Modelling the Bandwidth Allocation Problem in Mobile Service-Oriented Networks

Bo Gao and Ligang He

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Outline

• The problem
  – Mobile Service-Oriented Networks (MSONs)
  – Service Bandwidth Dependency and Allocation

• Solution
  – Leontief Input-Output Model (Economics)
  – Network I-O Model (MSONs)

• Results
Mobile Service-Oriented Networks
Mobile Service-Oriented Networks

Bandwidth Dependency? Allocation?
Mobile Service-Oriented Networks

Leontief Input-Output Model

Exchange of Goods and Services in the U.S. for 1947 (in billions of 1947 dollars)

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<tr>
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$C = \begin{bmatrix} .4102 & .0301 & .0257 \\ .0624 & .3783 & .1050 \\ .1236 & .1588 & .1919 \end{bmatrix} \quad \begin{bmatrix} d = 39.24 \\ 60.02 \\ 130.65 \end{bmatrix}$

consumption matrix
demand vector
Leontief Input-Output Model

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- **Consumption matrix**: 
  \[ C = \begin{bmatrix} .4102 & .0301 & .0257 \\ .0624 & .3783 & .1050 \\ .1236 & .1588 & .1919 \end{bmatrix} \]

- **Demand vector**: 
  \[ d = \begin{bmatrix} 39.24 \\ 60.02 \\ 130.65 \end{bmatrix} \]

\[ x = Cx + d \]

\[ x = (I - C)^{-1}d = \begin{bmatrix} 82.40 \\ 138.85 \\ 201.57 \end{bmatrix} \]

\( x \) - Equilibrium Production Level
Households buy output of business as the final demand

Households sell labor and other inputs to business as inputs to production

Business purchases from other business to produce their own goods

Modern industry ecosystem

\[ x = Cx + d \]
MSON returns the result as production

Mobile user requests services as the final demand

Service communicates with each other service to meet external demand

\[ x = Cx + d \]
## I-O Models in (M)SONs

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## I-O Models in Economics vs (M)SONs

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\[
x = \begin{cases} 
Ax + d \\ 
\text{production} & \text{intermediate demand} & \text{external demand}
\end{cases}
\]

\[
x^\uparrow = \begin{cases} 
A^\uparrow x^\uparrow + c^\uparrow \\ 
\text{uplink cost} & \text{relayed uplink demand} & \text{self-initiated demand}
\end{cases}
\]

\[
x^\downarrow = \begin{cases} 
A^\downarrow x^\downarrow \\ 
\text{downlink cost} & \text{relayed downlink demand}
\end{cases}
\]

\[
\omega_{i,j} = \begin{cases} 
0 & \text{if } \Theta(s_i) = \Theta(s_j), \\
1 & \text{otherwise.}
\end{cases}
\]
Application of Network I-O Model

I-O Based Adaptive Model

$$\min_{\tilde{\lambda}} \| \lambda - \tilde{\lambda} \|_2$$

s.t. 
$$(A^\top - I)\tilde{x}^\top + \lambda \circ \beta \circ \rho = 0$$
$$A^\top \tilde{x}^\top - \tilde{x}^\top = 0$$
$$\tilde{b}_m = \sum_i \tilde{x}_i^\top + \sum_i \tilde{x}_i^\top, \quad \Theta(s_i) = m$$
$$\tilde{b}_m \leq b_m, \quad m \in \{M - \mu\}$$
$$\tilde{b}_\mu \leq \tilde{B}_\mu$$

s.t. 
$$(A^\top - I)\tilde{x}^\top + \tilde{\lambda}^\prime \circ \beta \circ \rho = 0$$
$$\tilde{\lambda}_i^\prime = \lambda_i, \quad \Theta(s_i) = \mu$$

s.t. 
$$(A^\top - I)\tilde{x}^\top + \tilde{\lambda}^\prime\prime \circ \beta \circ \rho = 0$$
$$\tilde{\lambda}_i^\prime\prime = \lambda_i, \quad \Theta(s_i) \neq \mu$$
Application of Network I-O Model

- Group B ($s_{26} \sim s_{50}$)
- Group A ($s_{1} \sim s_{25}$)
- Administrator ($s_{51}$)

- $(\lambda, \lambda)$
- $(\lambda, \tilde{\lambda})$
- $(\lambda, \tilde{\lambda}')$
Summary

• Mobile Service-Oriented Networks
• Extend Leontief’s I-O Model in Economics to a Network I-O Model
• Application of Network I-O Model
Thank you

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