.3431670

1 INTRODUCTION
Recent advancements in artificial intelligence (AI) and machine learning (ML) are paving the path to autonomous and self-driving networks: networks that measure, analyze and control themselves in an automated manner, reacting to changes in the environment,

Figure 1: System overview. The (logical) network controller receives in input traffic statistics and outputs new flow routes and power on/off commands.

Poster: A Distributed Reinforcement Learning Approach for Energy and Congestion-Aware Edge Networks

Alessio Sacco
alessio_sacco@polito.it
Politecnico di Torino

Flavio Esposito
flavio.esposito@slu.edu
Saint Louis University

Guido Marchetto
guido.marchetto@polito.it
Politecnico di Torino

ABSTRACT
The abiding attempt of automation has also pervaded computer networks, with the ability to measure, analyze, and control themselves in an automated manner, reacting to changes in the environment (e.g., demand) while exploiting existing flexibilities. When provided with these features, networks are often referred to as "self-driving". Network virtualization and machine learning are the drivers. In this regard, the provision and orchestration of physical or virtual resources are crucial for both Quality of Service guarantees and cost management in the edge/cloud computing ecosystem. Auto-scaling mechanisms are hence essential to effectively manage the lifecycle of network resources. In this poster, we propose Relevant, a distributed reinforcement learning approach to enable distributed automation for network orchestrators. Our solution aims at solving the congestion control problem within Software-Defined Network infrastructures, while being mindful of the energy consumption, helping resources to scale up and down as traffic demands fluctuate and energy optimization opportunities arise.

CCS CONCEPTS
• Networks → Network algorithms; • Computer systems organization → Redundancy; • Computing methodologies → Reinforcement learning.

KEYWORDS
reinforcement learning, self-driving networks, auto-scaling

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

CoNEXT '20, December 1–4, 2020, Barcelona, Spain
© 2020 Association for Computing Machinery.
ACM ISBN 978-1-4503-7948-9/20/12...$15.00
https://doi.org/10.1145/3386367.3431670

1 INTRODUCTION
Recent advantages in artificial intelligence (AI) and machine learning (ML) are paving the path to autonomous and self-driving networks: networks that measure, analyze and control themselves in an automated manner, reacting to changes in the environment,

Figure 1: System overview. The (logical) network controller receives in input traffic statistics and outputs new flow routes and power on/off commands.

e.g., demand [2, 7]. One relevant tract of autonomous networks is the ability to auto-scale the resources up and down in harmony with the traffic demand. Traditional threshold-based and recent ML-based policies are often unable to address the high complexity of networks and satisfy carrier-grade requirements such as reliability and stability.

State-of-the-art solutions hardly combine these features altogether, such as [4] whose primary goal is the energy efficiency, or [6], which automatically scales Virtual Network Function instances via an ML classifier. Although reinforcement learning is emerging as a valuable technique to solve many network problems, as in [5, 8], there is no solution incorporating network information to automatically and efficiently orchestrate network resources in a distributed manner.

To this end, we present Relevant, a reinforcement learning approach that aims at learning how to scale without requiring any prior network knowledge. The design goal of Relevant is to mitigate traffic congestion while saving energy by adjusting and optimizing itself as needed. In contrast to other studies, our solution does not require any human instructions to define control policies that efficiently choose network elements to stay active while guaranteeing performance goals. Additionally, the learning process is distributed to more agents to overcome a single entity deployment’s typical drawbacks. In such a way, the knowledge about the environment, needed to decide the best action, is limited yet intelligently used by the controllers. The state space of the Q-learning problem across each agent refers to the global network, but is obtained through an information exchange protocol rather than via a more invasive central metrics collector. In this context, the controller collects statistics about the underlying network and sends the elaborated information to the peers. The distributed detection of congestion exploits a large number of SDN switches spread across
the topology as probes. This leads to a multi-agent reinforcement learning setting, which can drastically enhance the centralized strategy.

2 SYSTEM DESIGN

Our system consists of a multi-controller architecture to manage a significant amount of statistics and possible actions to implement. The controller monitors the state of each switch to detect if one of the following events occurs: the switch is overloaded (congestion), the switch in under-utilized and can be deleted (cost-saving), the switch fails, and the connectivity can be no longer guaranteed (failure). With the network partition, the controller supervises a subset of switches and communicates with the other controllers to obtain a consistent network view.

The decision logic is the fruit of a (self-)learning process, built upon the reinforcement learning (RL) framework. In our solution, each RL agent uses the one-step Q-learning algorithm [9]. Figure 1 shows the components and functionalities involved during the process. The agent interacts with the underlying network and performs actions, where each action is associated with a reward. The reward function mimics the objective of reducing the energy cost and catering to the application requirements. We model this in the reinforcement learning problem, whose actual goal is to maximize the long-term discounted reward per action.

The agent collects the statistics and combines them with previous historical data. Data are then passed to the optimizer module, which enforces the RL process and outputs the best possible strategy. The decision logic is split across multiple controllers to improve the ability to react to failures of network resources. By continuously monitoring the devices’ status, the controller can detect which element is failing, and accordingly react. During this phase, the routing module computes new paths for the flow affected by the fault.

3 CONCLUSION

We proposed ReLevant, a system that allows deploying network resources tracking the network utilization. The network agent can dynamically activate or deactivate links and nodes in an “as needed” fashion to minimize the energy consumption and the resulting costs. The decision logic is split across multiple controllers to improve the management of a large quantity of information needed for accurate actions. We expect that our system will enable both high application satisfaction and minimal management costs when deployed over more challenging environments. Future steps will include extensive evaluation of ReLevant’s behavior in these contexts and an in-depth analysis of the learning process.

4 ACKNOWLEDGEMENT

This work has been partially supported by Comcast and by NSF awards CNS-1647084, CNS-1836906, and CNS-1908574.

REFERENCES


