

Optimal Contract Design for Dynamic Sharing of Infrastructure and Spectrum

Zongyun Xie, zongyun.xie@northwestern.edu
Randall A. Berry, rberry@northwestern.edu

Northwestern
McCORMICK SCHOOL
OF ENGINEERING

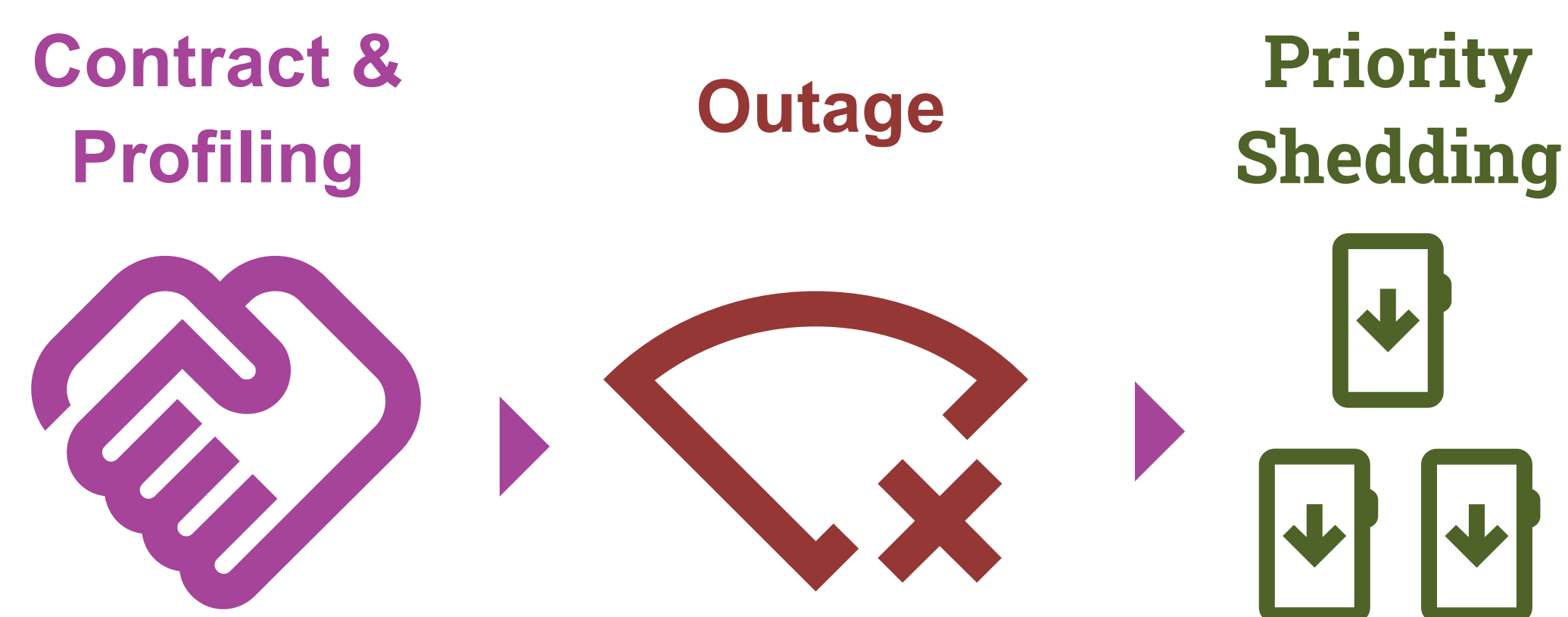
BACKGROUND

- Sharing infrastructure and spectrum (e.g., MOCN, O-RAN) significantly reduces deployment costs for wireless operators.
- However, when **spectrum is intermittently available** (e.g., incumbent activity in CBRS), an Infrastructure Network Provider (INP) must **shed traffic during outages**.
- We focus on optimal traffic-shedding contracts for **risk-averse Service Providers (SPs)**.

RESEARCH QUESTIONS

We employ contract theory to design optimal shedding policies. We want to address:

- What constitutes the **optimal shedding allocation** for risk-averse SPs?
- How does an SP's risk aversion and traffic volume impact this policy?
- How do market outcomes shift under **vertical integration** (when the INP owns an SP)?



The INP offers a menu of contracts, SPs select their preferred options, assuming **complete information**.

An incumbent user (e.g., Navy radar in CBRS) suddenly claims the band. The network's available capacity drops from K to L .

The INP executes the optimal contract.

METHODS AND MATERIALS

We consider a monopolist INP and N SPs. Each SP is characterized by a traffic demand $k_i > 0$ and a risk aversion parameter $\gamma_i \in (0,1)$.

- Network State:** Capacity is nominally K but drops to $L < K$ during a spectrum outage (probability ϵ).
- The Contract:** The INP offers (p_i, c_i, x_i) , representing the price, compensation, and fraction of traffic shed during an outage.
- Optimization:** Assuming CARA utility:

$$U_i(W_i) = 1 - e^{-\gamma_i W_i}.$$

The INP minimizes the Social Cost, which is the sum of the SP's risk burden and the INP's expected compensation payout.

RESULTS

Theorem 1: Optimal Shedding Policy

Given optimal compensation, the shedding fraction for any unsaturated SP scales inversely with the product of risk aversion and traffic volume:

$$x_i^* \propto \frac{1}{\gamma_i k_i}.$$

Key Insight

Larger or more risk-averse SPs shed a proportionally smaller fraction of their traffic, effectively realizing classical syndicate risk-sharing in wireless networks [1].

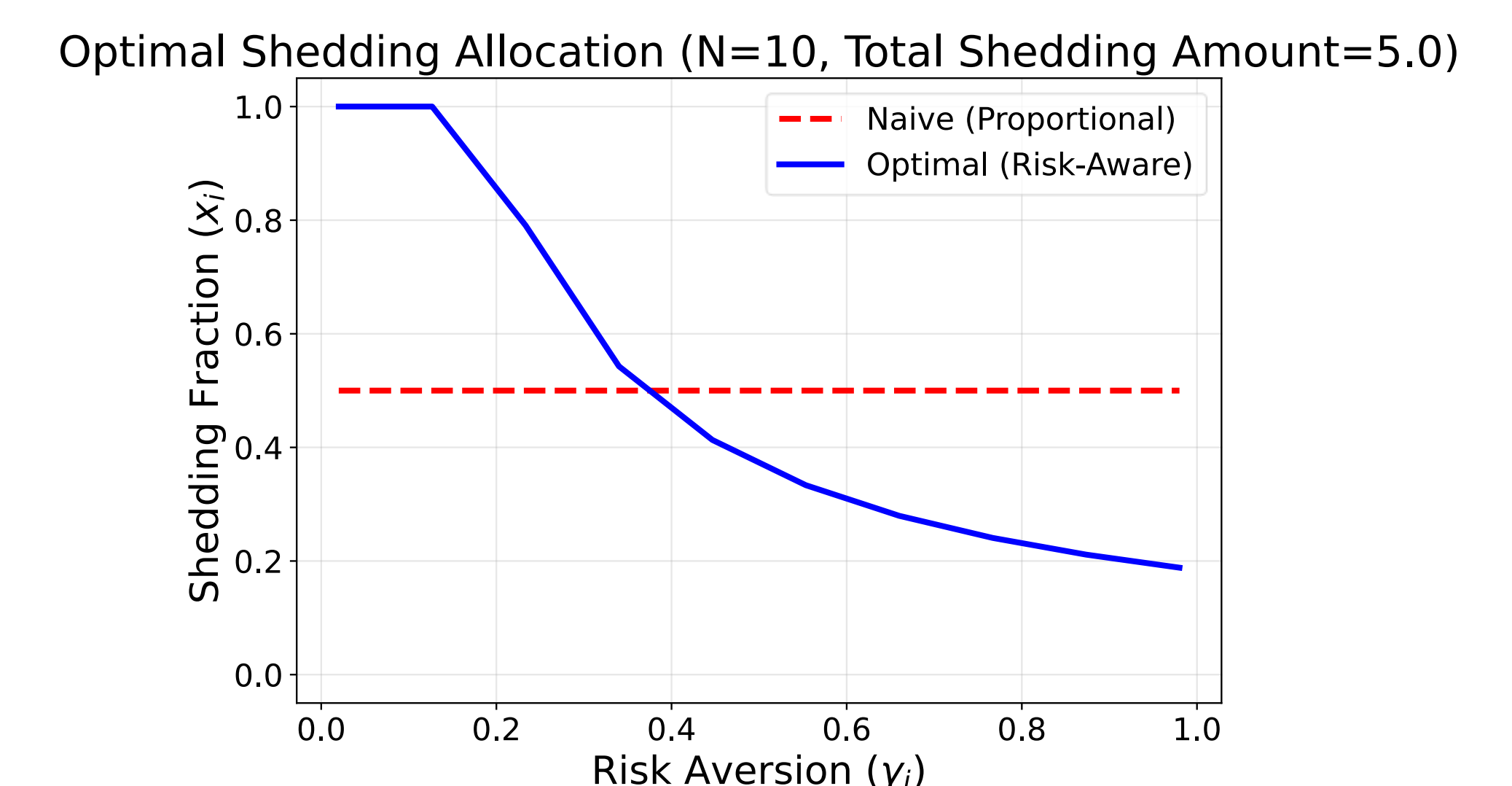
Theorem 2: Vertical Integration

If the INP owns one SP (SP_0) and internal transfers have lower transaction friction than external ones ($\theta_{\text{int}} < \theta_{\text{ext}}$), a capacity threshold M_{rev} dictates priority.

Key Insight

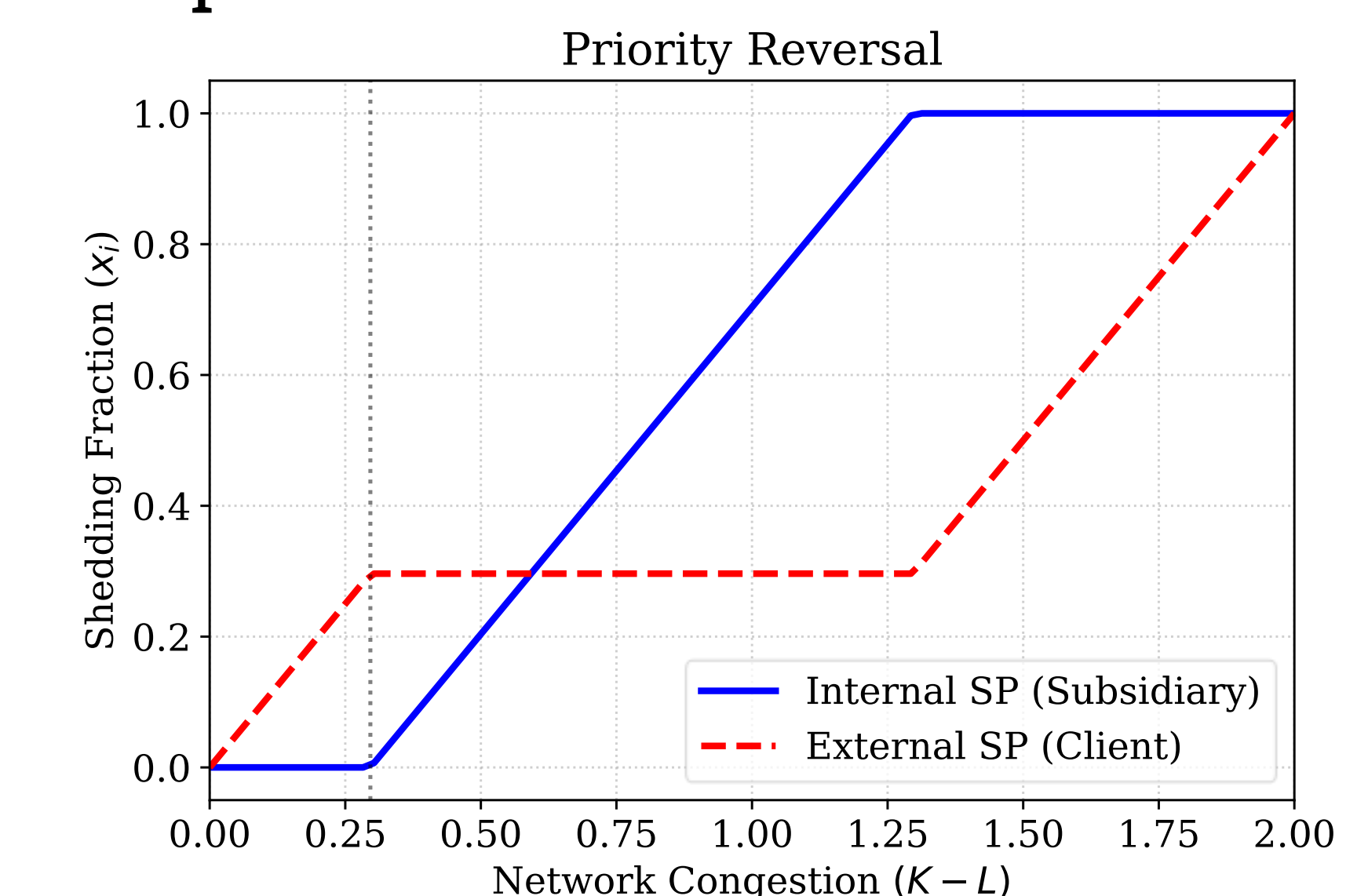
Priority Reversal: When the capacity shortfall $< M_{\text{rev}}$, the internal SP is fully protected. **When the shortfall $> M_{\text{rev}}$, the internal SP acts as a shock absorber** to protect high-value external contracts.

NUMERICAL RESULTS



Optimal Allocation (Fig. 1)

Risk-tolerant SPs (low γ_i) are saturated first, while risk-averse SPs are protected.



Priority Reversal (Fig. 2)

Simulating $N = 2$ confirms that but absorbs excess shock during severe crises. An internal subsidiary is protected during minor fluctuations

ACKNOWLEDGEMENTS

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REFERENCES

- [1] Wilson, R., "The Theory of Syndicates", Econometrica, 1968.
- [2] Berry, R., et al., "The value of sharing intermittent spectrum", Management Science, 2020.