Exploring Trade-offs in Operator's Profit and User Utility through Bandwidth Demand Control

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INTRODUCTION

A communication network can be seen as a system reflecting the goals of it's stakeholders - the operator and the users.

Key problem in network management:

- Allocation of resources which satisfies some objective.
- Typically follows *either* user goals *or* operator's goal.
- In this work, we aim for an objective involving both aspects.
- Our objective involves *profit* and *utility*, where these are a function of user data rates.
- We use a **utility function** to represent the **value** received by the user from the network.
- Utility function also carries the information about the price a user is willing to pay and about its demand.

OBJECTIVE:

Given a profit constraint, how should we set prices to drive users into choosing such demand which maximises total user utility and while achieving the prescribed profit?

SYSTEM OVERVIEW **(Also see Figure 1 top right)**

1. Operator running the proposed algorithm sets link prices in the network.

2. User, according to their individual utility functions, choose data rate which maximises their surplus.

3. This demand generates revenue for the operator, but also some packet loss which diminishes the revenue.

4. Operator can balance between profit and total utility, knowing that for a given profit, the total utility is maximised.

The total value provided by the network is maximised and the operator's profit constraint satisfied.

PROBLEM FORMULATION

Maximise total utility subject to a minimum profit constraint:

$$\max_{f} U = \sum_{i \in \mathcal{F}} U_i(f_i), \quad \text{s.t. } \pi \geq \pi_{min} \qquad (1)$$

Demand

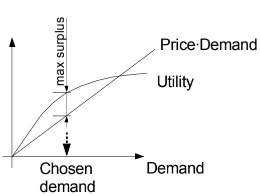
Profit is given by:

$$\pi = \sum_{i \in \mathcal{F}} p_i f_i (1 - L^{(i)})$$

Packet loss in buffers: reduces profit.

Price: controls demand.

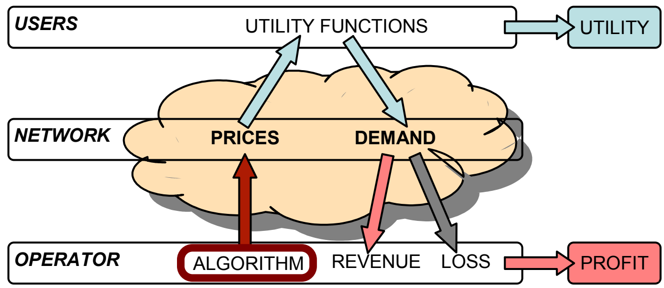
Price p_i controls demand f_i – user maximises surplus:



SOLUTION CONCEPT

- Based on the well-known problem of Network Utility Maximisation (*NUM*).
- Benefits from distributed calculation.

Figure 1 – System overview



ILLUSTRATIVE EXAMPLE

Objective: Maximise total utility of 3 flows subject to Profit $\pi \geq 5.40$
Equivalent to:

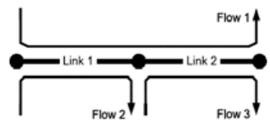
Maximise $U_1(f_1) + U_2(f_2) + U_3(f_3)$

subject to

$x_1 \leq 3 \cdot k_1$

$x_2 \leq 4 \cdot k_2$

Link capacities

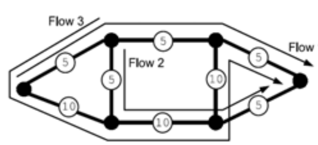


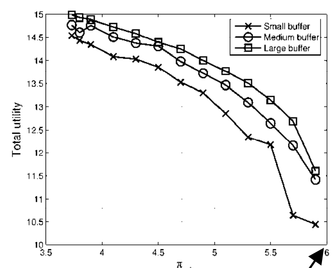
ALGORITHM ITERATION → SOLUTION

k_1	1.00	1.13	1.06	0.97	0.94
k_2	1.00	0.95	0.87	0.79	0.70

Profit	**4.82**	**4.86**	**5.11**	**5.31**	**5.43**
Utility	11.46	11.50	11.12	10.61	10.15
Profit [%]	0	+0.76	+5.95	+10.15	+12.56
Utility [%]	0	+0.35	-2.96	-7.37	-11.41

NUMERICAL EXAMPLE





Profit constrain

CONCLUSION AND FUTURE WORK

We presented a method for controlling the trade-off between utility and profit in a loss network. The proposed algorithm allows the operator to maximise the total value provided to the users while achieving a given profit. This work is a step towards combining users' and operator's interest. Our current work tackles joint routing and bandwidth allocation, non-concave utility functions and application to inter-domain scenarios.

REFERENCES

[1] Mayer D. and Barria J.A., "Bandwidth Allocation for a Revenue-Aware Network Utility Maximisation ", IEEE Communications Letters 11 (7) pp.634-636 (2007)