Market Structures for Efficient Spectrum Sharing

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Research Motivation

- Much work on design of spectrum markets

  - e.g. auction design.

- Instead focus here is on the broader impact of different market structures and spectrum sharing technologies.

  - e.g. incentives to invest, competition with existing providers.

Two Initial Examples

- Competition with open spectrum.

- Investment and sharing among licensed providers.

Open Spectrum

- Great success in supporting WiFi services.
  - Operates at higher frequencies, relatively short propagation distances.
- Interest in having open spectrum at lower frequencies
  - e.g. TV white spaces.
  - Can support much longer propagation distances

- Our focus: open spectrum that can offer competitive service to licensed providers.
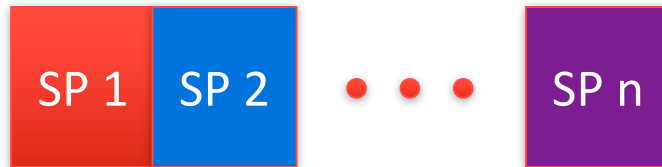
Openness

- **The good:** lower barriers to entry, increased competition

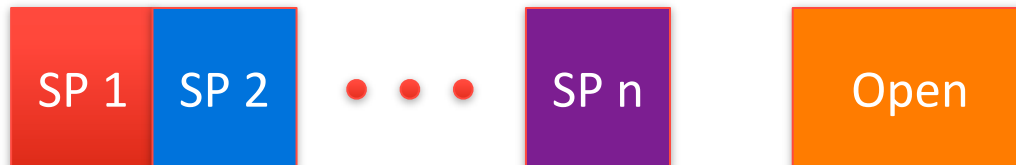- **The bad:** risk of excessive interference, "tragedy of the commons"

Approach
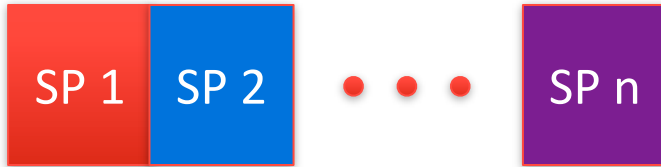
SP 1 | SP 2 • • • SP n

Approach

SP 1   SP 2   • • •   SP n

- Consider a set of service providers (SPs).
  - *Incumbent SPs* have exclusive licensed bands
  - *Entrant SPs* have no licensed bands

Approach

| SP 1 | SP 2 | ● ● ● | SP n | Open |

- Consider a set of service providers (SPs).
  - *Incumbent SPs* have exclusive licensed bands
  - *Entrant SPs* have no licensed bands

- Study the effect on total welfare from adding open spectrum.
  - All incumbents and new entrants can use the open band.

Model

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- Customers choose provider based on *delivered price = price + congestion cost.*
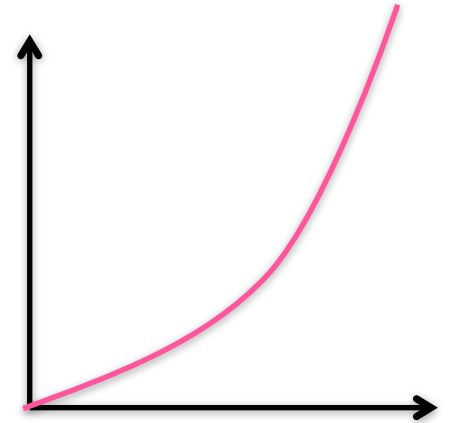
Congestion Externalities
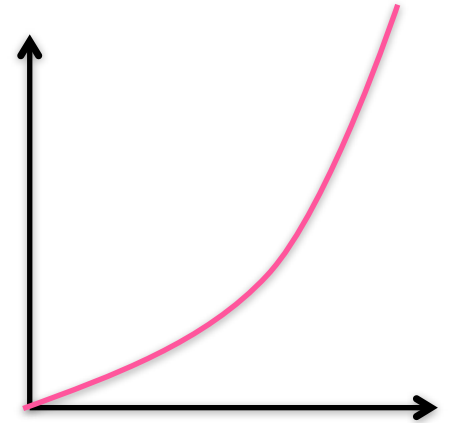
Congestion Externalities

- All customers in ith licensed band experience *congestion cost* of $l_i(x_i)$.
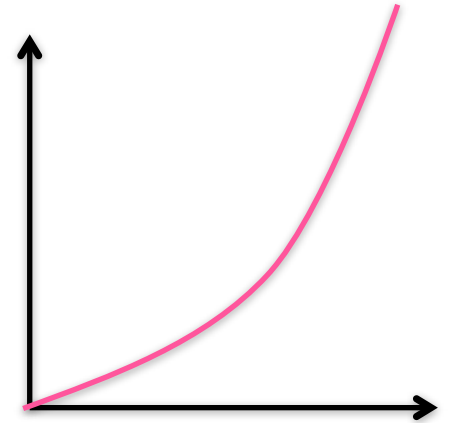
  – Increasing, convex.

Congestion Externalities

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  – Increasing, convex.

- Customers in unlicensed band experience congestion cost $g(X^w)$

  - $X^w = \sum_i x_i^w$ (*total* number of unlicensed users)
  - Also increasing, convex.

Results

- Prices in open spectrum go to zero.
- Adding an insufficient amount of open spectrum can result in overall economic welfare *decreasing*.
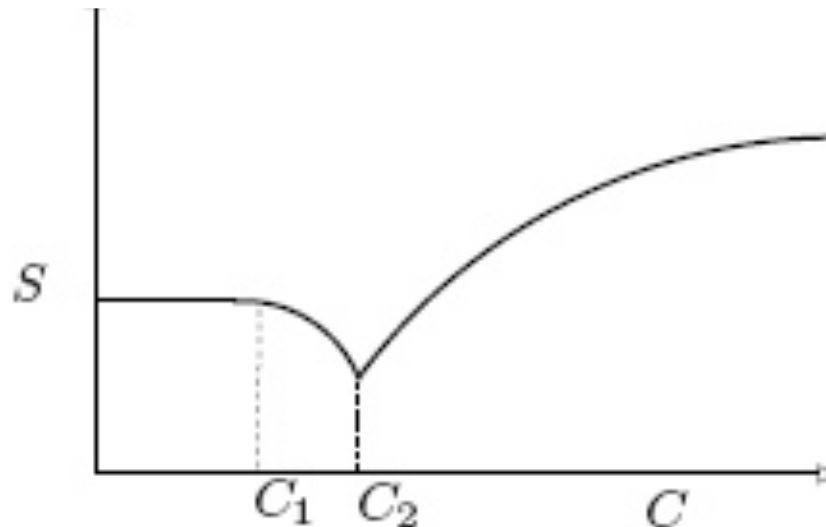
Extensions

- Multiple users classes
  - consumer welfare can decrease do to "sorting" of users.

- Adding investment.
  - may see only a single monopolist arise
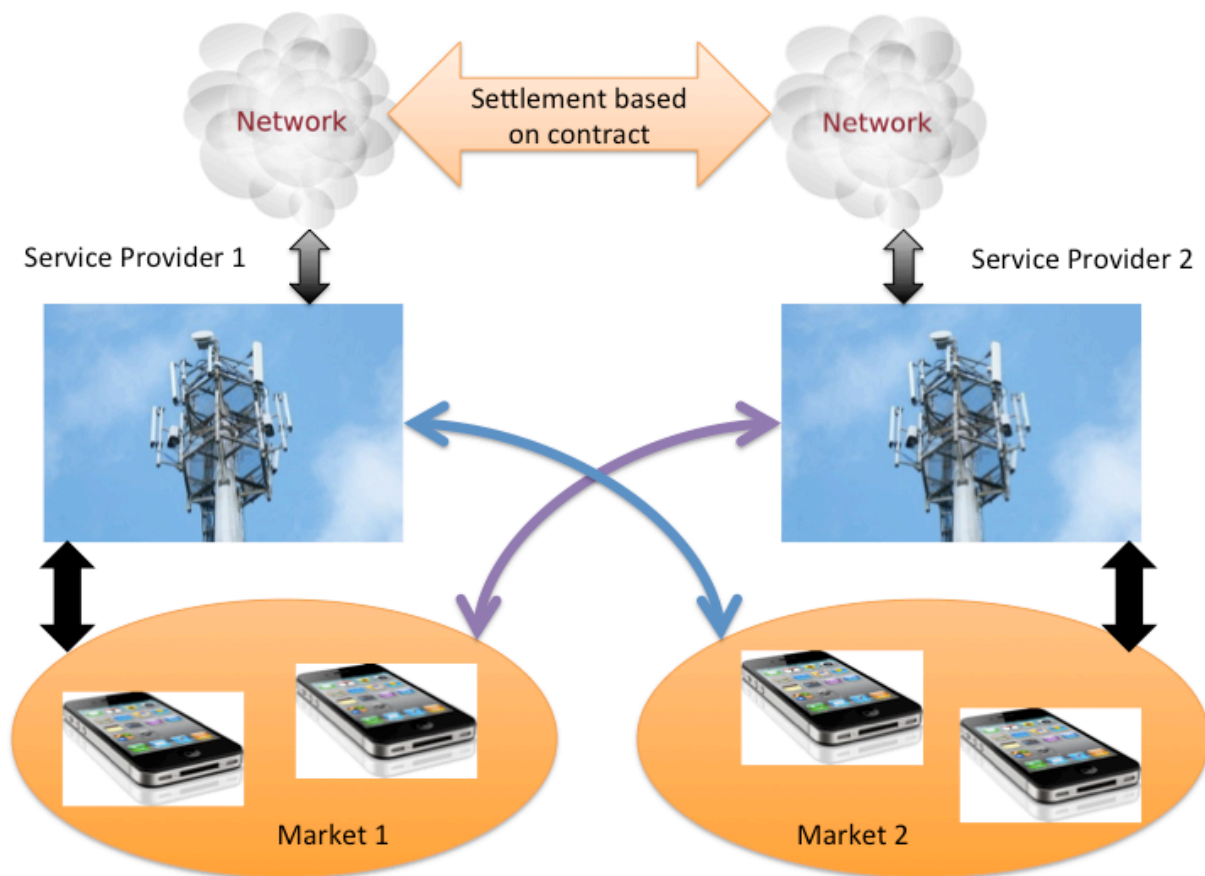
Capacity Sharing

- Currently wireless providers share capacity via roaming agreements.

  - Main motivation is to increase coverage.

  - Also various forms of tower/infrastructure sharing.

- Here consider more extensive capacity sharing for meeting variable demand during times of congestion.

- **Main question:** how does sharing influence providers investment decisions?

Problem Set-up
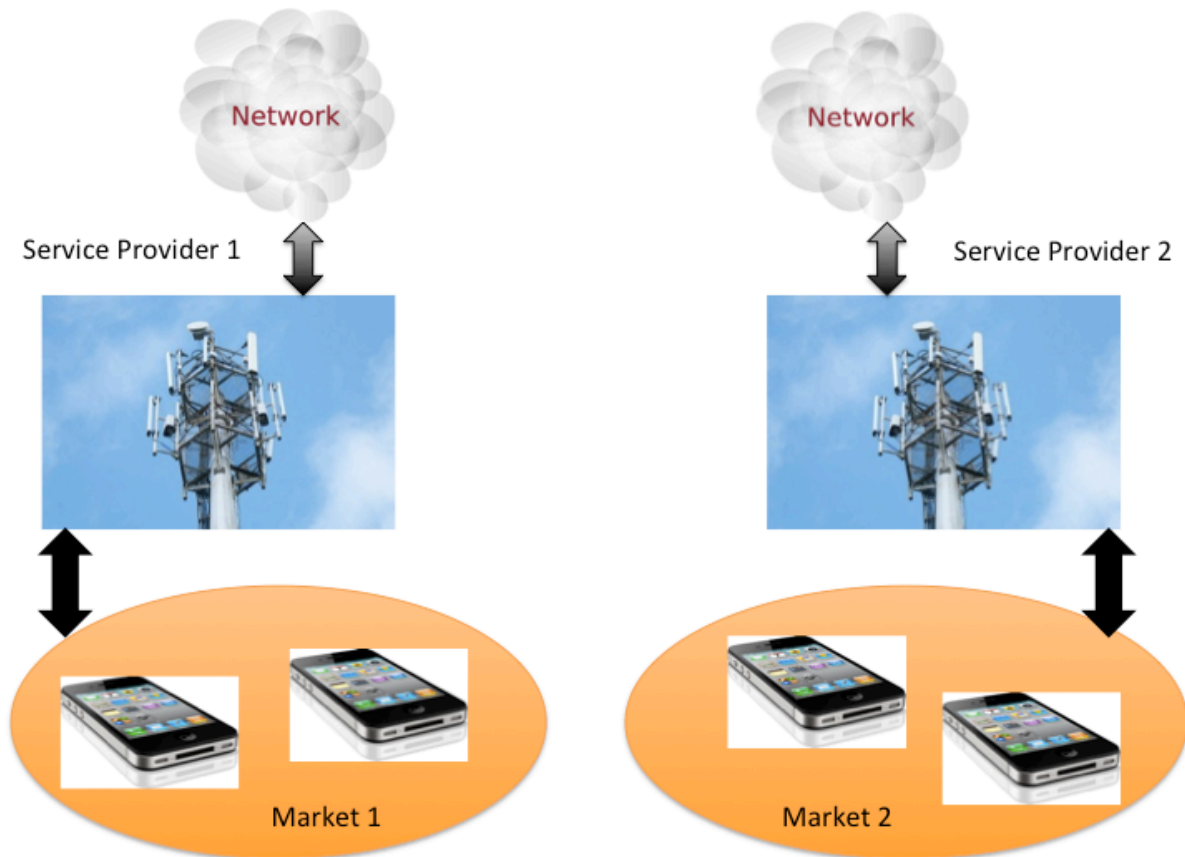
- Two Service providers

- Each with own pool of customers (fixed).

- Demand is variable.

- Fixed payment for each customer served.

- Without sharing: demand > capacity => revenue lost.

Sharing Scenario

- Allow Sharing at times of congestion
- Providers share revenue
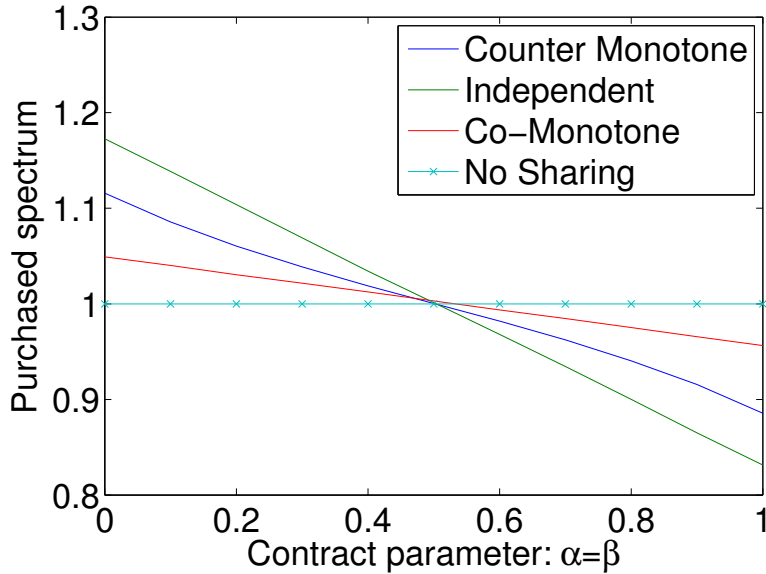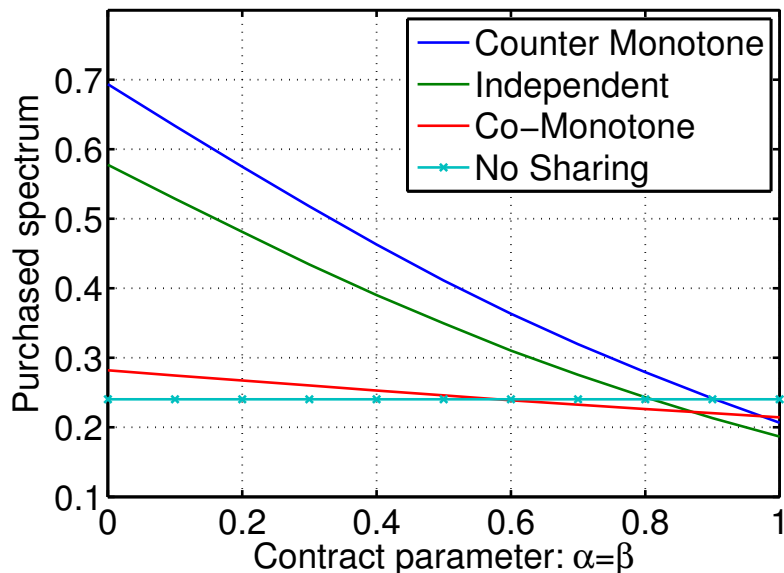- Customers see no extra cost.

Approach

Mobile News Stand

- Adapt newsvendor model to model capacity procurement in face of uncertain demand.

- Newsvendor model applies to single firm.

- With sharing, firms capacity choices become coupled.

- Model this as a game.

Results

uniform demand

Weibull demand

- Can characterize the equilibria of sharing game under different demand distributions and sharing rules.

- More profit from sharing going to spectrum owner encourages greater investment

- More investment with less positive correlation in demands.

Conclusion

- Some simple models to shed light on how different approaches to spectrum sharing can impact overall welfare and investment incentives.

- often in counter-intuitive ways!

- Models can be enriched in many ways from both an economic and wireless networking perspective.