Network Slicing in the on-board Next-generation of train communication networks

David Kule Mukuhi*[2],Léo Mendiboure*, Rodrigue Fargeon[2], Sylvain Cherrier*, Pierre-Yves Petton[2], Marion Berbineau*, Rami Langar*.
*Université Gustave Eiffel, [2]SNCF-SA

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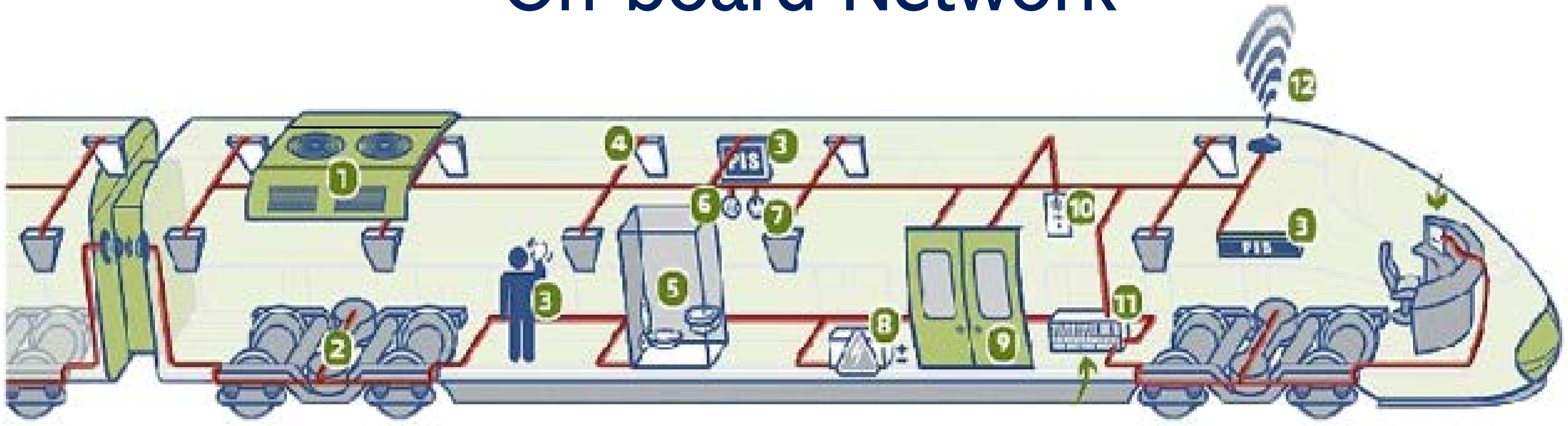
Agenda

1. Context
2. Problem
3. State of the art
4. Our proposal
5. Questions

On-board Network



1. Air Conditioning/Ventilation
2. Bearing temperature (SIL 2)
2. Speed measurement (SIL 2)
2. Lateral vibration (SIL 2)
2. Breaks
2. Traction
3. Passenger Information
4. Lights
5. Water tanks
6. Audio announcement
7. Video surveillance
8. Batterires
9. Doors
1. Emergency communication
11. Data protection (black box)
12. Train-to-wayside communication

TCMS

- Automatic Train Protection (ATP) SIL 4
- Automatic Train Operation (ATO)
- ETCS
- Breaks
- Train Fleet Management Systems [SIL 0 to SIL 2]
- Passenger Information System (PIS) [SIL 0 to SIL 2]

OOS

- CCTV
- Infotainment onboard train devices.
- Automatic passenger counting.
- Vehicle positioning-service (also exists in TCMS domain)
- Fare management or ticketing.
- Driving assistance system.
- E-schedule (schedule for the driver).
- Diagnostic systems and CBM (condition-based maintenance) (service exists in the TCMS domain as well).
- Passenger Information System (PIS)

COS

- User equipment access (example Wi-Fi hotspots).

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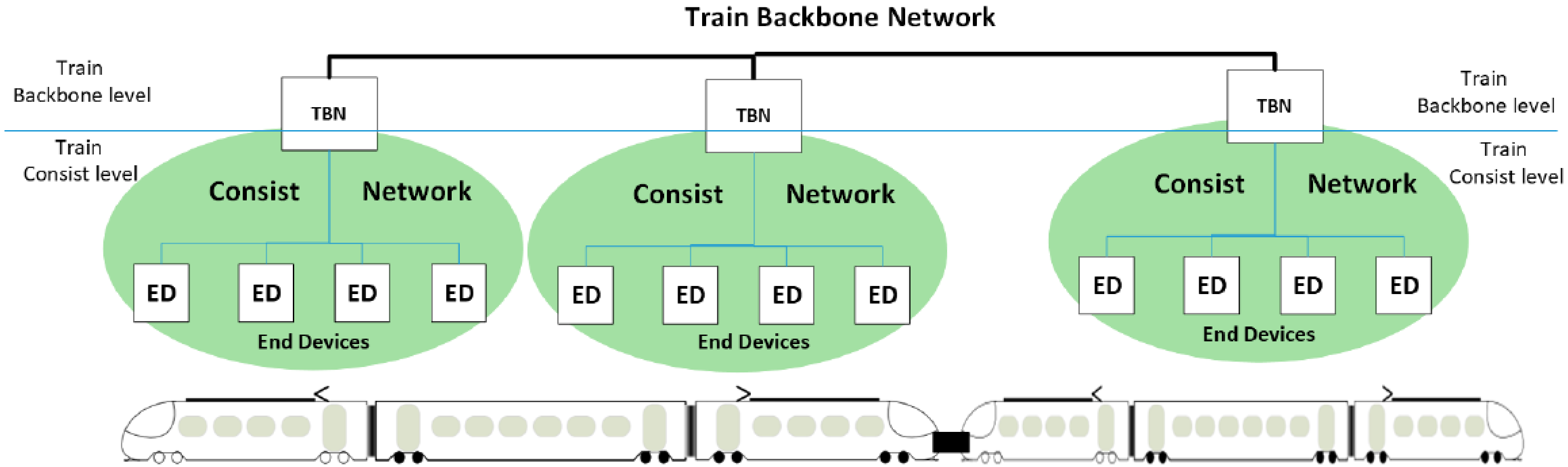
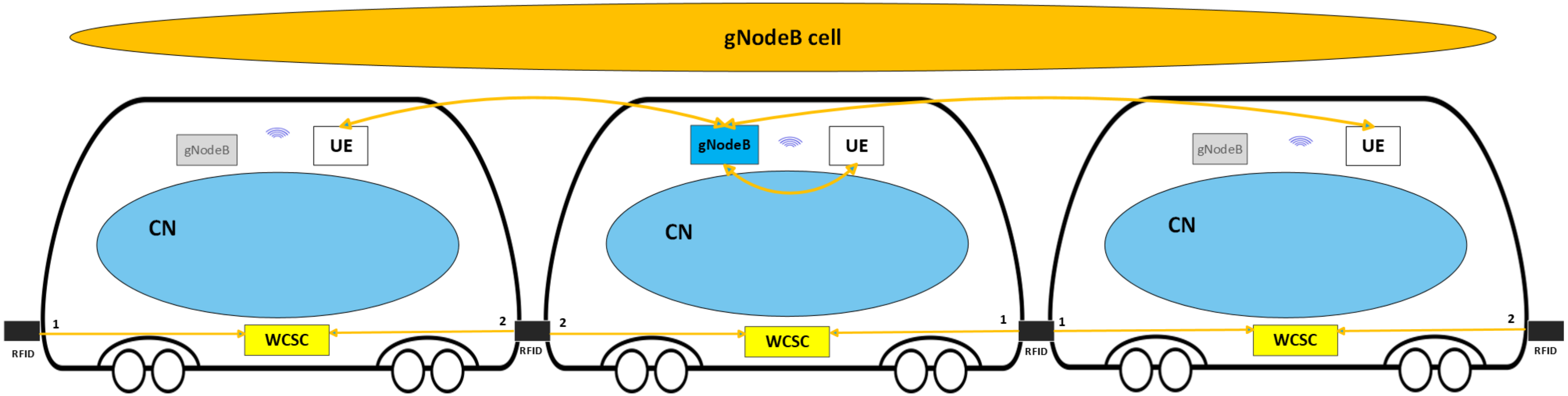
From Wired Train BackBone



To Wireless Train Backbone



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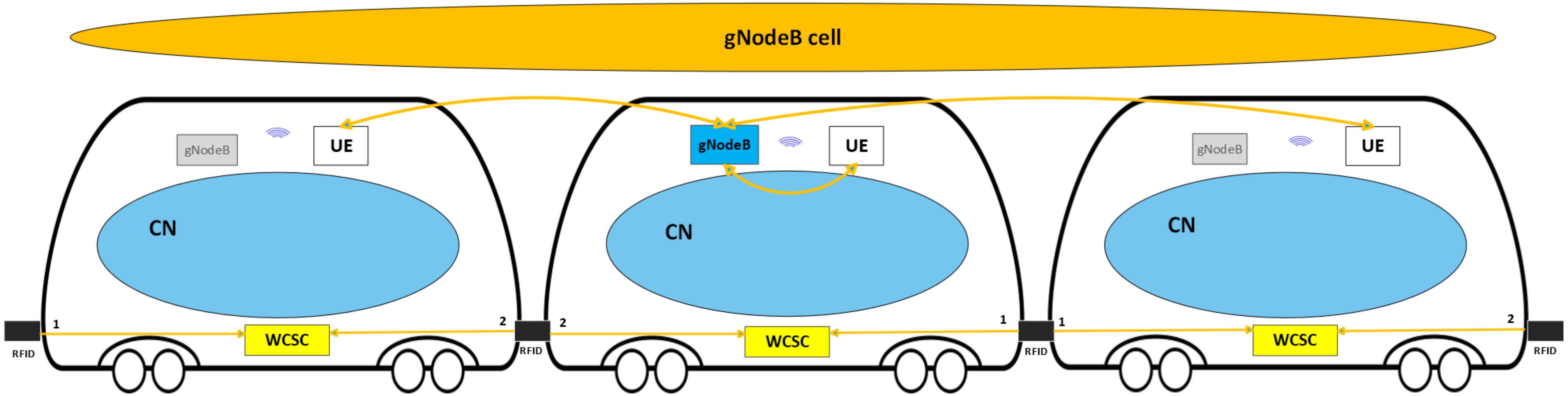
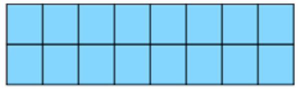
How do we share radio resource for all Networks ?

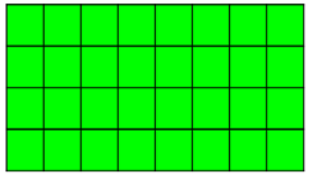


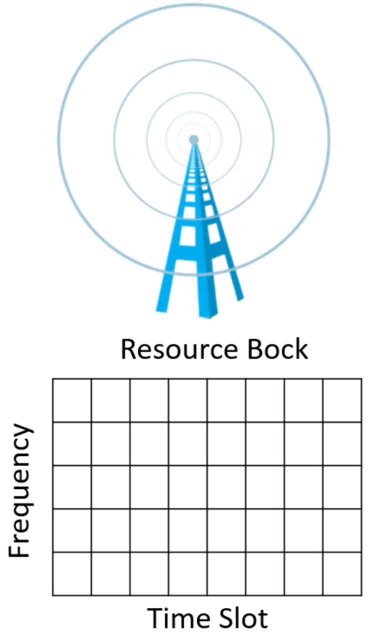
1. **Critical Services:**
10 Mbps, 20 ms

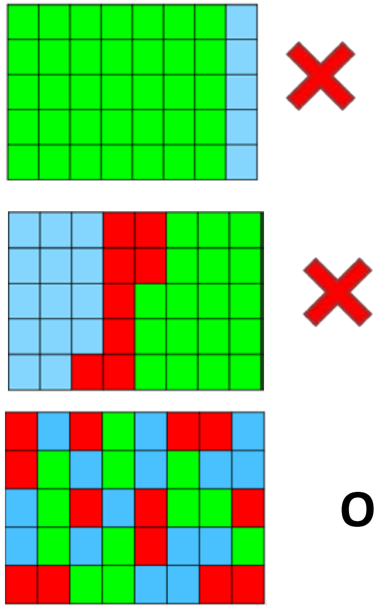
2. Operational Services
20 Mbps, 100ms



3. Customer service
40 Mbps, 250ms







Non-efficient

Non-optimal

Optimal ?

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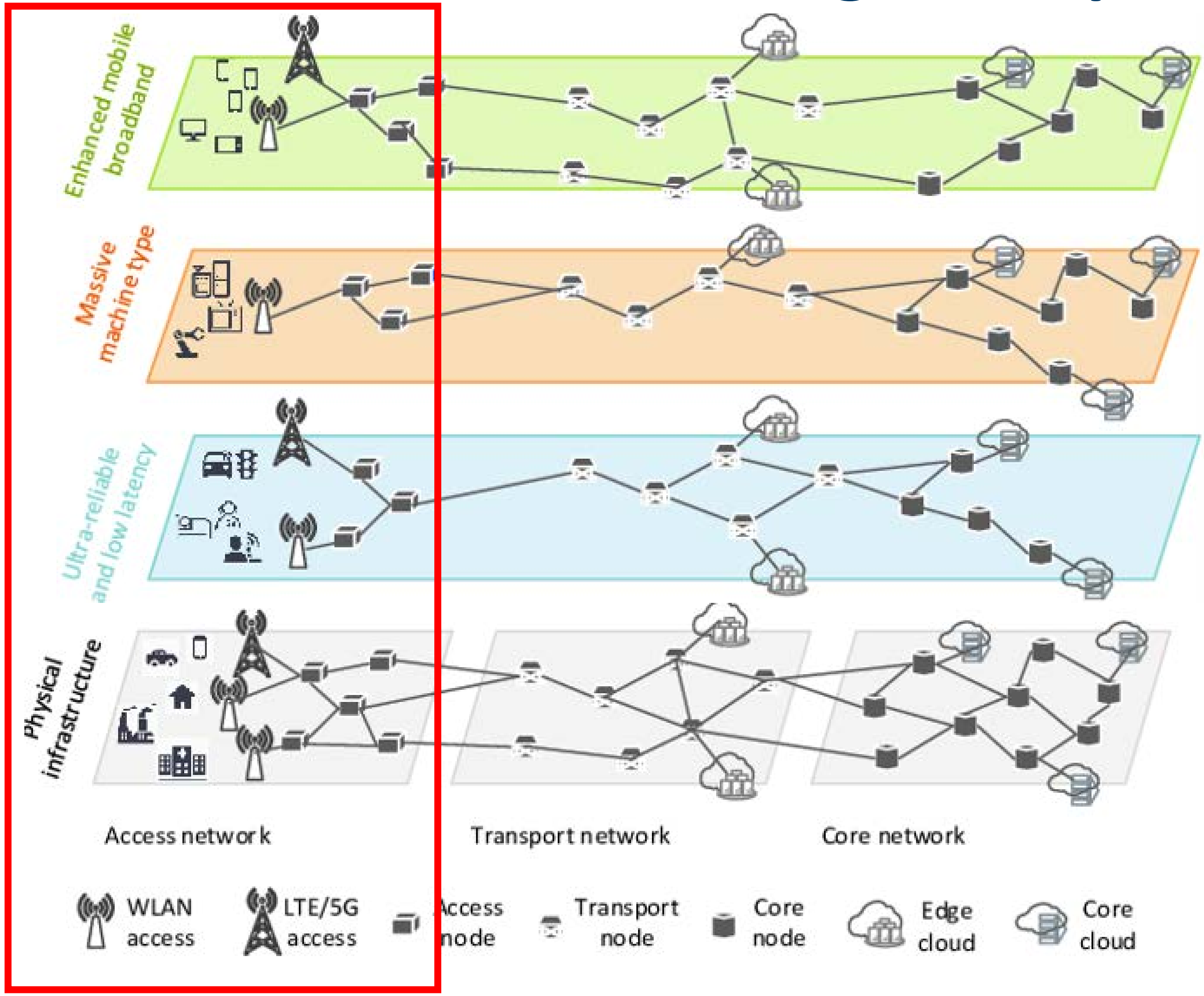
Network Slicing Principle

Focus RAN



Service Provider (internet)

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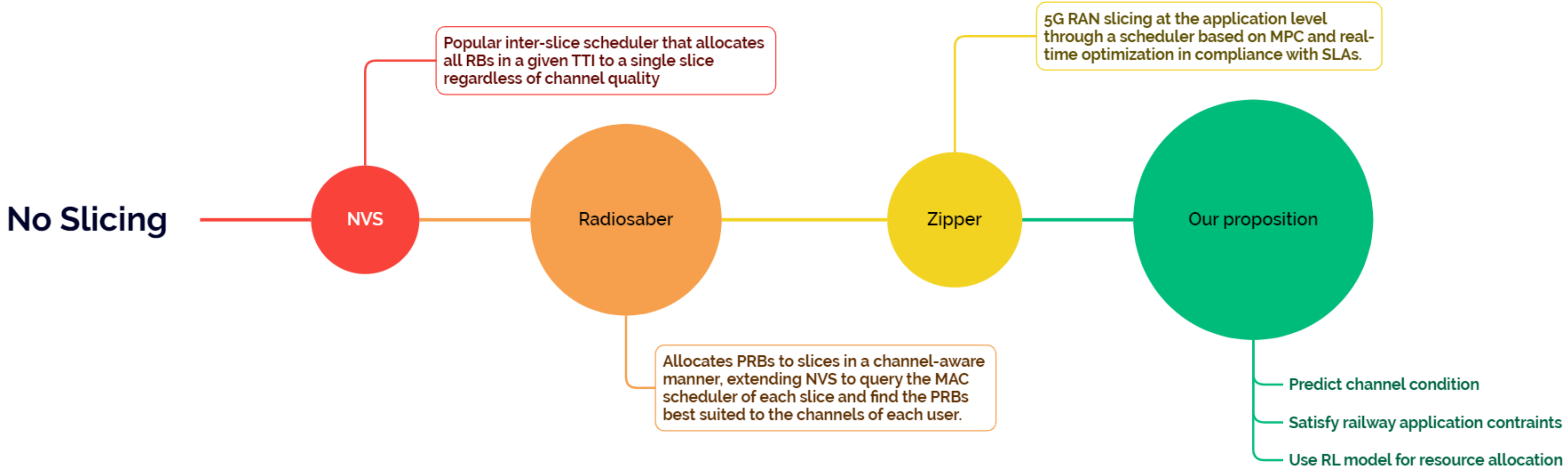
State of the art



[1] R. Kokku, R. Mahindra, H. Zhang, and S. Rangarajan, "NVS: a virtualization substrate for WiMAX networks," in *Proceedings of the sixteenth annual international conference on Mobile computing and networking*, Chicago Illinois USA: ACM, Sep. 2010, pp. 233–244. doi: 10.1145/1859995.1860023.
[2] C. Yongzhou, Y. Ruihao, H. Haitham, and M. Radhika, "Channel-Aware 5G RAN Slicing with Customizable Schedulers," *20th USENIX Symposium on Networked Systems Design and Implementation (NSDI 24)*, pp. 1767--1782, Apr. 2023.
[3] A. Balasingam, M. Kotaru, and P. Bahl, "Application-Level Service Assurance with 5G RAN Slicing," *21st USENIX Symposium on Networked Systems Design and Implementation (NSDI 24)*, Apr. 2024.

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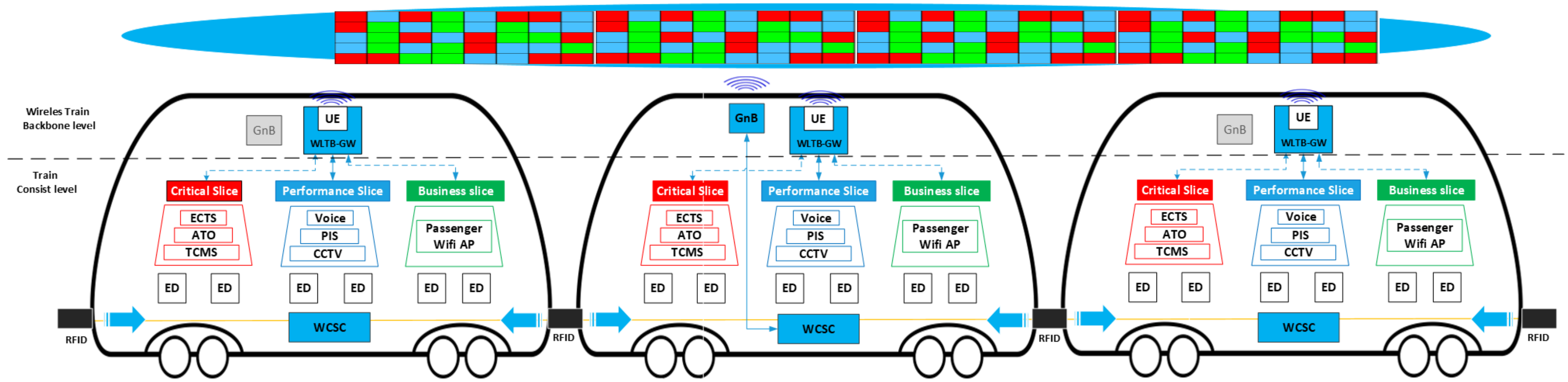
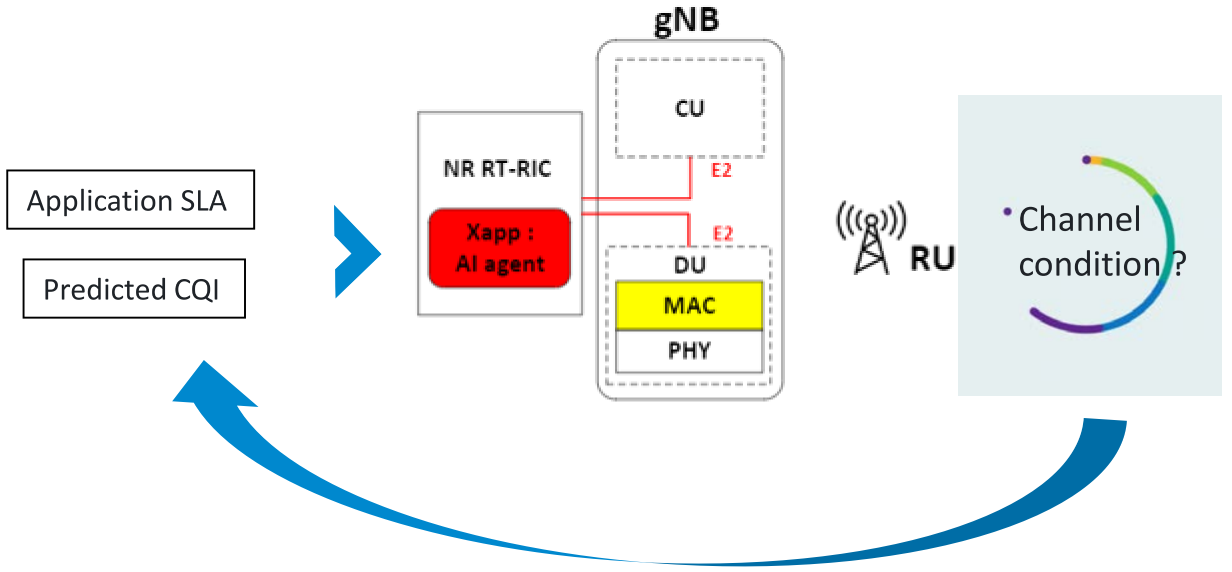
Our contribution





1. **Predict Channel condition**
2. **Satisfy Hetergeneous Railways constraints**
3. **Assign RB using RL model**

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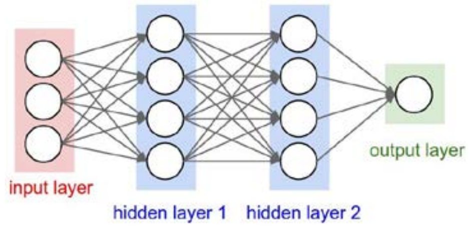
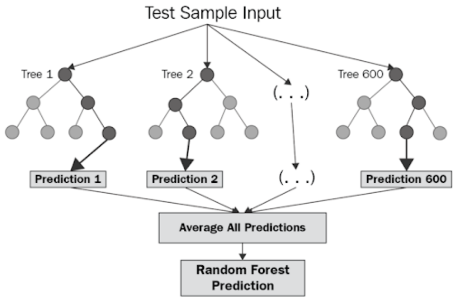
CQI Prediction Results

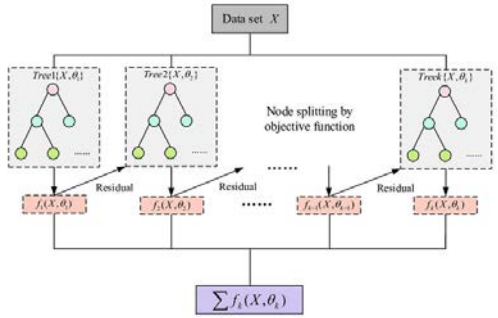
- **LSTM** [1] **:** Neural network model known for time series forecasting and its ability to capture long-term dependencies using memory cell to prevent overfitting



- **Random Forest** [2] **:** ensemble learning technique that builds multiple decision trees to improve accuracy and reduce overfitting in regression tasks.



- **XGBoost** [3] **:** optimized gradient-boosting algorithm that enhances decision trees' performance, known for its speed and accuracy,



The dataset is divided into 80% of data for training, 10% for validation and 10 % for Testing

Model	Val accuracy	SMAPE	Tolerance 5%	Test accuracy	SMAPE	Tolerance 5%
Xgboost	**93,86**	**6,14**	**71,26**	**89,47**	**10,53**	**36,24**
LSTM	92,52	7,48	58,57	89,61	10,38	28,3
Random Forest	93,30	6,70	55,63	88,89	11,11	29,03

[1] S. Hochreiter and J. Schmidhuber, "Long short-term memory," *Neural Computation*, vol. 9, no. 8, pp. 1735-1780, Nov. 1997. doi: 10.1162/neco.1997.9.8.1735
[2] L. Breiman, "Random Forests," *Machine Learning*, vol. 45, no. 1, pp. 5-32, 2001, doi: 10.1023/A:1010933404324.
[3] T. Chen and C. Guestrin, "XGBoost: A Scalable Tree Boosting System," in *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, 2016, pp. 785-794, doi: 10.1145/2939672.2939785.

CQI Prediction Results

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Conclusion

- XGBoost are better performance over all
- Accuracy decrease when prediction horizon is long

Implications

- Use XGBoost predictions
  - upto 1 sec in static channel condition
  - Upto 500ms is stable condition
  - No prediction during unstable channel condition
- Error Threshold between channel should be trigger based on stand deviation of channel data

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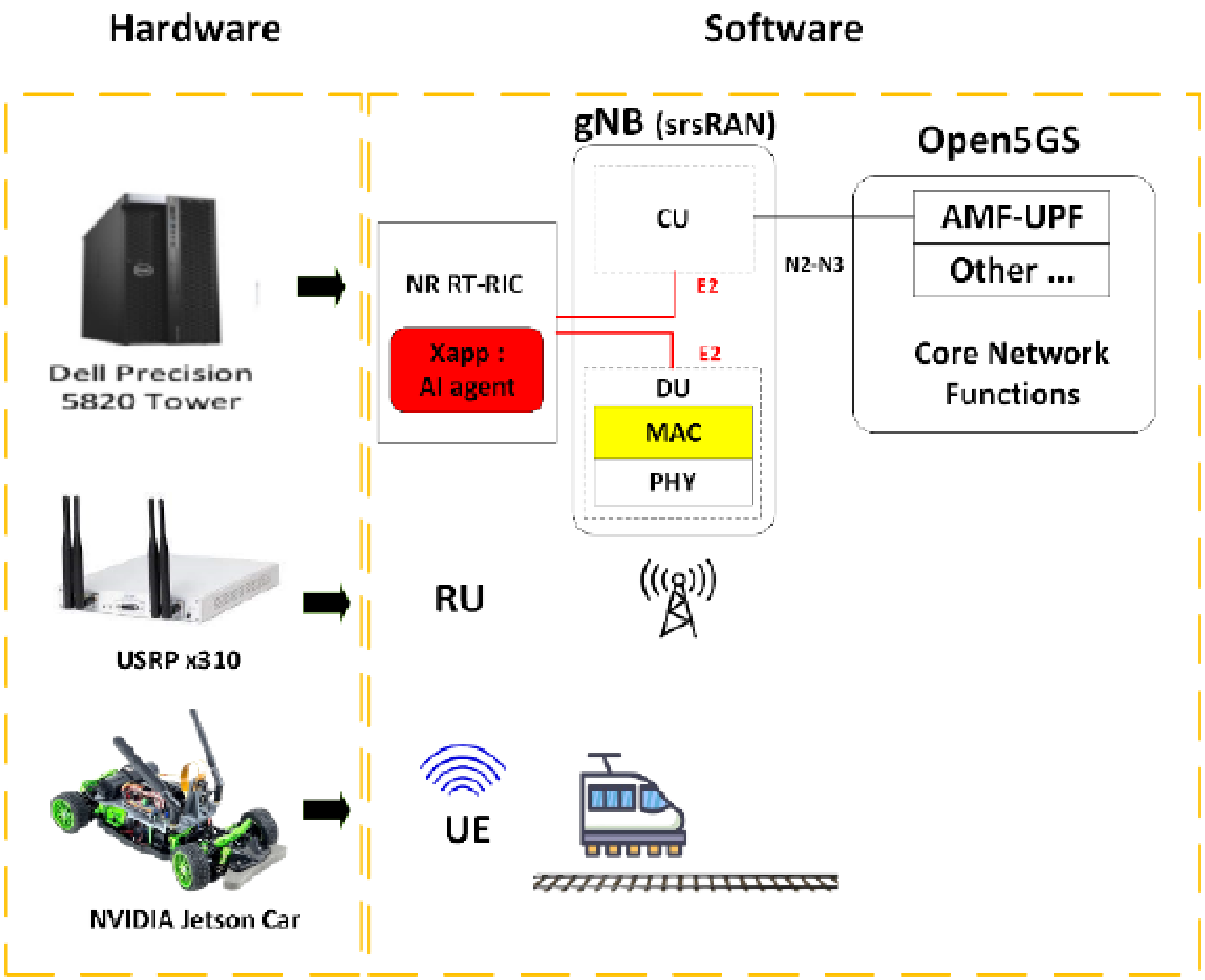
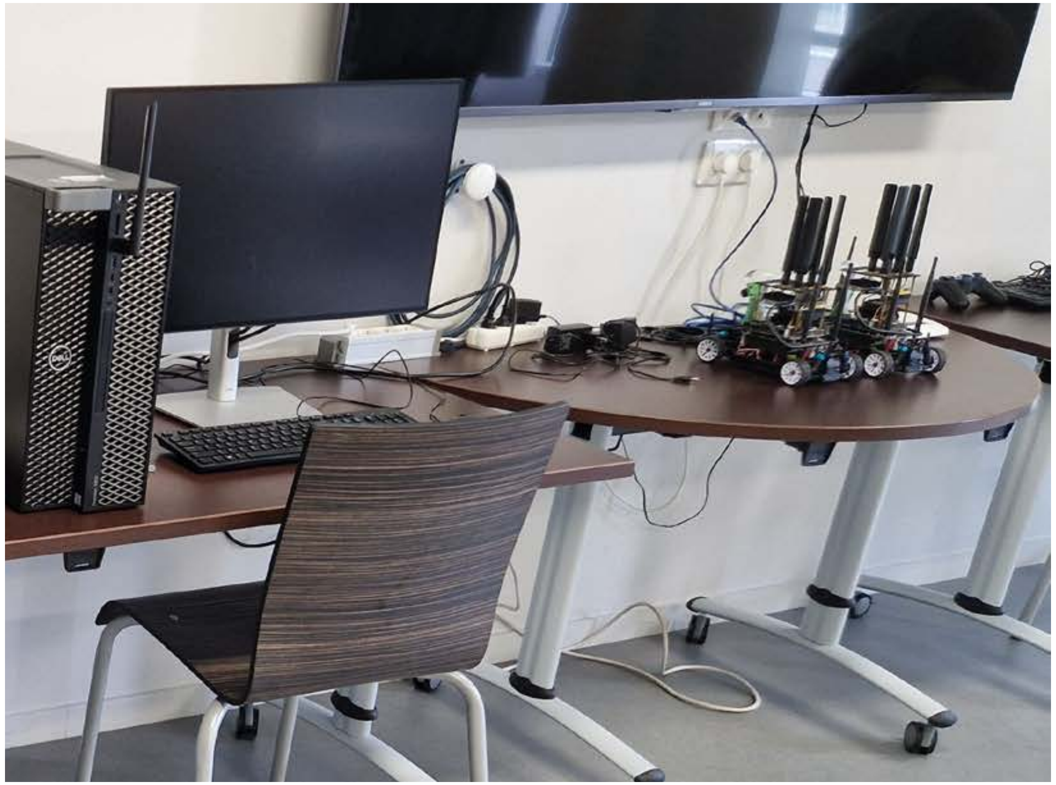
Testbed





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Conclusion

1. Leverage Network slicing in NG-TCN
2. Use ML to implement an intelligent Slice resource allocator
   - Satisfy Hetergeneous Railways constraints
   - Predict Channel condition
   - Assign RB using RL model

Perspectives

1. CQI prediction

2. PRB Allocation Model

- Model selection
- Performance comparison

3. Algorithm evaluation

- Performance evaluation

THANK YOU