OpenNetLab: Open Platform for RL-based Congestion Control for Real-Time Communications

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Real-Time Communications (RTC)

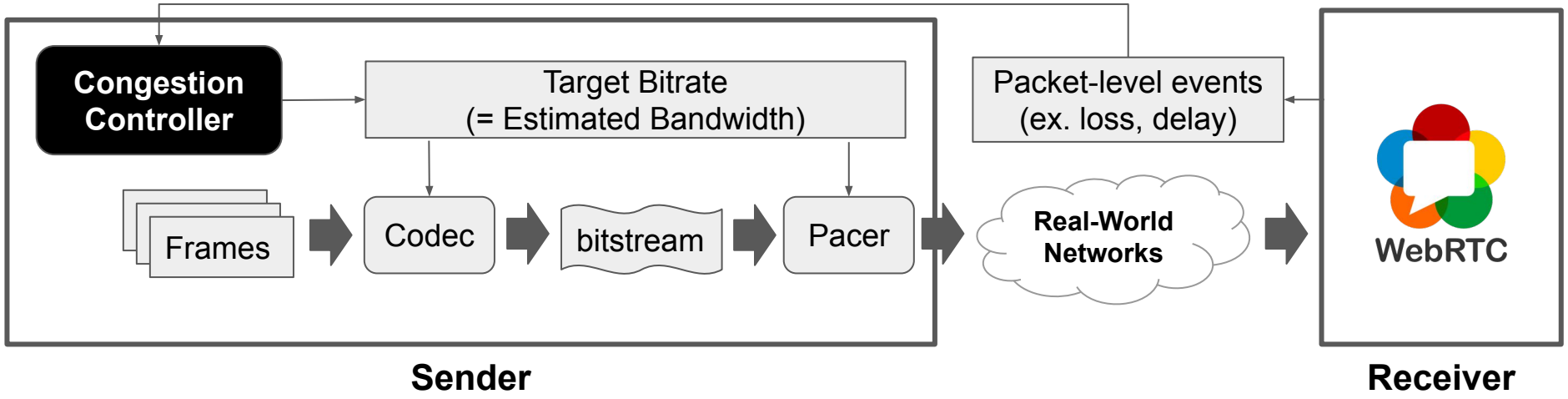
- Popularity and importance of RTC
  - Sharp increase during the COVID-19 pandemic
  - Video conferencing, live commerce, live streaming services

In 2025, RTC is expected to

- Take 17% of internet video traffic
- Make 217.3B $ revenue worldwide

Congestion Control (CC) for RTC

- Accurate bandwidth estimation is the key factor in achieving high QoE



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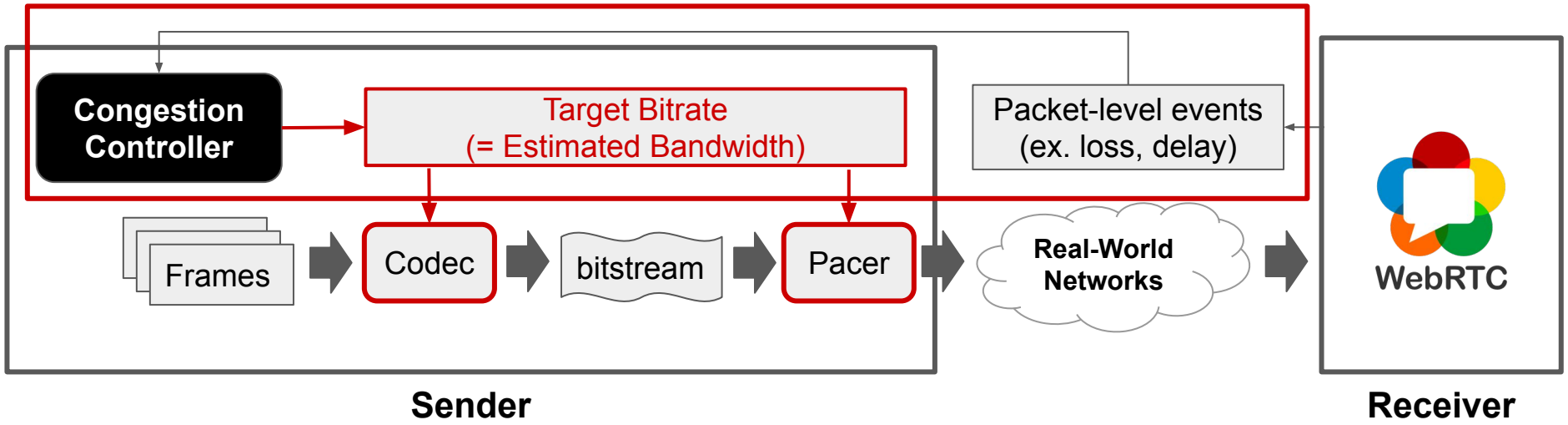
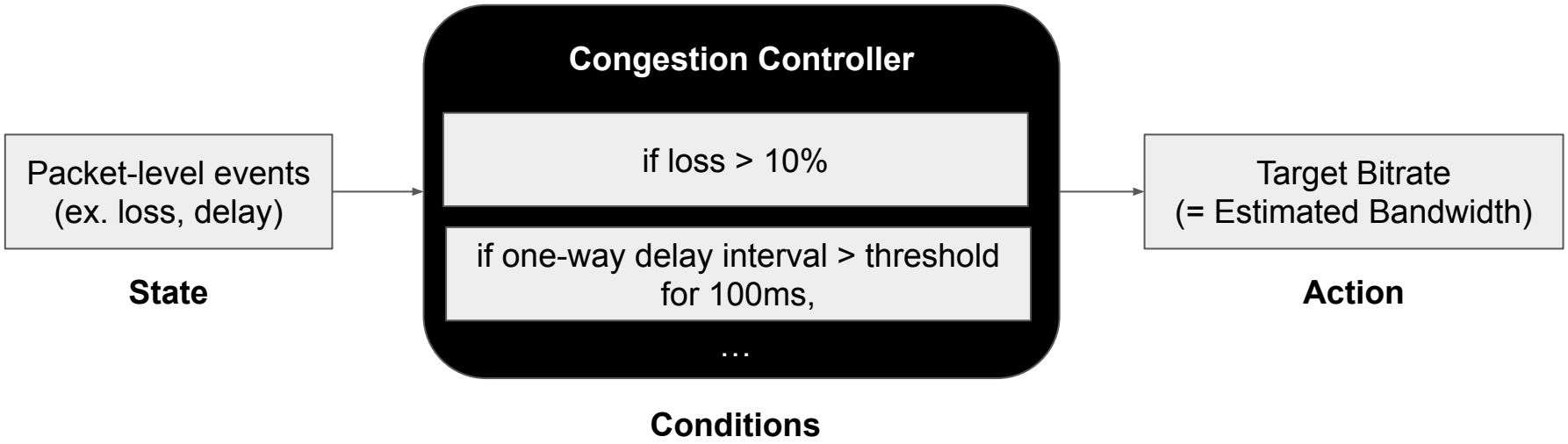


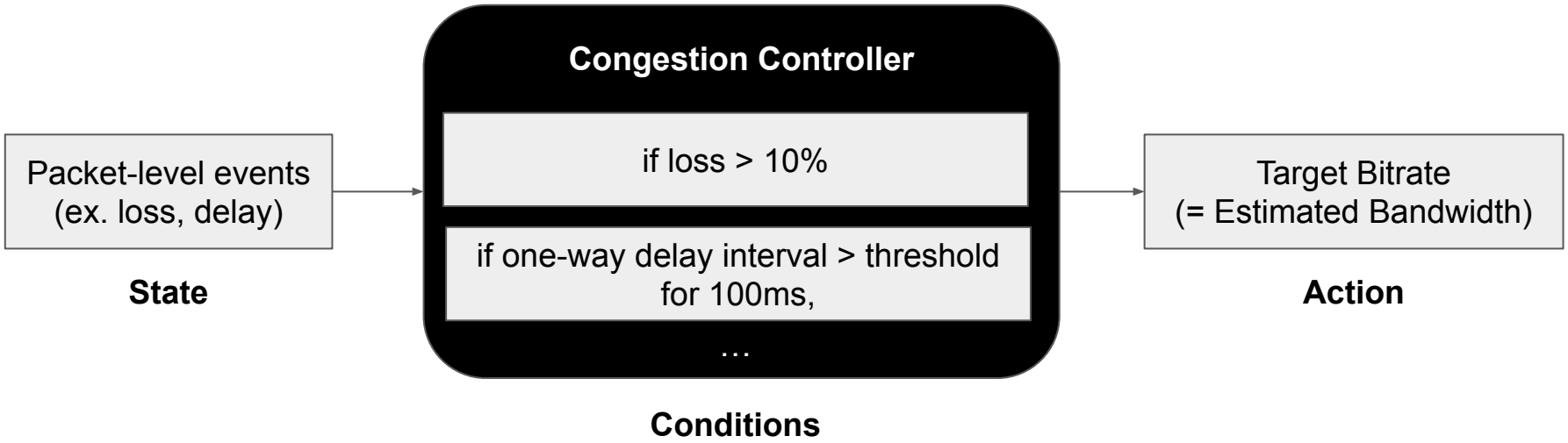
Congestion Control (CC) for RTC

- Rule-based CC: ex. GCC
- Hardwired mappings between predefined conditions and actions



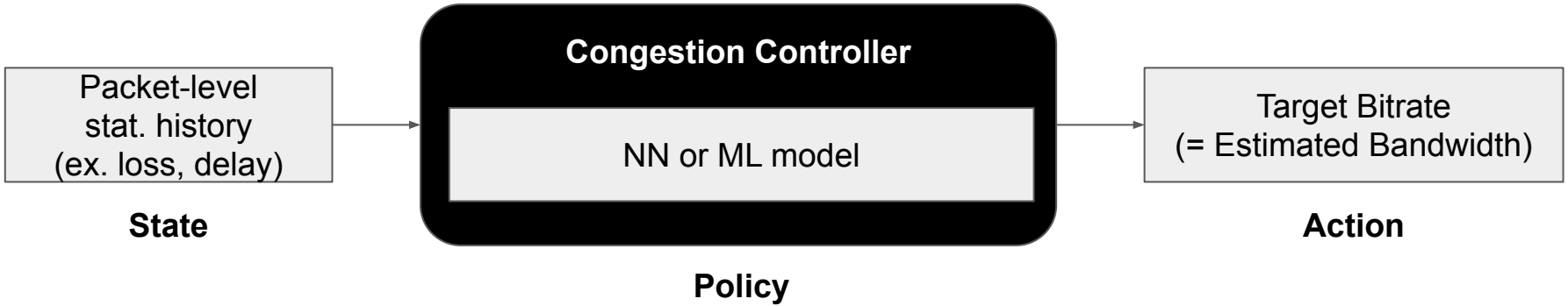
Congestion Control (CC) for RTC

- Rule-based CC: ex. GCC
- **Limitation** of the hardwired mapping-based congestion control
  - Cannot adapt to patterns that aren't predefined
  - Severe performance degradation when underlying assumptions are violated



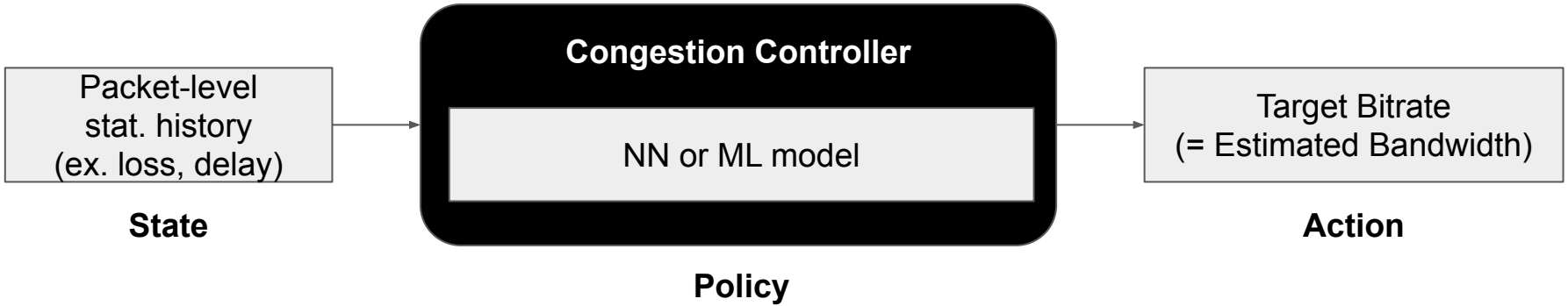
Congestion Control (CC) for RTC

- RL-based CC aims to overcome the limitations of rule-based CC
- Learns to adapt actions based on observed network performance statistics



Congestion Control (CC) for RTC

- RL-based CC aims to overcome the limitations of rule-based CC
- **Benefits** of learning to adapt congestion control decisions
  - Flexible: can adapt to patterns that aren't predefined



Status Quo: Training/Evaluation

- No common, open platform for training & evaluation
  - Trained with in-house simulators or live traffic

Algorithm	Approach	Target Scenario	Online vs. Offline Training	Training/ Evaluation Data	Validation Environment	Open Sourced
CoRR'19 R3Net	RL-Based	Audio/video call	Offline	Synthetic traces	Custom testbed	X
MobiCom'19 Concerto	RL-Based	Live commerce	Offline, Simulator	Closed traces	Production traffic	X
MobiCom'20 OnRL	RL-Based	Live commerce	Online	Production traffic	Production traffic	X
MobiCom'21 Loki	RL-Based	Live commerce	Offline + Online	Production traffic	Production traffic	X

Status Quo: Validation

- No common, open testbed for fair comparison
  - Validation in closed testbeds or in the wild

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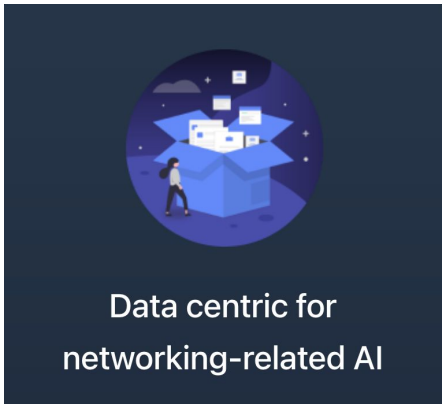
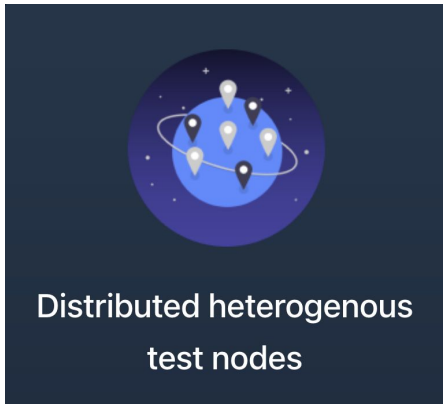
OpenNetLab

- What is OpenNetLab?
  - Next-generation data-driven open networking research platform
  - Community effort including 10+ universities in Asia
  - More information on APNet'21 Keynote talk
- This talk covers one of projects on OpenNetLab for RL-based CC for RTC





OpenNetLab for RL-based CC for RTC

- An end-to-end open platform for RL-based CC for RTC as a community resource for researchers

Fast training
& Reproducible evaluation

Validation
under real Internet

OpenNetLab for RL-based CC for RTC

- Easy to use interface
- High fidelity: WebRTC + ns-3
- Fast & reproducible

Simulator

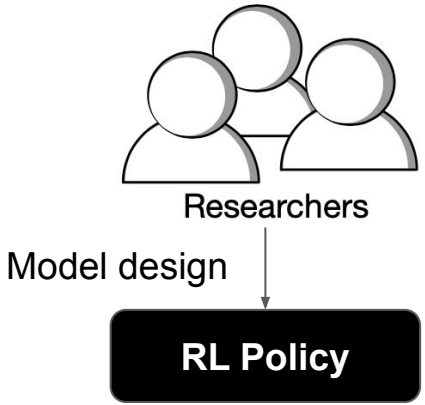
Fast training
& Reproducible evaluation

- Diverse network types
  - Cellular, wired, wireless
- Geo-distributed nodes across 9 universities in Asia

Testbed

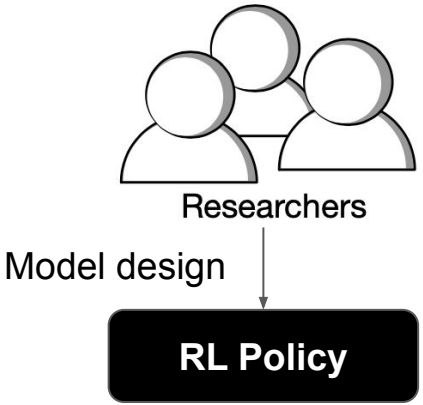
Validation
under real Internet

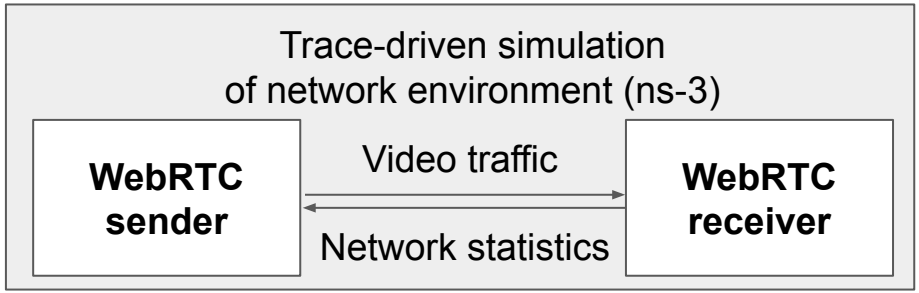
Fast Training & Reproducible Evaluation with Simulator



- Python-based easy-to-use interface
- Can port tens of widely used RL libraries
  - ex. OpenAI gym or Ray RLlib

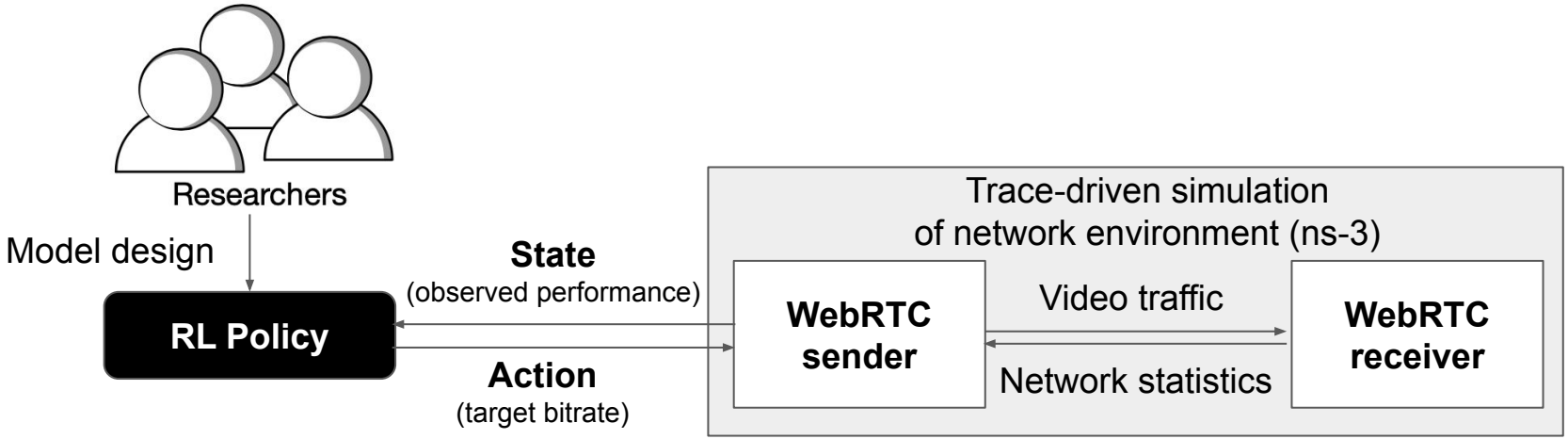
Fast Training & Reproducible Evaluation with Simulator





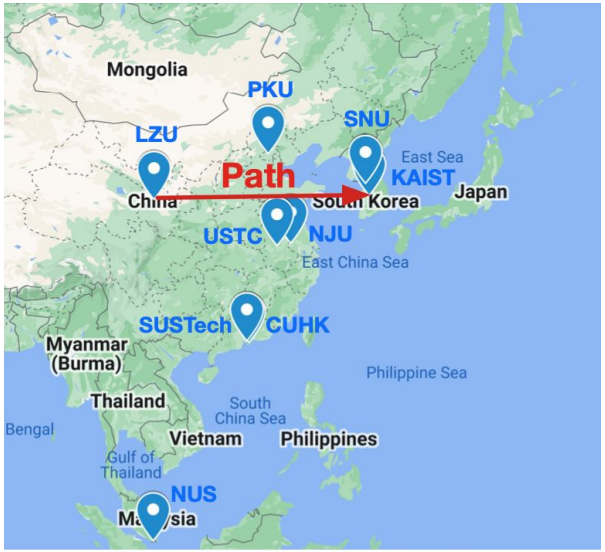
- Fast & reproducible simulation with ns-3
- High-fidelity simulation via real WebRTC sender/receiver

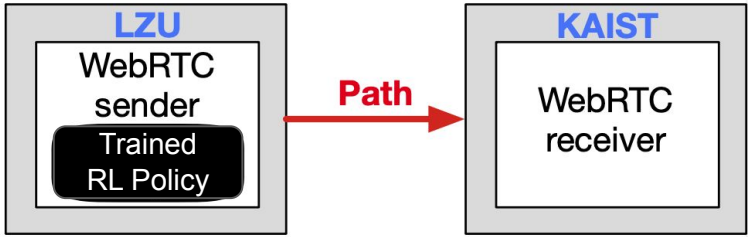
Fast Training & Reproducible Evaluation with Simulator



- Learn to adapt **actions** based on **observed performance**

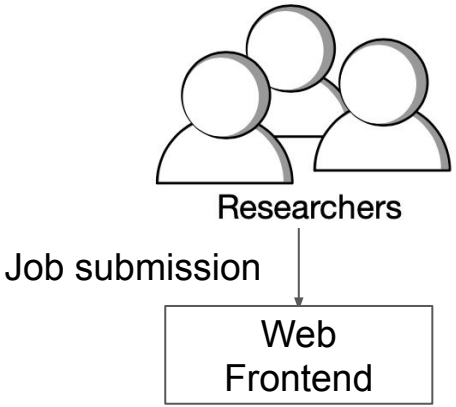
Validation & Fair Comparison with Real Internet Testbed





- Diverse network types: Cellular, wired, wireless
- Geo-distributed nodes across 9 universities in Asia

Validation & Fair Comparison with Real Internet Testbed



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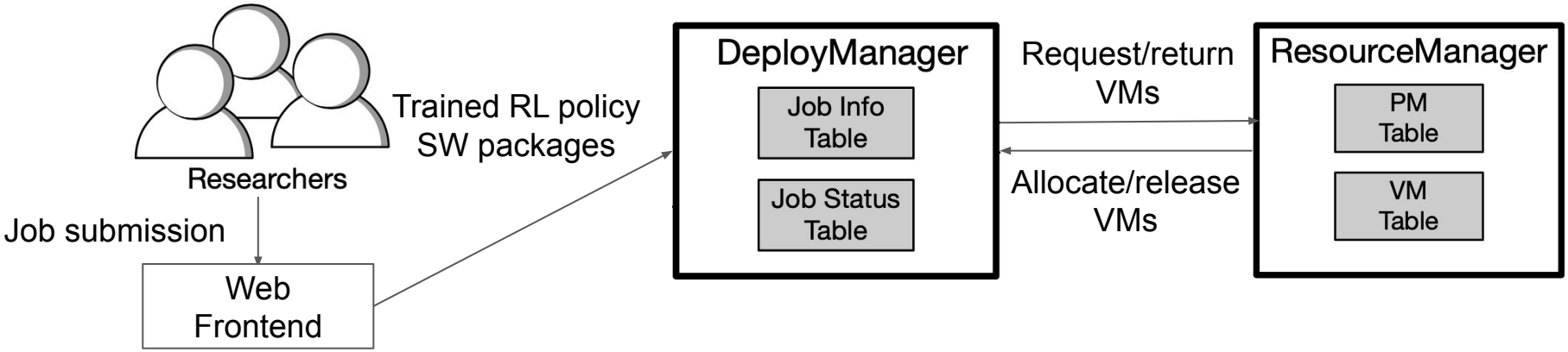
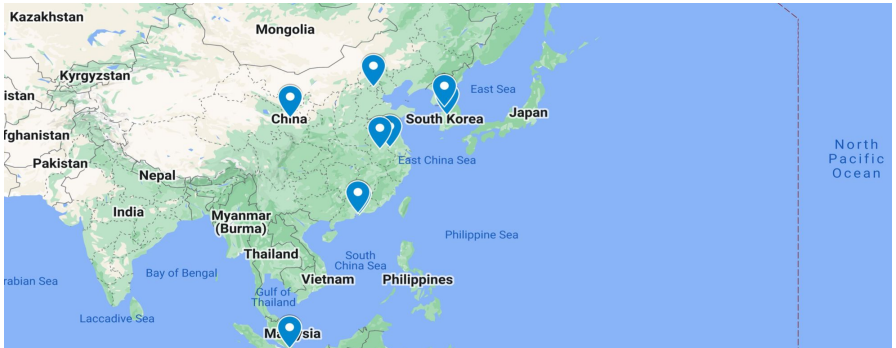
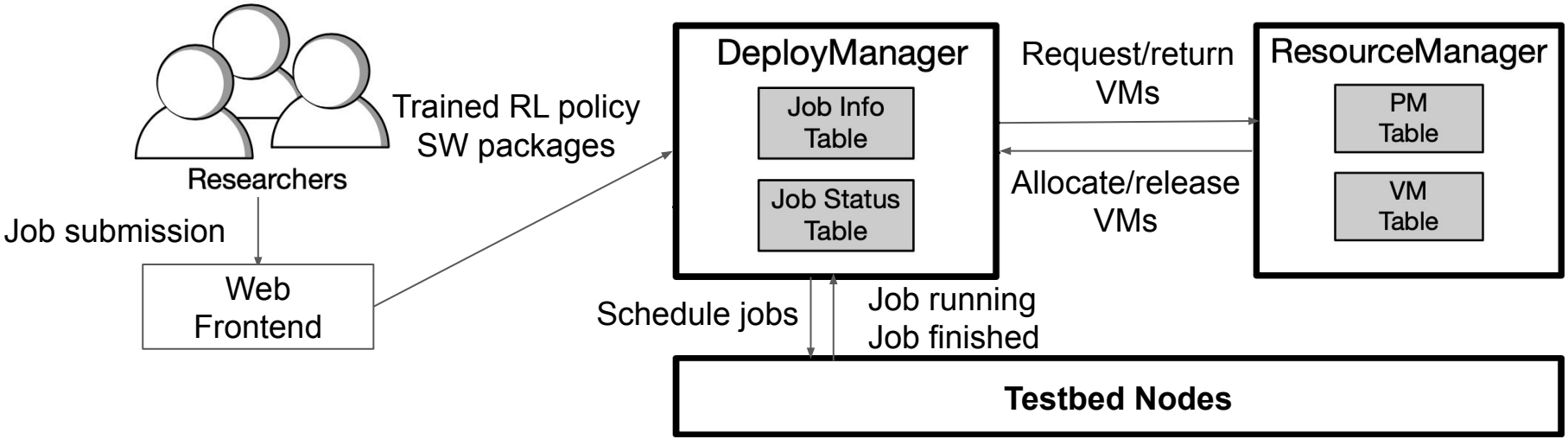
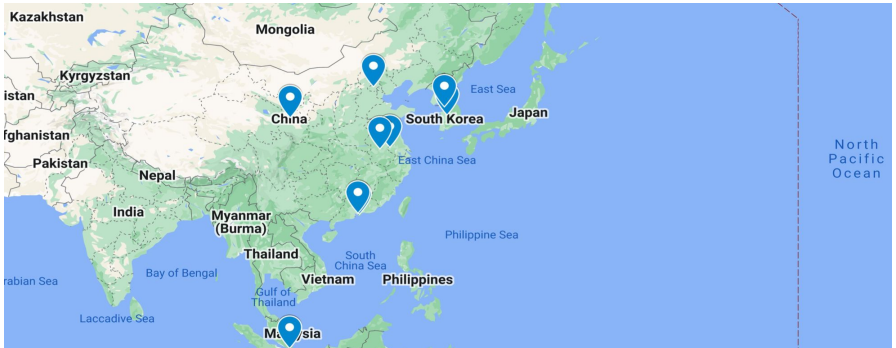


Testbed Nodes



Validation & Fair Comparison with Real Internet Testbed





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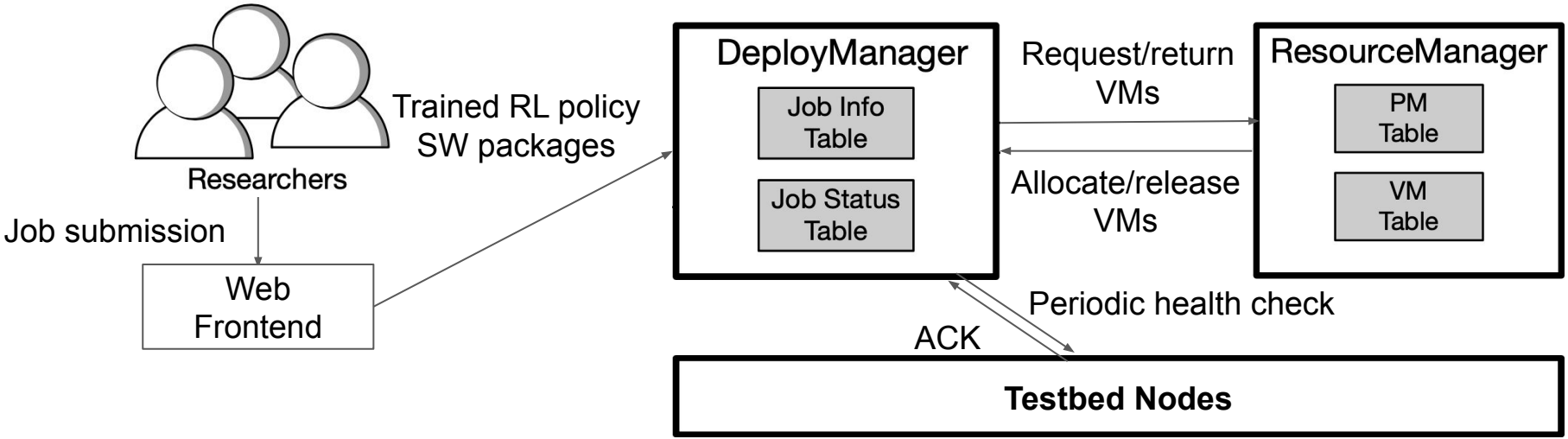
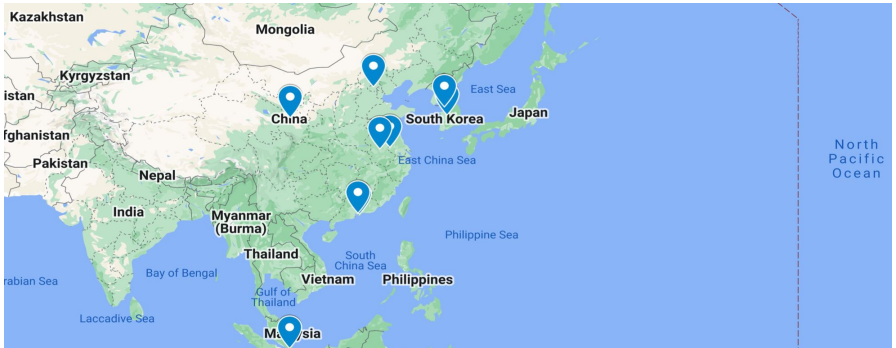




OpenNetLab: Contribution to Research Community

- Three network scenarios with different bandwidth and latency characteristics
- Scoring: weighted sum of network score & media quality score
  - Network score: weighted sum of delay, loss, receiver-side throughput
  - Media quality score: video score (VMAF), audio score (DNSMOS)

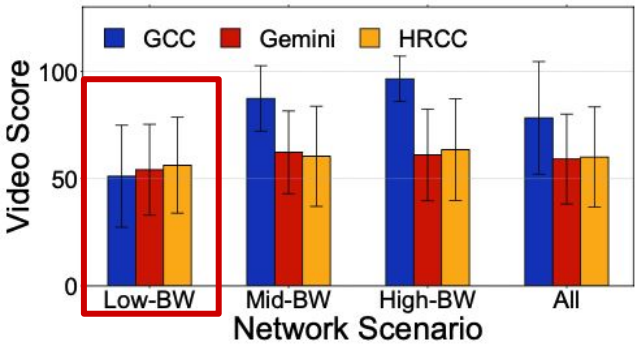
Grand Challenge on

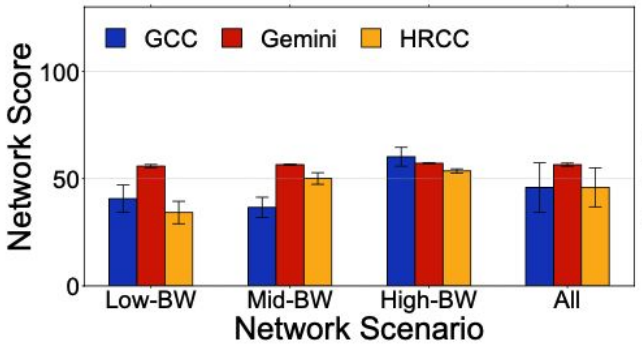
Bandwidth Estimation for Real-Time Communications

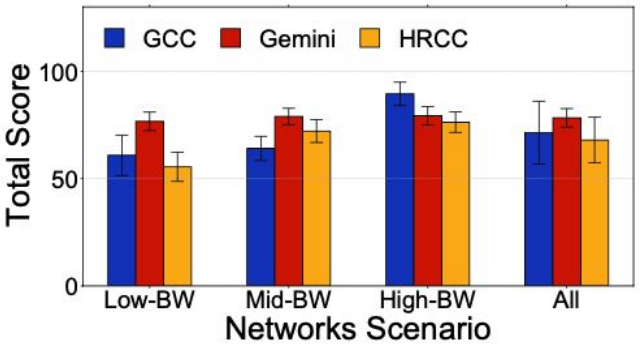
Node 1	Node 2	Bandwidth range	Mean RTT
Beijing (Wi-Fi with weak signal)	Hong Kong (Wired)	<1Mbps	55ms
Beijing (Mobile)	Hong Kong (Wired)	2 - 3Mbps	62ms
Lanzhou (Wired)	Hong Kong (Wired)	>10Mbps	30ms

OpenNetLab: Contribution to the Research Community

- OpenNetLab contributed to training & validation of state-of-the-art RL-based CC
  - Baseline: widely used rule-based GCC
  - HRCC (published in MMSys'21), Gemini (challenge winner)







RL-based CC outperforms GCC on video quality under low bandwidth network path

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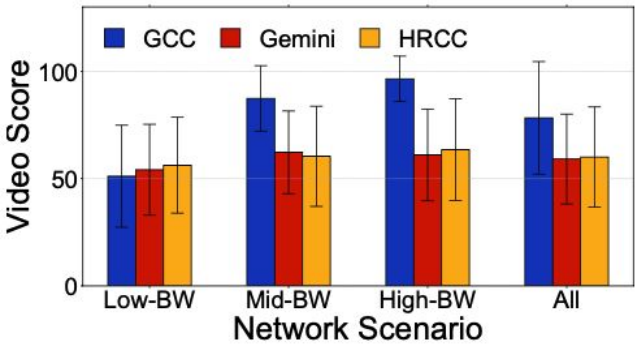

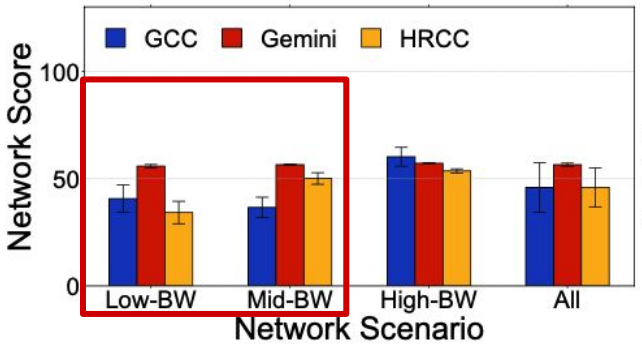

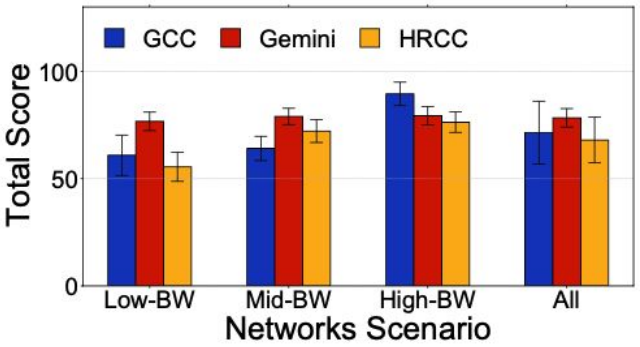

RL-based CC outperforms GCC on network performance under low & mid bandwidth network path

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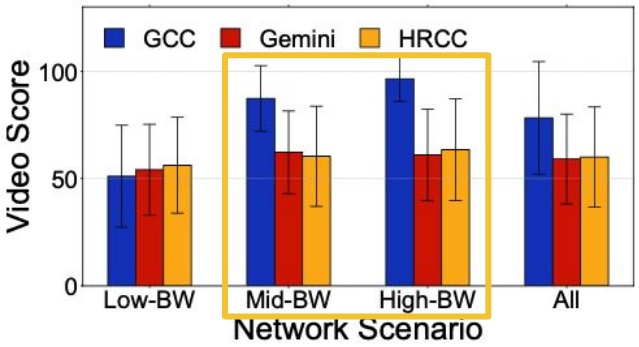

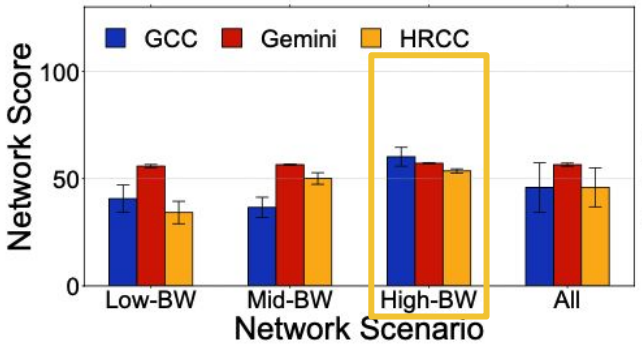

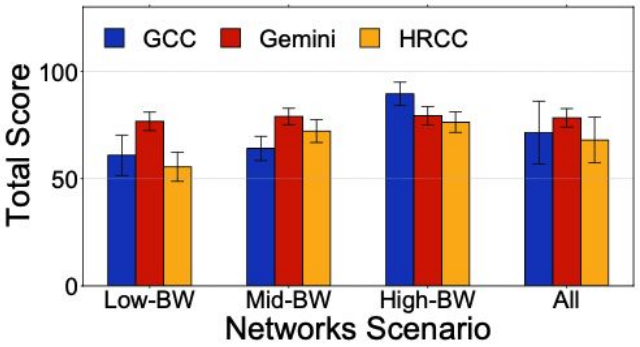

Future Work

- Open dataset and model zoo
  - Trace collection under heterogeneous network types of real Internet
- Common reference set of 7 state-of-the-art CC algorithms
  - Rule-based: MMSys'16 GCC
  - CC-codec co-opt: NSDI'18 Salsify
  - Online learning-based: NSDI'18 PCC-Vivace, ICML'19 PCC-RL
  - RL-based: MobiCom'19 Concerto, MobiCom'20 Loki, MMSys'21 HRCC

Conclusion

- OpenNetLab: an end-to-end platform for RL-based CC for RTC.
  - Fast training
  - Reproducible evaluation
  - Validation under real Internet
- Try OpenNetLab RTC tools: https://github.com/OpenNetLab/
- More information on https://opennetlab.org/

Q & A