ITU-ML5G-PS-014: Build-a-thon(PoC)

Autonomous Resource Allocation for Emergency Network Slice

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30 NOV 2021

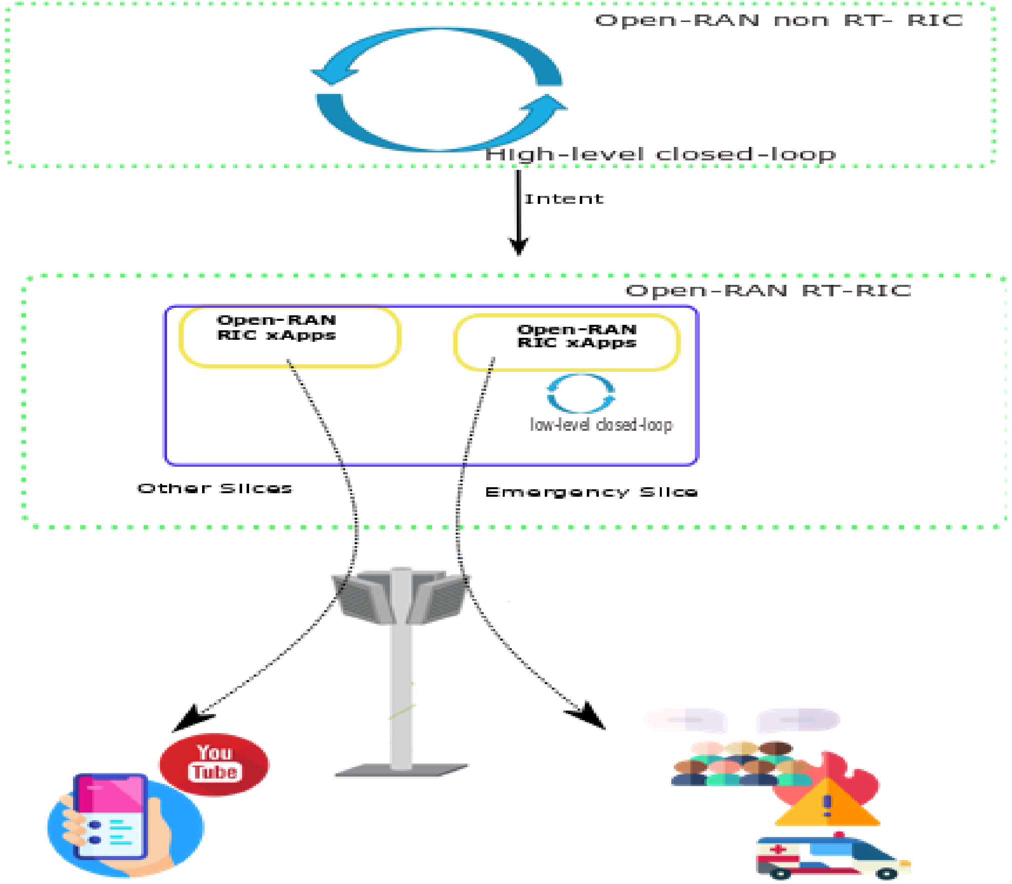
HOST: ITU FOCUS GROUP AUTONOMOUS NETWORKS (FG-AN)

Problem Definition

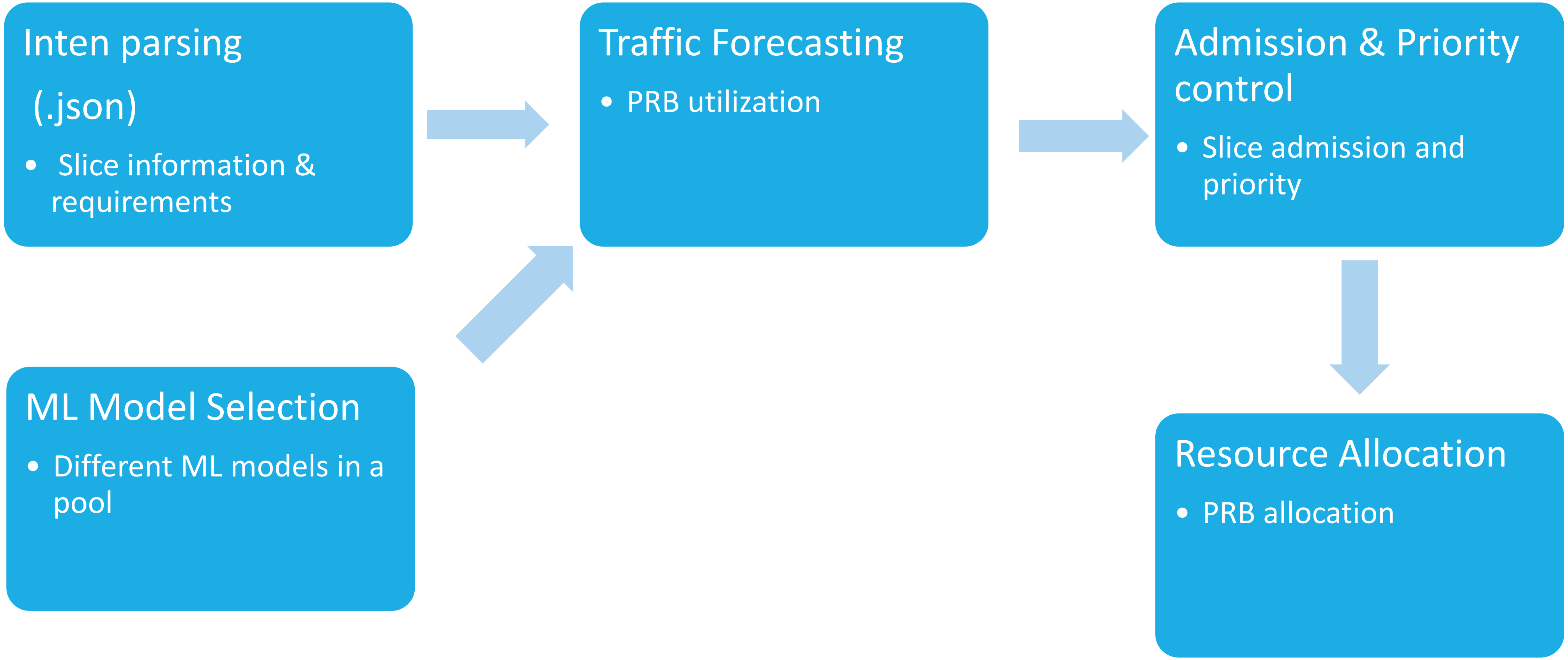
Make resource allocation decision for

emergency slice İn an autonomous way:

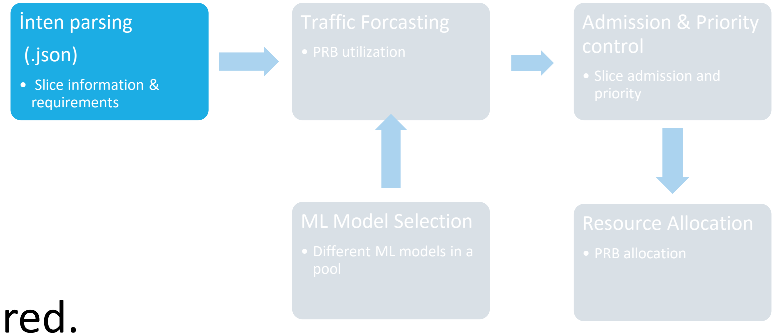
- ❑ Get & parse high-level intent
  - Requirements for ES
  - Information regarding data and ML models
- ❑ Make traffic analysis
- ❑ Admission & priority control
- ❑ Make resource allocation



Building Blocks



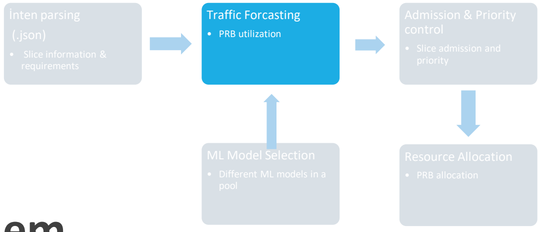
Intent Parsing



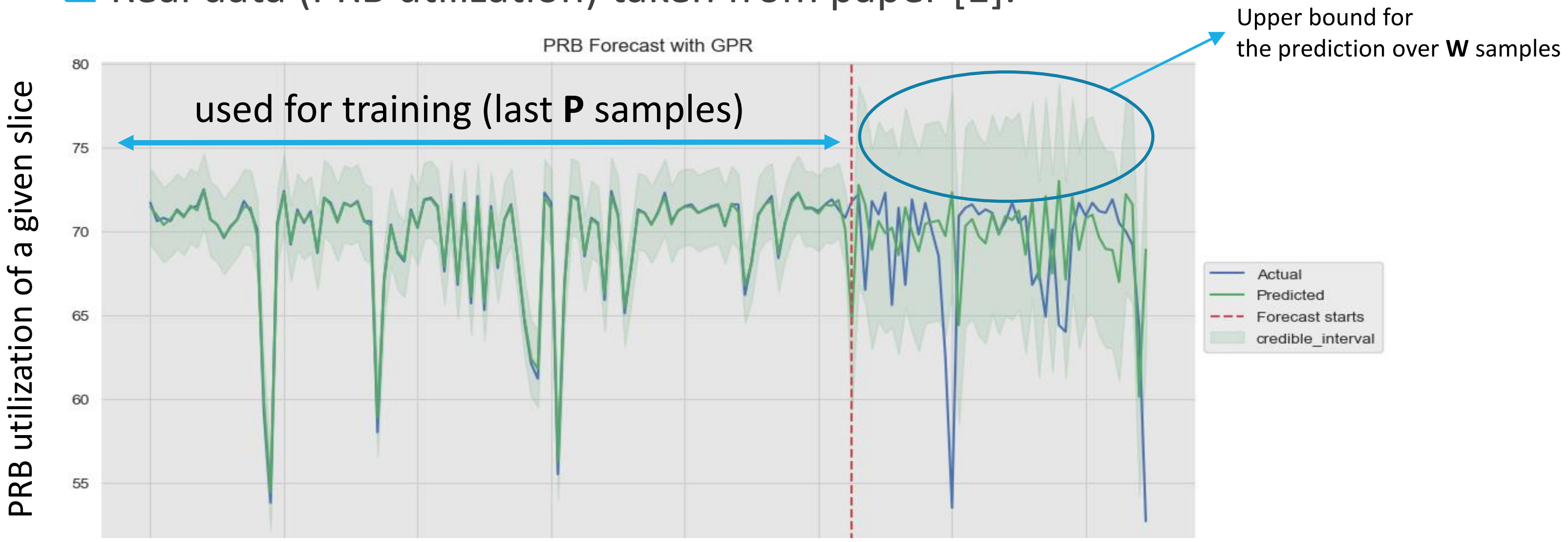
- We get intent from higher-loop (Open-RAN NonRT-RIC).

- Indicates if there is an emergency case and monitoring xApp is triggered.
  - Information about where data and ML models are.

Traffic Forecasting



- We monitor RAN resource utilization
  - Checks for available PRBs for emergency slice
  - We apply Gaussian Process Regression (GPR) for time-series forecast of PRB utilization
- We develope this building block as a **RIC xApp. This is our first RIC xApp for this problem.**
- Real data (PRB utilization) taken from paper [1].



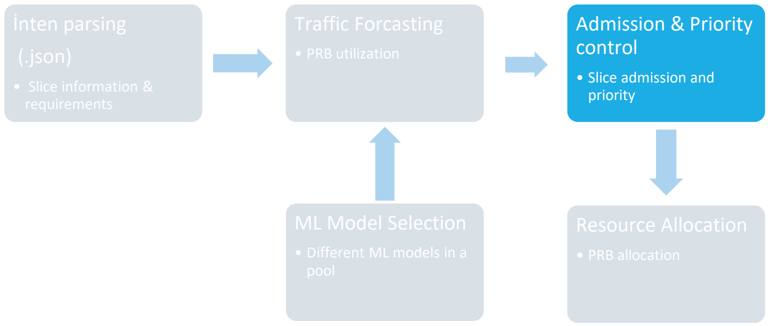
- Trained with 1000 samples
- Data normalized by 100
  - [0.717 0.706 0.708 0.706 …]
- Matern kernel is selected
- Retrain GPR at every ~15 min.

PRB utilization forecasting-Mean absolute error (MAE) and Root Mean Squared Error (RMSE)

MAE, RMSE for future 4000 points	MAE RMSE for future 2000 points
0.077, 0.147	0.046, 0.081

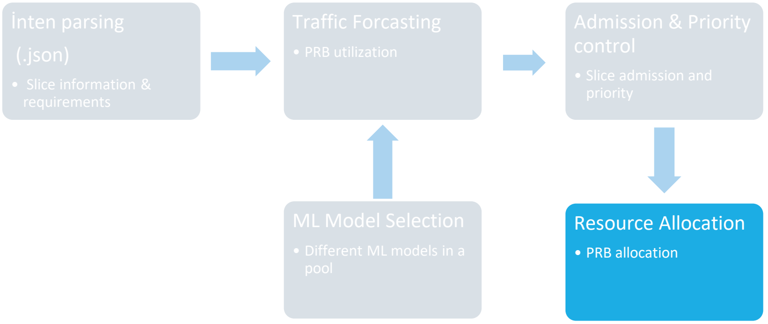
[1] Vaclav Raida , Philipp Svoboda, Markus Rupp : “Real World Performance of LTE Downlink in a Static Dense Urban Scenario - An Open Dataset “ , IEEE GLOBECOM 2020.

Priority Control



- Level of emergency
  - Protect the existing slices first (ES is the second priority)
    - Algorithm 1 (ALG 1)
  - Always give the first priority to ES
    - Algorithm 2 (ALG 2)

Resource Allocation



- ALG 1 and ALG 2 decide on resource allocation
  - How many PRBs should we allocate for ES?

- Resource Allocation block is implemented as **RIC xApp. This is our second RIC xApp.**

ALG 1

IDEA: Amount of PRBs allocated to other slices are not always used (underutilization). Predict unused PRBs of other slices (leftover from other network slices) and allocate them to ES.

Resource allocation

(ALG 1)

For each other slice n
Step 1: Train GPR with the latest P training data
Step 2: Forecast PRB utilization over the next W samples with GPR
Step 3: Calculate maximum possible PRB utilization with prediction bounds
Step 4: Calculate forecasted PRB usage over next W samples
End

Step 5: Calculate available PRBs for Emergency Slice -> P_{ES}
Step 6: Allocate PRBs to ES -> P_{ES}

<u>Example: Two slices</u>

Total system PRBs = 100

Amoun of PRBs allocated to first slice is 40, utilization is %80 (predicted)-> **8** PRBs unused

Amoun of PRBs allocated to second slice is 60, utilization is %90 (predicted)-> **6** PRBs unused

PRBs allocated to emergency slice is **8 +6 = 14** PRBs

ALG 2

IDEA:Emergency slice needs **E** amount of PRBs (fixed). Allocate the available PRBs to ES first. If it is not enough borrow PRBs from other slices. Aim is to always give **E** PRBs to ES. ES has the first priority [2],[3].

Resource allocation

(ALG 2)

Solve an optimization problem:

Total PRBs given to slice n

PRB needed for slice n at time t

Number of PRB taken from slice n at time t to be used for emergency slice

$$\min \sum_{t=1}^{W} \sum_{n}^{N} \underbrace{\max\{0, x_n(t) - (T_n - y_n(t)\}}$$

We damage slice n this amount by taking PRBs from it

$$\text{s.t.} \quad 0 \le y_n(t) \le T_n \ \forall n$$

$$\underbrace{\sum_{n}^{N} y_n(t) \ge E}_{\text{Guarantee that emergency slice gets enough PRBs}}$$

Transform this problem to a solvable integer problem

[2] X. Foukas et al., "Orion: RAN Slicing for a Flexible and Cost-Effective Multi-Service Mobile Network Architecture," in ACM MobiCom, 2017.

[3] Armin Okic, Lanfranco Zanzi, Vincenzo Sciancalepore, Alessandro Redondi, Xavier Costa-Pérez, " π-ROAD: a Learn-as-You-Go Framework for On-Demand Emergency Slices in V2X Scenarios ", IEEE INFOCOM, 2020.

ALG 2 (cont.)

IDEA: Emergency slice needs **E** amount of PRBs (fixed). Allocate the available PRBs to ES first. If it is not enough borrow PRBs from other slices. Aim is to always give **E** PRBs to ES. ES has the first priority.

Resource allocation

(ALG 2)

Solve an integer programming using auxiliary variable u_n:

$$\min \sum_{t=1}^{W} \sum_{n}^{N} u_n(t)$$

$$\tilde{x}_n(t) + o_n(t) - (T_n - y_n(t)) \leq u_n(t)$$

$$0 \leq y_n(t) \leq T_n \ \forall n$$

$$\sum_{n}^{N} y_n(t) \geq E$$

$$u_n(t) \geq 0$$

$$x_n(t) = \tilde{x}_n(\mathrm{t}) + o_n(t)$$

Actual PRB usage at time t in future. This cannot be known in advance

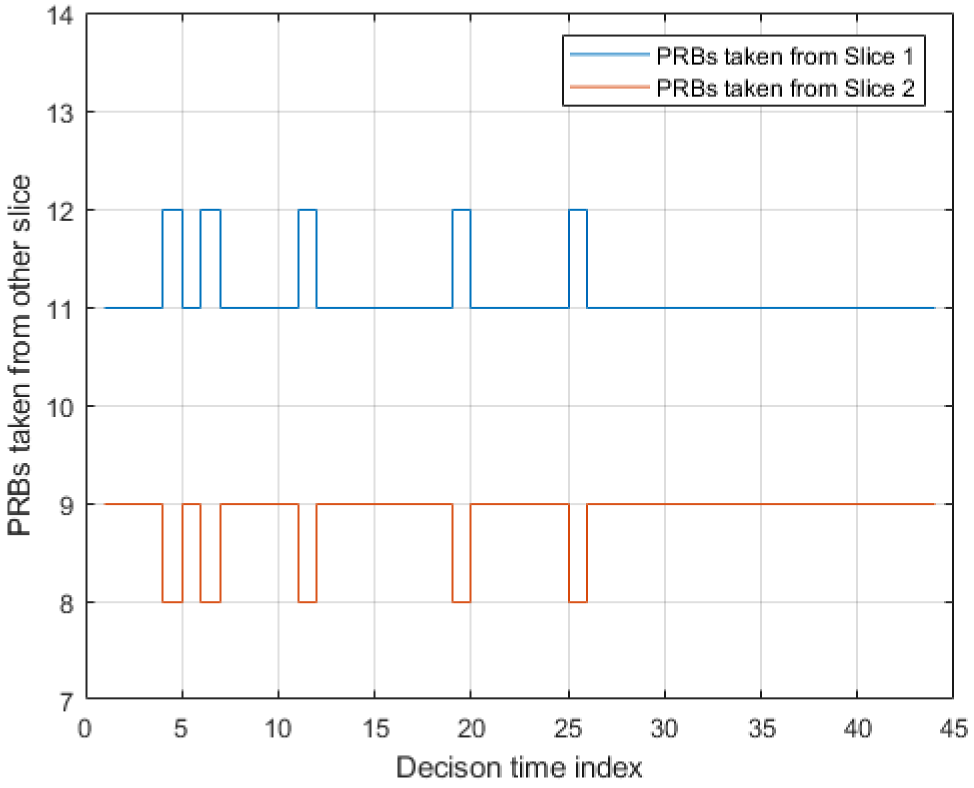
Estimated PRB usage with GPR

Estimation error. Upper bound can be used provided by GPR.

We have implemented ALG1 & ALG2 and next we will show a demo for ALG2

Experiment: resource allocation

- Two other slices:
  - 40 and 60 PRBs allocated these two slices
  - Network has 100 PRBs (ES should borrow from others)
- Emergence slice needs **E = 20** PRBs

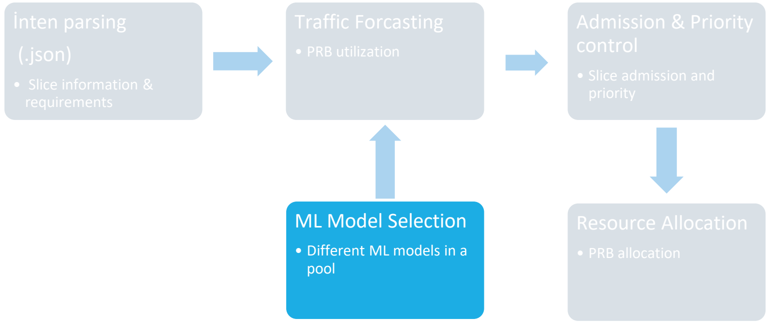


- Result from the Figure: at every decision-time, sum of the PRBs is always 20, which ES needs.

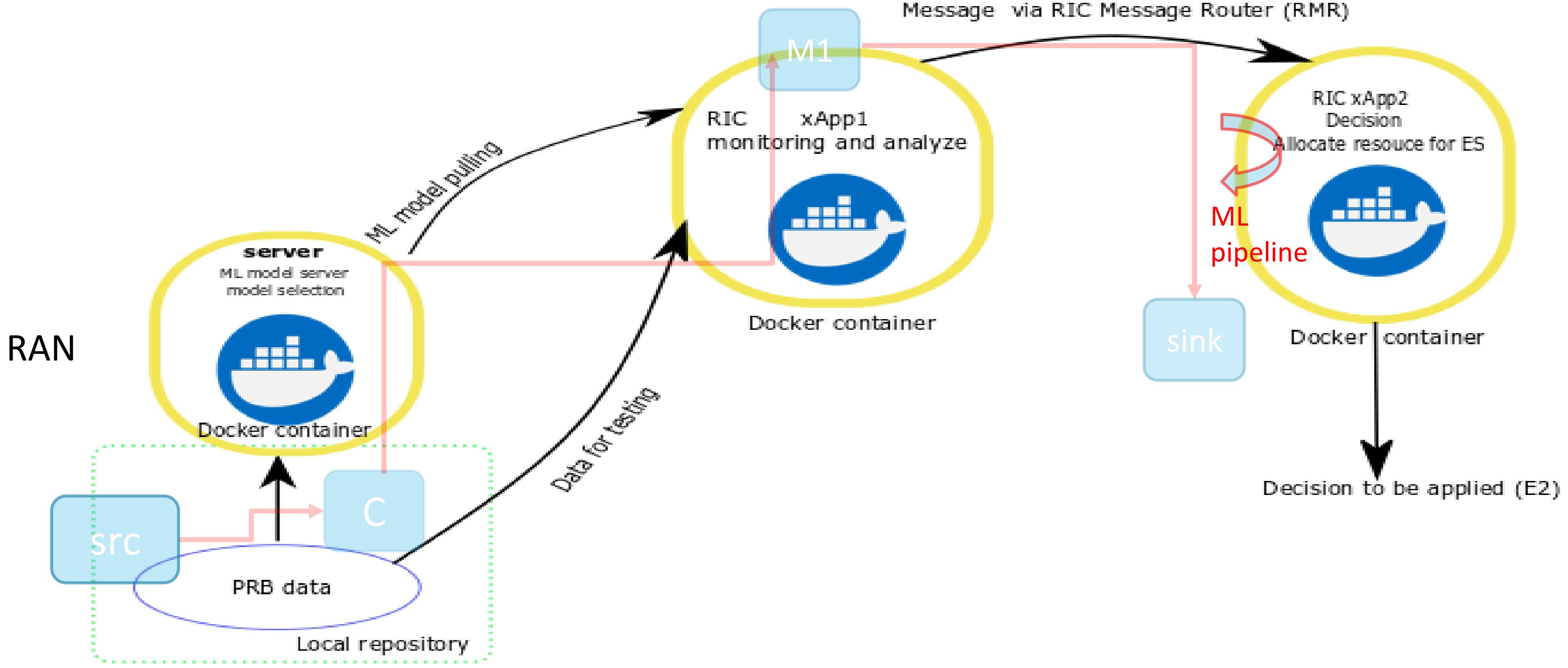
ML model selection for forecasting

- Different ML models with different performance, complexity and cost can be available in a ML pool.

- We implement this scheme as a microservice.
  - Webserver stores different ML models
  - Possible to fetch different ML models when forecasting



Our implementation

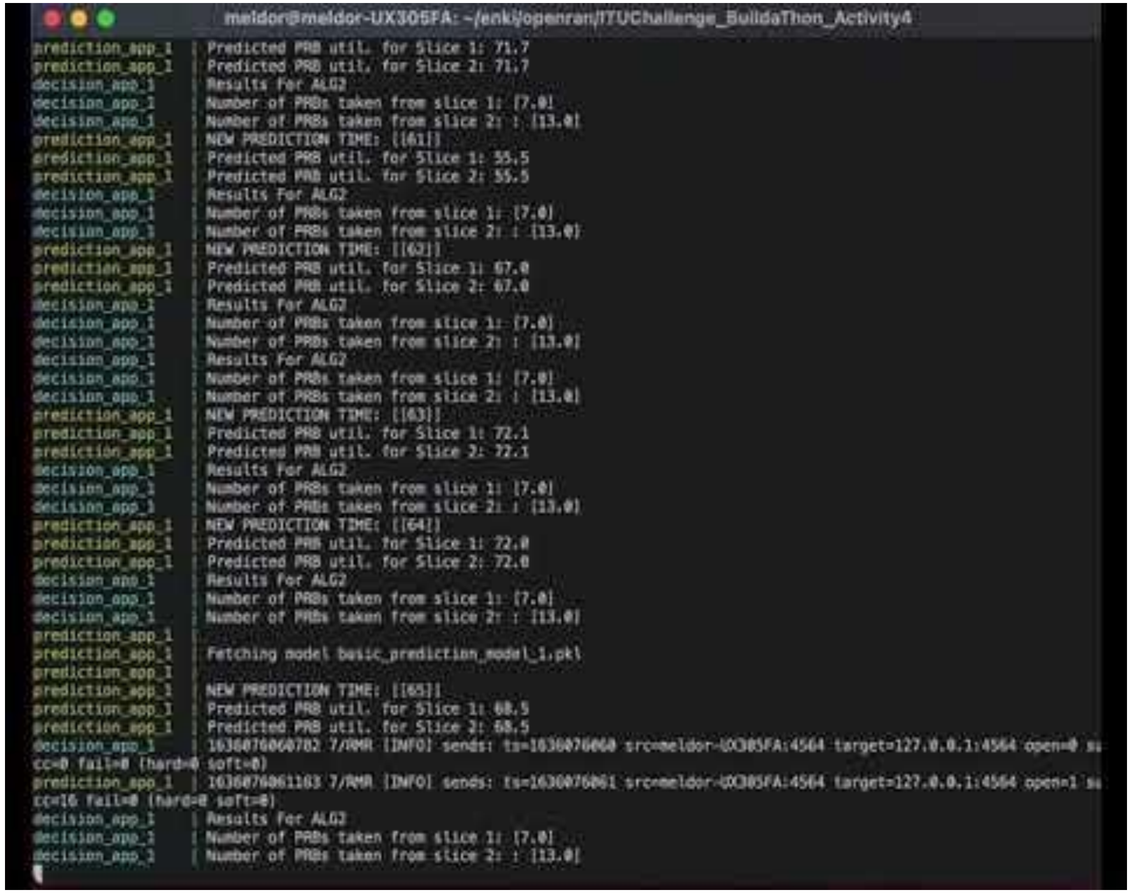


- Implemented RIC xApp1, xApp2 and server as a microservice.
- These xApps can communicate through a RIC (O-RAN messaging) message.
  - e.g., xApp1 can send prediction to xApp2 over the network

PoC Demo

We have a quick demo:

- ❑ Ubuntu 20.04 Works fine
- ❑ Need docker and docker compose



https://drive.google.com/file/d/1ouqhouvHlZiYOotnKqFHyIB8JUDdAFlF/view?usp=sharing

Check for details: https://github.com/ITU-AI-ML-in-5G-Challenge/ITU-ML5G-PS-014-Build-a-thon-PoC---Team-AUTOMATO-

Conclusion and Future Works

- A PoC for autonomous slice management
- Resource allocation handled
  - Prediction with machine learning & linear optimization
- Flexible and modular O-RAN RIC xApps design

Future Works:

- Integration of all xApps to testbed, real O-RAN infrastructure
  - Real autonomous closed loops
- ML optimizations & improvements
- Dynamic estimation of emergency slice

This work has been supported by Scientific and Technological Research Council of Turkey (TÜBİTAK, grant no. 120E485)

Thank you for listening!

Q & A

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