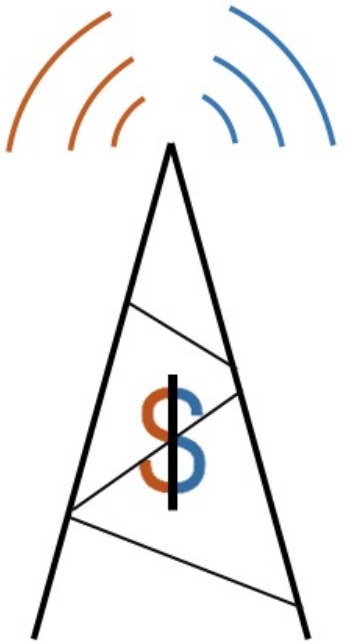
Optimization of infrastructure sharing in telecommunications networks



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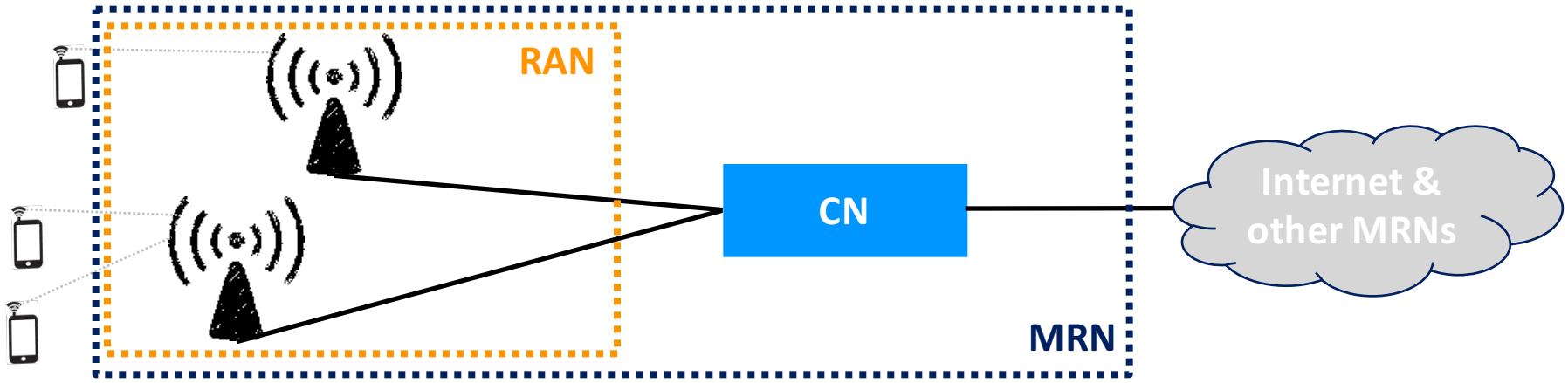
Context and motivation

RAN: Radio Access Network
MRN: Mobile Radio Network
CN: Core network
MNO: Mobile Network Operator



Infrastructure sharing: joint use and/or deployment of a subset/all network elements by at least two MNOs.

Why do MNOs need to share?

Explosive growth of mobile data

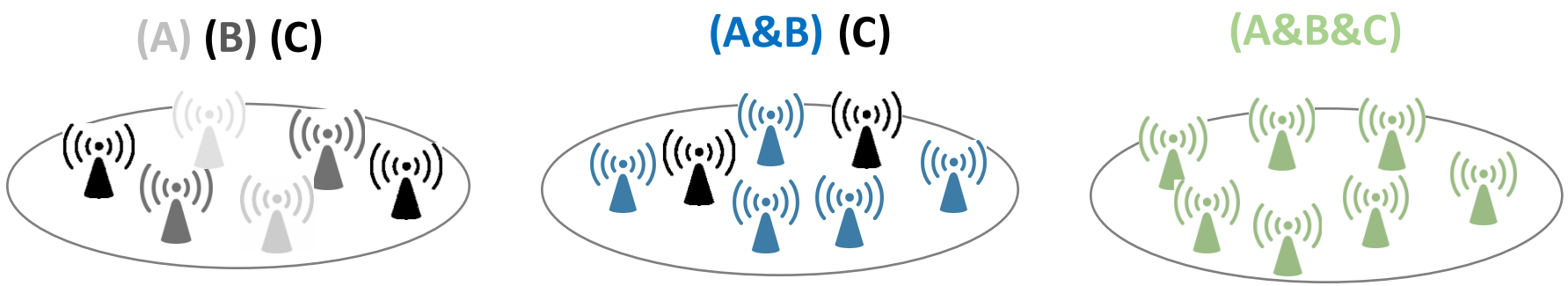
– Network densification **(more nodes)**
– More spectrum **(scarce resource!)**
– Migrate to new technologies 2G→5G

→ High CAPEX & OPEX + Decreasing revenues = Individual investment little profitable!

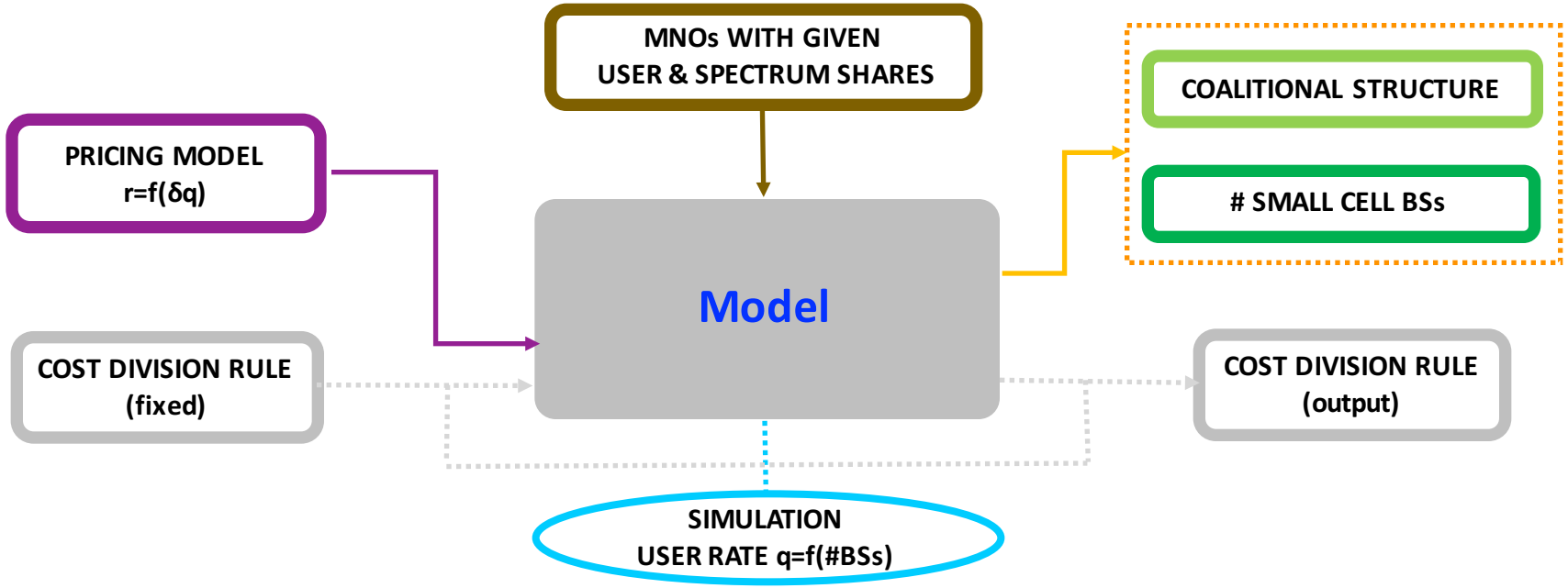
Infrastructure sharing → lower CAPEX + OPEX
Spectrum sharing → higher utilization

Research project

- **Research question:** Under which technical, economic and regulatory settings are MNOs incentivized to enter long-term sharing agreements?
- **Methodology:** Mathematical programming & game theory
- **Baseline Scenario:**
  - A set of MNOs with fixed market shares coexist over a (set) of geographical area(s)
  - MNOs plan to upgrade their network by deploying a layer of LTE small cell Base Stations (BSs)
  - Problem: determine the coalitions that will be created and # of BS they activate



Schematic representation & assumptions



- **Quality of service:**
  - Users of a coalition have the same quality of service
- **Cost division rule:**
  - **Fixed**: according to the market share
  - **Output of the model**: cost divisions that guarantee coalition stability
- **Spectrum sharing:**

  w/o spectrum pooling: each BS has a fixed amount of spectrum, despite the size of coalition activating it
  w/ spectrum pooling: each MNO contributes with a given amount of spectrum, members of a coalition pool together their available spectrum

Modeled scenarios

[1]: w/o spectrum pooling + fixed cost division rule

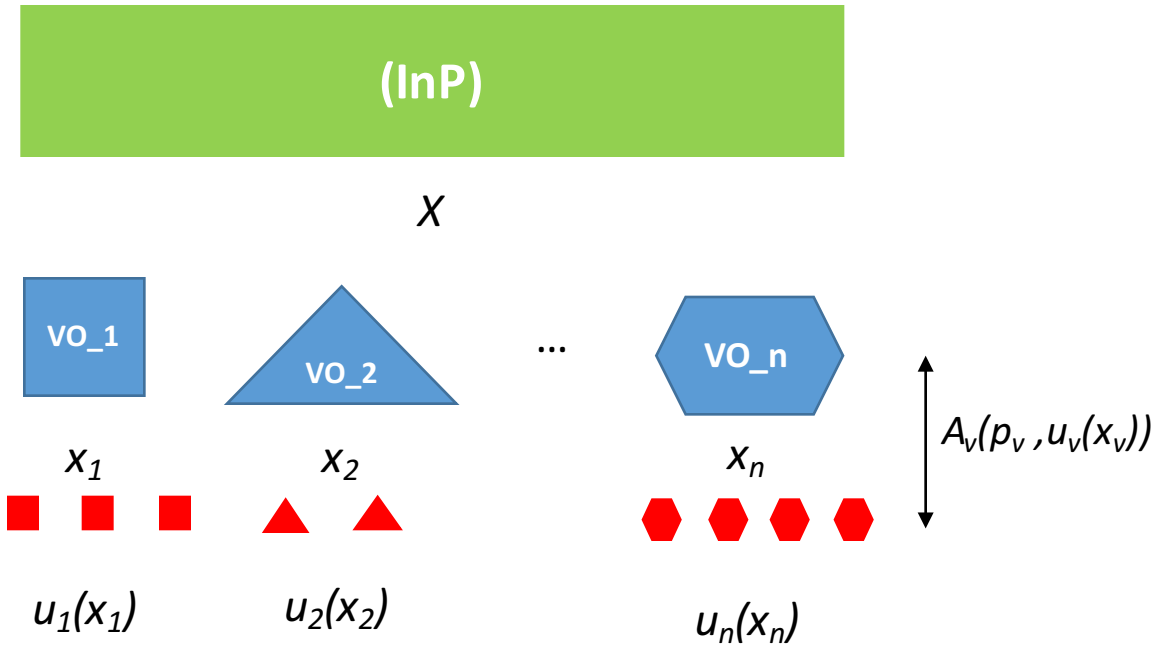
- **Two types of coalitional structures:**
  - **Socially optimal:** (imposed by a regulator) maximizing the quality of service – **MILP formulation**
  - **Stable:** maximizing each MNO profit (revenues-cost) - **Non Transferable Utility (NTU) cooperative game**
- **Key findings:**
  - Assume 3 MNOs A, B, C with # of users n_A<n_B<n_C: as we increase δ, the outcomes are (ABC)…(AB,C)…(A,B,C)
  - Generally more incentive to collaborate to maximize MNOs' individual profits w.r.t. maximizing the quality of service
  - **Infrastructure sharing w/o spectrum pooling: Tradeoff between cost reduction and service degradation due to contention → when users are willing to pay more, MNOs and users are better off if no sharing occurs!**

[2] & [3]: w/ spectrum pooling + cost division rule outcome of the game

- **Stable coalitional structures: GNEP [2] and NTU and TU cooperative games [3]**
- **Key findings:**
  - Fixed cost division rule not necessarily stable (not in the core)
  - Cost division rule suggests a way to reward MNOs providing more spectrum and introducing little contention
  - **Infrastructure sharing w/ spectrum pooling: Service degradation due to contention outweighed by spectrum pooling gain!**

[1] L.Cano, A.Capone, G.Carello, M.Cesana and M.Passacantando, "On optimal infrastructure sharing strategies in mobile radio networks", IEEE Transactions on Wireless Communications, February 2017
[2] L.Cano, A.Capone, G.Carello, M.Cesana and M.Passacantando, "Non-cooperative game approach for RAN and spectrum sharing in mobile radio networks", European Wireless, May 2016
[3] L.Cano, A.Capone, G.Carello, M.Cesana and M.Passacantando "Cooperative infrastructure and spectrum sharing in heterogeneous networks" in IEEE Journal of Special Areas in Communications, September 2016

Ongoing work



How to divide the total resource X of an active BS?

- **Strategy of VO *v*:** x_v
- **Payoff from strategy profile** $x=\{x_v\}_{v=1...n}$ **:** $g_v = r_v(x_v) - c_v(x)$

Nash Equilibria not always on the Pareto frontier → Nash bargaining for non convex payoff domain

Infrastructure Provider (InP)

- Zero profit entity which deploys and maintains a unique network infrastructure over a set of planning periods: **multi-period facility location problem**
- Has estimates of the aggregate user demand in each period
- Objective: **Min-cost** network providing a **minimum quality of service** for all users

Virtual Operators (VO)

- VO *v* selects the amount of resource x_v *(out of the available X)* to maximizes its payoff $g_v = r_v(x_v) - c_v(x)$
- Serves identical users characterized by the same utility function $u_v(x_v)$
- *D*etermines the price p_v maximizing their profit based on the user acceptance probability function

Users

- Characterized by an acceptance probability $A_v(p_v, u_v(x_v))$

Thank you for your attention ☺