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New scenarios for resource slicing and sharing beyond 5G networks

Antonio Capone

Moscow Wireless Week
October 1-3, 2018



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School of Industrial and Information Engineering

We are interested to student exchanges at Bachelor, Master and PhD levels in all areas of Engineering









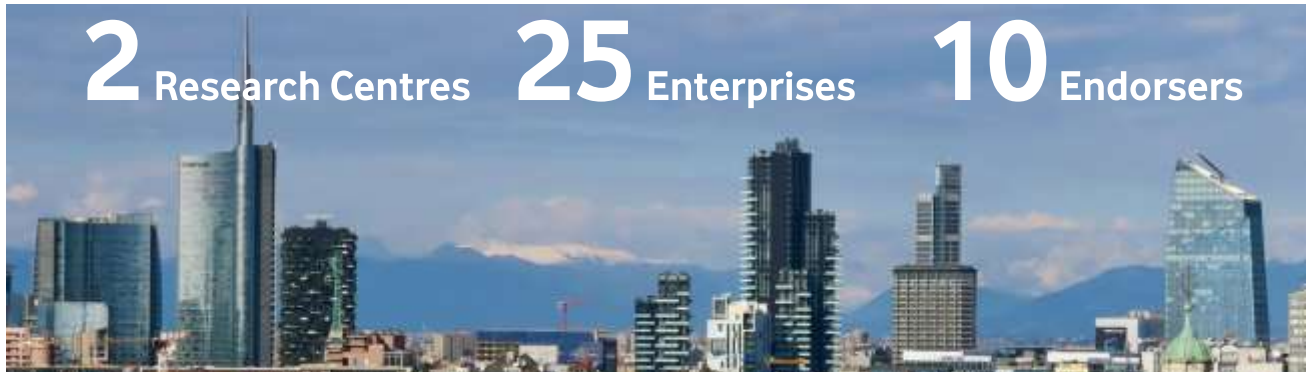
QS WORLD UNIVERSITY RANKINGS®

2018
By subject

	World	EU
Engineering & Technology	17	6
Architecture & Built Environment	9	5
Art & Design	5	2

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5G trial in Milan with Vodafone



Multi-disciplinary research @ POLIMI

5 departments
11 research groups

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Bioengineering
Design

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41 Use Cases across 7 sectors with high social relevance

Health & Wellbeing

9	Connected Ambulance Robotics for hospital & surgery Wearables	Increased access to and efficiency of health services

Security & Surveillance

5	Security of railway stations Enhanced public safety and emergency services	Enhanced public safety

Smart Energy, Smart Grid & Smart City

3	Smart Energy & Smart Grid Smart City & Smart Campus Citizen 4.0	Public services management efficiency

Mobility & Trasport

4	Urban Cross Traffic Cooperation Enhanced assisted driving	Enhanced mobility safety

Manufacturing & Industry 4.0

12	Cooperative robotics Enhanced retail experience Smart agriculture	Production efficiency and better use of scarce resources

Education, Learning & Entertainment

7	Classes 4.0 e Augmented Reality VR for immersive experience Tourism 4.0	Access to education and entertainment

Digital Divide

1	Fixed Wireless Access	Broadband connectivity to remote areas

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Joint work with

some colleagues:

- Giuliana Carello, Matteo Cesana (Politecnico di Milano)
- Ilaria Malanchini, Vinay Suryaprakash (Nokia Bell Labs)
- Mauro Passacantando (University of Pisa)
- Brunilde Sansò (Ecole Polytechnique de Montreal)

… and PhD students (doing the actual work):

- Özgür Umut Akgül
- Lorela Cano
- Alessandro Lieto



European project H2020
ACT5G
http://act5g.itn.liu.se









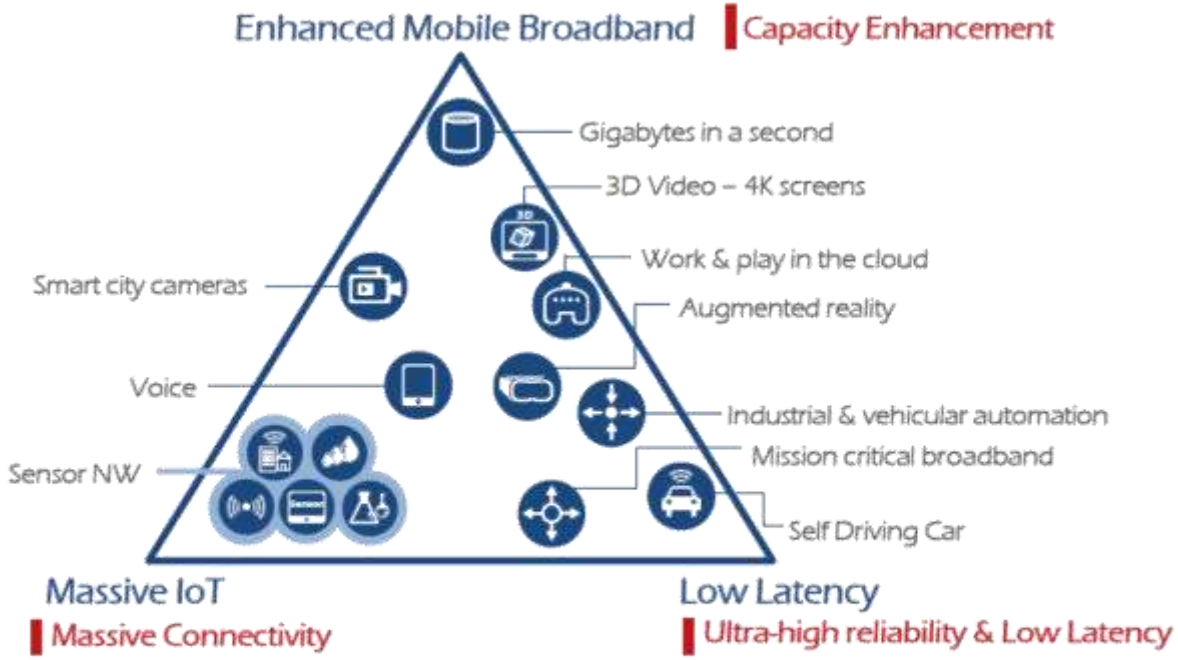




Why do we slice a wireless network?

Multiple working points for 5G networks

- For the first time 5G allows to optimize
  - not only **rate performance**
  - but also: energy consumption, reliability, number of users, …
- Obviously **not all at a time**
- Managing **multiple working points** depending on applications is easier done on somehow separated network portions

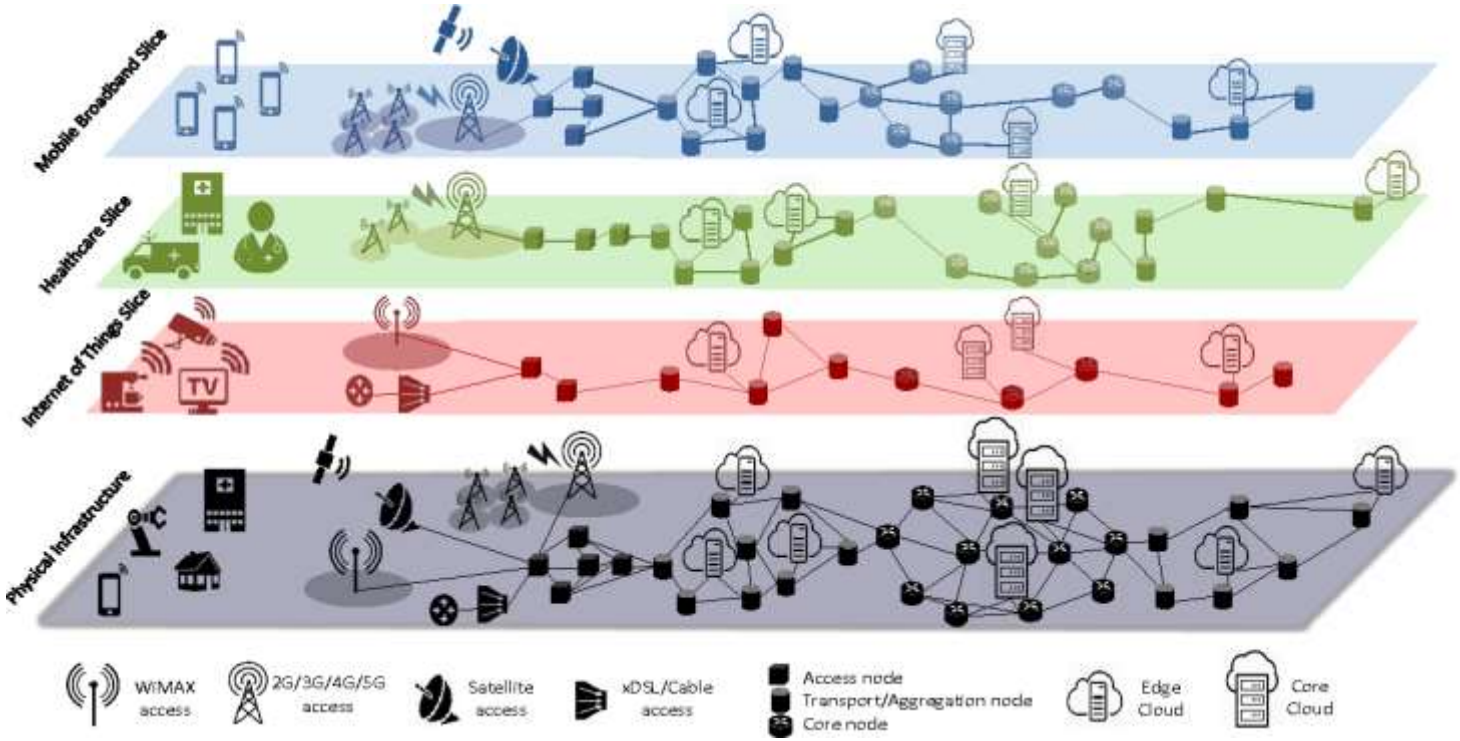


(Source: ETRI graphic, from ITU-R IMT 2020 requirements)

Specialized network functions and edge computing

- The **virtualization** approaches of new network architecture
- **Specialized service chains** depending on applications
- Easy integration with **edge computing** modules in application domain

- **Selling network and computing resources** to vertical applications is easier done in separated and optimized chunks



A sliced network is more easily shared

- Network slicing potentially allows an **easier sharing of the infrastructure** and its resources
- A **reshaping of mobile market** can modify the value chain that over the years has increasingly favored OTTs
- New **regulatory trends** (in some regions like Europe) are pushing for **wholesale** approaches for telco services
- Trying to allow the entrance in the market of **strong players of vertical domains** with local roots

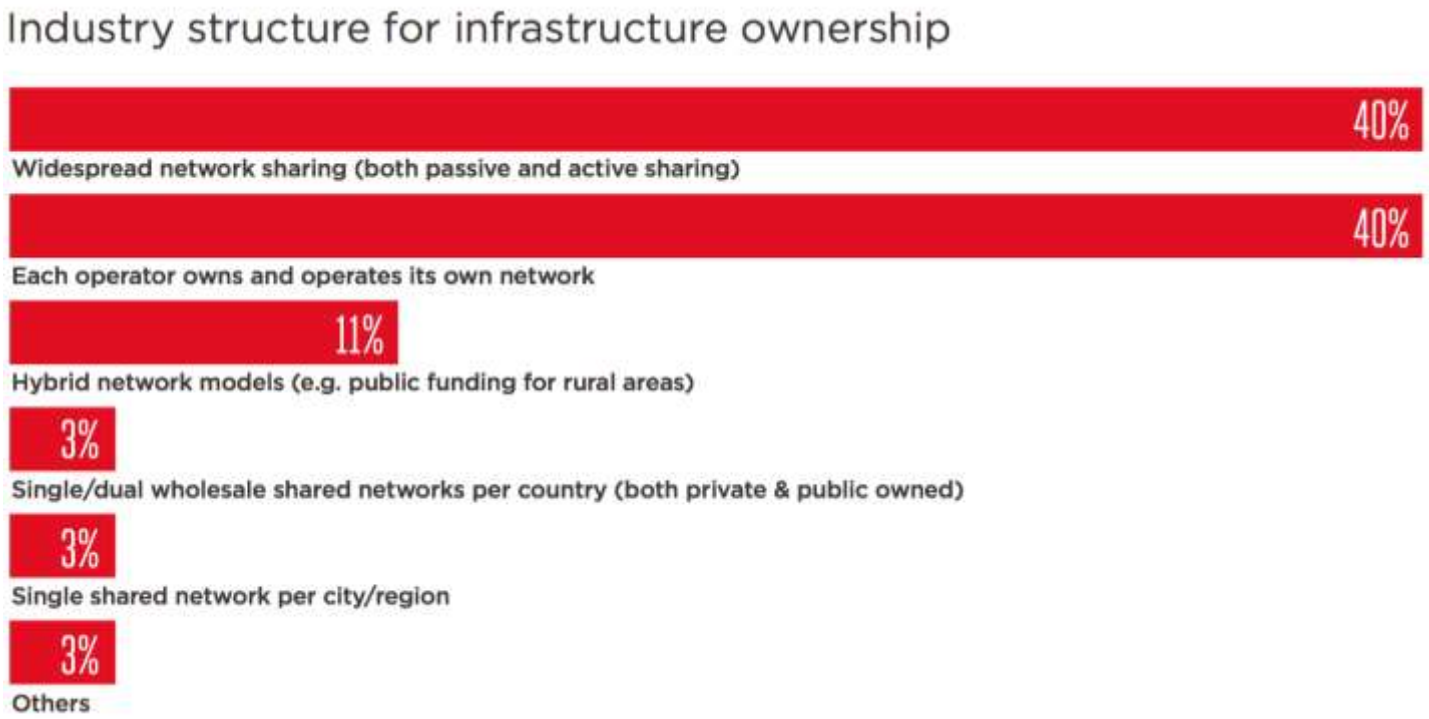




Is infrastructure and resource sharing convenient?

To share or not to share, this is the question

Question: What will be the most common industry structure for infrastructure ownership in 5G era?

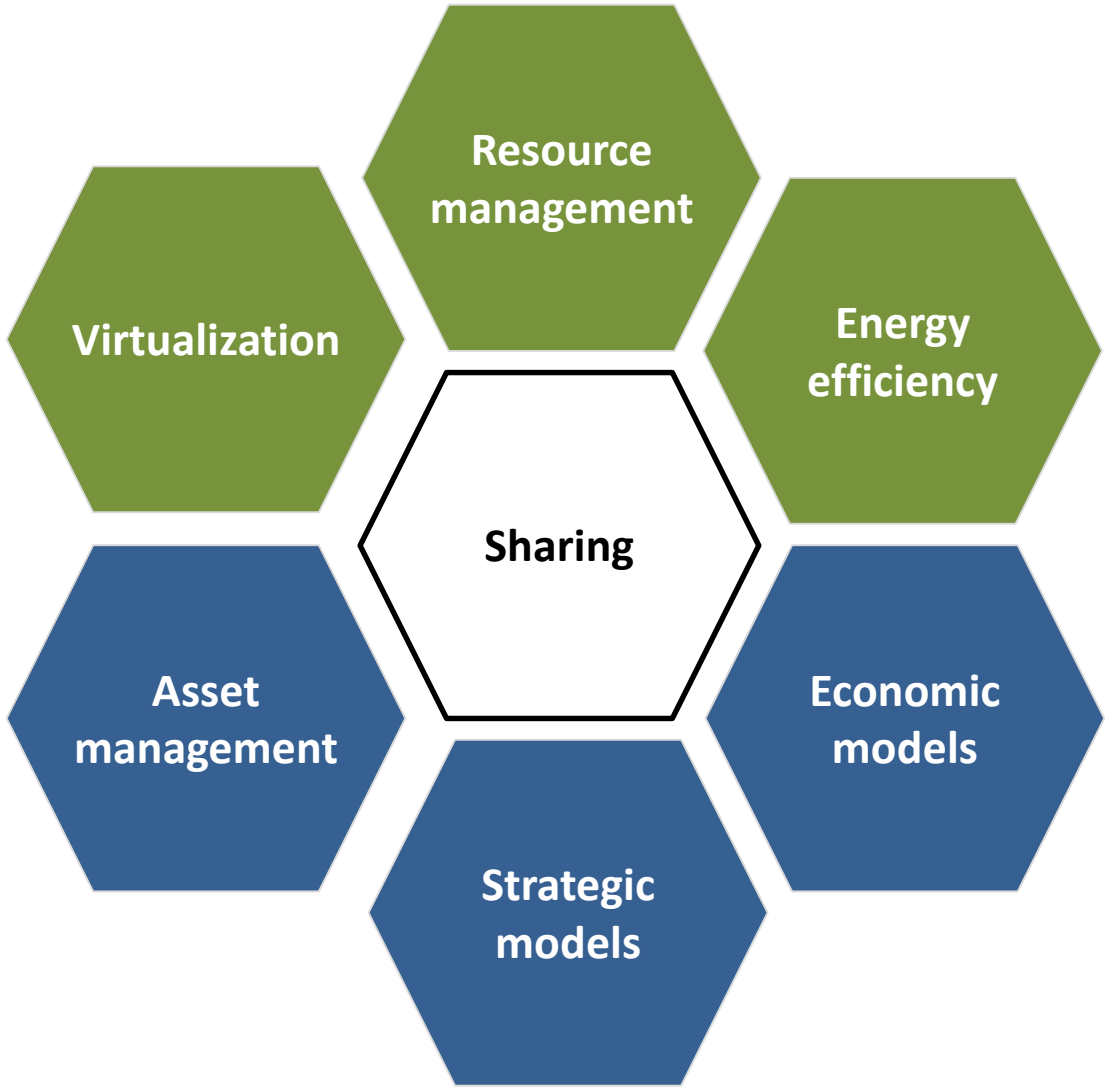


Operators survey

Source: GSMA, “The 5G Era”, survey on 750 operators’ CEO survey, 2017

State-of-the-Art

- **Technical approaches**
  - How to virtualize service and network portions
  - How to manage resources in shared environment
  - How to save energy
- **Economic approaches**
  - Strategic planning for operators
  - Asset management and market strategy
  - Economic models of sharing



The missing link: perceived user quality and willingness to pay





- We have developed a **model** for mobile operators to **estimate user perceived quality** based on network statistical counters
- We have defined a simplified **simulation model for associating quality indicators to sharing scenarios**
- We have used a common model for associating quality perceived and willingness to pay

Modeling convenience to share

- **Objective**: provide a techno-economic framework which evaluates the viability and profitability of infrastructure sharing under different technical, economical and regulatory settings.

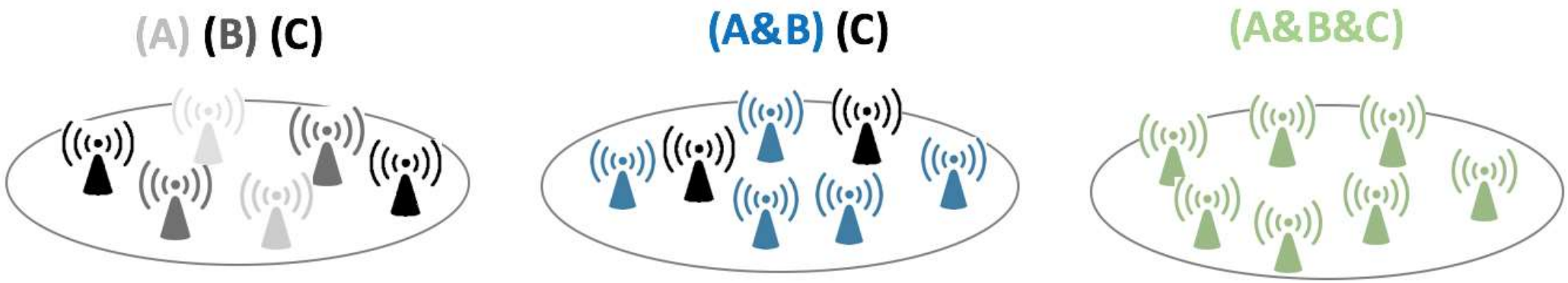
- **Methodology**: mathematical programming and game theory

- **Focus**: Small cells deployment

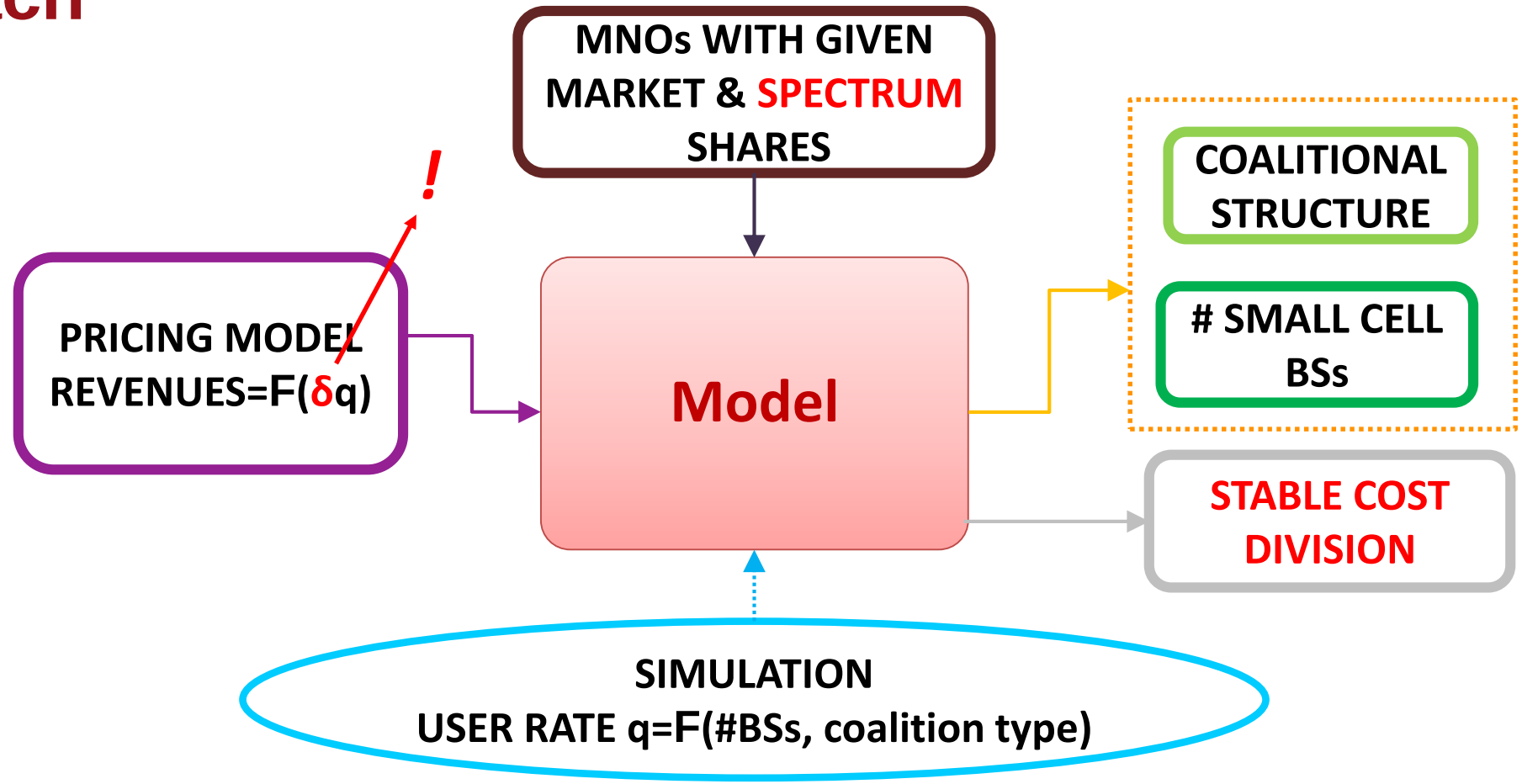


Scenario

- A **set of MNOs** with given market shares coexist in a given geographical area
- MNOs plan to **upgrade** their network by deploying a layer of **small cell Base Stations** (BS)s
- **Problem**: Will MNOs invest? If so, which coalitions will be created and how many BSs will they deploy?



Approach

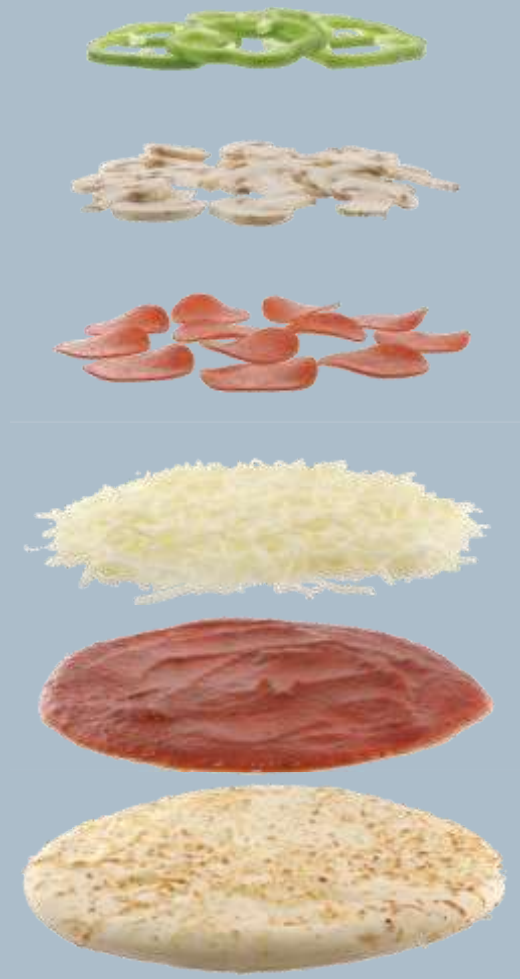


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[JSAC16] L.Cano, A.Capone, G.Carello, M.Cesana, M.Passacantando. Cooperative infrastructure and spectrum sharing in heterogeneous mobile networks. IEEE Journal on Selected Areas in Communications, 34(10):2617–2629, 2016.

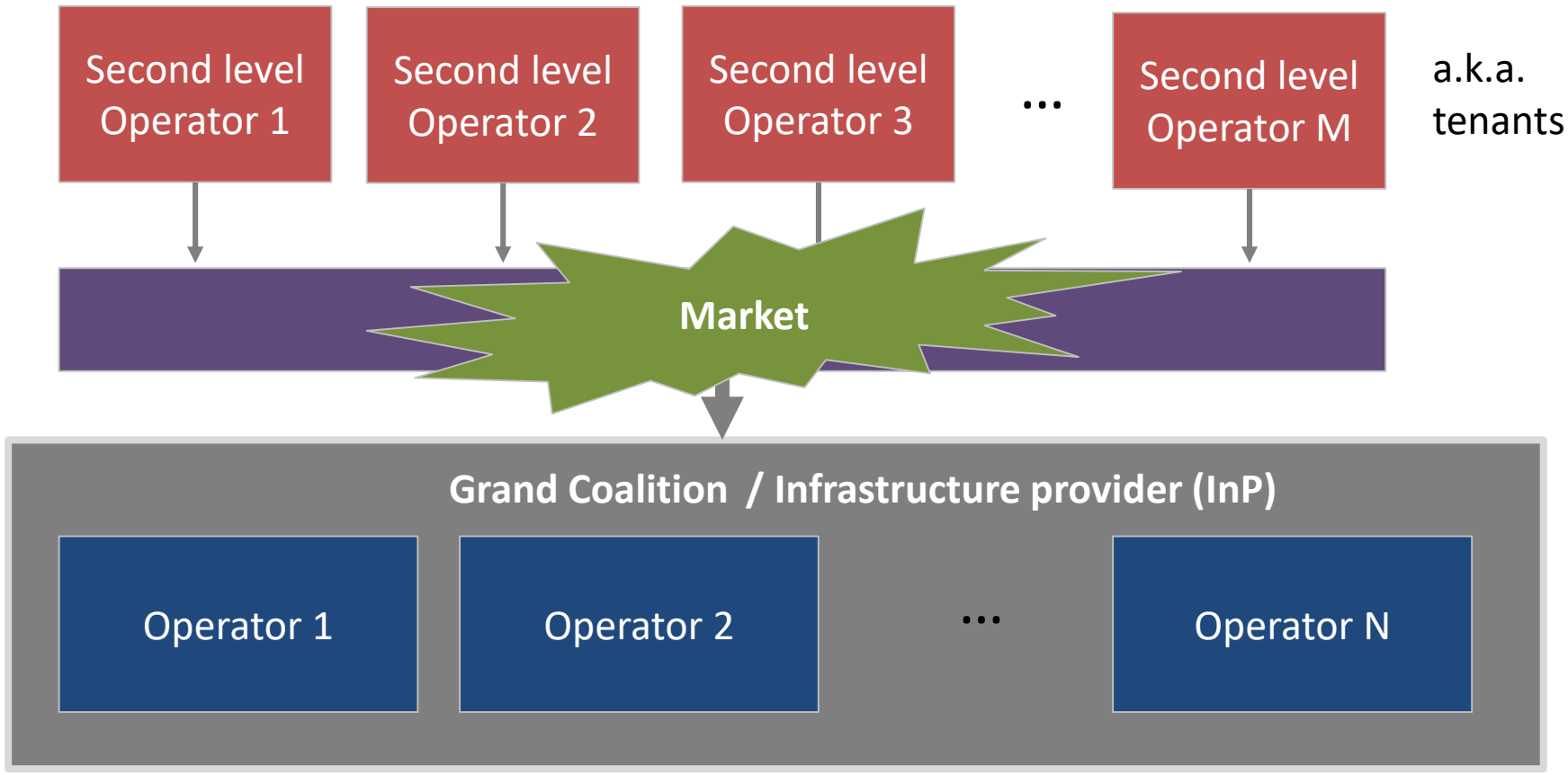
Model and key findings

- **MNOs are profit-maximizing entities** (regulator does not intervene) modeled as a **non-cooperative** and as a **cooperative game –** w/o & w/ transferable utility
- **Stable network sharing configuration**: Nash Equilibria (NE) of the non-cooperative game / core of cooperative game
- **Key Findings**:
  - Decreasing δ makes **sharing more convenient** since MNOs cannot afford individual more congested networks
  - **Grand coalition fast becomes stable for vast majority of instances** (spectrum pooling gain > quality degradation due to sharing)
  - **Stable cost divisions** reflect the MNOs individual market and spectrum share e.g. an MNO with a large spectrum holding & few users can be exempted from the infrastructure cost



How can we move from sharing to market layering?

Infrastructure Provider(s) - InP



- Assuming no-competition among infrastructure providers (**InP**)

A market? … similarities

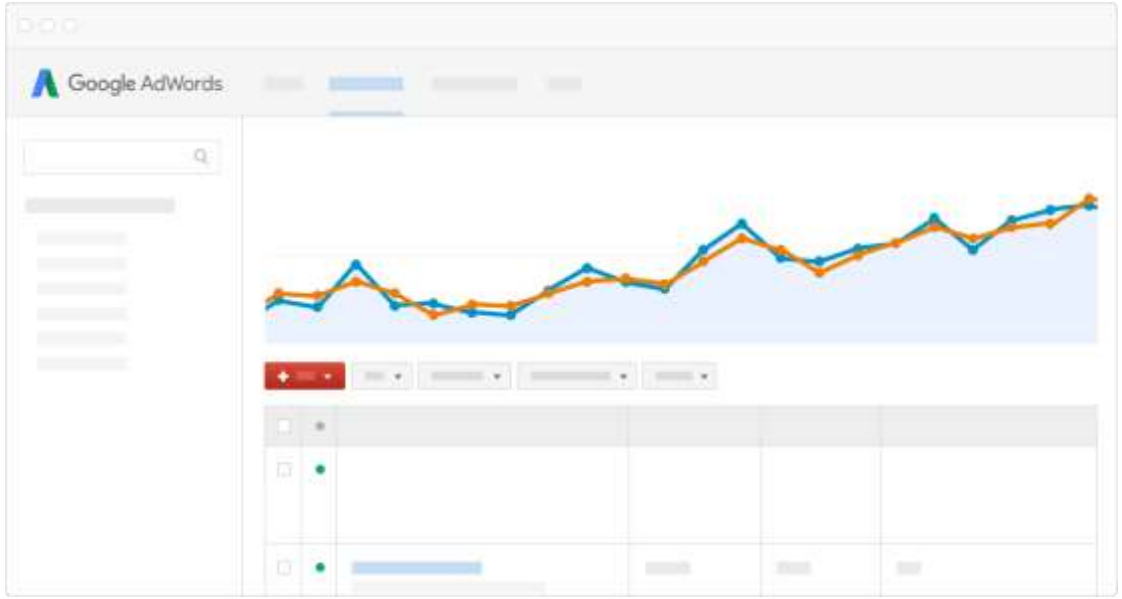


Energy market

Time granularity from days to minutes

Ads market

Time granularity from minutes to seconds



Assumptions

- The **InP behave *fairly*** in the resource allocation phase
- **Virtual Operators trade** the amount of **resources** according to their users' needs (estimation/prediction of traffic load, type, distribution, channel qualities, etc.)
- **Pricing** model ensures that the InP has **enough money** to cover recurrent costs and expand capacity

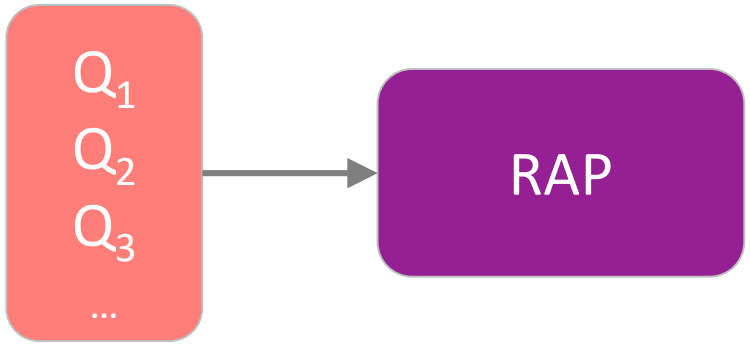


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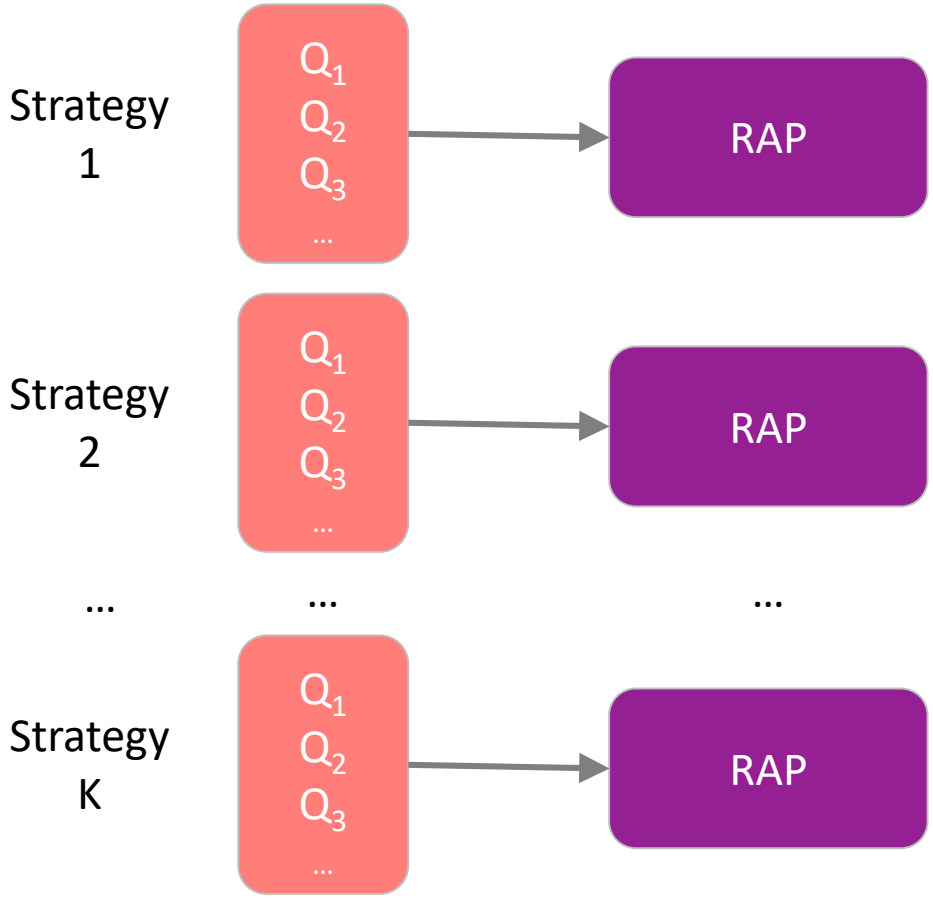
Resource allocation problem

- Given traffic estimation, virtual operators can set a quality target Q_i depending on their business model
- **InP resource allocation problem (RAP)**:
  - Assign resources to virtual operators
  - so as to maximize overall quality
  - Subject to fairness constraints



Business strategy

- Changing the quality targets (and traffic estimations), operators can influence the resource allocation

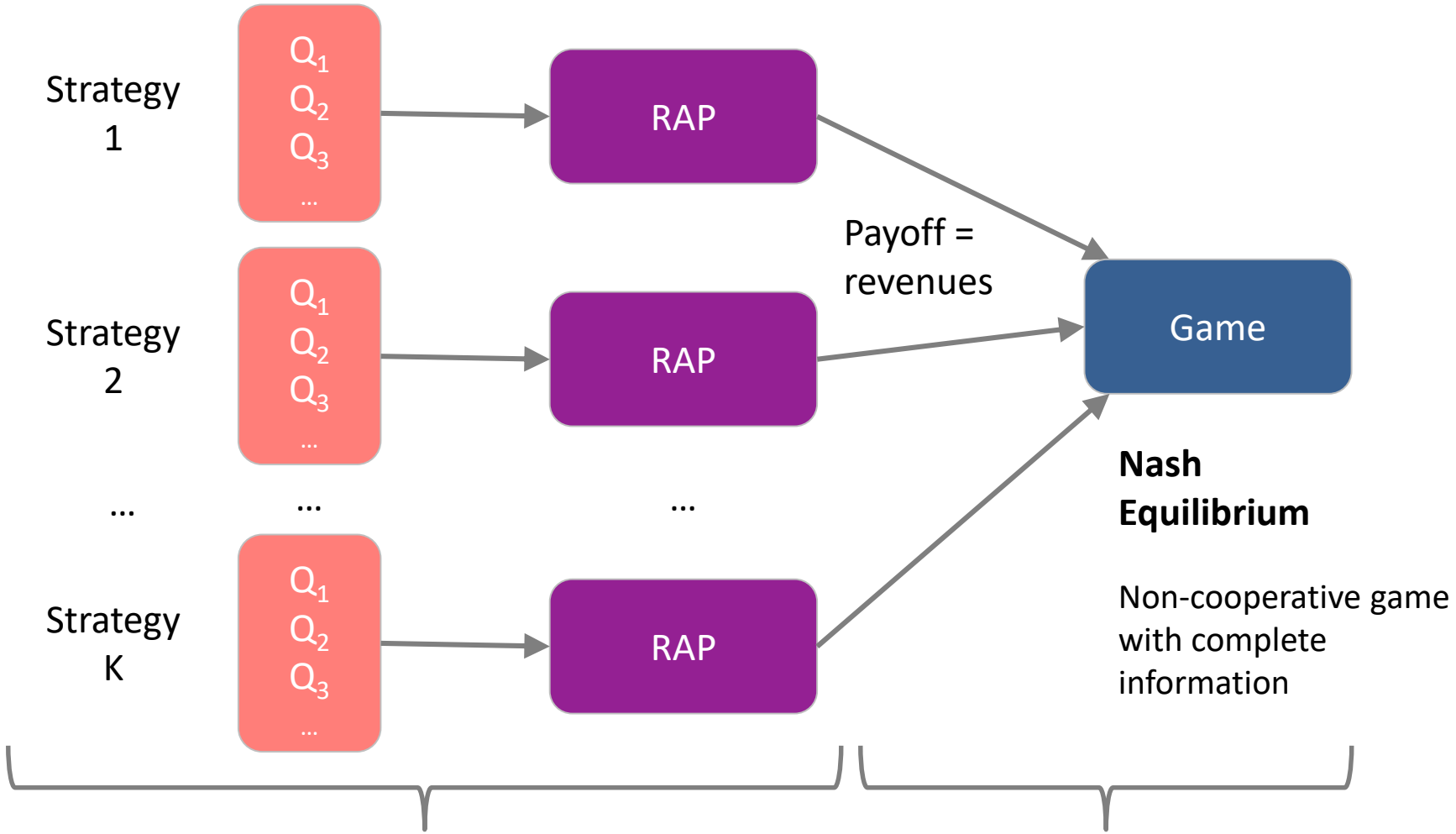


How to differentiate strategies ?

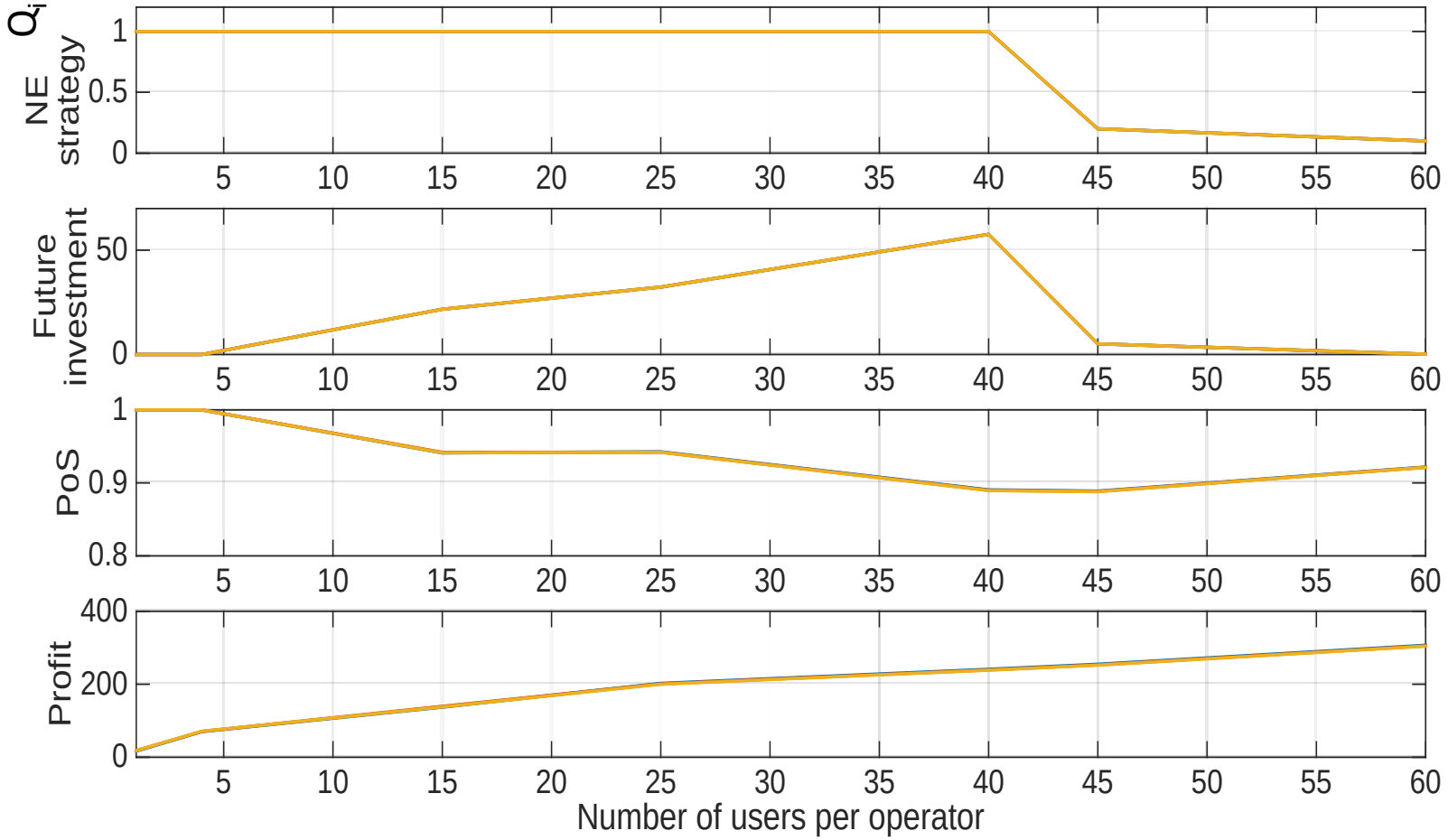


Costs and revenues !!!

Market competition

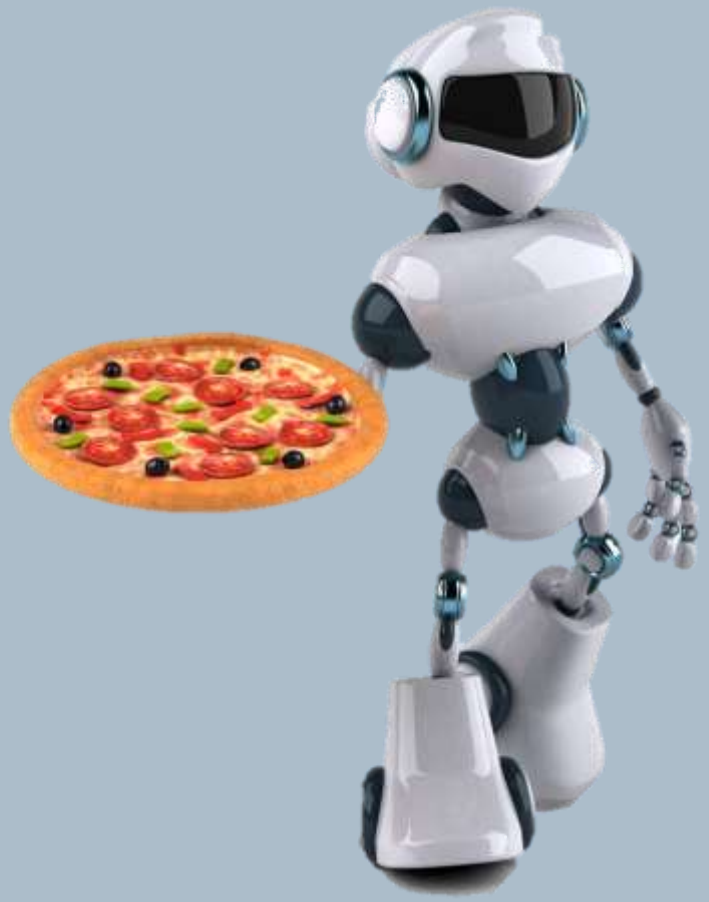


Example results



Work in progress:

- Modelling competition among infrastructure providers
- Fundamental to show that the approach is feasible also during transition from traditional market to the new one

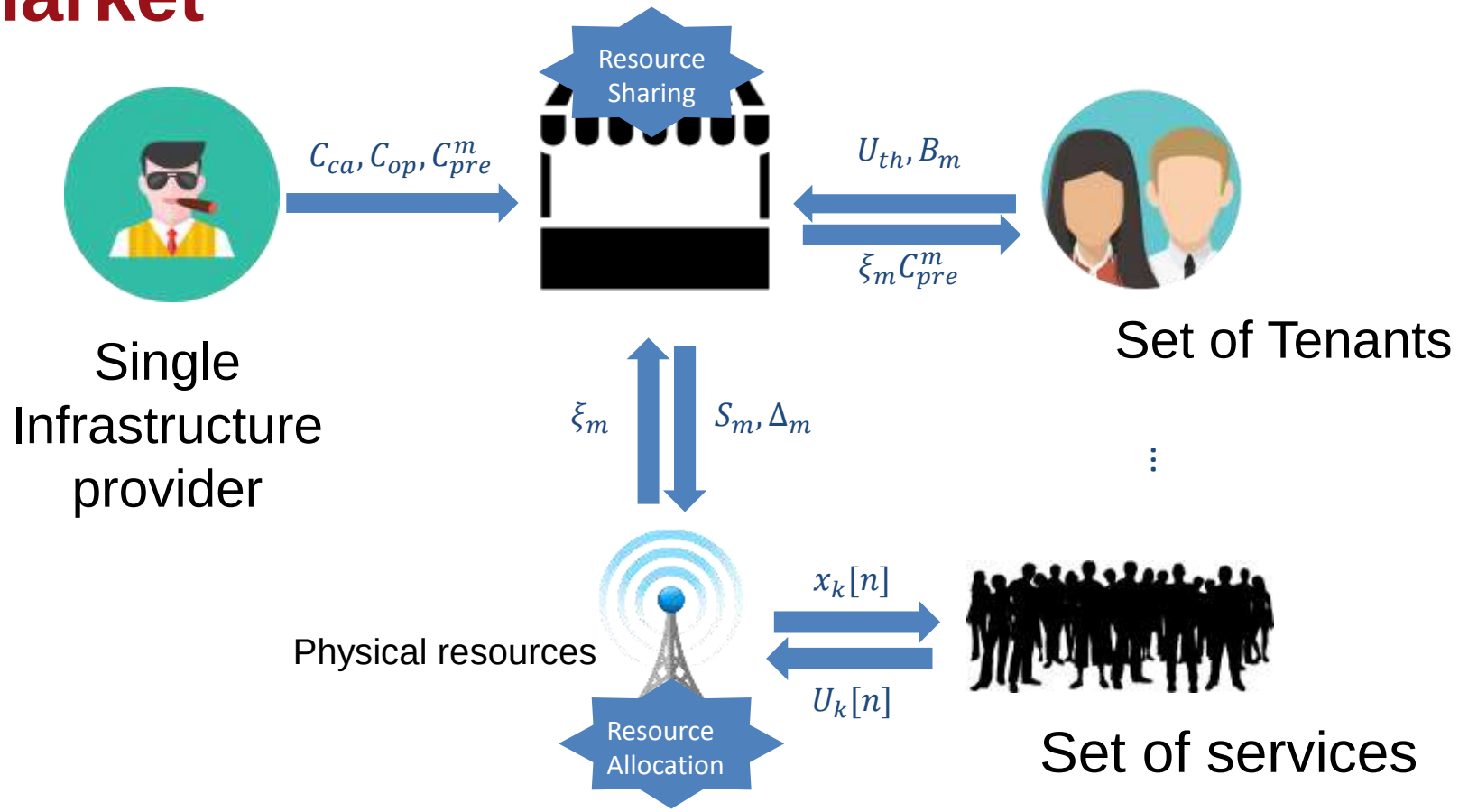


Can trading become automated?

How to make trading more dynamic?

- The idea is that we can automate the **pricing model** and combine it with real-time **resource scheduling**
- We add **flexibility** since scheduler is able to exploit **variations in traffic** (volume and mix)
- The business **strategy** remains **under control of virtual operators**
- Diversity in **traffic mix** can be accounted for (**tenants of specialized slices**)

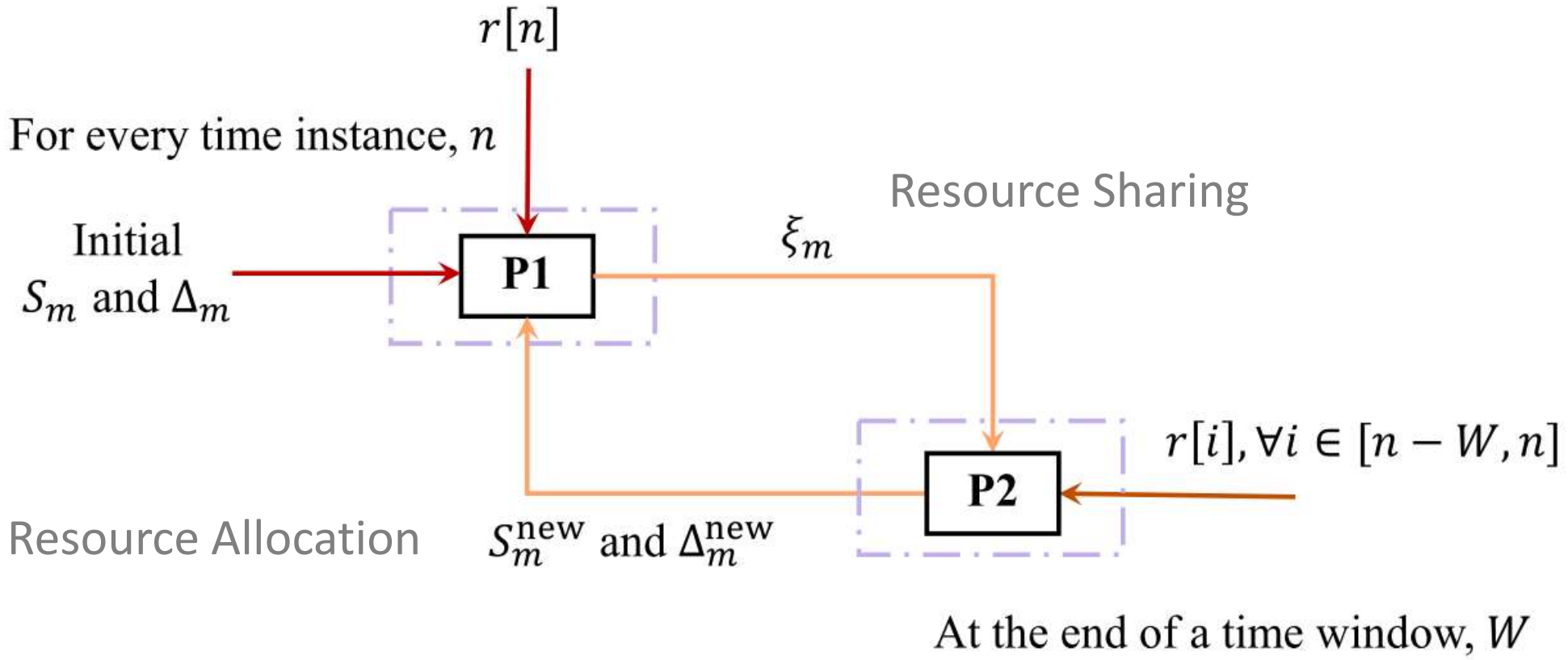
An automated market



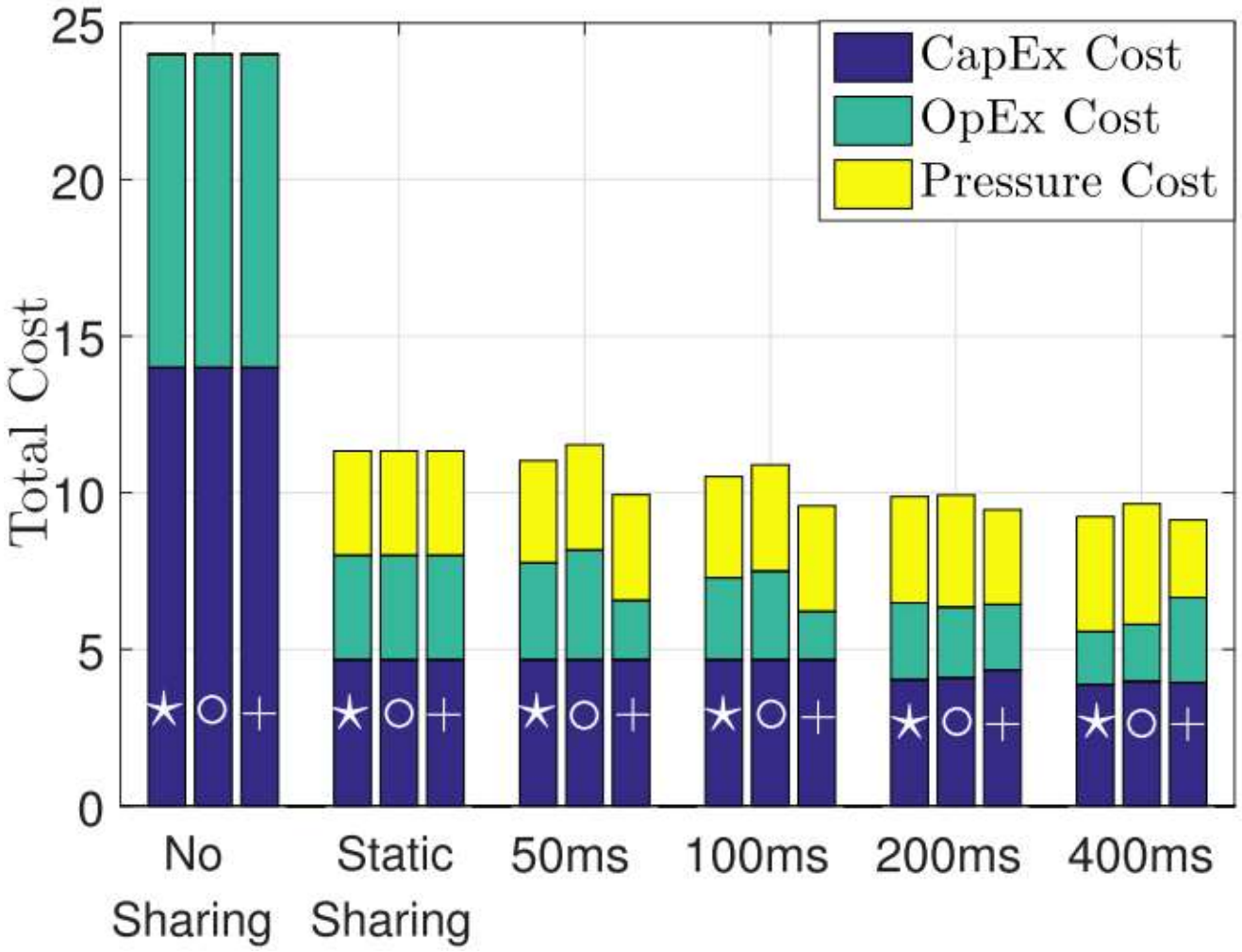
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Two Step Solution Framework: Anticipatory networking



Example results



Work in progress:

- Defining an interface between automated trading and resource scheduling
- Modelling long term SLAs into trading strategies in multi-cell scenarios

Conclusion

- **Sharing is a need** for the evolution of mobile networks
- Like in different sectors, the creation of a:
  - **layered market**
  - with **automated trading**

  appears a natural evolution
- **Technical solutions for making resource allocation algorithms suitable for being exposed on a market like this are still to be defined**



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Thanks!

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