MARLIN: Soft Actor-Critic based Reinforcement Learning for Congestion Control in Real Networks

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The Networking Environment

- **A ″savage″ environment**
- **Highly heterogeneous**
- **Stochastic**
- **Data flows at high-speed rates**

Congestion Control

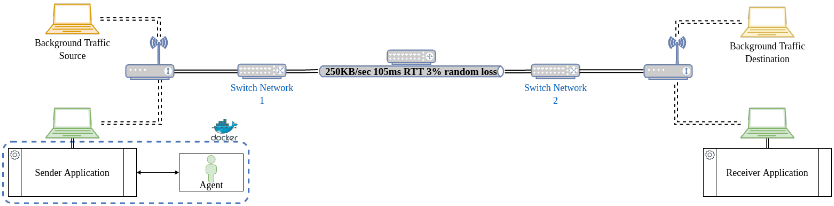
- The channel can saturate causing delays and re-transmissions
- Different heuristics are used (eg. **TCP Cubic**)
- **Congestion Window (CWND):** control over bytes allowed to be **in-flight**
- Heavy congestion can induce a link to an impracticable state

Some questions to answer...

Sim-based RL solutions presented limitations.

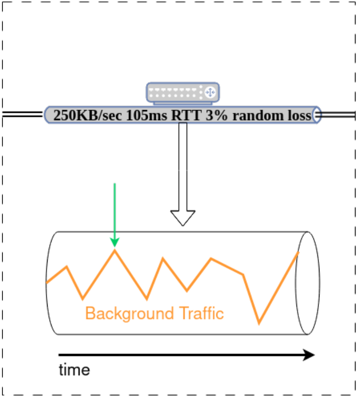
- *How can we face delays?*
- *How can we formulate a RL setting for the problem?*
- *How to deal with real, competitive traffic?*
- *Is it going to transfer to the real networks?*

The Environment


Background Traffic Source
Switch Network 1
250KB/sec 105ms RTT 3% random loss
Switch Network 2
Background Traffic Destination
docker
Sender Application
Agent
Receiver Application

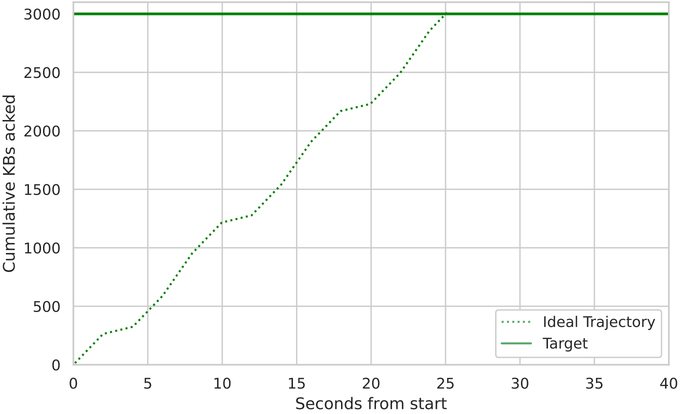
Dumbbell network.

The agent experience



An Infinite-horizon task with PEB

Evaluation

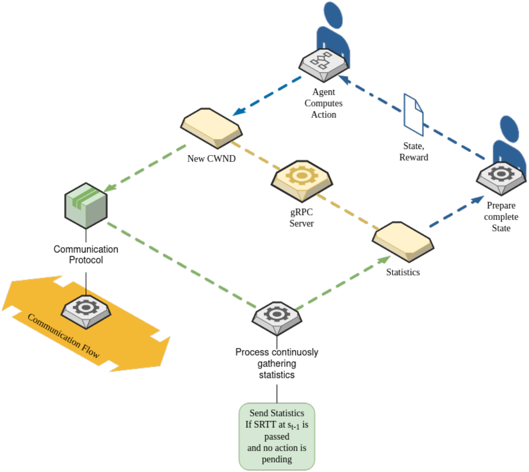


What we want the agent to do.

RL Keypoints

- **Action space:**$[-1, 1]$ tweaking the CWND
- **Non-blocking** communication
- **Learning algorithm:** Soft Actor-Critic (SAC)
- **PEB** during training, file transfer for testing
- **Episodic training**

Agent-Protocol communication



Statistics → State → Action → Reward

State

	Feature	Description		Statistic
1	Current cwnd	Current cwnd	1	Last
2	KBs Sent	Amount of KB sent *	2	Mean
3	New KBs sent	Amount of KB acked *	3	STD
4	Acked KBs	Amount of KB acked *	4	Min
5	Packets sent	Packets sent *	5	Max
6	Retransmissions	Number of packets retransmitted *	6	EMA
7	Instantaneous Throughput	Throughput *	7	Difference from Previous
8	Instantaneous Goodput	Goodput *		
9	Unacked KBs	Amount of KBs in flight		
10	Last RTT	Last rtt detected *		
12	Min RTT	Min rtt *		
12	Max RTT	Max rtt *		
13	SRTT	Smoothed rtt *		
14	VAR RTT	rtt variance *		
		* During the last rtt timeframe		

Every feature has 7 nested statistics with a 10 observations history.

Reward (1/2)

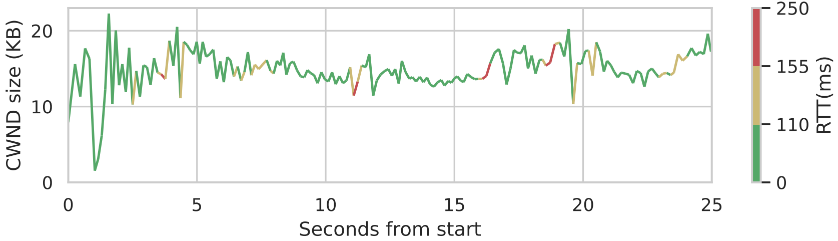
$$r_t = -\frac{target_t}{target_t + acked\_kilobytes_t^{cumulative}} \tag{1}$$

Reward (2/2)

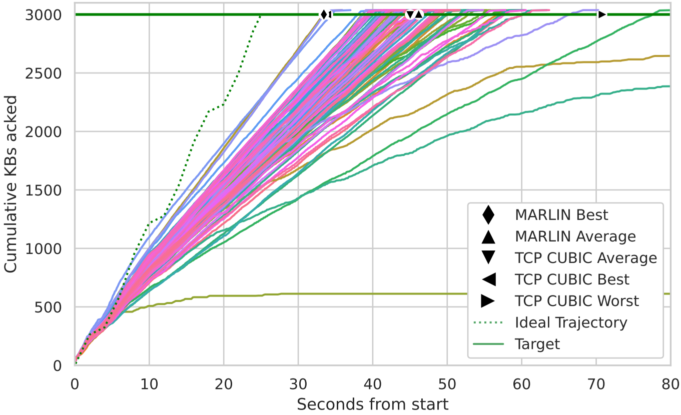
$$r_t = -\frac{target_t}{target_t + acked\_kilobytes_t^{cumulative} * (1 - penalties)} \tag{2}$$

$$penalties = \begin{cases} \alpha \frac{rtt_{diff}}{rtt_{min}^{ema}}, & \text{if } \frac{rtt_{diff}}{rtt_{min}^{ema}} < 1 \\ 0.99, & \text{otherwise} \end{cases} \tag{3}$$

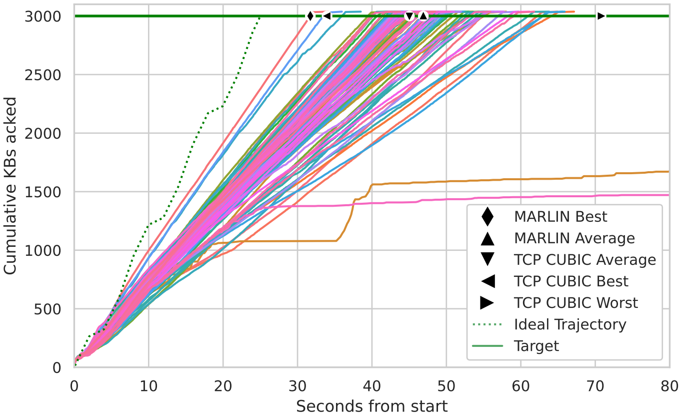
Agent in action



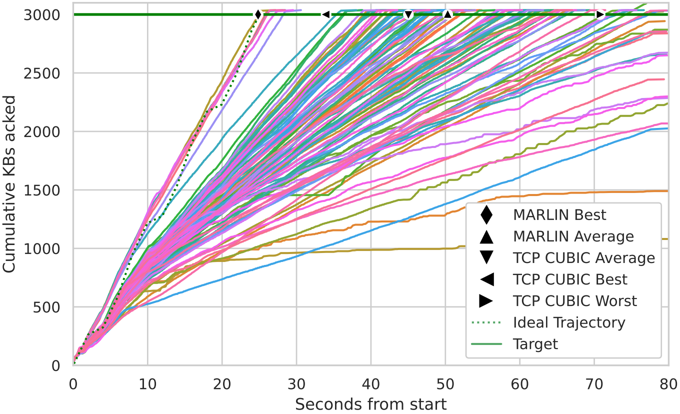
Results (1/3) - Single Traffic Pattern



Results (2/3) - Traffic Pattern Permutations



Results (3/3) - Alternative Reward



…more questions for future research.

Can we benefit from:

- *going from sim to real?*
- *using episode truncation to speed up training?*
- *Formulate a better state?*
- *integrating other ML models into the pipeline?*
- *letting the agent decide* ***when*** *to take an action?*

GitHub Repository

Backup - Hyperparameters

Hyperparameter	Value
Training steps	1×10^6
History length	10
Training episode length	200
Learning rate	3×10^{-4}
Buffer size	5×10^5
Warm-up (learning starts)	1×10^4 steps
Batch size	512
Tau	5×10^{-3}
Gamma	0.99
Training Frequency	$1/episode$
Gradient Steps	-1 (same as episode length)
Entropy regularization coefficient	″auto″ (Learned)
MLP policy hidden layers	$[400, 300]$

Table: Hyperparameters used in our experiment.

Backup - Reward

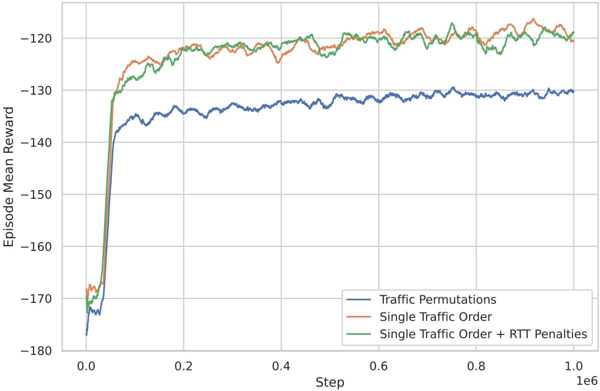


Figure: Rolling mean during training

Backup - Alpha

$$\alpha = \begin{cases} 1, & \text{if } |\frac{rtt_{diff}}{rtt_{min}^{ema}}| > 0.6 \\ 0.5, & \text{if } 0.1 < |\frac{rtt_{diff}}{rtt_{min}^{ema}}| \leq 0.6 \\ 0.3, & \text{if } 0.05 < |\frac{rtt_{diff}}{rtt_{min}^{ema}}| \leq 0.1 \\ 0.1, & \text{otherwise} \end{cases} \tag{4}$$

Backup - Traffic Patterns

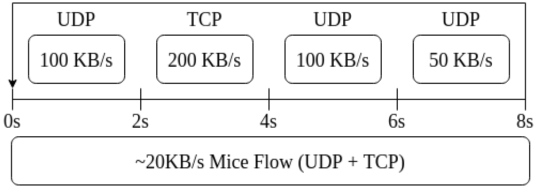


Figure: Generated Traffic Patterns

Backup - Traffic Patterns 2

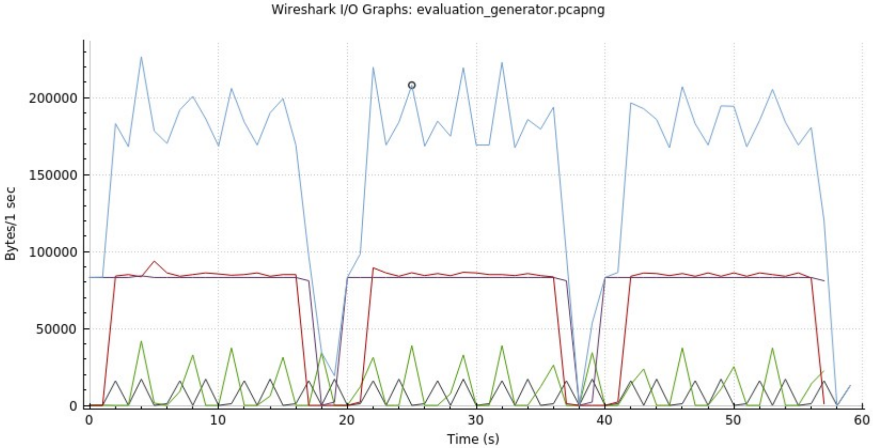


Figure: Generated Traffic Patterns