

Etude d'un problème de tarification en télécommunication

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1. Introduction

Revolution in Telecommunications

- Technology platform that makes it easy to create and offer new communications services
- Traditionally, **large regulated and protected monopolies** have dominated the telecommunication market.
- The market for communications is **now competitive**



How does the pricing of communications services differ from the pricing of other goods?

- Network externality effect
- Sunk costs (80% of the cost: transmission lines, routers, servers)
- Difference between data and telephony networks (packet switching or circuit switching)



Things are getting more complex

- New applications (from technology layer to physical layer)
- Costs decrease, many unpredictable aspects (interconnection, bottleneck services, technology evolution)
- Demand grows extremely fast, unpredictable
- Generally the sales of the communication services and content service are bundled and priced as a single service



Conclusion

Network Services have to be priced in a context of uncertainty and rapid growth.

New issues :

- **Control of quality of service** provided to the users.
Manage congestion problem through pricing control
Adjust prices to ensure that services are provided to users that benefit most and are most willing to pay
- **Interconnection services**



■ Correct view on charging

- Charging provides a mean for the operator to:
 - Obtain revenue and make profit
 - Control the network
 - Improve value of services to users
 - Provide stability and robustness
- Charging should provide
 - The right incentives to users
 - Important information to network controllers
- Charging should be
 - Simple but not simplistic
 - Understandable, implementable, competitive



Plan

- 1 Introduction
- 2 Historical Overview
- 3 (De)Regulation and Pricing
- 4 Telecommunication networks
- 5 Network Design Problem
- 6 Focus on FT Problem
- 7 Bilevel Programming
- 8 Joint Design and Pricing (Model, Solution method)
- 9 Conclusion
- 10 Extension



2. Historical Overview (US)

Phase 1: Unregulated Monopoly (Western Union and Bell)

- 1844: Development of telegraph
 - 1876: Voice telephone
- ⇒ Focused on telephone development in major cities, high prices, slow growth

Phase 2: Rapid entry of many companies (1893–1907)

⇒ Prices reduced, deep rural portions penetration, growth accelerated

Non Interconnected competition

Phase 3: Regulated monopoly (1907 – 1960)

Political control of its prices in exchange for political protection from competition



Phase 4: Regulated monopoly structure gradually transformed into a competitive structure

Phase 5: Telecommunication Act in 1996

Promote the competition in and deregulate the local exchange market

Interconnected competition

3. (De)Regulation and Pricing

■ Regulation?

– In the past:

a specified **rate of return** which ensured financial viability while keeping the prices « **low** » for consumers (cross-subsidizing local calls through relatively high prices for long distance and international calls)

– More recently:

focus on prices which encourage dynamic elements such as efficiency, innovation and flexibility

Key instruments

Price regulation: price cap, partial deregulation

Interconnection practice and Access Pricing regulation



■ Pricing?

Cost Oriented Pricing

Not unique (Common cost)

Necessary Conditions:

- Fairness (subsidy free prices)

- Defensive against competition (sustainable prices)

⇒ Stable prices



■ Pricing in practice

Difficulties:

- cost of producing any arbitrary bundle of services is unknown
- common cost which can not be attributed to any particular service

Key principles:

- cost causation
- objectivity
- transparency



Remark: historic and current cost

Historic cost: actual amount paid to purchase the various factors.

Current cost: cost of equipment if it were bought today

? Cost definition

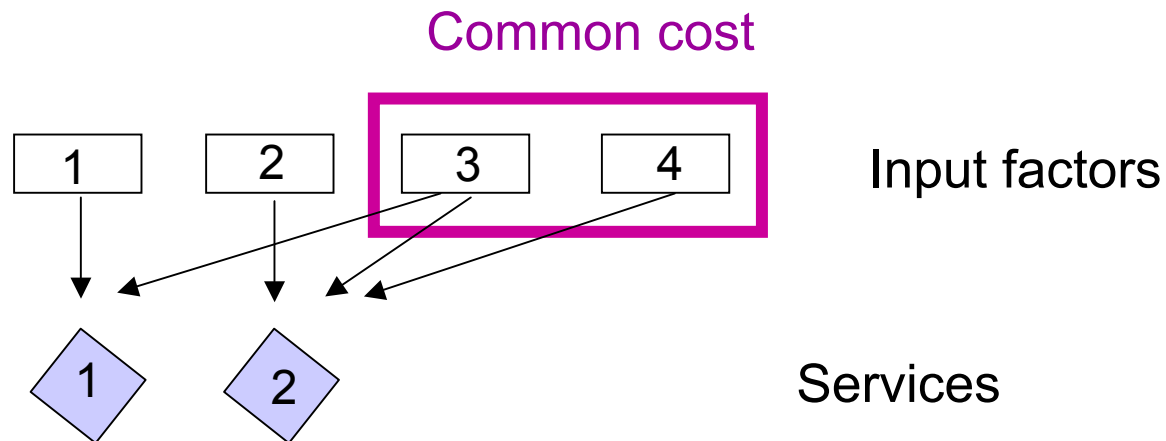
The cost function is not explicitly known as a function of the service quantity produced

Fully Distributed Cost (FDC)

Prices related to accounting informations.

The basic idea is to divide the overall cost that the firm incurs amongst the various services that are being sold.

The methodology should be mechanizable.



Top Down Approach



Service i produced in quantity y_i

Variable cost $VC_i(y_i)$, and shared cost $SC(y)$ ($y=(y_1, \dots, y_n)$)

$$P_i(y_i) = VC_i(y_i) + \gamma_i SC(y)$$

$$\sum_i \gamma_i = 1$$

For example γ_i proportional to:

$$y_i p_i / \sum_j p_j y_j$$

$$VC_i(y_i) / \sum_j VC_j(y_j)$$

$$y_i / \sum_j y_j$$



- γ_i known \Rightarrow construction of prices is trivial and can be done automatically using accounting data

-Based on historical costs

-Problems with FDC based prices:

- No reason that FDC based prices are optimal or stable

- FDC based prices may hide inefficiencies



Long Run Incremental Cost (LRIC)

Bottom-up Approach

Example:

A firm offers quantity y_1 and y_2 of services 1 and 2.

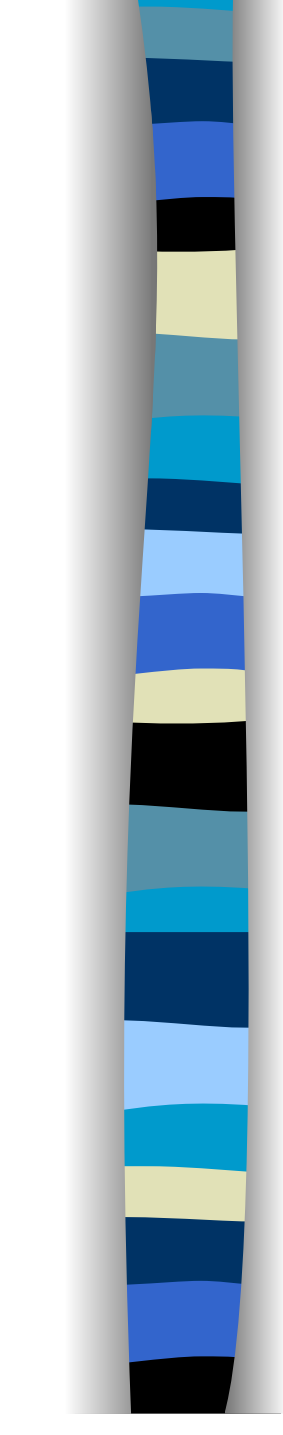
$C(y_1, y_2)$ the cost of the mix.

$LRIC(y_1) = C(y_1, y_2) - C(y_2)$ where $C(y_2)$ is the cost for a facility whose production plan is optimized to produce only type 2 services at production level y_2 .

Problem: Accounting records hold only the actual cost

$C(y_1, y_2)$.

?Evaluating $C(y_2)$?


$$C(0, y_2) \geq C(y_2)$$

Calculation of $C(0, y_2)$ from the accounting reports may be Inaccurate:

$$C(y_1, y_2) - C(\text{elements for } y_1) \geq C(0, y_2)$$

(!! Common cost)

Bottom up approach in which $C(y_2)$ and $C(y_1)$ are constructed from scratch, by building models of fictitious facilities that produce just one or the other of the products



Remark:

The sum of prices constructed according to LRIC will not cover the production cost:

$$\begin{aligned} \text{LRIC}(y_1) + \text{LRIC}(y_2) &= C(y_1, y_2) - C(y_2) + C(y_2, y_1) - C(y_1) \\ &\leq C(y_1, y_2) \end{aligned}$$

Distribute common cost among services:

Approach known as **LRIC+**



-LRIC+ based on current costs

-Subsidy free prices

-Problems with LRIC+ based prices:

- LRIC+ models built from scratch

- Not based on accounting procedures



Advantages and disadvantages of FDC and LRIC+ based prices

Advantages of FDC based prices that use historic cost:

- easier to develop and understand
- based on accounting data
- easy to audit by specialists

Disadvantages

- no incentives for improving the efficiency of the provider
- depend on arbitrarily chosen coefficients

LRIC + combined with bottom-up models using current costs has the **advantages** that:

- it generates subsidy free prices
- it does not include inefficiency

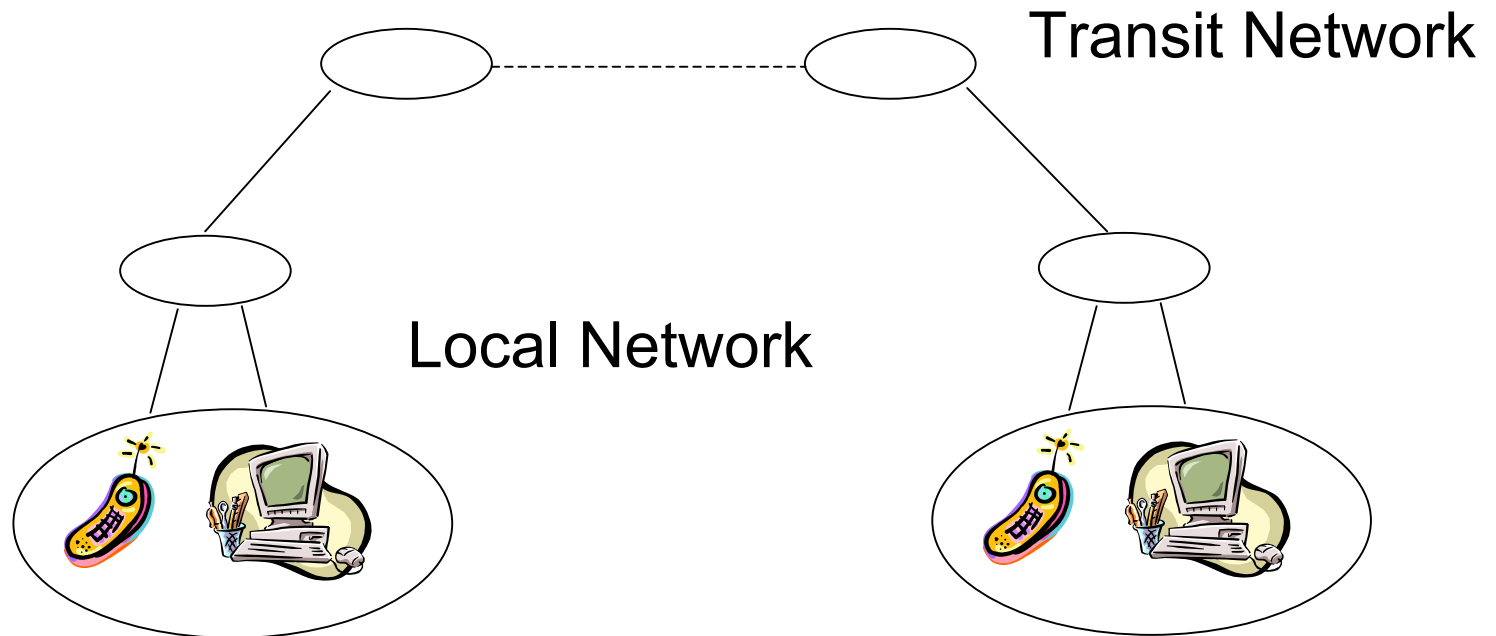
and the **disadvantages** that:

- hard to develop
- accountants find them hard to understand

4. Telecommunication Networks

Telecommunications description

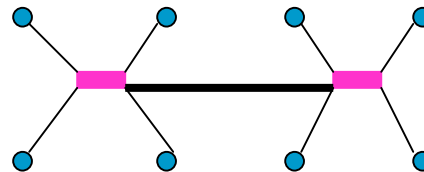
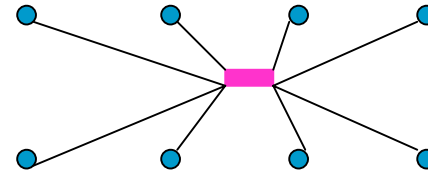
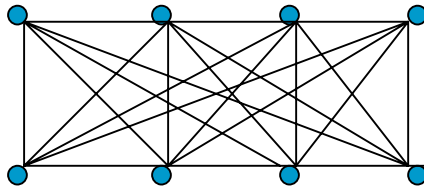
Telecommunications can be defined as the service of enabling electronic transfers of information from one point to another or from one point to multiple points

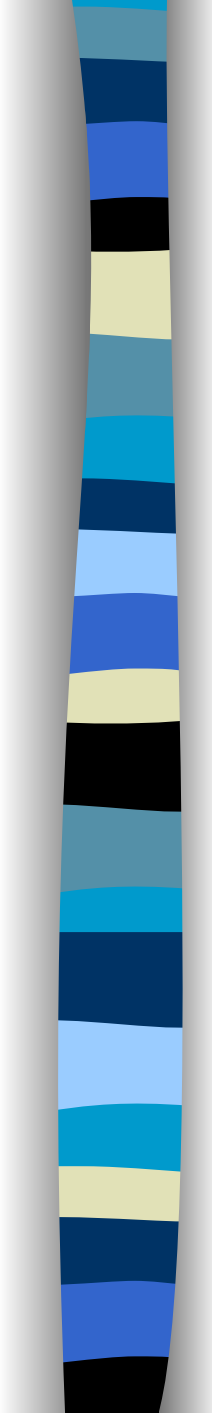


Transmission of a signal and a switching function

■ Network design issue

- Trade-off between switching and transmission
(take advantage of potential sharing of structure costs in the network)





-In the **local access network**, a minimum cost network can typically be represented by a **spanning tree** network (minimal connected network)

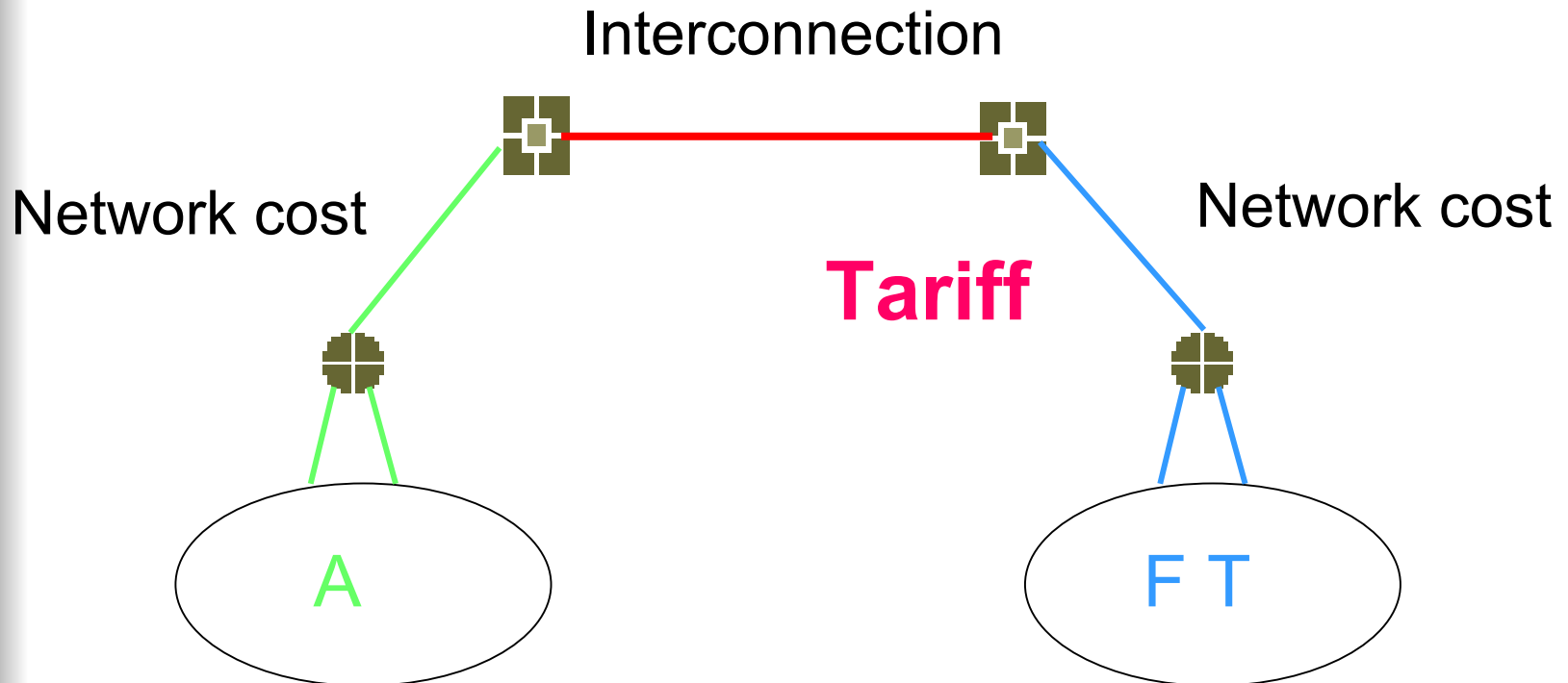
-In the **interoffice or inter-city networks**:
(optimal tradeoff between the length of a route between any two points and the economies of scale that can be achieved by aggregating traffic)

■ Interconnection

«*The commercial and technical arrangements under which services providers connect their equipment, networks and services to enable customers to have access to the customers, services and networks of other providers* » (Int. Telecom Union)

A large number of interconnected operators:

- in France, 107 operators (03/02/2000)
- for France Telecom: 200 international operators





■ Pricing Interconnection

Important issue in competitive telecommunication market because of differences in the costs of network using different technologies and asymmetries in call patterns associated with entrants and incumbent

Today, interconnection is regulated.

Challenge: encourage an efficient competitive entry and avoid an inefficient one.

Main pricing rules :

- bill and keep: compensation arrangement; no monetary transfers
- Cost based Interconnection Pricing (Fully distributed cost pricing, Long run incremental costs, ..)



Interconnection Costs:

- costs incurred in provisioning each network for the seamless transfers of calls through the appropriate software modifications of switches
- cost of dedicated transport facilities connecting two networks
- cost of switching and interoffice trunking capacity of each network to accommodate the additional peak traffic generated by the interconnection

Example: Interconnections Tariffs (FT, 2003)

Interconnection (BPN) : 3984,1 Euros / year

Bundle (2 megabits) : 753,2 E

Normal Tariff

Reduced Tariff

Blue Night Tariff

	Fixed Charge	E/min	Fixed Charge	E/min	Fixed Charge	E/min
Simple Transit	0,00365	0,00901	0,00235	0,00581	0,00156	0,0038



5. Network Design Problems

Network Design problems arise in a wide variety of telecommunication or transportation applications.

Planning levels:

- Strategic planning
- Tactical planning
- Operational planning



Generic Design Problem

Given the cost for installing any link on a network as well as the cost for routing any one of several commodities on any installed links, what is the least cost configuration of the network that meets service requirements?

Difficult to solve:

Large number of possible network configurations

Mixed Integer Programming Model



- References:

- B. Gendron, T.G. Crainic and A. Frangioni, *Multicommodity Capacitated Network Design, Telecommunications Network Planning*, Sanso, Soriano (eds), Kluwer Academic Publishers, Norwell MA, 1-19, 1998.
- A. Balakrishnan, T.L. Magnanti and P. Mirchandani, *Network Design, Annotated Bibliographies in Combinatorial Optimization*, Dell'Amico, Maffioli, Mortello (eds.) Wiley-Interscience, 311-334, 1997.
- T.L. Magnanti, R.T. Wong, *Network Design and Transportation Planning*, *Transportation Science*, 18, 1-19, 1984.
- M. Minoux, *Network Synthesis and Optimum Network Design Problems: Models, Solution Methods and Applications*, *Networks*, 19, 313-360, 1989.



Mixed Integer Program

\mathcal{A} Set of arcs

\mathcal{N} Set of nodes

c_a^k Operating cost per unit on $a \in \mathcal{A}$ for k

f_a Fixed opening cost on $a \in \mathcal{A}$

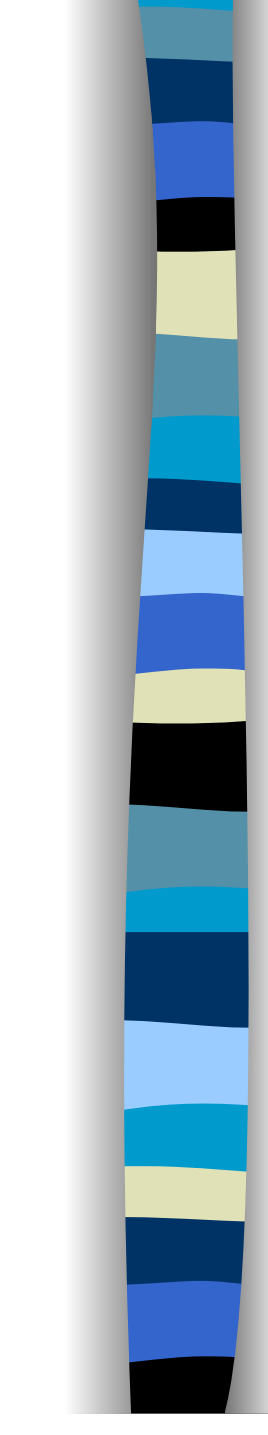
\mathcal{K} Set of origin-destination pairs $(o(k), d(k))$

n^k Demand for a commodity k

x_a^k Commodity k flow on $a \in \mathcal{A}$

v Binary variable for opening arc a

γ_a Capacity on arc a

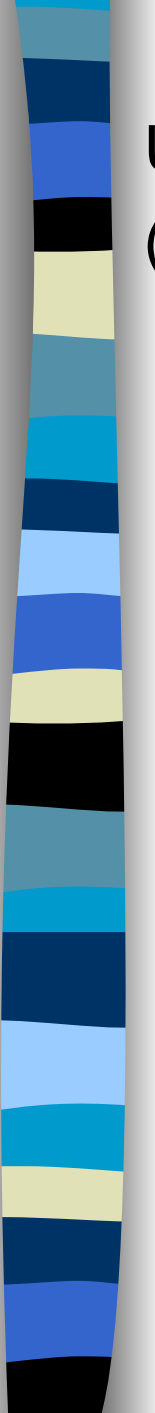


$$\begin{aligned}
 \min_{x,v} \quad & \sum_{k \in \mathcal{K}} \sum_{(i,j) \in \mathcal{A}} c_{ij}^k x_{ij}^k + \sum_{(i,j) \in \mathcal{A}} f_{ij} v_{ij} \\
 \text{s.t.} \quad & \sum_{j:(i,j) \in \mathcal{A}} x_{ij}^k - \sum_{j:(j,i) \in \mathcal{A}} x_{ji}^k = b_i^k \quad \forall i \in \mathcal{N}, \forall k \in \mathcal{K} \\
 & \sum_k x_{ij}^k \leq \gamma_{ij} v_{ij} \quad \forall (i,j) \in \mathcal{A}, \forall k \in \mathcal{K} \\
 & x_{ij}^k \leq \min\{n^k, \gamma_{ij}\} v_{ij} \quad \forall (i,j) \in \mathcal{A}, \forall k \in \mathcal{K} \\
 & x_{ij}^k \geq 0 \quad \forall (i,j) \in \mathcal{A}, \forall k \in \mathcal{K} \\
 & v_{ij} \in \{0, 1\} \quad \forall (i,j) \in \mathcal{A}
 \end{aligned}$$



There are many ways to classify network design models

- Simultaneous or non-simultaneous flows
- Fixed costs or fixed and variables Costs
- Capacitated or uncapacitated
- Individual commodities capacities or bundle capacities shared by commodities
- Single route or bifurcated routes
- Topological restrictions or not



Uncapacitated Network Design Problem (UNDP)
(No Capacities, Fixed and Variables Costs, No Topology restrictions, Simultaneous Flows)

NP HARD PROBLEM

Steiner Tree Problem is a special case of UNDP
(Magnanti 1984)

Uncapacitated Network Design Problem

$$\min_{x,v} \sum_{k \in \mathcal{K}} \sum_{(i,j) \in \mathcal{A}} c_{ij}^k x_{ij}^k + \sum_{(i,j) \in \mathcal{A}} f_{ij} v_{ij}$$

$$\text{s.t.} \quad \sum_{j:(i,j) \in \mathcal{A}} x_{ij}^k - \sum_{j:(j,i) \in \mathcal{A}} x_{ji}^k = b_i^k \quad \forall i \in \mathcal{N}, \forall k \in \mathcal{K}$$

$$x_{ij}^k \leq n^k v_{ij} \quad \forall (i,j) \in \mathcal{A}, \forall k \in \mathcal{K}$$

$$x_{ij}^k \geq 0 \quad \forall (i,j) \in \mathcal{A}, \forall k \in \mathcal{K}$$

$$v_{ij} \in \{0, 1\} \quad \forall (i,j) \in \mathcal{A}$$

Lagrangean Heuristic

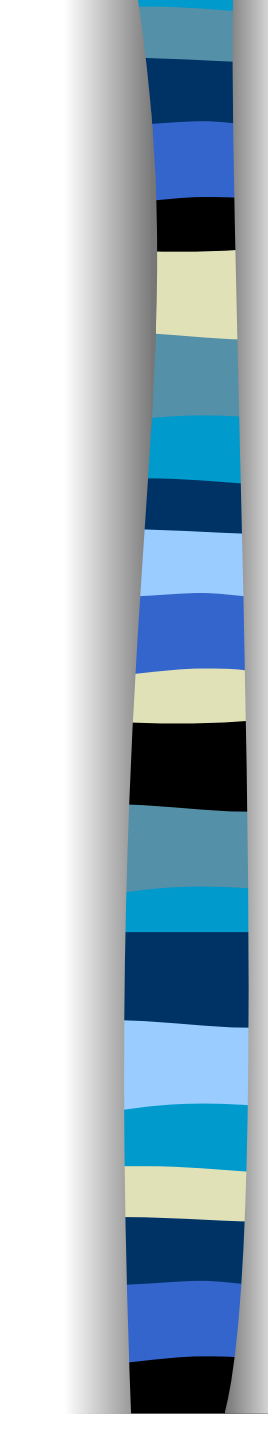
(Holmberg and Hellstrand 1996)

Lagrangean Sub-Problem

$$\begin{aligned} ZL(u) = \min_{x,v} & \sum_{k \in \mathcal{K}} \sum_{(i,j) \in \mathcal{A}} n^k c_{ij}^k x_{ij}^k + \sum_{(i,j) \in \mathcal{A}} f_{ij} v_{ij} \\ & - \sum_{k \in \mathcal{K}} \sum_{(i,j) \in \mathcal{A}} u_{ij}^k (v_{ij} - x_{ij}^k) \\ \text{s.t.} & \sum_{j:(i,j) \in \mathcal{A}} x_{ij}^k - \sum_{j:(j,i) \in \mathcal{A}} x_{ji}^k = e_i^k \quad \forall i \in \mathcal{N}, \forall k \in \mathcal{K} \\ & x_{ij}^k \geq 0 \quad \forall (i,j) \in \mathcal{A}, \forall k \in \mathcal{K} \\ & v_{ij} \in \{0, 1\} \quad \forall (i,j) \in \mathcal{A} \end{aligned}$$

Dual Lagrangean

$$\max_{u \leq 0} ZL(u)$$



$$\begin{aligned}
 ZL(u) = \min_{x,v} & \sum_{k \in \mathcal{K}} \sum_{(i,j) \in \mathcal{A}} (n^k c_{ij}^k - u_{i,j}^k) x_{ij}^k + \\
 & \sum_{(i,j) \in \mathcal{A}} (f_{ij} - \sum_{k \in \mathcal{K}} u_{ij}^k) v_{ij} \\
 \text{s.t.} & \sum_{j:(i,j) \in \mathcal{A}} x_{ij}^k - \sum_{j:(j,i) \in \mathcal{A}} x_{ji}^k = e_i^k \quad \forall i \in \mathcal{N}, \forall k \in \mathcal{K} \\
 & x_{ij}^k \geq 0 \quad \forall (i,j) \in \mathcal{A}, \forall k \in \mathcal{K} \\
 & v_{ij} \in \{0, 1\} \quad \forall (i,j) \in \mathcal{A}
 \end{aligned}$$