UC San Diego
JACOBS SCHOOL OF ENGINEERING
Electrical and Computer Engineering

TEXAS A&M UNIVERSITY

WCSNG
Wireless Communications Sensing and Networking

EdgeRIC: Empowering Real-time Intelligent Optimization and Control in NextG Cellular Networks

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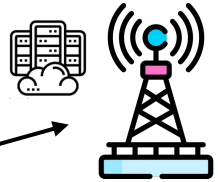
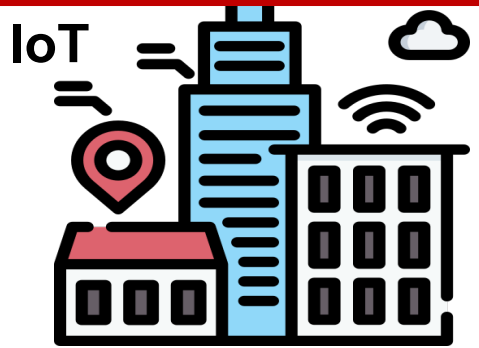
Towards Cloud Native Everything

- NextG cellular networks must support highly diverse end users



Cellular Networks can no longer be one-size-fits-all

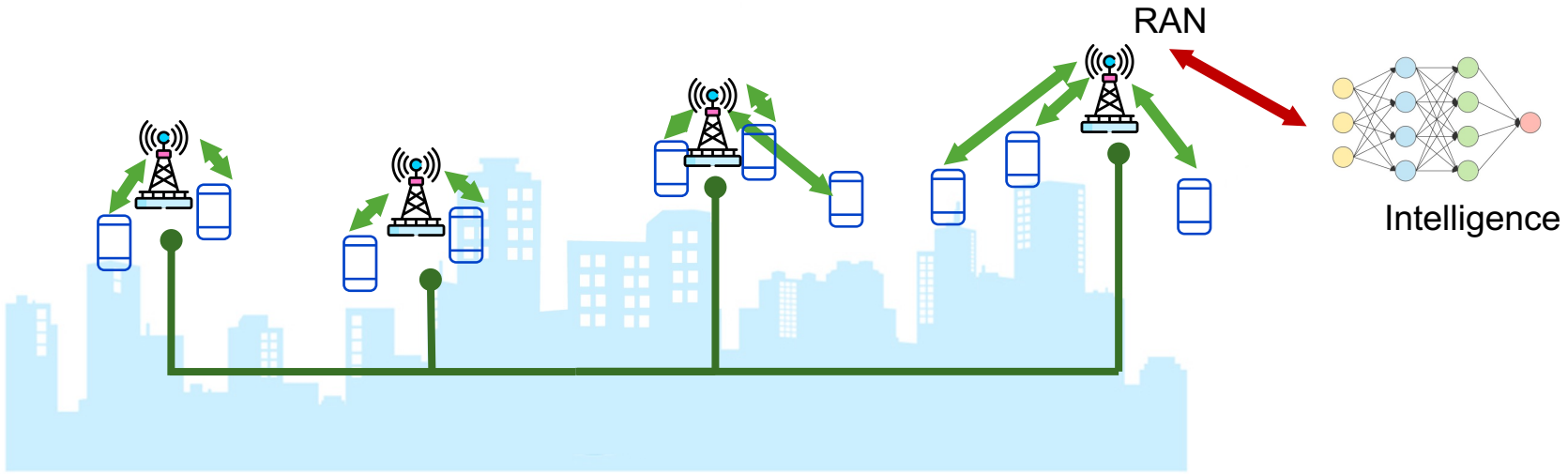


high reliability

low latency
high throughput

low latency
high reliability

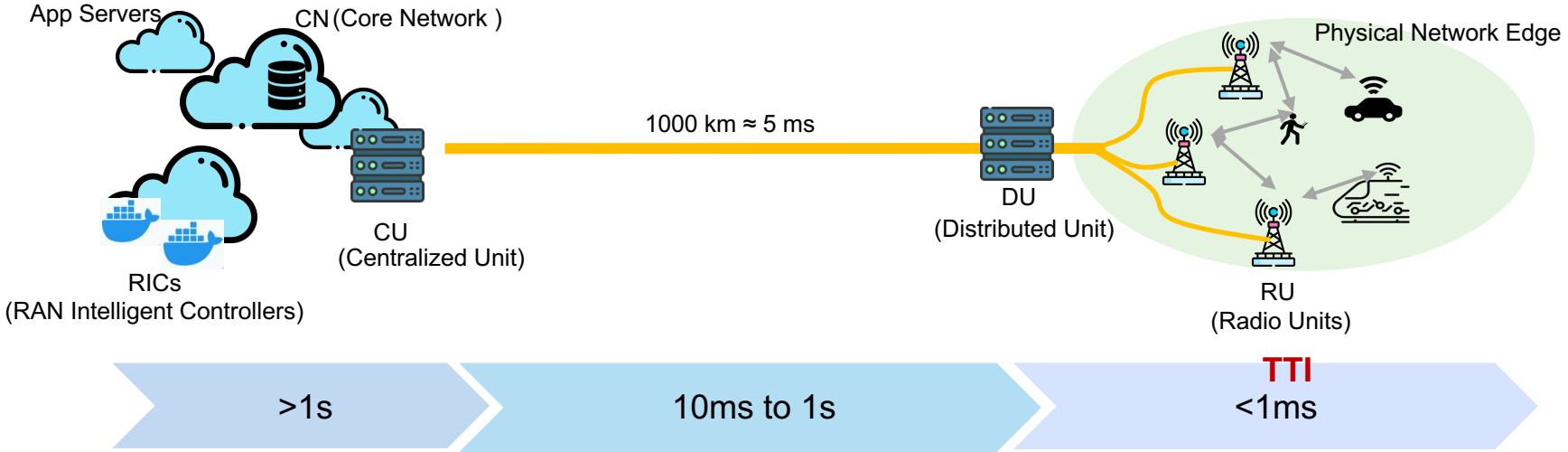
Towards RAN Intelligence and Automation



- Radio Access Networks (RANs) need AI/ML to deliver the potential of xG networks
- A decoupled framework is needed to execute/deploy AI/ ML (RICs)

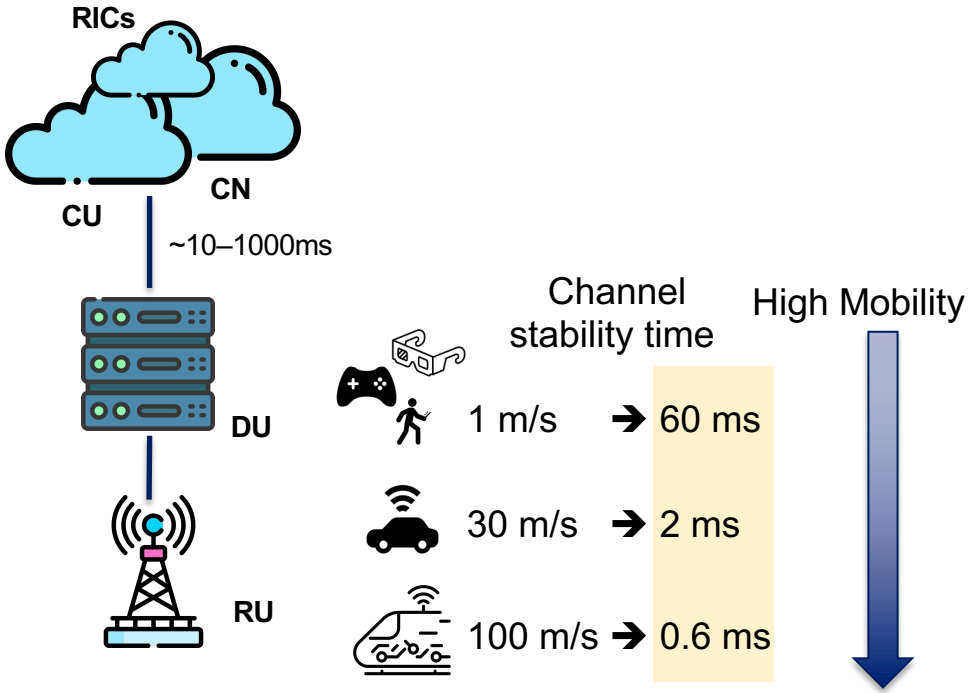
Open Radio Access Networks

- Industry trends towards disaggregation, interoperability and open interfaces for radio access networks (O-RAN)
- Industry trends towards RAN intelligent controllers (RICs) as a decoupled framework to AI/ ML capabilities to the cellular stack



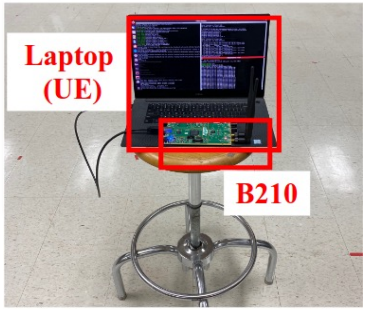
Issue I: Cloud-RICs are at least > 10 ms

- Near-RT RIC: Total propagation/processing delays ~ 10 ms to 1000 ms
- Wireless channel is highly unpredictable



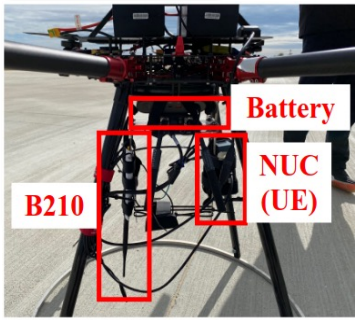
Can existing RICs support live adaptations to dynamic mobile links?

Real world channel changes fast!

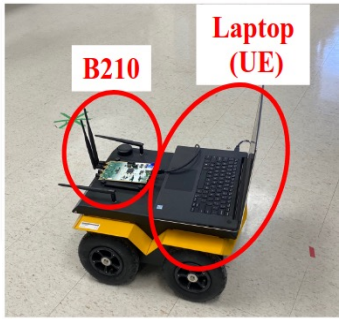


(a) Turntable

(b) Car

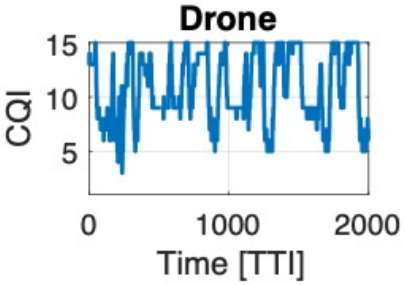


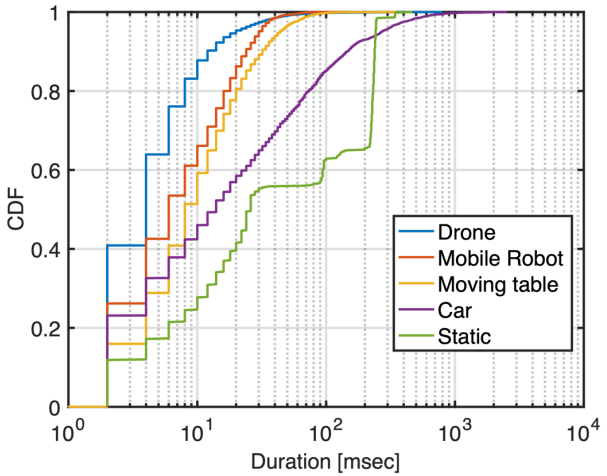
(c) Drone



(d) Mobile Robot

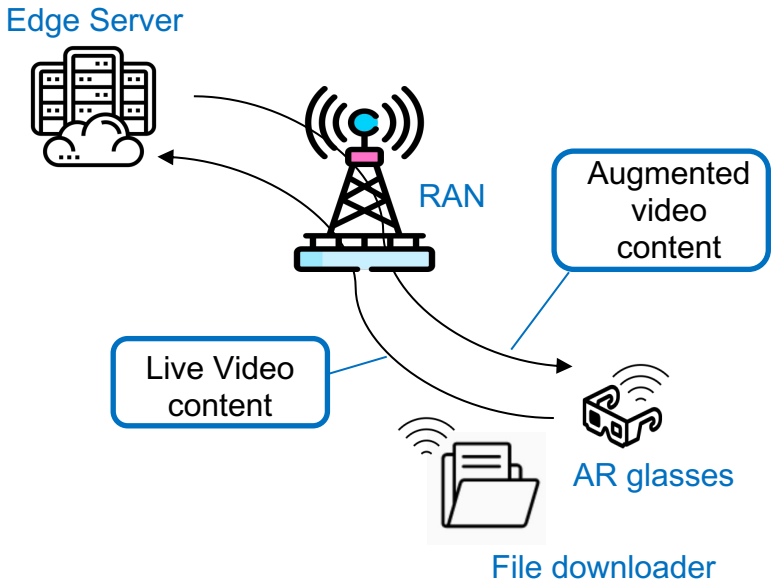
- Experiment setup: Real world channel traces (Channel Quality Indicator - CQI) collected for various mobility scenarios
- Observation: CQI changes in less than 5ms





Issue II: RAN functions are application agnostic

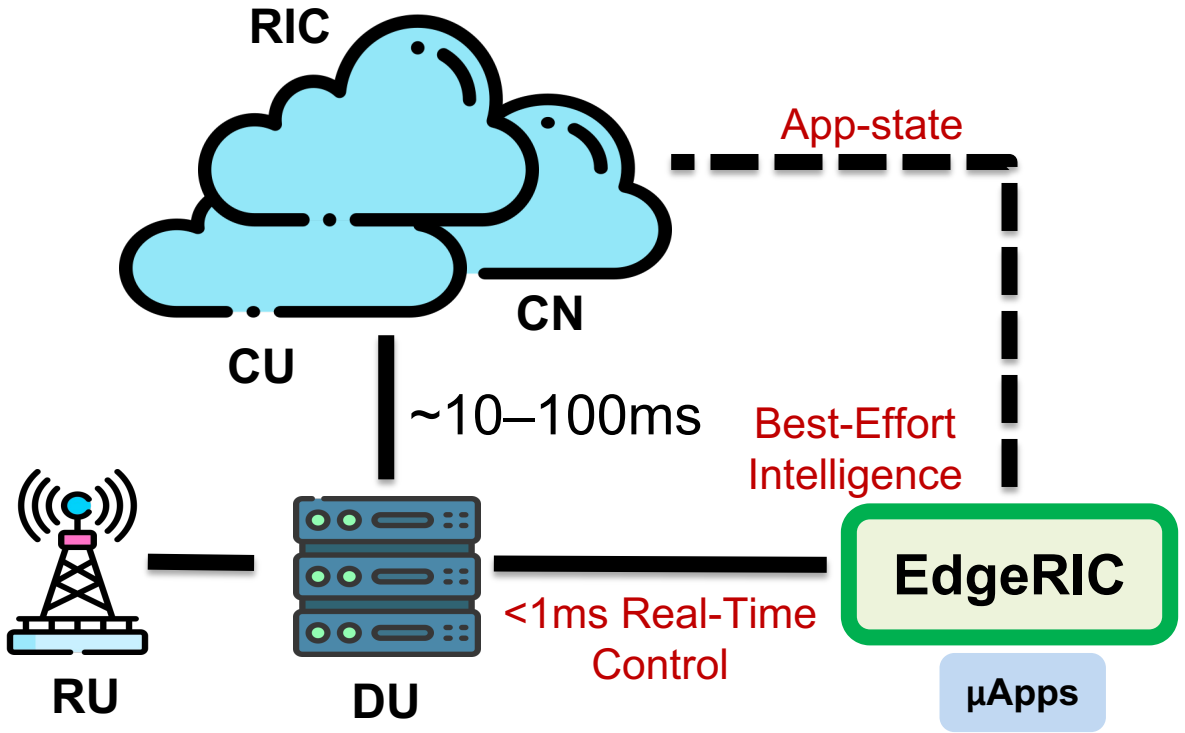
- Lower layer RAN functions are application agnostic
- Problem Scenario:
  - If the video stream freezes, it may lead to choppy videos and end user dissatisfaction.
- Solution: Application state awareness can facilitate user prioritizing to deliver a QoE (Quality of Experience) optimal network



Can we incorporate application awareness in cellular network functions?

EdgeRIC – Real Time RAN Intelligent Control

- Integrate application-aware intelligent control into PHY and MAC
- Enable unprecedented lower-layer intelligent optimizations with a **disaggregated** compute model running as a microservice



EdgeRIC: Key Contributions

Realtime

TTI level synchronization **(<1ms)** between RAN and EdgeRIC

Application State Awareness

Shared database with cloud-based systems

Ease of Deployment

Open source

µApp development with off-the-shelf ML codebases

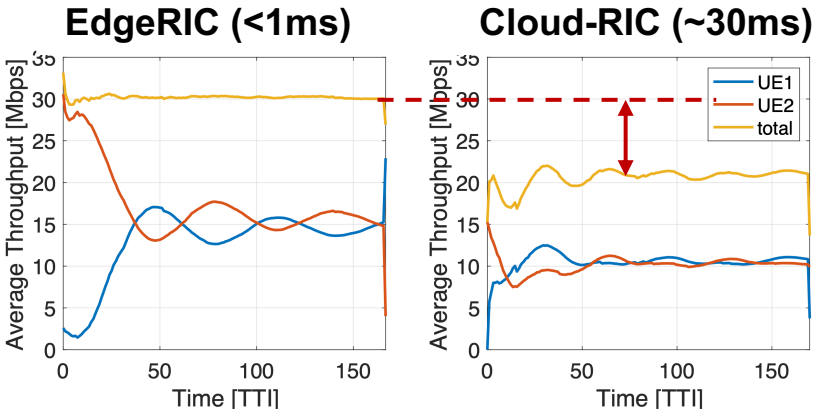
Emulator Module

Facilitate offline **training of ML models**

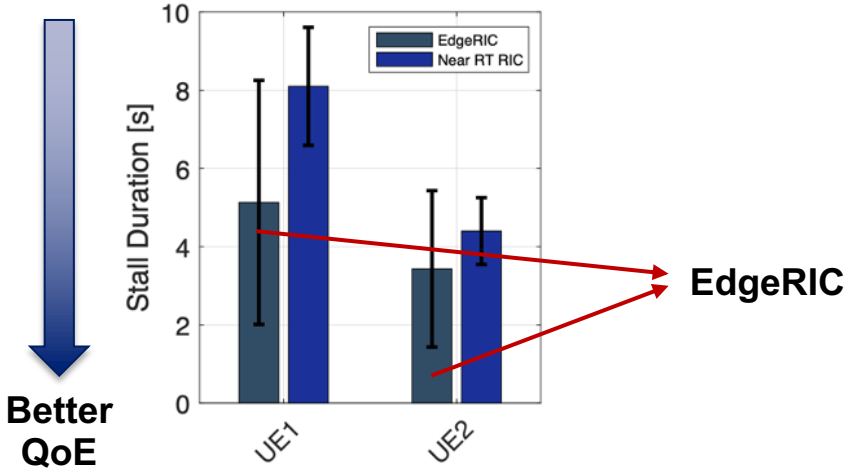
Deploy an example µApp and demonstrate real-time AI-in-the-loop with over the air experimental results [srsRAN cellular stack]

Bottom Line Up Front

- Scheduling decisions made at **TTI timescale** supports a higher system throughput

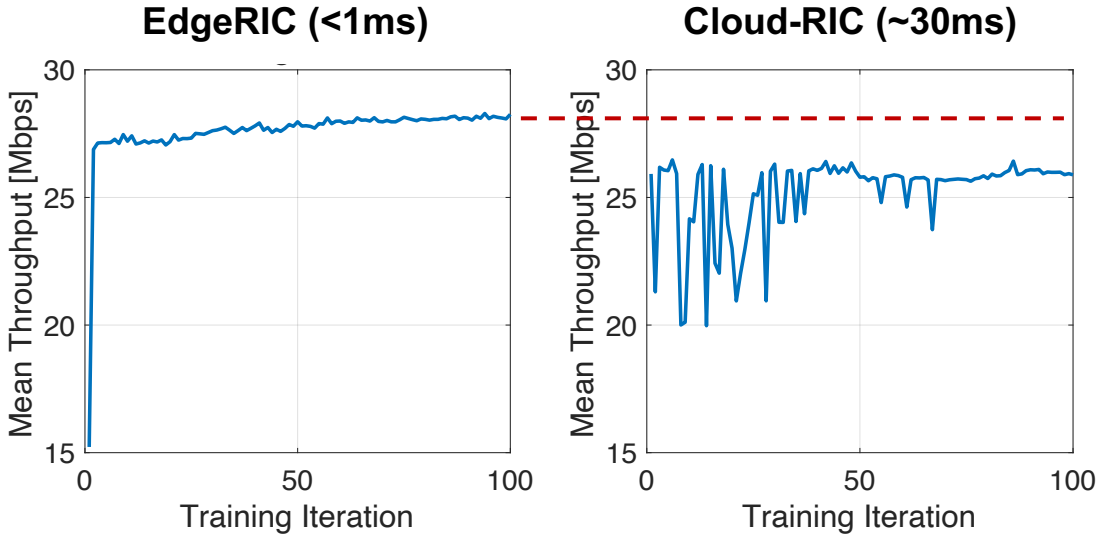


- **Application aware** intelligent scheduling decisions in **real-time** achieves significantly better QoE



Bottom Line Up Front

- Closed loop control and training breaks down with jittery delayed feedback



EdgeRIC: Key Features

Real-time connectivity to RAN stack

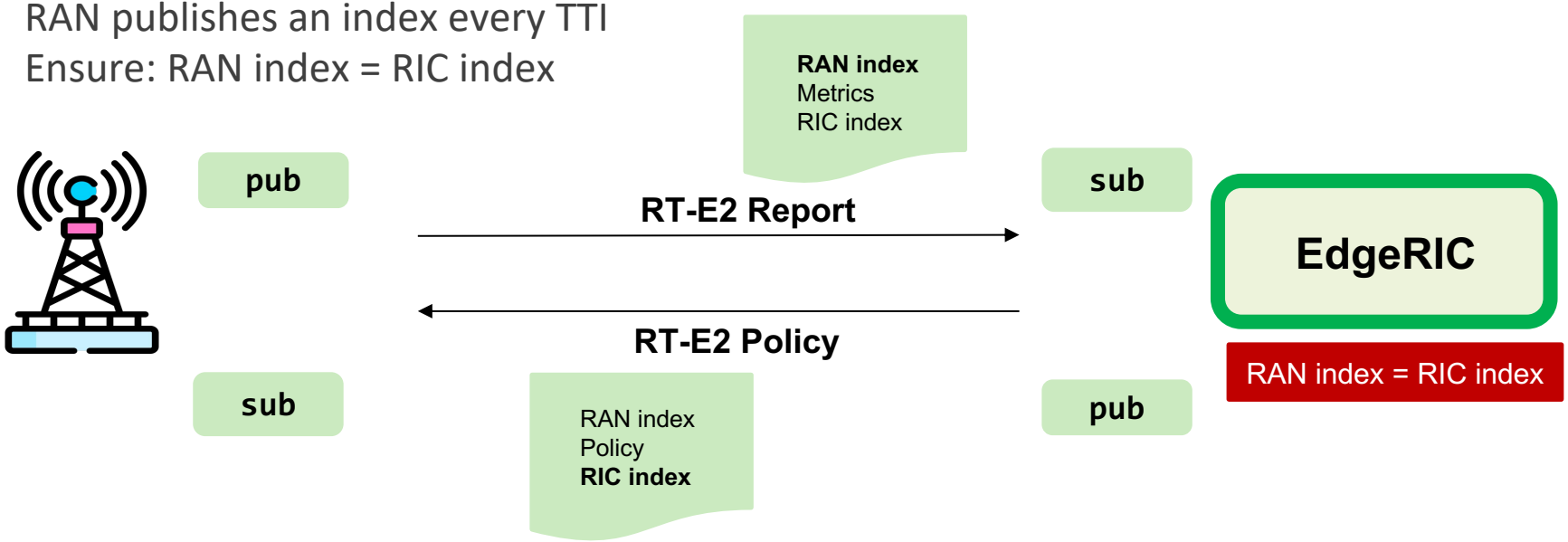
Realtime

TTI level synchronization (<1ms) between RAN and EdgeRIC

Low overhead Messaging [RT-E2] – ZMQ

Realtime Sync with TTI index

- RAN publishes an index every TTI
- Ensure: RAN index = RIC index

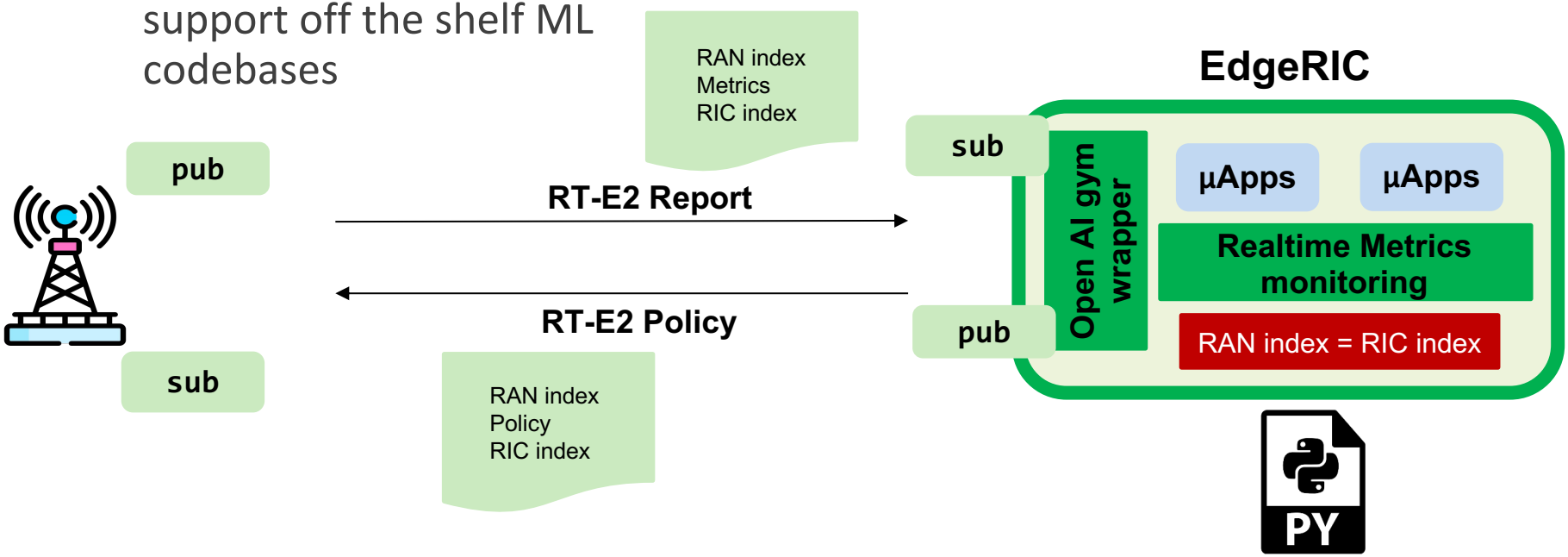


µApp development interface

Ease of Deployment

Open source/ **µApp development** with off-the-shelf ML codebases

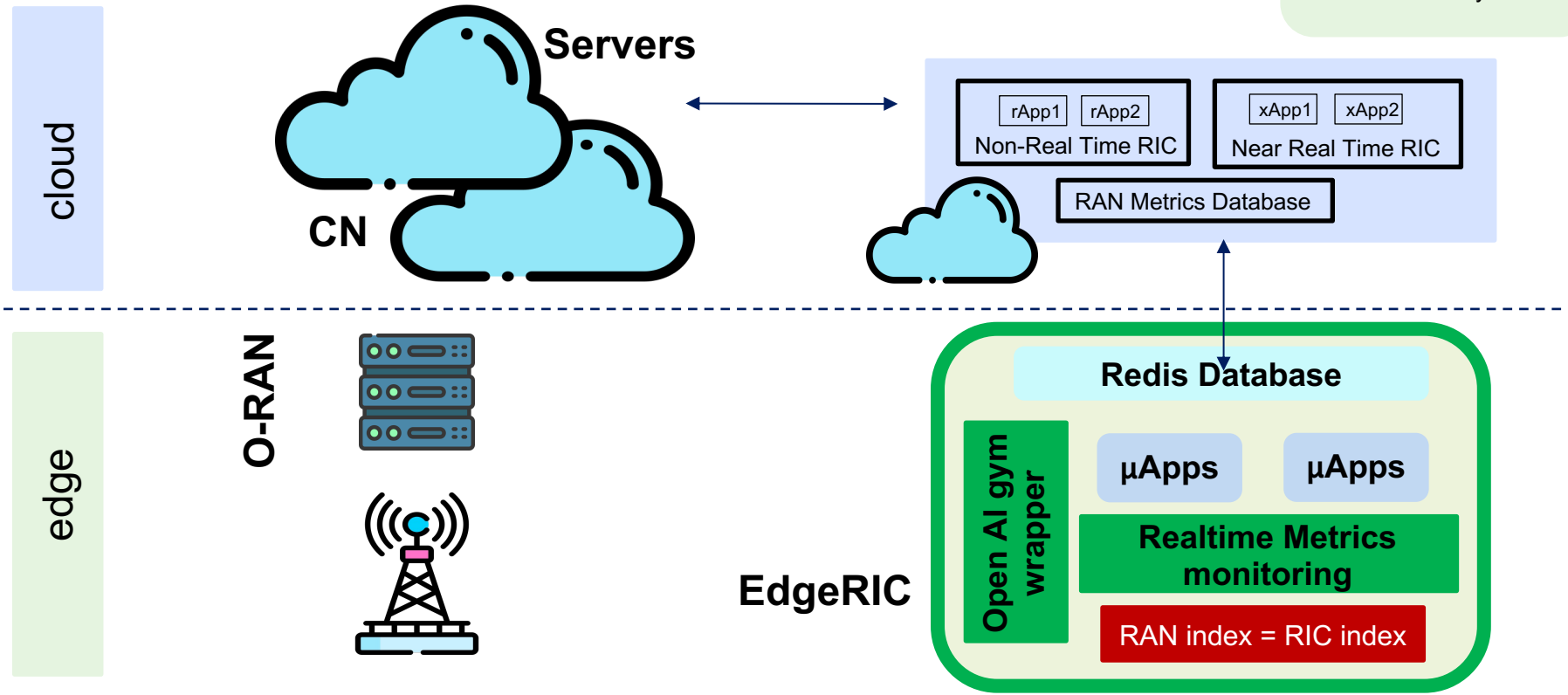
- OpenAI gym interface to support off the shelf ML codebases



EdgeRIC shares database with cloud

App state awareness

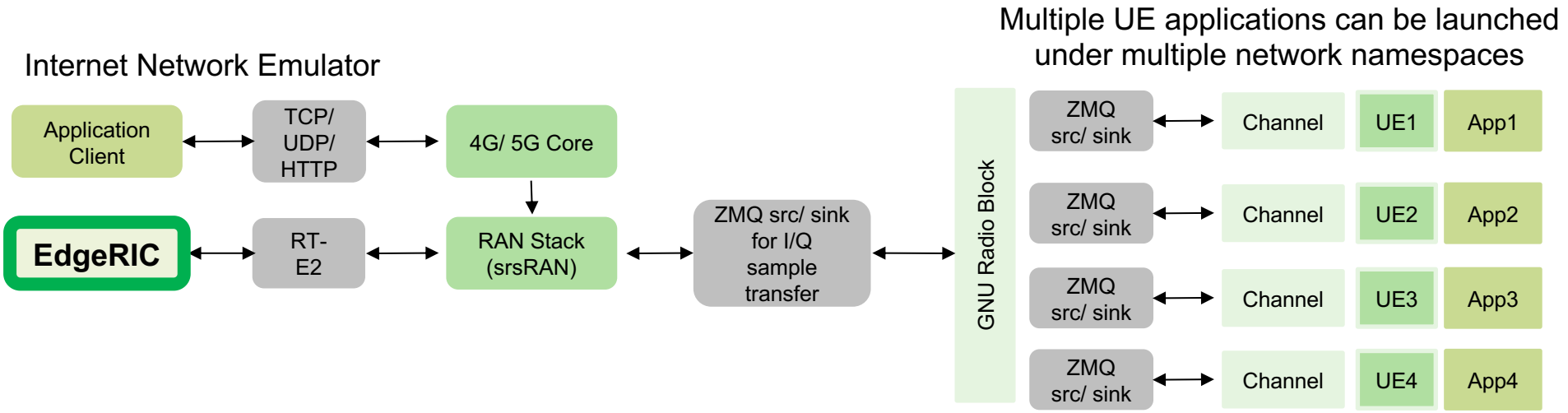
Shared database with cloud-based systems



EdgeRIC emulator module with srsRAN

Emulator module

Facilitate offline training of ML models

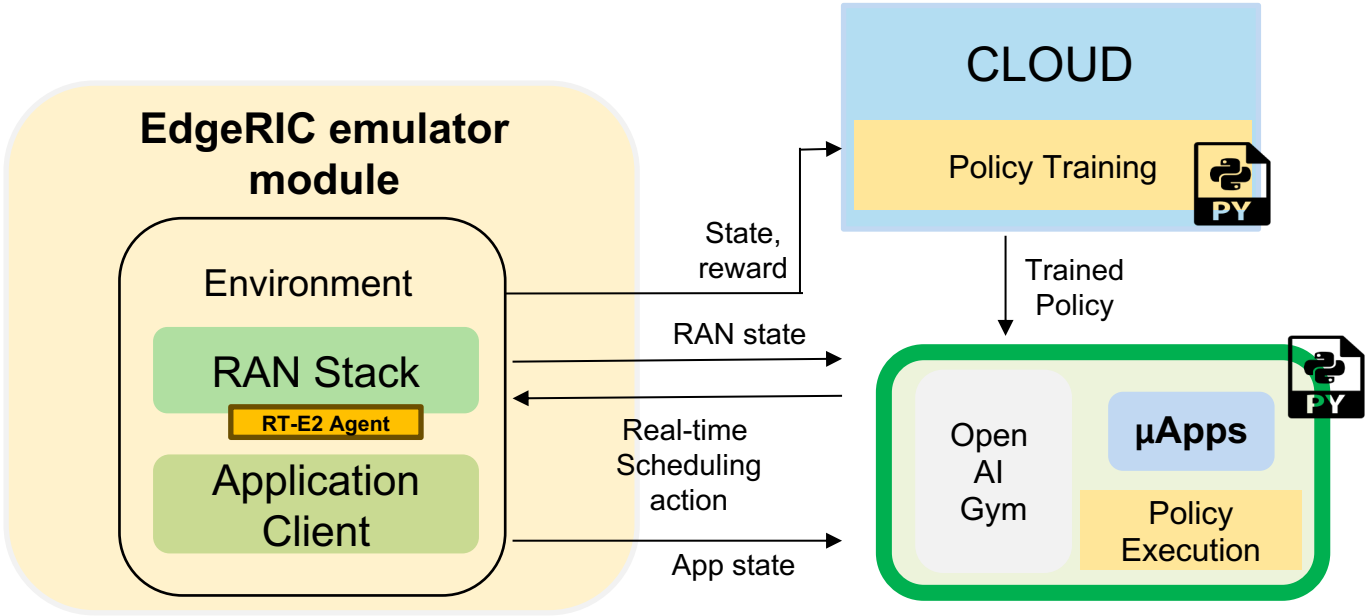


Emulator module for network data generation and offline policy training

An example µApp:
An intelligent resource scheduler at the 5G MAC (Medium Access Control) layer

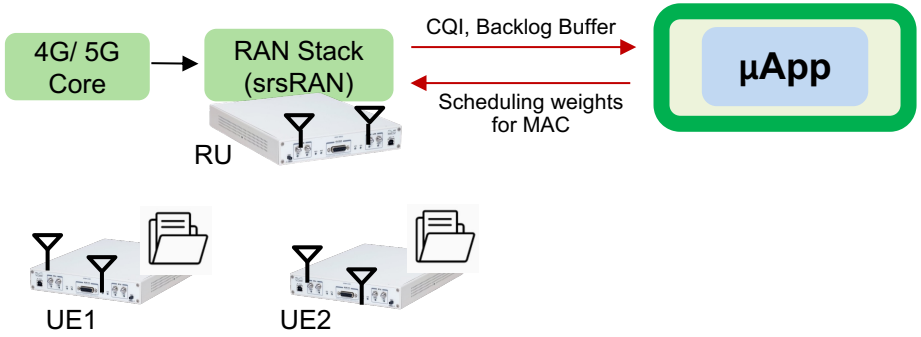
- Scenario 1: Scheduling to **enhance total system throughput**
- Scenario 2: Scheduling to **improve Quality of Experience** of a video streaming application

Reinforcement Learning based scheduling



µApp deploys an RL agent for the scheduling decision

Scenario 1: Enhancing system throughput

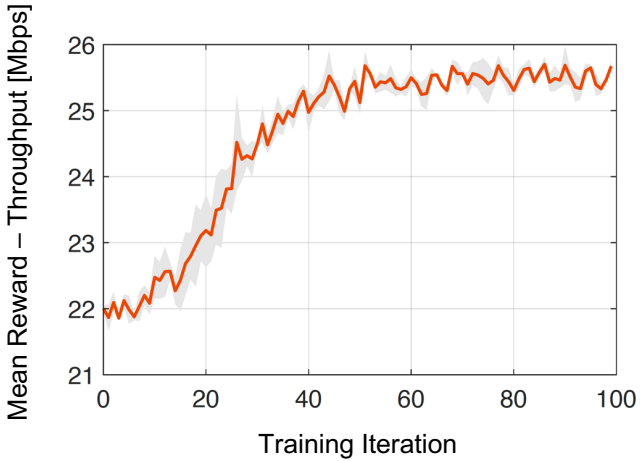


RL specifications

State $(s[t])$	$B_i[t], CQI_i[t]\ \forall i$
Action $(a[t])$	$w_i[t]\ \forall i$
Reward $(r[t])$	*total throughput*

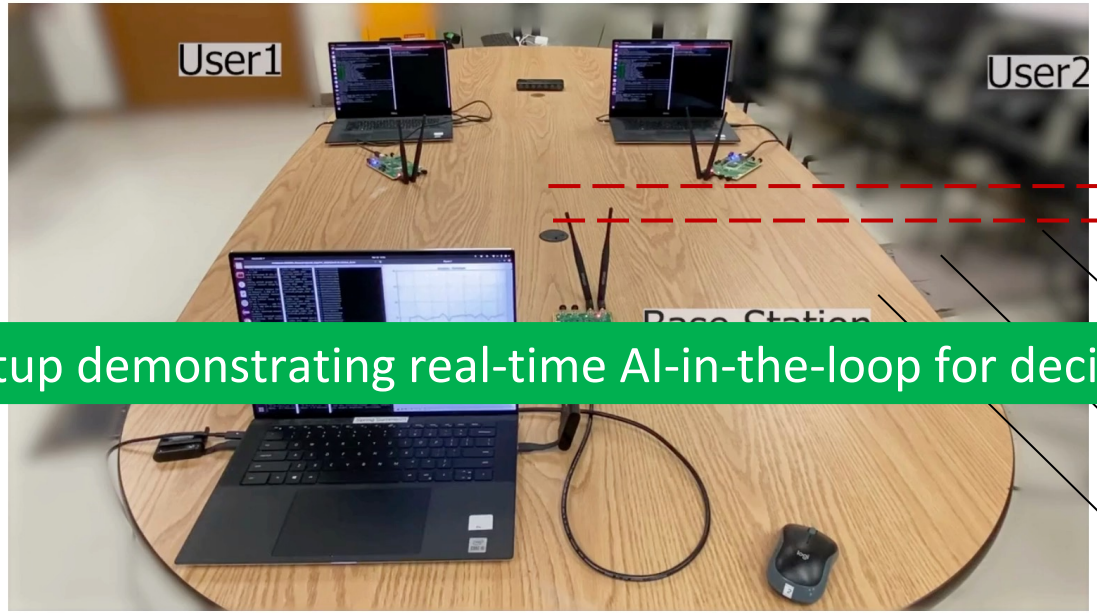
B_i: Backlog buffer
CQI_i: Channel Quality indicator

Training RL based scheduling policies on **EdgeRIC emulator module**



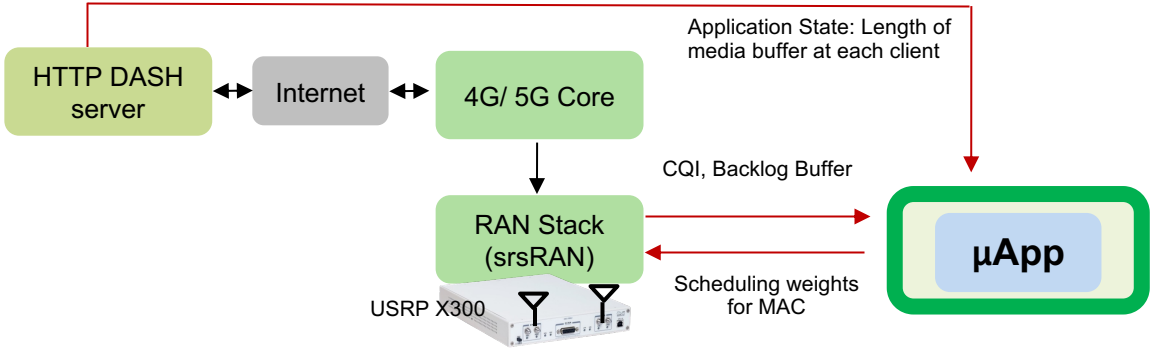
μApp policy enhances total system throughput with **real-time decisions**

Demo: Enhancing system throughput

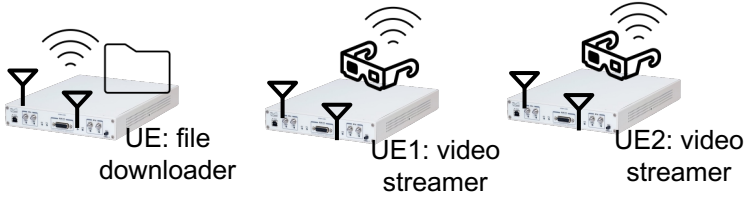


Experiment setup demonstrating real-time AI-in-the-loop for decision and control

Scenario 2: Maximizing Video QoE



Target scenario: Real World Content streaming with EdgeRIC



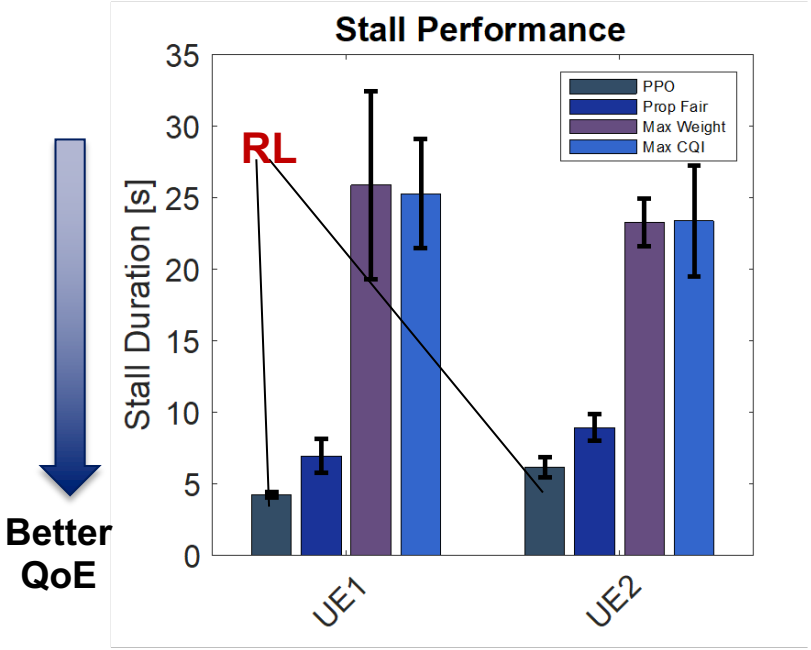
RL specifications:

MB_i: Media Buffer

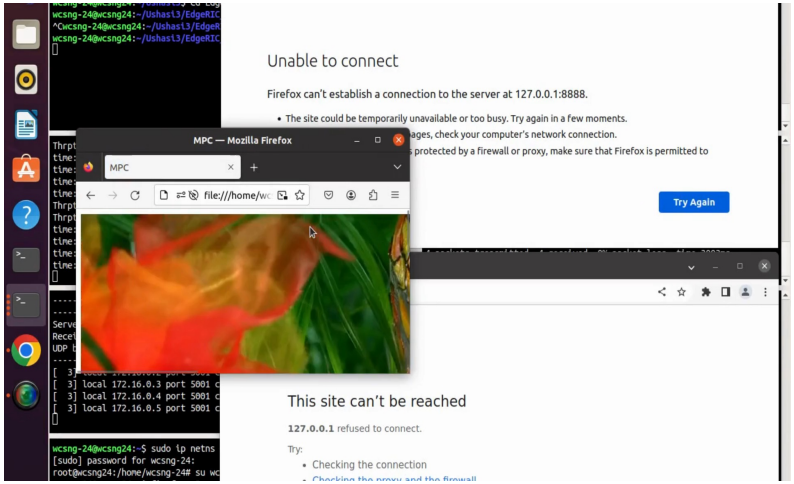
State ($s[t]$)	$B_i[t], CQI_i[t], MB_i[t]\ \forall i$
Action ($a[t]$)	$w_i[t]\ \forall i$
Reward ($\sum_i r_i[t]$)	$r_i[t] = \begin{cases} -20, & \text{if } MB_i[t] < 2\ sec \\ +2, & \text{otherwise} \end{cases} \quad \forall i$

µApp policy reduces video rebuffering time with **application state awareness**

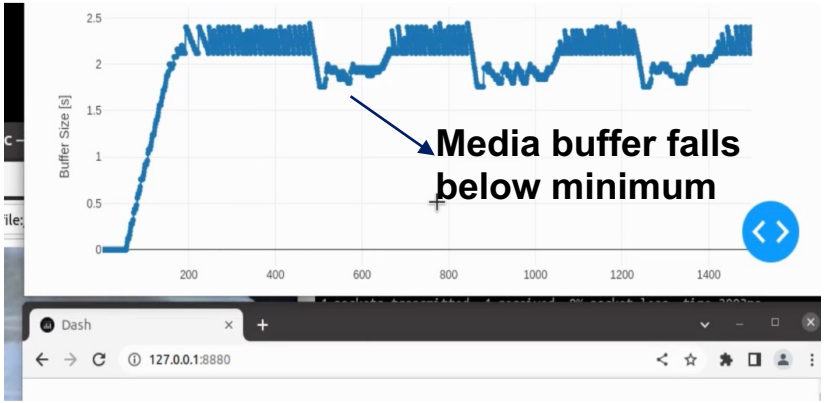
Evaluation: Video Streaming with EdgeRIC



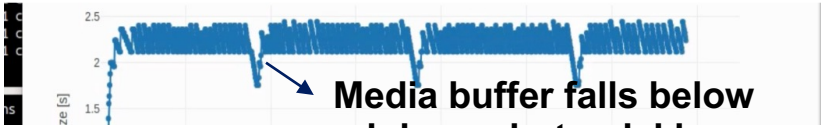
Demo: Video Streaming with EdgeRIC



Media buffer evolution with Max Weight scheduler



Media buffer evolution with RL scheduler



Application aware real-time scheduler effectively reduces rebuffering time

Key Takeaways

- **Real-time network intelligence** needed to keep up with the changing wireless channel
- **Application aware network intelligence** can deliver better quality of experience
- **Emulator module** bridges sim-to-real gap for training ML models
- Built on top of **open-source** network stacks, made publicly available for community research

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Open-source code:

- Emulator module
- EdgeRIC - over the air module

https://github.com/ushasigh/EdgeRIC-A-real-time-RIC