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New scenarios for resource slicing and sharing in beyond 5G networks

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Joint work with

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… and PhD students (doing the actual work):

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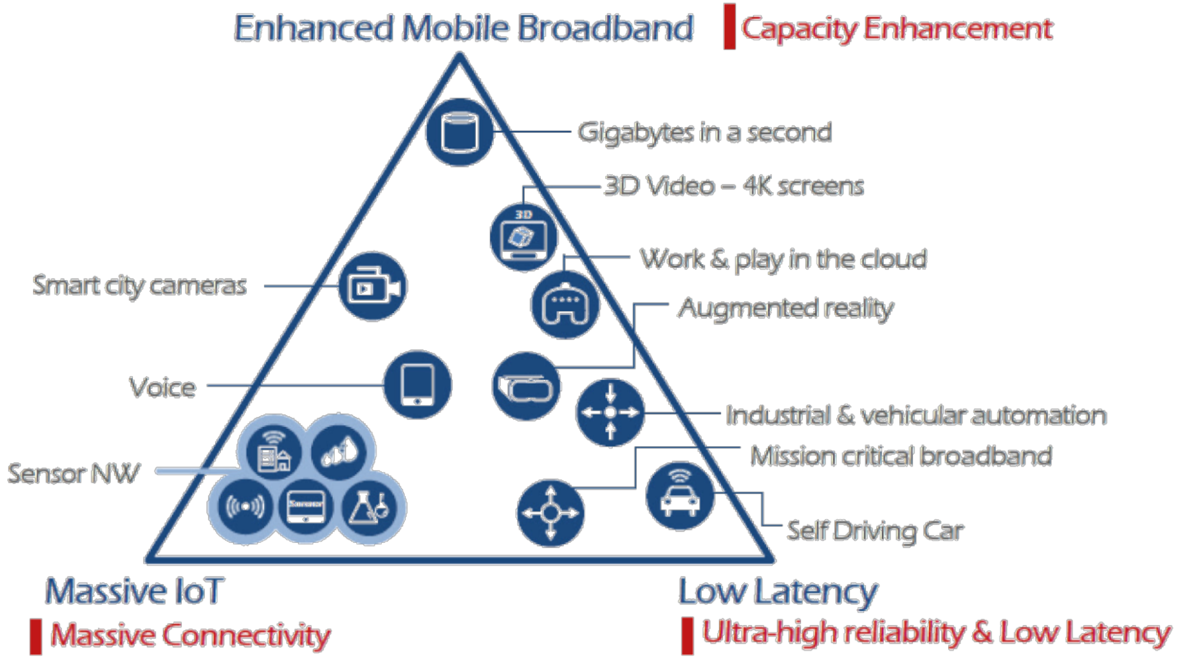
European project H2020
ACT5G
http://act5g.itn.liu.se

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 **<u>not all at a time</u>**
- Managing **multiple working points** depending on applications is easier done on somehow separated network portions

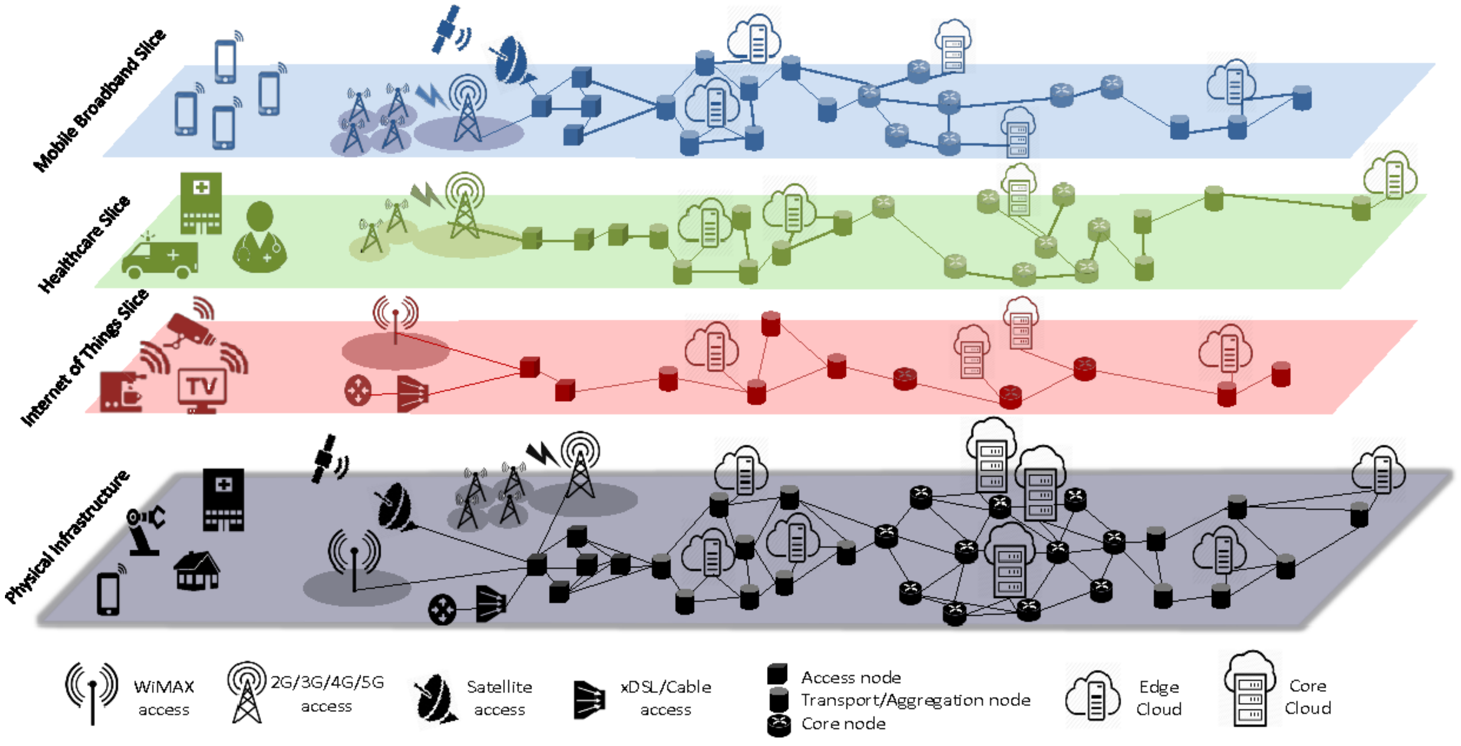


(Source: ETRI graphic, from ITU-R IMT 2020 requirements)

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?

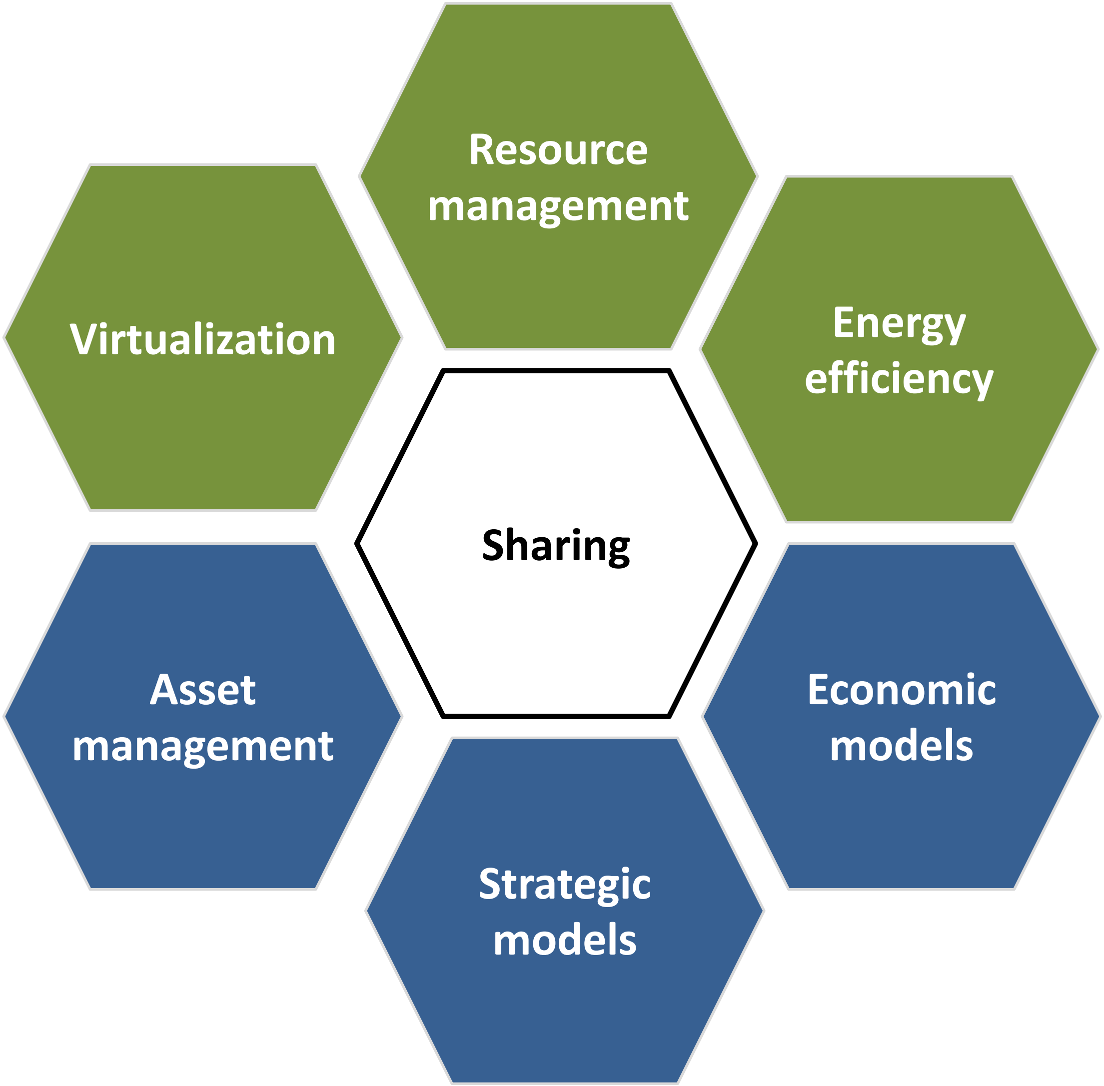
Industry structure for infrastructure ownership

Operators survey

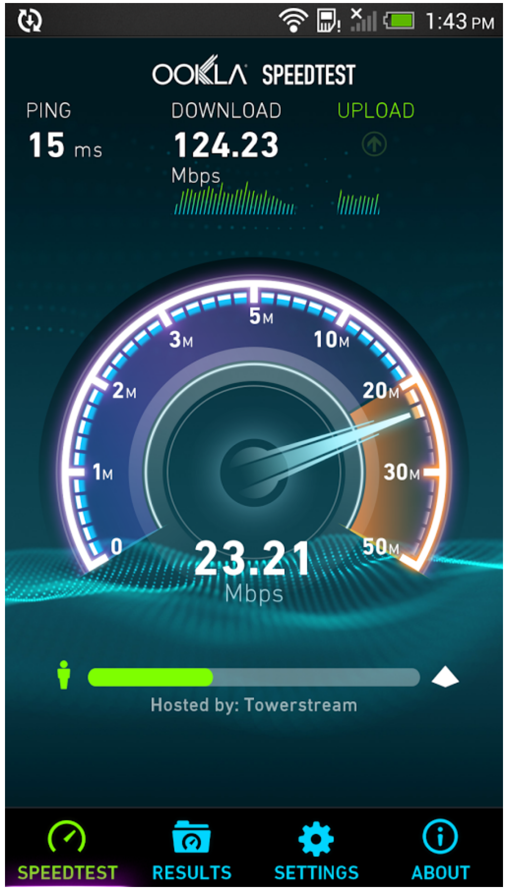
Source: GSMA, “The 5G Era”, survey on 750 operators’ CEO survey, 2017

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

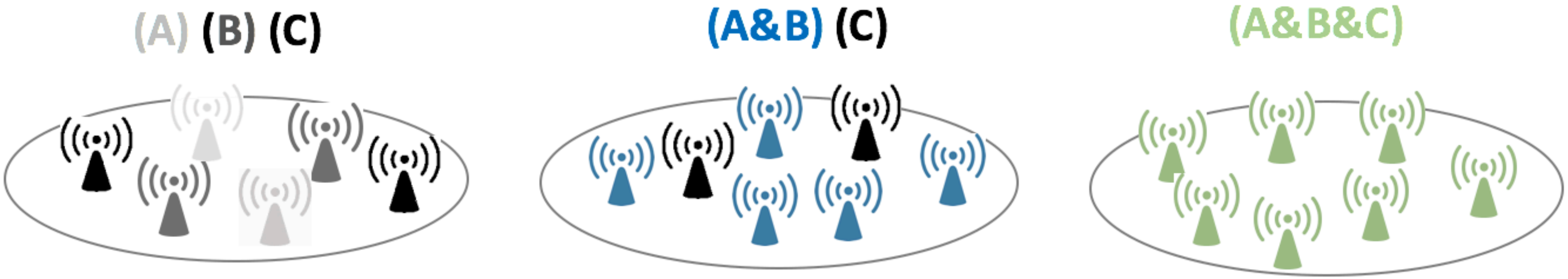
- **Objective**: provide a techno-economic framework which evaluates the viability and profitability of infrastructure sharing under different technical, economical and regulatory settings.

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

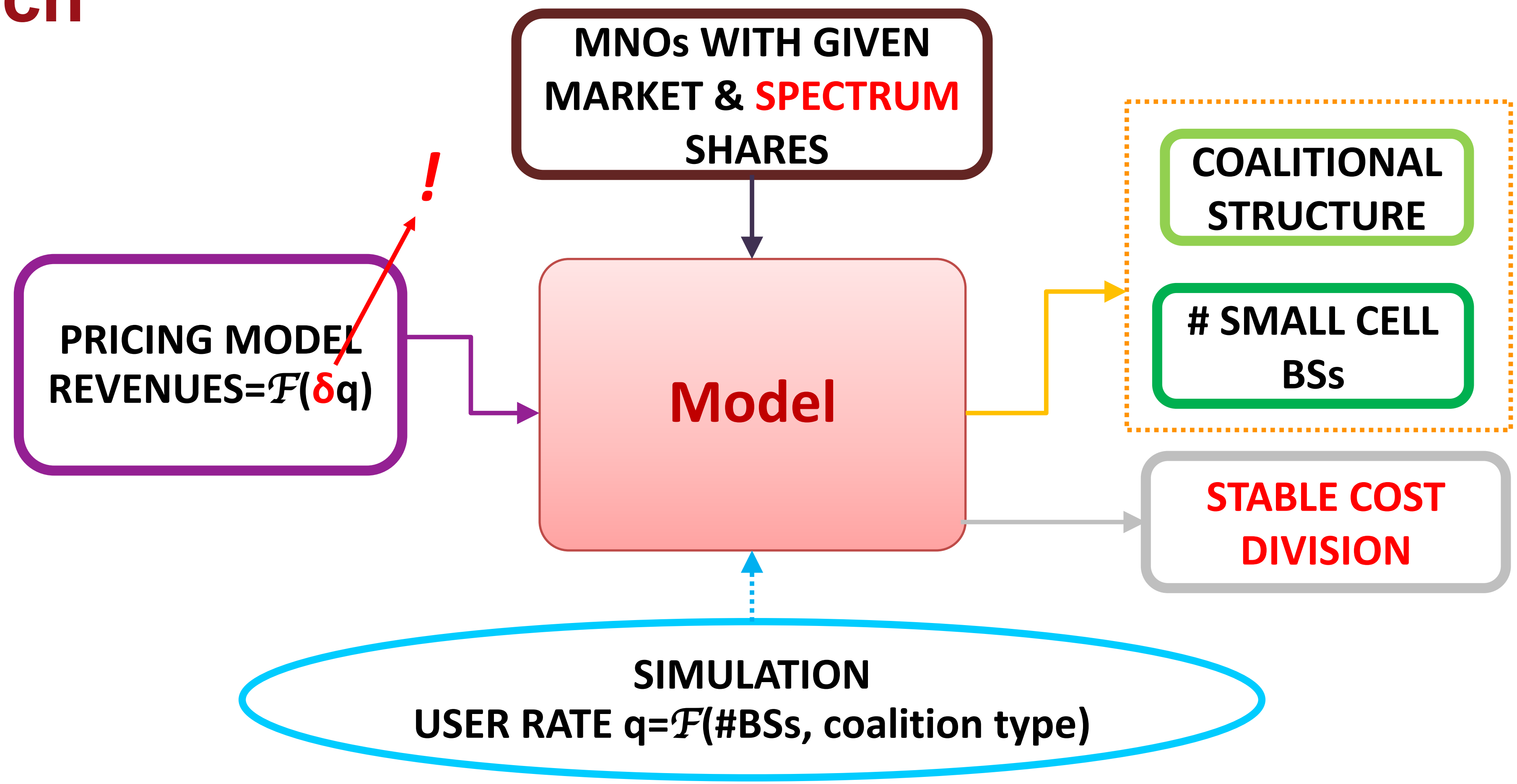
- **Focus**: Small cells deployment

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

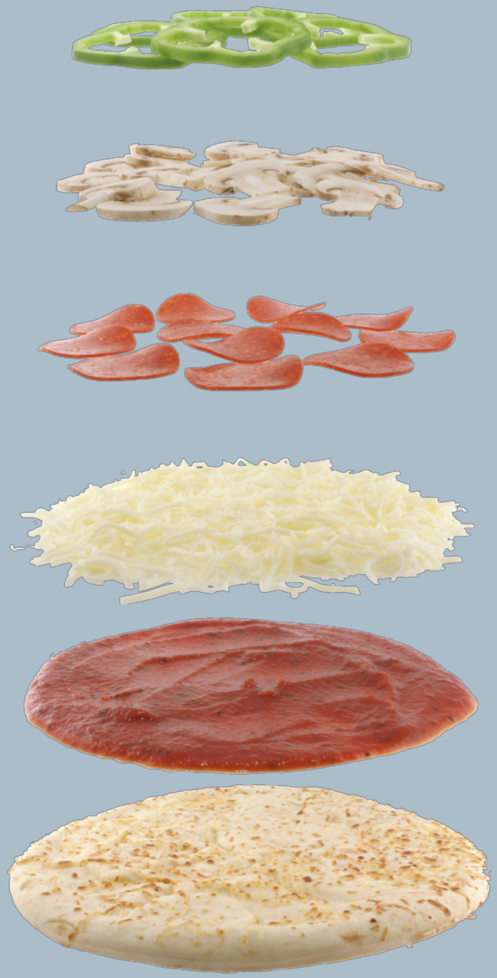


[TWC17] L.Cano, A.Capone, G.Carello, M.Cesana, M.Passacantando. On optimal infrastructure sharing strategies in Mobile Radio Networks. IEEE Transactions on Wireless Communications,16(5):3003–3016, 2017.

[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.

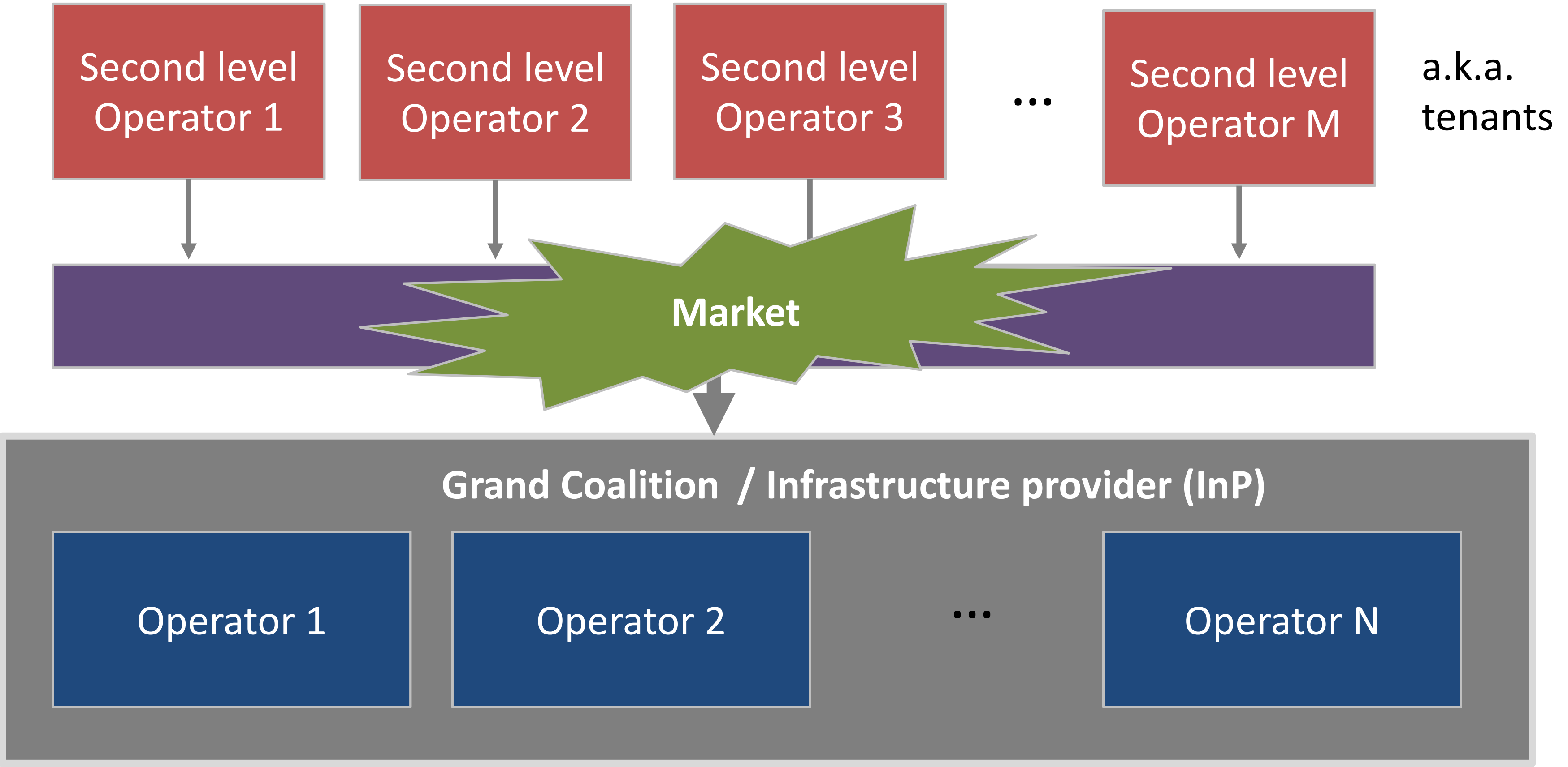
Model and key findings

- **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
  - <u>**Grand coalition fast becomes stable for vast majority of instances**</u> (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

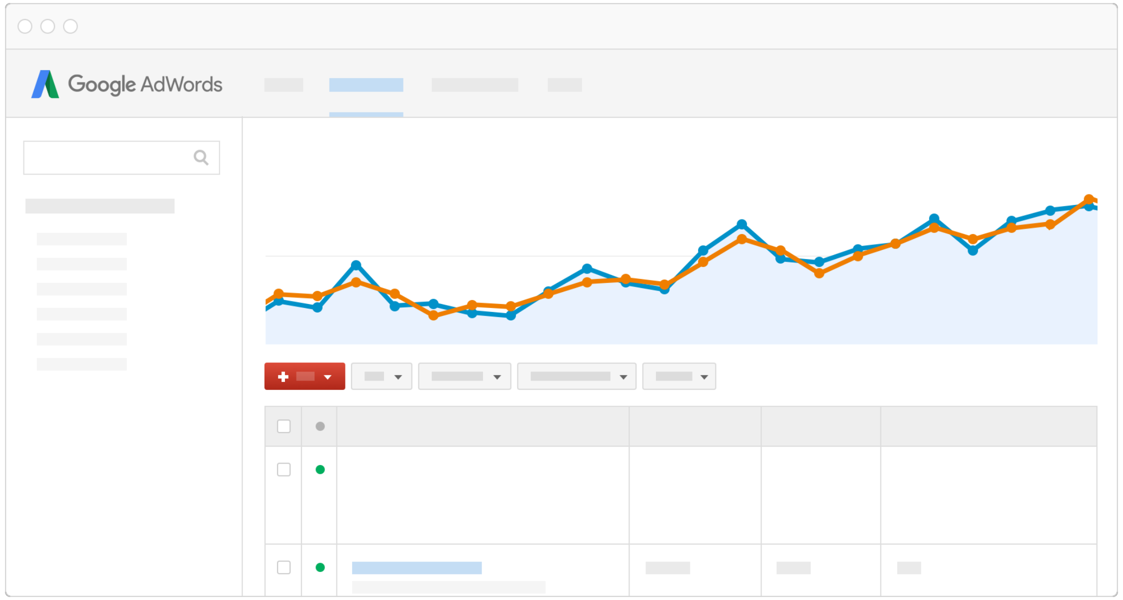


- Assuming no-competition among infrastructure providers (**InP**)

A market? … similarities

Energy market

Time granularity from days to minutes



Ads market

Time granularity from minutes to seconds

Assumptions

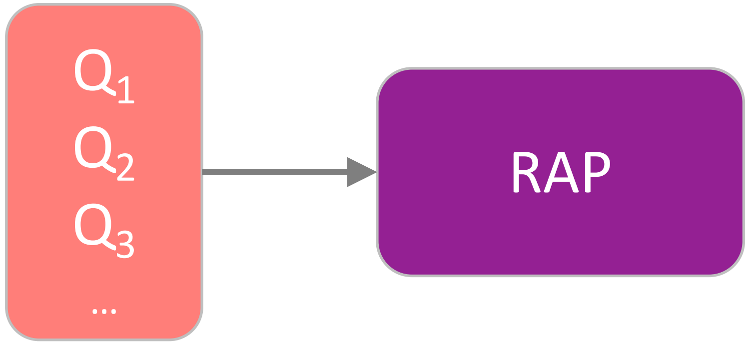
- The **InP behave *fairly*** in the resource allocation phase
- **Virtual Operators trade** the amount of **resources** according to their users' needs (estimation/prediction of traffic load, type, distribution, channel qualities, etc.)
- **Pricing** model ensures that the InP has **enough money** to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

[Globecom18] A. Lieto, I Malanchini, A. Capone, "Enabling Dynamic Resource Sharing for Slice Customization in 5G Networks", IEEE Globecom 2018, Abu Dhabi, UAE, 9-13 Dec. 2018

[WiOpt17] A. Lieto, I. Malanchini, V. Suryaprakash, A. Capone, "Making the Case for Dynamic Wireless Infrastructure Sharing: a Techno-Economic Game", WiOpt 2017 RAWNET workshop, Paris, May 15, 2017.

Resource allocation problem

- Given traffic estimation, virtual operators can set a quality target $\boldsymbol{Q_i}$ 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

Strategy 1 — Q_1, Q_2, Q_3, … → RAP

Strategy 2 — Q_1, Q_2, Q_3, … → RAP

… — … → …

Strategy K — Q_1, Q_2, Q_3, … → RAP

How to differentiate strategies ?

Costs and revenues !!!

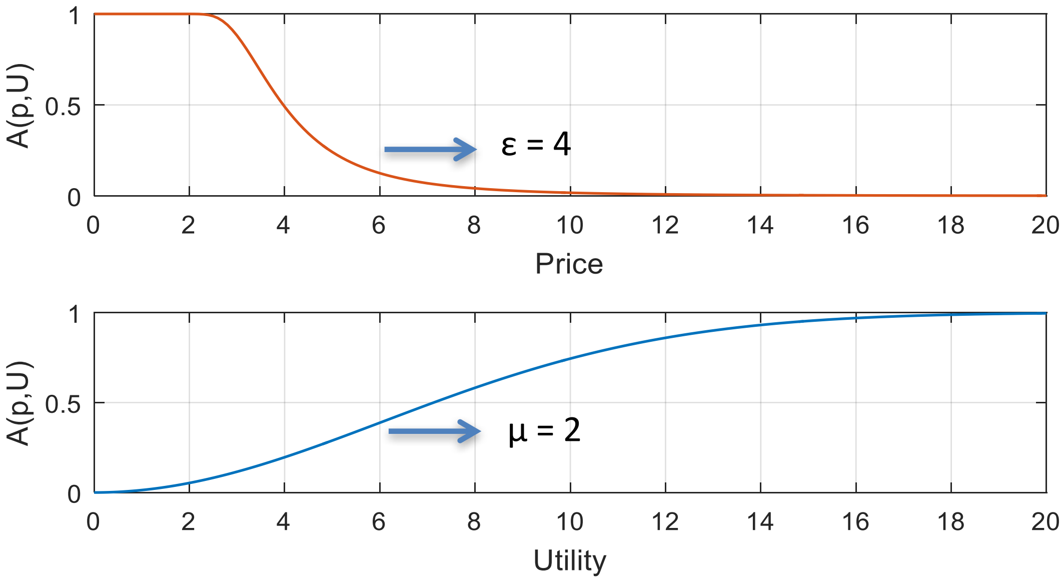
Costs and revenues

Capex + Opex + Pressure cost

To guarantee investments for capacity expansion

Revenues based on acceptance probability based on prince and quality [BLZZ03]

$$A(p,U) = 1 - e^{-Cp^{-\epsilon}U^{\mu}}$$



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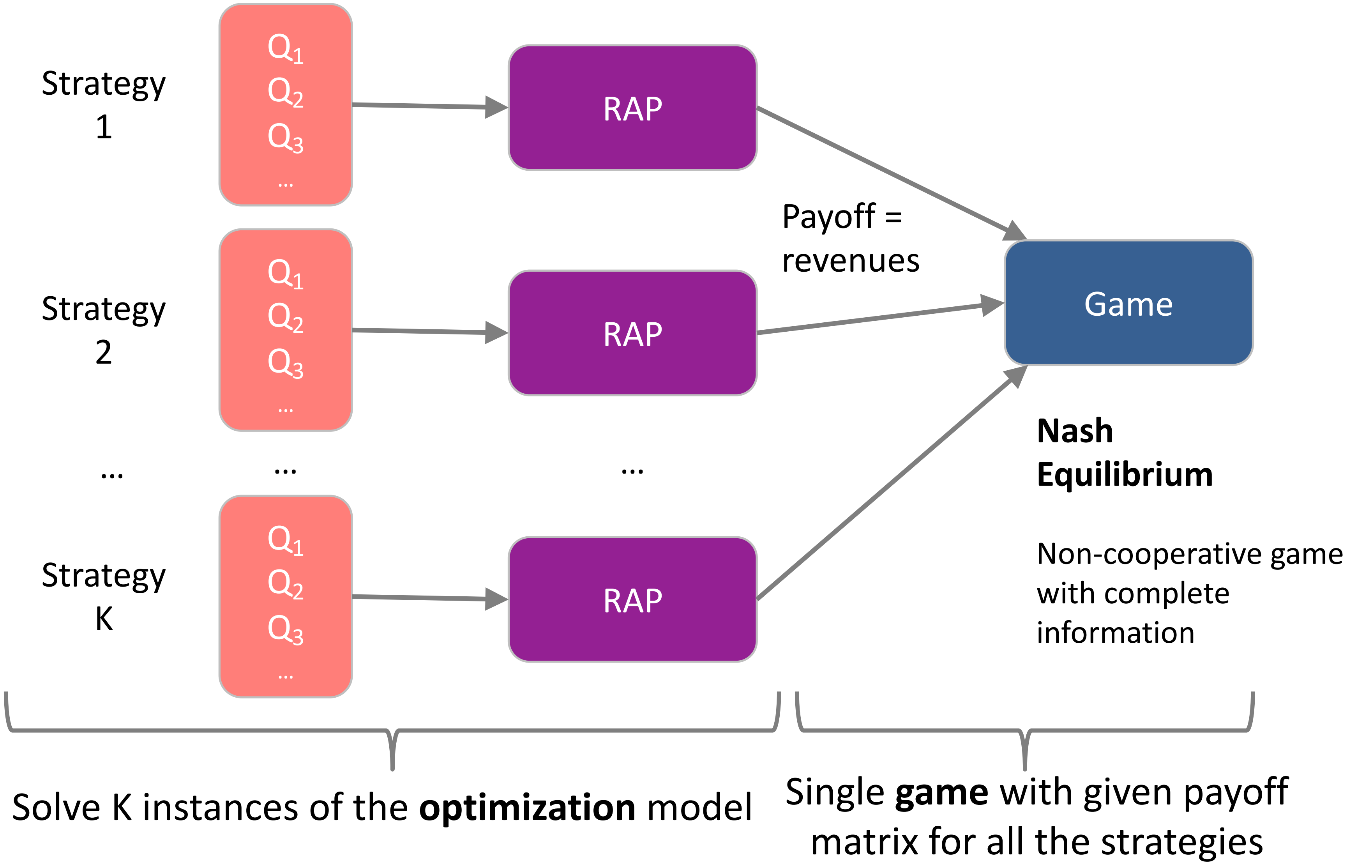
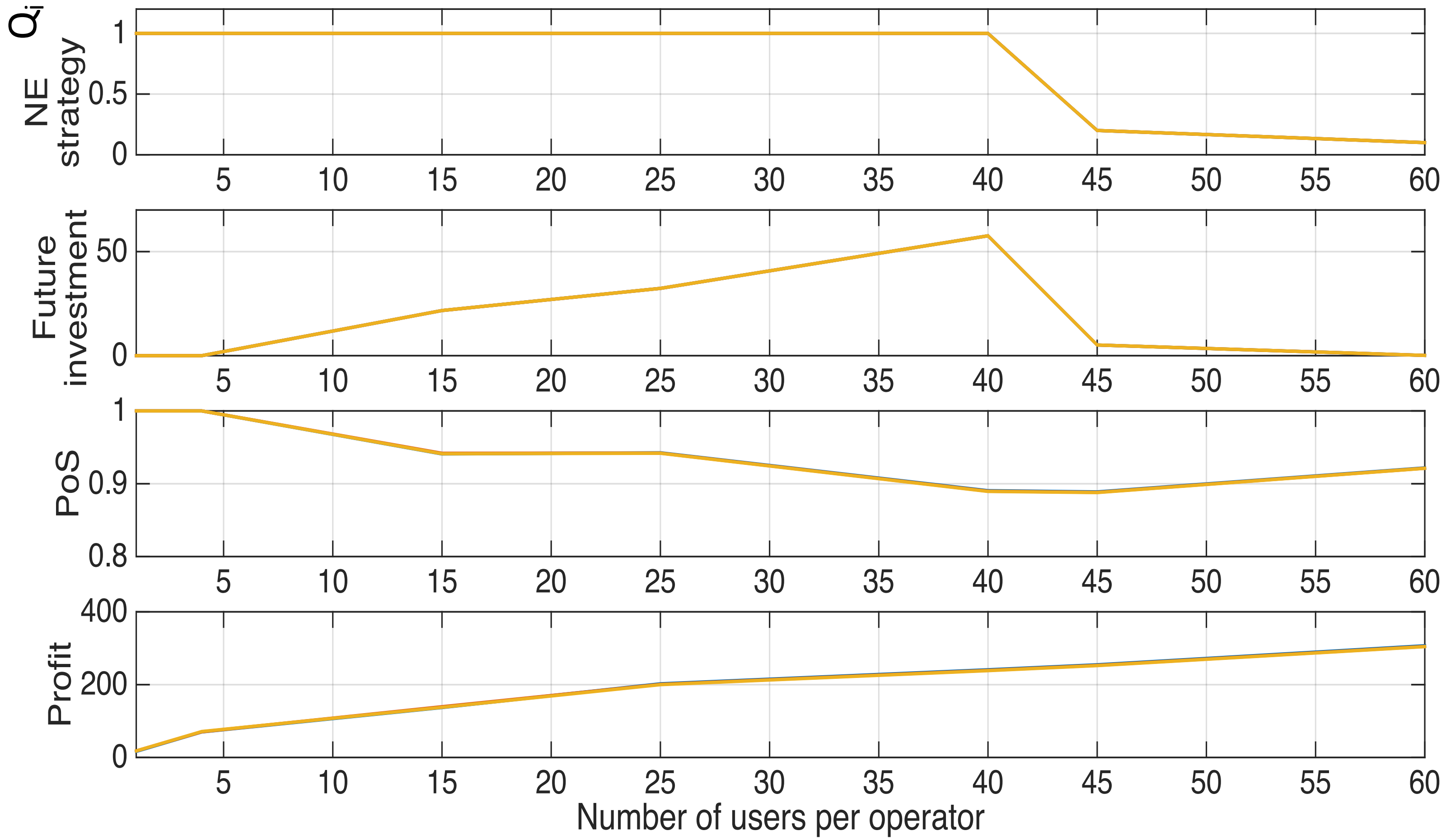
Market competition

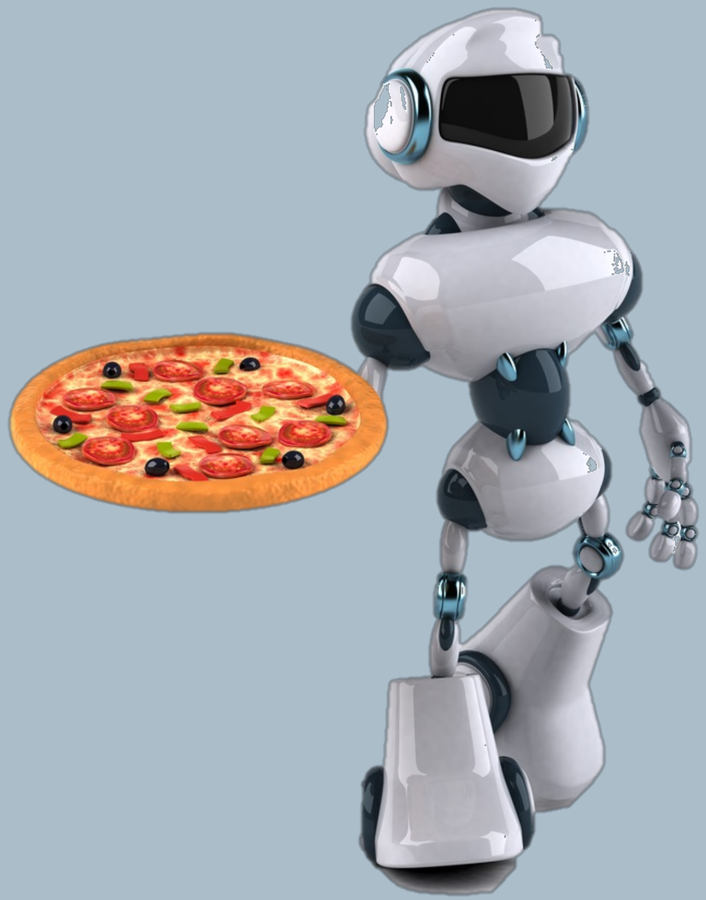


Example results



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

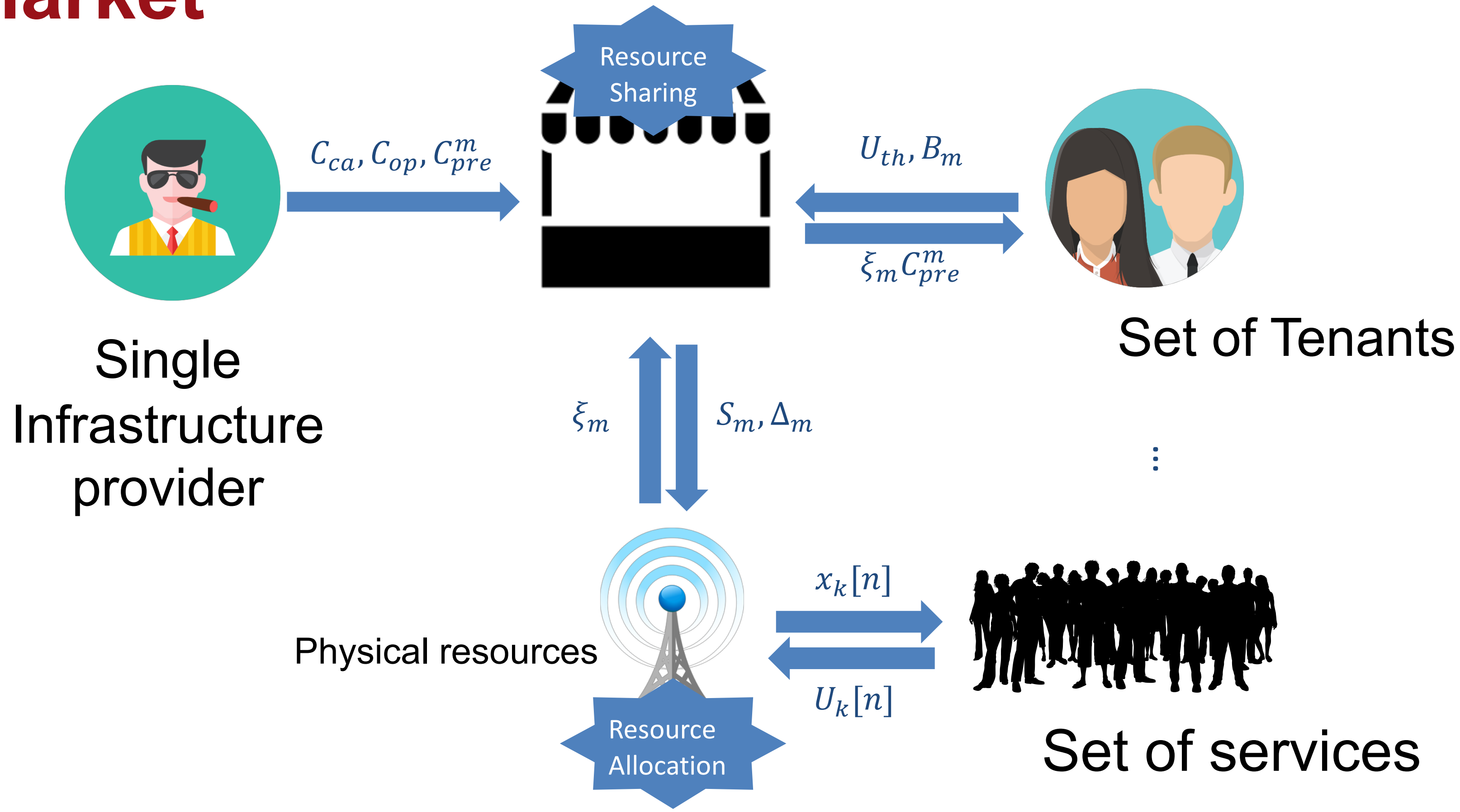


Can trading become automated?

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**)

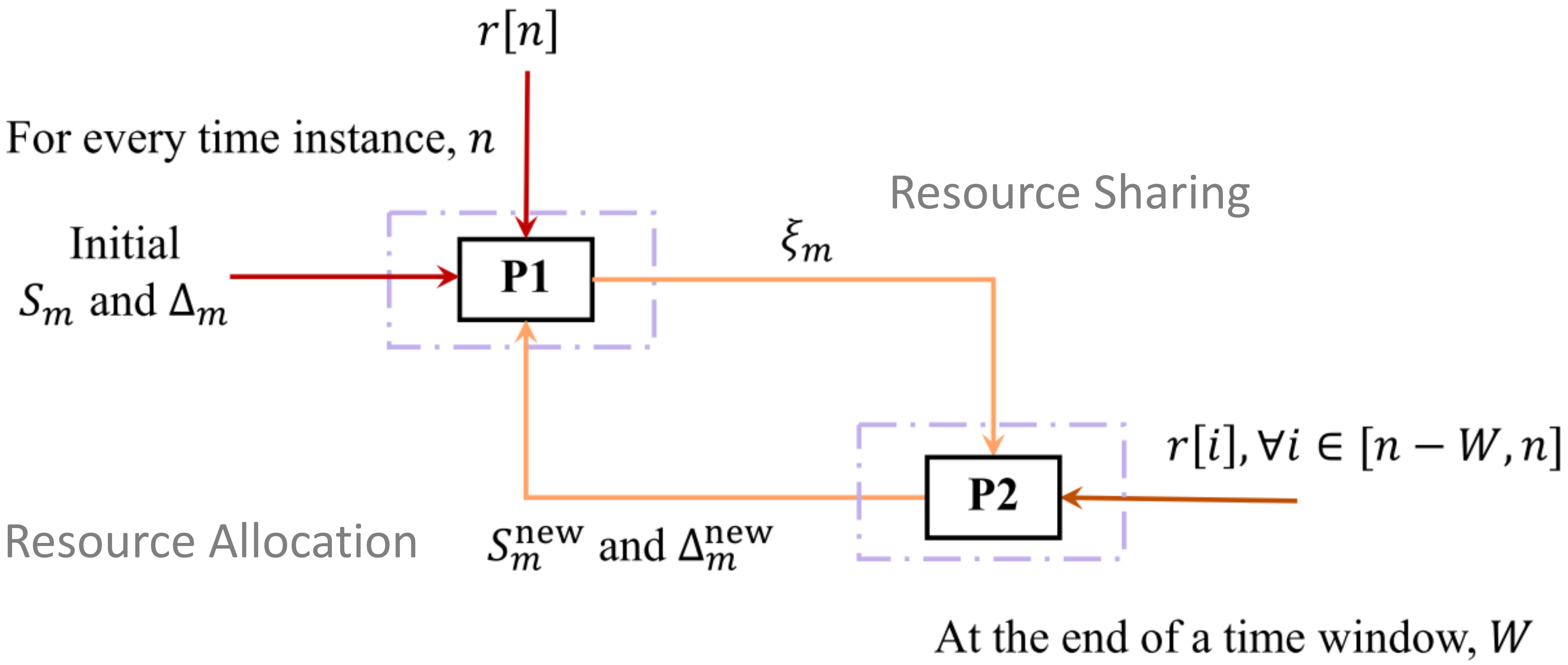
An automated market



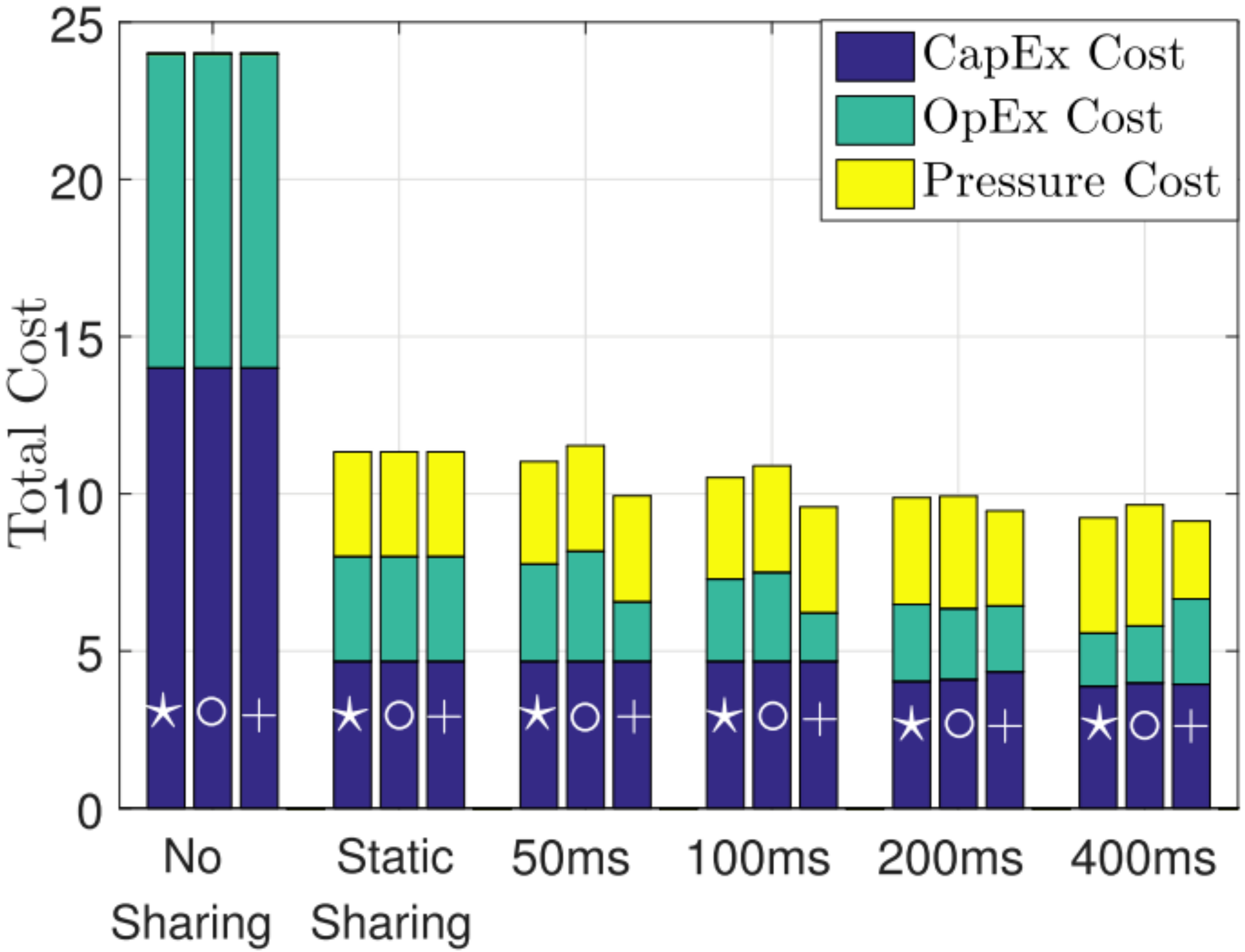
[ICC17] O.U. Akgul, I. Malanchini, V. Suryaprakash, A. Capone, "Dynamic Resource Allocation and Pricing for Shared Radio Access Infrastructure", IEEE ICC 2017

[Globecom17] O.U. Akgul, I. Malanchini, V. Suryaprakash, A. Capone, "Service-aware Network Slice Trading in a Shared Multi-tenant Infrastructure", IEEE Globecom 2017

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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