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

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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 $D_2 < K_2$:

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

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Service 1 separate</th>
<th>Service 2 separate</th>
<th>Shared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Fees</td>
<td>$p_1$</td>
<td>$p_2$</td>
<td>$p_1$, $p_2$</td>
</tr>
<tr>
<td>Fixed Costs</td>
<td>$c_1$</td>
<td>$c_2$</td>
<td>$c_s$</td>
</tr>
<tr>
<td>Variable Costs (incurred for each unit of realized demand)</td>
<td>$v_1$</td>
<td>$v_2$</td>
<td>$v_{s1}$, $v_{s2}$</td>
</tr>
<tr>
<td>Variable Costs (incurred irrespective of realized demand)</td>
<td>$a_1$</td>
<td>$a_2$</td>
<td>$a_{s1}$, $a_{s2}$</td>
</tr>
</tbody>
</table>
Model: Separate Networks

- Service 2 Revenue when $D_2 > K_2$:
  - Reprovisioning Ability:
    - A fraction $\alpha$ 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, $\mathbb{E}(R_2|K_2)$, for a given provisioned level $K_2$:
  \[ \mathbb{E}(R_2|K_2) = \int_0^{K_2} R_2(D_2 < K_2|K_2) f_{D_2}(D_2) \, d(D_2) \]
  \[ + \int_{K_2}^{D_2^{\text{max}}} R_2(D_2 > K_2|K_2) f_{D_2}(D_2) \, d(D_2) \]

- Optimal Provisioning Level (for demand distribution: $U[0, D_2^{\text{max}}]$)
  \[ K_2^* = \frac{(1 - \alpha)(p_2 - v_2 - a_2)D_2^{\text{max}}}{(1 - \alpha)(p_2 - v_2) + \alpha a_2} \]
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\}

\[+ (p_1 - v_1 - a_1)D_1 - c_1 \]

Profit from Service 1

\( \Pi_{sep} \) captures the impact of reprovisioning

Profit from Service 2

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

\[
\Pi_{shTR} = \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)
\[+ (p_1 - v_{s1} - a_{s1})D_1 - c_s \]

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Choice of Infrastructure

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

\[ (a_2K_2^* - a_{s2}K_{s2}^*) > 2\gamma \]

• 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

No reprovisioning possible (all excess demand is lost)

$p_2 - v_{s_2} a_{s_2} > p_2 v_2 - a_2$

separate-shared-separate

No need for prior provisioning

$p_2 - v_{s_2} a_{s_2} < p_2 v_2 - a_2$

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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!

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