



Aalto University

# Evaluating the Economic Impact of Cognitive Radio with a Three-player Oligopoly model

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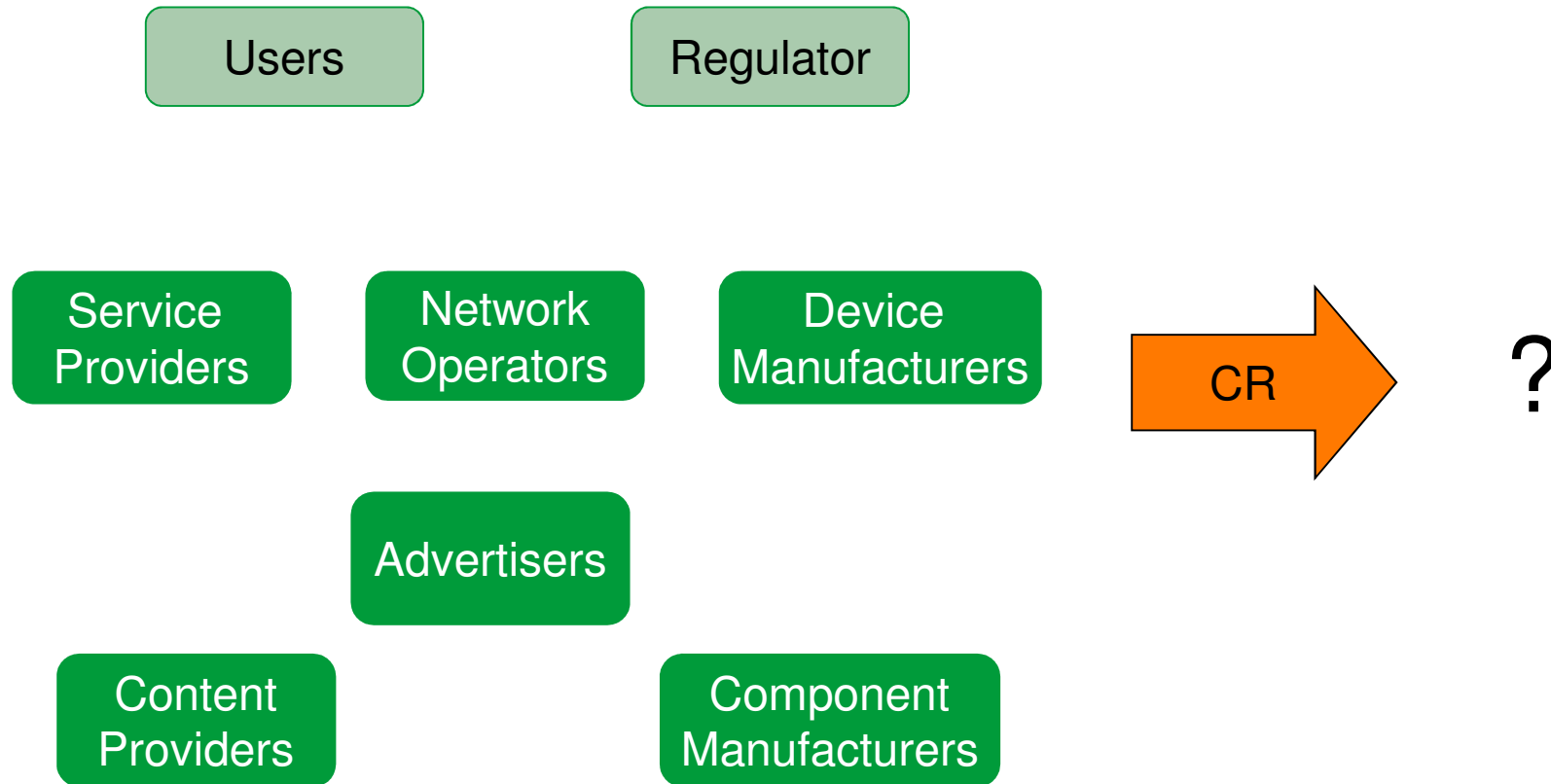
# Background

- Expertise in operations research and math. modeling
- Co-authors: Arttu Klemettilä, Mikko A. Uusitalo (NRC) and Carl Wijting (NRC)
- CR project with Nokia Research Center
- **Research question:**
- How does CR influence mobile communications?

# How does CR change the markets?

- Define the scope and research questions
  - Create model or game
  - Identify key players and their relations
  - What are the players' actions or decisions?
  - What are the payoffs or utilities?
- 
- How does Cognitive Radio change all this?

# Players and their roles



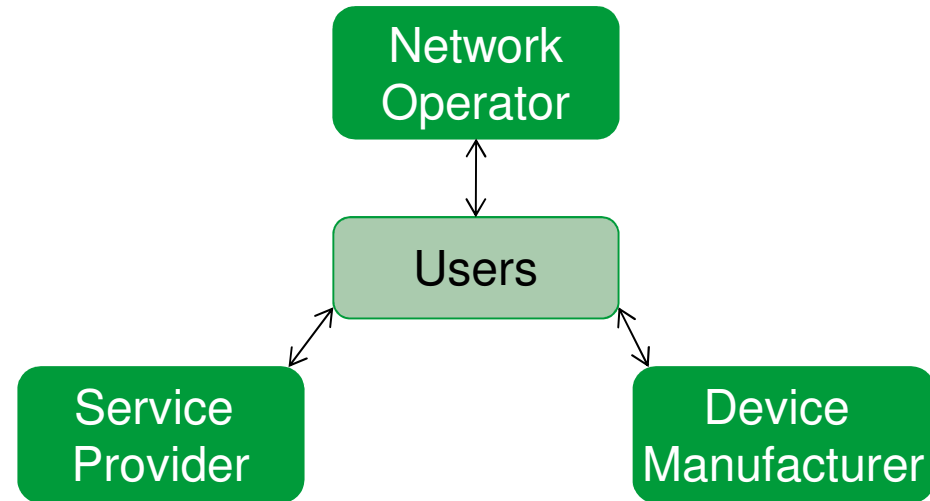
# How does CR change the markets?

- Regulatory change
  - new market mechanism and spectrum access rules
  - roles and their importance may change
  - emergence of new roles and players
- Technological change
  - change of consumer behavior, utilities and costs
  - new services vs. improving old services
  - improve connections and capacity
- How will CR even be implemented?

# Three-player model

- Oligopoly model
- One per business sector
- Set price to maximize profit
- Prices influence demands through elasticities

➔ Nash equilibrium



Demand :

$$D_1 = D_{1,0} - E_{1,1} \cdot p_1 - E_{1,2} \cdot p_2 - E_{1,3} \cdot p_3$$

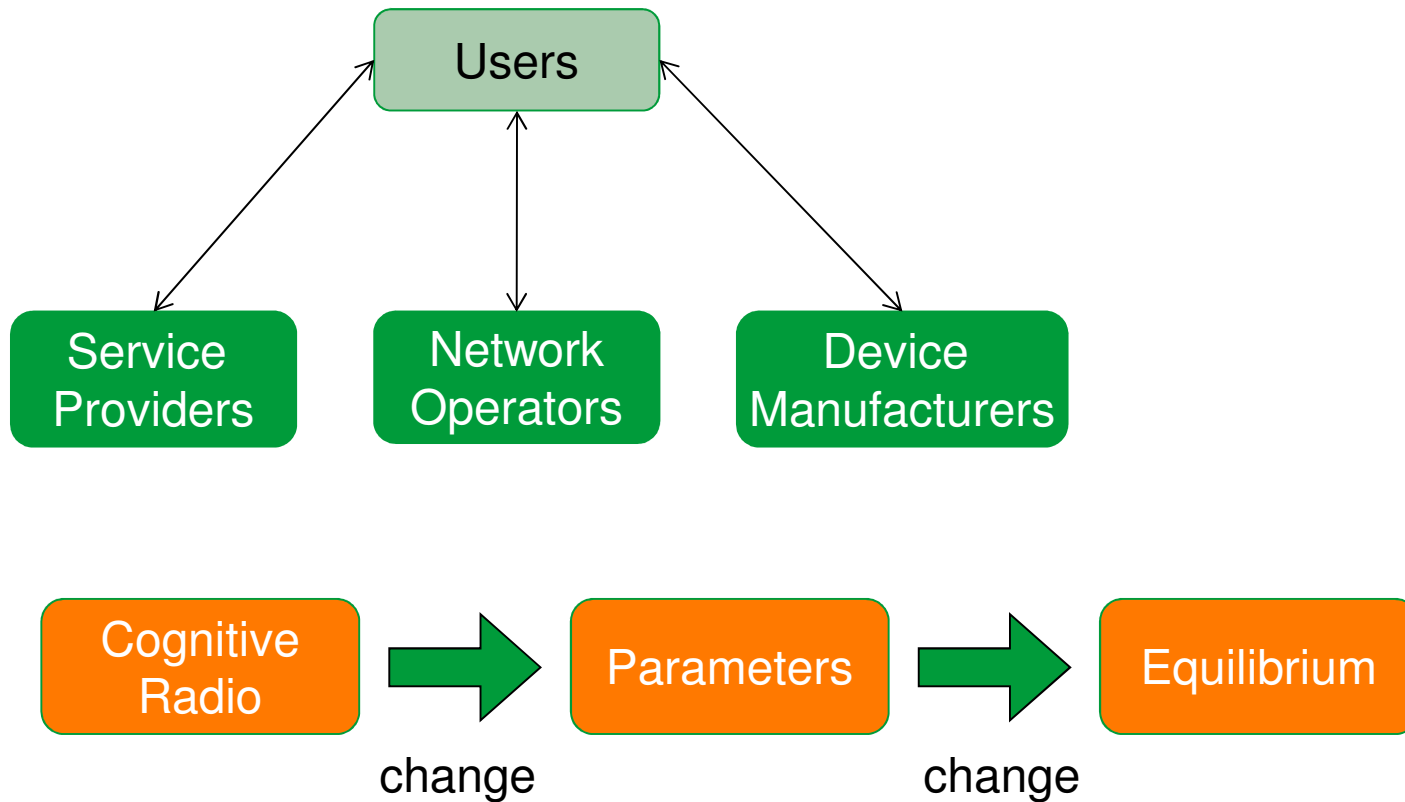
Profit:

$$U = (p_1 - c_1) \cdot D_1$$

Elasticity :

$$E_{i,j} = \hat{E}_{i,j} \cdot D_{i,0} / p_{j,0}$$

# Evaluating the impact of cognitive radio



# How does CR change the parameters? Parameter Estimation Network:

## Implementations

- Database
- CCR
- Mesh
- ?
  
- The alternative methods to make CR possible

## Effects from CR

- Higher datarate
- Longer Range
- More Capacity
- Local information
- ...
  
- Database costs
- Device costs
- Complexity
- ...
  
- Immediate effects of CR
- Determine the effect on the parameters

## Related Services

- Data intensive Internet access
- Popular services
- Advertisement based
- Voice calls
- New types of service?
- ...
  
- Different types of services that benefit from CR
- Relative size helps determine intensity of change

( This graph is just an example )



# Basic scenarios

Even growth	Fast device replacement	Free Services	Service explosion
+10/+10/+10	+20/+10/+10	+10/+20/+10	+10/+10/+20

- Four scenarios to validate the model and study the basic properties
- Numbers represent growth factors for Device / Network / Services

# What can we study with the model?

- What are the benefits of cognitive radio?
- Effect of limited spectrum?
- Different types of demand parameter changes
- Effect of competition
- Possible coalitions

# Some general results

- Growth in one demand affects the markets differently
- Timing in coalitions important

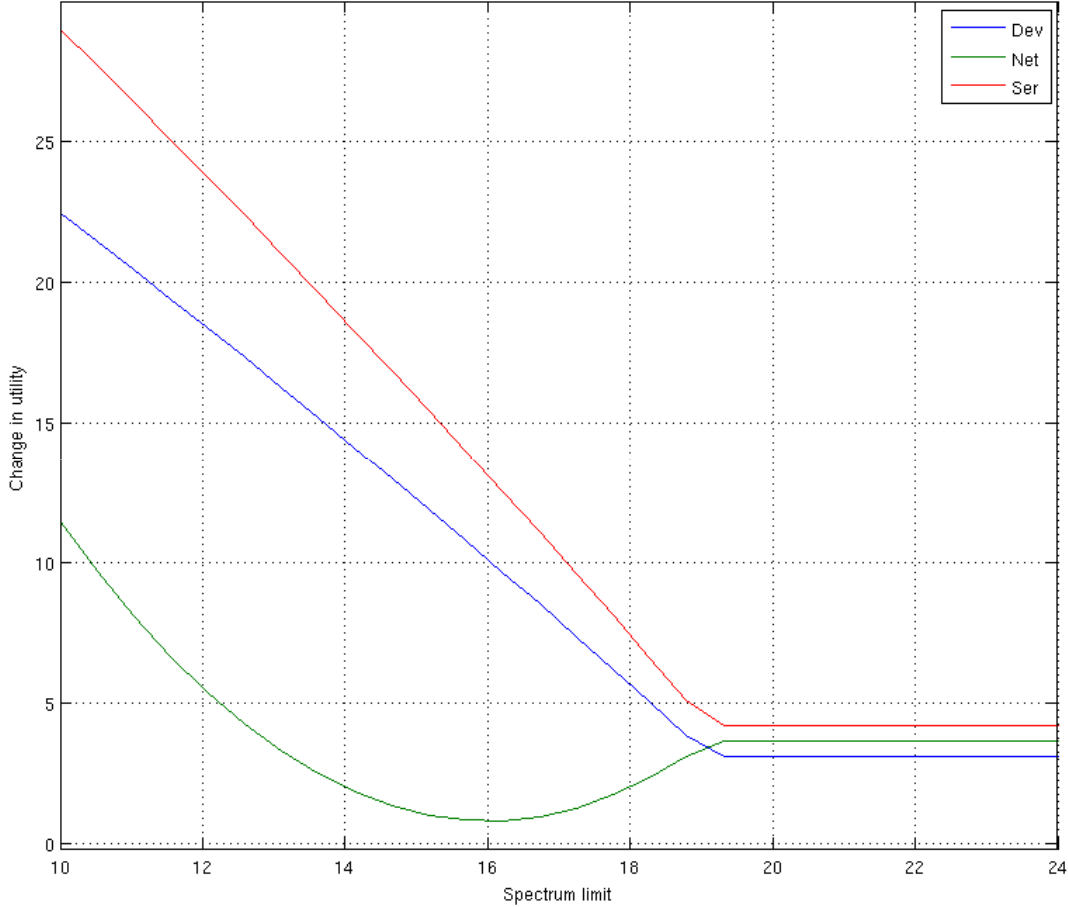
Scenario 2: Fast device replacement

	Price	Demand	Profit
Device	+2.4 %	+14.2 %	+18.6 %
Network	-0.3 %	+4.3 %	+3.6 %
Service	+0.4 %	+6.3 %	+7.6 %

CHANGES IN PROFITS WITH DIFFERENT DEVICE DEMAND GROWTHS

Pop./trendy growth	20 / 0	15 / 5	10 / 10	5 / 15	0 / 20
Device	15.5 %	17.2 %	18.6 %	19.6 %	20.1 %
Network	9.0 %	6.3 %	3.6 %	1.0 %	-1.7 %
Service	8.9 %	8.2 %	7.6 %	6.9 %	6.2 %

# Impact of limited spectrum



# Conclusions

- CR will benefit all players with the estimated demand and cost changes
- Significant benefits may come to parties that are not directly influenced
- What are the good business models to share these benefits between the firms?

# Thank you!

- Any questions or comments?