TOWARDS ENFORCING NETWORK SLICING IN 5G NETWORKS

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CONTENT

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1. INTRODUCTION AND PROBLEMATIC

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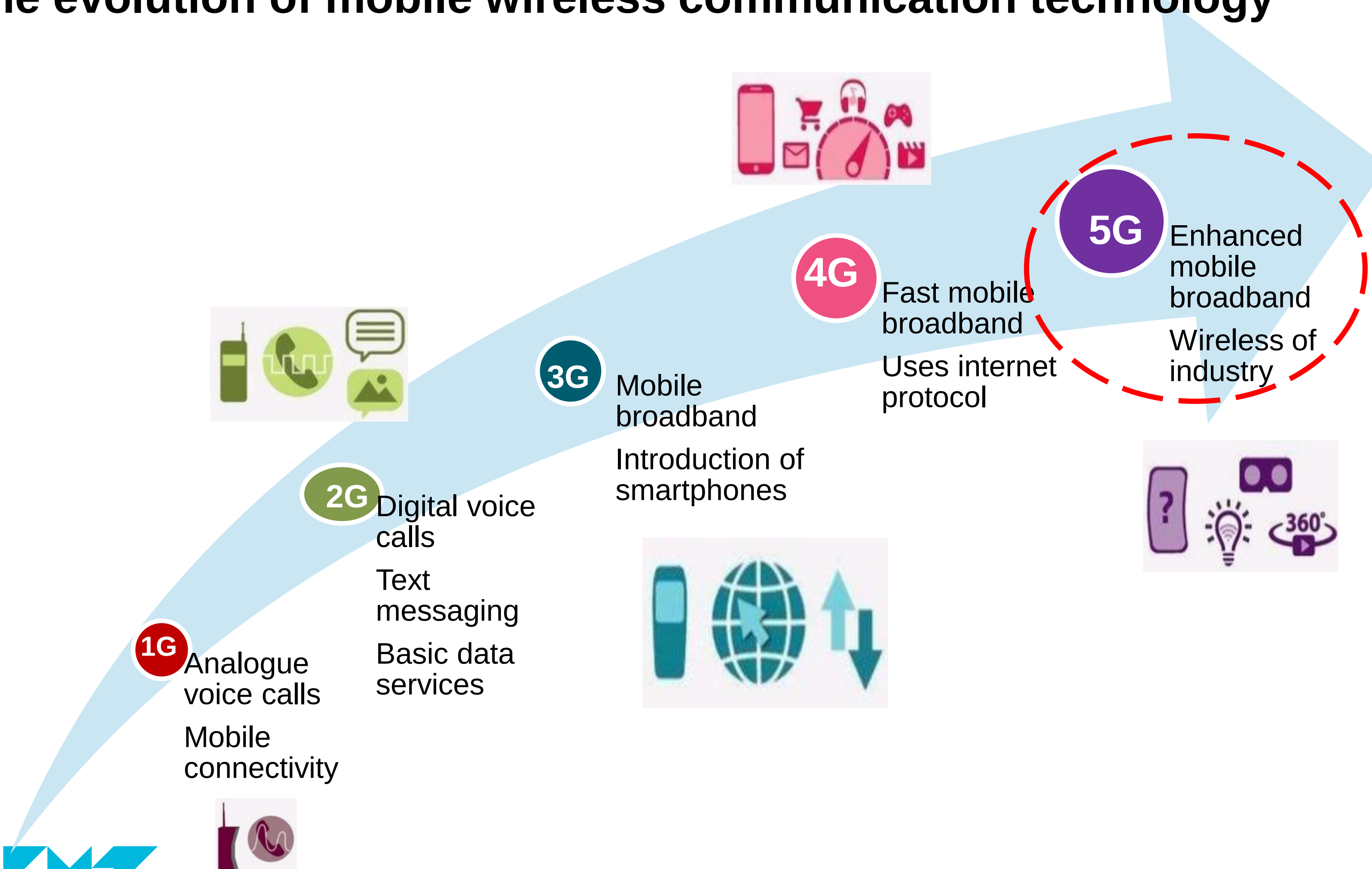
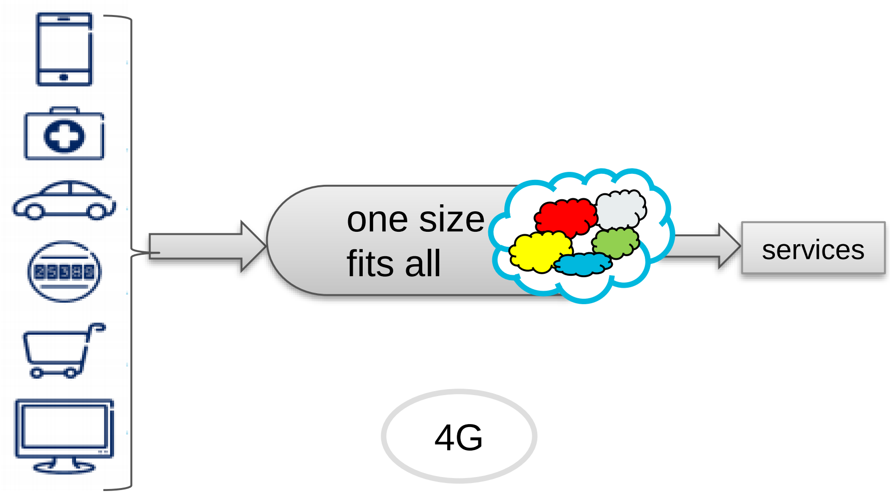
INTRODUCTION AND PROBLEMATIC

- **The evolution of mobile wireless communication technology**

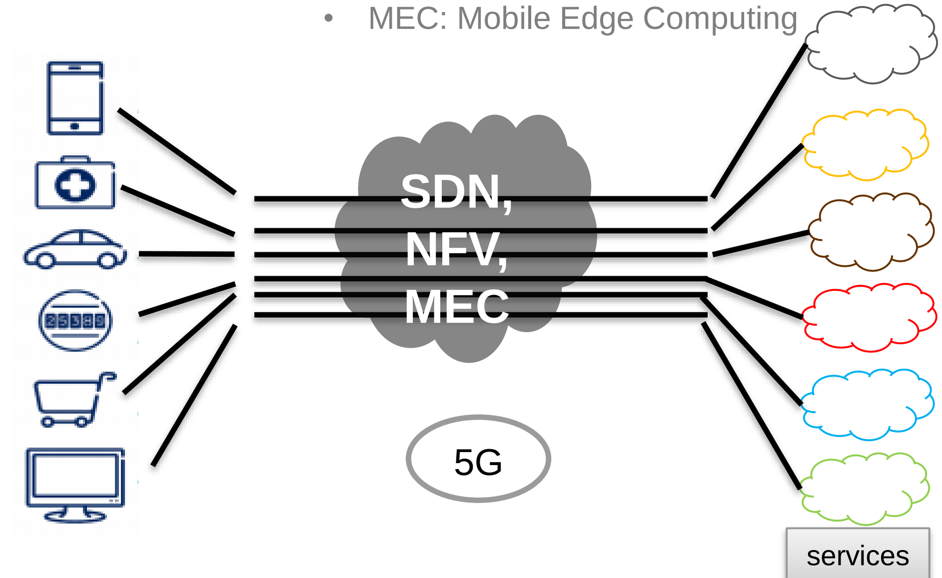


Network slicing

- SDN: Software Defined Networking
- NFV: Network Function Virtualization
- MEC: Mobile Edge Computing



Same architecture for all types of services

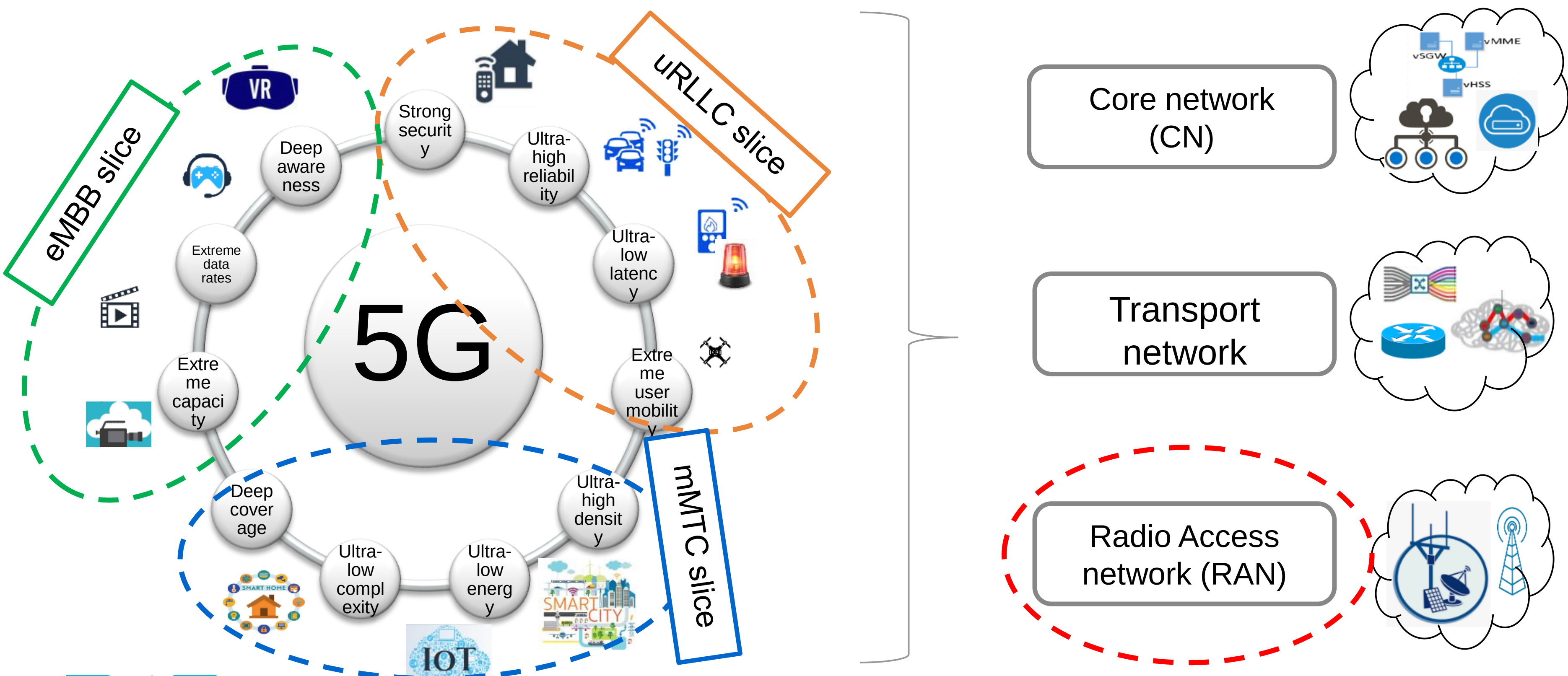


Modifying the architecture according to services using several technologies SDN, NFV, MEC ..

- Allows the creation of multiple virtual networks atop a shared physical infrastructure.
- Allows service providers to build end-to-end virtual networks adapted to application needs.
- Allows to deploy only the functions necessary to support particular customers and particular market segments.

- **Network slicing**

- **eMBB**: Enhanced Mobile Broadband
- **uRLLC**: Ultra Reliable and Low-Latency Communication
- **mMTC**: massive Machine Type Communication



RAN slicing main challenges

- RAN Programmability
- Flexible RAN Virtualization and Functional Split
- Slice Resource Management and Isolation

Introduction and Problematic

RAN slicing main challenges

- RAN Programmability
- Flexible RAN Virtualization and Functional Split
- Slice Resource Management and Isolation
    - Sharing and the algorithmic aspects of resource allocation between network slices
    - Dynamic creation and management of network slice
    - The market constraint

The bandwidth or frequency spectrum resources limitation

2. CONTRIBUTIONS

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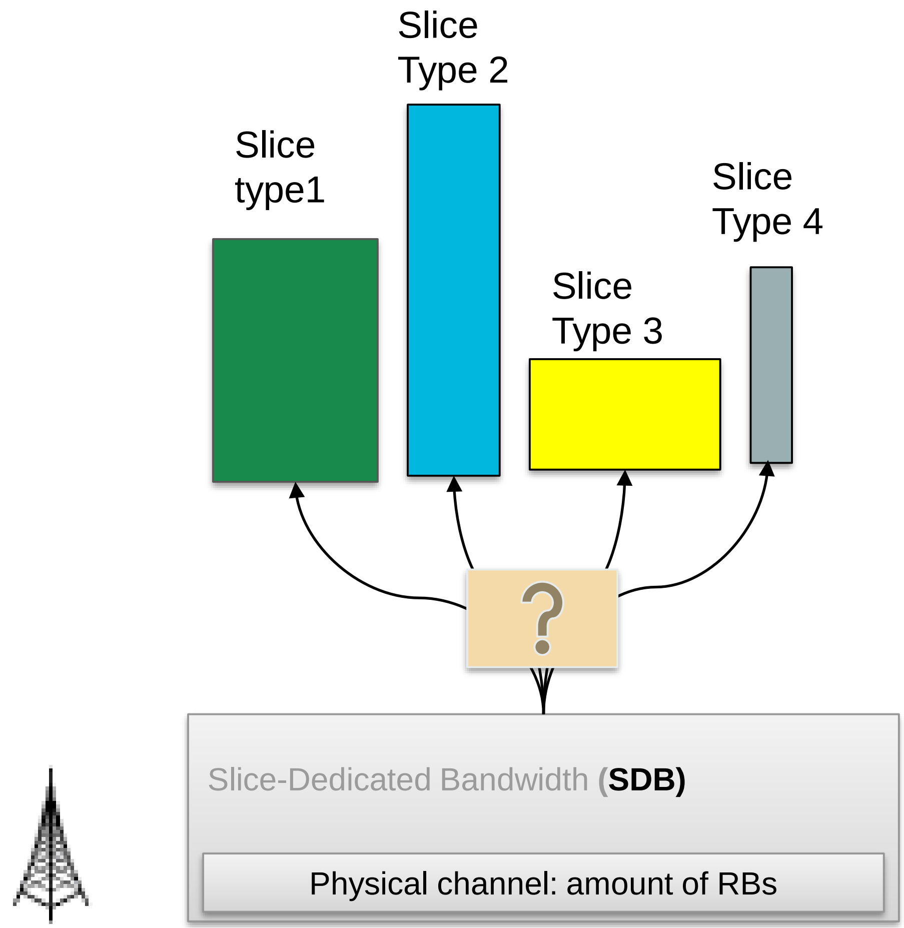
2.1. DYNAMIC SLICING OF RAN RESOURCES FOR HETEROGENEOUS COEXISTING 5G SERVICES

- **Sharing network resources between defined slices represents a crucial challenge in the network slicing**

How to share the available radio resources (pRB) among deployed slices in RAN?



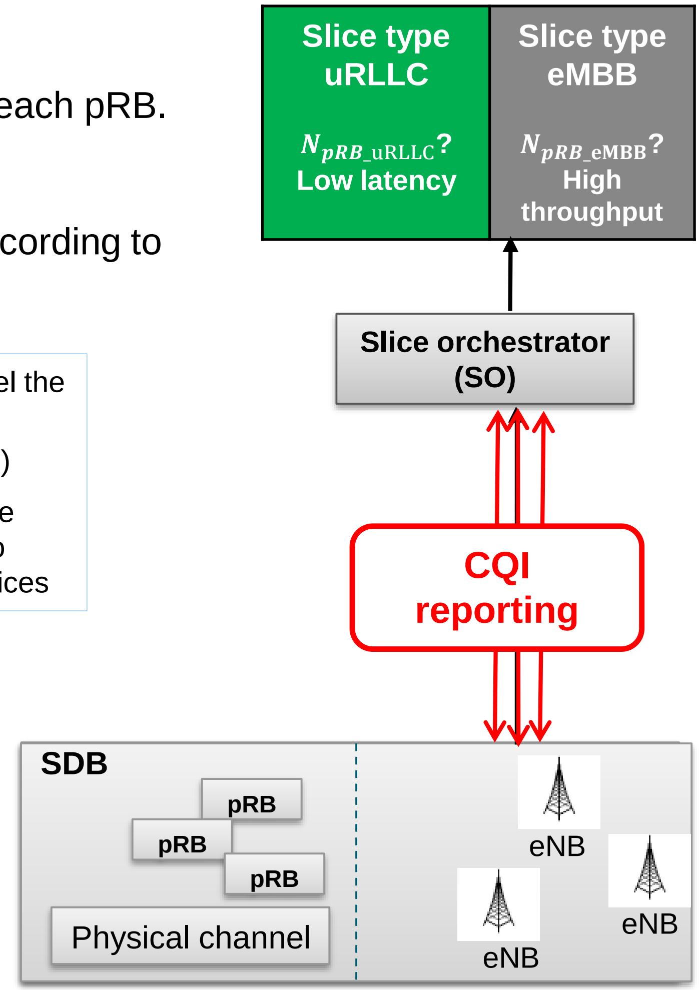
- **pRB:** physical resource block

RAN Level

2.1. DYNAMIC SLICING OF RAN RESOURCES FOR HETEROGENEOUS COEXISTING 5G SERVICES

- **How to calculate the number of physical resource block NpRB needed by each slice dynamically?**

- We use two formulas (1 & 2) to estimate the NpRB for each slice type, based on the slice template information and the channel quality indicator (CQI) value reported by the eNB to the SO.
- Use the CQI values to dynamically estimate and update the rate of each pRB.
- We apply the fair share between the NpRBs found for each slice according to the SDB limit.



eMBB slice: Use a simple formulas to derive the necessary *NpRB*

$$N_{\mathrm{pRB\_eMBB}} = \frac{N_{\mathrm{users}} * d_{\mathrm{App/user}}}{d_{\mathrm{pRB}}} \qquad (1)$$

uRLLC slice: Use the M/M/1/K to model the calculation of NpRB:

$$N_{pRB\_uRLLC} = \frac{\mu\_opt * \mathrm{Average\_packet\_size}}{d_{\mathrm{pRB}}} \qquad (2)$$

μ_opt is estimated numerically, while the objective is to find a value that allows to guarantee the max latency of uRLLC slices

- **pRB**: physical Resource Block
- **Nusers:** number of users
- $d_{App/user}$: data rate of user required by the application running on top of the slice
- **dpRB**: rate of pRB
- μ_{opt}:: service rate

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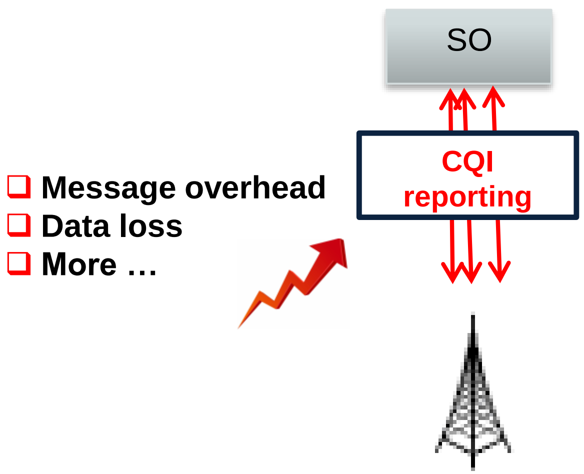
2.1. DYNAMIC SLICING OF RAN RESOURCES FOR HETEROGENEOUS COEXISTING 5G SERVICES

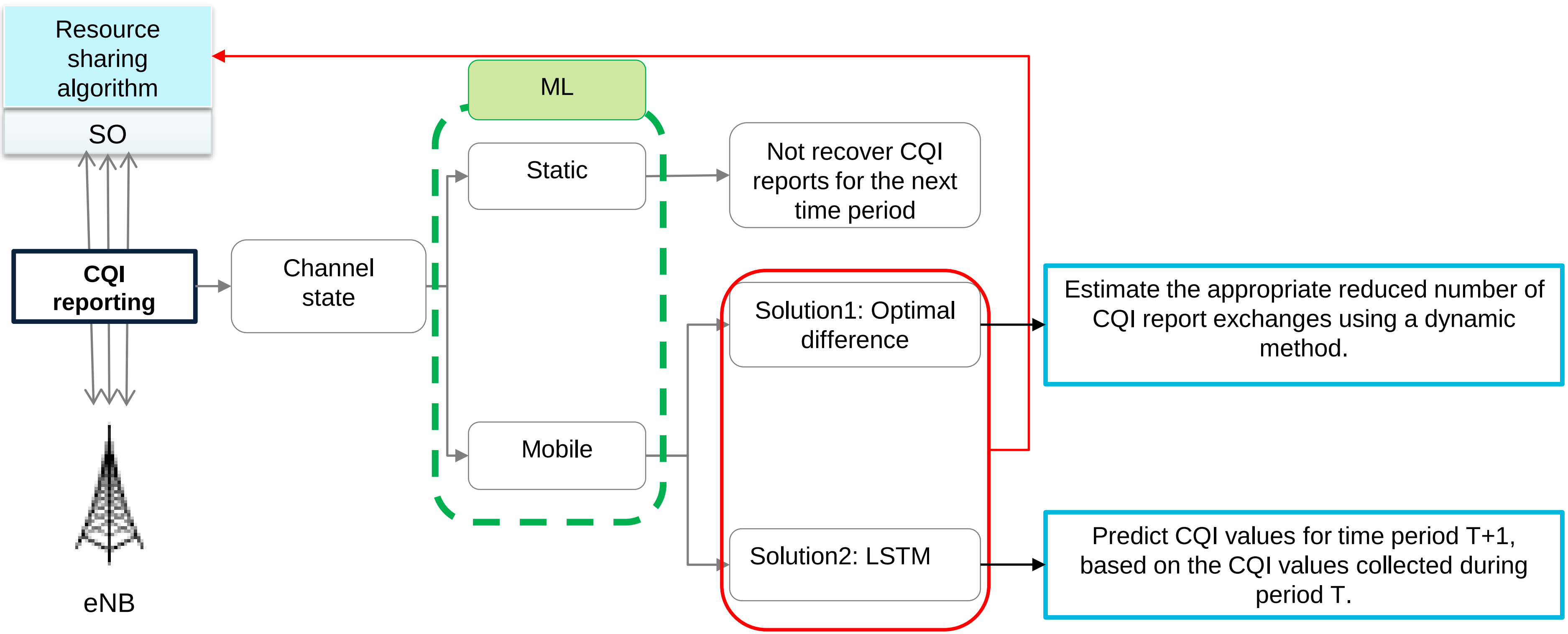
- Our algorithms derive well the NpRB required by heterogeneous slice requirement, up to the bandwidth limit.
- Our algorithms ensure the dynamicity of the slice resource allocation based on channel quality indicator (CQI) feedbacks between slice orchestrator (SO) and eNB.



- **How to reduce the signaling frequency of CQI reporting between the SO and eNB?**
- **How does this signaling reduction not affect the accuracy of the SO to estimate the amount of the radio resources?**

2.2. DATA-DRIVEN RAN SLICING MECHANISMS FOR 5G AND BEYOND

How to Maintain a good View at the SO Level While Mitigating CQI Overhead ??



LSTM: Long Short-Term Memory

2.2. DATA-DRIVEN RAN SLICING MECHANISMS FOR 5G AND BEYOND

- Our solutions provide a dynamic algorithm of resource allocation between slice while ensuring a reduced CQI overhead between the SO and the eNB.

- The performance of the resource allocation algorithms degrades after exceeding the number of network resource limits.

Slice Admission Control

Network resources limit constraint

The concept of revenues in the slice resource allocation

2.3. ON USING REINFORCEMENT LEARNING FOR NETWORK SLICE ADMISSION CONTROL IN 5G

- **Network slicing enables the apparition of new players in the market:**

The consumers, or tenants, requesting for a network slice

Slice requests

- $Nres^{i}_{reqDL}$ and $Nres^{i}_{reqUL}$
- $Htime$
- P^{i}_{req}
- Priority of the slice

Intelligent module

- Reinforcement learning
- Deep Reinforcement learning
- Regret matching

Accept or Reject Slice Request

Infrastructure Provider

The owner of the network infrastructure and may offer its resources as a service for a given cost

- Maximize InfProv reward
- Allocate all required resources

- $\boldsymbol{Nres^{i}_{reqDL}}$ **and** $\boldsymbol{Nres^{i}_{reqUL}}$: The physical resources needed to satisfy the requirement of a network slice in DL and UL respectively.
- $\boldsymbol{Htime}$: The requested hosting time of each network slice in the Infrastructure provider.
- $\boldsymbol{P^{i}_{req}}$: The price that a slice tenant pays to InfProv for the used resources.
- **Priority of the slice**: It depends on the application running on the corresponding slice. It is based in our model on $Htime$ and P^{i}_{req}.

2.3. ON USING REINFORCEMENT LEARNING FOR NETWORK SLICE ADMISSION CONTROL IN 5G

- Cumulative InfProv reward ⇔ Accepting slices
- Cumulative InfProv Penalty ⇔ Accepting slices without sufficient resources

✓ Our solutions ensure a high reward for InfProv, with very low to no penalty.

✓ RM achieves the best performance, followed by DQL and QL.

3. CONCLUSION AND PERSPECTIVES

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3. CONCLUSION AND PERSPECTIVES

3.1. CONCLUSION

- Provide dynamic resource sharing algorithms between heteregenous slices.
- Provide methods to reduce overhead occurring through the CQI feedbacks between the SO and the eNB, in the concept of network slicing.
- Deal with bandwidth limits while considering the concept of network slicing in the market.
- The algorithms we propose are based on various methods including some new ML algorithms integrated into the wireless network in general and network slicing in particular, which lead to enforce an e2e ML in network slicing.

3.2. PERSPECTIVES

Two level admission control (UEs/slice and slices/InfProv)

- Admission control between slice and users.

Multi-cell RAN resource allocation

- The introduced resource allocation algorithms in this thesis consider a single SO and eNB. However, the developed algorithm can be expanded to a multi-cell RAN.

e2e Network slicing in the market

- Our solution could be applied in various parts of the network (core and transport networks) in the concept of slice market.

AI-driven RAN

- RAN operations including radio resource allocation can be automated by integrating the AI into the RAN.

Enforcing e2e ML in network slicing

- Integrate ML algorithms (particularly distributed multi agent RL) for the management of the e2e network slicing.

PUBLICATIONS LIST

[1] Sihem Bakri; Pantelis A Frangoudis; Adlen Ksentini: "Dynamic slicing of RAN resources for heterogeneous coexisting 5G services", GLOBECOM 2019, IEEE Global Communications Conference, 9-13 December 2019, Waikoloa, HI, USA

[2] Sihem Bakri, Maha Bouaziz, Pantelis A. Frangoudis, and Adlen Ksentini : "Channel stability prediction to optimize signaling overhead in 5G networks using machine learning", ICC 2020 IEEE International Conference on Communications, Dublin, Ireland.

[3] Sihem BAKRI, Bouziane Brik, and Adlen Ksentini: “On using reinforcement learning for network slice admission control in5G: offline vs. online”, accepted in Wiley International Journal of Communication Systems.

[4] Sihem BAKRI, Pantelis Frangoudis, Adlen Ksentini, and Maha Bouaziz: ‘’Data-driven RAN slicing mechanisms for 5G and beyond’’, Submitted to IEEE Transactions on Network and Service Management.

Thank You
For Your Attention

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