\Orchestrating a brighter world

vrAIn

A Deep Learning Approach to Virtualized Radio Access Networks

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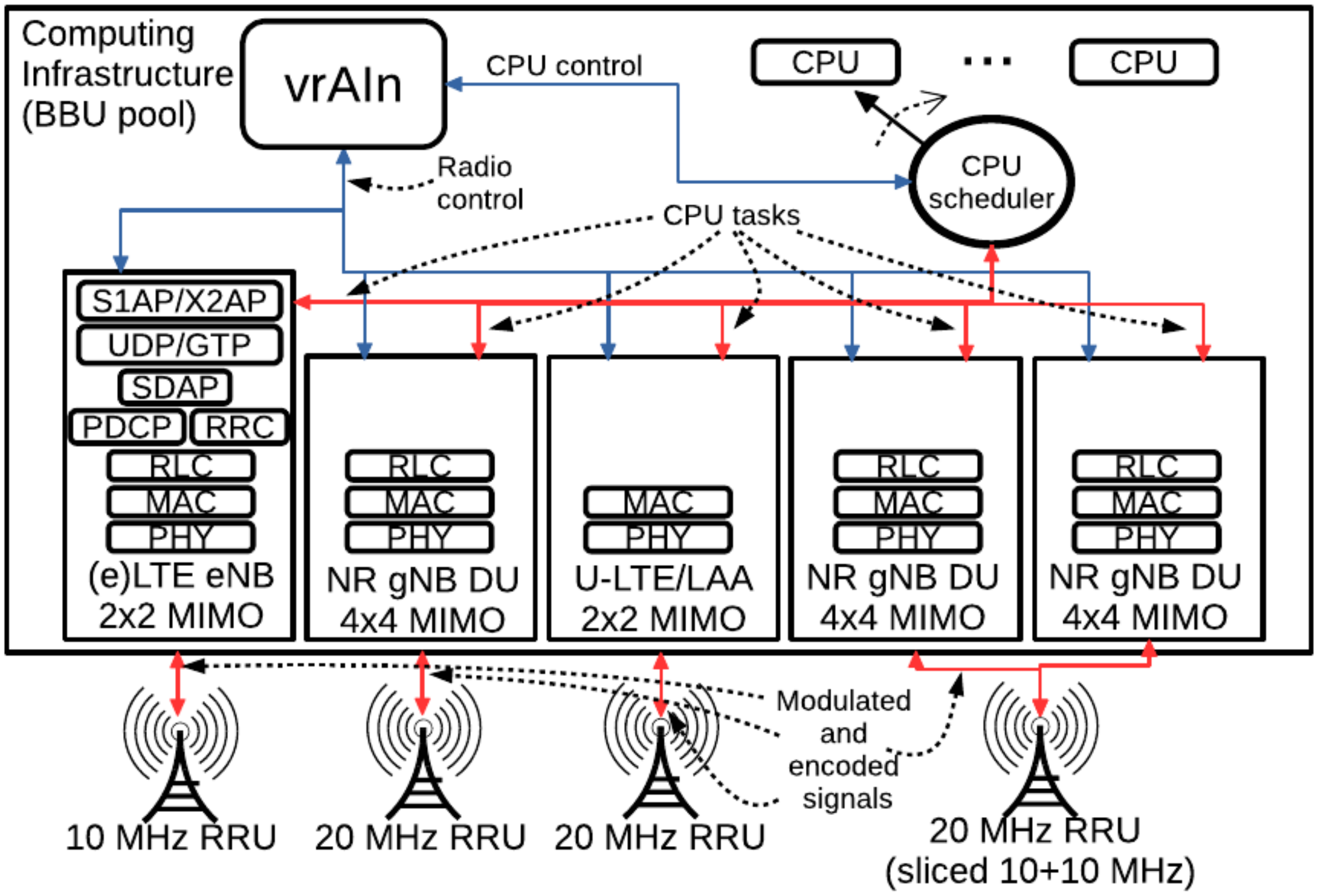
Why vRAN?

- Virtualized RAN (vRAN) **centralizes softwarized** radio access points (RAPs[1]) into **commodity** general-purpose computing infrastructure.
  - **Advantage 1:** Statistical multiplexing gains from resource pooling (via **centralization**)



[1]Base Transceiver Station (BTS) in 2G, NodeB in 3G, enhanced NodeB (eNB) in 4G, next-generation NodeB (gNB) in 5G, etc.

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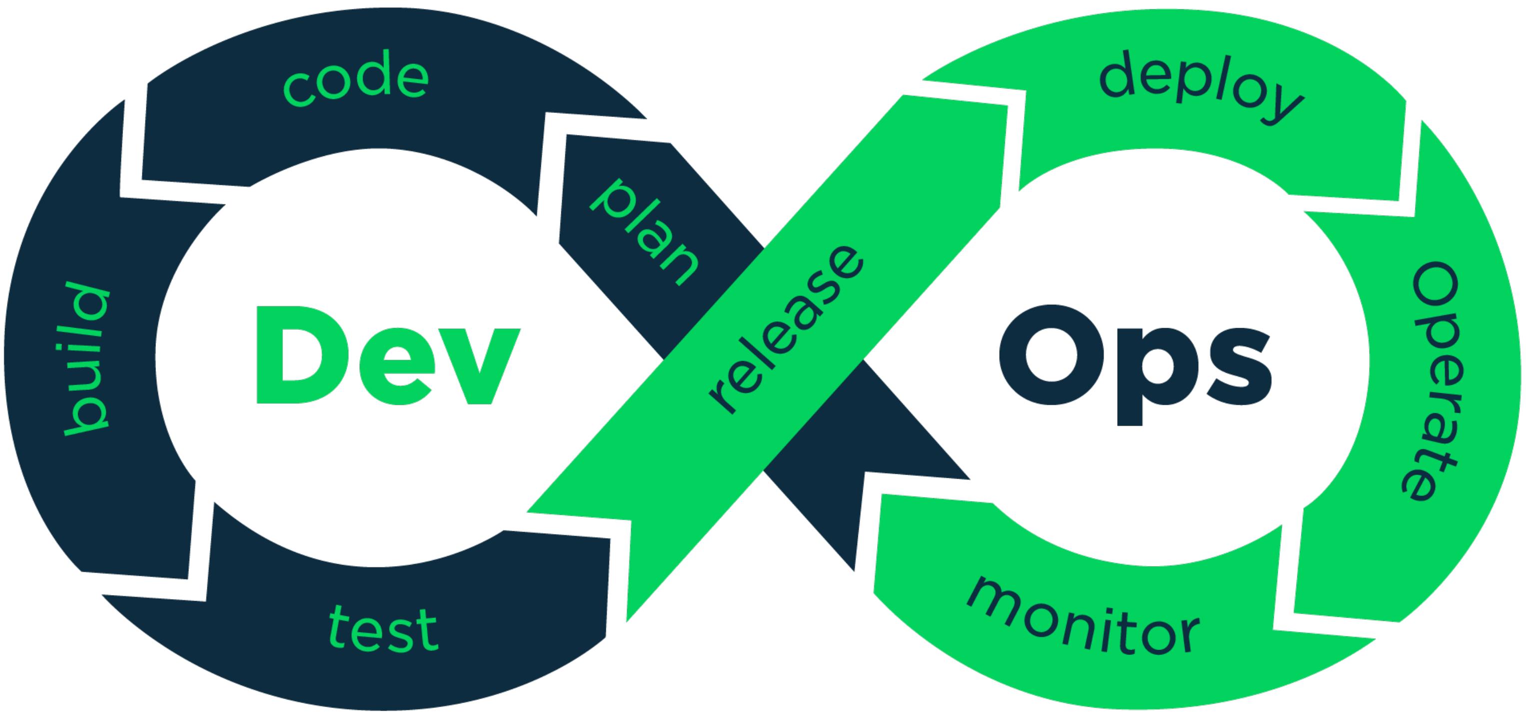
  - **Advantage 2:** Agile update roll-ups such us security patches, protocol upgrades, bug fixes, CI/CD, agile, DevOps, etc. (via **softwarization**)



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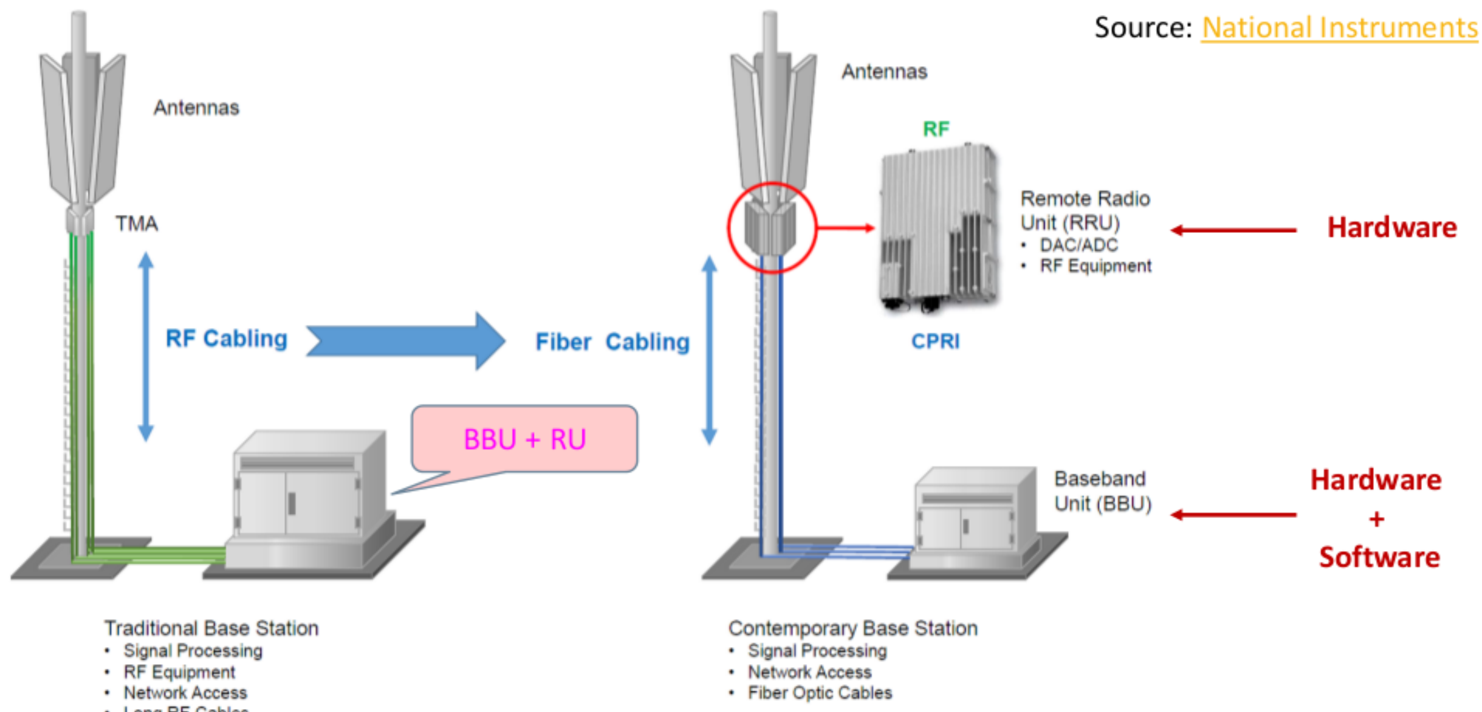
Contemporary RAN

Source: National Instruments



*From 3G4G Blog (http://www.3g4g.co.uk/)

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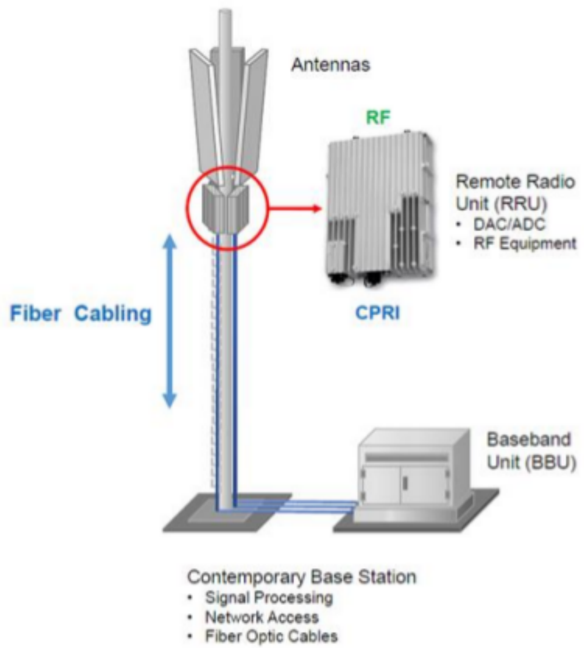
vRAN (Open RAN)



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- Propietary Hardware
- GPP based COTS Hardware (SDR)
Can be purchased from any ODM/OEM/RAN hardware vendor

Open Interface
Any vendor software can work on this hardware

COTS Server
+
Proprietary Software with virtualized functions

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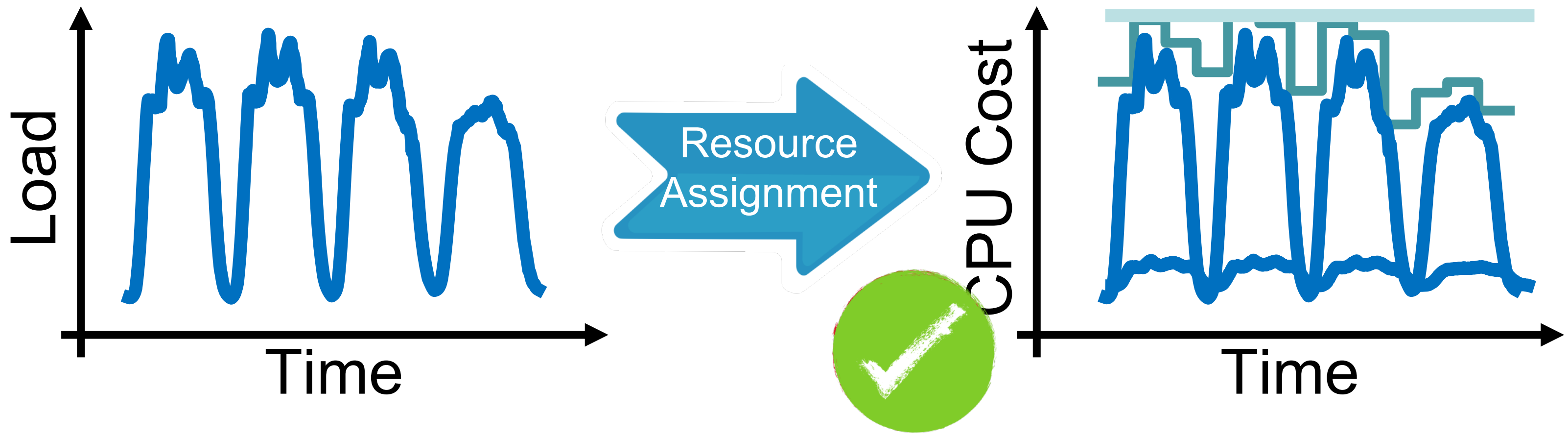
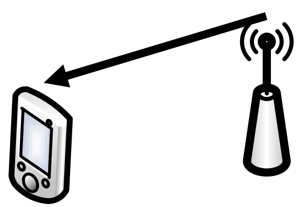
The resource orchestration problem

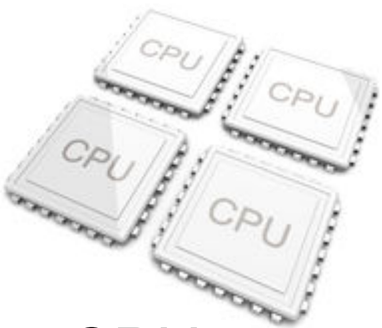


Resource assignment depends on many factors such as…

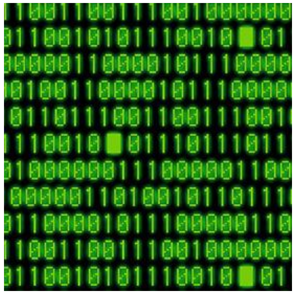
User Demand



Channel Conditions

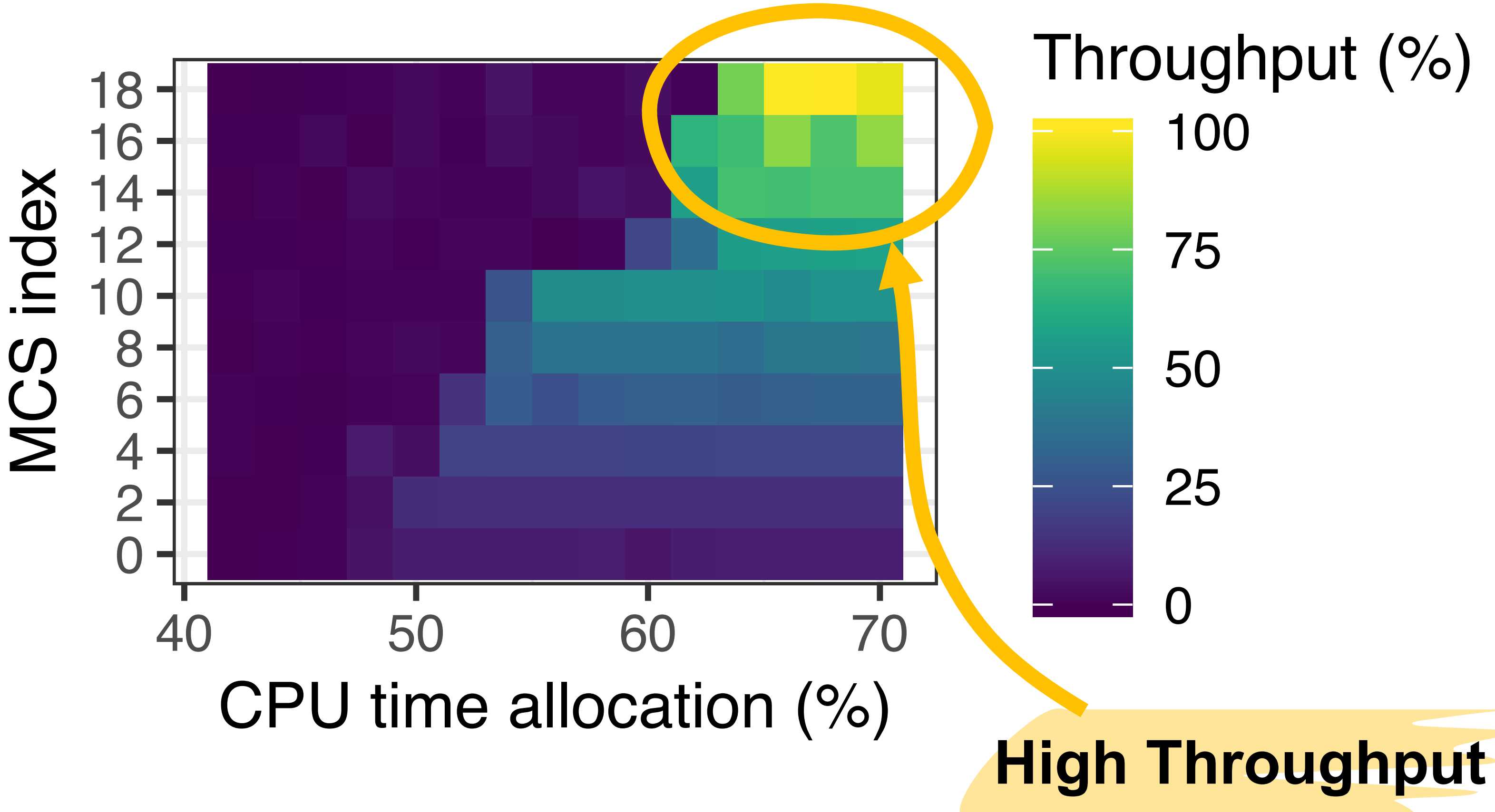


CPU Platform



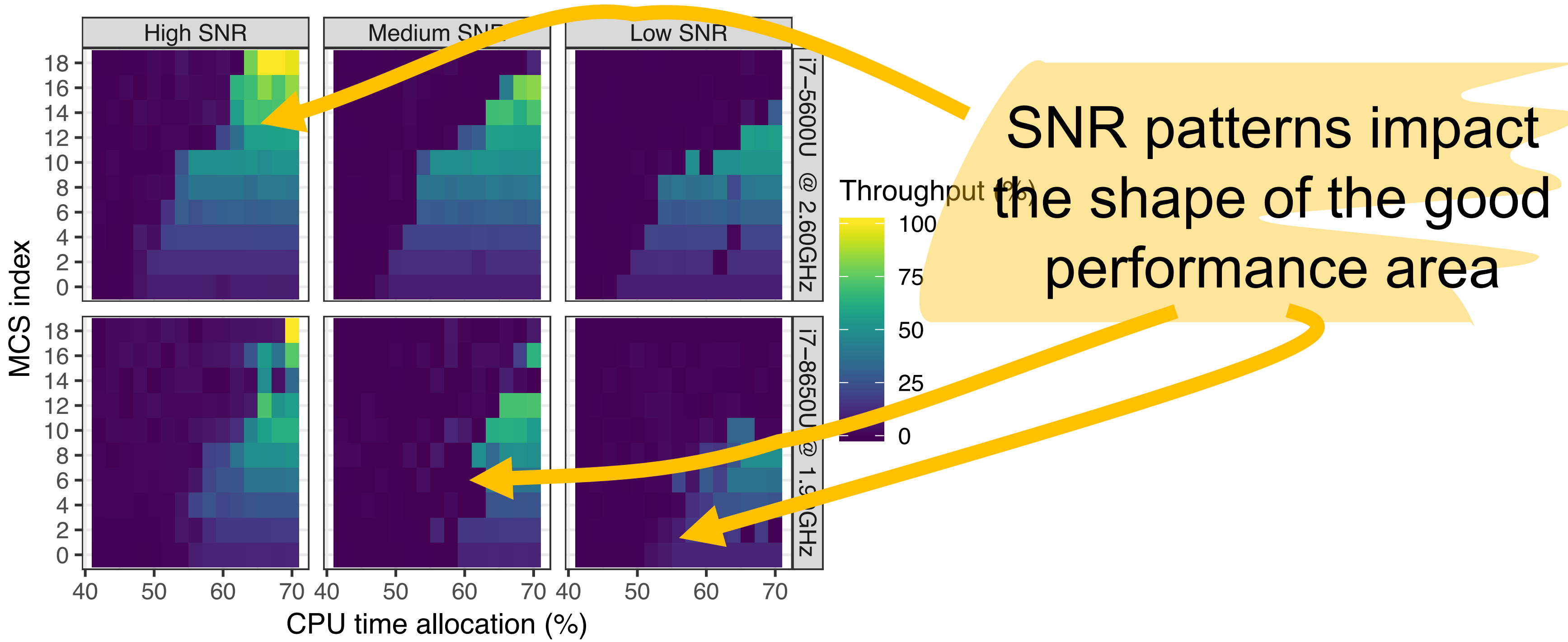
SW stack, functional split

The resource orchestration problem



SRSLTE

The problem is far from trivial



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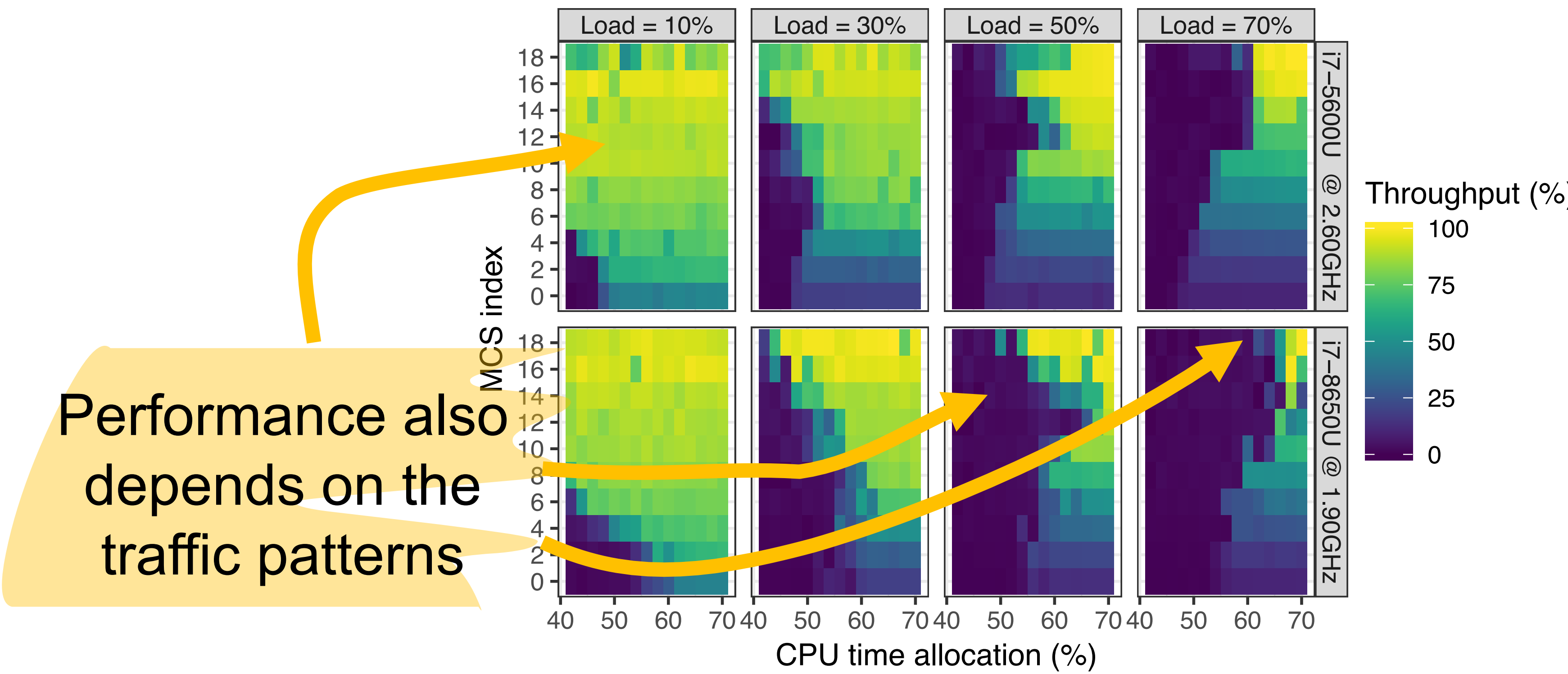

The problem is far from trivial

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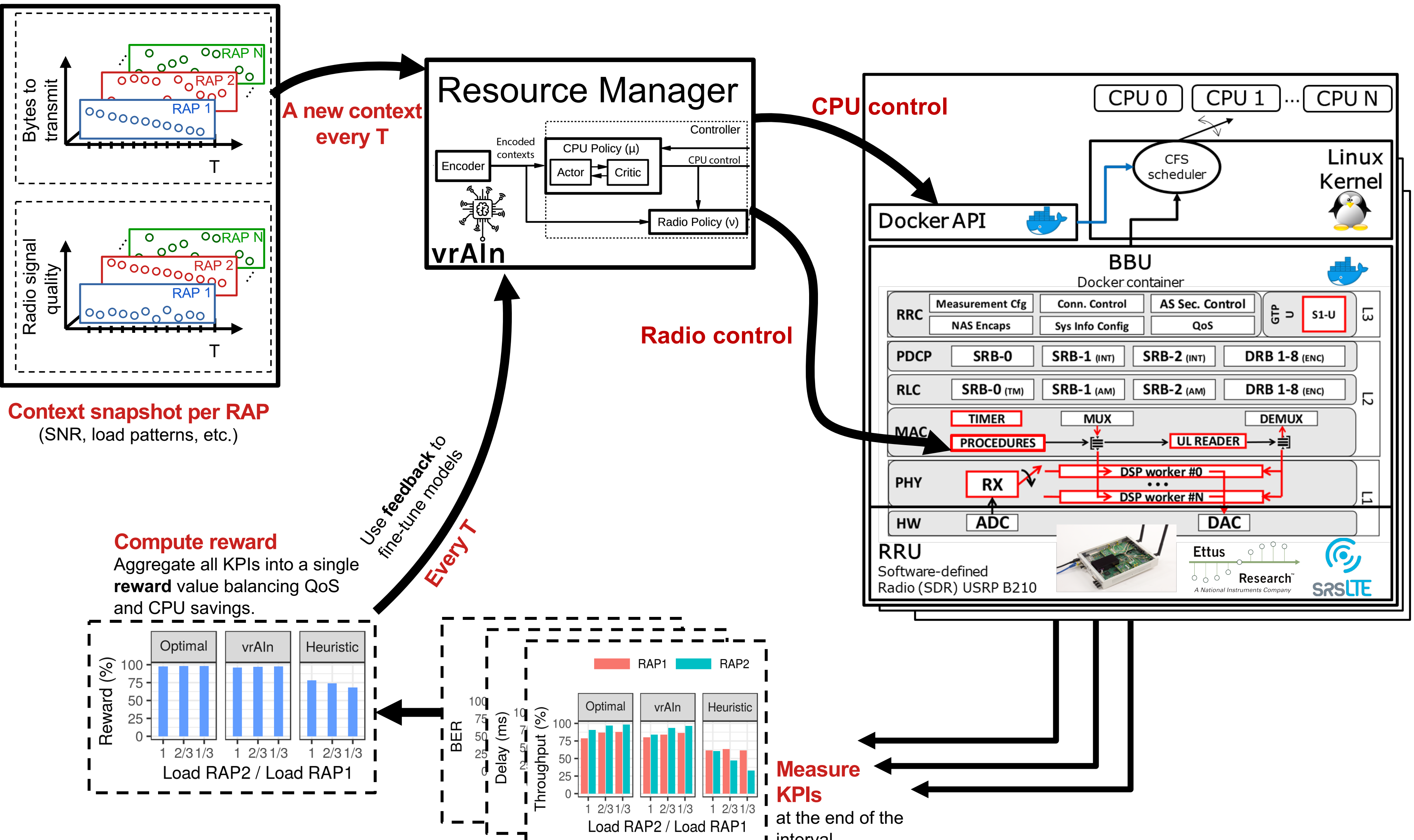
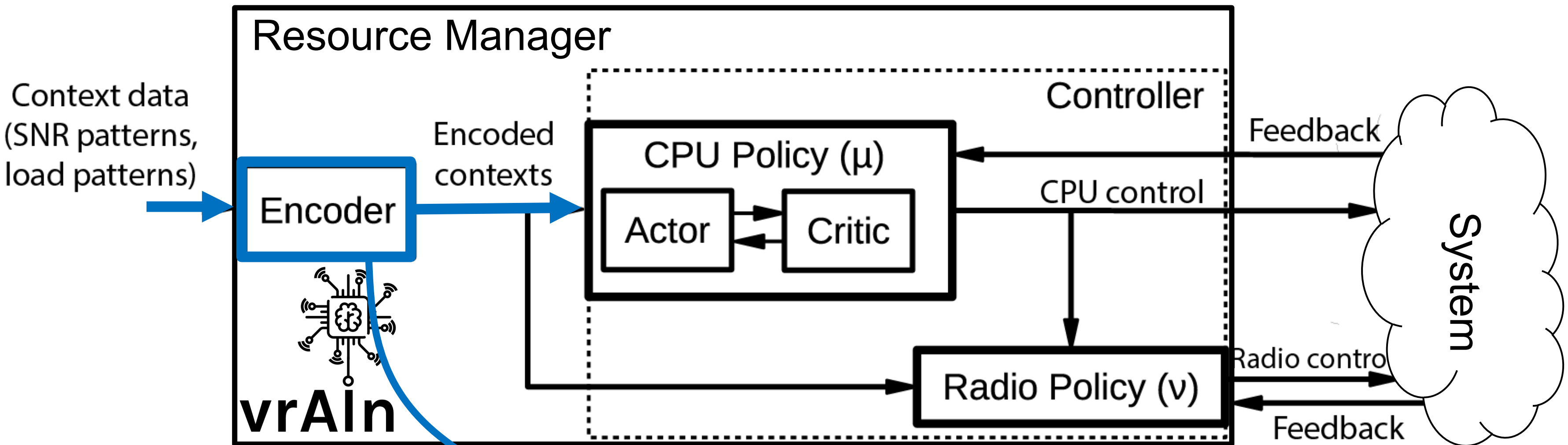
Performance is a very complex function of the contexts and the resource assignment
→ Deep Learning

vrAIn: AI based vRAN resource controller

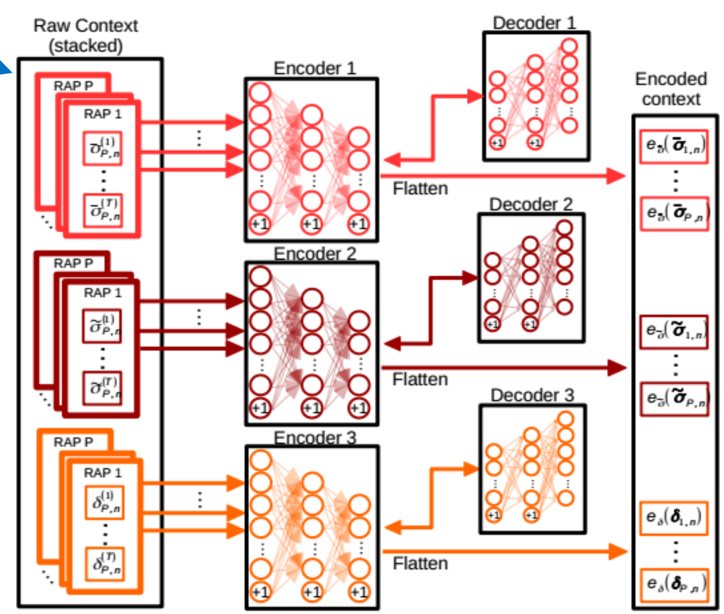


vrAIn: Challenges and Solutions



Challenge #1:
Dimensionality of the input contexts

Solution:
3 Sparse autoencoders to reduce the dimensionality



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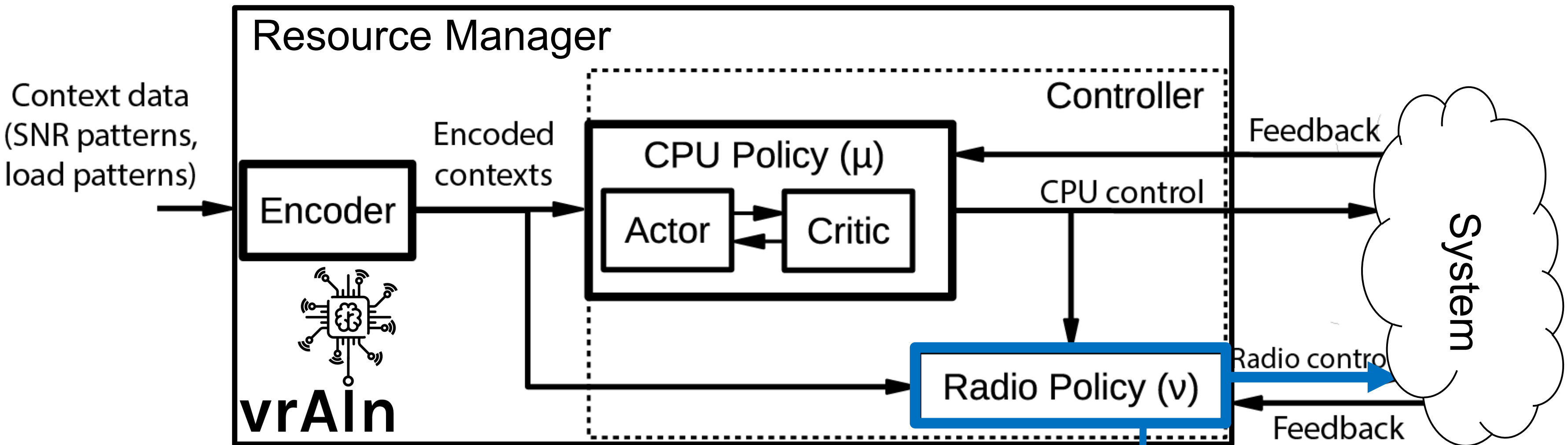
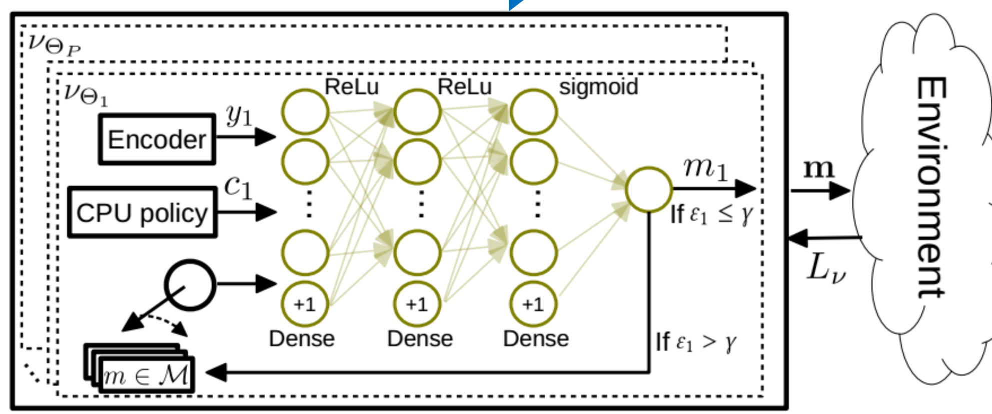
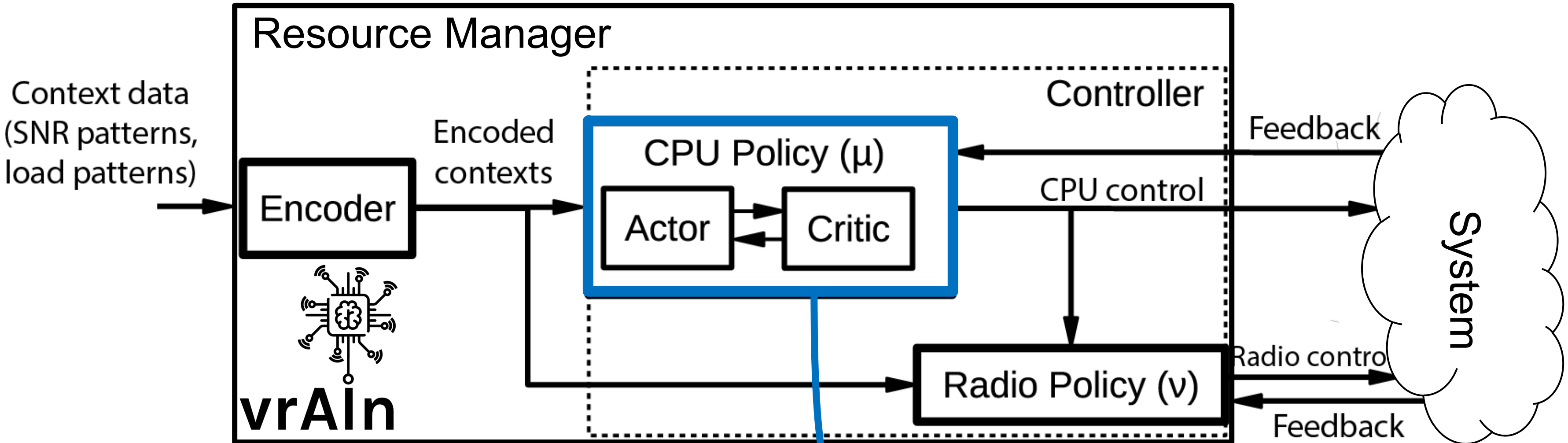


Challenge #2:
Heterogeneity of the action space (continuous and discrete)

Solution:
Decoupling of the radio and the CPU policy

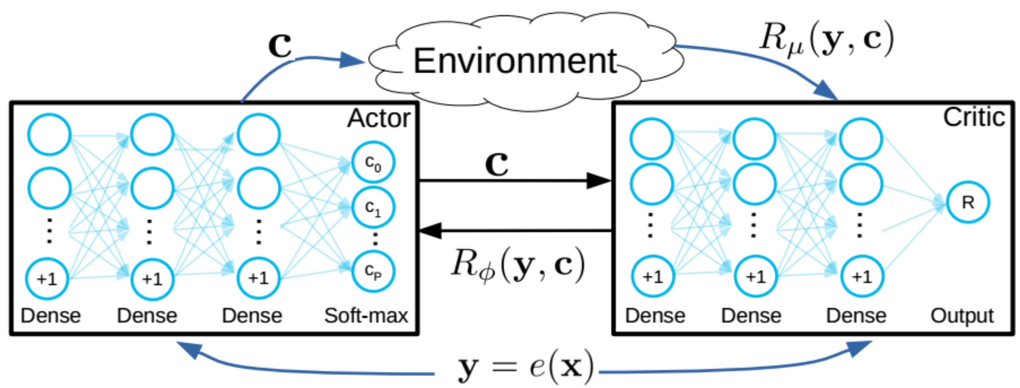


vrAIn: Challenges and Solutions



Challenge #3:
N-dimensional continuous controls for the CPU policy

Solution:
Deep Deterministic Policy Gradient



Evaluation results: Unlimited Resources

Scenario 1

- Unlimited CPU resources
- One virtual Base Station

Objective:

- Minimize the costs while satisfying the QoS

Evaluation results: Unlimited Resources

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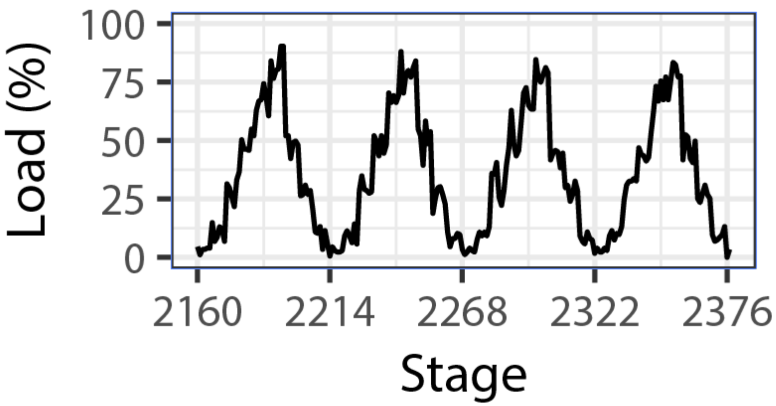
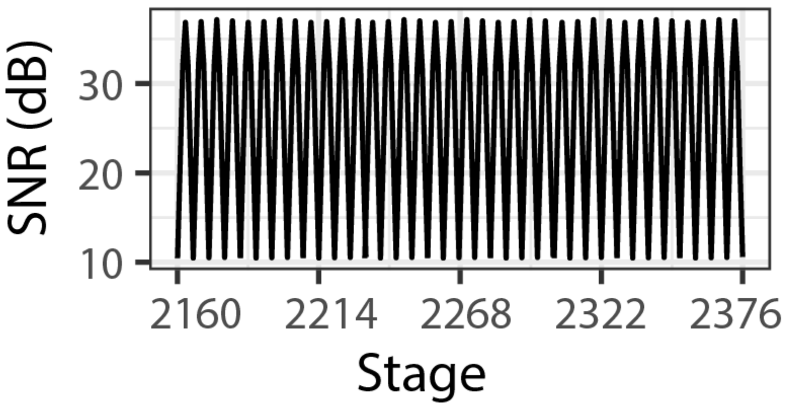
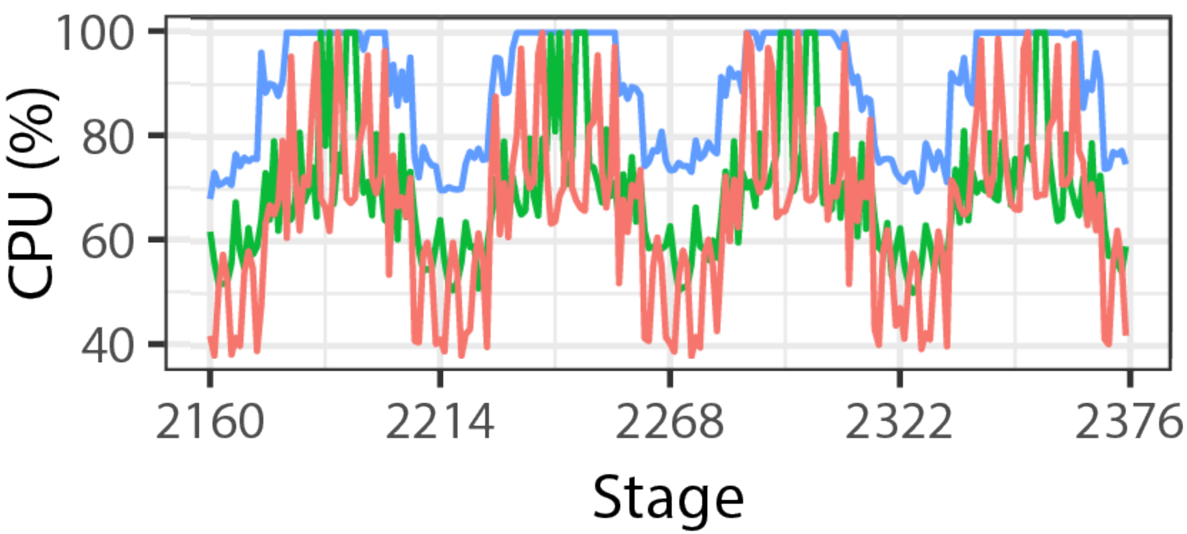
Contexts:





vrAIn CPU allocation:



	Average CPU Savings
High QoS	14%
Medium QoS	26%
Low QoS	39%

Evaluation results: Limited Resources

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Scenario 2

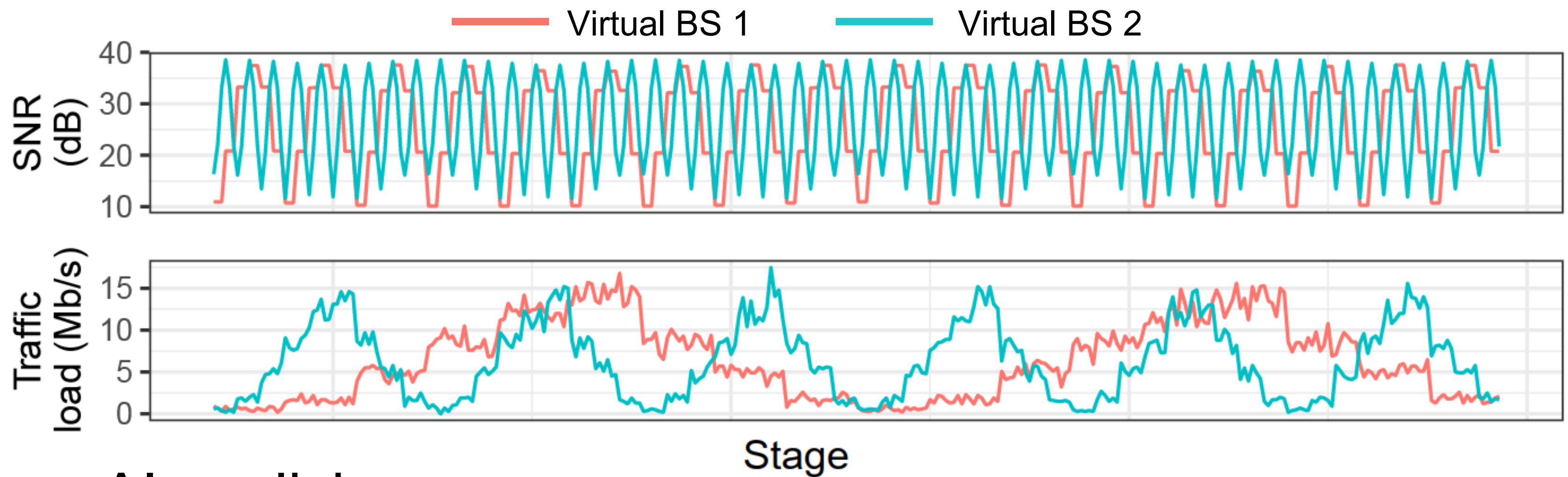
- Limited CPU resources (one core)
- Two virtual Base Station

Objective:

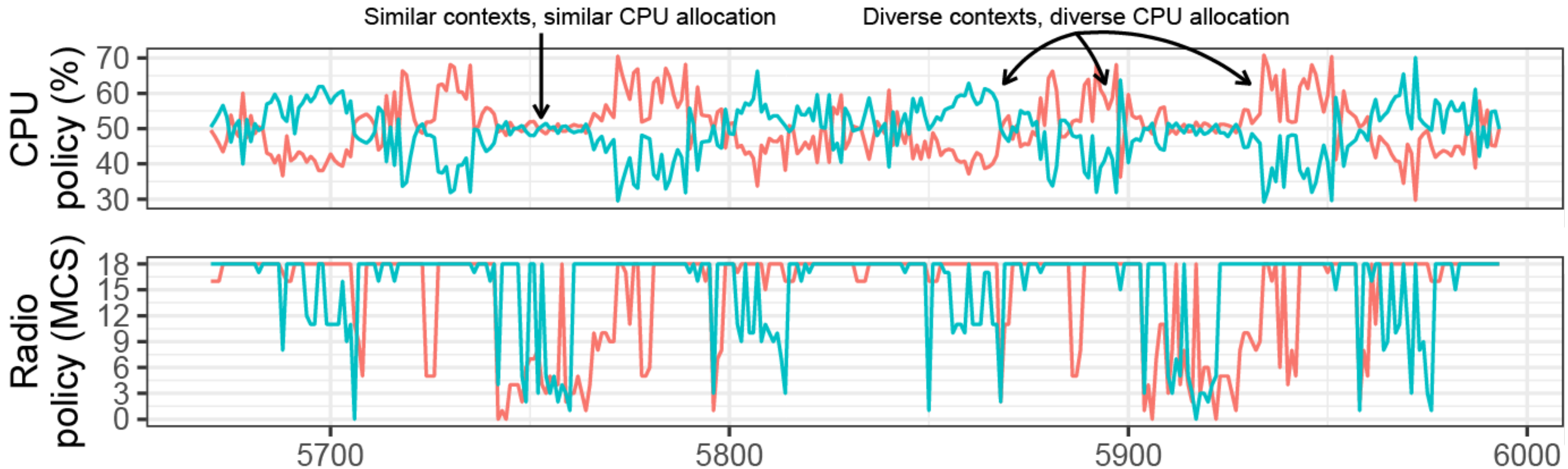
- Maximize the performance of both virtual BSs

Evaluation results: Limited Resources

Contexts:



vrAIn policies:



vrAIn achieves zero decoding error

Conclusions

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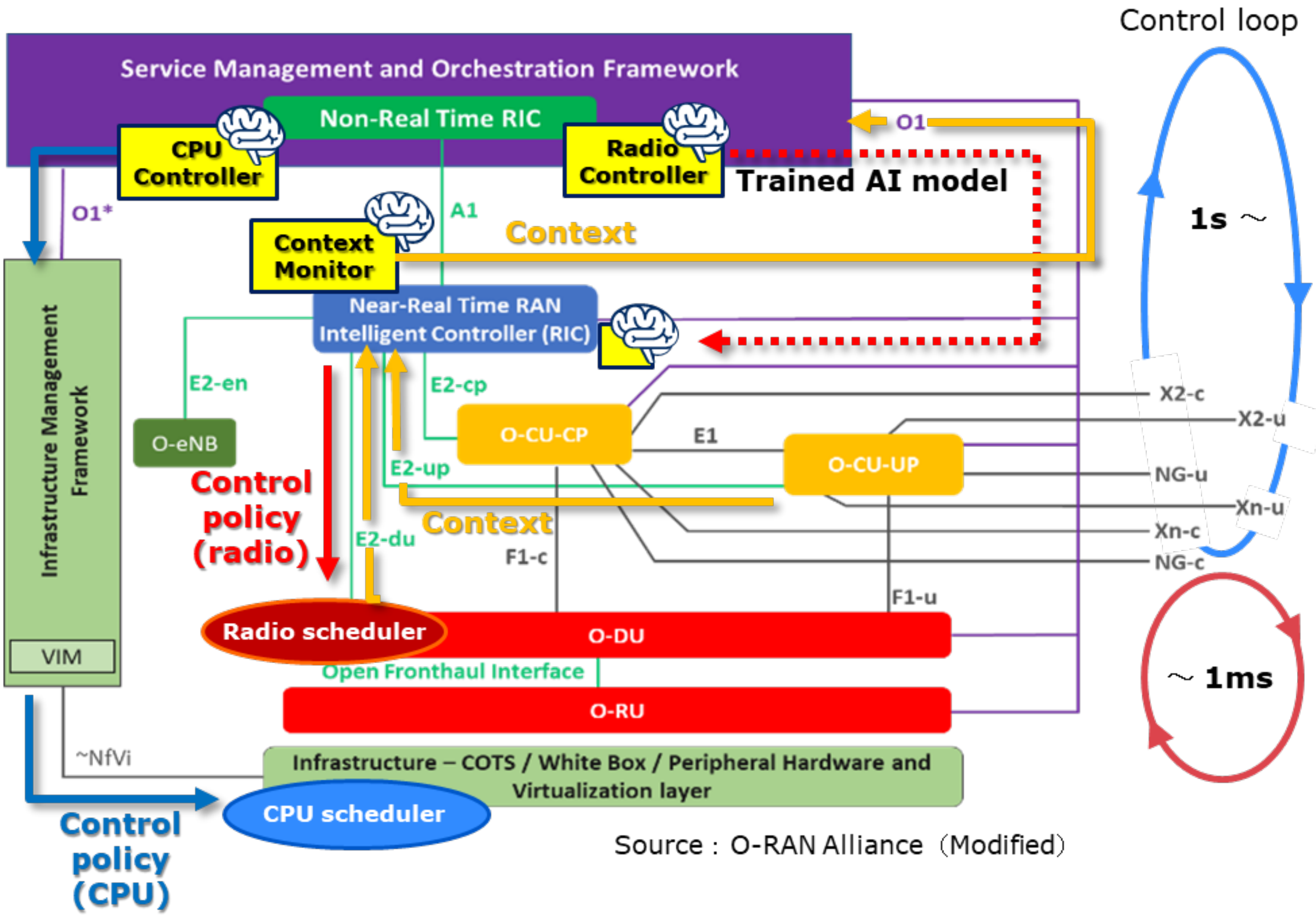
- The performance of a virtual BS is a very complex function of the contexts and the resource assignment, motivating the use of **Deep Learning**.

- We solve the problem using a novel combination of **Sparse Autoencoders**, a **Reinforcement Learning** algorithm and a **Neural Network Classifier**.

- Our solution **minimizes the costs** with unlimited resources and **maximizes the performance** with limited resources. With respect to state-of-the-art solutions, vrAIn achieves…
    - **CPU savings ~30% with unlimited resources.**
    - **Throughput increase ~25% per virtual Base Station.**

- We trained our models with **real data** and implemented a **proof-of-concept** of the solution.
    - **Dataset in https://github.com/agsaaved/vrain**

Integration of vrAIn into O-RAN



Source : O-RAN Alliance (Modified)

Reward function

$$r(\mathbf{x}, \mathbf{a}) := \sum_{i \in \mathcal{P}} \mathbb{P}\left[q_{i,x_i,a_i} < Q_i\right] - M\varepsilon_i - \lambda c_i$$

Decoding Error Probability

Empirically computed by sampling every subframe (UL) or via HARQ

CPU allocation

Buffer State (random variable)

Empirically estimated by sampling every Buffer State Report (BSR) in UL

Target mean buffer state (bytes)

An easy measure of delay

Constant Parameters

M is a large value

λ is a small value