Shared Versus Separate Networks
The Impact of Reprovisioning

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Overview

- Introduction & Motivation
- Model
- Solution Methodology
- Results
- Conclusions

Introduction

- Innovation creates new network services
- How are these services to be deployed?
- Key Questions:

  (1) What is the correct choice of Infrastructure?
  - Combine services onto a single shared network?
  - Create dedicated networks for each service?

  (2) Which economic factors influence the choice and how?

Motivation Examples

- IT & Facilities Management services
  - *e.g.* Internet & HVAC systems
- Video and Data services
  - *e.g.* Internet & IPTV services
- Broadband over Powerlines

Solution Options

- Shared Network Solution
  - Pros:
    - Possible economies of scope in fixed and variable cost components
  - Cons:
    - Cost of 'upgrading' network features to accommodate services with disparate requirements
    - Increases operational and troubleshooting complexity
- Separate Network Solution
  - Pros:
    - Easier operation saves costs
  - Cons:
    - Higher costs of creating dedicated networks
- One option: Compare Infrastructure choices based on optimal profit

Technical Considerations

- New services have demand *uncertainty*
  - Over-provisioning is expensive (unused resources)
  - Under-provisioning is costly too, but
    - Dynamic resource "*reprovisioning*" is becoming feasible
    - But some penalty may be incurred

Model

- A Two-Service Model is developed
  - Service 1 (existing service) & Service 2 (new service with uncertain demand)
- Need to choose infrastructure that gives maximum profit, given the demand uncertainty
- Provider's profit depends on:
  - Service Fees: p_1, p_2 (fixed & exogenous)
  - Realized Demand
  - Costs:
    - that are incurred irrespective of how many users join (provisioning, operational, fixed costs)
    - that depend on the actual number of users supported (access equipment, billing)

Model Parameters

- Service 2 revenue:
  - Revenue when $D_2 < K_2$:

Cost varying with realized demand

Cost varying with provisioned resources

Fixed costs

$$R_2(D_2 < K_2) = (p_2 - v_2)D_2 - a_2K_2 - c_2$$

Cost Component	Service 1 separate	Service 2 separate	Shared
Service Fees	p_1	p_2	p_1, p_2
Fixed Costs	c_1	c_2	c_s
Variable Costs (incurred for each unit of realized demand)	v_1	v_2	v_{s1}, v_{s2}
Variable Costs (incurred irrespective of realized demand)	a_1	a_2	a_{s1}, a_{s2}

Model: Separate Networks

- Service 2 Revenue when $D_2 > K_2$:
  - Reprovisioning Ability:
    - A fraction "α" of the excess demand can be accommodated

$$R_2(D_2 > K_2) = (p_2 - v_2 - a_2)(K_2 + \alpha(D_2 - K_2)) - c_2$$

- Expected Revenue, $\mathbf{E}(R_2|K_2)$, for a given provisioned level K_2:

$$\begin{aligned}\mathbf{E}(R_2|K_2) &= \int_0^{K_2} R_2(D_2 < K_2|K_2) f'_{D_2} d(D_2) \\ &+ \int_{K_2}^{D_2^{\max}} R_2(D_2 > K_2|K_2) f'_{D_2} d(D_2)\end{aligned}$$

- Optimal Provisioning Level (for demand distribution: $U[0, D_2^{\max}]$)

$$K_2^* = \frac{(1-\alpha)(p_2 - v_2 - a_2) D_2^{\max}}{(1-\alpha)(p_2 - v_2) + \alpha a_2}$$

Solution Methodology

- Service 1 is an existing service
  - with a stable demand= D_1, provisioning level: $K_1=D_1$
  - Revenue: $\Pi_1 = (p_1 - v_1 - a_1)D_1 - c_1$

- Total Revenue from Service 1 and Service 2 networks, $\Pi_{sep} = \Pi_1 + \Pi_2$:

$$\Pi_{sep} = \left\{\frac{(p_2 - v_2 - a_2)D_2^{max}}{2}\left(1 - \frac{(1-\alpha)a_2}{(1-\alpha)(p_2 - v_2) + \alpha a_2}\right) - c_2\right\} + \left\{(p_1 - v_1 - a_1)D_1 - c_1\right\}$$

Profit from Service 1

captures the impact of reprovisioning

Profit from Service 2

- Similarly, Total Revenue in the Shared network option will be:

$$\Pi_{shr} = \frac{(p_2 - v_{s2} - a_{s2})D_2^{\max}}{2}\left(1 - \frac{(1-\alpha)a_{s2}}{(1-\alpha)(p_2 - v_{s2}) + \alpha a_{s2}}\right) + (p_1 - v_{s1} - a_{s1})D_1 - c_s$$

Choice of Infrastructure

- Shared is preferred over separate when $\Pi_{shr} > \Pi_{sep}$

Depends on provisioning decision

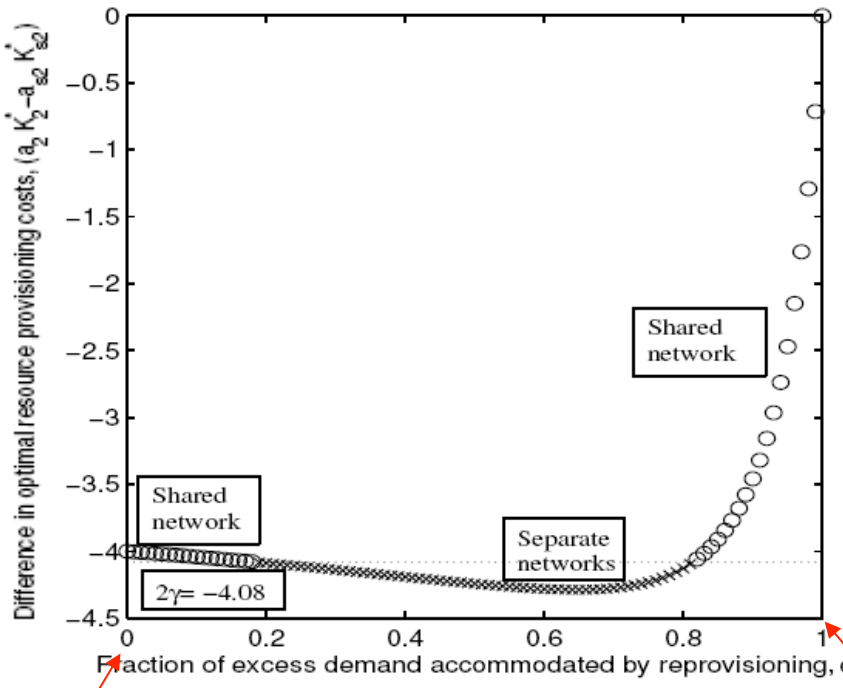
$$(a_2 K_2^* - a_{s2} K_{s2}^*) > 2\gamma$$

Independent of provisioning decision

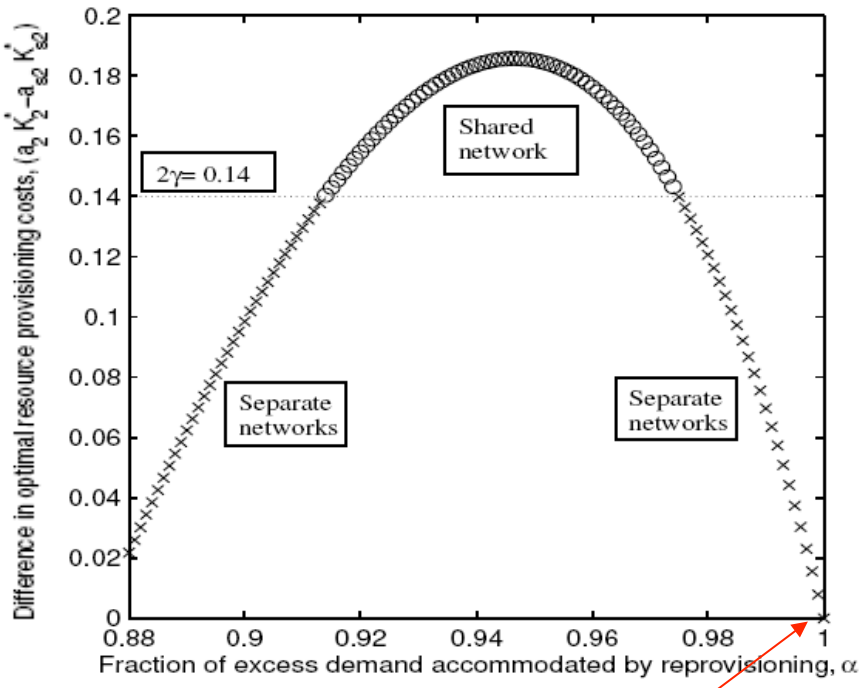
- Impact of system parameters:
  - Varying cost parameters affect the choice of infrastructure
    - Shared to Separate (or Separate to Shared).
  - Surprisingly, ad-hoc “reprovisioning” ability also impacts in even more interesting ways!

Impact of Reprovisioning

shared-separate-shared



separate-shared-separate



No reprovisioning possible (all excess demand is lost)

No need for prior provisioning

$p_2 - v_{s2} - a_{s2} > p_2 - v_2 - a_2$

No need for prior provisioning

$p_2 - v_{s2} - a_{s2} < p_2 - v_2 - a_2$

Conclusions

- Generic model captures economies and diseconomies of scope that differentiate *shared* and *separate* networks
- Most interesting aspect is that reprovisioning can also affect the outcome
  - We understand why this happens in some cases but not all
  - We hope to soon be able to provide a complete analysis of when and why reprovisioning matters

Thank You!